Orthographic Learning via Self-Teaching: Evidence from Mandarin Chinese

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Abstract

This dissertation investigates the orthographic learning process of a non-alphabetic Chinese script via self-teaching. Orthographic learning is the process by which children commit word forms to memory. Successful orthographic learning leads to automaticity with word recognition; in turn, automated, efficient word recognition facilitates fluent reading. The self-teaching hypothesis proposes that reading fluency is built up via a self-teaching mechanism that empowers orthographic learning of new words on an item-by-item basis. Central to the self-teaching mechanism is phonological recoding. The internal structure properties of Chinese characters and the sublexical phonology and semantics also permit developing readers to self-teach Chinese orthographic forms.

More than 80% of the Chinese characters are phonograms. Taking advantage of the phonetic and semantic radicals embedded in Chinese phonograms, four studies were carried out following Share's (1999) self-teaching paradigm. The first two targeted young readers in Grade 3, whereas the other two studies focused on children in Grade 2. Participants were asked to independently read aloud short texts where the internal structure of target pseudocharacters and the number of exposure were manipulated. Two posttests, including an orthographic choice task and a spelling task, were administered both immediately after the reading phase and after a 3-day interval to measure orthographic learning. The overriding aim of all studies was to explore the possibility of orthographic learning via self-teaching in the visually complex, traditional Chinese script used in Taiwan and Hong Kong, as distinct from the simplified Chinese script used in China. Other aims were to look into issues as to whether radicals play a role in Chinese orthographic learning.

Study 1 examined the effect of Zhuyin on Chinese orthographic learning. Zhuyin is the phonological aid system used to list pronunciations alongside unknown characters in Taiwanese child books; Zhuyin is completely transparent and alphabet-like. Based on the self-teaching hypothesis, extraneous phonological aids, such as Zhuyin, would divert children's attention away from orthographic details. Favoring this prediction, the results on both posttest measures depicted a significantly stronger learning effect in conditions without Zhuyin than those with Zhuyin.

Following up on the finding that Zhuyin did not give rise to optimal orthographic learning in Chinese, Study 2 looked at the issue whether phonetic radicals are sufficient for functional learning of Chinese orthographies. One of the fundamental tenets in the self-teaching theory is that phonological recoding is critical to orthographic learning. Zhuyin does not aid the process of Chinese orthographic learning by offering accurate pronunciations as much as previously assumed; it is thus arguable that the phonological recoding opportunities afforded by the phonetic radicals embedded in target pseudocharacters are crucial in learning to read Chinese. Through the manipulation of the availability of phonetic radicals embedded in targets, Study 2 reported a more robust learning effect on both posttest measures when targets were embedded with a phonetic radical than without.

Similar to morpho-semantic information in English, the semantic hint embedded in Chinese characters might be another useful resource that unskilled readers can bring to bear upon Chinese orthographic learning. Study 3 tested the cueing effect of semantic radicals by embedding targets with cueing and non-cueing semantic radicals. Children performed significantly better in conditions with cueing semantic radicals than non-cueing ones; this demonstrated that the semantic radicals embedded in characters also modulated Chinese orthographic learning to a certain extent.

Semantic transparency has been documented to influence Chinese word recognition; it is possible that semantic transparency also has an impact on orthographic learning. With the working definition that semantic transparency in orthographic learning refers to the semantic relatedness of an embedded semantic radical in relation to the semantic information that is to be instantiated into the target from the context, Study 4 manipulated thus the semantic relatedness between the level of embedded semantic radical and that of the context semantics. The results from Study 4, though not statistically significant, exhibited a general trend towards better learning in semantic opaque conditions. The finding might arise from the fact that, unlike established readers, 2nd grade children have yet to fully appreciate the semantic aspect at a global level.

Taken together, the dissertation provided support to Chinese orthographic learning via self-teaching. Consistent with the self-teaching hypothesis, orthographic learning was evidenced with significantly more targets selected and more target spelling patterns reproduced than other alternatives. In general, the self-teaching hypothesis is also valid to account for learning to read in a non-alphabetic script, like Chinese. Taiwanese children learning to read a visually more complex, traditional Chinese script exploited the phonetic and semantic information that is embedded in the writing system to self-teach orthographic details. The self-teaching aspect of orthographic learning is hence universal across disparate writing systems, and phonology is also the key to learning to read Chinese.

Zusammenfassung der Dissertation

Diese Dissertation beschäftigt sich mit Fragen des orthographischen Lernprozesses einer nicht-alphabetischen, chinesischen Schrift durch Self-Teaching. Orthographisches Lernen ist definiert als der Prozess, durch den Kinder im Gedächtnis Repräsentationen von Wortformen anlegen. So werden automatisierte Worterkennung und damit flüssiges Lesen möglich. Die Self-Teaching-Hypothese besagt, dass sich die automatisierte Worterkennung durch einen Mechanismus selbstständigen Lernens entwickelt, der Kinder befähigt, die Orthographie neuer Wörter Item für Item zu erlernen. Für diesen Mechanismus ist die phonologische Rekodierung wichtig. Auch die chinesische Orthographie kann aufgrund der internen Struktur der Schriftzeichen und aufgrund der sublexikalischen Phonologie und Semantik durch Self-Teaching erworben werden.

Mindestens vier Fünftel aller chinesischen Schriftzeichen sind Phonogramme. Die phonetischen und semantischen Radikale, die in die chinesischen Phonograme eingebettet sind, wurden für vier Experimente nach dem Self-Teaching-Paradigma (Share, 1999) genutzt. An den ersten zwei Experimenten nahmen Drittklässler teil, die anderen beiden waren auf Zweitklässler abgestimmt. Alle Teilnehmer wurden gebeten, selbstständig Kurztexte vorzulesen. Die innere Struktur des Target-Pseudo-Schriftzeichens und die Häufigkeit seiner Darbietung wurden innerhalb der Kurztexte manipuliert. Sowohl unmittelbar nach der Lesephase als auch nach einem dreitägigen Intervall wurden zwei Tests durchgeführt, eine orthographische Entscheidungsaufgabe und eine orthographische Produktionsaufgabe, um den Erfolg des orthographischen Lernens zu erfassen. Das vorrangige Ziel der Experimente war es zu untersuchen, inwiefern orthographisches Lernen im Sinne der Self-Teaching-

Hypothese in der visuell komplexen, nicht-alphabetischen chinesischen Schrift möglich ist. Darüber hinaus wurde untersucht, ob Radikale eine Rolle in diesem Lernprozess spielen.

Experiment 1 untersuchte den Einfluss von Zhuyin auf den orthographischen Lernprozess im Chinesischen. Zhuyin sind spezielle Zeichen in taiwanesischen Kinderbüchern, die Informationen über die Aussprache unbekannter Schriftzeichen geben. Zhuyin ist vollständig phonologisch transparent und dem Alphabet ähnlich. Basierend auf der Self-Teaching-Hypothese würden externe phonologische Hilfsmittel, in diesem Fall Zhuyin, die Aufmerksamkeit der Kinder von den orthographischen Details ablenken. Diese Vorhersage wurde durch die Ergebnisse von Experiment 1 bestätigt: In den Bedingungen ohne Zhuyin zeigten sich in beiden Tests deutlich stärkere Lerneffekte als in den Bedingungen mit Zhuyin.

Im Anschluss an die Beobachtung, dass Zhuyin orthographisches Lernen im Chinesischen beeinträchtigt, befasste sich Experiment 2 mit der Frage, ob phonetische Radikale ausreichend für funktionales Lernen der chinesischen Orthographien sind. Gemäß der Self-Teaching-Hypothese ist davon auszugehen, dass die phonologische Rekodierung kritisch für das orthographischen Lernen ist. Trotzdem (und entgegen der Annahme) unterstützte Zhuyin, also die Angabe der genauen Aussprache, den Prozess des orthographischen Lernens im Chinesischen nicht. Eine mögliche Erklärung dafür ist, dass die Information zur phonetischen Rekodierung, die in das Target-Pseudo-Schriftzeichen selbst eingebettet sind, entscheidend dazu beitragen, Chinesisch lesen zu lernen. In Experiment 2 wurde die Verfügbarkeit der eingebetteten phonetischen Radikale in den Targets manipuliert.

In beiden Tests zeigte sich ein robusterer Lerneffekt für Targets mit gegenüber Targets ohne phonetisches Radikal.

Ähnlich der morpho-semantischen Information im Englischen kann das semantische Radikal in chinesischen Schriftzeichen eine weitere nützliche Ressource im Erwerb der Lesefähigkeit im Chinesischen sein. Experiment 3 untersuchte den Cueing-Effekt semantischer Radikale, indem entweder solche semantischen Radikale in die Target-Pseudo-Schriftzeichen eingebettet wurden, die einen Hinweis (Cue) auf die Bedeutung geben, oder solche, die keinen Hinweis liefern. Die Teilnehmer zeigten signifikant bessere Leistungen, wenn das semantische Radikal auf die Bedeutung des Targets verwies, als wenn es keinen Hinweis bot. Das Ergebnis weist darauf hin, dass semantische Radikale in ihrer Funktion, auf die Bedeutung der Schriftzeichen hinzuweisen, ebenfalls einen Beitrag zum Erwerb der chinesischen Orthographie leisten.

Es ist bekannt, dass die semantische Transparenz den Worterkennungsprozess im Chinesischen beeinflusst. Es ist zu vermuten, dass sie auch das orthographische Lernen beeinflusst. Semantische Transparenz wird als Grad der Übereinstimmung der Bedeutung des semantischen Radikals mit der Bedeutung des gesamten Schriftzeichens definiert. Letztere soll in den Experimenten dieser Studie aus dem Kontext erschlossen werden. Folglich manipulierte Studie 4 die Übereinstimmung zwischen der Target-Bedeutung, die der Kontext nahelegte und der Bedeutung, auf die das semantische Radikal schließen ließ. Es zeigte sich ein genereller, wenn auch nicht-signifikanter Trend in Richtung besserer Lernleistungen für die Bedingungen mit intransparenten semantischen Radikalen. Dies könnte damit zusammenhängen, dass Zweitklässler im Unterschied zu Erwachsenen den semantischen Aspekt auf globaler Ebene noch nicht vollständig nutzen können.

Zusammenfassend unterstützt die Dissertation die These, dass die chinesische Orthographie in einem Prozess des Self-Teaching erworben wird. Im Einklang mit der Self-Teaching-Hypothese äußerte sich orthographisches Lernen darin, dass Target-Schriftzeichen häufiger korrekt ausgewählt und häufiger korrekt geschrieben wurden. Ganz allgemein bedeutet das, dass die Self-Teaching-Hypothese auch dann gilt, wenn es um den Erwerb der Lesefähigkeit in einer nicht-alphabetischen Schrift geht. Taiwanesische Kinder lernen die traditionellen chinesischen Schriftzeichen, die visuell komplexer sind als das vereinfachte Skript, das in China benutzt wird. Dabei profitieren sie auch von den phonetischen und semantischen Informationen, die in die Schriftzeichen eingebettet sind, wenn sie sich selbst die orthographischen Details beibringen. Der selbstlernende Aspekt im orthographischen Lernprozess ist wohl universell in unterschiedlichen Schriftsystemen zu finden, und Phonologie spielt auch im Chinesischen für den Erwerb der Lesefähigkeit eine zentrale Rolle.

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Abbreviations

DRC	dual route cascaded model
GPC	grapheme-to-phoneme conversion
OPC	orthography-to-phonology correspondence
PAL	paired-associate learning
RAN	rapid automatized naming
SVR	simple view of reading
UPP	universal phonological principle
VWFA	visual word form area

Chapter 1

Introduction

1.1 Literacy and Orthographic Learning

Literacy skills, fundamentally both reading and spelling competences, lie in the heart of primary education, such that they aid the acquisition of lexical and world knowledge in the course of later scholastic life. According to Ehri (2000), learning to read and learning to spell are two sides of a coin. Put it another way, "reading and spelling are manifestations of the same underlying knowledge source" (Ehri, 1997, p. 262). Indeed, there is compelling evidence that the two skills exploit the same underlying word representations (Burt & Tate, 2002).

The interconnectedness of reading and spelling is well-founded on the grounds that spelling performance is positively correlated with reading skills (Allyn & Burt, 1998; Burt & Butterworth, 1996; Burt & Tate, 2002; Pennington, Lefly, Van Orden, Bookman & Smith, 1987; Stanovich & West, 1989) and that skilled word recognition is found mostly among good spellers (Burt & Fury, 2000; Holmes & Ng, 1993). The single-lexicon view is further substantiated in Frith's (1980) study where children's performance on spelling and reading tasks exhibited moderate to high correlations. Of importance, this view is collectively advanced in theories dealing with reading acquisition (e.g., Ehri, 1986; Perfetti, 1992) as well as spelling processes (Simon & Simon, 1973; Templeton, 1991). The transfer effect of reading and spelling practices is established to go both ways in the process of forming word representations in orthographic memory (Conrad, 2008), though children do not always benefit symmetrically from the two genres of practice in orthographic development (Ehri, 1997; Shahar-Yames & Share, 2008).

Taken together, reading and spelling are closely related to each other through the shared knowledge base of word forms. In this sense, research into the acquisition of word forms conflates the two traditionally disparate lines of research: learning to read and learning to spell. Nonetheless, most of the well-specified models of word spelling and word reading do not address the crucial issue of how orthographic representations come to be committed to memory. Recently, a small number of studies have taken up the issue by adapting training approaches to look into children's and adults' learning of orthography (Bailey, Manis, Pedersen, & Seidenberg, 2004; Burt & Blackwell, 2008; Chalmers & Burt, 2008; Cunningham, Perry, Stanovich, & Share, 2002; Dixon, Stuart, & Masterson, 2002; Ehri & Saltmarsh, 1995; Johnston, 2000; Share, 1999). At the initial stage of reading development, reading beginners are explicitly instructed on word orthographies at school, but beyond the beginning years of literacy education a great deal of orthographic learning takes place inadvertently during independent reading (Nagy, Anderson, & Herman, 1987; Nagy, Herman, & Anderson, 1985). It is thus interesting to take a closer look into the process of incidental acquisition of word items via independent reading during orthographic development.

In short, one of the most fundamental building blocks underlying the rudimentary literacy accomplishment—automated word recognition—is unequivocally buttressed by a large stock of well-specified word forms. The process leading up to automaticity with word recognition is hence the main research focus of orthographic learning; orthographic learning thereby refers to the process by which novice readers move from reading each word strenuously via phonological recoding to effortlessly, swiftly word reading via automated, fluent word recognition. An orthographic lexicon is theoretically posited to be interconnected to a phonological component and a semantic component; successful orthographic learning of a word item would lead to swift, accurate activation of its phonological and semantic information through the visual input of this given word. Skilled readers are able to retrieve meaning and sound rapidly and fluently when they are engaged in reading. Studies have also established that children incidentally add word spellings and meanings into their lexicon during reading, and that when asked to spell, they draw on the forms that they retained in memory (Anderson, 1996; Ku & Anderson, 2001; Jenkins et al., 1984; Shu et al., 1995; Werner & Kaplan, 1952).

All in all, orthographic learning is supposed to be a universal process for children en route to becoming literate, regardless of the surface scriptal difference in writing systems. To the exception of Liu and Shiu's (2011) study focusing on non-alphabetic Mandarin Chinese, recent evidence of orthographic learning has been predominantly coming from investigations of alphabetic languages, such as Hebrew (Share, 1999, 2004), English (Cunningham, 2006; Kyte & Johnson, 2006) and Dutch (de Jong & Share, 2007). Despite extant literature on orthographic development focusing nearly exclusively on alphabetic languages, the acquisition of the word forms in the orthographic memory is also one of the central issues to research of non-alphabetic Chinese reading development. To date, there is a paucity of research literature on Chinese orthographic learning. One of the reasons is that it is either conceptually difficult or not obvious, at first sight, to apply theories devised on the basis of alphabetic scripts to the logo-syllabic Chinese script. The present dissertation is dedicated to addressing issues in relation to Chinese orthographic learning, with a view to complementing current reading theories and to better understanding literacy acquisition across orthographies.

1.2 Research Aims of the Dissertation

The dissertation seeks to shed light on how orthographic learning in Chinese unfolds via self-teaching and what mechanisms and resources children draw upon in order to acquire word representations. One other goal is to show that orthographic learning is one of the universals that should be common in the process of language acquisition across various orthographies.

Moreover, the dissertation attempts to provide a general literature overview on learning to read in alphabetic and Chinese logo-syllabic writing systems. As a considerable part of existing research literature is based on alphabetic languages, we also offer a review of findings and theories on Chinese reading acquisition to address this imbalance.

1.3 Organization of the Dissertation

The dissertation is arranged as follows. Before delving into the realm of Chinese orthographic learning, chapters 2 and 3 will supply background knowledge of some major concepts and theories of reading acquisition for both alphabetic languages and Chinese, in order to set the stage for the chapters to come.

Chapter 2 aims to review the major theories related to learning to read in alphabetic languages, dominantly in English. Some theoretical details and empirical evidence will then be provided for a discussion on orthographic learning in alphabetic writing systems.

Starting with an introduction to the features of Chinese writing system and insights into internal structures of characters, chapter 3 also looks at theories accounting for learning to read in Chinese. At the end of the chapter, we will be making a case for how the self-teaching hypothesis (Jorm & Share, 1983; Share, 1995) could be a valid, general framework to study Chinese orthographic learning as well.

With prior chapters setting the stage for better understanding and appreciation of research questions and hypotheses in the dissertation and on the basis of Share's (1995, 1999) speculation concerning Chinese orthographic development, chapter 4 presents the research questions and hypotheses to be put to test in the four experiments in chapters 5 and 6. During orthographic learning, children are expected to bring whatever it is offered in a script to bear on the acquisition process. Thus, chapter 5 concentrates on the phonetic aspects of the Chinese script, whereas chapter 6 on the semantic aspects.

Chapter 5 consists of Studies 1 and 2, specifically investigating the general application of Share's self-teaching hypothesis (Jorm & Share, 1983; Share, 1999, 1995; Share & Jorm, 1987) to account for orthographic learning in Chinese via self-teaching, and the issue as to whether, in natural text reading, phonetic decoding is enough to give rise to functional learning effect (i.e., Zhuyin).

Chapter 6 is composed of two studies, too. It looks into the peculiar role of semantic radicals internal to Chinese characters that might also have an effect on orthographic learning, as is the case with Chinese lexical processing. Study 3 explores the effect of semantic cueing form semantic radicals in orthographic learning, and Study 4 examines the effect for semantic transparency in the course of orthographic development.

Chapter 7 closes up the whole dissertation by presenting some key conclusions from the studies conducted in the dissertation, and illustrates the limitations of the current research, followed by a discussion on the pedagogical implications. Last but not least, the chapter provides some insights for future research concerning orthographic learning.

Chapter 2

Review on Learning to Read in Alphabetic Languages

In chapter 2, a brief review of reading theories intends to cover single word reading and reading development in alphabetic languages, mainly in English. Not until Share's (1995) self-teaching model was one of the common drawbacks of the extant reading theories being addressed; all of them were unable to explicate satisfactorily the process of how word representations that are fundamental to fluent reading come to be specified in orthographic memory in the very first place. The self-teaching theory fills the void by specifically capturing the process in which sound and word forms are associated in reading acquisition, and it thus complemented reading models currently available, such as the dual route models, the connectionist models, the stage theories, etc.

The purpose of chapter 2 is to look at models concerning single word reading and reading development and to point out their lack of success when it comes to accounting for the initiation of word forms establishment in mental lexicon. The final sections of the chapter are dedicated to expounding the theoretical tenets of Share's (1995, 2008) self-teaching hypothesis and the current status of empirical findings in support of the theory. The literature review here would serve as a point of departure to explore Chinese orthographic learning via self-teaching and to appreciate related issues in a Chinese context.

2.1 The Not-So-Simple View of Reading and Orthographic Learning

The process of learning to read has been modelled as Reading Comprehension (RC) as the function of Decoding (D) and Listening/Linguistic Comprehension (LC), succinctly formulated into RC = D × LC (Gough & Tunmer, 1986; Hoover & Gough, 1990). In essence, the so-called simple view of reading (SVR) conceives reading acquisition as being composed of word decoding and comprehension.

There are only nuanced differences between the linguistic and reading comprehension skills. Both genres of comprehension skills are generally acquired in the natural development of learning to speak, whereas decoding skills, otherwise, demand awareness and experiences to the print materials that are not an offshoot of the normal course of conversations. The vital role of decoding or word reading is, without a doubt, enshrined in the SVR formula, as Hoover and Gough (1986, p.128) have asserted that 'decoding is also of central importance in reading, for without it, linguistic comprehension is of no use'. This view is also supported by studies demonstrating that decoding skills have very accurately predicted later reading comprehension (e.g., Lesgold & Resnick, 1982; Juel, 1988).

However, some ambiguity in how the construct of decoding is conceptualized has arisen from the original choice of the term *decoding* within *the simple view* (Kirby & Savage, 2008). In a strict sense, decoding is synonymous with serial decoding through grapheme-to-phoneme conversion (GPC) rules. For that matter, Ouellette and Beers (2010) argued that decoding in the SVR model is, in fact, more pertinent to word recognition in general, as word recognition may encompass not only serial decoding, but also orthographic learning (Ehri, 2005; Ouellette & Beers, 2010; Share, 1995). Indeed, Share and his associates (Jorm & Share, 1983; Share &

Stanovich, 1995) established that the acquisition of orthographic representations necessary for fluent word identification that leads to undisrupted reading comprehension is developed as a result of successful orthographic learning via phonological decoding (Share, 1999, 2004). On this view, orthographic learning is one of the most pivotal learning processes underlying word recognition. Though it is not equated to reading *proper*, it is itself one of the most important building blocks on which learning to read is based.

Albeit simplistic, the original SVR framework allows for better understanding of reading acquisition and better arrangement of teaching practices (Rose, 2006). Nonetheless, factors, such as fluency (Johnston & Kirby, 2006; Kirby, 1988; Kuhn & Stahl, 2003), reading strategies (Dole, Duffy, Hoehler, & Pearson, 1991), vocabulary knowledge, word recognition and orthographic learning (Ouellette & Beers, 2010), have been proposed to be taken into consideration in the model. The complex interactions of these newly proposed components underlying the SVR model entail, hence, the necessity of a "not-so-simple" view of reading to broaden the extent to which the SVR model may account for variance in reading acquisition (Braze, Tabor, Shankweiler, & Mencl, 2007; Johnston & Kirby, 2006).

In sum, the not-so-simple view of reading is of relevance to this dissertation, in that it captures more aptly the interplay between print reading and oral language skills by particularly emphasizing that the importance of successful attempts at orthographic learning via phonological decoding leads to a skilled word recognition system. Reading theories would not be complete without taking orthographic learning into account.

2.2 Theories of Single Word Reading

Learning to read is essentially visual encounters with print words that are to be associated to their phonological forms in children's speech vocabulary. Despite the fact that the ultimate goal of reading is to comprehend the contents of texts, reading is mostly about words, not least because indispensable to fluent reading is effortless, automated word identification that, in turn, rests on reliable establishment of orthographic memories acquired via reading (Perfetti, 1992, 1997). According to *the verbal efficiency theory* (Perfetti, 1985), precise word recognition, in itself, does not suffice to ensure fluent reading comprehension. Prior to that, word-coding skills must be elevated to an efficient and automatic level, such that "the freedom from deliberate attention to word identification allows children to attend more to meaning, to use contextual information to facilitate the construction of meaning, and to reflect more broadly upon the content that is read" (Juel, 1991, p.676; Muter, Hulme, Snowling, & Stevenson, 2004; Schwanenflugel, Meisinger, Wisenbaker, Kuhn, Strauss, & Morris, 2006). The emphasis on speed or automaticity of word processes is adequate, but not enough, though.

A prerequisite to automaticity with word identification is solid knowledge about word forms, which is concordant with *the lexical quality hypothesis* (Perfetti & Hart, 2002). Fully-specified word forms are the ones that have fully developed internal orthographic representations, together with their phonological and semantic specifications. In a highly interactive reading architecture, words that are highly specified are, however, autonomous and automatic in the sense that they can be retrieved through the visual input code alone and that the process of word recognition is thus an unconscious, unstoppable one. The well-known Stroop effect is a case in point. When the name of a color is not printed in a color denoted by the name (e.g., the word "blue" printed in red ink instead of blue ink), naming the color of the word takes longer and is more prone to errors than when the color of the ink matches the name of the color. Unequivocally, the Stroop effect demonstrates that a skilled word-recognition system is not subject to strategic control and cannot be switched on and off at will (Castles & Nation, 2006).

Automated, efficient word recognition is one of the critical requirements for successful text comprehension (Adams, 1990; Gough, 1993; NICHD, 2000; Perfetti, 1985; Stanovich, Nathan, West, & Vala-Rossi, 1985 Vellutino, Tunmer, Jaccard, & Chen., 2007). Most theoretical approaches to word recognition posit explicitly three units for lexical representations in memory: orthography, phonology and semantics. However, these models differ in the ways that they account for the cognitive processes implicating the three units when words are read *online*.

Dual Route Models

One of the most dominant models is the dual route theory that postulates the presence of two internal paths for word recognition (Coltheart, 1978, 2001, 2005, 2006; Coltheart, Curtis, Atkins, & Haller, 1993, see Figure 1). Two of the crucial premises in the representational/symbolic model are that, first of all, it assumes a mental lexicon where each word possesses a localist representational entry of itself, and that a mental storage unit for GPC rules is hypothesized.

A "lexical route" and a "non-lexical route" are distinguished in order to accommodate empirical findings as to word familiarity and spelling regularity. The former is to recognize acquainted words in print as a whole unit by sight, while the latter is called upon to process unknown words or pseudowords via GPC rules. What's more, exception words can be read accurately only via the lexical route, and pseudowords only via the non-lexical route.

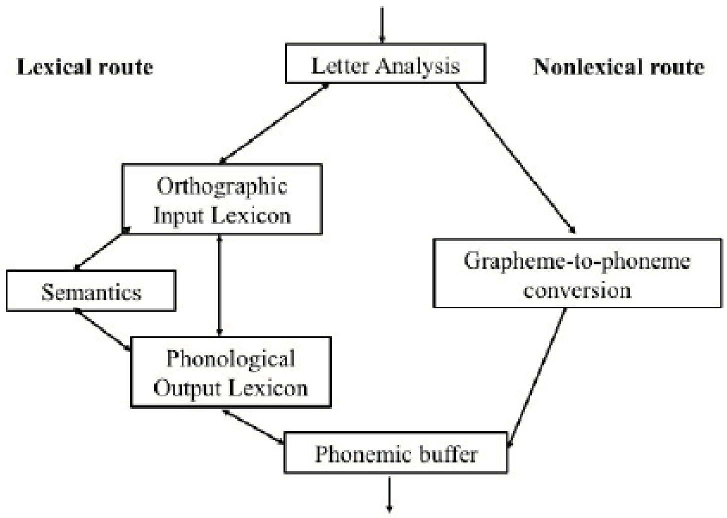

Figure 1. The dual route model of reading aloud (Source: Coltheart et al., 2001)

Recently, Coltheart, Rastle, Perry, Langdon, and Ziegler (2001) have successfully offered the dual route cascaded (DRC) model, a computationally implemented version of the dual route model. The DRC model is consistent with *the overlapping wave model* (Siegler, 1996), positing that the lexical and non-lexical paths are both activated simultaneously to identify a given word, and that, eventually, the lexical route will win over the non-lexical route after repeated exposures to this word for the sake of economy and efficiency. A feedback mechanism is also integrated into the system to more swiftly and accurately aid recognition of common, recurrent symbol-sound patterns.

In spite of its robust explanatory power to account for the bulk of the behavioral data on a range of lexical effects, the dual route model is not a proper model for reading development, in that it fails to provide an answer to the critical issue concerning the occurrences of transition from a given word being sounded out via the indirect/non-lexical route during initial exposure to finally being identified fluently by sight via the direct/lexical route.

Connectionist Models

An alternative theoretical approach to account for word reading is the connectionist models. Within the variants of connectionist models, word information is uniformly postulated to be distributed in different, posited memory units also representing phonological, orthographic and semantic components. All information components of a given word are connected through a learning mechanism resembling the connections of a neural network, and activation in one unit leads to activation in the rest of interconnected units in the whole network and at different hierarchical levels (Plaut, McClelland, Seidenberg, & Patterson, 1996).

When there is an occurrence of a pattern of activation within and across the network at different levels that subsequently leads to an excitation beyond the threshold level, words are consequently recognized with the resulting accurate pronunciations. With repeated encounters with word forms that enhance connections among the memory units and lexical learning, "a dynamical system settles into a stable pattern of semantic activation over several time steps, based on continuous but time-varying input" (Harm & Seidenberg, 2004, p. 669).

Just like in the revised dual route model, word reading also has two processes in the connectionist models as well: one for phonological decoding in order to read pseudowords and regular words, i.e., orthography to phonology; the other for direct accessing lexical representations of regular sight words and irregular words, i.e., orthography via semantics to phonology (Roberts, Christo, & Shefelbine, 2011). One of the key distinctions of connectionist models from the dual route models is that there is no GPC route.

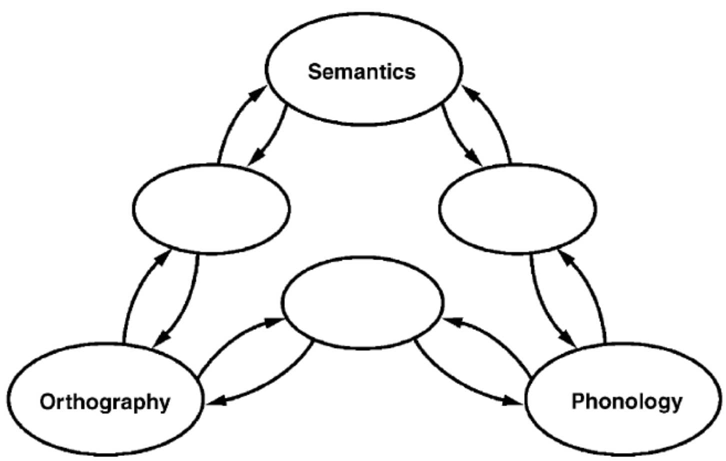

Figure 2. The triangle model of word recognition (Source: Seidenberg, 2005)

Alternately, the connectionist models capture the way how word recognition develops by training a neural net by means of back-propagation between the orthographic and phonological units. This algorithm involves the gradual, slow reduction of discrepancy between the desired and actual outputs of the network by changing the weights on the connections between units when they are simultaneously active. In the case that the two units are associated (a correct response), the connections will be strengthened, but where they are not (an incorrect response), the connections will be weakened. Each change in weight is rather gradual. Accordingly, learning a word takes many trials of feedback and instructions. This runs counter to the clear findings in the literature reporting that learning to read can and often *does* happen uninstructed among young children.

Studies (Share, 1995, 1999, 2004) showed that developing readers learn to read mostly without explicit instruction and outside assistance during exposures to words and that even as few as one single encounter with words could lead to robust, durable learning effect of orthographies. Despite a stronger focus on learning, connectionist models, e.g., the triangle model (Harm & Seidenberg, 2004; Seidenberg, Plaut, Petersen, McClelland, & McRae, 1994, see Figure 2), are not perfect to account for reading development, in that a massive number of trials are required to be directly fed into the network (see Share, 1999, for a discussion) and the posited learning mechanism demands constant feedback and instruction that defy the context of human word reading.

2.3 Theories of Reading Acquisition

Obviously, the reviewed theories of visual word recognition, e.g., the dual route models and the connectionist models alike, concentrate fairly much on the later stage of actual developmental process in the stage or phase theory. The present section is intent on reviewing theories from the perspective of reading development. Theories of learning to read have mainly employed two paradigms for modelling reading acquisition. On the one hand, there are stage theorists; on the other hand, alternative theoretical approaches emphasize the nonstage, incremental nature of acquisition of lexical representations. Except for the outdated nonstage theory proposed by Goodman (1976) and Smith (1971), phonology is acknowledged to play a crucial part when it comes to helping the child to establish word-specific representations in each of these theories. The whole idea of phonology facilitating the acquisition of orthographic memory is picked up and elaborated in the theory for orthographic learning (Jorm & Share, 1983; Share, 1995).

Stage/Phase Theories

Several developmental schemes of reading acquisition have been advanced to portray reading as going through a succession of stages or phases. They converge on the notion that understanding the alphabetic principle is an indispensable insight that enables the connection between printed words and their phonological information to be established (Ehri, 1991), but they differ in their assumptions as to what is acquired and how developing readers apply what they acquired in a given reading process. The discussion here will focus on the models of Frith (1985) and Ehri (1984, 1985, 1987, 1991).

Frith's (1995) proposal postulated three stages of development: starting with a logographic stage, then moving to an alphabetic stage and finally to an orthographic stage. In the starting stage, children without any knowledge of decoding identify words by means of their salient graphic features, such as the letter pattern "ll" as in "hello". Urged by the need to learn to spell, children move into the alphabetic stage where words are decoded through their increasing knowledge of symbol-sound correspondences during exposure to print. Frith (1985, p.318) argued that the GPC rules arm novice readers with 'an important self-teaching mechanism which enables them to successfully read unfamiliar words.' Lastly, the orthographic stage is reached when the growing orthographic knowledge empowers children to swiftly identify words bypassing the necessity of sounding them out all the time.

A variant of the stage-like view is built on previous stage theories and further developed by Ehri (1987, 1991, 1994, 1995). Ehri employed the term "phase" rather than "stage", for she believed that these processing stages are likely to be fuzzier at the edges. Four phases constitute her phase model (see Figure 3), and the transition between phases is continuous and overlaps. The first is a pre-alphabetic phase where children exploit visual cues to recognize and memorize words, followed by a partial alphabetic phase in which children have acquired rudimentary alphabetic information enabling partial phonetic cue reading. When moving into the full alphabetic phase, children possess complete knowledge of GPC rules that allow them to phonologically recode unfamiliar words and to form complete connections between phonological and orthographic forms. During the consolidated alphabetic phase, the decoding skills require fewer efforts and less attention, as children are exposed to more and more words. Eventually, word reading becomes unitized when "words come to be read as single units with no pauses between word parts" (Ehri, 2005, p.169). This is an important feature of sight word reading, because larger chunks or units help reduce the memory load required to store visual word memory (Baddeley, 1986, 1992).

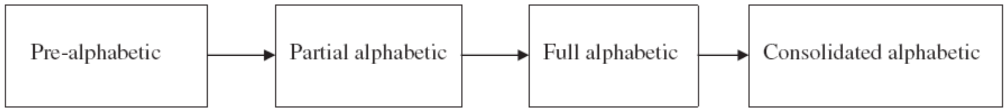

Figure 3. A schematic representation of Ehri’s phases of reading (Source: Beech, 2005)

Commonly, the stage and phase models both start off with a visual stage, pass through a stage that underscores phonology, and end up with another visual stage. “Such a conception not only has a potentially useful practical implication for teachers in that they can monitor and structure the stage of progress of the developing reader, but it also has important ramifications for any theory of reading development” (Beech, 2005, p. 50). However, stage and phase models do not go unchallenged. Main challenges are, for example, that Frith’s model does not succeed in elaborating on the transitions between different stages (see Snowling, 1998, for a review). Moreover, some theorists reject the universality of developmental sequences in reading by highlighting the differences inherent in individual readers and in orthographic depth of writing systems and scripts (Snowling, Hulme, & Goulandri, 1994; Stuart & Coltheart, 1988). Stage or phase theories, though acknowledging the crucial role of phonology in reading acquisition, do not clearly explicate the dimension of reading in which word forms are secured in orthographic memory for sight word reading.

Nonstage Models of Reading Acquisition

The nonstage models that were proposed in the 1970's were obviously obsolete but they were worthy of a mention here (Ehri, 1978; K. S. Goodman, 1976; K. S., Goodman & Y. M. Goodman, 1979; Smith, 1971, 1973; cf. Juel, 1991). In stark contrast to the *qualitatively* defined stages indexed by progressively maturated deployment of decoding strategies in stage/phase theories, the nonstage theories posit only one reading process independently of the proficiency of readers and, instead, they focus on the *quantity* of information processing strategies (e.g., semantic and syntactic knowledge) readers bring to bear upon their reading task (K. S. Goodman, 1976). K. S. Goodman and Y. M. Goodman (1979, p.148) asserted that "there is only one reading process. Readers may differ in the control of this process but not in the process they use."

On this view, reading involves the search for meaning in which, rather than specific graphic information, linguistic and world knowledge serve best the purpose. In the nonstage models, increased language skill is expected to lead to a gain of reading skill.

A strong version of nonstage models was put forward by Smith (1971) who reduced the utility of graphic information in reading to the minimum. Built on the suggestion of Gibson (1965) as to how letter recognition is based on their physically distinctive features, Smith (1971, 1973) has extended it to word recognition by arguing that the printed gestalt are similar to Chinese logograms.

All things considered, these nonstage accounts above are not compatible with the myriad of empirical data demonstrating the important role of phonology and word representational formations in reading development. They also fail to account for the role of orthographic processing by outright constraining reader's reliance to only syntactic and semantic information.

Nonstage Incremental Theory

Sharing the nonstage notion conceptualized in the nonstage models, Perfetti (1992) has presented an alternative theoretical account of reading development, i.e., the restricted-interactive (R-I) model that highlights the incremental acquisition of word representations. In this model, these word representations "can be accessed by their spellings (quantity acquisition) and changes in the *specificity* and *redundancy* (quality dimensions) of individual word's representations" (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001, p. 39).

Autonomous word representations that are specified and redundant can drive recognition bypassing the need for sublexical computation, or support from top-down feedback from semantics (Ehri, 1992; Perfetti, 1992; Share, 1995). Specificity refers to the requirement for orthographic representations to accurately encode the unique position-correct letters for individual words. Meanwhile, these representations augment their phonological redundancy at phonemic and lexical levels, such that word pronunciations are facilitated through letter- and word-level processes. Increasing specificity and redundancy result in high quality, fully-specified representations that input code alone can reliably activate in a skilled orthographic word-recognition system.

The incremental streak of the theory originates from its claim that the increased language skills and word knowledge give rise to increased reading skills. The incremental aspect is founded on studies of Munakata, McClelland, Johnson, and Siegler (1997) and Rayner et al. (2001) that argued that accumulated exposures to printed words and encounters with the world gradually lead readers to the acquisition of various sorts of knowledge and that the gradual shift of strategies between novice and skilled readers is hence a function of the quantity and complexity of the information that has been assimilated.

The lexical quality hypothesis (Perfetti & Hart, 2002) *does* somewhat touch on the issue as to the establishment of word representations in reading development, but still, it does not thoroughly account for the bootstrapping process that comes to be known as orthographic learning, nor does it detail the underlying mechanisms.

All the theories presented above, though accounting for reading development from different standpoints, are compatible in many aspects. Of importance, most of them are in general agreement with the fundamental assumptions that decoding skills unfold with experience and instructions, and that a good grasp and application of the alphabetic principle to reading would lead children to achieving reading skills in early reading acquisition (Juel, Griffith, & Gough, 1986; Share, 1995). On the other hand, a common, key weakness is their failure to address how children independently accomplish the orthographic learning process (MacEachron, 2009).

2.4 Orthographic Learning via Self-teaching: Theory and Evidence from Alphabetic Languages

Previous sections in this chapter have examined some theoretical accounts for word reading and reading development. We have arrived at the conclusion that one of the common shortcomings in these theories on learning to read is that neither of them is sufficient to account for how novice readers become expert readers, i.e., how an automatic, efficient word recognition comes to be built up in the first place. The process by which word representations are accumulated and specified is best accounted for by Share's (1995) self-teaching hypothesis. Its theoretical accounts and current empirical findings are presented and discussed in the coming sections.

Orthographic Learning

The ultimate goal of successful orthographic learning is automatic, effortless word recognition that is vital to fluent reading. Orthographic learning, thereby, refers to the specific process by which readers move from laboriously sounding out unacquainted words to identifying them fluently, rapidly by sight (Castles & Nation, 2006; Ehri, 2005). Automaticity with word recognition is fundamental to the facilitation of text comprehension in reading, just as automaticity is relevant to a wide range of human activities, such as playing piano, driving, and so on (Bloom, 1986). The proficiency in word identification is, however, no guarantee of good text comprehension, as exemplified by so-called hyperlexic readers who are reported to be characterized by good word reading skills, yet low intelligence and hence bad comprehension (Nation, 1999).

Efficient word recognition is underpinned not only by the volume of printed word representations in the mental lexicon, but also by the quality or specificity of the internal representations that encapsulate word-specific letter arrangement (Perfetti, 1992; Ouellette & Beers, 2010; Share, 2008). Experienced readers have at their disposal thousands of internalized and fully-specified word forms, in addition to the general knowledge of orthographic rules. Whether the orthographic knowledge is stored individually at the word level as theorized in the localist DRC models or in a distributed manner within a multi-layered connectionist network as conceptualized in the triangle models, there is a broad consensus that one of the main challenges for the developing readers is to compile knowledge of orthographic representations specifying the identity and order of word sequences in a clear and detailed manner (Booth, Perfetti, & MacWhinney, 1999; Perfetti, 1998, 2007). Orthographic representations are then amalgamated with phonological, morphological, syntactic, and semantic information (Ehri, 2005; Share, 1995). Theories of learning to read have agreed upon the vital role of phonology in this compilation process (Ehri, 2001; Perfetti, 1992).

Taken together, Share (1995) based his self-teaching hypothesis on *the orthographic bootstrapping hypothesis*, “the idea that attempting to decode an unfamiliar word is a form of self-teaching that allows the child to acquire an orthographic representation for the word” (Rayner et al., 2001, p.38). In this sense, self-teaching is a powerful and sustainable mechanism in the course of children’s orthographic development where rote learning through direct item-by-item instruction of characters is not viable when children are confronted with an avalanche of new words every year (Mason, Anderson, Omura, Uchida, & Imai, 1989; Taylor &

Taylor, 1983) and contextual guessing for content words must fail with a predictability at a mere 10% of the cases (Gough, 1983).

Necessarily, research on orthographic learning lies at the core of literacy development, concentrating on the issues of exactly how developing readers manage to accumulate so impressive a reservoir of general and word-specific orthographic knowledge. One theoretical framework that successfully offers some specification as to how readers acquire the orthographic knowledge is Share's (1995) self-teaching hypothesis. In the dissertation, this approach is hence adapted to investigate the issues regarding orthographic development. The following sections provide an overview of the self-teaching model and existing empirical data in support of the theory.

2.4.1 The Self-Teaching Model of Orthographic Learning

The self-teaching model of orthographic learning (Firth, 1972; Jorm 1979; Jorm & Share, 1983; Share & Jorm, 1987; Share, 1995) postulates that the fully-specified orthographic representations indispensable for rapid, efficient visual word identification are essentially self-taught and acquired incidentally when children read independently by means of phonological recoding. In short, two basic principles lay the foundation for the self-teaching notion: phonologically recoding unknown or unfamiliar words and the ensuing opportunities to associate sound information to its word-specific orthographic details.

In line with a considerable number of studies available that have demonstrated efficient phonological processing skills are one of the most imperative conditions for the successful buildup of a word recognition system for efficient reading (e.g., Adams, 1990; Brady & Shankweiler, 1991; Castles & Coltheart, 2004; Jorm, Share, McLean, & Matthews, 1984; Rack, Snowling, & Olson, 1992; Wagner & Torgesen, 1987), the ability to translate unfamiliar printed words into their spoken equivalents acts as the self-teaching means by which a reader is empowered to independently acquire orthographic representations and consequently add them to the sight orthographic lexicon.

Simply put, exhaustively recoding word strings phonologically is the key to draw readers' attention to map the order and identity of letters onto the phonological details, i.e., to link the printed forms to their spoken equivalents. Each successful decoding attempt would serve to strengthen and update the bonding between phonological and orthographic representations. Orthographic learning resembles fast mapping (Carey, 1978; Carey & Bartlett, 1978; Castles & Nation, 2006; Markson & Bloom, 1997; Swingley, 2010), as typically developing readers (Hogaboam & Perfetti, 1978; Manis, 1985; Reitsma, 1983; Share, 1999, 2004) and skilled adult readers (Brooks, 1977) alike need only a minimal number of subsequent exposures to the same word before the word becomes well-specified in the orthographic lexicon. That being said, it is worth noting that the self-teaching opportunities created by phonological recoding alone might not give rise to complete orthographic learning (Share, 2008).

Over and above the phonological ability, individual differences in relation to orthographic learning come from orthographic processing skills, i.e., the ability to assimilate word-specific and general orthographic knowledge swiftly and accurately (Barker, Torgesen, & Wagner, 1992; Cunningham, Perry, & Stanovich, 2001;

Cunningham & Stanovich, 1990, 1993; Stanovich & West, 1989). According to Share's self-teaching hypothesis, visuo-orthographic processes are parasitic on phonological recoding (Share, 1995, 1999). In Share's (1995) own words, phonological decoding is the *sine qua non* of reading acquisition, whereas visuo-orthographic processing is deemed as a secondary contribution to variance in orthographic learning. These two sources make independent, differential contribution to the process of learning to read (Castles, Datta, Gayan, & Olson, 1999; Manis, Custodio, & Szeszulski, 1993; Stanovich, Siegel, & Gottardo, 1997; Treiman, 1984), with the phonological component accounting for the lion's share of variance in reading ability.

The first key feature to the self-teaching model is hence the tenet of phonological primacy and the secondary role played by orthographic processing in orthographic learning. Self-teaching is possible at very early onset of reading development when novice readers possess some rudimentary letter-sound knowledge and phonological sensitivity—two factors that are critical co-requisites in reading acquisition (Share, 1995, 2008). Despite the general agreement that phonological recoding and orthographic processing are both key determinants of variance in word recognition, researchers have not yet reached a consensus on exactly how these abilities are defined. Most of them (Bowey & Muller, 2005; Castles & Nation, 2006; Cunningham et al., 2002; Share, 1999) refer simplistically to phonological recoding, explicitly or implicitly, as the knowledge of print-to-sound knowledge, for the obvious reason that the symbol-sound knowledge works as a very powerful mnemonic device to enable orthographic learning.

Nonetheless, in his treatise on self-teaching, Share (1995) has pointed out that phonological recoding is a generic term that covers a very wide range of cognitive skills associated with speech-based information in reading, and that the term is not merely confined to the application of letter-sound correspondence rules (for a discussion, see Share, 1995, p.152). In a way, the definitional conundrum would inevitably impede the conceptualization of reading theories and confound somewhat the interpretation of empirical data.

The lack of clarity in regard to the construct of the ability to process orthography has also been noted (e.g., Wagner & Baker, 1994; Vellutino, Scanlon & Chen, 1995), as orthographic processing has been defined in relation to either the procedural or the declarative knowledge in the literature (Berninger, 1994, 1995). Along the procedural line of definition, orthographic processes are equated to the ability to form, store, and access orthographic representations (e.g., Frith, 1985; Szeszulski & Manis, 1990). For another, the declarative dimension of orthographic knowledge denotes that it be a reader's general knowledge about permissible orthographic patterns as well as about word-specific representations (Vellutino, Scanlon, & Tanzman, 1994).

A more comprehensive definition for orthographic processing merging the declarative and procedural components is upheld by Cunningham, Nathan and Raher (2011) and has been supported by a number of studies (Cunningham et al., 2001; Hagiliassis, Pratt, & Johnston, 2006) showing that most measures in common use for orthographic processing in the literature—spelling, orthographic choice, homophone choice, etc.—are arguably reported to measure the component processes underlying the orthographic construct (see Cunningham et al., 2011, for a review).

Another feature that is closely related to phonological recoding in the self-teaching model is the concept of "lexicalization". Share (1995, 2008) conceptualized phonological recoding as a developmental process in which phonological processing units become increasingly larger in phonologically recoding unfamiliar word. Over time with constant reading exposure, this leads children to the more accurate and highly sophisticated knowledge of relationships between sound and forms. Before establishing conventional decoding skills, most novice readers of alphabetic languages begin to self-teach with a rudimentary, manageable set of one-to-one letter-sound knowledge as well as with the utility of context.

The incipient symbol-sound correspondences, albeit invariant and ill-defined, supply children with the opportunity to generate approximate pronunciation candidates to be compared with the extant reservoir of oral vocabulary. As young reader's orthographic knowledge (e.g., lexical constraints, morphological knowledge, morphemic constraints, etc.) expands with increasing exposure to print, phonological recoding would be concurrently under the growing modulation of consistency effects (Coltheart & Leahy, 1992; Zinna, Lieberman, & Schankweiler, 1986) and analogy-based responses (Marsh, Desberg, & Cooper, 1977; Marsh, Friedmann, Welch, & Desberg, 1981). As print exposure accrues and lexicalization persists, the primordial bottom-up decoding skills would eventually turn into "an ever-changing and self-refining process" that ultimately results in a bidirectional interaction between decoding skills and orthographic knowledge (Share, 2008, pp.12-13). The by-product of lexicalization is a far more sophisticated set of decoding skills than crude, invariant knowledge of letter-sound correspondences.

Third, self-teaching is relevant to the acquisition process of every printed word, and the self-teaching hypothesis thereby takes an item-based view. As distinct from stage models theorizing learning to read as sequences of developmental phases, the drift away from the popular notion of stage progression is motivated by the fact that new items are continuously added to increase the repository of readers' print vocabulary throughout their reading lifespan irrespective of the proficiency of readers. The item-based view accommodates nicely conflicting findings that resulted from familiarity-frequency issues (Jorm & Share, 1983; Share, 1995, 1999).

The self-teaching hypothesis contends, therefore, that whether readers attempt to read a word via sight recognition or via phonological decoding depends on the particular word, not on a particular stage of development. Familiarity with words is the decisive factor of how readers would approach to reading the word in question. That is, high-frequency words, i.e., words that one has been frequently exposed to, are identified automatically, efficiently by sight, while low-frequency words, i.e., those that are rarely encountered or never seen before in print, are recognized through a treatment of phonological decoding. For readers of all proficiency levels, frequent encounters with a given word form lead eventually to automaticity with the word; automaticity is thus characteristic of a specific word, not readers (Cunningham et al., 2011). Simply put, each word item would undergo a developmental process before being added fully to sight reading vocabulary lexicon.

To sum up, the self-teaching model is by far the most widely acknowledged, well-developed theory to explicate children's orthographic development. With only a few simple principles and features, Share's self-teaching model is powerful in that it accommodates a myriad of experimental findings (see Share, 1995, for details).

Evidence in direct support of the model that has emerged over the past decades is discussed in the following sections.

2.4.2 Empirical Findings from Alphabetic Languages

Table 1

An overview of the self-teaching paradigm and posttest measures for orthographic learning (Source: Castles & Nation, 2006, p. 164)

Phase I: *Exposure and phonological decoding*	Phase II: *Test of orthographic learning*	*Evidence for orthographic learning*
Child reads aloud story about "the coldest place in the world", as follows: North Greenland is a place they say is the coldest in the world. The name of the city is Yait. In Yait, there is snow and ice all year round. The temperature is always around 0, and it is dark most of the day. There is always a cold wind blowing in from the North. But there are also some good things to do in Yait. You don't have to hurry to put your food in the refrigerator to keep it cold. And there's always lots of ice for your drinks. In summer there is sunlight all day and all night, so you can go skiing and skating any time you want, even at night. In Yait you don't have to put on sunscreen when you go outside, because the sun is never too hot. And there are no flies in Yait to worry about. There is also a lake that is always frozen, so you can't ever fall in. But most of all, people are very nice and friendly.	1. *Homophone Choice:* Child asked, "Remember the coldest place in the world—was it *Yait, Yate, Yoit*, or *Yiat*?" 2. *Naming Reaction Time:* Time taken to read aloud Yait versus Yate 3.*Spelling:* Child told, "Write down 'yait', the coldest place in the world".	1. *Homophone Choice* (*Yait*) chosen more often than homophone foil (*Yate*) 2. *Naming Reaction Time: Yait* read faster than *Yate* 3. *Spelling:* Spelling Y-A-I-T produced more often than Y-A-T-E

Working in Hebrew, Share (1999) devised an experimental paradigm employing more naturalistic reading conditions (see Table 1 for an example). Studies on orthographic learning of different orthographies have adapted a variation of this paradigm. In the original paradigm, children are exposed to texts embedded with target pseudowords (e.g., yait) to be acquired. After the exposure phase, the robustness of their orthographic learning is reflected by results from such tasks as orthographic choice task where one of the choices is a homophonic foil (e.g., yate), naming where the onset or latencies of naming targets is measured, and spelling where participants are required to reproduce the exact target forms. Results generally converge on more targets being selected correctly in the orthographic choice task, targets being named faster, and more target spelling patterns being reproduced. These results have been considered demonstrating orthographic learning through self-teaching.

Orthographic Learning and Orthographic Depth

Cross-linguistic efforts to investigate the self-teaching hypothesis have accentuated its universalistic aspect. Supporting evidence of the model has emerged from research employing orthographies that vary in degree of orthographic depth, such as a highly regular, shallow Hebrew consonantal script (Share, 1995, 1999, 2004), a slightly opaque Dutch script (de Jong, Bitter, van Setten, & Marinus, 2009; de Jong & Share, 2007; Reitsma, 1983), and a complex and less transparent reading system of English (Bowey & Muller, 2005; Cunningham, 2006; Cunningham et al., 2002; Ehri & Saltmarsh, 1995; Kyte & Johnson, 2006; Nations, Angells, & Castles, 2007).

Collectively, cross-language studies have converged on the evidence that unassisted phonological recoding makes positive contribution to children's orthographic learning. However, it is obvious that studies based on readers of different orthographic depth have led to somewhat mixed results (Frost, 2005; Goswami, Ziegler, Dalton, & Schneider, 2001; Seymour, 2005). The granularity and transparency of a given language certainly exert some influences in reading (Wydell & Butterwort, 1999). The divergent results across orthographies are thus best understood by means of the *orthographic depth hypothesis* formalized in Katz and Frost's (1992) study. This theory contends that:

> "Shallow orthographies are more easily able to support a word recognition process that involves that language's phonology. … Deep orthographies encourage a reader to process printed words by referring to their morphology via the printed word's visual-orthographic structure" (p. 71).

Having built on the orthographic depth hypothesis, Share (2004, p. 291) has proposed the *orthographic sensitivity hypothesis* to account for his conflicting data from early orthographic development. Share (2004, experiments 2 and 3) had first-grade Hebrew readers read short story texts with embedded target novel words; though decoding accuracy was higher than 90%, orthographic learning was intriguingly not evident. According to his *orthographic sensitivity hypothesis*, "a transparent orthography encourages a pattern of reading behaviour reminiscent of surface dyslexia, in which children rely on mappings between orthography and phonology when reading" and "only after sufficient exposure to a significant number of words do children begin to develop orthographic sensitivity" (Castles & Nation, 2006, p. 166). Moreover, Share asserted that "in deeper orthographies, readers do not often have the luxury of simple one-to-one correspondences", and that they are thus obliged to look beyond "low-level phonology and consider higher-order regularities that are often word-specific" (p. 292). However, without direct evidence available to support this view, the hypothesis remains speculative till further investigation with first-graders learning to read a deep orthography.

The Role of Phonology in Self-Teaching

At the general level of testing the self-teaching hypothesis, numerous studies have confirmed a critical relationship between phonological recoding and orthographic learning (Bowey & Muller, 2005; Cunningham, 2006; Cunningham et al. 2002; de Jong & Share, 2007; Kyte & Johnson, 2006; Share, 1999, 2004). Share (1999, experiment 2) established the irrepressibility of phonology in orthographic learning by minimizing phonological processing through concurrent articulation that brought about significantly diminished orthographic learning, providing direct evidence that orthographic learning is not solely attributable to brief visual exposure. That said, Kyte and Johnson (2006, p. 180) and Cunningham et al. (2011) suggested that some orthographic learning still observed in the concurrent articulation condition arose from "residual phonological processing".

Cross-linguistic evidence also lends credence to the proposition that children self-teach via phonological recoding in silent reading that is more close to real-life daily reading environment. The hypothesis that silent reading would allow children to bypass phonological decoding during the acquisition of words was refuted by findings from Bowey and Muller (2005, 2007) with English-speaking children and those from de Jong and Share (2007) with Dutch-speaking pupils. The foregoing studies found comparable orthographic learning effects in both silent and oral reading in all posttests but the naming task in de Jong and Share (2007) where somewhat superior performance was observed in the oral reading condition. The discrepancy might have followed from different types of naming measures used in the studies and the orthographic depth of the two scripts.

The Contribution of Orthographic Skills

Cunningham and her colleagues (Cunningham et al., 2002; Cunningham, 2006; Cunningham et al, 2011), although not disputing the primacy of phonological decoding in self-teaching, have argued that the operation of orthographic processing is not entirely parasitic on phonological ability by demonstrating that orthographic skills and that phonological skills contribute separately to the development of fluent word recognition.

Findings in support of the arguments were provided by Cunningham's research group (Cunningham et al., 2002; Cunningham, 2006) that orthographic learning is predicted by readers' prior orthographic knowledge, operationalized through orthographic choice, letter-string, and homophone choice tasks in experiments, when variance accounted for by phonological recoding is statistically controlled for. These subtle orthographic processing abilities *did* account for individual difference in reading acquisition. Convergent results indicated clearly the secondary contribution of orthographic processes to fluent word recognition.

The Effect of Exposure

Orthographic learning cannot happen without exposure to printed materials. As a matter of course, print exposure should by definition predict reading to a certain degree. Indeed, robust orthographic learning via self-teaching in silent reading has clearly showed the beneficial contribution of print exposure to unique variance in both word recognition and orthographic processing (Cunningham et al., 2001; Cunningham & Stanovich, 1993). Individual differences in orthographic processing were found to result partially from print exposure (Braten, Lie, Andreassen, & Olaussen, 1999; Chateau & Jared, 2000; Cunningham & Stanovich, 1990, 1993).

Within the self-teaching framework, Nation et al. (2007) confirmed that learning increases in proportion to the number of exposures. One study (Share, 2004) investigating Hebrew-speaking children has reported equivalent orthographic learning across one, two, and four exposures. In contrast to Share's finding of durable orthographic learning with one trial (after three, seven and 30 days), Nation et al. (2007) did not replicate the results in the seven day condition. The issue of whether a single learning trial would produce reliable, durable orthographic learning is far from definitive and requires more research.

The Effect of Durability

Few studies have evaluated the storage and subsequent access of orthographic processing. Share (2004) investigated the durability of orthographic processing by assessing the performance of learning target orthographies after one, seven, and thirty days from the initial reading exposure. Among Hebrew third-graders, he found reliable learning results after seven days, and even after thirty days with only a slight deterioration of orthographic memory. Looking at English-speaking children, some studies reported only modest learning effect after six days (Bowey & Muller, 2005) and seven days (Nation et al., 2007).

There is always the possibility that the durability of orthographic memory might vary across orthographies with distinct inconsistent relationships between the spoken and word representations. Thus, Cunningham et al. (2011, p.271) construed the conflicting findings in Hebrew and in English in the way that "the acquisition of orthographic representations in English may not be quite as durable as observed in more shallow orthographies or may require additional repetition over time."

The Effect of Context

The beneficial role of context in orthographic learning is highlighted in self-teaching through Share's (1999) experimental realization resorting to connected text reading, as distinct from Reitsma's (1983) single word reading paradigm. Interestingly, some findings from studies within the self-teaching framework utilizing regular word items in their experiment design ran counter to this view (Cunningham, 2006; Lindi, Perfetti, Bolger, Dunlap, & Foorman, 2006; National et al., 2007). Results from

Landi et al. (2006) have outright challenged it by reporting a detrimental effect of context on orthographic learning.

Recent research by Wang and her colleagues addressed the issue of context in self-teaching by comparing the role of context for regular and irregular words in their experiments, revealing a facilitative effect of context on the acquisition of irregular pseudowords, as against a null result for regular ones (Wang, 2012; Wang, Castles, & Nickles, 2011). This finding bears out Share's (1995, p. 154) theoretical account in relation to context that states that "contextual information may play an important developmental role in supplementing partial or incomplete decoding stemming from weak phonological decoding skill or phonetically recalcitrant ('irregular') words". Arguably, the top-down contextual information is critical to orthographic learning when decoding is compromised, not least because the context facilitates children's correct selection of pronunciations among the candidates they would generate.

The Effect of Semantics

Before formal literacy education starts, children already possess a repository of oral vocabulary knowledge. The pre-existent semantic knowledge of spoken words has been documented to be correlated to reading ability (Nation & Snowling, 1998, 2004). Orthographic learning is thus to be modulated by the prior semantic knowledge that children would bring to bear on reading. However, mixed results have been reported as yet.

McKague, Pratt and Johnston (2001) pre-exposed first graders to the meaning of target words and found no effect for semantic pre-exposure on orthographic learning.

The null result was replicated by Duff and Hulme (2012, Experiment 2) who also provided evidence for a null effect of word meaning on learning regular pseudowords. On the other hand, counter-evidence came from Ouellette and Fraser (2009) reporting that the effect for semantics is significantly noticeable on the word identification task, but not on the spelling task.

Drawing support from previous studies showing a positive correlation between meaning-based information and reading irregular words (e.g., Bowey, & Rutherford, 2007; Nation, & Cocksey, 2009; Nation, & Snowling, 1998; Ouellette, 2006; Ricketts, Nation, & Bishop, 2007), Wang (2012) concluded that, just like the role of context in orthographic development, it is likely that vocabulary knowledge would come into play only when phonological recoding is compromised. The issue as to how word semantics influence the learning of regular and irregular words remains to be further explored.

Rapid Automatized Naming (RAN)

One cognitive skill that is closely related to reading skill is phonological retrieval, or the efficient access to phonological codes of lexical items stored in long-term memory. Phonological retrieval is frequently operationalized through the measure of rapid automatized naming (RAN) in the literature where the capability of fast, automatic naming of known visual items, i.e., digits, letters, and colors, is measured (Bowers, Sunseth, & Golden, 1999; Manis, Doi, & Bhadha, 2000). Bowers and Wolf (1993, p. 70) specified that "slow letter/digit naming speed may signal disruption of the automatic processes which support induction of orthographic patterns, which, in turn, result in quick word recognition." Dyslexic readers are reported to be worse off on RAN tasks (for an overview, see Wolf, Bowers, & Biddle, 2000).

However, within the self-teaching framework, Cunningham and colleagues (Cunningham, 2006; Cunningham et al., 2002) have tested first and second graders on a composite of RAN measures and concluded that RAN did not significantly predict orthographic learning once decoding ability was partialled out. It remains unclear to what extent the variance of RAN would account for individual differences in orthographic learning. Cunningham et al. (2010, p.270) argued hence that "at least in these particular studies, the effect appeared to be masked and/or overwhelmed by the potent effects of decoding accuracy." This line of research should be further pursued to shed light on the role of RAN in orthographic development.

Paired-Associate Learning (PAL)

According to the self-teaching hypothesis (Share, 1995, 1999), the opportunity to phonologically recode unfamiliar/unknown words ensures readers to associate spoken forms to their orthographic representations. This pairing process between the spoken form and the orthography of a given word is conceptualized as a form of verbal-visual paired-associate learning (PAL). Prior research has reported that PAL skills are found to contribute uniquely to word reading (Hulme, Goetz, Gooch, Adams, & Snowling, 2007; Windfuhr, & Snowling, 2001). Dyslexic readers also showed more difficulty on tasks requiring PAL skills, and even more so when the

PAL tasks are verbally related (e.g., Gascon, & Goodglass, 1970; Messbauer, & de Jong, 2003; Vellutino, Steger, Harding, & Philips, 1975).

That being said, it has been proposed that, other than just simply PAL skills across modalities, a general learning mechanism might underlie the cause of impaired orthographic learning (Byrne et al., 2008; Castles & Nation, 2008). In Wang's (2012) case study, she assessed dyslexics PAL skills on three pairings of two modalities, i.e., visual-visual, visual-verbal, and verbal-verbal. Notwithstanding normal phonological decoding, the surface dyslexia case showed impairment in all three PAL tasks in relation to controls. This was probably the main reason why orthographic learning was compromised in her study. In keeping with Byrne et al.'s view, Wang argued that 'the impaired orthographic learning was not due to a specific problem learning visual-verbal associations but a more general learning ability" (2012 ,p.230). This implies that the relationship between orthographic learning and decoding posited in the self-teaching hypothesis may not be as straightforward as it has been assumed. Chances are that PAL measures may tap into the posited global learning-rate factor that directly influences the acquisition of orthographic representations and the ability to acquire spelling and decoding skills. This issue still deserves further research.

The sections above reviewed the theoretical aspects and identified issues concerning the self-teaching hypothesis. The information provided in the current chapter will be a useful point of reference to appreciate and understand the self-teaching model as well as relevant issues in a Chinese context that are presented and discussed in the following chapter.

Chapter 3

Orthographic Learning in Chinese via Self-Teaching

The sheer volume of Anglophone and alphabetic language research has given rise to doubts on the generalizability of their findings to other languages and orthographies (e.g., Perfetti, Liu, & Tan, 2005; Seymour, 2005; Ziegler & Goswami, 2005, cf. Share, 2008a, for a review), particularly in reading development (e.g., Aaron & Joshi, 2006; Harris & Hatano, 1999; Mannhaupt, Jansen, & Marx, 1997; Ziegler & Goswami, 2005) and skilled reading (Frost, 1998, 2005; Perfetti, Liu, & Tan, 2005). What is most pertinent to the current dissertation is that there always exists the possibility that the self-teaching mechanisms in orthographic learning might vary across orthographies, as has been found for some variables with important associations in early reading acquisition (Cunningham, 2002; Wimmer, 1996; Wimmer, Mayringer, & Landerl, 2000).

One of the objectives of the dissertation is to address the Anglophone, alphabetic dominancy in reading research, by investigating the learning of non-alphabetic Chinese orthographic forms in the framework of Share's (1995) self-teaching hypothesis. Though the non-alphabetic Chinese script does not permit GPC rules in reading, it is evident that children learning to read Chinese make good use of whatever they are offered in the Chinese script, e.g., phonetic and semantic radicals, to optimize their learning process. Presumably through statistical learning, young Chinese children develop awareness of radicals—sublexical units that provide phonetic or semantic information (Lee, 2009). Current research in Chinese reading development aims to make contributions to our understanding as to the generalities and specificities of reading acquisition across writing systems of different orthographic depth.

The purpose of this chapter is to set the stage for understanding and appreciation of the research questions and hypotheses of the whole dissertation in chapter 4. For this purpose, chapter 3 is made up of sections that provide the background knowledge of the Chinese language and its unique writing system, together with an overview on theories of Chinese reading. In so doing, these sections serve the purpose of making the case for why and how the self-teaching hypothesis is also valid and can be generalized to account for orthographic learning in Chinese to a certain extent.

3.1 Features of the Chinese Language and Writing System

Traditionally viewed as a logographic system, Chinese uses a non-alphabetic script that is rather arbitrary in terms of orthography-to-phonology correspondence (OPC) rules (Yin & Weekes, 2003). Logography, pure and simple, entails the basic unit of writing being associated with a unit of meaning (i.e., the morpheme) in the spoken language. Along this line of definition, the Chinese writing system *does* have a streak of logography, in that the unit of interface between written forms and spoken language in Chinese is indeed the morpheme. Yet, equally important, a morpheme coincides with a spoken syllable at the same time in Chinese. That is, the mapping from spelling to sound is syllable-based. Syllable boundaries are neatly marked by character separation in written Chinese.

The past two decades have seen a sizeable body of evidence from psycholinguistic research clearly indicating that most characters are automatically, analytically decomposed into subcharacter constituents that either hint on sound or meaning in the process of visual word recognition in Chinese (Law, Yeung, Wong, & Chiu, 2005; Liu, Chung, McBride-Chang, & Tong, 2010). Characters are thus segmental in relation to orthographic, morphological and syllabic information (Leong, Cheng, & Mulcahy, 1987; Leong & Tamaoka, 1998; Shu & Anderson, 1997). In other words, although Chinese cannot be pronounced by recourse to GPC rules, as is the case with alphabetic systems, sound information in Chinese can still be inferred from OPC rules, albeit only reliable to a certain extent. Besides, semantic cues are sometimes extractable in characters to give a rough indication on the semantic category at the whole-character level. Again, a pure logographic writing system denotes direct mapping from symbols to comprehensive meaning, which Chinese is not. The initial task of learning to read Chinese is also boiled down to linking the printed words to the spoken forms that have already existed in children's repertoire of oral vocabulary; after repetitions, these words are then possibly identified by sight (Lee, 2009).

Taken together, it is more linguistically correct when the Chinese writing system is characterized as a morphosyllabic (DeFrancis, 1989; Perfetti & Zhang, 1995) or morphographic (Garman, 1990; Weekes, Yin, Su, & Chen, 2006) script. For Chinese, phonology is also documented to be involved in lexical processing (Ho & Bryant, 1997b; Leong et al., 1987; Tan & Perfetti, 1995), sentence comprehension (Tzeng, Hung, & Wang, 1977), and reading acquisition (Chow, McBride-Chang, & Buttress, 2005; McBride-Chang & Ho, 2000). The centrality of phonological processing skills to reading is arguably relevant for both alphabetic orthographies and non-alphabetic scripts, such as Chinese (Chan & Siegel, 2001; Hu & Catts, 1998). All in all, there *does* exist a relationship between the Chinese script and its phonological and morphological properties. Noteworthily, nowadays there is only about 1% or 2 % of characters used in modern times with recognizable pictographic content (DeFrancis, 1989; Perfetti, 2003). There might have been more of them in history, but, over time, most of their initial pictographic meaning is seldom evident or lost nowadays.

Phonological Structures of Chinese Syllables

Unlike in an alphabetic writing system, each grapheme in Chinese maps onto a spoken syllable which is a morpheme at the same time. The syllable is hence the basic speech unit in Chinese. There are only about 400 syllables, disregarding the four lexical tonal differences or voice inflections—high, rising, falling-rising and falling (Taylor, 2001). The tones considered, then there are about 1,277 syllables in modern spoken Mandarin by one count (Chao, 1976), which is still far less than over 8,000 syllables in English (DeFrancis, 1984). With one syllable averagely corresponding to 11 morphemes, homophony is prevalent in Chinese reading (Lee, 2009; Miller, 2000). Different morphemes are generally represented in writing by a different character, and morphemic information and context are hence critical to differentiate homophonic morphemes.

In comparison with English, the syllable structures in Chinese are fairly simple in that they do not consist of consonant clusters (e.g., as found in the English word "street") of any sort (Duanmu, 2000). Moreover, open syllables abound in spoken Chinese, just as in Korean and Hebrew. Li and Liu (1988) estimated that, of all syllable structures, open syllables constitute (54% CV structure, e.g., 大 /da4/, 到 /dao4/; 8% V structure, e.g., 阿 /a1/, 愛 /ai4/) about 62% and that the remaining 38% have a final consonant (33% CVC structure, e.g., 張 /zhang1/, 顛/dian1/; 5% VC structure, e.g., 安 /ang1/, 陽 /ian2/).

Strokes, Radicals, and Characters

Although the fact that one morpheme corresponds to one syllable portrays a relatively uncomplicated relationship between the spoken Chinese and its script, the sublexical relationship, i.e., the relationship between internal structures of characters and language, is rather complex. Chinese characters are readily distinguished into two broad categories: simple characters (mostly nonphonograms) and compounds (mostly phonograms). The former are those composed of stroke patterns that cannot be further divided into components, e.g., 刀 (/dou1/, knife), while the latter are decomposable into semantic or phonetic components, e.g., 好 (/hao3/, good) that can be divided into 女 (/nu3/, female) and 子 (/zi3/, offspring). In a basic sense, all characters are simply combinations of 24 distinct strokes that are the smallest structural units carrying neither meaning nor pronunciation (Li, 1989); the number of strokes in a character range from one to 34 and thus defines visual complexity in Chinese (Ho, Yau, & Au, 2003; Shu, 2003).

More importantly, strokes are further organized into a larger psychological processing unit—a radical. By some accounts, there are about 200 semantic radicals (Shen & Bear, 2000) that sometimes would cue semantic category of the whole character, and 800 phonetic radicals (Hoosain, 1991; Wang & Yang, 2008) that would sometimes hint at the phonological information of the whole character. The combination of strokes into radicals would reduce the "chunk size", which in turn lessens demands on working memory capacity (Pak, Chen-Lai, Tso, Shu, Li, & Anderson, 2005). As sublexical units, radicals allow children to analyse characters and not to memorize them by rote, which thereby would speed up the decoding process and the acquisition of character-specific representations (Kang, 2010). To recapitulate, radicals would help “children to store a large number of compound characters more systematically in memory and to learn new characters more easily” (Chen, Shu, Wu, & Anderson, 2003, p. 121). Indeed, this line of findings has been consistently presented (Chua, 1999; Wu, Zhou, & Shu, 1999), illustrating that “Chinese readers *do* chunk strokes of a character into components, radicals, or even a whole character” (Pak et al., 2005, p. 439). Radicals possess important and complex functions as input units to Chinese character recognition (Taft & Zhu, 1997; Feldman & Siok, 1999).

The most dominant Chinese character structure is phonetic compounds (e.g., 盯 /ding1/, stare), also known as phonograms (Tzeng, 2002; Zhang, 1994) which is the term adapted throughout the entire dissertation. Predominantly, they are comprised of a semantic radical (e.g., 目, eye) and a phonetic radical (e.g., 丁 /ding1/). About 80% to 90% of Chinese characters are compounded (Huang & Hu, 1990; Kang, 1993; Zhu, 1987); Shu, Chen, Anderson, Wu, and Xuan (2002) report that about 72% of the characters taught in primary school fall into the class of phonograms. Configurationally speaking, horizontally structured characters are by far the most prevalent of all phonograms (around 90%). As a rule of thumb, most of the phonograms have a semantic component on the left and a phonetic component on the right (Wang, 1981), though there are no real rules governing possibilities of radical positions.

While some radicals are themselves legal characters in possession of independent meaning and sound, some are not. Research on lexical processing abounds in support of the view that Chinese semantic and phonetic radicals are both functionally and psychologically real entities (Fang & Wu, 1989; Feldman & Siok, 1997; Feldman & Siok, 1999; Lee, Tsai, Su, Tzeng, & Hung, 2005; Taft & Zhu, 1997; Taft, Zhu, & Peng, 1999; Zhou & Marslen-Wilson, 1999 a, b). The decomposition of characters into larger orthographic processing chunks, i.e., radicals, than strokes is supposed to facilitate the buildup of orthographic forms and to acquire new compound characters more systematically and efficiently (Anderson, Li, Ku, Shu, &, Wu, 2003).

3.1.1 Phonetic Radicals and Their Phonological Function

A phonetic radical is the orthographic unit that would encode or specify the phonological information of a given character, in contrast to alphabetic languages in which the sound of a word is assembled by the phonology of all letters in it. Phonetic radicals are that which offer potential mappings between Chinese orthography and phonology, although their reliability is limited in character reading. In over 80% of all cases, phonetic radicals hint at the whole-character pronunciations, either giving away exact pronunciations or partial sound information, such as the onset or the rime (Alber, 1989; Yin, 1991; Zhou, 1987). In any case, Chinese is not purely logographic, but of speech-based nature (DeFrancis, 1989). The script-sound relationship is also defined in terms of regularity and consistency (Fang, Horng, & Tzeng, 1986; Lee, 2009; Lee et al., 2005), just like English (Jared, 1997a, b, 2002). Knowledge of phonetic regularity is generally in place by Grade 2 (Ho & Bryant, 1997b), while the awareness of phonetic consistency begins to develop at Grade 4 (Lee, 2009; Shu, Anderson, & Wu, 2000).

Phonetic Regularity

Spelling-sound regularity defines the mapping relationships between orthography and phonology on the sublexical level in Chinese (Fang et al., 1986; Hue, 1992; Lien, 1985), as characters with a regular pronunciation pattern are faithfully represented by the sound of their embedded phonetic radicals. For example, a regular character, e.g., 油 /you1/, shares the same pronunciation as its embedded phonetic radical 由 /you1/. On the other hand, an irregular character is defined as either sharing partial sound information with its embedded phonetic radical (i.e., initials or rhymes), e.g., 抽 /chou1/, or not showing any relevance to the pronunciation of its embedded phonetic radical, e.g., 迪 /di2/ (see Table 2).

Table 2
Examples for classifying Chinese phonograms into regularity and consistency (Source: Tzeng, 2002, p.6)

	Regular	Irregular
Consistent	Phonetic radical: 巨 /ju4/ 距, 炬, 拒, 詎, 鉅: /ju4/	Phonetic radical: 泉 /quan2/ 線, 腺: /xian4/
Inconsistent	Phonetic radical: 由 /you2/ 油, 軸: /you2/ 鈾, 釉, 柚: /you4/	Phonetic radical: 由 /you2/ 迪, 笛: /di2/ 軸, 妯:/zhou2/ 袖, 岫:/xiou4/ 抽:/chou1/

There is some disagreement with respect to how frequently phonetic radicals indicate precise phonological information and how often they provide partial information. Alber (1989) and Zhou (1987) claim phonetic radicals provide exact pronunciations in 48% of the cases and partial phonological information in 39%.

Yin (1991) reports that in only 36% of cases do phonetic radicals indicate precise phonological information of the character, that 48% of cases provide partial information, and that in 16% of cases they are completely unrelated.

Shu and Anderson (1999) conducted an analysis of characters taught in teaching practices throughout primary school years, and reported that the percentage of regular phonogram characters increases from 48% taught in Grade 1 to 87% taught in Grade 6, with an increase from 29% to 48% of those having a pronunciation identical or similar to the phonetic radical (disregarding changes in lexical tones). Furthermore, low frequency characters are more likely than high frequency ones to exhibit a regular pattern in terms of their pronunciation, with more than 96% of very low frequency (fewer than 1 per million) characters sharing the identical pronunciation with their embedded phonetic components (Perfetti et al, 1992; Shu & Anderson, 1999).

Intriguingly, despite the limited validity of phonetic radicals in signaling whole character's pronunciation, Pollastek, Tan and Rayner (2000) have found that the radical's phonology is still activated in fluent reading performance, even for characters containing an invalid phonetic. It is suggestive that phonology plays a more significant role in Chinese reading than previously thought.

Phonetic Consistency

Likewise in English (Jared, 1990, 2002), the other way to describe Chinese orthography-to-phonology mappings is the concept of consistency. The consistency of a character is defined at the lexical level by looking at the set of orthographic neighbors that share the same phonetic radical. According to Fang et al.'s (1986) definition of consistency for Chinese, a character is consistent only when all the characters in its set of orthographic neighbors sharing the same phonetic radical have the identical pronunciation; otherwise, it is an inconsistent character (see Table 2, for examples). Although not all phonetic radicals are legal characters, Chinese readers are still able to infer pronunciation of unknown characters by means of the look-up of characters sharing the same phonetic radical in their lexicon (Lee & Tzeng, 2008). For Chinese reading, consistency is thus a better way to index script-sound relations than regularity is.

To sum up, in parallel to *the alphabetic principle* in English, researchers have named the sublexical symbol-sound mapping "the phonetic principle" (Anderson et al., 2003) or "the orthography-phonology correspondence (OPC) rules" (Ho & Bryant, 1997a). This is the overarching graphophonological insight central to learning to read Chinese.

3.1.2 Extraneous, Auxiliary Phonological Aids to Read Chinese: Zhuyin, Pinyin

In China, children learn to read in a visually simplified Chinese script, whereas children in Taiwan and Hong Kong learn to read in a traditional Chinese script that is visually more complex than the simplified one. In different Chinese societies, e.g., in China, Hong Kong, and Taiwan, characters are also taught in different ways. Owing to the relatively arbitrary mapping relationship between orthography to phonology, novice Chinese readers are taught Pinyin in China and Zhuyin in Taiwan during the beginning weeks of 1st grade before children begin to learn their own morpheme-based system. Irrespective of the OPC rules, children in Hong Kong learn to read in a more holistic way by using a look-and-say approach (Chung, Ho, Chan, Tsang, & Lee, 2011).

Pinyin adapts letters of the Roman alphabet and is an alphabetic, phonetic system. New, unknown characters are to be annotated with Pinyin till Grade 6. The letters of Pinyin represent individual phonemes in Mandarin speech, making it a real alphabetic transcription system. Similarly to the teaching practice in China, Taiwanese children are taught to read Zhuyin (or Zh-Yin-Fu-Hao, see Figure 4 for an example), a sub-syllabic phonetic system that adopts 37 symbols for syllable onsets or rimes (Chang, 1981). In contrast to phonetic transcription via Pinyin, the vowel and coda components within the rime are not separately coded in the Zhuyin system. Despite the differences between the two auxiliary phonetic systems, the Pinyin system is taught in a similar way to Zhuyin by introducing 21 consonantal initials, followed by 37 rimes (i.e., vowels and nasal finals) (Lehmann, 1975).

Both extraneous orthography phonetic scripts, i.e., Pinyin and Zhuyin, have the common goal of helping children to form the association between accurate speech sounds and visual symbols without outside assistance. However, the inherent difference in the nature of auxiliary phonetic aids imparted to novice readers might have an effect on Chinese reading acquisition across different Mandarin-speaking societies (e.g., Cheung & Ng, 2003).

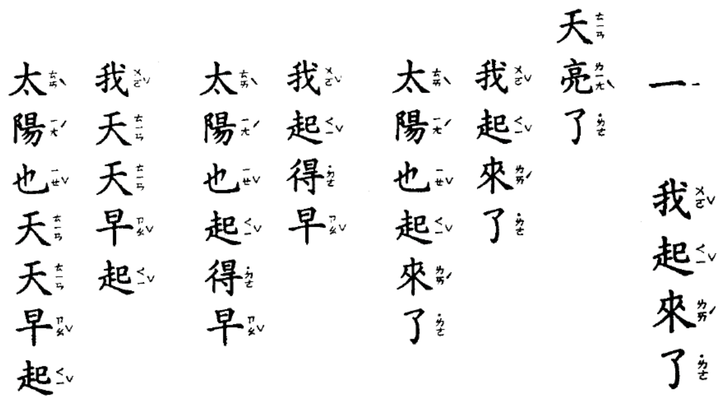

Figure 4. An extract from the Chinese language textbook for 1st-graders in Taiwan. The Chinese characters appear on the left with the smaller Zhuyin symbols to the right, arranged vertically. The symbols that sometimes appear on the right of the Zhuyin indicate the lexical tone in which the word is spoken. (Source: Huang & Hanley, 1997, p.251)

3.1.3 Semantic Radicals and Their Semantic Function

Chinese is by no means a pure logographic script where the readers could derive precise meaning straightforwardly with a mere look at the ideographs or pictographs. The exact, rich, complex and subtle meaning of each Chinese character has to be learned individually (Ho, Wong, & Chan, 1999). The salience of meaning aspect in Chinese script is overemphasized relative to alphabetic scripts, owing to the scriptal difference in Chinese logo-syllabic and alphabetic orthographic forms (Perfetti, 1997). That said, one of the orthographic processing units in Chinese is the semantic radical that encodes or specifies the semantic category or attributes of a character that would contribute to rough meaning on the whole character level.

To be precise, Zhang and Peng (1993) have documented that the radical of a character facilitates readers to retrieve the defining features of the semantic category of the category (e.g., "having feathers" for the "bird" category) but not its characteristic (e.g., "being able to sing" for the "bird" category). It is thus apparent that the semantic cueing function of the radical *per se* is only limited to signifying a broad category of meaning. Analogously, English also represents units of meaning to some degree (Carlisle, 1988; Ramsden, 1993), as etymology reveals connections between the morphological origins of different words, and, hence, tends to give away some semantic information. For instance, *sign* shares the same origin as and is related in meaning to, *signal, signature, signify*, and *significance*. In this sense, the Chinese script might not be as unique as previously thought after all. The only difference would lie in the fact that semantic radicals, unlike affixes in English, are not phonologically realized at all on the whole-character level. Therefore, morphological and phonological information in Chinese can be more readily distinguished, while in alphabetic scripts, like English, morphemes and phonological units might be confounded (Shu et al., 2006).

At the sublexical level, semantic radicals influence character recognition in Chinese (Feldman and Soik, 1999a, b; Flores d'Arcais et al., 1995; Zhou & Marslen-Wilson, 1999a, b), just like phonetic radicals (Ho & Byrant, 1997a; Ho, Wong, & Chan, 1999); they are psychologically real entities in lexical processing. Studies have demonstrated that children are able to infer meanings of unfamiliar characters by means of semantic radicals (Hatano, Kuhara, & Akiyama, 1981; Kuhara-Kojima & Hatano, 1995; Li, Anderson, Nagy, & Zhang, 2002; Shu & Anderson, 1997). Based on these findings, Li et al. (2002) went on to argue that using radicals helps children to ease up memory load. Imaging studies also observed activation in various areas in the brain that are in charge of processing phonetic and semantic radicals (Bi et al., 2007). Arguably, awareness of morphemic units would help developing readers to tone down the arbitrary relation between meaning and form that characterizes the Chinese language (Feldman & Siok, 1999a, b).

Semantic Transparency

Other than the semantic cueing functionality of the semantic radicals *per se*, the semantic transparency effect on the character level has also been documented in Chinese lexical processing (e.g., Feldman & Siok, 1999a, 1999b; Law et al., 2005; Li & Chen, 1999). The dynamic relationship between Chinese characters and their embedded semantic radicals leads to various degrees of semantic transparency defined by the meaning relatedness between the semantic radical and the whole character that the semantic radical is embedded in. For example, Li and Chen (1999) reported that lexical decision latencies of low-frequency items were modulated by semantic transparency; participants reacted much more quickly to semantically transparent characters than opaque ones.

Yin and Rohsenow (1994) distinguished the magnitude of relatedness into four levels: 1) representing a meaning category into which the character fits, e.g., 銅 */tong/, copper*, with an embedded semantic radical, 金, *metal*; 2) having a direct relationship with the character's meaning, e.g., 飯 */fan/, cooked rice*, with an embedded semantic radical, 食, *eat*; 3) having an indirect relationship with the character's meaning, e.g., 城 */cheng/, city*, with an embedded semantic radical, 土, *dirt*; and 4) no relationship at all with meaning of the character, e.g., 漢 /han/, Chinese, with an embedded semantic radical, 氵, *water*. The first two are grouped as semantically transparent, while the other two as semantically opaque.

3.2 Previous Research on Learning to Read Chinese

Now that we have covered how the Chinese writing system operates, the background knowledge is of great help to grasp how phonology and orthography contribute to the acquisition of Chinese reading. To begin with, we look at single Chinese character reading, detailing the findings available; then, we turn to reading theories for Chinese. The cognitive skills that are critical to learning to read Chinese will be discussed first.

3.2.1 Cognitive Skills Underlying Literacy Acquisition of Chinese

A key set of skills to reading Chinese has been identified (e.g., McBride-Chang & Liu, 2008), including phonological process skills (Ho & Bryant, 1997b; McBride-Chang & Ho, 2000), speeded naming (Ho & Lai, 1999), morphological awareness (Li et al., 2002; McBridge-Chang, Shu, Zhou, Wat, & Wagner, 2003), and visuo-orthographic processing (Huang & Hanley, 1997; Siok & Fletcher, 2001), among others.

The cognitive skills associated with reading Chinese are rather similar to reading alphabetic languages (e.g., Adams, 1990; McBride-Chang, 2004; Tong, McBride-Chang, Shu, & Wong, 2009), and the non-alphabetic Chinese script *does* have some kind of phonological information for readers to capitalize on in reading development. It appears to be universal across different languages that the mastery of a writing system involves converting speech into a visual code (Li et al., 2010).

Generally speaking, it is expected that the way children learn orthographic forms across different scripts and writing systems would converge at the macro level, but diverge somewhat at the micro level.

Evidence from neurolinguistic studies of reading paints a similar picture. The left temporal parietal cortices known for the print-to-sound phonological processing are activated not only for GPC mappings in reading alphabetic scripts (Paulesu et al., 2001; Shaywitz et al., 1998), but also for OPC mappings during Chinese reading (Kuo et al., 2001, 2003, 2004). In relation to visuo-orthographic processing, there is a common cortical route for reading, known as the visual word form area (VWFA) where target visual word forms are processed across disparate writing systems, including Chinese (Cohen et al., 2000, 2002; McCandliss, Cohen, & Dehaene, 2003; Bolger, Perfetti, & Schneider, 2005). On top of that, Bolger et al. (2005) reported that the right-hemisphere regions participate in Chinese reading to provide additional support to process certain specific graphic form properties of Chinese characters.

Phonological Processing

Psycholinguistic research has substantiated a greater importance of phonology in reading Chinese than previously assumed, not least because any full-fledged writing system is essentially speech-based (DeFrancis, 1989; Perfetti, 1997). No matter how limited the presence of phonological cues is in written form, using phonological elements to process written languages may arguably be a universal pattern in reading development (Chow et al., 2005; Hu & Cutts, 1998). That said, the differential weighting of levels of phonology in relation to reading acquisition is likely to depend on the languages and orthographies to be learned (Goswami, 1999;

McBridge-Chang, 2004; Ziegler & Goswami, 2005). For example, children exposed to a phonemically-based English script would exhibit a somewhat different development pattern of phonological awareness from those exposed to a morphosyllabic Chinese script. This would result in the variance of reading acquisition across orthographies.

Based on the three primary phonological processing skills (Wagner & Torgesen, 1987) that strongly correlate with alphabetic reading, studies that looked into the role of phonology in the acquisition of reading Chinese also generally administered tasks along the three dimensions (McBride-Chang & Ho, 2000): phonological awareness, phonological recoding, and verbal short-term memory. The three dimensions of phonological processing have been documented to be of great relevance in learning a Chinese logo-syllabic writing system as well and are discussed in the following sections.

Phonological Awareness

Phonological awareness is tapped in and correlated with character recognition. Syllable awareness is found to be the strongest predictor of character reading in both cross-sectional (McBride-Chang, Bialystok, Ching, & Li, 2004; McBride-Chang & Ho, 2000; McBride-Chang, Tong, Shu, Wong, Leung, & Tardif, 2008) and longitudinal analyses (Chow, McBride-Chang, & Burgess, 2005; McBride-Chang & Ho, 2000). Even after some measures, e.g., working memory, rapid naming, vocabulary, and non-verbal IQ, were statistically controlled for in these studies, it has still predicted up to 20% of the variance in character recognition among 3- to 6-year-old children (Newman, Tardif, Huang, & Shu, 2011).

Other studies measured also onset and/or rime awareness as a core of phonological sensitivity in cross-sectional studies (Chen, Anderson, Li, Hao, Wu, & Shu, 2004; Leong, Tse, Loh, & Hau, 2008; McBride-Chang et al., 2004; McBride-Chang, Cho, Liu, Wagner, Shu, & Zhou, 2005; Shu, Peng, & McBride-Chang, 2008; Siok & Fletcher, 2001; So & Siegel, 1997) and longitudinal designs (Ho & Bryant, 1997a, 1997b; Hu & Catts, 1998), reporting that onset/rime awareness still predicted the reading ability of 3- to 8- year-olds even after working memory, rapid naming, vocabulary and nonverbal IQ were all statistically controlled for. Leong, Chen and Tan (2005) took these findings as evidence in support of the importance and usefulness of analytical reading via heightened orthographic consistency of the phonetic radicals on the onset or rime level in Chinese reading acquisition.

Nonetheless, the conclusions for a relationship in Chinese between phoneme-level awareness and reading are still not definitive. Measuring phonological awareness on phoneme-level tasks in Chinese words, studies have also demonstrated that novice Chinese readers showed less phoneme-level awareness than their English counterparts and that, in comparison with phonological awareness at the levels of syllables and onset/rime, the relationship between phonemic awareness and reading appeared to be little (Huang & Hanley, 1997; Leong et al., 2005; Li, Shu, McBride-Chang, Liu, & Xue, 2009; Siok & Fletcher, 2001).

Discrepant results across studies were likely to arise from phonological training by means of different auxiliary phonetic transcription systems, e.g., Pinyin and Zhuyin, in different Chinese societies (e.g., Huang & Hanley, 1994, 1997; Leong et al., 2005; Lin, McBride-Chang, Shu, Zhang, Li, & Zhang, 2011). One recent study by Newman et al. (2011) noted that performance on phoneme deletions among 6- to 8-year-olds was clearly correlated to reading ability even when syllable and onset/rime awareness, vocabulary, and pinyin knowledge were all controlled for. One other potential cause for this piece of contradictory findings is supplied by Shu et al. (2008) who suggested a dynamic relationship between levels of phonological awareness and reading ability in the course of Chinese reading acquisition. The conflicting results from the study of Newman et al. (2011) could consequently be also ascribed to the evolution and growth of phonological awareness over the course of Chinese reading acquisition. Taken together, phonological awareness at various grain size levels still matters in learning to read in such a logo-syllabic script as Chinese.

Phonological Recoding and Rapid Automatized Naming (RAN)

One of the three dimensions of phonological processing skills refers to the ability to convert visual representation of a word or symbol into its abstract phonological code (Wagner & Torgesen, 1987); this is commonly operationalized by RAN tasks where the speed and automaticity of symbol recognition is measured (Wolf, Bally, & Morris, 1986). The RAN-related tasks have been reported to reliably predict unique variance in word recognition among impaired and normal reading in learning to read alphabetic languages (e.g., Ackerman & Dykman, 1993; Blachman, 1984; Bowers, 1989; Wimmer, Mayringer, Landerl, 2000; Wolf et al., 1986; Wolf, O'Rourke, Gidney, Lovett, Cirino, & Morris, 2002).

A voluminous body of literature has converged on naming speed as a potent predictor for reading in Chinese, as Chinese word identification is fairly arbitrary and a RAN measure taps the ability to learn the arbitrary links between Chinese prints and sounds (Manis et al., 1999). Existing studies demonstrated RAN significantly correlated with character recognition among kindergarten, Grade 1, and

Grade 2 students from Taiwan, Hong Kong, and China (e.g., Chow, et al., 2005; Hu & Catts, 1998; McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005; Leong et al., 2008; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; McBride-Chang & Zhong, 2003; Wang, 2005).

The study conducted by Liao, Gerogiou, and Parrila (2008) is one of the first to directly investigate the relationship between RAN and the accuracy and fluency of Chinese character recognition. The findings have demonstrated that when age, nonverbal intelligence, phonological sensitivity, short-term memory, and orthographic processing were controlled for, RAN uniquely predicted fluency in Grade 2 as well as accuracy and fluency in Grade 4. This corroborated that RAN gains more and more importance as children progress to higher grade levels. Following studies in alphabetic languages (Bowers & Swanson, 1991; Bowey, McGiugan, & Ruschena, 2005; Compton, 2003; Georgiou, Parrila, & Kirby, 2006) documenting measures of RAN Letters and RAN Digits (“alphanumeric RAN”) better predicted reading than measures of RAN Objects and RAN Colors (“nonalphanumeric RAN”), Liao et al. (2008) have also established that the graphological RAN task, e.g., RAN Zhuyin, accounted for more Chinese reading variance than RAN Colors.

Moreover, Chinese dyslexic children have been consistently found to be deficient in RAN tasks, just as their English counterparts (Wolf et al., 2000). Impairments in RAN, together with deficient visuo-orthographic processing, affect as much as 50% of dyslexic children (Ho et al., 2004; Ho, Chan, Tsang, Chung, & Lee, 2006). Deficiency in naming speed is arguably a fair indicator of the disruption in automatic processing that is implicated in the retrieval of orthographic patterns.

More research is still required to clarify the role of RAN and its relation with orthographic skills in Chinese reading development.

Phonological Memory and Paired-Associate Learning (PAL)

Beginning to read is essential to combine visual and speech information together. In the matching process, it is imperative that sounds and verbal information are kept in the short-term memory, such that stable print-sound associations can be formed subsequently (Chung et al., 2011). In doing so, the long-term learning of the phonological structure of the language can be supported (Baddeley, Gathercole, & Papagno, 1998). Deficiency in the short-term store for phonological information is likely to bring about hindered development of associations between visual symbols and units of speech sounds and learning of verbal vocabulary. For young, normally achieving children learning to read alphabetic languages (Hulme et al., 2007; Wang, 2012; Windfuhr & Snowling, 2001) and Chinese (Kang, 2010) alike, good visual-verbal PAL skills are reported to lead to effectively establishing the mapping link between spelling (orthography) and sound (phonology). In other words, successful Chinese character acquisition capitalizes also on children's ability to activate and maintain a visual and a verbal representation (i.e., character and its pronunciation) at the same time. As such, a new association is to be formed between the two in long-term memory as well. Just like in research focusing on alphabetic languages, studies have established that Chinese dyslexic children were impaired in learning words where paired-associate learning was tapped (Ho et al., 2006; Li et al., 2009).

The relatively arbitrary mapping relationship between orthography and phonology in Chinese might even accentuate the role of PAL, especially visual-verbal PAL as theoretically assumed by McBride-Chang and Ho (2000) in Chinese reading development. However, there is evidence from research in alphabetic languages indicating that impaired orthographic learning does not simply arise from specific difficulty with visual-verbal association (Byrne et al., 2008; Wang, 2012). Assumedly, a general PAL mechanism is more likely to be implicated in reading acquisition. More efforts are needed to shed light on the role of PAL across modalities in relation to Chinese orthographic development.

Visuo-Orthographic Processing

Despite the centrality of phonological processing abilities to the reading development for both English (e.g., Wagner, Torgesen, Rashotte, & Hecht, 1997) and Chinese (e.g., Ho & Bryant, 1997a, c; Hu & Catts, 1998; McBride-Chang & Ho, 2000) in the literature, there are obvious reasons why visuo-orthographic processing is highly likely to be of greater importance in reading Chinese logo-syllabic script than in learning to read alphabetic scripts. One of the intrinsic characteristics of Chinese writing system is the fact that Chinese word reading is not a linear assembly of letter sounds as exemplified in alphabetic writing systems. Chinese characters are visually complex and thus contain much more visual information to be encoded than English words do (e.g., Chen & Kao, 2002).

Based on previous studies reporting that the processing of Chinese homophones activated the phonology of homophonic graphic forms and visual discrimination among the homophones (Tan & Perfetti, 1999), the nature of rampant homophony of written Chinese constrains the reliability of phonological or sound information in identifying or decoding Chinese characters, which would thus demand somewhat stronger reliance on visuo-orthographic skills than is required to read alphabetic scripts. Indeed, the visuo-orthographic processing, or "children's awareness of conventional rules in structuring Chinese characters and to identify or distinguish real Chinese characters from a set of pseudocharacters, noncharacters, and visual symbols" (Tong et al., 2009, p.428), has been identified to be one of the most important factors for Chinese character reading and writing acquisition (e.g., Huang & Hanley, 1995; Li, Fu, & Lin, 2000). It has also been found to effectively distinguish a subset of children with and without developmental dyslexia in Chinese (Ho, Chan, Lee, Tsang, & Luan, 2004; Ho et al., 2002).

Though some studies bundle up visually related skills to form a construct of visuo-orthographic skills, the two skills are in fact two distinct constructs. Visual skills that encompass visual discrimination and visual memory are general across cultures and languages. On the other hand, orthographic knowledge is language-specific and is defined as children's understanding of the conventions in a given orthography. Specifically, orthographic knowledge in Chinese includes the internal structures and positions of components at the subcharacter level, as well as the complex rules governing positional and function regularities (Shu, Chen, Anderson, Wu, & Xuan, 2003). The process of acquiring comprehensive orthographic knowledge and gaining full insight into internal structures of Chinese characters would normally take developing readers several years of explicit and implicit learning (Cheng & Huang, 1995; Ho et al., 2004).

In order to investigate the extent to which visual and orthographic skills are uniquely associated with the development of Chinese character reading when other linguistic abilities (e.g., abilities to process phonology and morphology) are controlled for, Li et al. (2010) carried out a study where they tested kindergartners and children from Grade 1 to Grade 3 in Beijing on visuo-orthographic tasks. In this study, visual skills were not uniquely correlated with character reading beyond kindergarten level; in contrast, orthographic skills strongly correlated to reading in primary school years, but not to pre-school reading. This finding concurs with the claim that the influence of orthographic skills on reading acquisition varies with age and reading experience (Juel et al., 1986). Similar to the development pattern of learning to read alphabetic scripts, reading in Chinese also progresses from a visual stage from the outset, and orthographic knowledge becomes more important as literacy development unfolds (Ehri, 1992; Ho et al., 2004; Kang, 2010).

Morphological Awareness

Morphological awareness in young English-speaking children is often conceptualized as the understanding of derivational suffixes that strongly influence reading processes (Carlisle, 1988; Casalis & Louis-Alexandre, 2000; Champion, 1997; Singson, Mahony, & Mann, 2000; Tyler & Nagy, 1989) and distinguishes good readers from poor ones. Likewise, morphology in Chinese has been established to facilitate reading unfamiliar characters (Hatano, Kuhara, & Akiyama, 1981; Kuhara-Kojima & Hatano, 1995; Li, Anderson, Nagy, & Zhang, 2002; Shu & Anderson, 1997). As well, it is a valid construct for distinguishing Chinese children with and without dyslexia (Chung et al., 2008; Leong, 1989; Shu et al., 2006).

According to Carlisle's (1995, p. 194) definition, morphological awareness is "children's conscious awareness of the morphemic structure of words and their ability to reflect on and manipulate that structure". One of the most related aspects of Chinese morphology to orthographic learning is hence the exploitation of semantic cueing functionality that is derivable from semantic radicals at the sublexical level. This specific skill is termed *radical awareness* (Li et al., 2002; Shu

& Anderson, 1997), denoting the sensitivity to the morphemic structure of Chinese characters necessary for Chinese reading. The knowledge of morphology is reported to be relatively limited among Chinese children in Grade 1, but it increases as children progress to higher grades; morphological awareness is documented fairly clearly among children in Grade 3 and beyond (Shu & Anderson, 1997). Packard et al. (2006) reported that children's ability to write characters can be enhanced with explicit instruction in the morphological structure of Chinese words.

3.2.2 Reading Theories of Chinese

With the necessary background knowledge of the Chinese language and writing system, we now turn to reading theories of Chinese. The first two sections focus on single character reading/identification, whereas the last reviews the stage theory adapted to Chinese reading acquisition by Ho et al. (2004), the only development theory to date that accounts for learning to read Chinese.

The Dual Route Model

Although the dual route model is used to account for word learning in English (cf. Wang, 2012), it is also employed as one of the common theoretical frames of reference used in studies for impaired Chinese reading (e.g., Ho, Chan, Chung, Lee, & Tsang, 2007; Weekes et al., 2006; Yin & Butterworth, 1992; see Ho et al., 2004 for a discussion). It is, nevertheless, interesting to look at how the dual route model could explicate Chinese character reading, in spite of the controversy over the availability of a sublexical route in its adaption to Chinese logo-graphic script.

Setting the dual route model in the context of Chinese character reading, there should be a lexical process that allows for accessing lexical representations to read non-phonograms, irregular phonograms, and regular sight characters, plus a sublexical process that applies the OPC rules to read phonograms and regular pseudocharacters. As in English, two subtypes of developmental Chinese dyslexia have also been identified, i.e., surface dyslexia—impairment in the access of the lexical procedure, and phonological dyslexia—the unavailability of the sublexical procedure (see Figure 5).

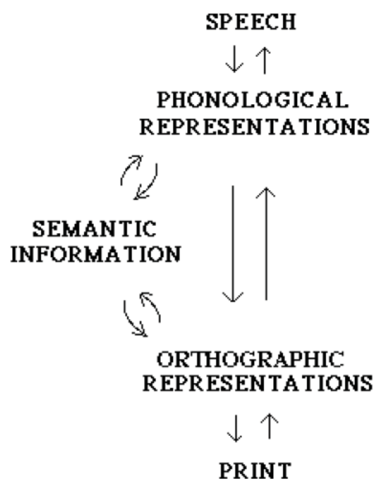

Figure 5. A functional model of word reading and spelling in Chinese (Source: Weekes, Yin, Shu, & Chen, 2006, p.601)

However, the explanatory power and theoretical credence of the dual route model is somewhat reduced here, due to the dispute on the existence of a sublexical route emerging from the inherent status of phonetic radicals embedded in phonograms in the Chinese script. When readers attempt to sound out a pseudo-phonogram, they would derive either directly from the sound of the phonetic radical if the phonetic radical in question is a legal character itself (i.e., the direct derivation strategy) or indirectly from the sound of other characters sharing the same phonetic radical if the phonetic radical in question is a bound form (i.e., the analogy strategy). The second way of inferring the pronunciation of a phonogram from its orthographic family when the embedded phonetic radical is not a legal character itself has led to the argument that reading Chinese pseudocharacters is mainly accomplished via the lexical route, because reading is critically attendant on knowing many other characters, no matter what the status of a phonetic radical is (Ho et al., 2007). The adequacy of the dual route model in a Chinese context might thus not be meaningful until the debate is resolved.

Stage Theory

Based on the evidence showing that, in the course of Chinese reading acquisition, children develop or refine reading-related skills, such as various levels of phonological awareness (e.g., Shu et al., 2008), orthographic knowledge (Cheng & Huang, 1995) and morphological awareness (Shu & Anderson, 1997). Ho et al. (2004) put forward a stage model of Chinese orthographic development. Similarly in the stage model of Frith (1985) and Gough, Juel, and Griffith (1992), Chinese children proceed through three stages in reading acquisition—logographic stage, cipher stage, and orthographic stage.

The logographic stage is one at which children read every character as a logography that is only achievable by means of associating some salient visual features with the sound. Children rely on visual skills to discriminate and memorize different orthographic units or shapes of characters. Phonological memory is also of great significance here as well, not least because the pronunciation of a Chinese character has to be retrieved from memory either via the direct lexical route or via the application of OPC rules.

At the cipher stage, unexperienced readers are increasingly aware of the orthographic regularities and the internal structure of Chinese (e.g., the positional and functional regularities of radicals at the subcharacter level) via word-specific learning. In turn, this empowers children to analytically decompose and decode unfamiliar characters. Accordingly, this relieves them of the need to learn characters by rote memory; in the meantime, children are able to self-scaffold in reading or spelling (Chliounaki & Bryant, 2007).

Children at the orthographic stage of Chinese reading acquisition process character components (e.g., radicals) and whole characters as whole, integral units in an automatic fashion. Word recognition is fluent and efficient. As decoding attempts and print exposure increase, sight vocabulary would accumulate and be directly accessed by the lexical route. At this point, morphological processes both at the word- or character-level become more important for comprehension (Kang, 2010).

The models presented above for Chinese character reading or Chinese reading development fail to provide a satisfactory, detailed account for the critical aspect of how unfamiliar Chinese characters eventually become sight vocabulary. Share's (1995) self-teaching hypothesis has offered a theoretical framework that nicely accounts for this respect in learning to read Hebrew (Share, 1999), English (Cunningham, 2006), and Dutch (de Jong & Share, 2007). Despite the distinctive surface scriptal difference between the Chinese logo-syllabic and alphabetic writing system, it is highly likely that the powerful, sustainable self-teaching mechanism is extendable to orthographic development of Chinese. Built on previous discussions concerning the Chinese writing system as well as theories and findings about Chinese reading acquisition, the next section sets out to expound how and why the self-teaching theory is an adequate framework within which Chinese orthographic learning is explored and investigated in the dissertation.

3.3 Orthographic Learning via Self-Teaching: The Chinese Case

This section provides a quick summary of previous research findings on learning to read Chinese, arguing for the case that learning to read Chinese, despite its inherent scriptal difference and the phonological information encoded in the logo-syllabic writing system, would generally abide by the tenets of Share's (1995) self-teaching hypothesis. Hence, this anticipates us for an adaptation of the self-teaching model to account for orthographic learning in Chinese.

As phonological recoding is the *sine qua non* for reading acquisition of alphabetic languages (Share, 1995, 1999), it is perhaps the same case with learning to read such a logo-syllabic orthography as Chinese. An overwhelming majority (i.e., 80% to 95%) of Chinese characters are phonograms that contain somewhat useful information on OPC rules to infer pronunciations of unknown or unfamiliar characters. The sound relationship between phonograms and their embedded phonetic radicals also exhibit a regularity and consistency pattern (cf. section 3.1.1), parallel to the concepts in English (e.g., Jared, 2002).

Readers exploit this internal property of characters and would thus have the possibility of phonologically decoding the characters to generate a number of potential candidate pronunciations (e.g., Anderson, Li, Ku, Shu, & Wu, 2003). Decoding an unfamiliar Chinese character depends on the phonetic value of only one orthographic unit (i.e., the phonetic radical) embedded in a given character (Ho, Law, & Ng, 2000). As such, young readers make the phonological codes available to access meaning in the mental lexicon.

Previous sections in the current chapter have presented an array of theoretical and empirical support to different levels and aspects of phonology-related skills for Chinese reading acquisition. Phonological sensitivity is the key to kick off the self-teaching process, which is consistent with plenty of studies showing that phonological awareness predicts or correlates strongly with Chinese reading development.

However, at the early stage of research on word identification in Chinese, the debate mainly revolved around the contributory power of phonological abilities and visual-orthographic skills to character learning. The salience of the semantic attributes in Chinese writing system led inevitably to the misconception epitomized by *the identification-without-phonology hypothesis* (e.g., Hoosain, 1991) that states that there is no involvement of phonological processing in visual recognition of Chinese characters, and that phonology is only activated posterior to meaning. As it is essential for reading to link printed forms to their spoken equivalents, the role of phonology appears to be crucial. In a broad sense, the surface level variance in different writing systems should not divert the orthographic learning path taken by beginning readers of different languages, as suggested by *the Universal Phonological Principle* (UPP, Leong, 1997; Perfetti, 2003) that states that 'in any writing system, the pronunciations are activated during reading at the earliest moment allowed by the units of the writing system (Perfetti & Liu, 2006, p. 225)'. All mature writing systems are essentially speech-based (DeFrancis, 1999; Perfetti, 2003); the difference they make in phonology lies only in the grain size of phonological information encoded in the orthography, i.e., the orthography-to-phonology mappings (Perfetti, 2003).

A great deal of evidence from studies on Chinese character recognition testing *the identification-with-phonology hypothesis* (Perfetti & Zhang, 1995a, b) also lent credence to the activation of phonology in reading Chinese from the lower character level all the way through to the higher sentence level (Cheng & Shih, 1988; Hung, Tzeng, & Tzeng, 1992; Lam, Perfetti, & Bell, 1991; Perfetti & Zhang, 1991), by means of tasks in semantic categorization (Chua, 1999; Xu, Pollatsek, & Potter, 1999), backward masking (Tan, Hoosain, & Peng, 1995), and semantic similarity judgments (Perfetti, Liu, & Tan, 2002; Perfetti & Zhang, 1995; Zhang, Perfetti, & Yang, 1999).

Simply put, studies testing *the identification-with-phonology hypothesis* confirmed that "the phonological units that are mapped by the writing system are activated as part of word identification" (Perfetti, Liu, & Tan, 2005, p.45). Rendered specifically in the context of learning to read Chinese, it means that "the phonological syllable is activated as part of character identification" (Perfetti et al., 2005, p. 45). Taken together, phonology has been demonstrated to be a constituent of orthographic recognition rather than a by-product of it across all writing systems. Accordingly, it is expected that, when learning to read Chinese, children would draw as much as possible on phonology offered in the non-alphabetic script.

Apart from the significant role of phonology, orthographic processing that is regarded in the self-teaching hypothesis as the secondary source of contribution to orthographic learning in learning to read in alphabetic writing systems is also critical to learning Chinese script for the visually complex form of Chinese characters (e.g., Huang & Hanley, 1995; Li et al., 2000; Li et al, 2006; Shu &

Anderson, 1998). According to *the orthographic depth hypothesis*, readers of deeper orthography must pay more visual attention to word-specific orthographic details to a greater extent than those learning a shallow orthography. It is likely that orthographic processes might have a differentially greater weighting in learning to read Chinese script than other alphabetic scripts. The greater importance of orthographic processing skills in learning to read Chinese than English arises from the absence of reliable symbol-sound correspondence that limits the use of phonological recoding strategy and the high occurrence of homophony (Lee et al., 2009; Miller, 2002; Perfetti & Tan, 1998). Some studies have found that phonologically related skills were comparatively less robust in predicting Chinese reading among children with developmental dyslexia and normal readers (Ho et al., 2002, 2004; McBride-Chang et al., 2005; Shu et al., 2006). That being said, it should be kept in mind that however influential the orthographic processing ability might be in learning to read in Chinese, phonological skills still take precedence in orthographic learning, not least because the main task for novice readers to achieve sight reading is to establish the link between orthographic representations and their corresponding oral vocabulary.

Central to the self-teaching idea is also that children pick up word representations unintentionally when they are engaged in phonological decoding during reading (Share, 1995, 2008). A similar idea can be traced back to studies of Shu, Anderson, and Zhang (1995) and Ku and Anderson (2001) where they found incidental learning of word meanings in both American and Chinese kids. Namely, the acquisition of new word items and word meanings occurred incidentally 'as a natural consequence of reading books, magazines, and newspapers' (Anderson, 1996, p. 64; Ku & Anderson, 2001; Shu et al., 1995).

Although Anderson and his colleagues (Ku & Anderson, 2001; Shu et al., 1995) focused, instead, on the acquisition of word meaning, their experimental paradigm apparently possessed a self-teaching streak. For example, Ku and Anderson (2001) asked 241 Taiwanese fourth-graders to read two long narrative texts (1513 and 1567 characters, respectively in total) where each text contained 32 target characters. After the reading exposure phase, meanings of target characters were gauged by a multiple-choice test where, out of four alternatives, participants had to select the right meaning that matched that of the target character they read in the two texts. In their experiment, the correct answer for "遷"居 (to move) was 搬移 (to move), and three distracters were (a) 拉著 (to pull, the meaning of 牽 which is a homophone of the target character), (b) 建設 (to build, the meaning of 造 whose radical was the same as that embedded in the target), and (c) 住的地方 ('a dwelling place, the meaning of 居).

Although the foregoing study did not include measures of orthographic learning, a telling indication from the incidental learning paradigms employed in the foregoing studies is that they are likely to have tapped the self-teaching mechanism. Participating children had to somewhat retain the character forms, whether these character representations were well- or under-specified, to be able to perform on the meaning match multiple-choice task that involved, indisputably, word identification to a certain degree.

Given different lines of evidence and arguments presented in this chapter, the self-teaching hypothesis is anticipated to provide a valid framework in which orthographic learning in Chinese can be investigated. For one thing, Chinese morphophonological script does not have a completely naught or arbitrary relationship between its spoken and written forms, as the embedded phonetic radicals in phonograms would sometimes give away useful phonological information. For another, the speech-based feature of Chinese script affords the opportunity for self-teaching, and similar paradigms for incidental learning have been successfully implanted. Liu and Shiu (2011) succeeded in adapting the self-teaching model to examine the issue of Chinese orthographic learning. Preliminary evidence from their Experiment 1 showed that Chinese children were able to self-teach orthographic forms in a simplified Chinese script. In their Experiment 2, they set out to test the hypothesis whether orthographic learning is parasitic on initial phonological decoding. 2^{nd} grade students learned targets either through a lexical decision procedure while engaged in concurrent vocalization during exposure, or a naming procedure. Replicating Share (1999, Experiment 2), the results showed that under conditions when opportunities for phonological decoding were minimized, i.e., the lexical decision with concurrent vocalization, orthographic learning was less robust than under naming conditions. This observation suggests a role of phonological recoding in Chinese orthographic learning. To supplement these findings, the dissertation intends to explore in more depth the issues revolving Chinese orthographic learning within the framework of self-teaching.

Chapter 4

Research Questions and Hypotheses of the Present Study

In chapter 3, a review of previous studies on learning to read Chinese reveals general similarities of the developmental pattern of Chinese reading acquisition to that of English. Generally speaking, reading development in both English and Chinese progresses from a visual stage through logographic stage to phonological stage (Ehri, 1992; Frith, 1985; Ho et al., 2004). Chinese word reading is involved with a battery of skills, such as phonological processing (Ho & Bryant, 1997a, b, c; Hu & Catts, 1998; McBride-Chang & Ho, 2000), visual-orthographic skills (Ho et al., 2003; Huang & Hanley, 1995, 1997; Siok & Fletcher, 2001), morphological awareness (Li et al., 2002; ; McBride-Chang et al., 2003; Shu et al., 2006; Wang et al., 2006), and speeded naming (Ho & Lai, 1999). Likewise, analogous skills are associated with word recognition across alphabetic scripts (e.g., Adams, 1990; Deacon, Wade-Woolley, & Kirby, 2007; McBride-Chang, 2004; Snowling, 2000).

The evidence and arguments presented in chapter 3 lend considerable support to the contention of Perfetti and his associates (Perfetti, 2003; Perfetti et al., 1992) that there are some universal aspects in reading across all orthographies. The universals for reading have also been reinforced by the neuroimaging line of evidence that reported variations in a universal cortical region for reading network in human brains (see Rayner et al., 2001, for a discussion). In line with *the orthographic depth hypothesis* (Katz & Frost, 1992; Seymour, Aro, & Erskine, 2004), differential weighting of various skills that are involved in learning a given script is highly likely to emerge, due to the level at which a script encodes phonological information.

Piecing together the findings in the literature on Chinese reading and the features of Chinese language and its writing system, the dissertation aims to explore Chinese orthographic learning with Share's (1999) self-teaching experiment paradigm. Despite the limited phonological information from phonetic radicals and semantic information from semantic radicals, Share (1995) has specifically suggested orthographic learning via self-teaching in Chinese:

> "If contextual information can help resolve decoding ambiguity…, one might speculate that in natural text, phonetic information [from phonetic radicals] may be sufficient for functional self-teaching. … It should also be kept in mind that the semantic radical sometimes provides meaning (ideographic and pictographic) 'clues' that are entirely absent in alphabetic scripts." (pp. 197-198)

Based on Share's claim, it is arguable that Chinese orthographic learning might be modulated by the availability and clarity of embedded semantic and phonetic radicals. The dissertation is motivated by Share's speculation. Novice readers are expected to capitalize on whatever information that is offered in the script in orthographic learning. In the case of Chinese, the radicals are likely to come to aid in the process of committing orthographic memory to the lexicon. Through four experiments conducted within the self-teaching framework, the research questions that are to be addressed in the dissertation are thus (1) to explore in Experiment 1 whether young Chinese reader can learn orthographic representations in a self-teaching manner and whether an external phonological aid system, i.e., Zhuyin, in this case, would lead to stronger learning effect than without it, (2) to test in

Experiment 2 whether phonetic decoding through phonetic radicals embedded in Chinese characters is sufficient for functional self-teaching in context, (3) to look into the cueing effect of semantic radical in the process of self-teaching Chinese orthographic representations, and finally (4) to investigate the effect for semantic transparency in Chinese orthographic development.

In summary, the hypotheses evaluated in the study of self-teaching hypothesis are as follows:

1. Evidence of self-teaching of target Chinese pseudocharacters will be found in posttest assessment of orthographic learning, indicating greater learning effect for target words in relation to homophonic and other alternatives.
2. Evidence of better learning will be found in Without Zhuyin conditions than With Zhuyin conditions, indicating that opportunities for phonological information from Zhuyin would somewhat mitigate the orthographic learning by detracting children's attention away from word-specific orthographies.
3. Targets embedded with a phonetic radical, i.e., phonograms, will be acquired better in reading than targets without an embedded phonetic radical, i.e., non-phonograms, showing that opportunities for phonological recoding should largely be derived from within the orthography and that phonological information afforded by phonetic radicals embedded in characters is sufficient for functional orthographic learning in context.
4. Targets embedded with cueing semantic radicals will be acquired more efficiently than those embedded with non-cueing semantic radicals, demonstrating that children *do* exploit the meaning cueing function of semantic radicals when learning to read Chinese orthographies.

5. Semantic transparency will lead to robust orthographic formation in memory, showing that children *do* attend to the subtle semantic relatedness on the radical and whole-character level.

Moreover, prior research has reported that orthographic forms are acquired rapidly with only a minimal number of exposures to novel words and are retained durably even after a month (Nation, Angell, & Castles, 2007; Share, 2004). One experiment in the dissertation also dabbled in the manipulation of the posttest time or the number of exposures, providing incipient insights into the effects of duration and exposure in the self-teaching context of a non-alphabetic, deep orthography, such as Chinese. The dissertation is also intent on comparing cross-language evidence for orthographic learning via self-teaching, with a view to delineating the general picture as to how and in what ways children of different writing systems diverge and converge.

Chapter 5

Self-Teaching Hypothesis and Phonological Recoding in Learning to Read Chinese

5.1 Study 1: Orthographic Learning of Chinese via Self-Teaching

Along with Liu and Shiu (2011), Study 1 is among the first to pioneer the investigation into the self-teaching theory in a Chinese context, and to address the question of whether orthographic learning takes place rapidly via self-teaching in learning to read in a non-alphabetic, or more correctly, a logo-syllabic Chinese script. The notion of self-teaching as a built-in mechanism for readers to independently commit lexical representations in memory is instrumental and valuable, not least because other ways of orthographic acquisition, e.g., direct instruction and contextual guessing, are out of the question (Gough, 1983; Mason, Anderson, Omura, Uchida, & Imai, 1989; Share, 1995; Taylor & Taylor, 1983).

Orthographic learning is the process whereby word spelling patterns are committed to memory such that they can be retrieved automatically rather than decoded (Ehri, 2005). This process occurs every time a novel word string is encountered and is to be acquired. Young and adult readers are reported to be able to swiftly commit the orthographic memory to the mental lexicon with only a minimal of exposures to the printed word forms (Kyte & Johnson, 2006; Share, 2004, 2008).

Just like learning to read alphabetic scripts, rapid orthographic learning was established for learning to read a simplified Chinese script in China; young children were able to learn target orthographies after six exposures (Liu & Shiu, 2011). It is questionable whether this finding on the acquisition of simplified Chinese characters can be generalized to Taiwanese children who still learn traditional Chinese characters that are visually more complex than the simplified ones. The present study sets out to explore this issue. Moreover, the number of exposure to targets is also manipulated, thus being the first study ever that offers some insight into the effect of exposure in Chinese orthographic learning. Based on findings available on fast mapping (Carey, 1978; Carey & Barlett, 1978) and rapid orthographic learning across orthographies (Cunningham, 2002; de Jong & Share, 2007; Liu & Shiu, 2001; Share, 1999, 2004), one could anticipate that children would also be able to rapidly self-teach orthographic forms in a visually more complicated Chinese script.

In the meantime, another focus of Study 1 is to clarify the role in orthographic learning of the external phonetic system, i.e., in this case, Zhuyin (cf. section 3.1.2), that is listed alongside characters in children's books and is intended to supply pronunciation, because Chinese orthography is highly opaque. According to Share's (1995, 1999) self-teaching hypothesis, it is predicted that Zhuyin may somewhat divert developing reader's attention from word-specific orthographic representations that are to be acquired. Based on the self-teaching hypothesis, phonological recoding should arguably stem from the orthography *per se*. That said, the importance of Zhuyin is not to be ignored; potentially, it leads children to crucial phonological awareness, e.g., a Chinese syllable can be segmented into onsets and rimes.

To summarize, Study 1 looks into rapid orthographic learning via self-teaching in Chinese and the effect of Zhuyin. Share's (1999) self-teaching paradigm is adapted here to investigate the acquisition of phonograms which constitute the majority of

Chinese characters. Pseudo-phonograms were invented and inserted into short text for children to read aloud independently. Reading for Chinese-speaking children is also to speech-recode word items first, such that they are held in memory for further phonological or orthographic analysis (Tzeng, Hung & Wang, 1978). Children learning to read Chinese are thus predicted to show strong phonological learning as well; error analyses would depict a trend in which most of the errors children made are sound-based ones. This chapter will close up by comparing cross-language evidence in the hope of delineating the general picture as to how and in what ways children of different writing systems diverge and converge.

5.1.1 Method

Participants

The sample was randomly drawn from 8 *Buxibans* (after-school tutoring centers where pupils of all levels would normally go; note that attending students do not necessarily perform badly at school). A total of 40 Taiwanese Grade 3 students (24 boys and 16 girls) took part in the present study. All of the children were native speakers of Mandarin Chinese with ages ranging from 9 years to 9 years 11 months, with a mean age of 9 years 6 months. The reading task and follow-up testing was held at the end of the third grade school year, during the months of July and August.

Participants were all normally achieving children, matched on age and an all-purpose language skill test: in this case, the latest monthly native language evaluation at their individual school. This evaluation always takes the form of an exam where Zhuyin/phonological skills, character production, comprehension, sentence constructions, etc., are all assessed at one go. All participants had scores ranging from 80 to 99 points out of 100 points (Mean = 93.16, SD = 4.52).

Design

The story texts and pseudocharacters were developed and designed on the basis of Share's (1999) experimental paradigm. Two types of tasks were administered to the participants: (1) the self-teaching task constituting reading aloud connected texts without any feedback or assistance, and (2) posttest assessments of orthographic learning, including an orthographic choice test and a spelling test.

Target characters

10 extremely low-frequency real characters (i.e., all phonograms) were selected and assigned to each of the following 10 categories: shoe, musical instrument, personal name, people/nation, fruit, car, flower, animal, star, and city. Coupled with the 10 selected low-frequency characters were 7 real characters having a very low frequency, and 3 pseudocharacters. Each pair shared the same phonetic radical and was manipulated to have the same pronunciation as their phonetic radical. Chinese phonology dictates that the 10 designated target pairs be all of one syllable. The visual complexity of the selected characters is controlled by their strokes; the mean stroke of the Set A is 11.2 (SD = 3.46), and that of Set B is 11 (SD = 2.45). Each individual character consisted of two radicals: a semantic radical to the left and a phonetic radical to the right, which is the most prominent way of structuring Chinese characters, i.e., phonograms.

With a focus on regular phonograms in the current study, the pronunciations of selected characters, if irregular, were manipulated, such that they all behaved in accordance with the regular pronunciation pattern. This manipulation was intended to liken the orthographic learning of Chinese to that of English, in which most words are regular in terms of pronunciations (Fang, Horng, & Tzeng, 1986; Hue, 1992; Lee et al., 2005).

In brief, regularity in Chinese is defined to the effect that the characters embedded with a phonetic radical share exactly the same pronunciation of their phonetic radical, regardless of the lexical tone. For example, "狡" is pronounced as /jiao/ whose pronunciation is identical to its phonetic radical "交" /jiao/. In a case like this, the original pronunciation stays unchanged. In contrast, a character, such as "被" pronounced as /bi/ would have to be manipulated to have the pronunciation /pi/, as is shared with its phonetic radical "皮" /pi/.

Short texts

10 short texts, either narrative or expository, were created. Each of the ten target character appeared 8 times in each text (see Appendix 5 for an example); parallel texts with only 4 exposures were created by replacing excessive targets with either a synonymous phrase or a pronoun. For instance, "Would you like to live in Teijia?" was altered to "Would you like to live in this town?". One of the texts was adapted from Share's (1999) study and translated into Chinese. The rest of texts were created for the current study and in strict adherence to a very similar format. The texts were all printed with 1.5-line spacing, each on a separate laminated A4 page in 20-point DFKai-SB font.

Text length ranged from 113 to 135 characters for conditions with four exposures (M = 119.1, SD = 7.36) and from 113 to 137 characters for conditions with eight exposures (M = 122.8, SD = 6.81). The texts were designed in a way that no difficulties were presented to normally achieving readers in Grade 3. A pilot study was carried out on a group of 11 children in Grade 3, and it confirmed the target characters and short texts were adequate for third-grade character acquisition.

Two versions of each story were further created for the purpose of counterbalancing. One version employed one of the alternate spellings of each target pair, and the other version used the other alternative left in the pair. Half of the sample saw one spelling of each pair (Set A), while the other half saw the alternative spelling (Set B). All the story sets had two variants: One accompanied by the phonological aid *Zhuyin* (being the norm for readers till the end of Grade 4 in Taiwan), and one without (see Appendix 5).

The self-teaching reading task

The self-teaching task resembled Share's (1999) experimental paradigm and was administered on an individual basis in two separate sessions. In a first session children read 10 stories. Three days later, children participated in a second session where their orthographic learning of the target characters was gauged by an orthographic choice task and a spelling task.

Comprehension. Immediately after each text, three comprehension questions were asked. The questions were designed to ensure that orthographic learning comes with text comprehension, as is the case with natural reading circumstances. Questions pertaining to each of the pseudocharacters were asked. To avoid the pronunciation of the pseudocharacter by the child, "Would you like to live in Teijia?" was paraphrased to “Would you like to live in this town?” Each correct answer to the questions scored one point. The mean number of the correctly answered questions was 27.03 (SD = 2.48), maximal score: 30 (3 questions times 10 texts), indicating that the general comprehension was mostly intact.

Target decoding accuracy score. The accuracy of the pronunciation of the target words was recorded *online* by the experimenter. A score of 1 was given each time a target was read correctly. An error was recorded if any change to the correct target pronunciation occurred. Independent analysis of the audiotapes was used to confirm the online scoring. In conditions with four exposures, out of the 40 possible correct pronunciations of the homophone targets (10 stories times 4 target characters), the proportion of correct pronunciations amounted to 93.38% (M = 37.35, SD = 5.61); in the conditions with eight exposures, out of the 80 decoding trials of the targets, 89.75% were correctly decoded (M = 71.8, SD = 18.22). Hence, the overall decoding accuracy for the target homophones was 91.57%—indicating that most of the targets were successfully decoded when encountered at the text reading phase.

Orthographic learning measures

The extent to which orthographic learning actually took place was assessed by two separate posttest measures given in the order listed. Slightly divergent from Share’s (1999) method, a naming task was excluded, for the reason that it has been claimed to potentially bias the results by increasing the number of exposures to target pseudocharacters (Bowey & Muller, 2005; Nation et al., 2007).

1. *Orthographic choice*. Children were prompted to recall the target homophone by a question (e.g., “Do you still remember the name of the hottest town on earth?”).

Subsequently, they were presented with four alternative spellings of the target word at random:

(1) The original target that appeared earlier in the reading text (e.g., 魻 /jia/). This character is a real, very low-frequent word unknown to participants. Its pronunciation was altered from its original /xia/ to match the pronunciation of its phonetic radical /jia/).

(2) The target's homophonic alternative (e.g., 狎 /jia/).

(3) A semantically related foil that shares the same semantic radical as the target but a different phonetic radical (e.g., 鮋 /yo/).

(4) A slightly modified non-word foil (e.g., 魻).

However, when confronted in the test without being able to recall the target character seen before, children were allowed to skip it, which was categorized as No-recall in later statistics analysis.

2. *Spelling*. Children were required to spell out each of the target character they had read about in the stories, immediately after the reading tasks and in another session three days afterwards. In this task, every attempt was made to elicit the reproduction of target characters. For instance, the experimenter asked a participant if he/she still recalled the name of the hottest town in the world. If the first prompt was in vain, the first phone of the target in question was then provided. Still failing to reproduce the target character in question, children would be further given the complete pronunciation of the target.

5.1.2 Results

The current experiment aimed to determine whether orthographic learning via self-teaching also occurs in Mandarin Chinese, a non-alphabetic language and to shed light on rapid orthographic learning process in Chinese via self-teaching. We begin by reporting results from the orthographic choice test and then results from the spelling task and children's spelling error patterns. Other issues will be reported following the order of effects of Zhuyin, exposure, and delay, and the salience of phonological learning.

Occurrence of orthographic learning in Chinese via self-teaching

The orthographic choice task entailed participants choosing the target item (e.g., ) over its homophonic foil (e.g., 狎), its semantic distractor (e.g., 鮋) and a nonword visual distractor (e.g., ). The proportion of targets, homophones, semantic distractors, nonwords, and no-recalls that were produced in the orthographic choice posttests is illustrated in Table 3. The targets identified correctly in the posttests immediately and following a 3-day interval stood at 86.25% and 86.75%, respectively. The outright excess of the chance level (25%) suggests that the orthographic learning *did* take place, although there was considerable variation in rates of orthographic learning.

Table 3

Proportion of targets, homophones, semantic distractors, nonword visual distractors, and no-recalls in the orthographic choice task in Study 1

		Target		Homophone		Semantic distractor		Nonword visual distractor		No-recall	
Exposures		M	SD	M	SD	M	SD	M	SD	M	SD
Immediately											
Four (n=100)											
	+Zhuyin	7.90	1.60	0.60	0.52	0.20	0.42	1.10	1.25	0.20	0.48
	-Zhuyin	9.10	0.99	0.50	0.71	0.20	0.42	0.10	0.32	0.10	0.32
Eight (n=100)											
	+Zhuyin	8.40	1.57	1.10	1.52	0.00	0.00	0.30	0.48	0.20	0.42
	-Zhuyin	9.10	0.74	0.20	0.42	0.60	0.70	0.10	0.32	0.00	0.00
3-day delay											
Four (n=100)											
	+Zhuyin	7.70	2.54	1.10	1.10	0.00	0.00	0.40	0.84	0.80	2.53
	-Zhuyin	9.00	1.89	0.50	1.27	0.40	0.70	0.10	0.32	0.00	0.00
Eight (n=100)											
	+Zhuyin	8.50	1.72	1.10	1.29	0.00	0.00	0.04	0.97	0.00	0.00
	-Zhuyin	9.50	0.71	0.10	0.32	0.04	0.52	0.00	0.00	0.00	0.00

Disregarding the posttest intervals, choices made on the target pseudocharacters overall were 86.5%. Their homophonic alternatives were selected at 6.5%, the semantic alternatives 2.25%, the nonword alternatives 3.13%, and no-recalls 1.63%. Another important indicator for robust orthographic learning is the fact that the selection rate of target characters outnumbered, by 6 times, that of all the other alternatives put together lends compelling support to the occurrence of orthographic learning in Mandarin Chinese via self-teaching.

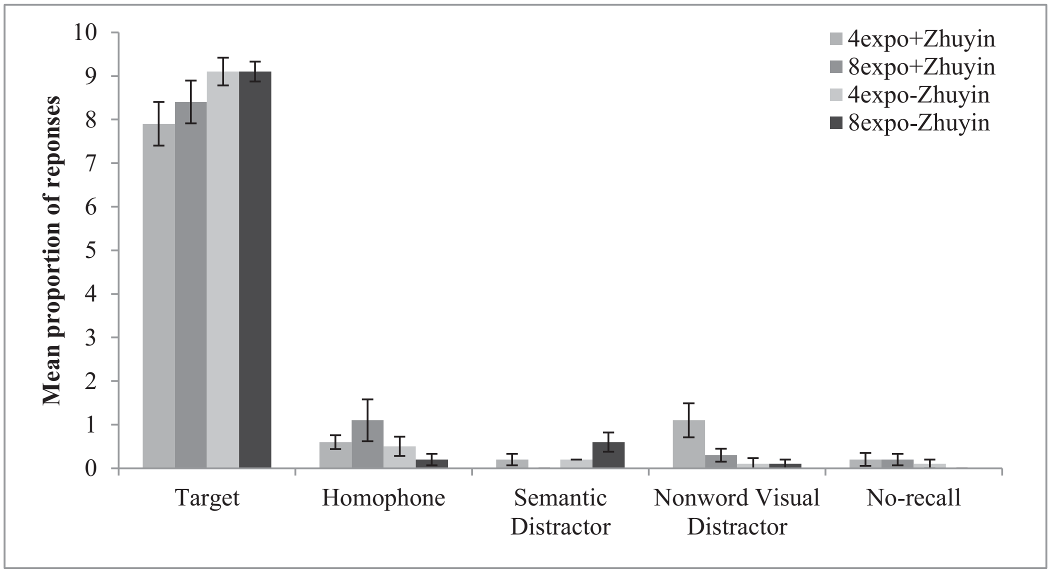

Figure 6. Mean responses from the orthographic choice task *immediately after exposure* in Study 1

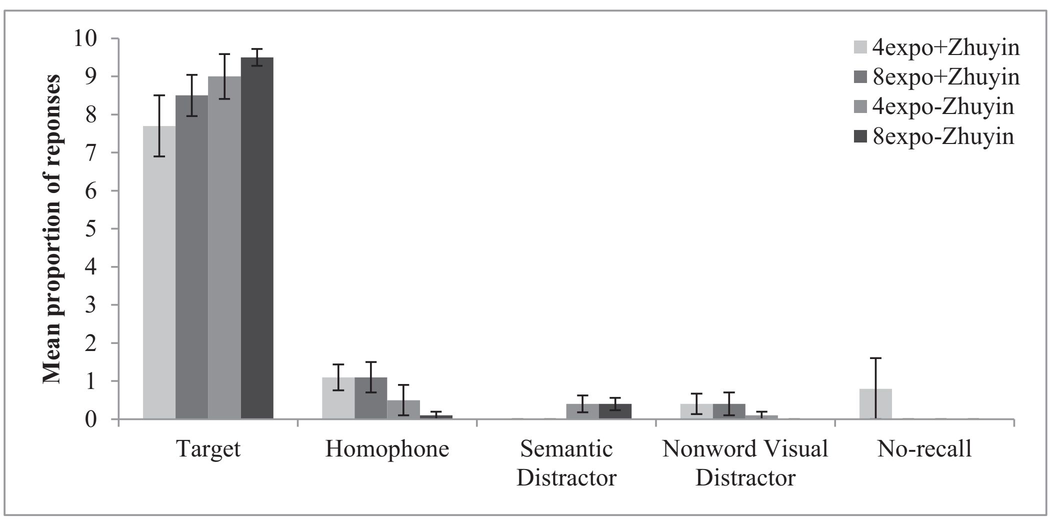

Figure 7. Mean responses from the orthographic choice task *after a 3-day interval* in Study 1

On the spelling task, a *whole-character* criterion was applied. Targets and their alternatives were only accepted as correct when they were reproduced identically to the ones previously seen in the orthographic choice task. Reproductions of the alternative homophonic foils of the target items were grouped as “homophonic spellings”, and all other responses as “other misspellings” (see Table 4).

Averaged across all conditions, participants correctly spelled 71% (SD= 2.33), 64% (SD= 2.30) immediately after the text-reading task, and 75% (SD= 2.37) after a 3-day interval. Moreover, the portion of homophonic reproductions overall stood at 12% in all cases (overall SD= 1.50, immediately after the text-reading task SD= 1.39, and after a 3-day interval SD= 1.61). Once again, the effect of orthographic learning via self-teaching was robust, as the overall spelling accuracy was way above the chance level and children used the target spelling pattern five times as often as they used the homophonic spelling pattern.

Effects of Zhuyin, exposure, and delay on orthographic learning

To investigate whether orthographic learning was modulated by phonological aids (e.g., Zhuyin), number of exposure and the length of delay, the proportion of correct target responses in each condition was entered into a 2 (phonological aid: With Zhuyin vs. Without Zhuyin) x 2 (exposure: four times vs. eight times) x 2 (posttest time: immediately after reading vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures.

In the orthographic choice task, the main effect of phonological aid was significant, F (1, 36) = 6.54, η_p^2= .15, p < .05, with better performance in Without Zhuyin conditions. However, there was no significant main effect of exposure, F (1, 36) =

1.20, $\eta_p^2 = .03$, $p = .28$, in line with Share (1999), de Jong and Share (2007) and de Jong et al. (2009) where no exposure effect was substantiated. Nor was there a significant main effect of delay, $F < 1.0$. Likewise, no effects of interaction were found significant between the posttest delay and the number of exposures, or between the posttest delay and Zhuyin, all *F*s < .5

Regarding the correct target spelling responses on the spelling task, there was no significant main effect of Zhuyin, nor did we find a significant main effect of number of exposures, all *F* values < 2.0. Contrary to the statistical analysis in the orthographic choice test, a main effect of delay was found significant in the spelling test, $F(1, 36) = 7.97$, $\eta_p^2 = .18$, $p < .00$. Also, there was a main effect of interaction between Zhuyin and the number of exposures, $F(1, 36) = 5.16$, $\eta_p^2 = .13$, $p < .05$, suggesting that better orthographic learning effect is potentially in proportion to the number of exposures when Zhuyin is provided. However, one caveat to this interpretation is that, generally speaking, orthographic learning in Without Zhuyin conditions showed better performance in most of the cases. No other interaction effects reached statistical significance, all *F*s < 2.0.

From the data given in Tables 3 and 4, it is obvious that children performed generally better on orthographic learning in the Without Zhuyin conditions than the children in the With Zhuyin conditions, irrespective of the number of exposures to targets and the interval between the text-reading task and posttest measures for orthographic learning.

Table 4

Proportion of targets, homophones, other misspellings, and no-recalls in the spelling task (*the whole-character criterion*) in Study 1

		Target		Homophone		Other misspelling		No-recall	
Exposures		M	SD	M	SD	M	SD	M	SD
Immediately									
Four (n=100)									
	+Zhuyin	4.70	2.11	0.60	0.52	1.70	1.70	3.00	1.94
	-Zhuyin	7.40	0.97	0.10	0.32	0.80	0.79	1.70	1.34
Eight (n=100)									
	+Zhuyin	7.10	2.08	0.80	1.13	1.20	1.23	0.90	1.10
	-Zhuyin	6.20	0.90	0.00	0.00	1.60	1.26	2.20	2.10
3-day delay									
Four (n=100)									
	+Zhuyin	6.30	2.11	0.40	0.52	2.00	1.89	1.30	1.16
	-Zhuyin	8.10	1.73	0.10	0.32	0.90	0.99	0.90	0.99
Eight (n=100)									
	+Zhuyin	7.30	2.50	0.70	1.06	1.70	1.89	0.30	0.67
	-Zhuyin	6.80	2.82	0.00	0.00	0.90	1.29	2.30	2.50

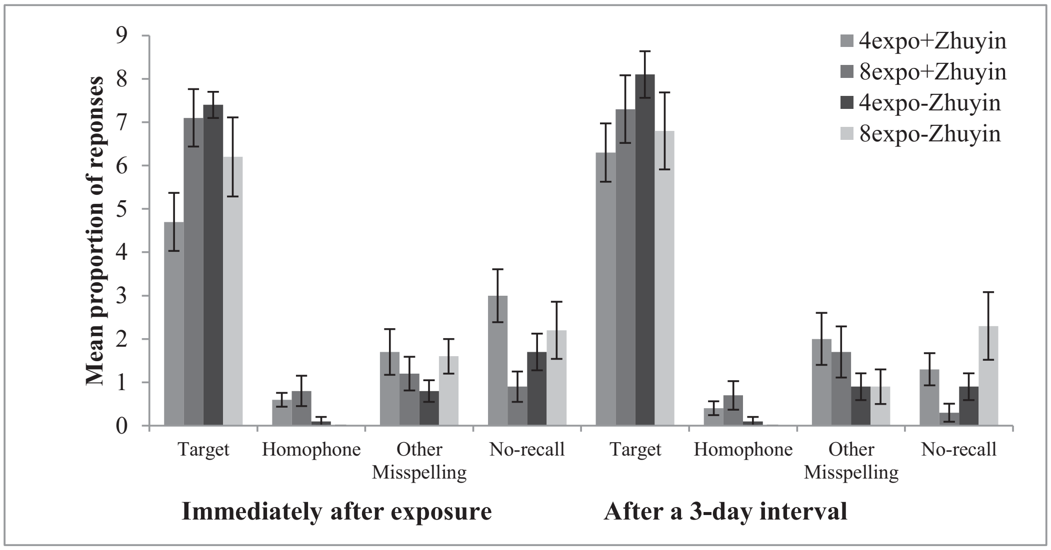

Figure 8. Mean responses from the spelling task (the *whole-character criterion*) in Study 1

Salience of phonological learning in orthographic learning

On both orthographic learning measures, phonological learning was apparent, as indicated by successful orthographic learning of target items and the fact that the homophonic characters alone witnessed an advantage over phonologically incorrect or deficit characters (semantic distractors, nonwords and no-recalls). Overall in the orthographic choice task, homophonic foils were significantly selected twice as often as other nonphonological distractors: for semantic distractors, $t = 3.39$, $p < .00$; for nonword visual distractors, $t = 2.81$, $p < .00$. The targets were chosen ten times as often as their homophonic foils, and it was highly significant in terms of the overall analysis ($t = 29.27$, $p < .00$), With Zhuyin condition ($t = 16.90$, $p < .00$) and Without Zhuyin condition ($t = 30.07$, $p < .00$), which altogether reinforced the validity of our observation that phonological learning has indeed taken place.

Robust preference for the correct character reoccurred in each and every one of the ten base target pairs across conditions.

On the spelling task assessed by *the whole-character scoring criterion*, it was apparent that when participants recalled any spelling patterns other than the target ones at all, they made more errors in the "other misspelling" category. A more refined and sensitive way to analyze the error patterns than the whole-character criterion was to look at the radicals produced in the spelling task. We introduced thus a *per-radical scoring criterion*. To gain insight into the distribution of erroneous reproductions of characters, it would be helpful if we take a detailed look into the errors they made. The per-radical scoring method differed from the former in the way that the homophonic spelling included both homophonic alternatives appeared in the orthographic choice test, plus those productions with the same phonetic radicals embedded in target characters but with different semantic radicals. Accordingly, responses by the *per-radical* criterion were scored as correct only when participants spelled out the exact printed forms that were shown to them at the text reading phase, similar to the whole-character criterion. Alternative homophonic spellings of the target items (i.e., homophonic foils in the orthographic choice test, e.g., "柀", or those reproduced with the same phonetic radical as in targets but with a different semantic radical, e.g., "絨") were recorded as 'phonological misspellings', and other responses were grouped as 'nonphonological misspellings'.

The overall spelling task scores based on the whole-character and per-radical criteria are shown in Figures 9 and 10, respectively. By comparing these two figures, it is obvious that most of the other misspellings were actually homophonic misspelling; they were all characters produced with the same phonetic radicals shared with the target characters at the reading task phase. The majority of errors in both recognition and spelling tasks were sound-based, providing further evidence of phonological learning.

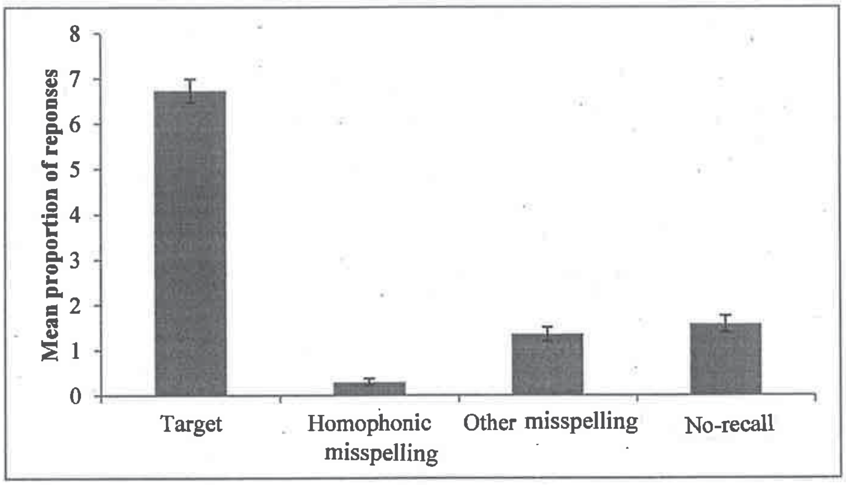

Figure 9. Overall mean responses from the spelling task (the *whole-character criterion*) in Study 1

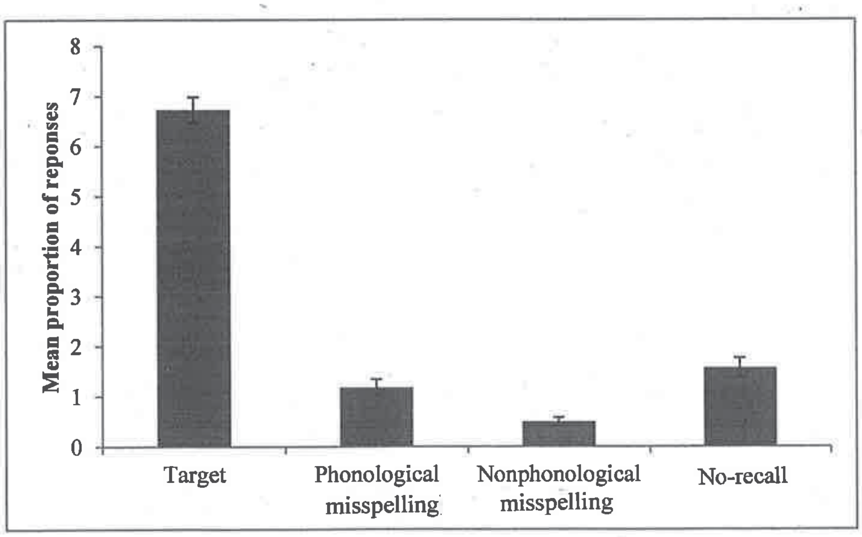

Figure 10. Overall mean responses from the spelling task (the *per-radical criterion*) in Study 1

Zhuyin effect on errors

Another issue of interest was whether the rate of homophone responses would change if Zhuyin was provided during the learning process via self-teaching. Since the selection rate of the target characters almost reached the ceiling on the orthographic choice task, the analysis of homophonic errors would not reveal much. Therefore, here we also entered the proportion of sound-based reproductions from the spelling tasks into a 2 (phonological aids: With Zhuyin vs. Without Zhuyin) x 2 (exposure: four times vs. eight times) x 2 (delay of posttest time: immediately after reading vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures.

By the *whole-character criterion*, there was no main effect of exposure or delay, Fs < 2.0. None of the interaction effect of the factors under study here reached statistical significance. However, a main effect for Zhuyin was found significant, $F(1, 36) = 9.50$, $\eta_p^2 = .21$, $p < .00$, the general trend being that more homophones were produced in conditions with Zhuyin than in conditions without Zhuyin.

By the *per-radical criterion*, there was also a significant Zhuyin effect, with the Zhuyin conditions containing more phonological misspellings, $F(1, 36) = 17.62$, $\eta_p^2 = .33$, $p < .00$; this indicated that the tendency to make sound-based errors was not evenly distributed across conditions and that the sound-based errors occurred more often in With Zhuyin conditions that in Without Zhuyin conditions. None of the interaction effects were found significant.

5.1.3. Discussion

Study 1 explored the occurrence of orthographic learning via self-teaching in Chinese. Third graders identified and reproduced accurately more target orthographic forms than alternative foils, immediately after the reading task and after a 3-day interval alike, with Zhuyin or without Zhuyin, with as few as four exposures to targets. The results from both posttest measures manifested compelling evidence for rapid orthographic learning via self-teaching, irrespective of the manipulation of the posttest time and phonological aids and the number of exposures. This replicated and extended Share's (1999) findings to a non-alphabetic orthography that is much less transparent than Hebrew and English. This corroborated our prediction that, even in a language outside the alphabetic writing system, orthographic learning should be equally functional within a self-teaching framework in learning to read natural languages.

Share (1995, 1999) mentioned that children learning to read Chinese rely upon a totally transparent alphabet-like script, i.e., phonological aids of so-called Zhuyin in Taiwan and Pinyin in China, which works merely as a self-teaching mechanism to learning characters listed alongside. Results from our experiment actually ran counter to this claim. Concerning the orthographic choice test, children reading texts without Zhuyin performed significantly better than children reading annotated texts. The performance on spelling was equally good in both conditions. Both posttest measures irrefutably demonstrated that in this study Zhuyin did not contribute as much as previously hypothesized to the learning process of orthographic forms in Chinese. Sound-based misspellings were also found under the influence of Zhuyin, with more homophones recognized or spelled in conditions with Zhuyin.

Interestingly, participants in the With Zhuyin conditions produced significantly more homophonic errors than those in the Without Zhuyin conditions. The specific error pattern suggests that providing Zhuyin in learning to read Chinese led to more homophonic errors. Probably, this could be attributed to the fact of phonological interference coming from Zhuyin. Findings in the present study suggested that Zhuyin, as an extra-orthography phonological system, would divert children's attention away from orthographic representations during reading. In other words, Zhuyin might not be the main source of opportunities for phonological recoding that is also central to Chinese orthographic development. This issue will be pursued further in Study 2.

Study 1 showed that Zhuyin is likely to attenuate learning Chinese orthography to a certain degree through its perfectly transparent symbol-to-sound function. Zhuyin might facilitate the acquisition of correct pronunciations, but would somewhat reduce children's attention to orthography to be learned. In the worst-case scenario, given that Zhuyin provides a perfect one-to-one correspondence, children might concentrate more on phonological decoding of Zhuyin, and thus assign less attention to the internal structure of target characters. This contradicts the primary goal of orthographic learning. Although orthographic learning is about forming solid amalgamation of orthographic, phonological and semantic information, the phonological gain, however, would come at the expense of the acquisition of detailed orthographic representations.

The pattern of error analysis depicted a trend favoring sound-based mistakes. In other words, more characters were produced with the same phonetic radical as the target, but with a semantic radical that was different from the target. Arguably, it could be taken as evidence that semantic radical should be learned partially on a visuo-orthographic basis, if not entirely through its meaning-based information. This conjecture converges with those of Seymour et al. (2003) and Katz and Frost (1992), who suggested that languages of transparent orthographies primarily exploit phonology, while those of opaque ones are conditioned to promote visual attention to orthographic structures.

That being said, not to be discounted is the tenet of self-teaching hypothesis that phonological recoding provides the indispensable opportunity for unskilled readers to attend to details of orthographic information. For one thing, Hung, Tzeng, and their colleagues found that speech recoding is an important factor in the process of reading a logographic writing system like Chinese (Hung et al., 1992; Tzeng & Hung, 1988; Tzeng et al., 1977). Our study supports this finding. The selection of homophonic foils in the orthographic choice tests and reproduction of phonological misspellings dominated the overall errors in both posttest measures. This demonstrated that even in a logographic writing system, it is also necessary for speakers to translate print into phonological codes, in such a way that they are able to retain the print forms in short-term memory for further linguistic processing and long-term memory for automated word recognition.

For another, orthography-to-phonology conversion rules (or, more precisely, phonetic radical-to-phonology conversion rules) in Chinese script permit readers to phonologically recode novel words to a certain extent. Pursuing this train of thought further, we should come to the argument that, at a basic level, the key source allowing for phonological decoding in the process of orthographic learning in Chinese should also stem from the orthography itself, in lieu of some kind of external phonological aids, such as Zhuyin or Pinyin. A follow-up experiment was designed in Study 2 to put the hypothesis to test.

Issues of whether the number of exposures affected the process of learning orthographic representations in Chinese were investigated as well. No effect of exposure was confirmed in any of the posttests. The orthographic learning effect was equally strong after four or eight exposures; it is concluded here that young children could learn a novel Chinese character with only as few as four exposures.

The effect for delay was rather inconsistent in the results of Study 1. We did not find a significant effect of delay in the orthographic choice test, whereas a significant delay effect was observed in the spelling task. The difference emerged here, possibly because spelling task taps different cognitive resources from the orthographic choice test that are likely to demand more highly specified orthographic details (Ouellette & Fraser, 2009; Shahar-Yames & Share, 2008). Furthermore, the spelling practice followed immediately after the exposure might have been the cause for better spelling performance after a 3-day interval (Ouellette & Fraser, 2009).

5.2 Study 2: Functional Self-Teaching through Phonological Information Afforded by Phonetic Radicals

Results from Study 1 indicated that children self-taught orthographic forms much better when there was not Zhuyin than when there was. It is apparent that the gains of pronunciations for unfamiliar characters by means of an extraneous phonetic system, such as Zhuyin, came somehow at the cost of orthographic acquisition. Share's (1995, 1999, 2008) self-teaching hypothesis posits that opportunities for phonological recoding should largely stem from within the orthography itself. As a follow-up study, Study 2 aims to test Share's (1999) claim that "any script which is functionally decidable in context, and sufficiently encapsulated to permit identification of specific lexical items (i.e., minimal homophony and homography), should permit functional self-teaching" (p.124). In view of features of the Chinese logo-syllabic script, one can fairly predict that when reading in natural text, phonetic information embedded in the Chinese characters and contextual information may be sufficient for functional self-teaching.

In chapter 3, numerous studies have established that Chinese children *do* exploit sublexical units for phonological information in different types of reading tasks (Lee et al., 2005) and that phonological sensitivity also predicts reading ability in Chinese reading development (Huang & Hanley, 1997; Hu & Catts, 1998). Arguably, phonology plays an important role in learning to read non-alphabetic Chinese script. Phonetic radicals embedded in characters may not be completely reliable, but, like in alphabetic scripts, there is also regularity and consistency in relation to print-to-sound correspondence. Children who have rough knowledge of the OPC rules and some phonological awareness of Chinese sound structures should be able to generate possible candidate pronunciations when they encounter an unfamiliar character. Together with their prior oral knowledge, contextual information would further aid the accurate selection of pronunciation for this character. Presumably, it is in the process of phonologically recoding the unfamiliar character that children learning to read Chinese incidentally acquire the orthographic representations of this given character.

Based on findings from Study 1 that showed attenuated orthographic learning of regular pseudo-phonograms in Zhuyin conditions, Study 2 intends to examine the possibility of phonetic radicals embedded in phonograms as the main source of phonological recoding in the process of Chinese orthographic learning. Within the self-teaching framework, the hypothesis was put to test through the availability of the sublexical phonological information, i.e. phonetic radicals, in Chinese characters. Half of the targets were regular phonograms and the other half were nonphonograms (i.e., characters that do not have a component hinting at the whole-character pronunciation). Without outside assistance, children read aloud text annotated with Zhuyin and, in the text, target characters appeared four times. Rapid orthographic learning should be observed in both conditions, but the conditions with phonograms are predicted to show stronger learning effect, indicating that phonetic information in context reading will bring about functional orthographic learning via self-teaching.

5.2.1 Method

Participants

22 children (14 boys, 8 girls) in Grade 3 participated in the experiment, whose mean age was 9.44 years (SD = 2.02); children's age ranged from 9 years 0 months to 9 years 11 months. The participants were randomly recruited from 2 *Buxibans* in the Taichung metropolitan region, Taiwan. Two of the participants were absent in the last session of the experiment and thereafter removed from the analysis.

The children were all normally achieving readers, and had been matched by the latest monthly native language evaluation. All children had a score ranging from 80 to 99 points out of 100 points (Mean = 95.35, SD = 3.51).

Materials and Procedure

The experiment design and materials used in Study 2 were similar to that of Study 1, except for two aspects: (1) Half of the novel target characters were those with a phonetic radical, and the other half without; (2) All target characters appeared only four times and all with Zhuyin. The orthographic learning performance was also gauged by an orthographic choice test and a spelling test.

Half of the targets in Study 2 were phonograms, like the target items in Study 1 that conformed to 80 to 90% of the formation rules of Chinese characters. The phonograms used in Study 2 had a semantic radical to the left plus a phonetic radical to the right that gave the exact pronunciation to the whole character (Lee et al., 2005, Tzeng, 2002). The other half of the target items used in Study 2 differed from the so-called phonograms in the respect that their internal structure did *not* contain a phonetic radical potentially offering any phonological contribution to the whole character at all. They are so-called "nonphonograms".

For example, in an orthographic choice task where a nonphonogram was the target: (1) the original target appeared earlier in the reading text (e.g., 爰 /yuan/); (2) the target's homophonic alternative (e.g., 楥 /yuan/. This character being a real word, its pronunciation was altered from its original /xuan/ to match the pronunciation of its phonetic radical /yuan/); (3) a visually similar foil (e.g., 爱); and (4) a slightly modified non-word visual distractor (e.g., 爰). Mean stokes of target characters in Study 2: phonograms = 12.2, SD = 1.30; nonphonograms = 7.8, SD = 2.77.

Just like in Study 1, in the event of being unable to recall the target character seen before, children were allowed to skip it, which forms the category "no-recall" in our statistical analysis.

Comprehension. The mean number of the correctly answered questions was 25.65 (SD = 3.22), maximal score: 30 (3 questions times 10 texts), indicating that the general comprehension was largely intact.

Target decoding accuracy score. The accuracy of the pronunciation of the target words was recorded *online* by the experimenter. A score of 1 was given each time a target was read correctly. An error was recorded if any change to the correct target pronunciation occurred. Independent analysis of the audiotapes was used to confirm the online scoring. In the present study, out of the 40 possible correct pronunciations of the homophone targets (10 stories times 4 target characters), the proportion of correct pronunciations amounted to 96.75% (M = 38.7, SD = 2.47). This is an indication that most of the targets were successfully decoded when encountered at the text reading phase.

5.2.2 Results

As is the case with Study 1, two tasks were administered in the current experiment to assess the robustness of the orthographic representations acquired by participants during the learning process.

Orthographic learning

Orthographic choice task

Orthographic learning was substantiated in the results. Across all conditions, correct selection of target characters stood at a 77.75 % (SD = 1.48), still by far exceeding the chance level (25%). Respectively, the orthographic choice test right after text reading had a correct selection rate of 81% (SD = 1.44) and the test following a

3-day interval had a rate of 73.5% (SD = 1.43). Both corroborated the occurrence of orthographic learning beyond chance level.

Phonological learning was still robust, as confirmed by the overall selection rate of alternatives: homophonic foils 10.5% (SD = 1.21), visually similar distractors 4% (SD = 0.53), nonword visual distractors 6.5% (SD = 0.74), and no-recalls 2.5% (SD = 0.47). Homophonic foils still had an advantageous majority in comparison with other distraction foils; they were selected about twice as often. However, the difference did not reach the significance level between homophonic foils and visually similar distractors, $t = 2.04$, $p = .06$ or between homophonic foils and nonword visual distractors, $t = 1.63$, $p = .12$. That said, the difference between homophonic foils and visually similar distractors fell just a little short of the significant level.

Spelling task

The spelling productions were grouped into three categories according to the forms reproduced by participants: target characters, phonological misspellings, and other misspellings. Only those reproductions faithful to the target characters that appeared in the reading task would score. Following the per-radical criterion applied to the spelling task analysis in Study 1, phonological misspellings were both those reproductions identical to the homophonic foils seen in the orthographic choice test, and those produced with the same phonetic radical embedded in the target character but with a different semantic radical. The reproductions falling outside of the two above-mentioned scopes were all grouped as "other misspellings".

Table 5

Proportion of targets, homophones, visually similar distractors , nonword visual distractors, and no-recalls in the orthographic choice task in Study 2

	Target		Homophone		Visually similar distractor		Nonword visual distractor		No-recall	
	M	SD	M	SD	M	SD	M	SD	M	SD
Immediately										
Overall (n=200)	7.80	1.48	0.90	1.14	0.30	0.55	0.40	0.60	0.30	0.57
Phonogram (n=100)	8.60	0.80	0.80	0.60	0.20	0.31	0.10	0.22	0.30	0.37
Nonphonogram (n=100)	7.90	1.12	0.90	0.89	0.30	0.49	0.70	0.49	0.30	0.37
3-day Interval										
Overall (n=200)	7.40	1.43	1.20	1.28	0.50	0.51	0.90	0.88	0.20	0.37
Phonogram (n=100)	7.70	0.67	1.10	1.10	0.70	0.49	0.20	0.31	0.20	0.31
Nonphonogram (n=100)	7.00	1.15	1.30	1.27	0.20	0.31	1.50	0.85	0.10	0.22

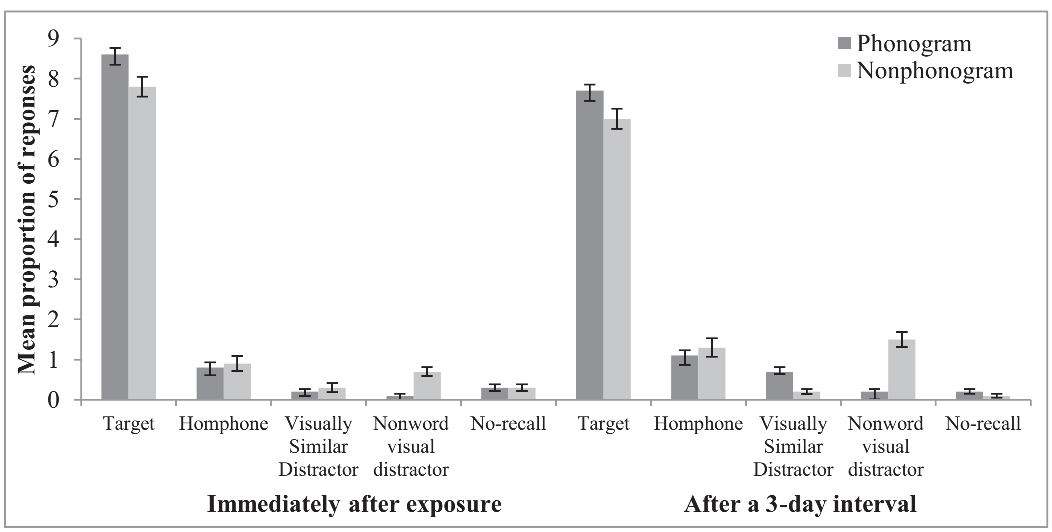

Figure 11. Mean responses from the orthographic choice task in Study 2

Spelling is even more taxing than recognition in that spelling draws on multimodal sources, such as language-related and motor-kinesthetic processing (Shahar-Yames & Share, 2008; Graham & Weintraub, 1996). Consistent with this, Table 6 clearly demonstrates that accuracy of spelling reproductions dropped by 10 to 15 percent, in comparison with the results from the orthographic choice test in Table 5. However, orthographic learning effect was still apparent in all conditions: the overall accurate reproduction of target characters stood at 58% (SD = 1.59) immediately after the reading task, and 60% (SD = 1.64) following a 3-day interval. Interestingly, the data here showed that there was a gap of about 20% difference in performance between conditions with phonograms and conditions with nonphonograms, immediately after the reading task: 71% (SD = 1.23) vs. 44% (SD = .83); after a 3-day interval: 76% (SD = 1.10) vs. 43% (SD = .88). Technically, spelling performance still reported a robust orthographic learning effect way beyond chance in both conditions, despite the fact that phonograms were acquired more reliably than nonphonograms.

Only the overall orthographic learning on the phonograms in our current experiment (74%) was comparable to what we obtained in Study 1 (67%), while nonphonograms were acquired at a lowly rate of 44% of occasions. The difference of 20% in the rate of orthographic learning in spelling performance demonstrated that the phonological information of phonetic radicals embedded in the pseudo-phonograms was extremely useful for children in orthographic development.

Table 6

Proportion of targets, phonological misspellings, other misspellings, and no-recalls in the spelling task in Study 2

	Target		Phonological misspelling		Other misspelling		No-recall	
	M	SD	M	SD	M	SD	M	SD
Immediately								
Overall (n=200)	5.80	1.59	0.50	0.76	0.80	1.05	2.30	1.08
Phonogram (n=100)	7.10	1.23	0.50	0.44	1.30	0.81	1.10	0.60
Nonphonogram (n=100)	4.40	0.83	0.40	0.52	1.70	0.81	3.50	0.79
3-day Interval								
Overall (n=200)	6.00	1.64	0.80	1.24	1.10	1.05	1.70	1.14
Phonogram (n=100)	7.60	1.10	0.80	0.68	0.70	0.49	0.70	0.59
Nonphonogram (n=100)	4.30	0.88	0.80	0.99	1.40	0.80	2.60	1.30

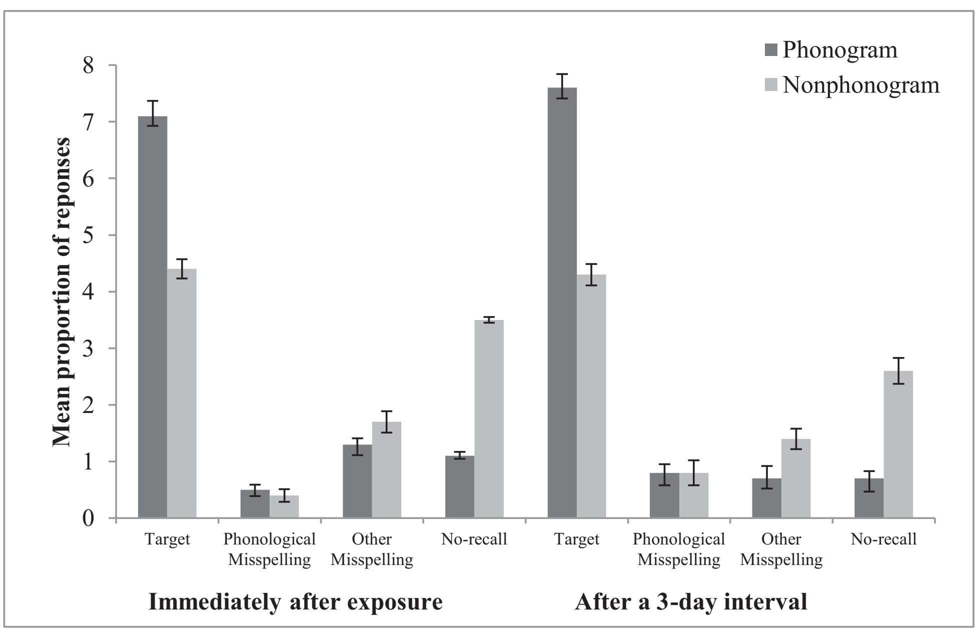

Figure 12. Mean responses from the spelling task in Study 2

Effect of phonetic decoding and delay on orthographic learning

To determine whether the influence of an embedded phonetic radical in a character would moderate the buildup of orthographic representations in the learning process, the proportion of correct responses was entered into a 2 (character type: phonogram vs. nonphonogram) x 2 (delay of posttest time: immediately after reading vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures on both factors.

Orthographic choice task

There was a main effect of character type on the learning of orthographic representations, $F(1, 19) = 7.12$, $\eta_p^2 = .27$, $p < .05$. The main effect of delay did not reach the significance level, $F(1, 19) = 2.19$, $\eta_p^2 = .10$, $p = .16$. The latter finding was in line with the result from Study 1. Moreover, there was a non-significant interaction effect between the type of characters and the delay of posttest time, $F(1, 19) = .04$, $\eta_p^2 = .00$, $p = .85$.

Spelling task

The two-way ANOVA indicated a significant main effect of phonetic radical on orthographic learning, $F(1, 19) = 40.71$, $\eta_p^2 = .00$, $p < .00$. There was no interaction effect of delay and character type, $F(1, 19) = .90$, $\eta_p^2 = .05$, $p = .36$.

With respect to phonological misspellings, there was no main effect of delay, $F(1, 19) =.02$, $\eta_p^2 = .00$, $p = .88$, or character type, $F(1, 19) = 2.27$, $\eta_p^2 = .11$, $p = .15$, nor was there an interaction effect of the two factors, $F(1, 19) = .04$, $\eta_p^2 = .00$, $p = .84$.

One more analysis on the other misspellings showed that a main effect of delay was established, $F (1, 19) = 31.41$, $\eta_p^2 = .62$, $p < .00$, and that a main effect of character type was also found, $F (1, 19) = 9.23$, $\eta_p^2 = .33$, $p < .00$. The significant main effect of character type in Study 2 indicated that when there is no phonological recoding, children appealed to visuo-orthographic strategies to learn orthographic representations, which resulted in more errors classified as "other misspellings" in the conditions with nonphonograms. There was, however, no significant interaction effect between effects of delay and character type, $F = (1, 19) = .21$, $\eta_p^2 = .01$, $p = .65$.

5.2.3 Discussion

Study 2 followed up on the issue of whether phonetic decoding is enough to give rise to a robust, functional orthographic learning effect in natural text reading. In Study 1 where all of the target items were regular phonograms, it was found that Zhuyin did not lead to better acquisition of characters in Chinese orthographic development. Built on this finding, Study 2 looked at the effect of phonetic decoding on orthographic learning, by contrasting learning two types of Chinese characters differing only in the embedded availability of phonetic radicals: phonograms (i.e., compound characters embedded with a phonetic radical) and nonphonograms (i.e., simple characters without a phonetic radical embedded). That is, the availability of embedded phonetic radical decides whether or not characters can be phonetically decoding in the present experiment.

Though overall results indicated robust orthographic learning had taken place, it was clear that young readers learned significantly better in conditions with phonograms than in nonphonograms, particularly in spelling tasks where more specific orthographic details were demanded for accuracy. The only possible cause of the difference in performance is ascribed to the availability of a phonetic radical embedded in the characters, i.e., phonetic decoding. This finding could be regarded as circumstantial evidence that learning to read Chinese orthography cannot be merely explained by visual exposure to target characters (Liu & Shiu, 2011, Experiment 2), as there is a huge drop-off of learning effect in the absence of phonetic radicals that offer phonological information.

Another insight came from the complexity of characters defined by the number of strokes. Being comprised of more strokes, phonograms are generally more visually complex than nonphonograms. Despite the more visual complexity in their physical forms, phonograms still enjoyed a great advantage in the process of learning Chinese orthography. It is another compelling piece of evidence in support of our claim that phonetic radicals help children to recode novel words phonologically, which facilitates the formation of novel characters in the orthographic lexicon.

The effect of phonetic decoding was substantiated in both the orthographic choice tasks and the spelling tasks. In line with the self-teaching hypothesis (Share, 1995, 1999, 2004), results in Study 2 lent strong support to the claims that orthographic learning in logographic orthographies such as Chinese also hinges on the opportunity of phonological recoding, and, more importantly, that the self-teaching opportunities afforded by phonological recoding should stem mostly from within the orthography, instead of externally from some kind of phonological aids, e.g., Zhuyin or Pinyin. To sum up, phonetic information from phonetic radicals embedded in characters is sufficient for young children to functionally self-teach orthographic forms in Chinese.

5.3 General Discussion

Along with Liu and Shiu (2011), the present studies explored orthographic learning via self-teaching in a non-alphabetic domain, pioneering the investigation of acquiring Chinese orthographic representations in a self-teaching context. Specifically in this chapter, it was established that children can self-teach to acquire orthographic representations in a traditional Chinese script that is visually more complicated than a simplified Chinese script. The current research also addressed issues regarding the utility of Zhuyin in Chinese orthographic learning, the functional role of phonetic decoding, and the effects of Zhuyin, exposure and posttest time. The goal was to shed light on the processes leading up to automated recognition on the individual item basis among groups of children learning to read in a logographic writing system. The findings from the two experiments proposed a relatively good fit to the self-teaching account, and hence expanded the explanatory power of the self-teaching hypothesis to an orthography that is not only non-alphabetic but is also deeper than English.

In both self-teaching experiments, children recognized and spelled the novel target characters more often and more accurately than homophonic or other alternatives with as few as four exposures. Effective, rapid orthographic learning in Chinese was evident. Contrary to the popular, ill-founded belief that the robust effect for orthographic learning in a logographic writing system entails outright visual learning, error analyses showed a strong general pattern of phonological learning, as evidenced by the large portions of speech-based misidentification and misspellings in all measures when the targets were not correctly recalled. Novice readers were inclined to recognize and reproduce novel characters based on their own mispronunciations, reinforcing the viewpoint that orthographic learning depends primarily on what children say instead of what they see (Share, 1999).

Study 1 showed that extra-orthography phonological aids, such as Zhuyin, did not lead to optimal performance on orthographic learning in Chinese. This finding corroborated our hypothesis built on the self-teaching account that children attended to Zhuyin for phonological information to the detriment of attention to orthographic details. The results from conditions without Zhuyin in Study 1 demonstrated that Zhuyin's role in learning to read is not as important as previously theorized, at least not among third-graders. Substantial orthographic learning was also documented without phonological aids. Together with Study 2, it is clear that phonetic information through phonetic decoding is sufficient for functional self-teaching in natural text reading. Share's conjecture (1995, pp. 197-198) was confirmed.

Though the current study did not carry out experiments similar to Share's (1999) experiments 2 and 3 that intended to eliminate the sole contribution of visual learning, the circumstantial evidence from Study 2 here clearly showed that character learning is highly unlikely to be exclusively ascribed to pure and simple visual exposure. This is in line with findings from Liu and Shiu's (2011, Experiment 2) study that replicated Share's results. In Study 2, developing readers performed far better in conditions with phonograms than with nonphonograms; that the orthographic memory of nonphonograms was difficult to retain even with Zhuyin listed adjacent is another piece of evidence against the visual learning account. The two types of Chinese characters differed from each other only in the availability of embedded phonetic radicals that allow for phonological recoding within the orthography. It is thus arguable that phonetic decoding matters in learning to read

Chinese orthography and that the opportunities for decoding should arise from within the orthographic system *per se*, namely, the phonetic radicals that are embedded in Chinese characters.

Consistent with the central tenet to the self-teaching theory that orthographic learning is accomplished primarily by way of symbol-to-sound translation, Grade 3 students in both experiments apparently exploited *online* the knowledge of orthography-to-phonology rules. They did not simply ignore or make wild guesses with unfamiliar characters. At the reading exposure phase, children demonstrated an excellent capability to predict *online* whole-character pronunciations by resorting to the phonological information at the phonetic radical level (Ho & Byrant, 1997 a, b; Tzeng, 2002; Yang & Ping, 1997). In conditions without Zhuyin, most target characters were sounded out either identically or with phonological similarity to the embedded phonetic radicals. Even in conditions with Zhuyin which should have given the exact whole-character pronunciations to the target, rhyming mistakes were still occasionally observed and recorded.

Studies 1 and 2 reported successful orthographic learning for target items that children were exposed to. These findings are in keeping with the item-based view that is central to the self-teaching model as well (Share, 1995, 1999, 2008). That is, learning to read is a function of the frequency to which readers are exposed to a particular word, as is distinct from the phase or stage theory (cf. Ehri, 1990, 1997). The rationale behind our choice of children in Grade 3 in the current study was informed by stage-based claims that early readers of Chinese only started to show radical awareness between Grade 3 and Grade 5 (Shu & Anderson, 1997; Nagy et al., 2002). In contrast, the findings of the present study clearly supported an item-based view. Third-graders were very efficient when asked to produce or predict target pseudocharacters unknown to them. They showed an excellent ability to infer the pronunciations on the basis of their existent, acquired insights into the internal structure of characters. It is apparent that they already possessed some working knowledge of radical awareness that allowed them to pinpoint more or less accurately the position of the semantic and phonetic radical. Coupling with this knowledge, the orthography-to-phonology rules enabled participant readers to generate candidate pronunciations for the characters to be read aloud. Arguably, radical awareness is commensurate with character recognition, both operating on an item-by-item basis at the early stages of reading development.

In summary, learning to read Chinese concurs broadly with the general framework of the self-teaching account. Armed with some symbol-sound knowledge and basic decoding skills, young readers of Chinese acquire detailed word-specific representations incidentally when attending to and phonologically recoding character forms during independent reading, even with limited exposure to these forms. These findings challenge the commonly made assumption that, in Chinese, orthographic processing is more important than phonological processing abilities. These self-teaching mechanisms are hypothesized to weigh differentially across different orthographies in reading acquisition (Wimmer, Mayringer, & Landerl, 2000; Wimmer, 1996). Results from this study focusing on Chinese reading acquisition indicate that phonology still holds the primary role, and that orthographic processing skills are only secondary, with the likelihood that orthographic skills weigh more in Chinese orthographic learning than in learning to read alphabetic scripts (Yang, 2001).

Cross-language comparisons generated an intriguing phenomenon. Chinese, the deepest orthography being studied to date is comparable to Hebrew (Share, 2004), a shallow consonantal script, in terms of overall performance on both recognition and spelling measures: 80% vs. 72% (Chinese vs. Hebrew pupils in Grade 3 on orthographic choice task); 55% vs. 63% (Chinese vs. Hebrew pupils in Grade 3 on spelling task). Comparing Grade 3 learners of Chinese and Dutch, a mildly opaque orthography, we find that orthographic learning effect in Chinese is still stronger on orthographic choice tasks than in Dutch, 80 % vs. 66%, and is otherwise similar on spelling tasks, 55% vs. 61% (Chinese vs. Dutch).

One potential account for these results could be that despite traditionally being viewed as a deep, logographic orthography, sound structures are relatively simpler in Chinese (Tong et al., 2009) than in Hebrew or Dutch; there are no consonantal clusters at all in Chinese (Duanmu, 2000) and every Chinese character is of one syllable. Additionally, different from English morphemes that can undergo fairly substantial changes in pronunciations, Chinese morphemes hardly change their pronunciations when being compounded with other characters (Nagy et al., 2002). For these reasons, developing readers of Chinese could bring more attentional and cognitive resources to bear on the formation of orthographic representations.

Given the results from the current study, Share's self-teaching theory is successfully extended to account for orthographic learning in Chinese. More research is still required to further clarify a range of important issues, such as effects of exposure and duration, and the role of semantic radicals embedded in Chinese characters, etc. The coming chapter thus looks into the effects of semantic radicals on Chinese orthographic development.

Chapter 6

The Role of Semantic Radicals in Chinese Orthographic Learning via Self-Teaching

6.1 Study 3: The Cueing Functionality of Semantic Radicals in Chinese Orthographic Learning

According to Liu and Shiu (2011) and as demonstrated in chapter 5, young children are able to quickly self-teach orthographic representations when reading in a simplified Chinese script and a visually more complex, traditional Chinese script, respectively. The self-teaching model is corroborated to be a good theoretical framework to study the learning process of opaque, non-alphabetic Chinese orthographies. Within the self-teaching framework, the semantic feature of the Chinese script is another potential factor that modulates the Chinese orthographic learning process. Study 3 is thus the first study till now to focus on Chinese orthographic learning in relation to the semantic radicals that constitute one other sublexical components contributing to Chinese lexical processing, in addition to phonological information embedded in Chinese characters. It is likely that children draw upon the semantic hint coming from the semantic radicals to aid the formation of orthographic representations, since using radicals helps children to ease off memory load in the course of Chinese lexical processing (Li et al., 2002).

Research into orthographic learning of different orthographies has overwhelmingly concentrated on the phonological aspect of the self-teaching theory. While the centrality of phonological skills to orthographic learning is unequivocal (Cunningham, 2006; Cunningham et al. 2002; Jorm & Share, 1983; Share, 1995, 1999, 2004; Share & Jorm, 1987), other contributing factors have also been identified. These include context (Share, 1999; Wang, 2012; Wang et al., 2010), word semantics (Castles & Nation, 2006; Ouellette, 2010; Ouellette & Fraser, 2009), morphology (MacEcharon, 2008; Ravid, 2001; Tong et al., 2009), print exposure (Nation et al. 2007; Share, 2004), spelling practices (Ouellette, 2010; Share & Yama, 2008), etc.

Semantics is among one of the most crucial factors in reading, as the role of semantics has a solid theoretical foundation in theories of reading acquisition. However, with the exception of only few studies (Berends & Reitsma, 2006; Castle & Nations, 2006; Ouellette, 2010; Ouellette & Fraser, 2009), research has rarely been devoted to orthographic learning in the light of semantics. Theoretical models for word reading, e.g., the lexical quality hypothesis (Perfetti, 2007; Perfetti & Hart, 2002), the lexical constituency model (Perfetti et al., 2005), the triangle model (e.g., Seidenberg & McClelland, 1989), and the dual route reading model (Coltheart et al., 1993), all assume a semantic constituent in their workings. Particularly, some of these models stress the significance of integration among phonology, semantics and orthography for efficient word recognition. Considering the contribution of meaning-based information to lexical processing, it is necessary to look at the role of semantics in the process of orthographic learning.

Ouellette and his associate (Ouellette, 2010; Ouellette & Fraser, 2009) have provided direct, empirical evidence for the beneficial effect of semantics in the process of English orthographic learning. They presented 4th graders novel nonwords paired with a picture and an oral definition, and novel nonwords without any semantic information. After 1 day and 4 days, participants were assessed on the effect of orthographic learning. A significant main effect of semantics was reported on the recognition task where better performance was observed on items presented with semantic information than those presented in isolation. Consistent with previous studies (e.g., Perfetti & Hart, 2002), the findings lend support to the view that the integration of relevant factors, e.g., phonological, orthographic and semantic information, leads to better orthographic learning than any factor single-handedly.

The characteristics of some rough meaning stemming from semantic radicals is, in fact, not peculiar to Chinse script, in that, similarly, English primarily represents units of meaning by means of morphology or etymology (cf. section 3.1.3; Carlisle, 1988; Devonshire & Fluck, 2010; Ramsden, 1993). In the study of Devonshire and Fluck (2010), clear findings were provided for the effectiveness of teaching children morphology. Children who were explicitly instructed on morphological structures of words performed better in spelling task than those in the control group. In the literature on Chinese reading, the salience of semantic aspect in this non-alphabetic script has motivated a large number of investigations along this line of research. Semantic radicals are found to influence Chinese lexical processing and character recognition (Feldman and Soik, 1999a,b; Flores d'Arcais et al., 1995, Zhou & Marslen-Wilson, 1999 a,b). Moreover, awareness of semantic radicals is reported to be bidirectionally associated to reading and vocabulary development (McBride-Chang et al., 2003).

Taken together, the benefit of an integration of factors, as described in some reading models, is intuitively expected in Chinese orthographic development. Given the inherent differences in the surface form of writing systems between alphabetic and logo-syllabic scripts, learning to read Chinese is likely to require abilities separate from phonological processing. Indeed, there is a significant role based on the orthography in learning to read Chinese. Phonograms are the most dominant class of characters in Chinese writing, whose internal, sublexical structure generally offers guidance on both orthography-to-phonology conversion and on semantic category at the whole character level (cf. section 3.1.1). Though semantic radicals behave similarly as affixes in alphabetic systems, they are not phonologically realized at the whole-character level. Hypothetically, the meaning-based information from semantic radicals embedded in characters would be integrated with the phonological and orthographic constituents, which facilitates the acquisition of Chinese characters in orthographic development.

It remains unclear whether the contribution of semantic radicals embedded in Chinese characters to lexical processing could be generalized to the process of orthographic learning. The research question in the present study is formulated as follows: Is the orthographic learning effect modulated by semantic radicals embedded in Chinese phonograms? The hypothesis evaluated in Study 3 is that better learning performance will be observed in conditions where targets are embedded with semantic radicals with a clear cueing meaning in and of themselves than in conditions where semantic radicals without a clear cueing meaning are embedded in targets, which indicates that the functional utility of semantic radicals *per se* will facilitate the buildup of Chinese orthographic forms. To test the hypothesis, Study 3 manipulates the meaning of semantic radicals embedded in pseudocharacters. Pseudocharacters were embedded with meaning-cued or non-cueing semantic radicals; all radicals were not semantically transparent in relation to semantic referents that were to be instantiated into the novel pseudocharacters from the context. This measure was taken to preclude confounding the effect of cueing functionality from semantic radicals themselves and the effect of semantic transparency.

6.1.1 Method

Participants

The sample was randomly drawn from 3 *Buxiban*s in Taichung metropolitan, Taiwan. A total number of 20 children in Grade 2 (11 boys and 9 girls) participated in the current study. Their age ranged from 7 years 7 months to 8 years 7 months, with a mean age of 8 years and 2 months (SD = 3.32). The reading task and follow-up posttest measures were all held at the inception of the second half of the second grade school year, during the months of March and April.

All of the participating children were native speakers of Mandarin Chinese, and were normally achieving children, matched on age and an all-purpose language skill measure, or the latest monthly/periodical native language evaluation at each individual school. Out of 100 points, participants had marks ranging from 80 to 99 points, M = 92.15, SD = 4.01.

Materials and Procedure

The experimental paradigm and materials were adapted from Studies 1 and 2 in Chapter 5 with adequate modifications to suit the purpose of the current study. They essentially resembled the one designed by Share (1999); only the naming measure was excluded. Children were asked to read short texts aloud without assistance or feedback where target characters appeared for a given number of exposures. After the reading task, the effect of orthographic learning was assessed by an orthographic choice test and a spelling task.

In the present experiment, the texts used in Studies 1 and 2 were slightly modified and the text length was reduced (see Appendix 6, for an example). Text length ranged from 95 to 107 characters (M = 100.9, SD =0.71). Texts were annotated with Zhuyin, i.e., a set of symbols intended for the provision of phonological information of characters that is listed alongside characters till Grade 6 in reading material, and embedded with targets that showed up four times in each text. The target pseudocharacters were either newly invented or modified on the basis of those used in experiments in Chapter 5 to meet the current manipulations.

The most dominant type of Chinese characters, i.e., phonograms, was under study here and the target pseudocharacters (M = 10.8, SD = 2.97) were manipulated in two within-subject conditions. Manipulations here were carried out on semantic radicals embedded in the target characters that went as follows:

1) Semantic cueing condition: Half of the story texts were embedded with pseudocharacters containing semantic radicals that possess a clear meaning in and of itself (M = 11.8, SD = 3.42). For example, the pseudocharacter 譈 /jiao/ has the semantic radical 言 to the left; the semantic radical in question possesses a clear meaning, indicating the action of talk.

2) Semantic non-cueing condition: The other half of the target pseudocharacters were the ones embedded with semantic radicals that possess a scant or ambiguous meaning in and of itself (M = 9.8, SD = 2.39). They would result in unclear or little to no concrete meaning. For example, the pseudocharacter 倩 /qing/ contains the semantic radical 彳 that does not have a clear meaning of its own.

The cueing meaning of semantic radicals was rated by a group of 20 native Mandarin Chinese informants. A list of 20 semantic radicals was given for rating on a five-point scale, with one being the least clear and five being the most clear in terms of the meanings of the semantic radicals. Those semantic radicals in semantic cueing condition all scored five points, while those in semantic non-cueing condition only one point.

It is also worth noting that the selected semantic radicals were manipulated in a way that they were not semantically related to the whole character, as the hypothesis being investigated here was to simply look at the semantic cueing functionality of semantic radicals alone. The pronunciation was also controlled, such that target characters would all have the same pronunciation as their phonetic radicals, i.e., their pronunciation patterns were all regular.

Comprehension. Immediately after each text, three questions were asked for comprehension check. The mean number of the correctly answered questions was 28.2 (SD = 2.38), maximum score: 30 (3 questions times 10 texts), indicating that the general comprehension was largely intact.

Target decoding accuracy score. The accuracy of the pronunciation of the target words was recorded online by the experimenter. A score of 1 was given each time a target was read correctly. An error was recorded if any change to the correct target pronunciation occurred. In the present study, out of the 40 possible correct pronunciations of the homophone targets (10 stories times 4 target characters), the proportion of correct pronunciations amounted to 88.13% (M = 35.25, SD = 3.14). This is an indication that most of the targets were successfully decoded when encountered at the text reading phase, though the decoding performance was not as good as observed in third-graders in Chapter 5.

Orthographic learning measures

The extent to which orthographic learning actually took place was assessed by two separate tasks in the following order in the current experiment, as seen in many other studies. Slightly divergent from Share's (1999) original method, naming task was excluded, because this measure might bias the results by increasing the number of exposures to target pseudocharacters.

1. *Orthographic choice*. First, children were prompted to recall the target homophone by a question (e.g., "Do you still remember the name of the hottest town on earth?"). Subsequently, they were presented with four alternative spellings of the target word in random order:

(1) The original target appeared earlier in the test text (e.g., 魻 /jia/). This character being a real word, its pronunciation was altered from its original /xia/ to match the pronunciation of its phonetic radical /jia/).

(2) The target's homophonic alternative (e.g., 狎 /jia/. This character also being a real word, its pronunciation was altered from its original /xia/ to match the pronunciation of its phonetic radical /jia/).

(3) A semantically related foil that shares the same semantic radical as the target but with a different phonetic radical (e.g., 鮋 /yo/).

(4) A somewhat visually modified non-word foil (e.g., 魻).

In the event of being unable to recall the target character in question, children were allowed to skip it. Such responses were recorded in "No-recall" category in our statistics analysis. This was a precautionary measure to preclude wild guessing which could confound the data.

2. *Spelling*. Children were required to spell out each of the target characters they had read about in the stories, immediately after the reading tasks and in another session three days afterwards. In this task, every attempt was made to elicit the reproduction of target characters. For instance, the experimenter asked a participant if he/she still recalled the name of the hottest town in the world. If the first prompt was in vain, the first phone of the target in question was then provided. Still failing to reproduce the target character in question, children would be further given the complete pronunciation of the target.

6.1.2 Results

The current experiment sought to determine whether students at Grade 2 can self-teach, as the self-teaching hypothesis predicts an early onset of self-teaching orthographic forms, and whether orthographic learning is modulated by the presence of semantic meaning that comes from semantic radicals embedded in Chinese characters. We begin by reporting on the learning effect of orthographic learning and then look at the cueing effect of semantic radicals.

Learning effect of orthographic learning

Orthographic choice test. This task demands children at Grade 2 to choose the target (e.g., 詨) over its other alternatives, e.g., homophonic foil: 珓, semantic distractor:  and visual distractor: , no-recall: when children fail to recall anything at all. The chance level was thus 25%, and it was observed that averaged across all conditions, orthographic learning occurred at 73% (SD = 1.41) immediately after text-reading and 68% (SD = 1.61) after a 3-day interval. Both were way beyond chance level.

Table 7

Proportion of targets, homophones, semantic distractors , nonword visual distractors, and no-recalls in the orthographic choice task in Study 3

	Target		Homophone		Semantic distractor		Nonword visual distractor		No-recall	
	M	SD	M	SD	M	SD	M	SD	M	SD
Immediately										
Overall (n=200)	7.30	1.41	2.40	1.46	0.30	0.55	0.10	0.44	0.00	0.00
Cueing semantic radical (n=100)	7.70	0.67	1.90	0.69	0.20	0.31	0.20	0.03	0.00	0.00
Non-cueing semantic radical (n=100)	6.90	1.01	2.80	0.99	0.20	0.03	0.10	0.22	0.00	0.00
3-day Interval										
Overall (n=200)	6.80	1.61	2.10	1.19	0.80	0.89	0.40	0.75	0.00	0.00
Cueing semantic radical (n=100)	7.50	0.97	1.60	0.83	0.70	0.59	0.20	0.31	0.00	0.00
Non-cueing semantic radical (n=100)	6.20	1.21	2.50	0.97	0.80	0.59	0.60	0.57	0.00	0.00

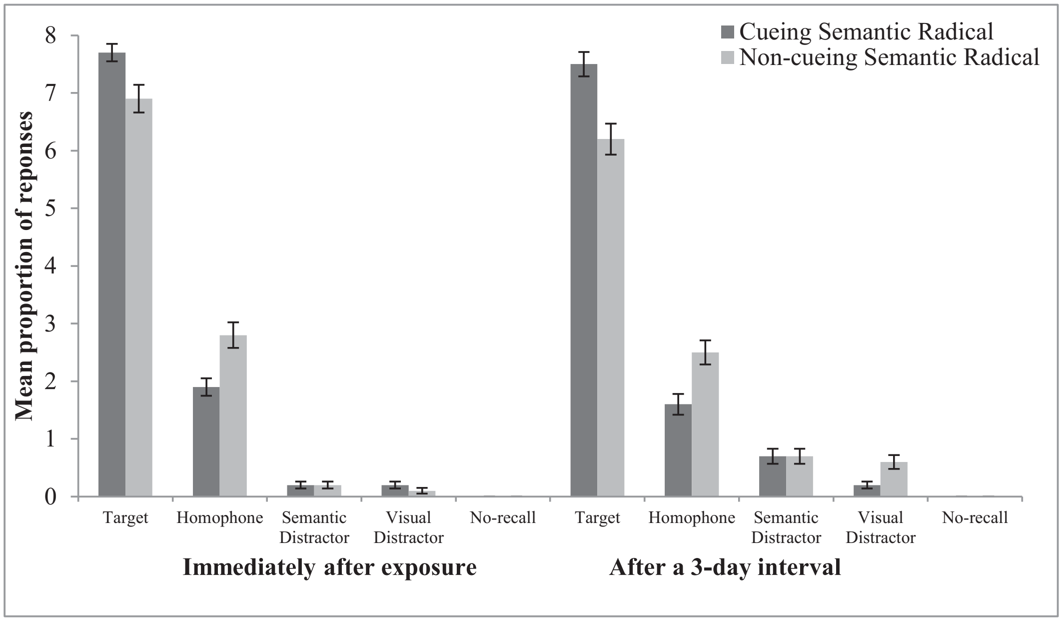

Figure 13. Mean responses from the orthographic choice task in Study 3

Targets were selected three times as frequently as their homophonic foils. Targets had a clear advantage over their homophonic foils: overall, $t\ (1, 39) = 11.67$, $p < .00$; immediately after reading task, $t\ (1, 19) = 7.91$, $p < .00$; after a 3-day interval, $t\ (1, 19) = 8.46$, $p < .00$. Apparent, rapid orthographic learning was documented in the orthographic choice measure for readers at Grade 2.

Spelling task. The whole-character criterion was adapted from chapter 5 and applied here; targets and their alternatives were only accepted as correct when they were reproduced identically to the ones previously seen in the orthographic choice task. Reproductions of the alternative foils of the target items were grouped as "homophonic misspellings", "semantic misspellings", "visual misspellings" and "no-recalls."

Pooling all conditions together, participants reproduced only 36% of targets correctly ($SD = 2.11$) immediately after the reading task, and 45% ($SD = 1.73$) after a 3-day interval. Considering the error pattern, it is obvious that when participants recalled anything other than the targets, homophonic foils were mostly reproduced, at 7 % of all cases immediately after text reading and at 4% of occasions after the 3-day interval. It is noteworthy here that more homophones were produced in the non-cueing conditions (immediately after reading: 9%, and after a 3-day interval: 8%) than in cueing conditions (immediately after reading: 5%, and after a 3-day interval: 2%). When asked to spell out exact character forms, children scarcely reproduced other distracting foils. Overall semantic misspellings occurred at a mere 1%, SD = .22; none of the visual misspellings were produced at all in any of the conditions.

Table 8

Proportion of targets, homophones, semantic misspellings , visual misspellings, and no-recalls in the spelling task (*the whole-character criterion*) in Study 3

	Target		Homophonic misspelling		Semantic misspelling		Visual misspelling		No-recall	
	M	SD	M	SD	M	SD	M	SD	M	SD
Immediately										
Overall (n=200)	3.60	2.11	0.70	0.86	0.10	0.22	0.00	0.00	5.70	2.15
Cueing semantic radical (n=100)	4.60	1.18	0.50	0.44	0.10	0.22	0.00	0.00	4.80	1.27
Non-cueing semantic radical (n=100)	2.40	1.20	0.90	0.69	0.10	0.22	0.00	0.00	6.60	1.34
3-day Interval										
Overall (n=200)	4.50	1.73	0.40	0.75	0.00	0.00	0.00	0.00	5.10	1.85
Cueing semantic radical (n=100)	5.60	1.06	0.20	0.31	0.00	0.00	0.00	0.00	4.20	1.02
Non-cueing semantic radical (n=100)	3.50	1.01	0.90	0.60	0.00	0.00	0.00	0.00	5.60	1.11

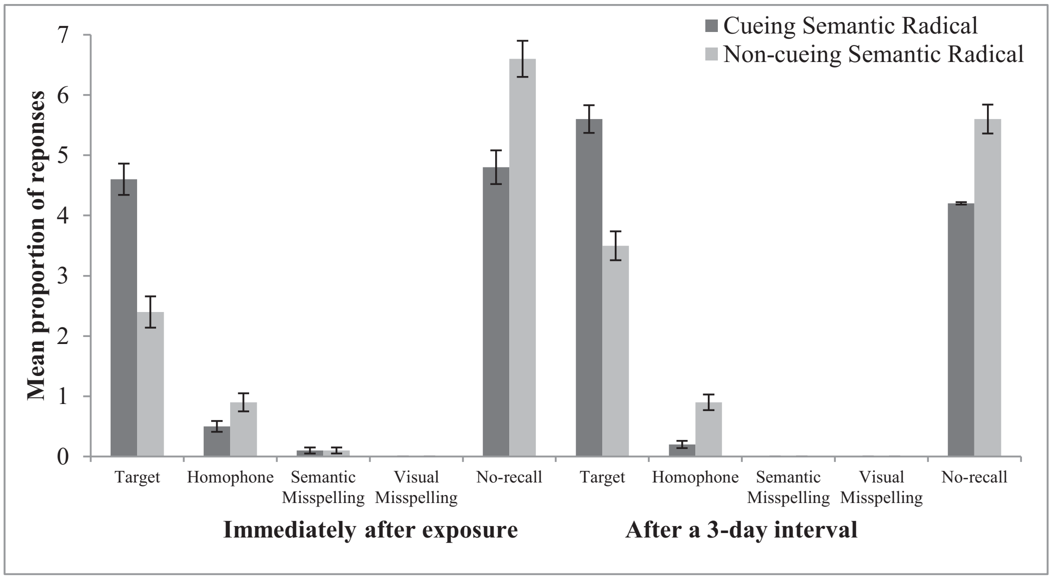

Figure 14. Mean responses from the spelling task (*the whole-character criterion*) in Study 3

The cueing effect of semantic radicals and delay

To investigate whether orthographic learning was modulated by the cueing effect of semantic radicals and the lapse of time of posttest measures, the proportion of correct target responses in each condition on both posttest tasks was entered into a 2 (type of semantic radicals: cueing vs. non-cueing) x 2 (posttest time: immediately after reading vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures.

Orthographic choice test. There was only a significant effect of delay, F (1, 19) = 4.61, η_p^2= .20, p < .05. The effect of semantic radical did not reach statistical significance, nor did the interaction effect of delay and type, all *F*s < 2.0.

Spelling task. An ANOVA revealed a significant effect of delay, F (1, 19) = 11.99, η_p^2= .39, p < .00, and also a significant cueing effect of semantic radical, F (1, 19) = 27.21, η_p^2= .59, p < .00. This suggests that when asked to fully specify orthographic detailed forms, developing children relied also on cueing functionality of semantic radicals embedded in characters. Yet no interaction effect was found, $F(1, 19) = .26$, $\eta_p^2 = .01$, $p = .61$.

Considering the data in Tables 7 and 8, it is obvious that children performed better on orthographic learning in the conditions with cueing semantic radicals than in the conditions with non-cueing semantic radicals, irrespective of the interval between the text-reading task and posttest measures for orthographic learning. Interestingly, participants in the conditions with cueing semantic radicals were generally inclined to produce less homophonic errors than in the conditions with non-cueing semantic radicals, which suggested that semantic radicals exerted some influence on orthographic learning when they had a clear meaning in and of themselves.

Phonological learning

On both orthographic learning measures, phonological learning was apparent, as indicated by the fact that the homophonic characters alone witnessed an advantage over phonologically incorrect or deficit characters.

Orthographic choice test. Homophonic foils were most frequently chosen when mistakes were made. Immediately after text-reading, homophonic foils were selected at 24% (SD =1.46), eight times more often than semantic distractors 3% (SD = .55); visual distractors were only selected at a negligible 1% (SD = .44). After a 3-day interval, homophonic alternatives (21%, SD = 1.19) were still chosen about three times as often as semantic distractors (8%, SD = .89), and visual distractors were only trivially selected at 4 % (SD = .75).

Analyzing homophonic foils alone in an ANOVA test, we did not find significant effects of delay, $F(1, 19) = 1.88$, $\eta_p^2 = .09$, $p = .19$, and type of semantic radicals, F (1,

19) = 4.29, η_p^2= .18, p = .05, nor an interaction effect between delay and type of semantic radicals, F < 1.0. Although no main effects were registered here, there was a general pattern showing that homophones were selected more often in conditions with non-cueing semantic radicals than in conditions with cueing semantic radicals (see Table 7).

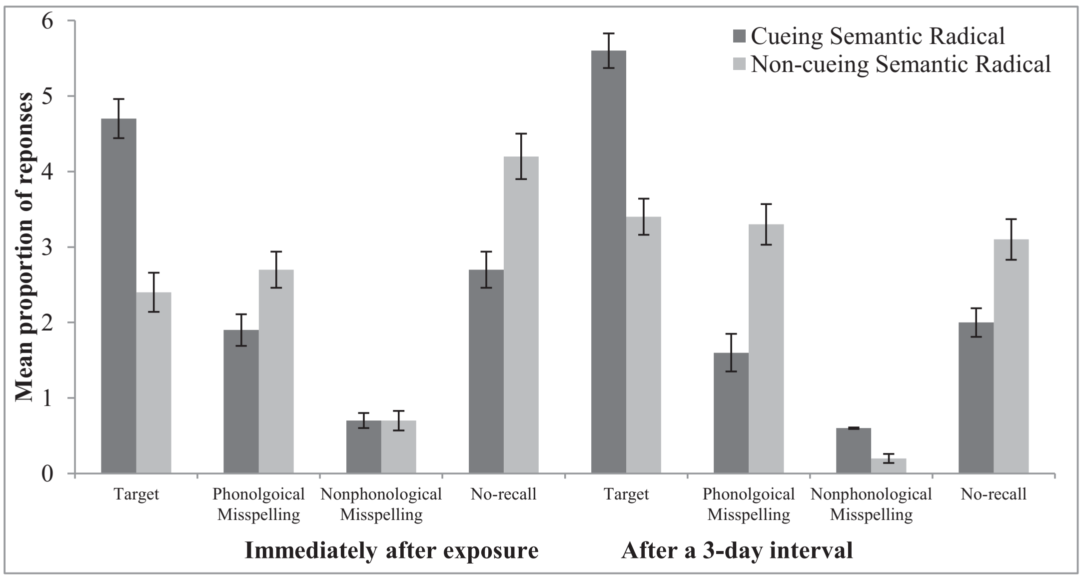

Figure 15. Mean responses from the spelling task (*the per-radical criterion*) in Study 3

Spelling task. On the spelling task assessed by the whole-character criterion here, it was apparent again that the largest share was the "no-recall" category where reproductions of characters were either unrelated to targets in terms of semantic radicals or phonetic radicals, or nothing was reproduced at all in this attempt. A more sensitive way to analyze the error patters than the whole-character scoring criterion was to look at the radicals produced in the spelling task. Therefore, we adapted here *the per-radical criterion* used in Studies 1 and 2.

According to the per-radical criterion, the responses were scored as correct only when participants spelled out the exact printed forms that were shown to them at the text reading phase, which is identical to the whole-character criterion. However, alternative homophonic spellings of the target items (i.e., homophonic foils in the orthographic choice test, e.g., “袚”, or those reproduced with the same phonetic radical as seen in targets but with a different semantic radical, e.g., “紱”) were recorded as ‘phonological misspellings’, and other responses were grouped as ‘nonphonological misspellings’.

The spelling task scores based on the whole-character and per-radical criteria are shown in Figures 14 and 15 respectively. By comparing them, we found that most of the no-recall responses were actually homophonic misspellings. That is, they were all characters produced with the same phonetic radicals shared by the target characters at the reading task phase. There is, therefore, conclusive evidence that the majority of errors in both recognition and spelling tasks were sound-based; this provides further evidence to phonological learning.

An analysis of variance (ANOVA) was run on the number of reproductions other than target characters. Homophonic misspellings occurred significantly more in the conditions with non-cueing semantic radicals than with cueing semantic radicals, $F(1, 19) = 6.77$, $\eta_p^2 = .26$, $p < .05$. The effect of delay and the interaction effect of delay and the cueing effect of semantic radicals both failed to reach statistical significance, all *F*s < 2.0. In terms of nonphonological misspellings, none of the effects was significant: the effect of delay, $F(1, 19) = 3.35$, $\eta_p^2 = .15$, $p = .08$; the effect of semantic radical transparency, $F(1, 19) = .66$, $\eta_p^2 = .03$, $p = .43$; the interaction effect between the two variables, $F(1, 19) = 1.36$, $\eta_p^2 = .26$, $p = .07$.

As regards no-recall, an ANOVA showed the effects of delay, $F(1, 19) = 7.73$, $\eta_p^2 = .29$, $p < .05$, and transparency of semantic radical, $F(1, 19) = 11.85$, $\eta_p^2 = .38$, $p < .00$ were found statistically significant, with significantly more frequent occurrence of no-recalls in non-cueing conditions than in cueing conditions both immediately after reading exposure and after a 3-day interval. However, the interaction effect of delay and transparency of semantic radical was not, $F < 1.0$.

6.1.3 **Discussion**

As is the case with previous research on orthographic learning in Chinese, the orthographic learning effect is clearly documented here for children in Grade 2 reading in a traditional, visually more complex Chinese script. Performance on both posttest measures for orthographic learning via self-teaching was above chance, with spelling tasks showing less robust learning effect.

The current experiment examined the role of sublexical semantic information in children's orthographic learning. Results showed that the cueing effect of semantic radicals had a decisive influence in the learning process; pseudocharacters embedded with a cueing semantic radical were acquired better than those with a non-cueing semantic in both posttest measures. Although the performance difference was not that clear on the word recognition task, a good 20% gap was decidedly observed on the spelling task. This could be taken as preliminary evidence in support of the claim that cueing semantic radicals aid the formation of word-specific orthographies in memory for developing Chinese readers.

Better performance on learning pseudocharacters with semantic radicals that possess a clear meaning supports the view that the presence of semantic information facilitates the activation of phonological codes and word decoding (Nation & Cocksey, 2009; Ouellette, 2010; Ouellette & Beers, 2010). Nonetheless, this may not be the full story, as developmental factors should also be taken into account. This line of argument will be further pursued in the section of general discussion.

The pattern of error analysis revealed that homophonic alternatives were most numerously selected when mistakes were made by novice readers. This is a clear indicator that phonological learning took place. Despite the cueing functionality of semantic radicals, it is obvious that the majority of developing readers brought phonological information to bear on the formation and reinforcement of orthographic forms in learning to read. This data is also suggestive of the fact that the non-cueing semantic radicals caused the word-specific forms to be less memorable, such that children were thus inclined to choose or reproduce more homophonic foils in conditions with non-cueing semantic radicals. Altogether, the results available are indicative of the memory reliance on both semantic cueing from semantic radicals and phonology in orthographic learning of Chinese. This concurs with the evidence from chapter 5, showing that phonology plays a principal role in learning a logographic orthography, such as Chinese.

The delay of posttest measures also reached significance, with better performance observed in the 3-day interval conditions, consistent with results from Studies 1 and 2, as well as Liu and Shiu (2011) that focused on Chinese orthographic development. It is likely that developing readers might have benefited from the spelling task administered right after the reading task, as a few studies have corroborated the facilitative contribution of spelling words to the solidification of word representations (Conrad, 2008; Ouellette, 2010; Sharar-Yames & Share, 2008).

The absence of the cueing effect of semantic radicals in identification tasks is likely to be attributed to the fact that this type of task drew on different cognitive operations from those required for spelling tasks where motor-kinesthetic processes are involved and fully specified character representations are demanded (Graham & Weintraub, 1996; Shahar-Yames & Share, 2008); orthographic choice tasks are considered thus less sensitive to measure orthographic learning.

6.2 Study 4: The Effect of Semantic Transparency in Chinese Orthographic Learning

Study 3 demonstrated that Chinese orthographic learning can be modulated by the cueing function of semantic radicals. Study 4 follows up to test another aspect related to semantic radicals, i.e., the effect of semantic transparency, which, speculatively, would have an effect on orthographic learning.

The dynamic relationship between Chinese characters and their embedded semantic radicals leads to various degrees of semantic transparency defined by the meaning relatedness between the semantic radical and the whole character that the semantic radical is embedded in. Yin and Rohsenow (1994) classified the magnitude of relatedness between whole characters and their sublexical semantic components into two broad groups: semantically transparent semantic radicals and semantically opaque semantic radicals (cf. section 3.1.3). The effect has been widely reported to influence lexical processing (e.g., Feldman & Siok, 1999a, 1999b; Law et al., 2005; Li & Chen, 1999). For example, Li and Chen (1999) reported that lexical decision latencies of low-frequency items were modulated by semantic transparency; participants reacted much more quickly to semantically transparent characters than the opaque ones. So far, the effect of semantic transparency is only evidenced in the realm of word identification that mainly reflects pre-existing word knowledge. However, given that the processes underlying word recognition and orthographic learning are different, the semantic transparency is defined differently in orthographic learning.

Learning novel Chinese orthographic forms should involve semantics at both the sublexical and contextual levels. Lupker (2005) has rightfully drawn our attention to the distinction in lexical processing between "the impact of the semantic context within which the word is processed and the impact of the semantic attributes of the word itself" (p.40). Orthographic learning looks at the very process leading up to established novel word representations; the semantic attributes from semantic radicals at the sublexical level have the potential to interact with the contextual semantics. Therefore, the working definition here is that the semantic transparency of semantic radicals in orthographic learning should be defined in relation to word semantics that is to be instantiated *online* into the word. The working definition differs from the definition of semantic transparency normally used in skilled character recognition experiments where experimental items are already known to participants.

The research question in Study 4 is the following: Is semantic transparency, i.e., the semantic relationship between the sublexical and contextual level, a factor that moderates Chinese orthographic learning? Taking advantage of Chinese writing system that offers a unique opportunity to look at the issue as to whether there is an interaction between the sublexical semantic from semantic radicals and character semantics on the lexical level, the hypothesis in Study 4 predicts that where there is a clear relatedness between a character and its embedded semantic radical, there will be better orthographic learning effect. This demonstrates semantic transparency modulates the learning process. In the present experiment, one group of target pseudocharacters was embedded with semantic radicals that were clearly associated with the semantic referents being instantiated into the target pseudocharacters from the context. The other group had semantic radicals that were completely irrelevant to the semantic referents that can be inferred from the context. All targets appeared 4 times with phonological aids (i.e., Zhuyin). Study 4 contributes hence to the understanding of dynamics in which sublexical and contextual semantics interact in Chinese orthographic development.

6.2.1 Method

Participants

A sample of 20 second graders, 8 male and 12 female, was randomly drawn from three classes in one of the primary schools in Taichung metropolitan, Taiwan to take part in the present study. All of the children were native speakers of Mandarin Chinese, whose age ranged from 7 years 6 months to 8 years 6 months, with a mean age of 8 years 2 months (SD = 1.93). The whole experiment and follow-up posttest assessment tasks were held in the middle of the second grade school year, during the months of March and April.

All of the participants were native speakers of Mandarin Chinese, and were all normally achieving children, matched on age and an all-purpose language skill measure, or the latest monthly/periodical native language evaluation at each individual school. This evaluation always takes the form of an exam where Zhuyin skills, character reproduction, comprehension, sentence constructions, etc., are all assessed at one go. All participants had scores ranging from 80 to 99 points out of 100 points, Mean = 92.55, SD = 3.69.

Materials and Procedures

The experimental paradigm was generally identical to that of Study 3, except for the manipulation of semantic transparency of pseudocharacters (M = 11.5, SD = 3.24). Two conditions were devised in the current experiment.

1) Semantically transparent condition: Half of the novel target characters were those with a semantic radical that was transparently linked with the semantic referent to be instantiated at the whole character level (M = 12.6, SD = 2.30). Examples: When a text mentioned a special car "輌 /tong/", we saw to it that a pseudocharacter was made up having a semantic radical that referred to a car "車". Or when a text dealt with a mythical animal "犄 /qing/", a pseudocharacter was invented embedded with a semantic radical that hinted on animals "牛".

2) Semantically opaque condition: This was the condition where semantic radicals were unrelated to the semantic referents to be instantiated into the target pseudocharacters (M = 10.4, SD = 3.91). For instance, a fictional star "猭 /yuan/" was introduced in a short text. We saw to it that the pseudocharacter here was embedded with a semantic radical "犭" that referred to animals. In so doing, the embedded semantic radical was not related at all to context semantics about the star being exceptionally shiny, etc. Pseudocharacters in this condition were created in this fashion to match their conditions.

All targets were manipulated to show a regular pattern in terms of their pronunciation and all appeared four times and all with Zhuyin. All the semantic radicals used in the current experiment were of clear meaning in themselves. The orthographic learning performance was also gauged by an orthographic learning test and a spelling test.

Comprehension. Immediately after each text, three questions were asked for comprehension check. The mean of the correctly answered questions was 28.3 (SD = 2.34), maximum score: 30 (3 questions times 10 texts), indicating that the general comprehension was mostly intact.

Target decoding accuracy score. The accuracy of the pronunciation of the target words was recorded online by the experimenter. A score of 1 was given each time a target was read correctly. An error was recorded if any change to the correct target pronunciation occurred. In the present study, out of the 40 possible correct pronunciations of the homophone targets (10 stories times 4 target characters), the proportion of correct pronunciations amounted to 87.13% (M = 34.85, SD = 3.11). This is an indication that most of the targets were successfully decoded when encountered at the text reading phase, though the decoding performance was again not as good as observed among third-graders in Chapter 5.

6.2.2 Results

The learning effect for orthographic forms was assessed by an orthographic choice test and a spelling task. The goal of Study 4 was to investigate whether orthographic learning in Chinese was modulated by the effect of semantic transparency.

Orthographic choice measure. Fast orthographic learning was also observed here, as the overall rate of target learning stood at 84% (SD = 1.63). In both immediately after the reading task and after a 3-day interval, the targets were selected 84% of the time as well, way beyond the chance level (25%). Table 9 showed that targets were selected at least six times more frequently than any of the alternative choices in the orthographic choice measure, and the overall selection of targets over homophonic characters reached statistical significance, $t\ (1, 39) = 14.86$, $p < .00$

Errors were dominated by homophonic foils, in the condition with immediate reading exposure: 12%, SD = 1.35, and in the condition with a 3-day interval: 13%, SD = 1.68, which indicated robust phonological learning. Disregarding the time of testing delay, phonological learning was stronger in semantically opaque condition than in semantically transparent condition, $t\ (1, 39) = -3.09$, $p < .00$.

To investigate whether orthographic learning via self-teaching in learning to read Chinese was modulated by the effect of semantic transparency and the lapse of time of posttest measures, the proportion of correct target responses in each condition was entered into a 2 (effect of semantic transparency: semantically transparent vs. semantically opaque) x 2 (posttest delay: immediately after reading exposure vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures.

No effects were found reaching statistical significance: the effect of semantic transparency, $F\ (1, 19) = 1.10$, $\eta_p^2 = .06$, $p = .39$; the effect of delay, $F < 1.0$; the interaction effect between the two variables, $F\ (1, 19) = 2.27$, $\eta_p^2 = .11$, $p = .15$.

Looking at homophonic foils alone, an ANOVA test reported a significant effect of delay with more homophone being produced in the delayed conditions, $F\ (1, 19) = 5.63$, $\eta_p^2 = .22$, $p < .05$, and a significant effect of semantic transparency with more homophonic foils being reproduced in semantic opaque conditions than in semantic transparent conditions, $F(1, 19) = 82.34$, $\eta_p^2 = .81$, $p < .00$. There was, however, no interaction effect between the two variables, $F < 1.0$.

Table 9

Proportion of targets, homophones, semantic distractors , nonword visual distractors, and no-recalls in the orthographic choice task in Study 4

	Target		Homophone		Semantic distractor		Nonword visual distractor		No-recall	
	M	SD	M	SD	M	SD	M	SD	M	SD
Immediately										
Overall (n=200)	8.40	1.63	1.20	1.35	0.30	0.44	0.30	0.44	0.00	0.00
Transparent semantic radical (n=100)	8.50	0.91	0.40	0.52	0.60	0.47	0.50	0.44	0.00	0.00
Opaque semantic radical (n=100)	8.20	1.25	1.80	1.25	0.00	0.00	0.00	0.00	0.00	0.00
3-day Interval										
Overall (n=200)	8.40	1.90	1.30	1.68	0.30	0.44	0.10	0.10	0.00	0.00
Transparent semantic radical (n=100)	8.90	0.76	0.50	0.55	0.40	0.41	0.20	0.20	0.00	0.00
Opaque semantic radical (n=100)	7.90	1.54	2.00	1.56	0.10	0.22	0.00	0.00	0.00	0.00

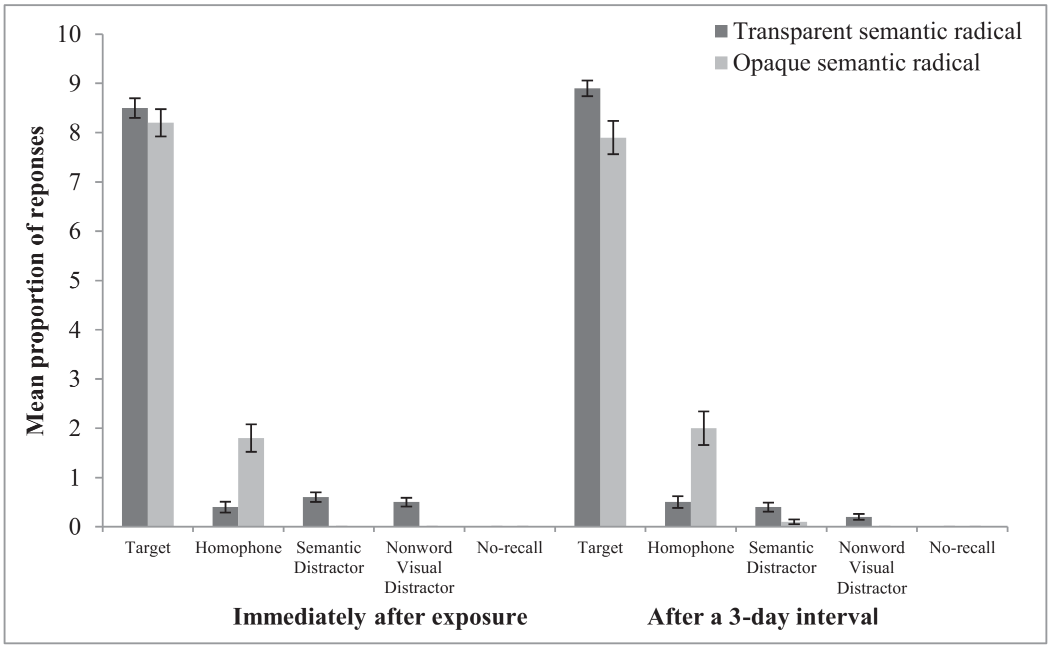

Figure 16. Mean responses from the orthographic choice task in Study 4

Spelling task.

The spelling measure had two criteria: the whole-character criterion and the per-radical criterion. The latter was applied to look into the error pattern in the orthographic learning process.

The whole-character criterion. The overall rate of orthographic learning stood at 42% (SD = 2.46) immediately after text reading and 56% (SD = 2.64) after a 3-day interval. Immediately after reading exposure, novice readers chose targets correctly in the semantically transparent condition at 37% (SD = 1.25) and in the semantically opaque condition at 47% (SD = 1.60), whereas, after a 3-day interval, targets were selected at 53%, SD = 1.46 in the semantically transparent condition and at 62%, SD = 1.62 in the semantically opaque condition.

An analysis of variance (ANOVA) with repeated measures 2 (effect of semantic transparency: semantically transparent vs. semantically opaque) x 2 (posttest delay: immediately after reading exposure vs. after a 3-day interval) revealed a significant effect of delay, F (1, 19) = .19, η_p^2= .50, p < .00. The effect of semantic transparency was not significant, F (1, 19) = 2.37, η_p^2 = .11, p = .14. Nor did the interaction effect between the two variables reach significance, F (1, 19) = 1.06, η_p^2 = .05, p = .32.

Table 10

Proportion of targets, homophones, semantic distractors , nonword visual distractors, and no-recalls in the spelling task (*the whole-character criterion*) in Study 4

	Target		Homophone		Semantic distractor		Nonword visual distractor		No-recall	
	M	SD	M	SD	M	SD	M	SD	M	SD
Immediately										
Overall (n=200)	4.20	2.46	0.70	1.17	0.10	0.22	0.00	0.00	5.10	2.17
Transparent semantic radical (n=100)	3.70	1.25	0.40	0.41	0.10	0.22	0.00	0.00	5.80	1.25
Opaque semantic radical (n=100)	4.70	1.60	1.10	0.83	0.00	0.00	0.00	0.00	4.20	1.25
3-day Interval										
Overall (n=200)	5.60	2.64	0.60	0.99	0.20	0.37	0.00	0.00	3.60	2.35
Transparent semantic radical (n=100)	5.30	1.46	0.50	0.44	0.30	0.37	0.00	0.00	3.90	1.35
Opaque semantic radical (n=100)	6.20	1.62	0.90	0.69	0.00	0.00	0.00	0.00	3.20	1.27

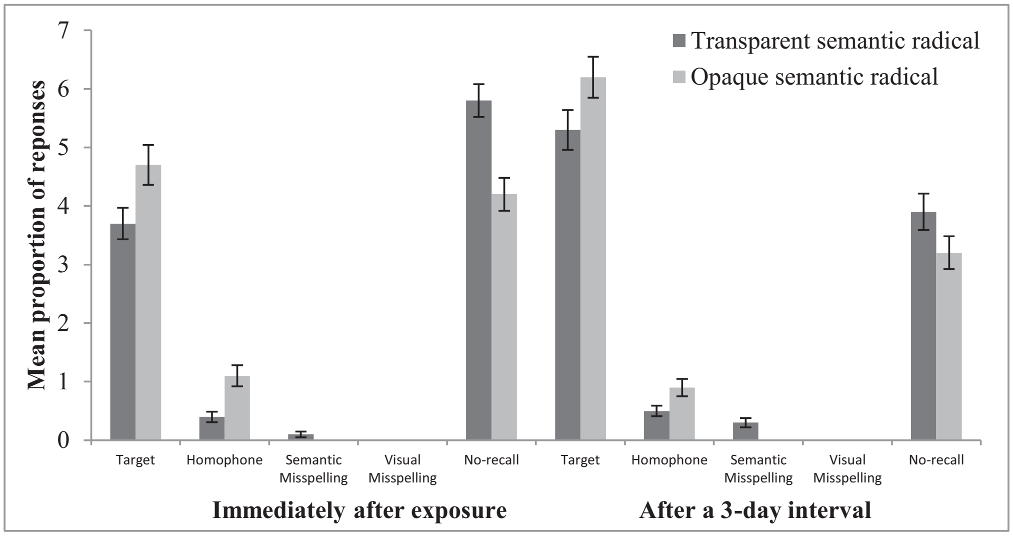

Figure 17. Mean responses from the spelling task (*the whole-character criterion*) in Study 4

The per-radical criterion. Since no effect whatsoever was found in the whole-character scoring method, the per-radical criterion would probably be more revealing and sensitive in terms of shedding light on the learning pattern. The proportion of reproductions in different categories (i.e., homophonic misspellings, semantic misspellings and no-recalls) was thus entered in to a 2 (effect of semantic transparency: semantically transparent vs. semantically opaque) x 2 (posttest delay: immediately after reading exposure vs. after a 3-day interval) analysis of variance (ANOVA) with repeated measures.

Likewise, there were not any significant effects or interaction effects in any of the three categories. Concerning homophonic misspellings, the effect of delay, the effect of semantic transparency, and the interaction effect of delay and semantic transparency were not significant, all Fs < 1.0. In terms of semantic misspellings, none of the effects were significant, all Fs < 2.0. Nor was there any significant main effects regarding No-recall, all *F*s < 3.0. Taken together, the results here showed that the effect of semantic transparency did not affect the error patterns in the orthographic learning process, neither.

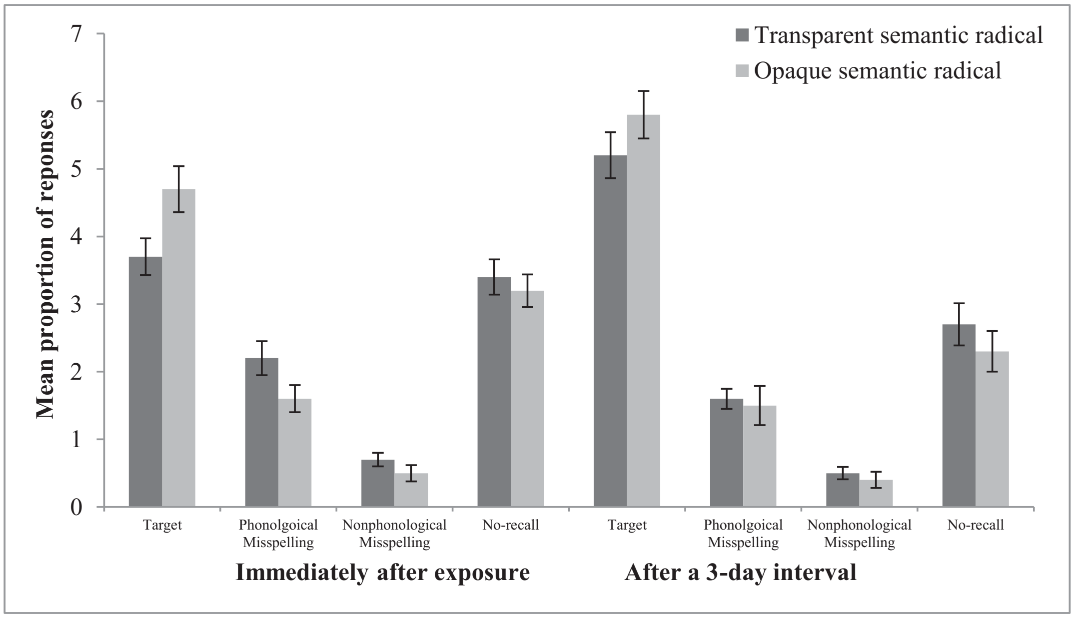

Figure 18. Mean responses from the spelling task (*the per-radical criterion*) in Study 4

6.2.3 Discussion

The objective of Study 4 was to investigate the effect of semantic transparency on learning the most dominant type of Chinese orthographic forms, i.e., phonograms, where semantic relatedness between the whole target pseudocharacter and its embedded semantic radical was either transparent or opaque. The findings in the present experiment showed again evidence for apparent learning of the orthographic forms via self-teaching to a modest degree. However, the effect of semantic transparency was not observed to moderate orthographic learning in any way.

Despite no significant effect for semantic transparency in the current study, immediately after reading exposure and after a 3-day interval alike, there is a general pattern favoring better learning in semantic transparent conditions than in semantic opaque ones and in the 3-day interval conditions than in immediately after reading ones. It could be construed as preliminary evidence for the claim that semantic transparency may not play a crucial role in orthographic development, at least for young second-grade readers of Mandarin Chinese.

In addition, considering other studies on Chinese reading development, although morphological awareness has been found burgeoning in pre-school children, it is documented that the morphological awareness, e.g., the radical awareness, is not fully developed until Grade 6 (Shu & Anderson, 1998, 1997; Tong et al., 2009). To put the current null results into developmental perspective, second-graders who are on their way to acquire or fine-tune their skills in relation to the morphological aspect fail to fully appreciate and make good use of the morpho-semantic cues that are associated with the concept of semantic transparency. Chances are that children at higher grade levels may appreciate semantic transparency in Chinese orthographic development than those at lower grade levels.

Another potential explanation for the null effect of semantic transparency is attributable to word regularity. Wang (2012) and Wang et al. (2010) reported that only when children learn irregular English words would the orthographic learning process be modulated by context information. Given that all of the pseudocharacters used in Study 4 exhibited a regular pattern in terms of the symbol-sound correspondence rules, it may hypothetically be the case that the semantic transparency effect would be more saliently involved in decoding irregular Chinese characters. Clarifications on this issue require further research.

6.3 General Discussion

Typically developing readers of alphabetic orthographies differing in the degree of orthographic depth are able to acquire solidified orthographic knowledge during oral text reading where no feedback or assistance is supplied (Cunningham, 2006; de Jong & Share, 2007; Share, 1999, 2004). Similar results are replicated again in chapter 6 among younger groups than those in chapter 5. Studies 3 and 4 established that even novice readers at Grade 2 can also swiftly self-teach orthographic representations in a visually more complex, traditional Chinese script. The effect for orthographic learning via self-teaching was above chance both in the orthographic recognition and spelling tasks. The findings were in tune with that from Liu and Shiu's (2011) study in which second-grade Chinese students read in a simplified Chinese script. Altogether, these results from Mandarin Chinese supported *the early onset hypothesis* formulated by Share (1995, 2008) in the self-teaching model. Arguably, children learning to read Chinese can start to self-teach in reading with context, when they possess rudimentary symbol-sound knowledge, plus minimal phonological sensitivity.

Studies 3 and 4 concentrated on the semantic factors that were involved in Chinese orthographic learning. Just as semantic radicals embedded in Chinese characters are proven to be relevant in lexical processing (Law et al., 2005), the relevance of semantic radicals to Chinese orthographic learning was also evidenced in the current studies. Study 3 showed that the cueing effect of semantic radicals *per se* had an effect on the character learning process, whereas Study 4 found no significant effect of semantic transparency on the likelihood of producing correct targets in both posttest measures.

The semantic cues from semantic radicals played a role in learning characters, with cueing semantic radicals being beneficial to orthographic learning. On the other hand, non-cueing semantic radicals exhibited diminished learning effect. This is in agreement with existing studies in support of the view that, when learning to read, Chinese readers approach characters to be acquired in an analytical manner, and, thus, decompose them in order to exploit sublexical information conveyed from phonetic or semantic radicals (Law et al., 2005; Liu et al., 2011). In response to Share's (1995) speculation on the semantic clues stemming from the semantic radicals, Study 3 provided preliminary evidence supporting the importance of semantic radical in phonograms.

In Study 4, the effect of semantic transparency in orthographic learning was defined in relation to the semantic referent being instantiated online into the target character. The absence of the effect for semantic transparency here does not, however, allow us to jump to the conclusion that orthographic learning in Chinese is not under the influence of the semantic transparency effect. The null results in Study 4 are possibly manifold.

First of all, based on Wang (2012) and Wang et al. (2011) who found that context information is only beneficial in irregular mappings in English, the occurrence of null results for a semantic transparency effect might have arisen from the manipulating of target pronunciations in the current study, such that target pseudocharacters were regular and shared the pronunciation of the phonetic radicals embedded in characters. Research with experiment designs directly contrasting the effect of semantic transparency on regular and irregular characters is urgently needed to shed light on this issue.

Second, Study 4 demonstrated that children in Grade 2 seemed to fail to bring the cues of semantic radicals in relation to context to bear on the orthographic learning process. It is likely that they have yet to reach the required level of orthographic knowledge before they can begin to thoroughly and efficiently analyze the morphological structures of their languages (Chung & Wu, 2007; Pinker, 1984; Silvestri & Silvestri, 1977). This is consistent with studies reporting that, with increasing reading experience, Chinese student learn to identify more characters, and start to link semantic radicals to the meanings of different characters, which cultivates an important aspect of morphological awareness (McBride-Chang et al., 2003; Shu & Anderson, 1997). Further studies focusing on children at various stages of reading development across languages are still required to shed light on the precise mechanisms by which reading, vocabulary development, and morphological awareness affect one another.

A third locus might have a paradigmatic origin. For one thing, each text in the current experiments has topicalized the target character, but novice readers are likely to come across more than one unknown or unfamiliar characters in naturalistic, daily reading environment. For another, with only five words in each condition and each word having a regular pronunciation, the memory demand of the paradigm was presumably not great enough to reveal the benefits that semantic transparency may bring along during the storage of and access to orthographic information in Study 4 (Ouellette & Fraser, 2009). The paradigmatic limitations might have distorted and affected real performance on children's orthographic learning.

As would be expected, higher accuracy in both studies was found in choosing the correct targets on the orthographic choice tasks than in reproducing correct target pattern on the spelling tasks. Research has showed that training effects are concomitant with adequate posttesting methodologies that correspond to the training method (Martin-Chang, Levy, & O'Neil, 2006; Shahar-Yames & Share, 2008; Ouellette & Fraser, 2009). In other words, an evident training effect in measures of visual word identification is to be found in a reading practice paradigm, while a paradigm incorporating spelling practice should benefit measures of spelling. The performance gap between recognition and reproduction of target spelling patterns is thus arguably attributable to inherent task natures of the two measures (Bosman & Van Orden, 1997; Perfetti 1997), as well as the different cognitive resources recruited to meet the two tasks (Ehri, 1997). If we extrapolate these findings to our results, it is expected that overall performance was found to be optimal on the orthographic choice tasks. By and large, the effect of posttest delay was evidently documented in all posttest measures in chapter 6, showing better learning effect after a 3-day interval. This is probably because the identification tasks and spelling practice right after the training phase provided extra exposures and thus led to better performance after a 3-day interval.

To date, there are only few studies available that deal with the issues on orthographic learning in Mandarin Chinese, let alone within the self-teaching framework. It is hence of great interest for the current study to look at and draw comparisons among these studies focusing on orthographic learning in Chinese. In contrast to the studies in chapter 5 and Liu and Shiu (2011) where overall results of the orthographic choice measure and spelling measure stood respectively at about 81% and 63% and 86% and 50 %, the current study reported around 70% and 40% on each task. In these studies, the differential performance in orthographic learning may reflect, a posteriori, different approaches to teaching to read in Taiwan and Mainland China, as well as different developmental stages in which children of different grades were at the moment of testing. Although the datasets from this chapter and Liu and Shiu's (2011) study both provided useful information on orthographic learning among 2nd grade students, they cannot be directly compared. Researchers should always be precautious when generalizing results even within a single language/orthography. In other words, there might be differences that emerge from learning to read in the simplified Chinese characters used in China and in the traditional Chinese characters used in Taiwan and Hong Kong.

In comparison with the two studies in the previous chapter that focused exclusively on Taiwanese children in 3rd grade learning to read Chinese, the performance gap is especially evident on the spelling tasks where overall spelling accuracy dropped off by 23% in the current study. Such a big variance between results combined across conditions from chapters 5 and 6 might arguably not to be ascribed single-handedly to the manipulations of semantic radicals in chapter 6.

Reading experience should be taken into account as well. The resulting learning patterns revealed by Grade 2 and Grade 3 children might reflect this factor. That is, the children in Grade 2 may not be as mature as their counterparts in Grade 3, in terms of the mastery or deployment of the necessary reading or learning abilities, print exposure, etc. Indeed, based on Ouellette's (2010) claim that the interpretation of data should take the developmental stages of children into consideration, it is highly probable that in the years leading to the 3rd grade, Grade 2 represents a particularly critical transition in the sense that novice readers turn from heavy reliance on visual skills to using orthographic cues in the process of becoming a more proficient reader. As a result, developing Chinese readers in Grade 2 are en route to drastically fine-tuning their reading skills, grasping more reading strategies and sharpening their awareness for as well as knowledge of Chinese phonology, morphology and radicals, etc. Therefore, much better performance was clearly observed among Grade 3 children in chapter 5 than among Grade 2 children in chapter 6. All in all, the comparison between the two grades could be taken to preliminarily suggest that the year leading up to Grade 3 is presumably critical for children learning to read Chinese.

Despite the focus on semantic factors in the current study, it is worthwhile to note again that sound-based errors were still numerous and predominant in error analyses both on the orthographic choice tests and the spelling tasks. It is indicative of the vital role that phonology-related information assumes in learning to read a non-alphabetic writing system like Chinese. This is in concordance with a plethora of studies supporting the importance of phonological information in Chinese reading (Perfetti, 2010; Perfetti, Liu, & Tan, 2005). In Studies 3 and 4, the pseudocharacters to be acquired at the training phase were apparently speech-recoded, and in turn, this led to the supportive role of phonology in the working memory processes involved in the amalgamation of orthographic, phonological and semantic information with regard to a word (Tzeng, Hung, & Wang, 1977).

Importantly, morphological awareness is involved in the acquisition of Chinese characters, in addition to phonology. Findings from this chapter indicated that for children as young as second graders the cueing functionality of semantic radicals was more important than semantic transparency in orthographic learning of Chinese. If the sublexical, morpho-semantic information of the semantic radicals is crucial in the Chinese orthographic learning process, one of the pedagogical implications would be to enhance this aspect in teaching practices.

The semantic salience of Chinese characters arises from the physical difference represented at the surface form of its script, in contrast to alphabetic ones.

The internal structure of phonogram characters in the Chinese writing system consisting of a semantic and phonetic component provides an opportunity to the study of orthographic learning that is inaccessible form studies using alphabetic writing systems. However, in Chinese and English alike, there is only limited research effort dedicated to investigating the morphology-related issues in orthographic learning (MacEcharon, 2008; Ravid, 2001). The current chapter presents a first step in this direction. Since sublexical semantics is found to play a role in Chinese orthographic learning, an interesting further step is to find out if vocabulary knowledge would also modulate the learning process. The line of research on semantics in orthographic learning process in Mandarin Chinese still requires further investigation.

Chapter 7

Summary, Limitations, and Contributions of the Current Research

The dissertation has offered findings on some key issues as regards Chinese orthographic development and thus made some contributions to the refinement of models for both skilled recognition and orthographic development. A summary of main findings and conclusions is offered here. Chapter 7 also looks at the limitations and pedagogical implications of the study. Finally, directions for future research are pointed out.

7.1 Summary of Main Findings and Conclusions

The studies designed in the dissertation have confirmed that Chinese orthographic learning also occurs rapidly via self-teaching. The dissertation added to the current orthographic learning literature that focuses mostly on alphabetic scripts, e.g., a Semitic consonantal Hebrew script (Share, 1999, 2004), a mildly opaque Dutch orthography (de Jong & Share, 2007; de Jong et al., 2009), a relatively deep English orthography (Cunningham, 2006; Wang et al., 2011), and, rarely, on a very deep non-alphabetic Chinese script (Liu & Shiu, 2011). The findings from the dissertation reported evident orthographic learning via self-teaching among young Taiwanese children learning to read in the traditional Chinese script that is visually more complex than the simplified Chinese script used in mainland China. Simply put, the self-teaching aspect of orthographic learning is not orthography-specific, and it is hence one of the universals that, through phonological recoding, typically developing readers are able to self-teach word representations across different orthographies.

First of all, the extraneous, auxiliary phonetic system, i.e., Zhuyin, is evidenced in Study 1 to be not of great help in the formation of word-specific representations among third-grade readers. That said, the importance of Zhuyin should not be overlooked. Chinese readers can be said to learn alphabetic reading through the phonetic system, “as a first step toward mastery of their own morpheme-based system” (Rayner et al., 2001, p.33). Literacy in alphabetic scripts is reported to draw Chinese readers’ attention to details of phonological structures (Read, Zhang, Nie, & Ding, 1986). In other words, completely transparent phonetic aids listed alongside Chinese orthographies may contribute to the growth of phonological sensitivity and awareness, but the benefit of Zhuyin offering exact character pronunciations is limited in the process of forming orthographic representations. The upsides of Zhuyin should come in the form of children’s enhanced phonological processing skills that, subsequently, ensure them to carry out phonological recoding of unfamiliar characters in the process of orthographic learning. The role of Zhuyin should be further clarified in the research of orthographic learning.

Study 1 reported better orthographic learning in conditions Without Zhuyin than With Zhuyin, indicating the possibility that the phonetic radicals may be the key source for functional orthographic learning in Chinese. Study 2 followed up this issue by manipulating the availability of embedded phonetic information and concluded that the phonetic information stemming from the phonetic radicals is critical to induce robust Chinese orthographic learning.

Error analyses of all four studies in the dissertation have painted a general picture of speech-based errors. That is, homophonic errors predominated when children were not able to recall the accurate target items. This type of error tended to share the phonetic radicals in the targets, rather than semantic radicals. For reading in a non-alphabetic script like Chinese, it is also imperative to turn words into corresponding phonological codes; as such, words can be stored in working memory (Tzeng et al., 1977). The availability of phonetic information is proved pivotal in Study 2 where phonograms were better learned than nonphonograms. It is highly likely that phonetic radicals offer the key mnemonic power that allows children to secure spellings in memory. Altogether, the findings and observations in the current dissertation converged on the important role of phonology in Chinese orthographic development.

Not to be ignored is, however, the role of semantic cues in Chinese character recognition. As the semantic category indicated by semantic radicals embedded in phonogram characters facilitates the comprehension of character meaning in lexical processing research, semantic radicals were empirically found to also somewhat modulate the orthographic learning effect in the current studies. The issue of whether the semantic radicals possess a clear meaning or not would have an influence on orthographic learning was put to test in Study 3. Phonograms were observed to be significantly better acquired when embedded semantic radicals were clear in terms of their meaning. However, the semantic transparency between an embedded semantic radical and its character was not established in Study 4 to have a significant effect in Chinese orthographic learning.

In sum, the current findings shed light on how children acquire Chinese orthographies. The self-teaching hypothesis (Share, 1995) is confirmed to be a valid framework in which to study also the process of learning a non-alphabetic orthography, like Chinese. In Chinese orthographic development, phonology plays an important role as well, not least because it provides the bootstrapping connection between extant spoken forms in children's mental lexicon and their corresponding printed forms. Though it remains unclear whether or not the results might be generalizable to other grade levels, findings in the dissertation have shown, at least, 2nd and 3rd graders exhibited reliable orthographic learning via self-teaching. In this respect, the findings from current research in Chinese (e.g., Liu & Shiu, 2011) converge generally on those from alphabetic languages in the literature available for orthographic development. Therefore, the dissertation provides direct support to the cross-linguistic validity of the self-teaching model.

7.2 Limitations

There are, however, limitations to the dissertation. To begin with, the work mainly focuses on the orthographic learning of the mainstream character structure in Chinese character formation—phonograms. It remains unclear whether the findings in the dissertation can be extended to the acquisition of simple characters that occupy altogether a mere 10 to 15% of all the whole volume of Chinese characters.

In hindsight, Share's (1999, 2004) self-teaching paradigm might not be an optimal paradigm for investigation on orthographic learning on several accounts. Improving on Reitsma's (1983) paradigm, Share (1999) integrated context into his experiments. However, the target words were somewhat topicalized in his self-teaching paradigm. With only one target word to be acquired in each short story text, children are more likely to perform at ceiling. This is also unnaturalistic and artificial, as in the everyday reading environment, more than one unknown or unfamiliar words are normally possible to show up in texts. Consideration of the incidental learning paradigm (Ku & Anderson, 2001) offers some improvements to better the popularized self-teaching experimental paradigm. That is, for future research intending to employ a self-teaching paradigm, it is necessary to see to it that the number of embedded targets be augmented in story texts, such that the testing environment would resemble more to naturalistic reading situations than that of Share's (1999, 2004).

Additionally, the questions being asked to check text comprehension were likely to have somewhat highlighted the target word. As a consequence, the attention of participating children may have been drawn to the target words to a greater degree than was necessary; in turn, this might have caused ceiling performance on orthographic choice tasks and exaggerated performance on spelling tasks. A neater design concerning the aspect of comprehension is perhaps to include a few filler questions to diffuse children's attention on target word learning. With these proposed improvements, future research is in a better position to evaluate children's performance on orthographic learning.

7.3 Pedagogical Implications

Based on findings from the dissertation, there are aspects in which education practice and policy could be improved upon. In addition to phonological awareness and the knowledge of phonetic principle, learning to read Chinese is also founded on the establishment of rich, high quality character forms and their corresponding pronunciations (Ehri, 2005; Share, 1995, 2008). These findings are in accord with evidence showing that phonological recoding offers the opportunity to acquire word representations (Bowey & Muller, 2005; Share, 1995). In practice, when children have difficulty decoding a character, sufficient wait time should be provided to allow them to attempt thoroughly to phonologically recode the character. In other words, outside assistance and help should refrain from giving away immediate feedback or correct sound information. In this way, children can benefit from the connection forming process at the attempts to phonologically recode words.

An inspection of teaching methods in the Chinese reading education literature would show that whole language teaching has been predominant in teaching developing Chinese children to read, especially in Hong Kong. This is understandable because emphases on meaning and comprehension coincide not only with the primal goal of reading, but also with the misconception that Chinese writing system is of pure logographic nature. The appreciation of phonological recoding should be made known to educators; more phonology exercises should be integrated in teaching practices. Teaching Chinese should shift toward more phonetic-focused instructions. In so doing, children learning to read Chinese are well-placed to benefit equally from the semantic and phonetic information that is offered in the Chinese script.

7.4 Future Research

Advances in research on orthographic learning have showed that phonological and orthographic processes are likely to be separate, but conceptually linked factors. This is also embodied in the self-teaching hypothesis by the phonology-primary/orthography-secondary tenet. Cunningham et al. (2001) and Hagiliassis et al. (2006) provided empirical evidence in support of separation of the two constructs to some extent. The phonological aspects have been extensively investigated, while more efforts should now be devoted to research into orthographic processes during orthographic development, for the knowledge gained in this area would also further clarify models of reading development and skilled word reading.

In particular, more research into Chinese orthographic learning is needed in every respect, ranging from print exposure through vocabulary knowledge to the influence of context, to name just a few. Because orthographic learning constitutes the building blocks of rapid word identification, a full investigation into the integration of phonology, orthography and semantics in the learning of new word forms would advance our understanding of how Chinese children develop into skilled readers.

Along the line of orthographic learning research, longitudinal studies are of the utmost use for now in terms of examining developmental changes in the cognitive skills that children bring to bear upon orthographic learning as they progress into higher grades. Studies focusing on both alphabetic and non-alphabetic orthographies should invest more efforts in this direction as well. The profiling of developmental changes in orthographic development across different orthographies and writing systems would contribute considerably to the comprehensive understanding of reading and orthographic development across different orthographies.

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Appendices

Appendix 1: Target Items and Homophonic Foils in Study 1

	Set A		Set B	
Pronunciation	Target	Homophone	Target	Homophone
/jao1/	珓	詨	詨	珓
/pi2/	柀	佊	佊	柀
/gong1/	仜	矼	矼	仜
/xing1/	浧	珵	珵	浧
/zhao1/	鞀	弨	弨	鞀
/tong2/	迵	絧	絧	迵
/zhong1/	狆	訲	訲	狆
/qing1/	棈	埥	埥	棈
/yuan2/	縓	獂	獂	縓
/jia3/	[illegible]	狎	狎	[illegible]

Appendix 2: Target Items and Homophonic Foils in Study 2

Pronunciation	Target	Homophone
/yuan2/	爰	楥
/jiao1/	詨	珓
/zhi3/	黹	⿰亻黹
/xing1/	珵	浧
/si4/	兕	⿰亻兕
/tong2/	迵	絧
/shi3/	豕	⿰氵豕
/qing1/	精	埥
/yuan2/	獂	縓
/rou2/	厹	⿰阝厹

Appendix 3: Target Items and Homophonic Foils in Study 3

Pronunciation	Target	Homophone
/jao1/	詨	珓
/pi2/	⿰白皮	柀
/gong1/	⿺廴工	矼
/xing1/	⿰阝星	瑆
/zhao1/	⿰爿召	弨
/tong2/	烔	絧
/zhong1/	狆	訲
/qing1/	⿰彳青	埥
/yuan2/	⿰忄原	獂
/jia3/	⿰魚甲	狎

Appendix 4: Target Items and Homophonic Foils in Study 4

Pronunciation	Target	Homophone
/jao1/	鞍	珓
/pi2/	詖	彼
/gong1/	矼	仜
/sheng1/	泩	坓
/zhao1/	柖	弨
/tong2/	軐	絧
/zhong1/	狆	柛
/qing1/	犄	埥
/yuan2/	獂	騵
/jia3/	鉀	坷

Appendix 5: Sample Text in Studies 1 and 2

Without Zhuyin

全世界最熱的地方

全世界最熱的地方，叫作台鉀。台鉀位在沙漠的正中央。在台鉀日溫可高到六十度。台鉀熱到連一滴水都沒有，車子開到那裡連輪胎也都會融化。在台鉀，房子都建在地面下。遠離太陽的熱。住在台鉀的人，每天都吃很多冰來散熱。台鉀的冰淇淋非常的冰。要是不習慣吃冰的話，最好要小心！你想住在台鉀嗎？

With Zhuyin

全世界最熱的地方

全世界最熱的地方，叫作台鉀。台鉀位在沙漠的正中央。在台鉀日溫可高到六十度。台鉀熱到連一滴水都沒有，車子開到那裡連輪胎也都會融化。在台鉀，房子都建在地面下。遠離太陽的熱。住在台鉀的人，每天都吃很多冰來散熱。台鉀的冰淇淋非常的冰。要是不習慣吃冰的話，最好要小心！你想住在台鉀嗎？

問題：

一、　這個地方為什麼特別？

二、　這個地方在哪裡？

三、　當這個地方非常熱時，　有什麼奇怪的事情發生呢？

Translation

The hottest place in the world

The hottest place in the world is called Taijia. Taijia is located right in the middle of the desert. In Taijia, the temperature can reach 60 degrees. Taijia is so hot that even there isn’t a drop of water at all and the cars that drive around there would have their rubber tires melted away.

The houses in Taijia are built underground, far away from the heat of the sun. The people living in Taijia eat a lot of ice cream everyday just to cool themselves down. The ice cream in Taijia is very icy. If you’re not used to eating ice cream, you’d better watch out! Would you like to live in Taijia?

Comprehension Questions

1. Why is the town in the story special?

2. Where is this town?

3. What strange things would happen in this town when it gets very hot?

Appendix 6: Sample Text in Studies 3 and 4

全世界最熱的地方

全世界最熱的地方在台鉀。車子開到那裡連輪胎也都會融化。在台鉀，房子都建在地面下。遠離太陽的熱。住在那裡的人，每天都吃很多冰來散熱。台鉀的冰淇淋非常的冰。要是不習慣吃冰的話，最好要小心！你想住在台鉀嗎？

問題：

一、這個地方為什麼特別？

二、這個地方房子蓋在哪？

三、當這個地方的人為何要吃很多冰？

Translation

The hottest place in the world

The hottest place in the world is Taijia. The cars that drive around there would have their tires melted away. The houses in Taijia are built underground, far away from the heat of the sun. The people living there eat a lot of ice cream everyday just to cool themselves down. The ice cream in Taijia is very icy. If you're not used to eating ice cream, you'd better watch out! Would you like to live in Taijia?

Comprehension Questions

1. Why is the town in the story special?

2. Where are houses built in this town?

3. What strange things would happen in this town when it gets very hot?