How to learn Chinese characters? Exploring the effectiveness of different learning methods in young Singaporean children

Toh, Wendy Hwee Bin

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**HOW TO LEARN CHINESE CHARACTERS?
EXPLORING THE EFFECTIVENESS OF
DIFFERENT LEARNING METHODS IN
YOUNG SINGAPOREAN CHILDREN**

**TOH HWEE BIN, WENDY
SCHOOL OF HUMANITIES
2019**

**How to Learn Chinese Characters?
Exploring the Effectiveness of Different Learning
Methods in Young Singaporean Children**

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School of Humanities

A thesis submitted to the Nanyang Technological
University in partial fulfilment of the requirement for the
degree of Master of Arts

2019

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	i
TABLE OF CONTENTS	ii
SUMMARY	iv
CHAPTER ONE INTRODUCTION	1
1.1 Introduction	1
1.1.1 Learning to Read Chinese in the Singapore Context	2
1.1.2 Explanation of Relevant Concepts	4
1.1.3 Study Aims	5
1.2 Literature Review	5
1.2.1 Visual Word (Character) Recognition Models	5
1.2.2 Key Processes in Single Character Reading	7
1.2.3 The Role of Handwriting & Phonological Encoding in Chinese Word (Character) Learning	17
1.2.4 Bilingual Literacy Development	21
CHAPTER TWO METHODS	25
2.1 Research Questions	25
2.2 Participants	26
2.3 Design	27
2.4 Training Stimuli & Learning Materials	28
2.5 Procedure	29
2.6 Measures	30
2.6.1 Pre-Test: Assessing Level of Radical Awareness (RA)	30
2.6.2 Immediate & Delayed Evaluation: Assessing Learning Outcomes	32
2.6.3 Post-Test: Assessing Visual Analysis Skills & Orthographic Awareness	33
2.7 Method of Analysis	34
CHAPTER THREE RESULTS	35
3.1 Post-Training Evaluation of Experiment 1	35
3.1.1 Immediate Evaluation	36
3.1.2 Delayed Evaluation	37
3.1.3 Comparison between the Low RA & High RA Groups	37
3.2 Post-Training Evaluation of Experiment 2	40
3.2.1 Immediate Evaluation	40
3.2.2 Delayed Evaluation	42

3.2.3 Comparison between the Low RA & High RA Groups.....	42
3.3 Post-Training Evaluation of Experiment 3.....	44
3.3.1 Immediate Evaluation	45
3.3.2 Delayed Evaluation	46
3.3.3 Comparison between the Low RA & High RA Groups.....	47
3.4 Post-Test Results of Experiments 1, 2 & 3: Transfer Effect Across Learning Modalities	49
3.5.1 The Effects of Learning Modalities on Visual Analysis Skills.....	49
3.5.2 The Effects of Learning Modalities on Orthographic Awareness.....	56
 CHAPTER FOUR DISCUSSION	59
4.1 Discussion	59
4.1.1 Effectiveness of Writing Modalities	61
4.1.2 The Role of Pinyin in the Singapore Context	63
4.1.3 The Issue of Radical Awareness & Some Pedagogical Implications	66
4.1.4 Limitations of the Study	69
4.2 Conclusion.....	69
 REFERENCES	71
 APPENDIX I.....	84
 APPENDIX II	86
 APPENDIX III	91
 APPENDIX IV.....	93

SUMMARY

Biscriptal literacy development can be challenging if the two writing systems are starkly different. Past research on early Chinese word reading and instruction has mainly focused on children in Mandarin-speaking societies or adult foreign/second language learners. Recently, the number of studies on biscriptal literacy development in children has been growing. In Singapore where majority of the children are learning both English and Chinese in early childhood, it is particularly important to study the methods of Chinese word instruction to understand how we can effectively support young bilinguals' reading development in Chinese.

Using several training paradigms, this study examined the immediate, retention and transfer effects after different modes of Chinese character learning among Primary One students in Singapore. The character learning experiments used the same sets of Chinese characters to study three different modalities (viewing, free writing and structured writing) and several different encoding methods (*Pinyin* – romanised phonetic coding system of the Chinese script, whole character, stroke sequence and radical knowledge) in six learning conditions.

To compare the differences in the learning outcomes, various aspects of character recognition were assessed for each learning condition. In addition, the study also investigated whether children's level of radical awareness (RA), which refers to the perception of radicals and components that make up compound characters, would mediate the effectiveness of specific learning conditions. Findings of Experiment 1 revealed that the presence of *Pinyin* during character learning affected character recognition (CR) accuracy by interfering with the orthographic form recognition (OR) and sound retrieval among the low RA children. For the high RA children, however, the interference effects of *Pinyin* seemed to be limited to meaning retrieval only as the absence of *Pinyin* helped them to remember meanings better. In Experiment 2, it was revealed that generally, the repeated practice of character writing was more effective compared to repeatedly writing its *Pinyin*, especially among the low RA children. The findings of Experiment 3 demonstrated that the structured writing modality was effective for character learning and retention, be it focusing on radical/component or stroke sequence. In particular, it helped children remember the orthographic forms of characters learnt better for a sustained period of time. The structured writing modality, regardless of its

focus, was found to be particularly effective for the low RA children in character learning as it allowed them to improve their learning outcomes.

The transfer effects of the trained characters on children's visual analysis skills and orthographic awareness were also assessed for each learning modality. The results suggest that both writing modalities were able to mitigate the adverse effect of low RA on children's visual analysis skills, regardless of their learning outcomes. The viewing only modality, on the other hand, was deemed less effective, as the adverse effect of low RA on children's visual analysis skills could be mitigated only if the learning outcomes were good.

Through this research, evidence regarding the differential effects of the learning modes has been gathered to help us understand which methods better cater to the learning needs of different groups of learners.

CHAPTER ONE INTRODUCTION

1.1 Introduction

Literacy development requires deliberate learning and spoken language provides a general foundation for literacy acquisition. In learning to read, learners have to acquire a set of reading skills that help them map the spoken language onto its written form to gain access to meaning from printed text within the context of the language. Languages are mapped onto their writing systems in different ways. Linguistic differences, the variations in orthographic depth, script configurations, and the different nature of writing systems make literacy learning in some languages harder than the others (Wang, Perfetti & Liu, 2005; Ziegler & Goswami, 2006; Perfetti et al., 2007). As a morpho-syllabic, logographic writing system, written Chinese, in particular, can be difficult for beginning readers due to its deep orthography, lack of grapheme-phoneme correspondences and visual complexity of its written script (Perfetti et al., 2007; Koda, Lü & Zhang, 2014; McBride-Chang et al., 2011). Unlike alphabetical languages, the orthography–phonology mapping of Chinese characters, the smallest meaningful unit of the written script, is complicated, inconsistent and unreliable. Therefore, learning to read in Chinese is an uphill task for many, especially for those who are not proficient in the oral language.

In Singapore, the home language shift towards the use of English has resulted in a student population with varied levels of Chinese language (CL) proficiency and contrasting attitudes towards Chinese language learning (Ministry of Education, 2011). Recognising this shift in language environment, the Ministry of Education (MOE) has been working on enhancing CL teaching to support the learning needs of students from diverse language backgrounds, especially those with limited exposure to the language as they tend to find CL learning challenging.

Despite the differences in written languages, reading involves processes that are universal. According to Ehri (2005), early reading primarily involves decoding, analogising and predicting unfamiliar words and visual word recognition (for familiar words). Visual word recognition or identification refers to the processing of printed words and its spontaneous access to the orthographic, phonological and semantic information of the words, without the need to decompose them (LaBerge & Samuels, 1974, as cited in Ehri, 2005). Visual word recognition is the most important and fundamental skill in reading development because the automaticity of the word recognition process helps to free up cognitive resources for reading comprehension (Curtis,

1980). This fundamental reliance on skilled word recognition for fluent reading and comprehension is universal across languages. Therefore, a preliterate child needs to first acquire visual word recognition skills, which will allow one to access and integrate multiple constituents of printed words, in order to read with fluency and accuracy. One of the primary goals of literacy instruction for beginning readers then is to help them develop this skill so that the word recognition process becomes effortless and automatic.

As word recognition is possible only when robust connections between its written form and its lexical constituents are established and incorporated into the mental lexicon of the learner and can be accessed fluently (Elgort, 2011), building a rich visual lexicon, i.e., sight vocabulary, is key to literacy development (Ehri, 2005). Therefore, it is important to focus on visual word learning in order to support children's reading development, especially for those lacking in oral proficiency or reading skills. Since children's reading development is dependent on formal instruction, there is a need to look into explicit vocabulary instruction which is deemed essential and effective in helping children strengthen their mental representations of printed words (Ehri, 2005; Biemiller & Boote, 2006).

Literacy development is dependent on experiential factors, i.e., language and literacy experience, which includes language use, home literacy practices and literacy instruction. Since literacy instruction falls within the domain of formal education, it is necessary to look into this area when addressing the issue of CL learning in Singapore.

1.1.1 Learning to Read Chinese in the Singapore Context

Learning to read is one of the key objectives of preschool and primary school education. As the preschool education aims to develop foundational language and literacy skills, literacy learning in the Chinese language focuses on learning the strokes and some common radicals for composing Chinese characters, recognising simple, high frequency characters and developing writing readiness skills (MOE, 2015). As children are only required to write simple characters when they are ready to do so, early word reading is often taught by pairing speech sounds with written forms through repeated exposure to the holistic patterns of Chinese characters on word cards. In the primary schools, children learn characters in two ways: characters that require recognition only (识读字) are taught through repeated exposure via word cards, while characters that require recognition and writing (识写字) are taught through repeated writing with stroke sequence. Although it is stated that children are required to develop radical awareness in the lower primary

years (MOE, 2014; MOE, 2006), radicals were hardly featured in the textbooks of the 2007 syllabus. There has been an attempt to rectify this in the revised curriculum (called 欢乐伙伴 in Chinese) introduced in 2015, with the inclusion of a list of radicals featured in each lesson and small sections highlighting the character(s) containing the featured radical(s). In addition, some of the character learning activities in the online learning resources also focus on the components of Chinese characters. However, the primary modes of Chinese character learning are still repeated exposure to the holistic patterns of the Chinese characters and repeated writing with stroke sequence. There is a lack of substantial explicit instruction on the internal structure of written forms, which may affect the development of radical awareness for efficient character recognition (Tong & McBride-Chang, 2010; Chang, Xu, Perfetti, Zhang & Chen, 2014) and decoding of novel characters encountered (Anderson, Li, Ku, Shu & Wu, 2003).

While it may be developmentally appropriate for young learners to learn Chinese characters through repeated exposure and help to reduce their negativity towards Chinese language learning by de-emphasising writing practice, it may not be effective as the traditional method of handwriting, as demonstrated by recent studies. By comparing different learning experiences and learning outcomes, these studies have affirmed that handwriting supports the learning of orthographic forms of Chinese characters (Guan, Liu, Chan, Ye, & Perfetti, 2011; Xu, Chang, Zhang, & Perfetti, 2013). It should be noted though that these studies were conducted on young adults learning Chinese as a foreign language, whose profile is considerably different from Singapore's young bilingual learners, as the latter are likely to have more exposure to the Chinese language during early childhood and have relatively fluent command of the spoken language with larger vocabulary sizes. Moreover, adult learners can rely on their metalinguistic awareness (Kurvers, 2015) and intrinsic motivation (Dornyei, 2001) to enhance second language learning, unlike young children.

Several studies on young native speakers have highlighted the important role of visual-orthographic skills in young Chinese learners' reading development (Tong, McBride-Chang, Shu & Wong, 2009; Anderson et al., 2013; Zhou et al., 2017) and promoted the use of *Pinyin* in learning Chinese characters (Shu & Liu, 1994; Lin et al., 2010; Lü, 2017). As these studies were mostly conducted in Chinese or Cantonese-speaking countries, the language environment that these children are exposed to is comparatively different from Singapore's multilingual environment. In Singapore, children, even those from predominantly Mandarin-speaking families, tend to have less exposure to spoken and written forms of Chinese than native speakers.

Furthermore, their diverse language backgrounds also mean that the language proficiency of children studying at the same level is wide-ranging, unlike native speakers or foreign language learners. Although there were a few studies looking at elementary and middle school children learning Chinese as a second or foreign language, the findings may not be directly applicable to the local context as their language background is also fairly different from Singapore's young English-Chinese bilinguals. Having to learn two orthographically distinct scripts simultaneously at a young age, our children may face more difficulties than other second or foreign language learners, who already have a stronger foundation in their first language, both in terms of spoken and written language (Bialystok, McBride-Chang & Luk, 2005; Koda, 2013).

Considering the importance of visual word learning in beginning readers and the difficulty in mastering reading in Chinese among English-Chinese bilinguals, this study aims to study how different modes of Chinese character learning can affect or enhance children's character recognition ability. In view of the different contexts of the overseas studies discussed earlier, it is necessary to examine the relevance and applicability of these research findings in the local context. As developing robust orthographic representations is particularly important in learning to read Chinese, the study will also focus on radical awareness to measure how advanced children are in orthographic learning and examine if this affects their learning outcomes. In particular, there is a need to find out how best to help Singapore children acquire Chinese characters effectively and enhance their orthographic representations of these characters so as to foster their reading development, as well as to cater to diverse needs due to the change of linguistic landscape.

1.1.2 Explanation of Relevant Concepts

Word recognition ability refers to one's performance in retrieving the orthographic, phonological and semantic information of words (Perfetti & Hart, 2002). As this study will focus on the identification of single Chinese characters, we will refer to this ability as 'character recognition ability'.

Radical awareness refers to the perception of semantic radicals and phonetic components that make up compound characters and the knowledge of their roles in cueing the meaning or sound of the character (Shu & Anderson, 1997; Ho, Ng & Ng, 2003).

Orthographic awareness refers to the perception of internal structures of complex characters and the knowledge of the regularities in forming characters, in particular, the positions of semantic

radicals and phonetic components within the spatial structure (Ho et al., 2003; Tong & McBride-Chang, 2010).

1.1.3 Study Aims

This study aims to achieve the following objectives through three character learning experiments.

- 1) To determine the effectiveness of different modes of Chinese character learning by evaluating the learning outcomes;
- 2) To examine the role of radical knowledge in Chinese character learning in young bilinguals;
- 3) To find out which mode(s) of Chinese character learning can enhance the character recognition ability of young bilinguals in Singapore.

1.2 Literature Review

The literature review will cover Chinese visual word recognition models, key processes in single character reading, the role of handwriting and phonological encoding in character learning, and biscriptal literacy development.

1.2.1 Visual Word (Character) Recognition Models

Triangle Model of Word Reading

According to Seidenberg and McClelland's triangle model of word reading (1989), which was based on the connectionist model, the word recognition process involves parallel activation of the orthographic, phonological and semantic constituents of the word via the interconnections among them. These interconnections between lexical constituents are weighted and the activations can vary in strength. During visual word recognition, both the orthography–phonology pathway and orthography–phonology–phonology pathway are activated but at different strengths. In beginning readers who rely on sounding out words, the orthography–phonology–phonology pathway is stronger than the orthography–phonology pathway. As one learns to read, their network structure is encoded with orthographic input. As one becomes more skilled in reading, the additional training or exposure would strengthen the orthography–phonology pathway. In other words, how a word is learnt or encountered affects the strength of its connections among its lexical constituents.

Seidenberg (2005) later used the notion of division of labour, rather than the competitive nature, to describe the pathways between the constituents of a word. The contribution of each pathway is dependent on other pathways and can vary according to factors such as learning experience and word properties. For skilled readers, both the visual and phonological pathways work together during visual word recognition. It is important to note that the model has demonstrated that the

pathways between constituents of a word can be affected by how a word is learnt. Therefore, it is necessary to examine these individual pathways when assessing word recognition ability.

Furthermore, the model can be used to explain the visual word recognition process in all languages as the computational principles are universal (Seidenberg & McClelland, 1989). The language-specific aspects of the process were accounted for in terms of the weight of the interconnections between lexical constituents, characteristics of the encoding and the division of labour between the pathways. In particular, it was noted that the computation of the orthography–phonology pathway was related to the depth of the orthography.

Two Models of Chinese Reading (Character Recognition)

Unlike English, Chinese phonology is relatively opaque, given the large number of homophones and phonetic components with multiple pronunciations. On the other hand, Chinese semantics is relatively transparent, as the semantic radicals often provide reliable cues to the meanings of the characters. Nonetheless, Yang, Zevin, Shu, McCandliss and Li (2006) demonstrated that Seidenberg and McClelland's triangle model of word reading is applicable to the Chinese language despite the differences between the two writing systems. Not only did they establish that the model can replicate the interaction effect of regularity and consistency with character frequency, they also found that the computational principles can also explain the orthography–semantics mapping of the Chinese language. In validating the model, Yang and colleagues (2006) found evidence to suggest that the qualitative differences in reading development across different languages are likely due to system-specific statistical regularities. Although reading acquisition involves the same learning mechanisms, the orthography–semantics pathway is stronger and better developed among Chinese learners.

Differing to some extent from Yang et al.'s model, Perfetti and Liu's Lexical Constituency Model (2006) reflects the time course of the activation of word constituents, that is, phonology is readily activated upon character recognition, while semantics processing is a much slower process. The architecture of the model is similar to the triangle model, with the critical addition of radical as the input level, as character recognition is initiated by orthographic information, that is, radicals. In their model, the semantic and phonological pathways have different strengths, with the latter being stronger due to the determinacy principle which favours form-form connections.

Given that Yang et al.'s model reflects the development trajectory of Chinese learners and a significant number of young participants in this study come from predominantly English-

speaking homes and tend to lack Chinese language proficiency, it is projected that they will have stronger orthography–semantics pathway. However, conditions involving *Pinyin* may result in stronger orthography–phonology pathway if it aids character learning.

Lexical Quality Hypothesis

In line with the triangle model of reading, the Lexical Quality Hypothesis proposes that the identification of words relies on high quality representations of all three lexical constituents, namely orthography, phonology and semantics (Perfetti & Hart, 2002). According to the hypothesis, higher lexical quality refers to better integration of its lexical constituents with robust bidirectional connections, which then allows for easy and consistent retrieval. Low lexical quality, however, hinders comprehension. Ehri (2005) also shared the view that full connections linking the orthographic representations of written words to their phonological and semantic representations have to be established in order to retain words in the memory. For skilled readers, however, character processing becomes more holistic and meaning driven, as their quality of lexical representation improved, allowing them to process forms and meanings concurrently (Tong & McBride, 2010).

While some studies relied on a single dimension measure, e.g. word reading test, to assess character recognition ability, others (Hsiung, Chang, Chen & Sung, 2017; Xu, Chang & Perfetti, 2014; Cao et al. 2013a; Xu et al., 2013) had demonstrated the differences in the strengths of these pathways when learning characters under different conditions. Considering the models discussed above, it is therefore important for this study to examine the individual pathways between lexical constituents concurrently when assessing character recognition ability as an effect of different character learning methods.

1.2.2 Key Processes in Single Character Reading

Chinese Writing System

Written Chinese is a mono-syllabic, morpheme-based logographic system and due to the opacity of Chinese phonology, learners are unable to make use of the grapheme-to-phoneme correspondence that learners of alphabetic languages rely on. Instead, skilled readers rely heavily on the direct access to meanings when reading Chinese characters. While the character is the basic unit, it can be further segmented into radicals/components, subcomponents and strokes. Chinese characters differ based on their internal structure (e.g. left-right, top-down, etc.), combination and configuration (i.e., position) of components within the characters, and stroke patterns (Shu, 2003). Due to the contrasting nature of orthographic structure in written Chinese,

the developmental reading strategies involved will also be different from those of alphabetical languages (Ziegler & Goswami, 2006).

Acquiring radicals/components is a key aspect of literacy development because they initiate character recognition (Perfetti & Liu, 2006). Other than pictograms and ideographs, more than 80% are compound characters made up of a semantic radical and a phonetic component, a unique feature of Chinese literacy. There are about 200 semantic radicals and 1100 phonetic components in the Chinese writing system (Shu, 2003). Among the compound characters, there are regular characters where the phonetic component provides consistent information about the character's pronunciation, semi-regular characters where the phonetic component provides limited information about the character's pronunciation, and irregular characters where the phonetic component does not provide information about the character's pronunciation. There are also semantically transparent characters where the semantic radical provides reliable information about the character's meaning, semi-transparent characters where the semantic radical provides reliable information about the character's meaning, and opaque characters where the semantic radical does not provide information about the character's meaning. Chinese phonology is relatively opaque, given the large number of homophones and phonetic components with multiple pronunciations. On the other hand, Chinese semantics is relatively transparent, as the semantic radicals often provide reliable cues to the meanings of the characters.

In view of the fundamental differences between Chinese and English scripts and writing systems, the cognitive processes underlying Chinese character recognition differ from those underlying English word recognition (Tan, Spinks, Eden, Perfetti & Siok, 2005; Perfetti et al., 2007), as the Chinese reader has to rely heavily on other processes, such as visual and orthographic processing, for fluent word recognition. Cognitive neuroscience research has shown that Chinese reading involves bilateral activation in occipital and fusiform regions for visual processing (Tan et al., 2001) and the left middle frontal gyrus for orthography–phonology conversion and orthography–semantics mapping (Siok, Perfetti, Jin & Tan, 2004).

As highlighted in many research studies (Huang & Hanley, 1994; McBride-Chang, Chow, Zhong, Burgess & Hayward, 2005; Siok & Fletcher, 2001; Tong, McBride-Chang, Shu & Wong, 2009), both visual skills and orthographic skills are vital stepping stones in learning to read Chinese. In other words, relying on oral language as the foundation to learning to read is inadequate, given the deep orthography and visually complex script of the Chinese writing system.

Visual Processing of Chinese Characters

Due to the complex visual-spatial features of the Chinese script, developing precise and lasting orthographic representations is particularly imperative for Chinese character recognition. Yet, the visual complexity of the Chinese script makes it difficult for learners to master the orthographic forms. Learners need to acquire the orthographic forms of between 3000 to 4000 different Chinese characters, in order to read (Perfetti et al., 2007; Li, Shu, McBride-Chang, Liu & Peng, 2012). Although simplified characters appear easier to learn to write, it may actually be harder to learn to read them because there are fewer visual features to help learners distinguish them apart (Chen & Yuen, 1991). Learners of the simplified script may therefore have to rely more on visual cues to discriminate the simplified characters. Unlike alphabetical systems where serial visual memorisation may be sufficient to encode letter string configurations, more visual attention and more cognitive resources are required to decode the visual information in Chinese characters. In order to discriminate the large amount of visual patterns in the Chinese script, learners need to recruit a combination of visual skills, including visual spatial analysis, visual memory skill and visual form constancy, during character recognition.

While Chinese reading models generally emphasise the role of radicals, some models (Perfetti & Tan, 1998; Ding, Peng & Taft, 2004; McBride, 2015) posit that multiple levels of lexical representation are required for character recognition. Based on the multi-level interactive-activation framework for the processing of Chinese words (Taft & Zhu, 1997; Taft & Chung, 1999), feature analysis of the orthographic form is the first stage of visual character recognition. Beginning with the basic features, e.g. strokes, within the Chinese character, each level of the character structure is activated in a hierarchical order by the level below it. Activation at the character level would then activate its semantic and phonological constituents. In a skilled reader, the feature analysis is carried out through component processing, therefore establishing representations at the radical level is important for character acquisition.

A study by Anderson and colleagues (2013) demonstrated that skilled readers have multi-level visual representations of characters, from the stroke to whole character level, whereas intermediate level representations tended to be fuzzy among developing and poor readers. Miller (2002, as cited in McBride-Chang et al., 2005) also demonstrated that children with limited literacy experience appear to process characters in a relatively holistic manner.

During the initial stage of visual character recognition, learners still do not have a perception of the character's internal structure and make-up, therefore they rely on self-selected stroke features

to help them remember the character. During this time, the constituent components within the characters do not appear to be easily separable to beginning readers as they lack the orthographic sensitivity (Chen, Allport, & Marshall, 1996; Ho, Ng, & Ng, 2003; Hsiao & Cottrell, 2009). After some time, they then progress to elementary character recognition (McBride-Chang, 2004), where characters are distinguished based on the visual features of the strokes and how the strokes are arranged within a character (Luo, Chen, Deacon, Zhang & Yin, 2013). This would involve forming a visual representation that captured the prominent visual feature(s) and their spatial relationships with other components/subcomponents within the character (McBride-Chang et al., 2005). For less complex characters with fewer visual cues, learners may holistically compare the visual configuration across characters. For this reason, visual skills have a significant role in the early stages of character acquisition (Siok & Fletcher, 2001). Those with weaker visual skills often face significant difficulty in discriminating visually similar characters and developing character recognition ability.

Chen, Anderson, Li and Shu (2013) found that beginning Chinese readers tend to remain in the visual processing stage for a longer period than beginning English learners, because of the complexity of the Chinese script which requires learners to attend to visual details and shape constancy. It was postulated that Chinese readers need more time to develop advanced, intricate visual skills and a large knowledge base of mental representations of components and characters, in order to progress in their reading development. Over time, as learners gain familiarity with the learnt characters, the amount of visual processing required to identify the characters will be reduced (Perfetti et al., 2007).

Studies have demonstrated the importance of visual skills in early stages of learning to read (Huang & Hanley, 1995; Siok & Fletcher, 2001; Hulme, Zhou, Tong, Lervag & Burgoyne, 2019). Moreover, McBride-Chang and colleagues (2011) found a bidirectional association between visual spatial skill and word reading ability. By demonstrating a link between visual skills and reading, McBride-Chang (2004) opined that visual skills might later help learners progress in their character recognition ability when they are able to visually detect specific orthographic patterns. In addition, Cao and colleagues (2013b) also found evidence that early stage visual processing does help learners form a visual representation that can support its orthography–semantics and orthography–phonology connections in long-term memory.

Given the spatial demands of the square configuration of Chinese characters, readers need to perform a fine-grained visual spatial analysis to activate the lexical constituents of a character

(Siok, Spinks, Jin & Tan, 2009). When learners are able to identify and become familiar with recurring stroke patterns, these familiar stroke patterns will help to reduce their cognitive load when learning new characters containing these patterns. Over time, as they are exposed to more print, they will accumulate a store of mental representations of radicals/components and an awareness of their functions and positions. This is what is referred to as radical knowledge in orthographic learning.

Orthographic Learning of the Chinese Script and Radical Knowledge

From Visual to Orthographic Processing

As learners progress in their reading development, they shift from focusing predominantly on visual features to using orthographic knowledge to read compound characters. This is because as the number of characters learnt expanded substantially, learners can no longer rely on visual processing to identify characters for their memory skills will be taxed to the extent that they become inefficient (McBride-Chang et al., 2005). Over reliance on rote memorisation was found to be associated with poor reading ability (Lin et al., 2009). Moreover, many characters are visually similar, making character recognition more challenging, as one learns more characters. When encountering visually similar characters, being able to tell them apart by distinguishing the components within would be helpful.

As written Chinese is a script–meaning system with a large number of compound characters, its mapping demands are distinct from the alphabetic systems. The reader may need to retain the orthographic form while retrieving its meaning or pronunciation (Perfetti et al., 2007), suggesting that higher working memory capacity may be involved. However, as learners gain character knowledge through their experience with print, they gradually develop perceptual accuracy and fine-tune their sensitivity towards the different patterns and strokes that make up the characters. As they encounter the recurring radical/component across different characters, they develop consolidated mental representations of these radicals/components. This helps to reduce the cognitive load in character recognition, allowing learners to differentiate different characters quickly.

In addition, they also develop knowledge about the functions and regularities of both the semantic radicals and phonetic components. Shu (2003) had observed that learners become sensitive to the useful information provided by semantic radicals as they accumulate more reading experience. By applying their knowledge about orthographic regularities, learners can work with larger orthographic units at the radical/component level, allowing quicker activation of

the visual-input lexicon and faster lexical access, thus reading efficiency is increased significantly (Taft, Zhu & Peng, 1999). For instance, one can identify a character quickly using the phonological information cued by the phonetic component of the compound character, rather than beginning from the lower levels, such as sifting through similar-looking subcomponents or strokes.

Knowledge about orthographic regularities also helps to reduce the reliance on pure visual memorisation for character learning and can be used as an aid to remember new characters efficiently (McBride-Chang, 2004; Ho, Ng & Ng, 2003). As radicals are basic units of processing during character recognition (Taft & Zhu, 1997), even for L2 learners (Wang, Perfetti & Liu, 2003), relying on them as functional orthographic units in learning can aid memory organisation (Xu et al., 2014). Lau and Leung (2004) found evidence that second graders in Hong Kong use radical knowledge to form mental representations of newly learnt characters. In a way, knowledge of sub-lexical components and characters mutually reinforce Chinese literacy development, therefore the ability to acquire and utilise orthographic knowledge is considered a key indicator of reading development.

The Role of Radicals/Components in Character Processing

Since visual character recognition is initiated by radicals, the radical/component is also viewed as an important orthographic unit in processing Chinese characters. The compound character reading process will also involve accessing semantic information encoded within the radicals of characters. An earlier model on character processing by Taft and Zhu (1997) had indicated the occurrence of sub-lexical processing at the radical/component level and suggested that the representations of the high frequency radicals/components would be more easily activated than those of low frequency radicals/components. As a result, characters comprising high frequency radicals/components were recognised more promptly and accurately than those comprising low frequency radicals/components.

In an updated model for character processing (Ding et al., 2004), it was proposed that simple and compound characters are represented at a different levels of the processing system. When a compound character is presented, only sub-lexical radicals/components that are in the same position will be activated. The activation of each radical/component is also accompanied by the activation of the character version of that radical/component. In order for a compound character to be recognised, the links between its components must be activated and the activation must spread within each other, so that the visual input can be accurately and promptly matched with

the target character (Pak et al., 2005). Simple characters, on the other hand, are activated by stroke-based features (Ding et al., 2004). Apart from the activation of shared features, inappropriate competitor units within the same level, such as similar and partly activated representations, will also be inhibited. Based on this model, it is important to build up a store of mental representations of the radicals/components so that the activation and inhibition processes can be accurate and spontaneous.

Similarly, Taft, Zhu and Peng (1999) and Perfetti and Liu (2006) also supported the hypothesis that character recognition involved the activation of representations at both the radical and character level. Chen, Allport and Marshall (1996) defined constituent components (i.e. recurrent, integral stroke patterns) as a functional orthographic unit due to their functional role in the visual-spatial processing of composite characters, rather than individual strokes. In view of their finding, they posited that learners develop sensitivity towards radicals and components through exposure to many different characters which contain the same recurring units.

Orthographic Processing & Knowledge

Considering the important role of radicals/components in the Chinese writing system according to the review above, orthographic processing is a core skill that learners need in order to develop character recognition ability. Orthographic processing skills refer to an understanding of how graphemic units should be written correctly in a given script (McBride-Chang, 2004) and the sensitivity to orthographic regularities of a written language (Castles and Nation, 2006). In written Chinese, this includes regularities of the character structure and functional and positional regularities of the radicals/components within characters (Tong & McBride, 2014). Knowledge about the regularities of an orthography is also known as orthographic knowledge. According to Ho and colleagues (2003), orthographic knowledge is developed through repeated encounters with the orthographic structures of a wide range of Chinese characters. With this knowledge, it was posited that learners acquire sensitivity towards orthographic regularities through statistical learning and rule-learning (Tong & McBride, 2014). Learners are able to subconsciously ‘notice’ the statistical properties and rules exhibited in the written language and use them in orthographic regularity learning.

Despite the lack of explicit formal instruction on semantic radicals and phonetic components in most Mandarin-speaking regions, children do acquire rudimentary orthographic knowledge of Chinese characters, such as the functional regularity and positional constraints of the sub-lexical components, through statistical learning and rule-forming at an early age and this knowledge

gradually becomes more specific and sophisticated with age and reading experience (Tong & McBride, 2014; McBride-Chang, Lin Fong & Shu, 2010; Ho et al., 2003). It was also suggested that orthographic knowledge development in Chinese follows a particular sequence, that is, character configuration, character structure, radical information, positional and functional regularities of semantic radicals and phonetic components (Ho, Yau and Au, 2003b, as cited in Yeung, Ho, Chan & Chung, 2016).

In alphabetical languages, awareness of the orthographic regularity, including the rules on the spatial and sequential order of orthographic units, affects one's word recognition ability (Berninger, 1994, as cited in Ho et al., 2003). In written Chinese, the positional regularity of radicals plays a crucial role in the orthographic structure of characters, hence radical awareness or knowledge is important for character acquisition. Stanovich and colleagues (1991) reviewed some studies on orthographic skills and reading and found that orthographic skills contributed a unique variance to the reading skill of both adults and children, after controlling for phonological processing skills. Liu and colleagues (2017) also found orthographic knowledge to be a strong predictor of word reading ability among Chinese elementary students, regardless of one's reading proficiency. This suggests that learners were making use of the orthographic cues in their reading process (McBride-Chang, 2004).

Considering the importance of orthographic knowledge on literacy development, it is therefore essential for learners to develop an awareness, and eventually acquire a good knowledge, of the structures and configurations of the Chinese characters, as well as the form and position of the components within the characters. In particular, as positional constraints of sub-lexical components and stroke patterns form a key part of Chinese orthographic regularity, developing an awareness of such positional constraints will help learners to recognise and distinguish between characters accurately, especially for characters comprising the same constituent components in different spatial structures (Tong & McBride, 2014).

Visual Chunking

To overcome the issue of inconsistency in grapheme-to-phoneme mapping in deep orthographies, learners also make use of bigger processing units, like rimes, in orthography–phonology mapping (Ziegler & Goswami, 2006). The Chinese system is somewhat similar to the English system, as learners use consistent information derived from characters/words sharing the same orthographic chunks. However, the Chinese phonetic components are far less reliable in their consistency. Shu and colleagues (2003) estimated that only 39% of compound characters in the Chinese

primary school textbooks contain phonetic components that provide useful cues to their pronunciation. Nonetheless, skilled readers still chunk strokes into larger perceptual units, such as radicals and simple characters, and apply radical knowledge to access the sounds and meanings of the characters as this increases the efficiency of compound character processing (Anderson et al., 2013).

Other studies also have demonstrated the effectiveness of visual chunking in encoding unfamiliar Chinese characters (Chang et al., 2014) and the association between visual chunking skills and children's reading ability (Pak et al., 2005).

A small group of Chinese readers, however, are highly proficient in reading but have much poorer writing ability ((Tso, Au & Hsiao, 2012). Considering that it is cognitively more demanding to write a Chinese character, it is likely that this group uses a more efficient strategy, i.e. holistic chunking, to recognise Chinese characters, without decomposing into its constituents, a process similar to face recognition. However, it should be noted that being able to overcome the orthographic difficulties in reading Chinese while working with a big processing unit is indeed unique.

Semantic Radicals & Phonetic Components

Studies have yielded evidence that components in semantic-phonetic compound characters play a key role in character processing (Feldman & Siok, 1999; Shu & Anderson, 1997). Therefore, children's radical knowledge, which forms the core basis of learning to read Chinese, is highly associated with reading ability (Ho et al., 2003). In their proposed developmental reading models, Tong and McBride (2010) found that the early development of radical awareness is regarded as a subsumed construct under orthographic processing in beginning readers, then progress into an independent construct among intermediate readers and eventually became integrated as a part of orthographic processing in older readers. Shu and Anderson (1997) found that proficient intermediate readers were able to derive the meaning of unfamiliar words through radical analysis.

Similarly, several studies on young native speakers have highlighted the important role of visual-orthographic skills in young Chinese learners' reading development (Tong et al., 2009; Anderson et al., 2013; Zhou et al., 2017). Studies of Chinese literacy development on children in Hong Kong and China have found that the processing of Chinese characters becomes more holistic and children's sensitivity to components (i.e. radicals) is more fine-tuned as they progress in word

reading with age and reading experience (Tong & McBride, 2010; Anderson et al., 2013; Tso, Cheung, Au & Hsiao, 2017). Anderson and colleagues (2013) found that children with advance reading skills are better in perceptual chunking of orthographic patterns, which is acquired over the years during elementary school, and this ability to see recurrent patterns was found to be correlated to one's reading proficiency. According to Tong and McBride (2010), being able to process forms and meanings simultaneously is an indication of improved quality of lexical representation. Drawing learners' attention to recurring components helps to strengthen learners' visual-orthographic representations of characters learnt and the acquisition of recurring components, in turn, helps to provide an anchor during character learning (Chang et al., 2014).

Furthermore, Li and McBride (2014) provided evidence of significant semantic priming effect over structure priming to demonstrate the role of semantic links in the organisation of children's mental lexicon. This suggests that the emphasis on semantic radicals may aid word learning, in line with other research on Chinese word reading (Feldman & Siok, 1999; Ku & Anderson, 2001; Ho et al., 2003). Yeung and colleagues (2016) also found close links between orthographic memory of semantic radicals and reading comprehension.

Although the phonetic component may not always be reliable in indicating the sound of a semantic-phonetic compound character, there is still some form of orthography-phonology correspondence (Chen, 1993) which Chinese readers can rely on. According to studies by Ho and Bryant (1997) and Li, Wang, Castles, Hsieh and Marinus (2018), young native learners were able to derive and learn the sounds of Chinese characters through their phonetic components. In Ho and Bryant's (1997) study, learners can better remember the sounds of new compound characters if the phonetic components are familiar to them. Li, Anderson, Nagy and Zhang (2002) compared the importance of character-level morphological awareness, which comprises morpheme awareness, homograph awareness and radical awareness, and phonological awareness in learning to read Chinese among native children at different stages of reading development and concluded that character-level morphological awareness, related to the knowledge of semantic radicals, is more important than phonological awareness.

Even without handwriting, orthographic-based typewriting may help to boost or preserve orthographic knowledge (Siok & Liu, 2018), reinforcing the importance of visual-orthographic skills in Chinese reading.

All the above findings highlight the need to focus on components, especially radicals, during the early stage of Chinese word learning. Indeed, studies have shown that explicit or deliberate instruction on radicals can facilitate character acquisition in children (Lam & McBride-Chang, 2013) and adult foreign/second language learners (Taft & Chung, 1999; Chang et al., 2014; Xu et al., 2014; Li et al., 2018; Jin, 2003). Yet in another report on the 2007 Chinese language syllabus by Liu and Zhao (2008), it was noted that teachers frequently used flashcards, known as *Zi Baobao* (Baby characters), to teach character recognition and word combinations. In the lessons observed in the report, teachers often conduct drills on recognising whole characters. In addition, the powerpoint was also used to introduce stroke sequence when teaching character recognition.

Based on the review above, visual and orthographic processing are important processes in early Chinese character recognition, that is, before one becomes skilled enough to achieve automaticity in word recognition. For learners developing character recognition ability, different methods of learning Chinese characters may have varying effects on these processes. Therefore, the current study will examine if different learning methods have any differential effects on children's visual analysis skills and orthographic awareness after the training sessions.

Furthermore, the literature has also demonstrated that one's orthographic knowledge facilitates subsequent character learning. Therefore, it is also necessary to consider one's level of orthographic knowledge when examining the effects of character learning. Taking into account the age range of the participants and their limited Chinese literacy learning experience, the thesis will focus on children's radical awareness as its effect is more prominent among learners at the emergent-literacy stage (Tong & McBride-Chang, 2010; Xu et al., 2014).

1.2.3 The Role of Handwriting & Phonological Encoding in Chinese Word (Character) Learning

When beginning to learn a new script, one needs to consciously attend to these features of the new script. As the Chinese script is visually complex in terms of the configuration and composition of its characters, it is important for novice learners to acquire accurate orthographic representations of the unique stroke patterns of individual characters, as well as visual-orthographic skills, in order to recognise Chinese characters and eventually develop automatic word recognition skills.

Handwriting

A number of studies (Hsiung et al., 2017; Cao et al., 2013a; Xu, Chang, Zhang & Perfetti, 2013; Guan et al., 2011), involving native children and adult second/foreign language learners, have

demonstrated that repeated writing practice enhances the orthographic representations of Chinese characters and orthography-semantics mapping. Therefore, writing has been argued to be a facilitating effect on learning to read Chinese characters.

This writing-on-reading effect involves two mechanisms, namely orthographic awareness and motor programming (Tan et al., 2005). Handwriting practice focuses learner's attention on the stroke composition and internal structure of characters, supporting the formation of precise orthographic representations, as well as robust orthography-semantics and orthography-phonology connections (Tan et al, 2005). Hand movement during writing also helps to couple sensory-motor information to the mental representations, forming long-term graphomotor memories of Chinese characters (Tan et al, 2005). In Tan et al.'s (2005) study, writing, in the form of character and pseudocharacter copying, was found to be a predictor of Chinese children's reading ability, supporting the writing-on-reading effect.

A recent study by Nakamura et al. (2012) discovered that there are two universal subsystems underlying the reading of handwritten words, one for identifying visual features and one for coding the motor patterns of handwriting gestures, and that the effects of the gestural pathway appear to be greater in reading Chinese characters. This implies that writing could contribute to word recognition, especially among beginners, as they rely on this premotor component for coding handwriting gestures to establish strong links with stored orthographic representations during the early stages of character learning (Lagarrigue et al., 2017).

Stroke Sequence

In handwriting practice, there are different methods of directing learner's attention to the visual-orthographic properties of characters to facilitate character learning. Stroke sequence, the commonly used method, provides a serial coding of the strokes in the character, which forms a part of the mental representation and is used as a cue to help learners access the word in the mental lexicon (Flores d'Arcais, 1994). Flores d'Arcais (1994) demonstrated the effect of serial coding in stroke sequence by showing that "early" strokes were better cues for word retrieval than "late" strokes. In addition, Boon (2010) also found a prominent effect of stroke sequence in the memory representation of characters and reading performance, suggesting that the stroke is a functional unit in processing Chinese characters. Preschool children in Hong Kong were also found to have enhanced orthographic awareness through learning stroke sequence (Lam & Chang, 2013). On the other hand, there were also studies that found no significant impact in

emphasising stroke sequence among adult foreign language learners (Hsiung et al., 2017) and primary school children in Hong Kong (Lo, Yeung, Ho, Chan & Chung, 2016).

A small-scale study on dyslexic bilingual children in Singapore showed that the stroke sequence method resulted in a higher rate of character learning, compared to viewing characters with *Pinyin* (Lee & Poon, 2014).

Phonological Encoding through *Pinyin*

Other than stroke sequence, phonological encoding is also often used to support character learning. As the Chinese script is a mono-syllabic, morpheme-based logographic system, its lack of grapheme-to-phoneme conversion means that learners need additional support, such as a phonetic tool, to learn the sounds of Chinese words. *Hanyu Pinyin* is an established phonetic coding system of the Chinese script, which uses 26 standard English letters and ‘ü’ to code the 21 onsets, 35 rimes and symbols to indicate the lexical tones of Chinese characters. The sounds of Chinese onsets and rimes are similar to English consonants and vowels to some extent. This system is widely used as a means to facilitate the recognition of Chinese characters both in China and Singapore. However, there are differing views about the use of *Pinyin* in helping learners read Chinese.

Some have defended the role of phonological awareness and the use of *Pinyin* in Chinese reading development. In a way, the alphabetic coding supports the formation of phonological representation. Siok and Fletcher (2001) verified the role of phonological awareness in the later stage of character acquisition and provided evidence to show that *Pinyin* can help native children’s Chinese reading development. Studies have also demonstrated that Chinese and Taiwanese children do focus on subsyllabic units as they learn to read Chinese characters through *Pinyin* or *Zhuyin Fuhao* (Huang & Handley, 1995; Leong, Cheng & Tan, 2005). In another study by Guan and colleagues (2011) on adult second language learners, it was evident that *Pinyin* enhances the phonological representations and the orthography-phonology connection during Chinese word learning and can therefore help to stabilise the pronunciations. In addition, *Pinyin* training has been found to foster the phonological sensitivity of native Chinese, especially syllable awareness (McBride-Chang, Bialystok, Chong & Li, 2004) and phonemic awareness (Cheung, Chen, Lai, Wong & Hills, 2001). Yan, Miller, Li and Shu (2008) also suggested that *Pinyin* is useful for beginning readers as it allowed them to use phonological mediation for lexical access to familiar concepts.

Other studies, however, found phonological awareness to be less salient in learning to read Chinese, unlike reading alphabetic scripts (Huang & Hanley, 1995; Yeung et al., 2011). Although phonological awareness can also affect the acquisition of Chinese characters, its extent is less than word-level morphological awareness (Ku & Anderson, 2001), which refers to the understanding of the morphological structure of compound words, and orthographic knowledge (Yeung et al., 2011). It is also likely that the enhanced phonological awareness in bilinguals may not necessarily promote literacy development if the two writing systems are different (Bialystok, 2006). Yin et al. (2011) also demonstrated that *Pinyin* knowledge does not directly contribute to Chinese reading, but is mediated by phonological awareness.

In terms of character learning, Chung (2002) provided evidence to show that the simultaneous presentation of *Pinyin* and Chinese character causes an interference which affects the initial attention to the target character and hence, the acquisition of its pronunciation. Shu and Liu (1994), on the other hand, validated the use of *Pinyin* in learning characters of familiar concepts.

Tan and colleagues (2013) examined the high proportions of poor readers in primary schools in three Chinese cities and discovered that the use of *Pinyin* input was negatively correlated with the children's reading scores, especially at the higher grade. There was no evidence that their reading ability was affected by non-verbal IQ and the time on computer use. Comparing different keyboard input methods, Siok and Liu (2018) also noted that the increasing use of pronunciation-based typewriting could negatively affect reading accuracy. It appears that the focus on phonology, through *Pinyin*, may be insufficient to sustain strong links between orthography, semantic and phonological constituents of the word.

Although children in Singapore is less likely to use *Pinyin* input to such an extent, their reliance on *Hanyu Pinyin* when reading Chinese is likely to shift their focus away from visual orthographic properties when learning Chinese characters. A recent incident involving a wrong Chinese character (读) being used for the slogan of the Speak Mandarin Campaign at a launch event (reported in *The Straits Times* on 10 July 2017) has argued to be a possible outcome of how *Pinyin* input has reduces one's sensitivity towards orthographic properties.

As oral language provides the foundation for literacy learning, stronger oral language proficiency is often associated with better reading skills (Zhou & McBride, 2018). In the case of L2 learners whose oral proficiency is still developing, their L2 reading development will somewhat be limited by their L2 oral proficiency (Swanson, Rosston, Gerber & Solari, 2008), particularly their

vocabulary knowledge (Zhou & McBride, 2018). Although learning *Pinyin* can help in some way with the mapping between spoken language and writing system by activating phonological information to trigger semantic processing in character reading (Spinks, Liu, Perfetti, & Tan, 2000), it may also cause L2 children to overly rely on *Pinyin* and could not focus on developing sensitivity towards orthographic structures and orthographic regularities, thus hindering the development of their character recognition ability.

Therefore, it is important to consider the effects of *Pinyin* in Chinese reading acquisition when examining the different learning methods.

Singapore Study on the Use of *Pinyin*

According to a study by Liow and Tng (2003) in the Singapore context, bilingual bicultural children's literacy acquisition is influenced by their home language. Among the children at Primary 5, the high correlation between English word spelling and *Pinyin* spelling suggested the possibility of phonemic awareness transfer from EL to *Pinyin*. This was despite an initial delay in phonological processing among predominantly Mandarin-speaking children at Primary 3. The study also found a correlation between Chinese character reading and *Pinyin* spelling among predominantly English-speaking children at Primary 5, suggesting that these children had relied on *Pinyin* to read Chinese characters. However, the Mandarin speakers obtained higher scores in Chinese character reading than English speakers at Primary 5. This implies that the effect of *Pinyin* in facilitating Chinese character reading may be limited in some way. While the stronger reading skills of the Mandarin speakers could be explained by the link between vocabulary knowledge and phonological memory skills (Thorn & Gathercole, 1999), it is also likely that relying less on *Pinyin* allows them to focus better on the visual properties of the characters to build up orthographic knowledge.

Currently, Singapore children start to learn *Pinyin* at Primary One. Among the weaker students, their skills in English phonics is likely to be at the developing stage, therefore, the phonemic awareness transfer from English to *Pinyin* may be problematic, causing interference or confusion, rather than supporting character reading. Another possibility is that the weak foundation in spoken Mandarin is preventing beginning Chinese readers from relying upon their developing spoken language resources to recognise Chinese words (Everson, 1998).

1.2.4 Bicultural Literacy Development

According to Bialystok (2006), young bilinguals learning to read in two different writing systems may be confused by the fundamentals underpinning each system. In her study, the Chinese–English learners benefitted less from the transfer of skills across languages. It is hard to learn these two scripts as their general mapping principles and the mapping details differ greatly. Some studies, on the other hand, found that there are shared processes of Chinese-English reading by establishing the transferability in bilinguals’ phonological and morphological (i.e. compounding awareness) skills across languages (Wang, Yang & Cheng, 2009; Zhang, Koda & Sun, 2012). In particular, Wang et al.’s (2009) study did not find cross-language transfer in terms of orthographic skills which are deemed to be language-specific. As high language proficiency is required to facilitate cross-linguistic transfer (Zhang et al., 2009; Zhang & Koda, 2012), balanced bilinguals are likely to face less difficulties in biscriptal literacy acquisition.

Since phonological awareness is less important in Chinese reading than character-level morphological awareness (Li et al., 2002), the transfer benefit may be limited to *Pinyin* learning and discrimination of similar-sounding characters. Therefore, for unbalanced bilinguals who are stronger in the English language, the core component skill of phonological analysis is not as useful when learning to read Chinese.

Furthermore, morphological awareness (i.e. compounding awareness) was found to account for early learners’ initial ability and growth rate in Chinese character reading (Lin, Sun & McBride, 2019). This implied that unbalanced bilinguals who are less experienced in written Chinese, may be at risk of falling behind in their Chinese reading development.

Given that the extent to which unbalanced bilinguals can transfer skills across languages is limited, they are likely to face difficulties when learning to read in Chinese. In the case of Singapore, a significant group of children are learning Chinese as a second language (L2) and because the L2 is neither the dominant societal language nor a non-dominant home language, they have limited opportunities to L2 exposure and usage, and lack intrinsic motivation, making L2 learning even more arduous.

Apart from developmental issues such as dyslexia, there are two likely reasons that may undermine children’s reading skills. Firstly, these are L2 learners with limited oral proficiency in Mandarin (Bialystok et al., 2005) and secondly, these children may lack home literacy experiences, as demonstrated by Sun’s (2019) study which found that majority of Singaporean children do not have frequent print exposure in Chinese and have less Chinese books than

English ones. As Chinese has numerous homophones, learners need to build up intact semantic and orthographic representations of these characters to be able to differentiate them. This would be challenging for learners with limited vocabulary knowledge. For L2 learners whose L2 oral proficiency is still developing, there may be a significant number of unfamiliar orthographic forms that they have to learn which are not yet established in their L2 oral vocabulary. As a result, learners can only rely on the visual form of the characters for lexical access (Wang et al., 2003). This makes character learning extremely difficult for such L2 learners, as this reliance on the visual forms for lexical access may hinder the development of sensitivity towards orthographic structures and orthographic regularities. When learners are stuck at the visual processing stage and having to deal with a large number of characters, they will require a greater visual memory load to memorise the orthographic forms of the characters.

The cognitive demands for reading different orthographies, including the sensitivity to visual features, differ according to the properties of each orthography. Since the structure of orthographic forms in the Chinese script involve much more visual complexity than the simple linear structure of alphabetic orthographies, Chinese character learning involve much more visual and orthographic processing than English word learning. According to the System Accommodation Hypothesis, learning to read Chinese as second language is substantially more difficult than learning to read another alphabetical language (Perfetti & Liu, 2005; Perfetti et al., 2007). For Chinese native speakers to learn English, they can tap on the existing cognitive resources to process English words. However, for English native speakers to learn Chinese as a second/foreign language, they have to recruit additional cognitive resources that are not needed in reading English (e.g. right visual areas) to process the visually more complex Chinese characters. This means that English-Chinese bilingual children have to acquire an even bigger set of visual skills to cater to biscriptal reading. In a way, this higher demand for visual and orthographic processing could greatly influence the trajectory of L2 reading development. Moreover, low ability learners may also face difficulty having to manipulate both sounds and visual information during reading. In particular, the visual workload involved in Chinese character recognition may pose a challenge to these learners. An error analysis study noted that poor readers tended to make errors related to phonological and visual processing during Chinese text reading (Wu & Anderson, 2007).

A study comparing character processing skills among native and L2 learners in a bilingual international school in Hong Kong found that L2 learners lagged behind native learners in their Chinese reading development. In terms of working memory, both groups performed similarly for

phonological working memory, but the L2 learners were weaker in their general working memory skills (Zhou & McBride, 2018). The association between weak working memory skills and poor reading indicates that L2 learners were somewhat deficient in their visuo-spatial working memory skills, thus preventing them from utilising both phonological and visual-spatial working memory efficiently for character recognition. The same study also found that L2 learners were less adept at utilising their orthographic awareness skills and orthographic memory for Chinese character reading (Zhou & McBride, 2018). Their delayed orthographic development could be attributed to the inadequacy of home literacy experiences. To compensate for this, they had to rely heavily on their visual spatial skills for character reading. It was also revealed that L2 learners tended to have limited oral vocabulary as they were lacking in their L2 oral proficiency (Zhou & McBride, 2018). This means that in many characters that they learnt, the semantics and phonology connections might be weak, making it more difficult for them to associate the lexical information with the orthographic form. It could also be possible that the high demand of resources for visual processing had compromised the strengths of semantics and phonology connections.

Summing the above, stark differences between the writing systems and the lack of proficiency in the spoken language and print exposure are challenging factors of biscriptal literacy development. It will be of interest to find out any of the learning methods is effective in remediating the effects of these factors. Since orthographic processing is language specific, examining the individual lexical pathways of character recognition concurrently will help to see if any of the learning methods is effective in helping young English–Chinese bilinguals in specific aspects, namely their orthographic processing skills, and strengthening the phonological and semantic representations.

It is hoped that findings from this study will contribute towards the small but growing literature on early reading and biscriptal literacy involving non-alphabetic writing systems.

CHAPTER TWO METHODS

2.1 Research Questions

Using several training paradigms, this study sought to gather evidence on the effects of different modes of Chinese character learning among Primary One students in Singapore by comparing the differences in their learning outcomes across various learning conditions. The study examined a total of six learning conditions over three experiments using the same sets of Chinese characters. The learning conditions involved different modalities (viewing, free writing and structured writing) and encoding methods (*Pinyin*, whole character, stroke sequence and radical knowledge). To assess the learning outcomes, the retrieval and retention of orthographic forms, orthography–phonology and orthography–semantics connections after undergoing different learning conditions were measured. The transfer effects of the trained characters on children’s visual analysis skills and orthographic awareness were also assessed for each learning condition. In addition, the study also investigated whether children’s level of radical awareness would mediate the effectiveness of specific learning conditions. By looking into the immediate, retention and transfer effects of using different learning modalities and encoding methods in character learning, the study provided a comprehensive evaluation of the different character learning modes.

Building upon the literature, the following research questions will be addressed in the respective experiments:

- Experiment 1: Does learning Chinese characters along with *Pinyin* interfere with or facilitate the accuracy of character recognition?
- Experiment 2: Does learning Chinese characters through repeated practice of character writing enhance the accuracy of character recognition?
- Experiment 3: Does learning Chinese characters by focusing on radical awareness during writing practice enhance the accuracy of character recognition?

By involving children from the same population and comparing their data across the three experiments, the study also examined the following:

- Do the different modalities, namely viewing the character, free writing of the character and structured writing of the character, have different effects on children’s visual analysis skills and orthographic awareness?

In each of the above analyses, the study also considered the question:

- Does children's level of radical awareness affect the effectiveness of different learning conditions?

It is hoped that this study would provide evidence on which mode(s) of character learning best benefit bilingual beginning readers in the context of learning a non-alphabetic language and will lead to significant implications for the Chinese language pedagogy. The research findings would inform if the existing curriculum and pedagogy is adequate and also serve as an important reference for respective stakeholders in making informed decisions about best practices for helping young learners to read in Chinese.

2.2 Participants

Seventy-one English-Chinese bilingual children participated in this study. The children were randomly assigned to the three experiments. However, five children were excluded from the analysis, as they had performed below chance during the immediate evaluation. This implies that they had difficulty staying focused during the training. There were no significant differences in the radical awareness (RA) scores among the three groups of children, $F(2, 63) = 0.35, p = .71$, indicating that the children in each experiment were matched in terms of their level of RA. Three children whose RA scores fell outside two standard deviations of the mean score were later excluded from the analysis, in order to obtain a more representative sample. Of the remaining 63 children, 22 were assigned to Experiment 1 (13 males, mean age 7.28 years), 21 to Experiment 2 (12 males, mean age 7.36 years) and 20 to Experiment 3 (10 males, mean age 7.47 years).

Parents' and children's consent was sought prior to the experiments and all children received a set of markers for their participation. Majority of the participants were recruited through eight student care centres located islandwide and the remaining few were recruited through word-of-mouth method. All experiments were conducted on a one-to-one basis, and all involved research assistants were trained to follow the standardised experiment procedures strictly. For children recruited through student care centres, the experiments were conducted in a quiet space within the compounds of the centres or schools. For children recruited through word-of-mouth method, the experiments were conducted in their homes.

All participants were generally healthy, with no known developmental, cognitive issues or medical conditions. At the time of experiments, these children were studying in Primary One in mainstream schools and had been taking the Chinese language as their mother tongue subject. Ethics approval has been obtained from the Nanyang Technological University (NTU) Institutional Review Board.

Parents were asked to complete a questionnaire to gather information about the participants' home language and literacy practices. Data from the parent questionnaire revealed that about 80% of the participants either had balanced exposure to both English and Mandarin or more exposure to English than Mandarin at home. The differences in terms of participants' home language did not vary significantly across the three experiments. For further details, please refer to Appendix 1. As for home literacy environment and practices, 60.94% of the participants had less than 20 Chinese books at home and 79.69% of the parents only read Chinese books to their children once in a while or rarely did so. On average, participants were exposed to Chinese print at about age three. The differences in terms of participants' home literacy environment and practices also did not vary significantly across the three experiments. For further details, please refer to Appendix 1.

2.3 Design

In each experiment, the within-subjects design was used where the same set of participants went through both the experimental and control learning conditions to learn two sets of similar characters. To eliminate sequence effects, the order of the learning conditions and the sets of training characters used was counterbalanced. The presentation order of the training characters was also randomised. All participants were subject to the following phases over two sessions:

- the first session comprised a pre-test on radical awareness and two training sessions with immediate evaluation (one for each learning condition);
- the second session, which took place approximately one week after the first session, comprised the delayed evaluation and post-test.

Each experiment used the same pair of character sets for the training sessions and the same set of materials for the pre-test, immediate and delayed evaluation, and post-test. Other than the training stimuli and learning materials which varied according to the encoding method for each learning condition, all other potential intervening variables, e.g. time of exposure, training and test procedures, were controlled for as much as possible across all three experiments.

The within-subjects design was adopted in order to eliminate the variability caused by individual differences when examining the differences between learning conditions (Witte & Witte, 2009).

To examine the first research question on the interference effects of *Pinyin*, Experiment 1 compared the viewing modality with and without *Pinyin*, as the experimental and control conditions respectively.

To examine the second research question on the effects of repeated character writing, Experiment 2 compared the free writing modality under two conditions: repeated character writing (without guidance) and repeated *Pinyin* writing. The *Pinyin* writing condition was selected as the other condition, rather than translation writing, as it would provide further evidence on the effects of *Pinyin* on character learning.

To examine the third research question on the effects of focusing on radical awareness (RA) during character learning, Experiment 3 compared the structured writing modality, which was repeated character writing with guidance on how to write the characters. This comparison would determine if the systematic focus on RA could provide better learning outcomes than the traditional approach of learning stroke sequence.

As each experiment focused on one modality (namely, viewing, free writing and structured writing, selected data across all three experiments were later compared using a between-subjects analysis to examine the differential effects across the three modalities. This comparison was possible because all three experiments adopted the same design.

2.4 Training Stimuli & Learning Materials

In each experiment, participants learnt two sets of six unknown compound characters (four with left-right structure and two with top-bottom structure) to familiar concepts across two learning conditions.

Both sets of training characters were matched in terms of their strokes (Mean: 11-12 strokes), chunks, (Mean: 3-4 chunks), frequency and concreteness. In each set, there were four semantically transparent characters, containing common semantic radicals that were not taught as radicals in Primary One, and two semi-transparent characters containing familiar components whose character versions had been taught in Primary One.

The training stimuli used single Chinese characters so that the character learning process was similar to what beginning readers go through to develop word recognition skills. Using single Chinese characters, instead of two-character compound words, as the training stimuli also made it possible to select two comparable sets of characters for the learning conditions, without the interference of the constituent characters within the compound words. By focusing on single Chinese characters, it would be possible to observe any transfer effect in visual analysis skills and orthographic awareness.

Short English translations were provided in the training stimuli to help children map the character to its meaning quickly. The English translations contained high frequency words which were easily understood by the children, regardless of their level of English proficiency. It was found that learning novel words with meanings enhances the lexical consolidation (Henderson, Weighall & Gaskell, 2013). In all learning conditions, the research assistants would first pronounce the characters for the children, then read out the English translations of the characters.

The visual layout of the training stimuli and learning materials was kept consistent across all learning conditions, except for aspects that drew the children's attention to the characters for each encoding method. In Experiment 1, only flash cards displaying the characters and English translations were used. The *Pinyin* of each character was also printed on the flash cards used in the *Pinyin* condition. In Experiment 2, both flash cards and handwriting worksheets were used. In both conditions, the *Pinyin* of each character was also printed on the worksheets. Blanks were provided in the worksheets for children to write the characters or *Pinyin*. In Experiment 3, both flash cards and handwriting worksheets were used. In the RA-focused condition, the semantic radicals and familiar components of the characters were highlighted in different colours. In the worksheets, the characters were broken down into two chunks and the English meaning of the semantic radicals were provided. In the stroke sequence condition, the whole characters were presented in black and the stroke sequence of each character was provided in the worksheets.

For samples of the training materials for each learning condition, refer to Appendix 2.

2.5 Procedure

Each participant was involved in two days of field work, with each session lasting about 1.5 hours. During the first session, participants began with the pre-test, then took a short break before starting the first training session. Immediately after learning the first set of six characters, they would be evaluated on their learning outcomes. After a 15-minute break, they return to learn

a second set of characters in the other learning condition within the same experiment. Immediately after learning the second set of characters, they would be evaluated on their learning outcomes.

At the start of the training sessions, participants were instructed to remember the orthographic form, meanings and the pronunciations of the characters learnt. During each training session, participants were given the chance to repeat the pronunciations and were corrected on their pronunciations. They also had to repeat the English translations of the characters. They were then given 90 seconds to practise writing each character, followed by a revision. In the viewing modality, the 90-second provision was split into three 30-second segments. In all conditions, participants had to go through each character three times before the evaluation.

A week later, the second session began with participants going through the first set of characters learnt previously, and repeated the same evaluation in the first session. Then they went through the second set of characters learnt, followed by the evaluation. After a short break, they had to complete the post-test which assessed their visual analysis skills and orthographic awareness of the learnt radicals, components and subcomponents. Participants were also given another short break during the post-test.

For samples of the training instructions for each learning condition, refer to Appendix 3.

2.6 Measures

The pre-test and post-test used in this study were adapted from or developed based on behavioural tasks of previous studies in Hong Kong and China (Tong & McBride-Chang, 2010; Anderson et al., 2013). Participants' performances in these tests were compared to make inferences about the effects of various learning conditions.

2.6.1 Pre-Test: Assessing Level of Radical Awareness (RA)

The pre-test assessed children's level of RA by measuring the following knowledge areas in a set of familiar semantic radicals and phonetic components:

- knowledge of functions of semantic radicals and phonetic components through a picture selection task,
- knowledge of functions and positions of semantic radicals through a picture-character mapping task,

- knowledge of functions and positions of phonetic components through a component-matching task.

Pre-Test Task 1: Picture Selection Task

The design of the picture selection task was based on Tong and McBride-Chang's (2010) semantic category choice task. Participants were presented four line drawings and asked to choose one that best depicted the meaning of the target pseudocharacter. The target pseudocharacters contained bound and free radicals from Primary One and Two word lists and the items were arranged based on the order of appearance in the word lists and children's familiarity (small pilot sample). A practice item was included to familiarise participants with the task. Line drawings of the task were sourced from the International Picture Naming Project at the UCSD Centre for Research in Language, Clipart Panda and Open Clip Art.

Pre-Test Task 2: Picture-Character Mapping Task

The picture-character mapping task was developed according to Tong and McBride-Chang's (2010) orthosemantic awareness task, which focused on the knowledge of semantic radicals. Participants were presented a line drawing and asked to select one of the four given characters that best matched the meaning depicted by the drawing. The target pseudocharacter was created based on a real character featured in Primary One word list and replacing the phonetic component. The other three options comprised a variation of the target pseudocharacter where the positions of the components were reversed, a character with the correct phonetic component and an incorrect radical, and the reverse variation of this character. The items were arranged based on the order of appearance in the word list and children's familiarity (small pilot sample). Two practice items were included to familiarise participants with the task. Line drawings of the task were also sourced from the International Picture Naming Project at the UCSD Centre for Research in Language, Clipart Panda and Open Clip Art.

Pre-Test Task 3: Phonetic Component Mapping Task

The phonetic component mapping task adopted the design of Tong and McBride-Chang's (2010) orthophonetic awareness task. Participants were presented four real characters and asked to select the one that best matched the sound of the target pseudocharacter. The target pseudocharacter was created based on a real character featured in Primary One word list and replacing the semantic radical. Apart from the real character used to create the pseudocharacter, the other three options comprised a character sharing the same phonetic component in a different position, a character sharing the same semantic radical as the target pseudocharacter and a

character that differed in both the semantic radical and phonetic component. The items were arranged based on the order of appearance in the word list and children's familiarity (small pilot sample). Two practice items were included to familiarise participants with the task.

By computing a total score for all three tasks, participants' RA levels were determined and the standardised RA scores obtained via the pre-tests were used as a covariate in the evaluation analysis. Participants' RA levels were used as an overall indicator of their emergent Chinese literacy skills which could vary as a result of a range of individual (McBride & Wang, 2015) and environmental factors, including their home language exposure and literacy practices (Shu, Li, Anderson, Ku, & Yue, 2002; Li & Rao, 2000). By controlling for participants' RA levels in the evaluation analysis, the study was able to determine the effectiveness of various learning methods used among participants at different levels of Chinese literacy development.

For samples of the pre-test tasks, refer to Appendix 4.

2.6.2 Immediate & Delayed Evaluation: Assessing Learning Outcomes

To assess the learning outcomes of each learning condition, the accuracy in character recognition (CR) was examined through its three evaluative components:

- orthographic form recognition, which indicated the quality of the mental representations of the orthographic forms learnt,
- the retrieval and retention of the meanings of the characters learnt, which indicated the strength of the orthography–semantics connection,
- the retrieval and retention of the sounds of the characters learnt, which indicated the strength of the orthography–phonology connection.

In the orthographic form recognition (OR) task, participants were asked to select the correct form from three characters with graphemic similarity. The other two given options differed from the target character by altering, deleting or adding one stroke. For a sample of this task, refer to Appendix 4.

In the meaning retrieval task, participants were given a meaning and asked to choose the corresponding character from the six learnt characters in the set.

In the sound retrieval task, participants were given a sound and asked to choose the corresponding character from the six learnt characters in the set.

Raw scores of the evaluation tasks were converted to percentage of correct responses for comparison analysis.

The post-training evaluation was conducted at two time points, immediately after the training session and after one week's delay. The delayed post-test assessed the retention effects of both learning conditions by repeating the same set of evaluation tests. The evaluation tasks were constructed following the common practice in word/character learning research.

2.6.3 Post-Test: Assessing Visual Analysis Skills & Orthographic Awareness

The transfer effects of the trained characters on children's visual analysis skills and orthographic awareness were assessed through the Detect Component Task and Component in Pseudocharacter Task respectively.

Detect Component Task

Adapted from the same task in Anderson and colleagues' (2013) study, the task involved participants identifying target radicals, components and subcomponents from a list of learnt and unknown real characters. A total of 18 sets of characters were tested, with six sets each on radicals/components from learnt characters, unfamiliar radicals/components, and subcomponents from learnt characters.

In order to ensure that the levels of difficulty were comparable among the 18 sets, each set of 36 characters had to contain six characters containing the target radicals/components/subcomponents and eight distractors. Of the distractors, four were characters that looked similar to the target characters and another four were characters that contained constituents that looked similar to target radicals/components/subcomponents. Participants were given 90 seconds to complete each set. The order of the target type was counterbalanced, while the order of the sets within each target type was randomised.

Raw scores of the task were converted to percentage of correct responses and then to rationalised arcsine units (Studebaker, 1985) for comparison analysis.

Component in Pseudocharacter Task

The task was adapted from Tong and McBride-Chang's (2010) pseudocharacter invention task. Participants were asked to select a character that looked the most correct from four given

pseudocharacters. Each set of pseudocharacters comprised the same pair of learnt radical/component and dummy component in four different configurations. There were two practice items and a total of 10 test items in the task. All items contained a different learnt radical/component, but were paired with the same dummy component throughout the task.

Raw scores of the task were converted to percentage of correct responses for comparison analysis.

For samples of the post-test tasks, refer to Appendix 4.

2.7 Method of Analysis

In each experiment, repeated measures analyses of covariance and follow-up pairwise comparisons were conducted on all evaluation and post-test measures to determine if there were any main effects of learning conditions and any interaction between the learning conditions and RA levels over time on subsequent character recognition. If there were significant interactions involving RA levels, further analysis were conducted to examine the differential effects of RA on the effectiveness of learning conditions over time.

To examine the different effects of different learning modalities on children's visual analysis skills and orthographic awareness, the data from selected learning conditions across the three experiments were extracted for comparison.

For all statistical analyses, the significance threshold was set at .05. Appropriate adjustments were made for multiple comparisons. Partial eta squared statistic was reported as the effect size as they could be used for between-subjects comparison in studies using the same design (Richardson, 2011).

CHAPTER THREE RESULTS

3.1 Post-Training Evaluation of Experiment 1

RQ1) Does learning Chinese characters along with Pinyin interfere with or facilitate the accuracy of character recognition?

Furthermore, we ask whether children's level of radical awareness affect the effectiveness of different learning conditions?

To examine the above question, the post-training evaluation data from Experiment 1 were analysed at two time points, that is, immediately after training and delayed (for about a week). In this experiment, the two conditions were (1) viewing the Chinese character with *Pinyin*, and (2) viewing character without *Pinyin*. Raw scores from the evaluation tasks were converted to percent correct scores.

For immediate evaluation, the accuracy scores for orthographic form recognition (OR), the retrieval of the meanings and sounds of characters learnt were subjected to a 3x2 repeated measures analysis of covariance (ANCOVA), with learning condition as the independent factor, and z-score of the pre-test on radical awareness (RA) as the covariate.

For delayed evaluation, the accuracy scores for OR, the retrieval of the meanings and sounds of characters learnt for both time points were subjected to a 3x2x2 repeated measures ANCOVA, with learning condition and time as the independent factors, and z-score of the pre-test on RA as the covariate.

These analyses would examine if the inclusion of *Pinyin* during Chinese character learning had any effects on children's accuracy of character recognition (CR), while controlling for their level of RA. In doing so, any remaining difference would be attributable to the learning conditions, since the two character sets were equivalent. If there were any interaction between CR task and learning condition, it would suggest that the differential effects of the learning conditions were constituent-specific, i.e., only certain aspect(s) of CR was affected.

Figure 1. Mean Scores (Percentage) of Immediate and Delayed Evaluation by Two Learning Conditions: Viewing With *Pinyin* vs Without *Pinyin*

3.1.1 Immediate Evaluation

Results of the immediate evaluation are summarised in Figure 1A. The analysis showed a significant main effect of CR task, $F(2, 40) = 3.31, p = .047$, partial $\eta^2 = 0.14$, where the mean score for OR ($M = 65.15, SD = 12.79$) was higher than the mean scores for meaning retrieval ($M = 55.68, SD = 19.82$) and sound retrieval ($M = 56.06, SD = 22.36$). Pairwise comparisons were insignificant, however, after adjusting for multiple comparisons.

Results also revealed a significant interaction between CR task and learning condition, $F(1, 40) = 1.38, p = .017$, partial $\eta^2 = 0.18$, when the RA score was controlled, indicating that the learning condition effect was greater in sound retrieval than other aspects of CR (see Figure 1A). Further comparison using Sidak correction found that the With *Pinyin* condition resulted in a lower mean score for sound retrieval ($M = 46.97, SD = 26.66$), compared to that of the Without *Pinyin* condition ($M = 65.15, SD = 26.66$), $F(1, 20) = 7.15, p = .015$, partial $\eta^2 = 0.26$. The learning condition effect also seemed to affect OR, as the mean score was higher in the Without *Pinyin* condition ($M = 68.18, SD = 13.78$) than the experimental condition ($M = 62.12, SD = 13.78$), but it failed to reach statistical significance, $F(1, 20) = 2.80, p = .11$, partial $\eta^2 = 0.12$. The results suggested that the presence of *Pinyin* during character learning might affect CR accuracy by interfering with the retrieval of sounds of characters learnt.

3.1.2 Delayed Evaluation

Results of the delayed evaluation are summarised in Figure 1B. The analysis revealed a significant main effect of learning condition, $F(1, 20) = 5.69, p = .027$, partial $\eta^2 = 0.22$, where the mean score for the With *Pinyin* condition ($M = 56.19, SD = 16.45$) was significantly lower than the mean score for the Without *Pinyin* condition ($M = 64.24, SD = 18.47$). As this main effect was largely driven by the data in the delayed evaluation, this suggested that the overall retention rate for Without *Pinyin* condition seemed to be better than the With *Pinyin* condition.

There were also two significant interactions. The significant interaction among CR task, learning condition and time, $F(2, 40) = 4.37, p = .019$, partial $\eta^2 = 0.18$, indicated the differential effects of time on different aspects of CR. In terms of retaining the meanings of characters learnt, the Without *Pinyin* condition resulted in an increased score during the delayed evaluation ($M = 66.36, SD = 23.79$), which was significantly higher than that of the With *Pinyin* condition ($M = 52.27, SD = 25.77$), $F(1, 20) = 9.18, p = .007$, partial $\eta^2 = 0.32$. This suggested that the presence of *Pinyin* could have affected children's ability to recall the meanings of characters learnt. In terms of retaining the sounds of characters learnt, the With *Pinyin* condition resulted in an increased score during delayed evaluation ($M = 58.33, SD = 26.38$), removing the initial gap ($M = 46.97, SD = 26.66$) with Without *Pinyin* condition during immediate evaluation, $F(1, 20) = 5.31, p = .032$, partial $\eta^2 = 0.21$. This indicated that the presence of *Pinyin* could have interfered with the retrieval of sounds during immediate evaluation, but this interference was no longer evident during delayed evaluation.

3.1.3 Comparison between the Low RA & High RA Groups

The significant interaction among learning condition, time and RA, $F(1, 20) = 5.93, p = .024$, partial $\eta^2 = 0.23$, indicated the differential effects RA had on the effectiveness of the learning conditions. As the effect of the RA score was also significant during immediate evaluation, $F(1, 20) = 5.02, p = .037$, partial $\eta^2 = 0.20$, it suggested that the various accuracy scores were affected by children's level of RA. It is therefore of interest to look into the effect of RA on accuracy scores, to find out how the effectiveness of different learning conditions were affected by children's level of RA. Two separate 3x2x2 repeated measures analysis of variance (ANOVA), with accuracy scores for OR, meaning and sound retrieval as the dependent factors and learning condition and time as the independent factors, were conducted for the low and high RA groups.

Figure 2. Mean Scores (Percentage) of Low and High RA Groups During Immediate Evaluation by Two Learning Conditions: Viewing With *Pinyin* vs Without *Pinyin*

Figure 3. Mean Scores (Percentage) of Low and High RA Groups During Delayed Evaluation by Two Learning Conditions: Viewing With *Pinyin* vs Without *Pinyin*

Results of the comparisons between the low and high RA groups are summarised in Figure 2 (Immediate evaluation) and Figure 3 (Delayed evaluation).

With reference to the significant interaction among CR task, learning condition and time discussed earlier, the split group analysis revealed that the lower score for sound retrieval in the

With *Pinyin* condition during immediate evaluation and its increase during delayed evaluation was largely driven by the low RA group. On the other hand, the improved score for meaning retrieval in the Without *Pinyin* condition during delayed evaluation was largely driven by the high RA group.

It was also noted that the learning condition effect on OR was evident in the low RA group. The group scored significantly higher in the Without *Pinyin* condition ($M = 60.0$, $SD = 18.03$) than in the With *Pinyin* condition ($M = 48.33$, $SD = 12.81$) during immediate evaluation, $F(1, 9) = 7.23$, $p = .025$, confirming that the presence of *Pinyin* during character learning might affect CR accuracy by interfering with OR among children with low RA. The interference effect on OR seemed to linger on as the difference was still evident during delayed evaluation, though to a lesser extent, $F(1, 9) = 3.92$, $p = .079$.

The group-based differences in the above comparisons demonstrated the differential effects of RA on the effectiveness of learning conditions over time. For the low RA children, the interference effects of *Pinyin* on OR seemed to be of greater concern than the effect on sound retrieval. In terms of retention, the absence of *Pinyin* did not appear to be particularly helpful in remembering sounds or meanings. For the high RA children, however, the interference effects of *Pinyin* seemed to be limited to meaning retrieval only as the absence of *Pinyin* helped them to remember meanings better.

Figure 4. Combined Scores (Percentage) of Learning Conditions (Viewing With *Pinyin* vs Without *Pinyin*) in Low and High RA Groups by Time of Evaluation (Immediate vs Delayed)

Comparisons of combined scores for each condition (see Figure 4) showed that during delayed evaluation, the high RA group improved significantly by 11.57% ($SD = 11.71$) in the Without *Pinyin* condition, $F(1, 20) = 11.73, p = .003$, partial $\eta^2 = 0.37$, while the low RA group declined by 7.89% ($SD = 11.71$), $F(1, 20) = 4.54, p = .046$, partial $\eta^2 = 0.19$. This again suggested that the Without *Pinyin* condition was effective among the high RA children, but not among the low RA children. The learning outcomes of the With *Pinyin* condition, however, were relatively consistent in both groups.

Pertaining to the viewing modality during character learning, the level of radical awareness did seem to affect the effectiveness of different learning conditions.

3.2 Post-Training Evaluation of Experiment 2

RQ2) Does learning Chinese characters through repeated practice of character writing enhance the accuracy of character recognition?

Does children's level of radical awareness affect the effectiveness of different learning conditions?

To examine the above question, the post-training evaluation data from Experiment 2 were analysed at two time points, that is, immediately after training and delayed (for about a week). In this experiment, the two conditions were (1) repeatedly writing the Chinese character (without guidance), and (2) repeatedly writing the *Pinyin*. Raw scores from the evaluation tasks were converted to percent correct scores.

The method of analysis was similar to that of Experiment 1 (refer to 3.1).

3.2.1 Immediate Evaluation

Results of the analysis showed a significant main effect of character recognition (CR) task (see Figure 5), $F(2, 38) = 7.15, p = .002$, partial $\eta^2 = 0.27$. Post hoc testing using the Bonferroni revealed that the mean score for OR ($M = 64.48, SD = 18.17$) was higher than the mean scores for meaning retrieval ($M = 51.59, SD = 16.10$) and sound retrieval ($M = 52.58, SD = 22.29$), $F(2, 18) = 6.73, p = .007$, partial $\eta^2 = 0.43$, indicating that the writing modality might be effective in helping children remember the orthographic forms of characters learnt.

Figure 5. Mean Scores (Percentage) of Immediate Evaluation in Experiment 2

More importantly, there was also a significant main effect of learning condition, $F(1, 19) = 6.06$, $p = .024$, partial $\eta^2 = 0.24$, when the RA score was controlled (see Figure 6A). Post hoc testing using the Bonferroni revealed that the Character condition resulted in a higher overall score ($M = 60.58$, $SD = 17.44$), compared to that of the *Pinyin* condition ($M = 51.85$, $SD = 19.48$), $F(1, 19) = 5.50$, $p = .03$, partial $\eta^2 = 0.22$. The results suggested that the repeated practice of character writing was more effective compared to repeatedly writing its *Pinyin*. The interaction effect was non-significant, $F(2, 38) = 0.306$, $p = .70$, partial $\eta^2 = 0.016$.

Figure 6. Mean Scores (Percentage) of Immediate and Delayed Evaluation by Two Learning Conditions: Writing Character vs Writing *Pinyin*

3.2.2 Delayed Evaluation

Results of the delayed evaluation are summarised in Figure 6B. The analysis revealed a significant main effect of time, $F(1, 19) = 5.58, p = .029$, partial $\eta^2 = 0.23$, where the overall score during delayed evaluation ($M = 63.43, SD = 13.08$) was significantly higher than the overall score during immediate evaluation ($M = 56.22, SD = 16.40$), $F(1, 19) = 5.07, p = .036$, partial $\eta^2 = 0.21$ (Bonferroni adjusted). This main effect of time suggested that both learning conditions seemed to aid in the retention of learnt characters. Although the previous experiment found interfering effects of *Pinyin*, the writing modality appeared to compensate for the interfering effects, even when repeatedly writing *Pinyin*. This could possibly be due to the strengthening of orthography–semantics and orthography–phonology pathways in the process of handwriting practice (Tan et al., 2005). It was also important that the layout of the writing sheet was designed such that it allowed the children to view the Chinese character and notice its orthographic form while writing the *Pinyin*.

There were also two significant interactions. The significant interaction between CR task and time, $F(2, 38) = 6.52, p = .004$, partial $\eta^2 = 0.26$, indicated the differential effects of time on different aspects of CR. During the delayed evaluation, both the mean scores for meaning and sound retrieval increased significantly ($M = 62.70, SD = 19.36, M = 66.07, SD = 16.95$), compared to those of the immediate evaluation ($M = 51.59, SD = 16.10, M = 52.58, SD = 22.29$), $F(1, 19) = 7.53, p = .013$, partial $\eta^2 = 0.28$, $F(1, 19) = 13.17, p = .002$, partial $\eta^2 = 0.41$. This suggested that repeated writing practice, be it character or *Pinyin* writing, helped children to remember meanings and sounds better. When children were writing the *Pinyin* in view of the Chinese character, it did not seem to interfere with the learning to the extent observed in the viewing modality.

3.2.3 Comparison between the Low RA & High RA Groups

The significant interaction among CR task, learning condition, time and RA, $F(2, 38) = 3.46, p = .042$, partial $\eta^2 = 0.15$, indicated the differential effects RA had on the effectiveness of the learning conditions over time. As the effect of the RA score was also significant during immediate evaluation, $F(1, 19) = 11.91, p = .003$, partial $\eta^2 = 0.39$, it suggested that the various accuracy scores were affected by children's level of RA. It is therefore of interest to look into the effect of RA on accuracy scores, to find out how the effectiveness of different learning conditions were affected by children's level of RA. Two separate 3x2x2 repeated measures analysis of variance (ANOVA), with accuracy scores for OR, meaning and sound retrieval as the dependent

factors and learning condition and time as the independent factors, were conducted for the low and high RA groups.

Figure 7. Mean Scores (Percentage) of Low and High RA Groups During Immediate Evaluation by Two Learning Conditions: Writing Character vs Writing *Pinyin*

Figure 8. Mean Scores (Percentage) of Low and High RA Groups During Delayed Evaluation by Two Learning Conditions: Writing Character vs Writing *Pinyin*

Results of the comparisons between the low and high RA groups are summarised in Figure 7 (Immediate evaluation) and Figure 8 (Delayed evaluation).

With reference to the significant interaction among CR task, learning condition, time and RA discussed earlier, the split group analysis revealed that the higher overall score in the Character condition during immediate evaluation and its increase during delayed evaluation was, to a larger extent, driven by the high RA group. In particular, the mean score for OR was higher in the Character condition ($M = 83.33$, $SD = 23.57$) than the *Pinyin* condition ($M = 63.54$, $SD = 31.48$) during immediate evaluation, but failed to reach statistical significance, $F(1, 7) = 3.60$, $p = .10$. During the delayed evaluation, the group's scores in both conditions levelled out, indicating that the high RA group might still benefit from repeated *Pinyin* writing over the longer term.

In the low RA group, the scores for meaning retrieval in the *Pinyin* condition during delayed evaluation ($M = 53.85$, $SD = 21.68$) was significantly higher than that during immediate evaluation ($M = 35.90$, $SD = 14.98$), $F(1, 12) = 10.69$, $p = .007$. This suggested that focusing on the *Pinyin* during character learning could eventually help the low RA children with meaning recall. In terms of other aspects of CR, the low RA group still scored slightly better in the Character condition, suggesting that repeated character writing might still work better for them.

The group-based differences in the above comparisons demonstrated the differential effects of RA on the effectiveness of learning conditions over time. For the low RA children, repeated character writing seemed to work better. In terms of meaning retention, repeated *Pinyin* writing could also be helpful. For the high RA children, however, the effectiveness of both learning conditions appeared to be similar after some time.

3.3 Post-Training Evaluation of Experiment 3

RQ3) Does learning Chinese characters by focusing on radical awareness during writing practice enhance the accuracy of character recognition?

Does children's level of radical awareness affect the effectiveness of different learning conditions?

To examine the above question, the post-training evaluation data from Experiment 3 were analysed at two time points, that is, immediately after training and delayed (for about a week). In this experiment, the two conditions were (1) repeatedly writing the Chinese character with a focus on the radical or familiar component, and (2) repeatedly writing the Chinese character with a focus on stroke sequence. Raw scores from the evaluation tasks were converted to percent correct scores.

The method of analysis was similar to that of Experiment 1 (refer to 3.1).

3.3.1 Immediate Evaluation

Results of the immediate evaluation are summarised in Figure 9. The analysis showed a significant main effect of character recognition (CR) task, $F(2, 36) = 22.59, p < .001$, partial $\eta^2 = 0.56$. Post hoc testing using the Bonferroni revealed that the mean score for OR ($M = 78.33, SD = 12.22$) was higher than the mean scores for meaning retrieval ($M = 51.25, SD = 20.14$) and sound retrieval ($M = 51.67, SD = 17.85$), $F(2, 17) = 15.61, p < .001$, partial $\eta^2 = 0.65$, indicating that the structured writing modality was effective in helping children remember the orthographic forms of characters learnt.

Figure 9. Mean Scores (Percentage) of Immediate Evaluation in Experiment 3

However, there was no significant main effect of learning condition, $F(1, 18) = 1.14, p = .30$, partial $\eta^2 = 0.060$, nor other interactions, when the RA score was controlled (see Figure 10A). The results indicated that the structured writing modality was effective for character learning, be it focusing on radical/component or stroke sequence.

Figure 10. Mean Scores (Percentage) of Immediate and Delayed Evaluation by Two Learning Conditions: Writing Character Focusing on Component vs Writing Character Focusing on Strokes

3.3.2 Delayed Evaluation

Results of the delayed evaluation are summarised in Figure 10B. The analysis revealed a significant main effect of time, $F(1, 18) = 9.40, p = .007$, partial $\eta^2 = 0.34$, where the overall score during delayed evaluation ($M = 66.67, SD = 17.69$) was significantly higher than the overall score during immediate evaluation ($M = 60.42, SD = 12.29$), $F(1, 18) = 9.87, p = .006$, partial $\eta^2 = 0.35$ (Bonferroni adjusted). This main effect of time suggested that both learning conditions seemed to aid in the retention of learnt characters.

More importantly, the analysis still showed a significant main effect of CR task, $F(2, 36) = 17.15, p < .001$, partial $\eta^2 = 0.49$, where the mean score for OR ($M = 76.67, SD = 12.60$) was significantly higher than the mean score for meaning and sound retrieval ($M = 57.08, SD = 19.39, M = 56.88, SD = 19.88$), $F(2, 17) = 9.50, p = .002$, partial $\eta^2 = 0.53$. This suggested that the both writing conditions were effective in helping children remember the orthographic forms of characters learnt for a sustained period of time.

There was also a significant interaction between CR task and time, $F(2, 36) = 5.32, p = .009$, partial $\eta^2 = 0.23$, indicated the differential effects of time on different aspects of CR. During the delayed evaluation, both the mean scores for meaning and sound retrieval increased significantly ($M = 62.92, SD = 22.58, M = 62.08, SD = 24.93$), compared to those of the immediate evaluation ($M = 51.25, SD = 20.14, M = 51.67, SD = 17.85$), $F(1, 18) = 8.32, p = .010$, partial $\eta^2 = 0.32, F(1, 18) = 7.24, p = .015$, partial $\eta^2 = 0.29$. This suggested that both repeated writing

practice, be it focusing on radical/component or stroke sequence, helped children to remember meanings and sounds better.

3.3.3 Comparison between the Low RA & High RA Groups

Although there was no significant interaction among CR task, learning condition, time and RA, $F(2, 36) = 2.25, p = .12$, partial $\eta^2 = 0.11$, the reported partial eta2 meant that the interaction effect accounted for 11% of the variances. Considering that the effect of the RA score was significant during immediate evaluation, $F(1, 18) = 8.94, p = .008$, partial $\eta^2 = 0.33$, and later became insignificant during delayed evaluation, $F(1, 18) = 3.90, p = .064$, partial $\eta^2 = 0.18$, it was likely that there was some change in the effect of RA in some way. To look into this, two separate 3x2x2 repeated measures analysis of variance (ANOVA), with accuracy scores for OR, meaning and sound retrieval as the dependent factors and learning condition and time as the independent factors, were conducted for the low and high RA groups.

Figure 11. Mean Scores (Percentage) of Low and High RA Groups During Immediate Evaluation by Two Learning Conditions: Writing Character Focusing on Component vs Writing Character Focusing on Strokes

Figure 12. Mean Scores (Percentage) of Low and High RA Groups During Delayed Evaluation by Two Learning Conditions: Writing Character Focusing on Component vs Writing Character Focusing on Strokes

Results of the comparisons between the low and high RA groups are summarised in Figure 11 (Immediate evaluation) and Figure 12 (Delayed evaluation).

The split group analysis revealed that main effect of time was largely driven by the low RA group, $F(1, 11) = 29.25, p < .001$, partial $\eta^2 = 0.73$, where the overall score during delayed evaluation ($M = 68.06, SD = 17.06$) was significantly higher than the overall score during immediate evaluation ($M = 57.87, SD = 15.53$) (Bonferroni adjusted). This main effect of time suggested that both learning conditions were effective in helping the low RA group with the retention of learnt characters. Such improvement was not observed in the high RA group. In particular, the improvement in scores were significant in the Strokes condition, where the mean scores for meaning and sound retrieval during delayed evaluation ($M = 63.89, SD = 29.16, M = 58.33, SD = 28.87$), were significantly higher than those during immediate evaluation ($M = 44.44, SD = 28.72, M = 43.06, SD = 27.94$), $F(1, 11) = 10.17, p = .009$, partial $\eta^2 = 0.48, F(1, 11) = 5.30, p = .042$, partial $\eta^2 = 0.33$.

Unlike the differential effects of RA on the effectiveness of learning conditions in the previous experiments, it was found that the Structured Writing modality was particularly effective for the low RA children because it allowed them to improve their learning outcomes such that their overall mean score during delayed evaluation ($M = 68.06, SD = 17.06$) was on par with the high RA group ($M = 64.58, SD = 20.02$). This learning outcome was clearly different from that of the

Free Writing modality in Experiment 2, where the low RA group still scored lower than the high RA group in the Character condition. In other words, the structured writing modality, regardless of its focus, was found to be particularly effective for the low RA children in character learning.

3.4 Post-Test Results of Experiments 1, 2 & 3: Transfer Effect Across Learning Modalities

RQ4: Do the different learning modalities, namely viewing the character, free writing of the character and structured writing of the character, have different effects on children's visual analysis skills and orthographic awareness?

In order to investigate the above question, the data from selected learning conditions across the three experiments were extracted for comparison. The viewing condition used data from the viewing without *Pinyin* condition in Experiment 1 and the free writing condition used data from the character writing condition in Experiment 2. For the structured writing condition, the data from both conditions in Experiment 3 were combined as there were no significant differences between the two conditions ($t(19) = 1.70, p = .11, d = 0.38$ for trained components; $t(19) = 0.38, p = .71, d = 0.085$ for trained subcomponents).

3.5.1 The Effects of Learning Modalities on Visual Analysis Skills

Rationalised arcsine transformation is applied to the data obtained from the Detect Component Task to normalise them for parametric statistical analysis (Studebaker, 1985). The transformed scores for trained components, trained subcomponents and untrained components in the Detect Component Task were then subjected to a mixed factor analysis of covariance (ANCOVA), with learning modality, namely viewing, free writing and structured writing, as the fixed factor, and z-scores of the pre-test on radical awareness (RA) as the covariate. This analysis would examine if the learning modalities had any effects on children's performance in searching for different types of components in the Detect Component Task and any interaction between the learning condition and performance for different component types, while controlling for their level of RA. If any interaction was found, it would suggest that the learning modalities had different effects on children's visual analysis skills. Results are summarised in Figure 13.

Figure 13. Mean Scores (Percentage) of Trained Components, Trained Subcomponents & Untrained Components in Detect Component Task

As the interaction between learning modality and RA score was non-significant ($F(2, 55) = 0.75$, $p = .48$, partial $\eta^2 = 0.026$), we could assume the homogeneity of the coefficient for the covariate across the levels of the factor.

The Levene's test showed no significant difference in variance within the dependent variable groups for the trained and untrained components, but showed significant difference in variance for the trained subcomponents.

Although the Levene's test was significant for the trained subcomponents, the spread-versus-level plot did not show a linear relationship between the mean and standard deviation, therefore it was assumed that the homogeneity of variance had not been violated.

Since the Mauchly's test of sphericity was significant, the Huynh-Feldt correction was used.

There was a significant main effect of component type ($F(1.92, 109.38) = 12.54$, $p < .001$, partial $\eta^2 = 0.18$), but no significant effect of learning modality nor interaction between learning modality and component type.

Post hoc testing using the Bonferroni correction revealed that both the scores for trained components ($M = 76.52$, $SD = 17.49$) and untrained components ($M = 75.32$, $SD = 14.55$) was significantly higher than the score for trained subcomponents ($M = 66.67$, $SD = 14.13$), $t(60) = 4.19$, $p < .001$, $d = 0.54$ and $t(60) = 3.97$, $p < .001$, $d = 0.51$ respectively.

The variation in scores for different component types in this sample was similar to those of Grade 2 children in Anderson et al.'s (2013) study, which revealed that subcomponents at this stage of development were merely perceptual chunks that had not yet stabilised.

Since there was no significant interaction between component type and learning modality ($F(3.84, 109.38) = 0.27, p = .89$, partial $\eta^2 = 0.01$), the various component type scores in all three learning modalities shared a similar trend as described above. In other words, none of the learning modalities resulted in more stable representations of the subcomponents.

The test of between-subjects effects also revealed that the RA score had a significant effect on the mean scores of the Detect Component Task, ($F(1, 57) = 5.61, p = .021$, partial $\eta^2 = 0.09$, but these scores did not vary across the learning modalities, $F(2, 57) = 0.97, p = .39$, partial $\eta^2 = 0.033$. Given that there was heterogeneity of variances in the trained subcomponents, $F(2, 58) = 6.59, p = .003$, it was likely that there might be an interaction between the learning modality and other factors.

Further analysis would be required to investigate if there were any other interactions that may affect the effect of RA, and hence task performance, in the various learning modalities. If there were, then it was likely that the effect of learning modalities might be different for different groups of children.

Learning Outcomes & Visual Analysis Skills

To investigate if there were any other interactions that may affect the effect of RA and visual analysis skills in the various learning modalities, I looked into the correlations of trained components score with RA score from the pre-test and evaluation score, i.e., mean of accuracy scores for orthographic form recognition (OR), the retrieval of the meanings and sounds of characters learnt during immediate evaluation, across the three learning modalities. Table 1 revealed that the relationships between the trained components score and RA score, as well as the evaluation score, were not the same across the three modalities. Correlation analysis showed a marginally significant correlation between the trained components score and RA score in the Viewing modality ($r(19) = .433, p = .05$) but not the other two modalities. The trained components score and evaluation score, on the other hand, were strongly associated in the Viewing and Free Writing modalities, $r(19) = .594, p = .005$ and $r(18) = .470, p = .036$ respectively. These results suggested that different modalities could have different effects on children's visual analysis skills.

Correlations			
Score_TrainedComponentt		Score_RadicalAwareness	Score_Evaluation
Viewing	Pearson Correlation	0.433	.594**
	Sig. (2-tailed)	0.050	0.005
	N	21	21
Free Writing	Pearson Correlation	0.170	.470*
	Sig. (2-tailed)	0.474	0.036
	N	20	20
Structured Writing	Pearson Correlation	-0.195	-0.070
	Sig. (2-tailed)	0.411	0.770
	N	20	20

** . Correlation is significant at the 0.01 level (2-tailed).

* . Correlation is significant at the 0.05 level (2-tailed).

Table 1. Correlations of Mean Scores of Trained Components in Detect Component Task with RA & Evaluation Scores Across Experiments

To include learning outcome as a factor in the analysis, the participants in each learning modality were split into two groups, high and low learners, based on the median evaluation scores of the respective modalities. As I was interested in the effects of the learning modalities, I conducted a separate analysis, i.e., mixed factor ANCOVA, to compare the scores of the trained components and trained subcomponents in the Detect Component Task, with learning modalities (3 conditions) and learning outcome (i.e., high, low learners) as the fixed factors, and RA score as the covariate. This analysis would examine if any interaction between the learning modality and learning outcome would have any effect on children's performance for different component types, while controlling for their level of RA. If any interaction was found, it would suggest that the learning modalities had different effects on children's visual analysis skills.

As the interactions between the two fixed factors (i.e., learning modality and learning outcome) and RA score, were non-significant ($F(2, 51) = 1.87, p = .17$, partial $\eta^2 = .068$ and $F(1, 51) = 1.60, p = .21$, partial $\eta^2 = .030$ respectively), we could assume the homogeneity of the coefficient for the covariate across the levels of the two factors.

The Levene's test showed no significant difference in variance within the dependent variable groups for the trained components, but was marginally significant for the trained subcomponents ($F(5, 55) = 2.426, p = .047$). The spread-versus-level plot did not show a linear relationship between the mean and standard deviation, therefore it was assumed that the homogeneity of variance has not been violated.

The 2x3x2 ANCOVA showed significant main effect for component type ($F(1, 54) = 24.30, p < .001$, partial $\eta^2 = 0.31$), as per previous analysis. More importantly, this analysis also yielded the predicted significant interactions between component type and learning outcome ($F(1, 54) = 9.95, p = .003$, partial $\eta^2 = 0.16$), as well as between the effects of learning modality and learning outcome on component type scores, ($F(2, 54) = 7.88, p = .001$, partial $\eta^2 = 0.23$). Findings are presented in Figure 14.

Figure 14. Mean Scores (Percentage) of Trained Components and Trained Subcomponents by Learning Modalities (Viewing, Free Writing & Structured Writing) & Learning Outcomes (Low vs High)

An analysis of simple main effects revealed that the high learners scored significantly higher for the trained components ($M = 82.36, SD = 16.60$) than low learners ($M = 71.0, SD = 16.58$), $F(1, 54) = 6.43, p = .014$ (Sidak adjusted), but scored similarly to the low learners for the trained subcomponents ($M = 65.26, SD = 15.14, M = 67.91, SD = 15.11$ respectively). This suggested that the learning modality was likely to have an effect on how children performed in searching for trained components in the Detect Component Task, even though the learning modality did not have an effect on the performance in the trained subcomponents search. The latter could possibly be due to the flooring effect in subcomponents, which prevented the group differences in performance to be observed.

An analysis of simple main effects also revealed that the high learners in the Viewing modality scored significantly higher for the trained components ($M = 85.97, SD = 15.70$) than the low learners in the same modality ($M = 59.03, SD = 15.64$), $F(1, 54) = 15.43, p < .001$ (Sidak

adjusted). Also, these low learners in the Viewing modality scored significantly lower for the trained components than the low learners in the Structured Writing modality ($M = 81.0$, $SD = 15.76$), $F(2, 54) = 5.49$, $p = .007$ (Sidak adjusted). This indicated that the Structured Writing modality could have helped low learners to improve their visual analysis skills, as demonstrated by the good performance in searching for trained components, unlike children in the other two modalities. In other words, children in the Structured Writing condition were able to perform well in the search for trained components, regardless of their learning outcomes from the training session. In the Viewing modality, children's performance in the search task was related to their learning outcomes from the training session. Therefore, structured writing is more effective in enhancing children's visual analysis skills. The Free Writing modality also appeared to be somewhat more effective than the Viewing modality as low learners' mean score for trained components was higher ($M = 72.95$, $SD = 17.08$), however the score difference failed to reach statistical significance.

According to Anderson et al. (2013), high scores of trained components indicated that these children had relatively stable visual representations of familiar components, which implied that they could be more advance in their visual analysis skills and possibly reading proficiency.

The above results suggest that learners using the writing modalities might not need to rely on the meaning and sound of a character to be able to recall its orthographic form, including the components within it. Therefore, these modalities were effective in improving learners' visual analysis skills. On the other hand, learners using the viewing modality needed to rely on the meaning and sound of a character to help them to recall its orthographic form, hence there was no improvement in the visual analysis skills of children who did not learn well during the training sessions.

Differentiated Effects of Learning Modalities on Children's Radical Awareness

It was also noted that the effect of RA was no longer significant in the second ANCOVA, where untrained components were not included the analysis. This suggested that the learning modality had mediated the effect of RA on children's performance in the search for trained components. To examine if there are any differentiated effects of the various learning modalities on children's RA, a 3x2x2 Analysis of Variance (ANOVA) was conducted on the trained component score, with learning modalities, learning outcomes and level of RA (low, high) as the independent variables.

The test of homogeneity of variance was not significant, indicating that the assumption of equal variances was been met. The results of the analysis indicated significant main effect for learning outcome, $F(1, 49) = 15.19, p < .001$, partial $\eta^2 = 0.24$, and significant interaction between learning modality and learning outcome, $F(2, 49) = 6.06, p = .004$, partial $\eta^2 = 0.20$, as per previous analysis. More importantly, the results also revealed a significant interaction among learning modality, learning outcome and RA level, $F(2, 49) = 3.74, p = .031$, partial $\eta^2 = 0.13$, indicating that how well the low RA group performed in the search for trained components was dependent on their learning modality and possibly their learning outcomes (see Figure 15). The high RA group, on the other hand, was relatively consistent in their performance, regardless of their learning modality and learning outcome. Note: The difference between low and high learners in the Free Writing modality for the high RA group was not comparable as there was only one low learner in that category.

Figure 15. Mean Scores (Percentage) of Trained Components in Detect Component Task by Learning Modalities & Learning Outcomes (Low RA Group)

In the low RA group, those who were high learners performed similarly well across the three learning modalities ($M = 82.59 \sim 92.0, SD = 10.60 \sim 17.49$), but those who were low learners in the Viewing modality performed poorly ($M = 49.92, SD = 14.50$), compared to those who were low learners in the Free Writing and Structured Writing modalities ($M = 74.65, SD = 17.03$ and $M = 78.54, SD = 11.47$ respectively), $F(2, 49) = 7.28, p = .002$ (Sidak adjusted). This indicated that both writing modalities were able to mitigate the adverse effect of low RA on children's visual analysis skills, regardless of their learning outcomes. In the Viewing modality, however, the

adverse effect of low RA on children's visual analysis skills could be mitigated only if the learning outcomes were good.

To verify the differential effects of both writing conditions compared to the Viewing modality, a one-way ANOVA was conducted on the group of children who had low level of RA and were low learners. The results showed that the effect of learning modality was significant, $F(2, 20) = 7.44, p = .004$, partial $\eta^2 = 0.43$. Post hoc analyses using the Scheffé post hoc criterion for significance indicated that the mean trained component score in the Viewing modality ($M = 49.92, SD = 14.50$) was significantly lower than those in the other two writing modalities ($M = 74.65, SD = 17.03$ and $M = 78.54, SD = 11.47$), $t(13) = 3.20, p = .016, d = 1.54$ and $t(12) = 3.62, p = .007, d = 2.23$ respectively (see Figure 16).

Figure 16. Mean Scores (Percentage) of Trained Components in Detect Component Task by Learning Modalities (Low Learners & Low RA Group)

This confirms our earlier analysis that the writing modalities were more effective, as they had a positive effect on the low RA children's visual analysis skills. The Viewing modality was deemed less effective, as its effectiveness was still dependent on the learning outcome.

3.5.2 The Effects of Learning Modalities on Orthographic Awareness

In order to investigate the second part of RQ4, i.e., whether different learning modalities have different effects on children's orthographic awareness, the data from the Component in Pseudocharacter Task for the Viewing, Free Writing and Structured Writing conditions from the three experiments were analysed. As the Shapiro-Wilks Test of Normality was significant, $W = 0.958, p = .024$, suggesting a deviation from normality, several transformations, rationalised

arcsine transformation, were applied in an attempt to normalise the data, but to no avail. As a result, ordered logistic regression was used to analyse the data, but it failed to obtain a significant model, $\chi^2 = 13.47$, $p = .264$.

Figure 17. Mean Scores (Percentage) of Component in Pseudocharacter Task by Learning Modalities (Viewing, Free Writing & Structured Writing) & Learning Outcomes (Low vs High)

Since parametric tests could not be conducted due to the violation of the normality assumption, the plots in Figure 17 were examined for any meaningful trends. In the low RA group, there were no significant differences across learning modality nor learning outcome. The mean scores of the Component in Pseudocharacter Task ranged from 48.75 ($SD = 8.35$) to 67.50 ($SD = 15.0$). In the high RA group, where the mean scores ranged from 36.0 ($SD = 26.08$) to 64.0 ($SD = 11.40$), there were no significant differences across learning modality nor learning outcome in both writing modalities. However, there appeared to be a notable difference between the low ($M = 36.0$, $SD = 26.08$) and high learners ($M = 56.67$, $SD = 23.38$) in the Viewing modality, $U = 6.50$, $p = 0.13$, $r_B = 0.57$. In addition, the low learners in the Viewing modality also appeared to score lower than those in the Structured Writing modality ($M = 63.33$, $SD = 23.09$), $U = 2.0$, $p = 0.12$, $r_B = 0.73$. Given the large effect sizes of these comparisons, the differences would likely be significant if the sample size were larger, suggesting that the effect of the Viewing modality on orthographic awareness could be similar to that of the visual analysis skills, i.e., the modality would be effective only if the learning outcome was good.

It was noted that the above trend was only observable in the high RA group but not the low RA group. The latter's performance in the task was rather random possibly because they could still

be at the early stage of developing orthographic skills and were relying mainly on processing characters as a whole. At this point, the effects of the three modalities on children's orthographic awareness were still inconclusive. Perhaps the trend might be clearer if the experiment had targeted older children with supposedly higher levels of RA.

CHAPTER FOUR DISCUSSION

4.1 Discussion

This study examined the effects of different Chinese character learning modes on subsequent character recognition (CR) ability in young English–Chinese bilinguals. Given the wide-ranging language proficiency and exposure of Singaporean children, the challenges children face in character learning are likely to differ from L1 learners in China, Hong Kong or Taiwan in some ways. Comparisons were made between the high and low radical awareness (RA) children to examine if the learning conditions affected children with less experience in written Chinese differently. Since the study adopted the within-subjects design and the data analysis controlled for children's RA, any differences between learning conditions were not a result of individual differences. Any significant interaction between learning conditions and RA indicated the differential effects of learning conditions among children with different levels of emergent Chinese literacy skills.

In **Experiment 1** which compared viewing characters without *Pinyin*, the results revealed that the presence of *Pinyin* during character learning might affect CR accuracy by interfering with the retrieval of sounds and meanings of learnt characters. Overall retention rate in the delayed evaluation also appeared to be better without *Pinyin*, suggesting possible interference from *Pinyin*. The group comparisons between the high and low RA children demonstrated the differential effects of RA on the effectiveness of learning conditions over time. For the low RA children, the interference effects of *Pinyin* on orthographic form recognition (OR) seemed to be of greater concern than the effect on sound retrieval. For the high RA children, however, the interference effects of *Pinyin* seemed to be limited to meaning retrieval only as the absence of *Pinyin* helped them to remember meanings better.

In **Experiment 2** which compared repeatedly writing the Chinese character (without guidance) and repeatedly writing the *Pinyin*, the results revealed that generally, the repeated practice of character writing was more effective compared to repeatedly writing its *Pinyin*. The delayed evaluation results also suggested that repeated writing practice, be it character or *Pinyin* writing, helped children to remember meanings and sounds better. It was also noted that when children were writing the *Pinyin* in view of the Chinese character, it did not seem to interfere with the learning to the extent observed in the viewing modality. The group comparisons between the

high and low RA children also demonstrated the differential effects of RA on the effectiveness of learning conditions over time. For the low RA children, repeated character writing seemed to work better. In terms of meaning retention, repeated *Pinyin* writing could also be helpful. For the high RA children, however, the effectiveness of both learning conditions appeared to be similar after some time.

In **Experiment 3** which compared repeatedly writing the Chinese character with a focus on the radical or familiar component, and that with a focus on stroke sequence, the results indicated that the structured writing modality was effective for character learning and retention, be it focusing on radical/component or stroke sequence. In particular, it helped children remember the orthographic forms of characters learnt better for a sustained period of time. The group comparisons between the high and low RA children demonstrated differential RA effects that were different from the previous two experiments. The structured writing modality, regardless of its focus, was found to be particularly effective for the low RA children in character learning as it allowed them to improve their learning outcomes.

Across all three experiments, there was no evidence of stronger orthography–phonology or orthography–semantics pathways as proposed by the models of Chinese reading (Yang et al., 2006; Perfetti & Liu, 2006), even in the learning conditions involving *Pinyin*. This could be due to the limited exposure the learners had with these characters during the controlled training sessions. As majority of the learners were still not well-acquainted with these characters, the pathways among the lexical constituents were still relatively weak.

The study also compared the different effects that different learning modalities, namely viewing, free writing and structured writing, have on children's **visual analysis skills** and **orthographic awareness**. The results suggest that both writing modalities were effective in improving learners' visual analysis skills, without the need to rely on the meaning and sound of a character to be able to recall its orthographic form and the components within it. Therefore, the writing modalities were able to mitigate the adverse effect of low RA on children's visual analysis skills, regardless of their learning outcomes. The viewing modality, on the other hand, was deemed less effective, as its effectiveness was still dependent on the learning outcome. This means that there was no gain in the visual analysis skills of children who did not learn well during the training sessions and the adverse effect of low RA on children's visual analysis skills could be mitigated only if the learning outcomes were good.

The effects of the three modalities on children's orthographic awareness were inconclusive. However, there was a trend that the effect of the Viewing modality on orthographic awareness could be similar to that of the visual analysis skills, i.e., the modality would be effective only if the learning outcome was good, but it was only observable in the high RA group but not the low RA group.

4.1.1 Effectiveness of Writing Modalities

One of the significant findings of this study was that Structured Writing modality could mitigate the adverse effects of low RA, regardless of their learning outcome. This is important because it provides convincing evidence for low learners to engage in repeated writing practice as it can effectively foster character learning, retention and improvement in visual skills. These results appear to be in line with the findings by Deng, Booth, Chou, Ding and Peng (2008), Longcamp et al. (2008) and Lagarrigue et al. (2017), which demonstrated that the greater activation of the superior parietal lobule for characters learned via handwriting led to increased accuracy through the processing of constituent components in Chinese characters (Deng et al., 2008). In repeated writing practice with a focus on radical/component or stroke sequence, learners attended to the components of the characters and the stability of the orthographic representations of components and characters were strengthened (James & Englehardt, 2012). Over time, this would help to promote the development of visuo-spatial skills, as well as orthographic awareness and sensitivity, which low learners lacked in.

As our results also showed that the writing modalities resulted in better performance in the visual analysis task than the viewing modality, it supports the hypothesis that the handwriting experience facilitates visual perception of characters. This means that for L2 learners whose visual and orthographic skills are lagging behind native learners, repeated writing practice appears to be the more effective method as it could help them acquire specific character forms and overcome the issues with visual and orthographic processing. As highlighted by Zhou and McBride (2018), visual and orthographic skills are two of the skills strongly correlated to Chinese L2 reading development, apart from Chinese vocabulary knowledge and phonological awareness skills. For L2 learners to make progress in their character recognition ability, they will need to employ learning methods that can remediate their lack of visual analysis skills.

Although the repeated character writing in Experiment 2 did help the low RA children remember the learnt characters better, their performance during the delayed evaluation was still weaker than the high RA children. On the other hand, the repeated character writing in Experiment 3, the low

RA children's performance during the delayed evaluation actually caught up and was on par with the high RA children. On this basis, I propose that repeated character writing without guidance may still be slightly less effective than structured writing. It is likely that by providing a focus on the radical/component or stroke sequence during writing practice, the learner's cognitive load is reduced as one does not have to struggle with trying to break down a character into its smaller, manageable components. Consequently, one could attend to the structure of the character, as well as the forms and positions of the components, resulting in the improvement of visual analysis skills. Furthermore, the reduction in the cognitive load required during character writing frees up working memory capacity so that one can readily make associations with its corresponding meaning and pronunciation. By coupling meaning and sound recall with visual processing, one is able to form a high quality orthographic representation while strengthening the lexical quality of the character learnt. As elaborated in the Lexical Quality Hypothesis (Perfetti & Hart, 2002), such high lexical quality is needed for retention (Ehri, 2005) and comprehension (Tong & McBride, 2010).

Although Cao and colleagues' (2013b) study, which compared reading, writing and visual chunking, did not find any significant behavioural differences, their event-related potential measures detected orthographic enhancement effects in the writing and visual chunking conditions. In this study, however, the orthographic enhancement effect of the handwriting experience was clearly evident in the behavioural measures, thus supporting Cao et al.'s (2013b) earlier findings.

In the study by Hsiung et al. (2007) which compared writing exercises and stroke order learning among adults learning Chinese as a foreign language, it was found that writing exercises enhanced the orthographic and semantic representations of the characters learnt, suggesting that handwriting practice strengthened the orthography–semantics connection of the character. However, no significant effect was observed for stroke order learning. Again, our findings are in line with these observations. In fact, this study provided a more detailed examination of the writing modality by comparing free and structured writing.

Chang and colleagues' (2014) conducted study on adults learning Chinese as a second language, comparing handwriting, visual chunking, passive reading and stroke-reporting in a grouped or distributed sequence, based on response times in a lexical decision task. In this study, however, handwriting was not found to be effective because the learners had to practise writing the character from memory. This is somewhat different from character copying which allows

learners to pay attention to the details of the visual configuration while encoding the details to memory through graphomotor programming. It is therefore not quite comparable to the usual character copying method in character learning.

In line with the above-mentioned studies, the present study also found some differences in the effects observed in the immediate and delayed tests. This delay effect is likely due to the consolidation processes involved in word learning (James, Gaskell, Weighall & Henderson, 2017) and instructional effects on long-term memory. According to Henderson et al. (2013), a new vocabulary requires an extended period of time before it can become integrated with the existing lexicon.

The results of this study have validated the importance of handwriting experience in early Chinese literacy acquisition. The writing modality provides learners an edge in early visual attention so that they can acquire a robust orthographic representation of the character. In doing so, the representation may be better retained and its links to meaning and pronunciation may be strengthened. In Singapore where written Chinese is less salient than Mandarin-speaking societies, this finding would be particularly important for learners with limited experience with Chinese print. By advocating for the need to include handwriting experience in early Chinese character learning, caution should be taken that getting children to mindlessly copying loads of the same characters is not to be supported. Specifically in this study, children were first introduced to the character, then given 90 seconds to do the writing with focused attention, followed by several rounds of repeated exposures to the character and meaning. It did not matter how many characters the child wrote within the 90 seconds. Moreover, it should be emphasised that children must reach a developmental stage that allows them to do some writing.

4.1.2 The Role of Pinyin in the Singapore Context

This study examined the role of *Pinyin* in the viewing condition. It was found that the low RA children's performance in OR appeared to be interfered by the presence of *Pinyin*, indicating that the presence of *Pinyin* had prevented these children from establishing precise mental representations of the orthographic forms of the learnt characters. As explained by Li and colleagues (2018) on the use of *Zhuyin Fuhao*, it could interfere with the development of robust orthographic representations by drawing learners' attention away from the characters, therefore it may impede orthographic learning.

Although the orthography–phonology pathway also appeared to be affected by the presence of *Pinyin* during immediate evaluation, the interference effect receded by the time of the delayed evaluation. For the high RA children, the interference effects of *Pinyin* seemed to be only limited to meaning retrieval, as the absence of *Pinyin* helped them to remember meanings better. This suggests that orthography–semantics pathway was stronger without the presence of *Pinyin* among this group. As high RA children had a better grasp of the Chinese writing system, they were likely to develop high quality orthographic representations, hence they were less likely to be distracted by *Pinyin*, similar to native Chinese children.

As the children did not score better in sound and meaning retrieval in the *Pinyin* condition, there is no evidence to indicate that *Pinyin* can aid character learning when the viewing modality is used. The present findings also do not support the hypothesis that *Pinyin* may result in stronger phonological representations or orthography–phonology pathways, as proposed by other studies (Guan et al., 2011; Yan et al., 2008). In Singapore, children are also learning English phonics to promote English literacy during preschool and early primary school years, hence it is likely that the introduction of *Pinyin* can be confusing for early learners, given that they use the same alphabet set to represent another phonological system. The problem may be further compounded by the fact that a significant proportion of the children may lack oral proficiency and phonological sensitivity in Mandarin, therefore they may have additional difficulty in utilising the *Pinyin* system for their learning. These findings seem to indicate the limited transferability of English phonological skills to the learning of Chinese characters in the viewing modality for Singapore children. However, other aspects of linguistic knowledge acquired through English, such as morphological awareness and comprehension skills, could be relevant and transferable during later stages of Chinese literacy learning (Wang, Yang & Cheng, 2009; Zhang, Koda & Sun, 2012).

Considering that developing precise orthographic representations of characters is a critical part of character acquisition, the interference effects of *Pinyin* on the low RA children’s ability to remember orthographic forms of characters is an important and concerning finding. It is evident that without repeated writing practice, the low RA children have difficulty developing high quality visual representations of characters learnt. The use of *Pinyin* at this early stage of character learning could hinder their progress in visual processing and subsequently, orthographic learning. If these children do not use learning methods that can rectify their weaknesses, their character recognition ability may be compromised.

On the contrary, the interference effects of *Pinyin* did not appear to be an issue in the writing modality, as demonstrated by the findings in Experiment 2. Although the low RA children did not learn better through repeated *Pinyin* writing, it did seem to help with meaning retention to a small extent. For the high RA children, the interference effects receded by the time of the delayed evaluation, suggesting that the high RA children were not affected by *Pinyin* in the writing modality. It is possible that the writing modality compensated for the interfering effects, even when repeatedly writing *Pinyin*, by strengthening the orthography–semantics and orthography–phonology pathways in the process of handwriting practice (Tan et al., 2005). It is also important that the layout of the writing sheet was designed such that it allowed the children to view the Chinese character and notice its orthographic form while writing the *Pinyin*.

Zhang and Reilly (2016) also found higher accuracy in recognising characters learnt via *Pinyin* writing than character writing. This could possibly be due to the result of attending to the visual features of the character during character writing but neglecting the orthography–phonology connection, which is quite common among beginning learners. The over-reliance on visual processing could have prevented them from utilising both phonological and visual-spatial working memory efficiently for character learning. On the other hand, *Pinyin* writing helps them to better encode the phonological representations of the characters learnt, hence the orthography–phonology connection is stronger and learners were better at identifying these characters when they appeared even though they only wrote the *Pinyin* during training. However, the quality of the visual representations of learnt characters were not assessed in this study.

While Experiment 2 was not specifically designed to evaluate the effect of *Pinyin*, the observation that *Pinyin* did not seem to interfere with the learning to the extent observed in the viewing modality, when children were writing the *Pinyin* in view of the Chinese character, is noteworthy. It suggests that if *Pinyin* is introduced in the ‘right’ way, it may still aid character learning. In view of the limited interference effects among the high RA children, it may be more beneficial if the low RA children learn *Pinyin* when they have accumulated more character knowledge. However, more research is needed to understand how this can be done.

For developing readers who already have a good foundation of character knowledge, *Pinyin* may be a quick and effective way to access the phonological representations of unfamiliar characters. With the help of *Pinyin*, the reader is able to focus on text comprehension. For these readers, their orthographic knowledge would have moderated their dependence on phonological memory in character learning (Ehri, 2014). However, for beginning learners who are still building up their

character knowledge, *Pinyin* can only aid character learning if it does not cause interference. Given that *Pinyin* is a totally separate system involving prelexical phonological computation (Frost, 2005), it can only aid in the initial process of character learning by providing an extra cue to its phonological representation. Alternatively, it may be more helpful to learn to use phonetic components to retrieve the phonological representations of the characters.

Even in China, it was found that *Pinyin* knowledge did not explain for Grade 1 children's performance in Chinese character reading, but had an effect on children's reading from Grade 2 onwards (Siok & Fletcher, 2001). This suggests that native children also need time to master *Pinyin* knowledge before it can be an effective aid to Chinese reading. Therefore, it may be necessary to review Singapore's use of *Pinyin* in early character learning, especially among those with low RA or weak oral proficiency.

4.1.3 The Issue of Radical Awareness & Some Pedagogical Implications

By taking into account children's level of radical awareness when evaluating the effectiveness of different learning methods, the study was able to identify how different methods affect the learning outcomes of children with different RA levels. Similar to Silverman and Crandell's (2010) study which found differential effects of instruction on children with varying levels of initial vocabulary knowledge, this study demonstrated that the structured writing modality helped children remember the orthographic forms of characters learnt better for a sustained period of time. In the viewing and free writing modalities, the children's performances were generally aligned with their RA levels, as indicated by their pre-test scores. In addition, the structured writing modality, regardless of its focus, was found to be particularly effective for the low RA children in character learning as it allowed them to improve their learning outcomes and be on par with the high RA children.

As with studies which attributed the wide variability in children's reading skills (McBride-Chang et al., 2005) and vocabulary learning (Sun, Yin, Amsah & O'Brien, 2018) to the differences in their cognitive skills and home literacy experiences, this study also found Singapore children of the same cohort to vary greatly in terms of their radical awareness. Furthermore, their learning outcomes were likely to be affected by their level of radical awareness and this will, in turn, affect their reading ability and development. As Chinese literacy is less likely to be a priority among Singaporean parents, majority of Singaporean children do not have frequent print exposure in Chinese and have less Chinese books than English ones, according to a study by Sun (2019). Yet, there are also a growing number of young children attending Chinese enrichment

classes which provide formal literacy instruction to preschoolers. These factors could result in the wide-ranging RA levels observed in the study's sample. Having demonstrated the differential effects of the learning methods studied, it is important that the appropriate methods be used for the respective groups of children so that learners' character recognition abilities can be effectively enhanced.

Although the current module combination system could help to cater to the learning needs of different groups of children, more can be done in the area of early literacy instruction to help narrow the gap in RA levels. Unlike children in Mandarin-speaking societies where written Chinese is salient in their day-to-day life, children in Singapore need to be intentionally exposed to Chinese print, for instance, in school. Therefore, it is hard for those with limited print exposure to detect the regularities in the Chinese writing system through statistical learning because they lack sufficient input and data in order for generalisation to occur. It is hoped that explicit formal instruction to raise awareness about the features of the Chinese script can help children with limited print experience better develop their radical awareness and apply this to learn or decode new characters. Raising children's RA level would provide them a stronger foundation for character learning.

In view of the study's findings, there are some pedagogical implications regarding Chinese character instruction to be considered.

Helping Children Develop Radical Awareness

It has been suggested that explicit instruction on the internal structures of Chinese characters may foster the development of radical awareness (Chang et al., 2014; Lam & McBride-Chang, 2013). Since the level of radical awareness can affect learning effectiveness, more should be done at an early stage, i.e. preschool years, through developmentally appropriate activities, to help children develop radical awareness. When introducing the strokes of Chinese characters to preschoolers, they can be asked to identify or trace the particular stroke in real characters (such as their own Chinese names), rather than searching for the stroke embedded as part of a drawing. This would help them understand that strokes make up the characters they see.

When preschoolers are older and are able to recognise some simple characters, start to introduce sequencing games to help them gradually identify the regularities in Chinese characters, from strokes, internal structure to radicals and components. In mathematical learning, children are often tasked to form patterns or identify incorrect entries in patterns. This is often done using

shapes, numbers, alphabets or pictures. To help enhance their sensitivity towards Chinese characters, characters can be used in these tasks. The purpose of using characters is not to teach them to recognise the characters, but expose them to an appropriate set of characters so that they can identify, or be sensitised to, patterns in them.

Chunking in Character Learning

Several studies have found visual chunking, that is, grouping characters sharing the same chunks in the learning process, beneficial to adult L2 learners (Chang et al., 2014; Xu et al., 2014), as this helps to lessen visual memory load during learning and strengthen the orthographic representations, as well as orthography–phonology and orthography–semantics connections.

In the Singapore curriculum, characters are learnt based on sequence in the texts. Therefore, it will be difficult to achieve such grouping. Furthermore, there is concern that young children may find them confusing. One suggestion would be for teachers to link the new characters to previous ones learnt that share the same chunk. This will help to reinforce their learning of the chunk and the characters containing it. Over time, this will help to raise their radical awareness and build up their radical knowledge.

Stroke Sequence and Focusing on Radicals/Components

This study did not find that focusing on radicals/components has an advantage over stroke sequence, possibly because both can help learners to decompose the characters into smaller parts and can serve as retrieval cues. Given that both are effective methods of encoding, they can be used simultaneously to aid character learning. For semantic radicals, meanings of the radicals will help to strengthen the orthography–semantics connection, while the phonetic components will help to enhance the orthography–phonological connections. For complex characters, highlighting familiar components will also be helpful as it reduces the visual memory load during learning. Furthermore, it helps to draw attention to the internal structure of Chinese characters. Stroke sequence is also useful in reducing memory load during learning when learners are familiar with the stroke sequence of specific radicals/components. Subsequently, these encoding methods will also enhance learners' learning of new characters as they can efficiently encode the orthographic forms of new characters in the memory with very little practice.

Other evidence-based methods of effective vocabulary instruction, such as learning through multiple modalities, providing contextual information and child-friendly explanations, and

repeated exposures (both in terms of frequency and depth of processing), can also be explored to enhance children's learning outcomes.

Apart from formal literacy instruction, parents also play a key role in fostering children's development of radical awareness by giving their children early exposure to and rich experience in Chinese print. Studies conducted in China, Hong Kong and Singapore have found home literacy practices (Shu et al., 2002), particularly the age at which parents teach their children to read Chinese (Li & Rao, 2000), to be a significant predictor of children's Chinese literacy development. Li and Rao (2000) had proposed that the complexity of the Chinese script could be a key factor why parental involvement is important to children's Chinese reading development. A regression analysis of this study's parent questionnaire data (Lau, Toh, & Chan, 2019) also demonstrated parents' role in their children's Chinese literacy development through the literacy practices they adopt at home. The discussion above could also help parents enhance their children's Chinese literacy experience at home.

4.1.4 Limitations of the Study

One limitation of this study is the small sample size. A larger sample size would yield more precise and reliable data, especially when making group comparisons. However, a larger research team would be required in order to collect the data within a limited period of time and higher manpower costs will be incurred.

Since the post-test on orthographic awareness post did not manage to yield significant results, the pre-test on radical awareness could have been repeated after the training to gauge the gain in radical awareness. This would add another dimension to evaluate the effectiveness of the learning methods.

Two other skills, working memory (Zhou & McBride, 2018) and statistical learning ability (Tong & McBride, 2014), as well as participants' language background and literacy learning experience, could also be considered to better understand children's development of character recognition ability.

4.2 Conclusion

For an inconsistent orthography like Chinese, having a strong foundation in the spoken language and rich home literacy experience is not adequate for Chinese literacy development. Formal instruction also has a significant role in contributing to a child's Chinese reading development,

especially when English-Chinese biscriptal literacy learning is an uphill task for those lacking intrinsic motivation. By focusing on the basic learning elements of encoding and modality, this study hopes to work on the most fundamental issue of character recognition in Chinese literacy learning.

Unlike most other studies which compared methods across modality and encoding methods (Chang et al., 2014; Cao et al., 2013b), this study compared methods of encoding within the same modality. This allows us to clearly observe the effects of encoding *per se*. By repeating the same encoding method in a different modality, it also revealed an interaction between the two.

Through this small scale research, evidence regarding the differential effects of the character learning modes have been gathered to help us understand which methods better cater to the learning needs of different groups of learners, and how children with different language proficiency and literacy experience may learn to learn Chinese more like native or foreign language learners.

Given that vocabulary knowledge, general working memory, lexical tone sensitivity, and orthographic awareness are most strongly correlated to Chinese word reading (Zhou & McBride, 2018), helping children to develop orthographic awareness and knowledge should be one of the key foci of early Chinese literacy instruction. This study has revealed on how wide-ranging Singapore Primary One children's levels of radical awareness are and how this has affected their learning outcomes, as well as the development of their visual processing skills. Some pedagogical suggestions have been offered based on the study's findings. It is hoped that adjustments can be made to Singapore's early Chinese literacy instruction so that children can work on these component skills effectively at an early stage, and eventually build up their visual and orthographic processing skills over time. Citing real-life examples from today's Secondary One and Two classrooms, students make mistakes, such as misreading 进 as 讲, writing 收拾 (shōushi, means to tidy up) as 收尸 (shōushī, means to collect the corpse) and writing 肮脏 (āngzāng, means filthy) as 安葬 (ānzàng, means to bury) due to weaknesses in orthographic processing and phonological sensitivity. It is therefore imperative that children develop good character recognition ability, in order to avoid such mistakes and build a strong foundation for the development of reading comprehension skills.

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APPENDIX I

Selected Data from Parent Questionnaire

Table 1a: Pattern of Child's Language Use

Child's Language Use	Experiment 1 (N=23)	Experiment 2 (N=20)	Experiment 3 (N=20)	Total
	Percent	Percent	Percent	Percent
Speaks English all the time, but almost never speak Mandarin.	8.7	10.0	0.0	6.3
Speaks English often, but speaks a little Mandarin.	47.8	45.0	45.0	46.0
Speaks English sometimes and speaks Mandarin sometimes.	17.4	40.0	45.0	33.3
Speaks a little English, but speaks Mandarin often.	21.7	5.0	5.0	11.1
Almost never speaks English, but speaks Mandarin all the time.	4.3	0.0	5.0	3.2
Total	100.0	100.0	100.0	100.0

$H(2) = 0.90, p = .64$

Table 1b: Pattern of Child's Language Exposure

Child's Language Exposure	Experiment 1 (N=24)	Experiment 2 (N=20)	Experiment 3 (N=20)	Total
	Percent	Percent	Percent	Percent
Hears English all the time, but almost never hears Mandarin.	4.2	0.0	0.0	1.6
Hears English often, but hears very little Mandarin.	29.2	40.0	25.0	31.3
Hears English sometimes and hears Mandarin sometimes.	45.8	55.0	70.0	56.3
Hears very little English, but hears Mandarin often.	20.8	5.0	5.0	10.9
Almost never hears English, but hears Mandarin all the time.	0.0	0.0	0.0	0.0
Total	100.0	100.0	100.0	100.0

$H(2) = 1.05, p = .59$

Table 2a: Child's Home Literacy Environment – Chinese Books

Number of Chinese Books at Home	Experiment 1 (N=24)	Experiment 2 (N=20)	Experiment 3 (N=20)	Total
	Percent	Percent	Percent	Percent
Less than 10	37.5	20.0	20.0	26.6
10 – 19	29.2	40.0	35.0	34.4
20 – 29	16.7	10.0	25.0	17.2
30 – 39	12.5	15.0	15.0	14.1
40 – 49	0.0	0.0	0.0	0.0
More than 50	4.2	15.0	5.0	7.8
Total	100.0	100.0	100.0	100.0

$H(2) = 1.79, p = .41$

Table 2b: Child's Home Literacy Practices – Frequency of Chinese Reading

Frequency of Reading Chinese Books to Child	Experiment 1 (N=24)	Experiment 2 (N=20)	Experiment 3 (N=20)	Total
	Percent	Percent	Percent	Percent
Daily	4.2	0.0	0.0	1.6
4 – 6 times per week	0.0	15.0	0.0	4.7
1 – 3 times per week	8.3	25.0	10.0	14.1
Once in a while	58.3	30.0	65.0	51.6
Rarely/Never	29.2	30.0	25.0	28.1
Total	100.0	100.0	100.0	100.0

$H(2) = 1.73, p = .42$

Table 2c: Child's Home Literacy Practices – Age of Exposure to Chinese Print

Mean Child's Age When Parent Started	Experiment 1 (N=20)	Experiment 2 (N=17)	Experiment 3 (N=19)
	Mean (SD)	Mean (SD)	Mean (SD)
(A) Teaching Child Chinese Characters	3.35 (1.77)	3.05 (1.54)	2.85 (1.87)
(B) Reading Chinese Books to Child	3.4 (1.79)	2.82 (1.88)	3.11 (2.33)

For Item (A), $F(2,60) = .45, p = .64$; for Item (B), $F(2, 53) = .38, p = .69$.

APPENDIX II
Samples of Training Stimuli & Learning Materials

Experiment 1 – With *Pinyin* Condition

烧	Burn
<u>shāo</u>	

Experiment 1 – Without *Pinyin* Condition

烧	Burn
---	------

烧

Burn

烧 shāo

烧	烧	烧		
shāo	shāo	shāo	shāo	shāo

shāo	shāo	shāo	shāo	shāo

烧

Burn

烧 shāo

烧	烧	烧	烧	烧

烧	烧	烧	烧	烧

烧

Burn

烧

火 (Fire) + 尧

E

烧	烧	烧		
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--	--	--	--	--

烧

Burn

烧

烧烧烧烧烧烧烧烧烧烧

烧	烧	烧		
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APPENDIX III

Samples of the Training Instructions for Learning Conditions

Experiment 1 – Viewing Modality

Cycle 1

This is _____. Let the child repeat after you.

If the child mispronounces, repeat one or two more times.

It means _____. Let the child repeat after you.

Now, you have 30 seconds to learn this word. Cover the English text with blank paper.
Do NOT let the child write characters with their fingers.

After 30s, move on to the next character.

Cycle 2 & 3

After all 6 characters have been completed, repeat the following procedure for two cycles.

What is this word?

If the child mispronounces or cannot recall, provide the answer. Let the child repeat after you.

It means.... (let child answer).

Now, you have 30 seconds to learn this word. Cover the English text with blank paper.

After completing Cycle 3, begin Training Evaluation.

Experiment 2 & 3 – Free & Structured Writing Modality

This is _____. Let the child repeat after you.

If the child mispronounces, repeat one or two more times.

It means _____. Let the child repeat after you.

In Experiment 3a, **the part on the left/bottom is** _____ 字旁/底, **it means/has to do with** _____. **The part on the right is** _____.

In Experiment 3b, **let us look at how we write this character.** Go through stroke by stroke with a pen to guide child.

Now, you have 90 seconds to write this word/pinyin.

Stop the child at 90s.

Before moving to the next word,

What is this word?

If the child mispronounces or cannot recall, provide the answer. Let the child repeat after you.

It means... (let child answer).

Move on to the next character. Repeat the same procedure.

After going through all the six characters,

Now we will go through the words we have just learnt.

This is... (let child answer).

If the child mispronounces or cannot recall, provide the answer. Let the child repeat after you.

It means.... (let child answer).

After going through all six characters, begin Training Evaluation.

APPENDIX IV

Samples of Test Materials

Pre-Test Task 1: Picture Selection Task

Pre-Test Task 2: Picture-Character Mapping Task

Pre-Test Task 3: Phonetic Component Mapping Task

纨

冠

纸

地

玩

Evaluation Task 1: Orthographic Form Recognition Task

铁

铁

铁

Post-Test Task 1: Detect Component Task

揪 护 获 拼 说 虎 盛 锐 碳
泪 青 计 谈 驳 发 别 买 磅
张 梦 这 为 得 毯 斧 跨 秋
焚 辉 驾 都 争 送 付 轰 伏

Post-Test Task 2: Component in Pseudocharacter Task

𩇛 霄 𩇛 𩇛