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Chapter One

Introduction

Reading is an important means to acquire world knowledge. It is a complex system of skills which involves various perceptual and cognitive processes such as visual, orthographic, phonological, syntactic, semantic and pragmatic processing; yet literate adults can do it fluently and effortlessly. Numerous studies have shown that orthographic (e.g., Ferrand & Grainger, 1993; Perfetti & Tan, 1998), phonological (e.g., Perfetti & Tan, 1998; Rayner, Sereno, Lesch, & Pollatsek, 1995; Van Orden, 1987), semantic (e.g., Meyer & Schvaneveldt, 1971; Stroop, 1935) and syntactic information (e.g., Frazier, Clifton, & Randall, 1983) is activated very early and automatically during the course of skilled reading.

However, reading occurs not as easily and automatically in children and illiterate adults, and there is a portion of the population suffering from reading problems. As some studies indicated, approximately 13.6% of the population can be classified as poor readers, whereas about 2.3% are dyslexics who have very severe reading difficulty (Rayner & Pollatsek, 1989; Shaywitz, Escobar, Shaywitz, Fletcher, & Makuch, 1992).

Researchers and educators are interested to know what cognitive components are crucial to reading and how a child becomes a skilled reader. These questions provoke extensive research, in part because unraveling the cognitive mechanisms underlying reading is very important both for teaching normal children to become successful readers,
as well as for training children and adults with language impairments (Adams, 1990; Menn & Stoel-Gammon, 1995; Perfetti, 1985).

To date, researchers in general suggest that the construct of phonological awareness is one of the most important factors affecting reading ability, second only to the knowledge of letter names and sounds (Bond & Dykstra, 1967; Chall, 1967), and more significant than social economic status, parents’ education, intelligence, vocabulary, and listening comprehension (e.g., Bradley & Bryant, 1983; I. Liberman & Shankweiler, 1979). Widely-accepted theories of reading acquisition such as stage theories (e.g., Chall, 1983; Ehri, 1998; Frith, 1985), the restricted-interactive theory (Perfetti, 1991) and the interactive analogy model (Goswami, 1993) include phonological awareness as a critical component of reading development and assume a robust correlation between phonological awareness and success in reading. This assumption has been supported by a large body of experimentation with normal children (e.g., Bradley & Bryant, 1983; Burgess & Lonigan, 1998; Cheung, 1999; I. Liberman, Shankweiler, Fischer, & Carter, 1974; Lundberg, Frost, & Petersen, 1988; Muter & Snowling, 1998; Perfetti, Beck, Bell, & Hughes, 1987; Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue, & Garson, 1997). Research with dyslexics suggests that deficits in phonological functioning are a major cause of poor reading, providing a corroboration of the centrality of phonological awareness in reading development (e.g., Bradley & Bryant, 1978; Bruck, 1992; Bruck & Treiman, 1990; Catts, 1996; Landerl, Wimmer & Frith, 1997; Olson, Wise, Conners, Rack, & Fulker, 1989; Rozin, Poritsky & Sotsky, 1971;

The general consensus of the centrality of phonological awareness is consistent with the theoretical perspective of an alphabetic writing system that graphemes, the basic symbols of writing, represent phonemes, the smallest perceptual units of speech (I. Liberman, Liberman, Mattingly, & Shankweiler, 1980). Phonological awareness\(^1\) usually refers to the ability to conceive of spoken words as sequences of sound or phonemic segments which correspond to the written units and to access and manipulate those segments in words (Gleitman & Rozin, 1977; I. Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977; Wagner & Torgesen, 1987). It is a kind of metalinguistic ability that requires the explicit knowledge of the phonological structure of speech, as opposed to normal conversation which involves mainly automatic and unconscious processing (Tunmer, Herriman, & Nesdale, 1988). Awareness of the linguistic structure of both the written and spoken language and the understanding of the relation between the two enables readers to derive the meanings of printed words that are visually unfamiliar but are in their speaking and listening vocabularies (Adams, Treiman, & Pressley, 1998). This connection between print and speech can be established through implicit induction from lexical representations (Fletcher-Flinn & Thompson, 2000) or

\(^1\) Some researchers use the terms "phonological awareness" and "phonemic awareness" interchangeably. However, there are subtle differences between the two, with the latter specifically referring to the conscious awareness of spoken words as consisting of isolated phonemes and the ability to manipulate those phonemes. Phonological awareness is a more general term which refers to the awareness of spoken words as consisting of sound segments, including syllables, subsyllabic units such as rimes and onsets, and phonemes.
through explicit training in letter knowledge (knowing the names and sounds of letters) (Adams, 1990; Perfetti, 1991). In fact, letter knowledge, together with phonological awareness, is found to be a strong predictor of preschoolers' and young readers' reading success (Bradley & Bryant, 1983; Byrne & Fielding-Barnsley, 1989; Chall, 1967; Muter, Hulme, Snowling, & Taylor, 1997; Shankweiler, 1999; Share, 1995; Treiman & Baron, 1983).

Is the importance of phonological awareness in learning to read universal across languages? Specifically, is there a similar relationship between phonological awareness and reading in a non-alphabetic language where the speech-writing mapping is less systematic and, if so, what is the nature of phonological awareness for a non-alphabetic language? So far, available research on these issues has generated mixed evidence.

The present study was intended to extend this line of research by focusing on the Chinese language. As will be described in Chapter three, Chinese is a logographic writing system where the script does not encode phonemes of the spoken language. Rather, Chinese characters map onto meaningful morphemes of speech and are pronounced as a monosyllabic unit. Thus, unlike English and other alphabetic systems that are abide by grapheme-phoneme conversion rules, in written Chinese, grapheme-phoneme mappings are impossible. The salient features of Chinese as morphemes and monosyllabic units have led some linguists to suggest that written Chinese is a morphemic or morpho-syllabic system (de Francis, 1989). In previous research on reading development, researchers
have inferred, based on the understanding of the characteristics of Chinese, that learning to read Chinese undergoes processes which are substantially different from learning to read alphabetic writings (Baron & Strawson, 1976; Rozin & Gleitman, 1977; Smith, 1985). By examining what cognitive processes are crucial to beginning Chinese reading, we can get an insight of how to teach children to learn to read Chinese and whether the central importance of phonological skills on reading is a universal phenomenon or is contingent on the linguistic characteristic.

This dissertation contains seven chapters. The following chapter provides a review of the research concerning the role of visual-orthographic and phonological processing on reading acquisition in alphabetic languages (English in particular). Chapter three introduces the characteristics of the Chinese language and presents a review of the research using Chinese. Chapter four first presents a brief analysis of some common and contrastive features of previous research on the role of phonological awareness in Chinese reading acquisition, then articulates the basic assumptions and questions of the present research. A common feature existing in the previous work on Chinese reading acquisition is that researchers generally treated phonological awareness as a single entity, and they assessed phonological awareness by using one or at most two tasks. As will be discussed in Chapter two, there are different levels of phonological awareness, namely phonemic, syllabic and subsyllabic (rime and onset), which may entail different relationships with reading success. Given that Chinese characters map onto the syllables but not phonemes of the speech, and that they have traditionally been conceived
of as analyzable into two sub-syllabic units -- the onset and the rime, it is likely that syllabic or onset-rime awareness is more important than phonemic awareness in Chinese. In addition, previous research focused on Taiwan and Hong Kong but not Mainland children. Because a learning tool known as Hanyu Pinyin which uses a set of Roman alphabet letters to represent the sound of characters is taught in Mainland China (see Chapters three and four for a detailed description of Hanyu Pinyin), it is likely that this pinyin system may affect the way children learn Chinese characters. Chapter four presents the questions to be addressed in this research. Chapter five reports the findings of a cross-sectional study where Mainland children's phonological and visual-orthographic processing skills, pinyin knowledge and reading ability were assessed and the correlations between these variables were obtained. Children from grades 1 to 5 were recruited in the study and the developmental pattern of reading acquisition was investigated from a cross-sectional perspective. Four tasks were used to assess phonological awareness, which tap both onset-rime and phonemic awareness. Chapter six reports a longitudinal study where children's reading ability and pinyin knowledge were assessed again one year later and the longitudinal relationship between the cognitive skills and reading ability was investigated. Chapter seven provides a general discussion and conclusion of the findings.
Chapter Two

Research on Reading Acquisition Using Alphabetic Languages

2.1 Word Recognition and Reading Comprehension: Two Fundamental Processes Involved in Learning to Read

Reading acquisition involves two fundamental processes: learning to decode the print (i.e., visually recognize the words), and comprehending the meanings of the print (Gough & Tunmer, 1986; Hoover & Gough, 1990). Comprehension skill is acquired in the course of learning to speak, and reading comprehension processes are very similar to listening comprehension processes. Decoding skill, however, requires special experiences that do not occur in the normal course of conversations. The characteristics of the writing systems may constitute constraints on the acquisition of decoding skill (Ehri, 1998; Goswami, 1999; Hoover & Gough, 1990; Landerl et al., 1997).

Past studies using alphabetic languages revealed that the relationship between reading comprehension and the ability to recognize words is quite strong (e.g., Biemiller, 1977; Curtis, 1980; Hoover & Gough, 1990; Perfetti & Hogaboam, 1975; Shanahan, 1984; Stanovich, Cunningham, & West, 1981). Moreover, it is suggested that efficient decoding skill is a keystone to successful reading comprehension (Calfee, Spector, & Piontkowski, 1979; Golinkoff & Rosinski, 1976; Torgesen, 1986). Contemporary reading research, as well as many reading development
theories, is therefore to a great extent focused on the processes of word recognition (Cole & Jakimik, 1978).

In the following sections, empirical evidence on the types of cognitive processes that influence beginning reading, operationally measured by word reading ability, will be reviewed.

2.2 Phonological and Visual-Orthographic Processing:

Two Basic Component Skills in Word Recognition

Reading begins with an encounter of a printed word. Thus, visual-orthographic processing of the visual input initiates the reading process. Processing of visual-orthographic information leads to the acquisition and reconstruction of lexical representations in long-term memory. It has been proposed that the essential development in learning to read is the acquisition of lexical representations, which involves both an increase in the number of orthographically addressable lexical entries and an increase in the quality of the lexical representations (Perfetti, 1992).

However, visual analysis only of the input is not sufficient for success in reading, because learners need to understand the meanings of words and represent the information processed in long term memory. To achieve this goal, learners must decode printed words to sound structures or phonological representations of spoken language, which helps keep information in short-term and long-term memory and integrate information from words and phrases into a coherent, dynamic state (Baddeley, 1986; Leonard, 1995). Preceding research has agreed that
visual-orthographic processing and phonological processing constitute two basic component skills in the beginning phases of learning to read and spell (Baron, 1977; Barron, 1980; Olson, 1985).

A question provoking considerable research interest is whether the visual-orthographic processing skill or the phonological processing skill (or both) is crucial to beginning reading. So far, numerous studies have been conducted to investigate this issue.

2.3 The Contribution of Visual-Orthographic Skills on Reading Acquisition

Visual processing generally refers to the processing of gross aspects of words that are independent of identifying letters, such as word length and word shape, whereas orthographic processing refers to the processing of the information specific to the letters making up a word, such as distinctive features of letters and specific letters (Rayner & Pollatsek, 1989). In a specific language, some letter patterns occur more frequently than others, some are more frequently located in specific spatial positions within words, while some are not permissible. These frequency and spatial position patterns in words are regarded as the orthographic information (Corcos & Willows, 1993). It is suggested that knowledge of orthographic information speeds up the word recognition process because expectancies of letter and letter groupings help converting the unit of perception from letters to groups of letters (Samuel, Miller, & Eisenberg, 1979).
There are a few studies investigating the role of visual skills on reading success. A study by Willows, Corcos and Kershner (1993) found that visual processing skills accounted for a portion of variance in reading in children aged 6 to 8. Visual processing skills were measured by (1) the block design and coding subtests of the Wechsler Intelligence Scale for Children -- Revised (Wechsler, 1974), (2) five subtests of the Test of Visual Perception Skills (Gardner, 1982), and (3) the Developmental Test of Visual-Motor Integration (Beery & Buktenica, 1981). Results of multiple regression analyses showed that visual processing skills collectively accounted for 18% of variance in word recognition and 17% of variance in reading comprehension, although memory and linguistic factors accounted for the largest portion of variance in their study.

Orthographic processing skills are also found to be related to reading acquisition. Olson et al. (1989) studied 86 pairs of twins (mean age = 10.3). They measured orthographic skills by having subjects push one of two buttons as quickly as possible to designate the word in word-pseudohomophone pairs (e.g., RAIN and RANE) that were presented on a computer screen. Phonological skills were measured by having subjects read pronounceable nonwords (e.g., CALCH) aloud as quickly and accurately as possible when each stimulus appeared on the computer screen. Results of hierarchical regression analyses showed that the independent contribution of orthographic and phonological skills to word reading performance were 10% and 8% respectively. Interestingly, they found that phonological, but not orthographic skills, were highly heritable (see also Hohnen & Stevenson, 1999, for a similar finding).
Some research suggests that the effect of orthographic skills on learning to read varies with age or reading experience. Juel, Griffith and Gough (1986) found that orthographic skills measured by the ability to recognize words that are incorrectly spelled accounted independently for 3% of variance in word reading ability in first graders and 20% of variance in second graders, whereas phonological skills measured by the ability to read nonsense words aloud accounted uniquely for 21% of variance in word reading ability in first graders and 4% of variance in second graders. This shift in influence between phonological and orthographic skills is in line with that of other studies that have found increased direct, non-mediated processing of words as readers become more skilled (Barron, 1981a; Posnansky & Rayner, 1977).

Research further points out that the impact of orthographic processing on reading may vary with the tasks used to assess reading achievement. Barker, Torgesen, and Wagner (1992) assessed the reading ability of 87 third graders (mean age = 9 years, 5 months) by using five different reading tasks: Untimed word reading accuracy, timed word recognition test, oral reading of words in context, silent reading of words in context, and accuracy for reading nonwords. Two measures of orthographic processing skills were used in their study. The first was the orthographic choice task which required the child to pick the correct spelling from two choices that sounded alike (e.g., BOTE vs. BOAT). The second task was the homophone choice task which required the child to first read a sentence (e.g., “What can you do with a needle and thread”?), then to choose from two real-word homophones (e.g., SO and SEW) the
word that represented the answer to the question. They found that, for all five of the reading measures, orthographic skills accounted for significant independent variance in reading ability after the effects of age, IQ (both verbal and nonverbal) and phonological ability measures were partialled out. Moreover, the role of orthographic processing in reading of text was stronger than for isolated words, which suggests that fluent access to visual word representations plays a special facilitative role in the reading of connected text. Furthermore, orthographic skills contribute more to the timed reading measure than to the measures that did not emphasize speed of response. These findings are consistent with Samuel et al.'s (1979) suggestion that orthographic information provides faster access to the mental lexicon and hence speeds up the word recognition process, which in turn leads to better text comprehension.

2.4 The Role of Phonological Processing in Reading Acquisition

Despite some evidence for the unique contribution of visual-orthographic processing in beginning reading, at present a dominant view has been that phonological processing is a better predictor of reading abilities than visual-orthographic processing. According to this view, learning to read and spell in English and other alphabetic writing systems depends upon phonological rather than orthographic skills; visual and orthographic processing is at best weakly related to reading acquisition (e.g., Barron, 1980, 1981b; Bradley & Bryant, 1978, 1983; Carr, 1981; Hogaboam & Perfetti, 1978; I. Liberman, 1971; Mitchell, 1982; Rutter,

Phonological processing is commonly referred to as a process converting visual representation of a word or a sentence into abstract phonological code. Phonological processing skills usually are taken to consist of the following three sub-components (Wagner & Torgesen, 1987): (1) phonological coding in short-term memory, (2) phonological representations in long-term memory, and (3) phonological awareness. So far different tasks have been used to access the three phonological skills.

Phonological short-term memory is usually assessed by tasks that either require the brief, verbatim retention of sequences of familiar verbal items like digits or words or require the repetition of novel verbal strings like nonsense words (Stone & Brady, 1995). These tasks access phonological short-term memory because they require the representation, or coding, of information in terms of its phonological features (Baddeley, 1986).

Rate of access to phonological information in long-term memory has typically been assessed by asking children to name, as rapidly as possible, a series of 30 to 50 familiar items (digits, colors, letters, or objects) printed on a page (Denckla & Rudel, 1976).

Numerous tasks have been used by researchers or in the classroom to test or teach phonological awareness skills (McBride-Chang, 1995; see Lewkowicz, 1980 for a comprehensive review). Tasks commonly used include alliteration/rhyme oddity (to identify the odd one out based on the initial or final sound) (e.g., Bradley & Bryant, 1983), phoneme counting
(to count the number of phonemes in a word) (I. Liberman et al., 1974), phoneme blending (to blend a sequence of isolated speech sounds into a word) (Fox & Routh, 1976; Williams, 1980), phoneme deletion (to pronounce a word by omitting a designated phoneme) (Bruce, 1964; Calfee, Chapman, & Venezky, 1972), and phoneme isolation (to name a designated phoneme in a word) (Wallach & Wallach, 1976).

Adams (1990) categorized the tasks of phonological awareness according to five levels of difficulty: (1) to hear rhymes and alliteration as measured by knowledge of nursery rhymes; (2) to do oddity tasks (comparing and contrasting the sounds of words for rhyme and alliteration); (3) to blend and split syllables; (4) to perform phonemic segmentation (such as counting out the number of phonemes in a word); and (5) to perform phoneme manipulation tasks (such as adding, deleting a particular phoneme and regenerating a word from the remainder). These tasks can also be classified based on the linguistic unit (syllable, onset-rime, phoneme) as well as the position (initial, middle, or final) of the unit that is manipulated (Stahl & Murray, 1994), or based on whether the test items are real words or pseudowords (Wagner, Torgesen, Laughon, & Simmons, 1993).

Previous research has demonstrated that performance on each of the three phonological tasks can predict growth in early reading skill, and children with reading disabilities also differ consistently from normal readers on each kind of task (see Adams, 1990; Brady & Shankweiler, 1991; Share & Stanovich, 1995). However, phonological awareness is,
among the three sub-components, the most important factor in affecting reading growth (Wagner et al., 1997).

### 2.5 Phonological Awareness and Its Relation with Reading

Nowadays, a robust correlation between phonological awareness and success in reading is well documented (e.g., Bradley & Bryant, 1983; Burgess & Lonigan, 1998; Cheung, 1999; Hatcher & Hulme, 1999; I. Liberman et al., 1974; Lundberg et al., 1988; Muter & Snowling, 1998; Perfetti et al., 1987; Wagner et al., 1997). This is true for various phonological awareness tasks such as phoneme blending (e.g., Hatcher & Hulme, 1999; Wagner et al., 1997), phoneme segmentation (e.g., Hatcher & Hulme, 1999; Juel et al., 1986), phoneme counting (e.g., Cheung, 1999; I. Liberman et al., 1974), phoneme deletion (e.g., Muter & Snowling, 1998; Wagner et al., 1997) and rhyme/alliteration detection (e.g., Bradley & Bryant, 1983; Wagner et al., 1997). The relation exists no matter whether intelligence is controlled (e.g., de Jong & van der Leij, 1999; Hatcher & Hulme, 1999; Juel et al., 1986) or not (e.g., Calfee, Lindamood, & Lindamood, 1973; I. Liberman et al., 1974; Wagner et al., 1997).

This finding of the importance of phonological awareness, specifically phonemic awareness, is consistent with the design principle of alphabetic writing systems that allows a close connection between the grapheme of writing and the phoneme of speech (I. Liberman et al., 1980). Each grapheme of the alphabetic writing systems typically represents one
phoneme. A string of graphemes can be translated into phonemes by using grapheme to phoneme correspondence rules, and the meaning of a word is derived through its phonology. Each grapheme/phoneme (e.g., a, b, or t) has no meaning by itself, but a specific combination of these graphemes/phonemes (e.g., bat or tab) conveys meanings. Such systems are primarily phonemic rather than phonetic, as is illustrated by the fact that the p in both pit and spit in the English alphabet system is one rather than two phonemes, even though the sounds are phonetically distinct ([pʰ] in pit, but [p] in spit).

From a biological perspective, our brain is specialized only for processing spoken language but not for processing written language (A. Liberman, 1992). This can be shown by the fact that many children experience reading difficulty without showing equivalent difficulties with the spoken language and that no formal instruction is required for learning to speak but intensive effort and instructions are required for learning to read. In order for reading and writing skills to develop, written language must establish close connections with the spoken language so that the central language device used to process speech can be used to process the written language. The close connections between written and spoken language should be established at a deep, abstract level not merely at a surface, physical level. For example, graphemes must become attached to phonemes, not simply to sounds within words for alphabetic languages.

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2 There is no universally-accepted definition of the phoneme. Some popular ones define phoneme as the speaker’s/listener’s internal representation of a single speech sound, which can have different phonetic features (e.g., Akmajian, Demers, Farmer, & Harnish, 1995), or as a group of similar speech sounds denoted by an alphabet (Coulmas, 1996).
The establishment of such connections, however, is not straightforward. Isabelle Liberman and her colleagues (e.g., I. Liberman et al., 1980) claimed that, due to coarticulation, speech is produced as a continuous stream of sound but not as individual phonological units one at a time. The elements of underlying phonological structure actually overlap with and influence each other. For instance, when we say the word *bad* (/bæd/), we close the lips to produce the bilabial consonant /b/, shape the tongue to produce the vowel /æ/, and move the tongue tip to a specific position to produce the alveolar stop /d/. In other words, we produce three phonological segments into a single pulse of sound instead of three distinct pieces of phonology. Indeed, on a sound spectrogram which displays the changing acoustic frequencies of spoken words over time, it is very difficult to tell where one word ends and other begins. The phonemic segments that comprise spoken syllables are abstract psychological entities that do not lie in the signal itself but lie in the brain. Children may vary in their ability to be consciously aware of the phonological structure of their language and to map print onto speech. The failure to acquiring this kind of metalinguistic awareness is found to be related to reading difficulty (e.g., Bradley & Bryant, 1978; Bruck & Treiman, 1990; Catts, 1996; Olson et al., 1989; Rozin et al., 1971; Shankweiler, 1999; Stanovich & Siegel, 1994; Vellutino & Scanlon, 1987; Wolf & Bowers, 1999).
2.6 The Nature of the Relationship Between Phonological Awareness and Early Reading

Given the extensive empirical evidence and theoretical perspective that phonological awareness is important to (alphabetic) reading success, it is important to understand the exact nature of the relationship between phonological awareness and reading. Three alternative views have been proposed (Wagner & Torgesen, 1987). First, phonological awareness influences reading development. Second, phonological awareness is a consequence of learning to read, and thus a by-product rather than a cause of the acquisition of reading skills. Third, the relationship between phonological awareness and reading development is bidirectional. So far each view has been supported with different sets of empirical data.

2.6.1 Phonological Awareness Affects Reading Acquisition

Research on the predictive role of phonological awareness on early reading generally adopts four approaches. The first approach uses longitudinal design in which performance on some phonological tasks, typically given in kindergarten when children have not yet learned to read, is obtained at the beginning of the research and performance on reading is obtained after a period of time. A significant correlation between these measures suggests a causal relationship, with phonological awareness predictive of later reading performance. Several studies have shown this
causal relationship (e.g., Stuart & Coltheart, 1988; Wagner et al., 1997).

For example, Wagner et al. (1997) conducted a five-year longitudinal study with 216 children who participated in the study from kindergarten to grade 4. Phonological awareness (oddity, phoneme deletion, segmentation and blending) and reading performance (single word and pseudoword reading) were measured once every year. Their results indicated, for every time period, children’s performance in phonological awareness influenced subsequent performance in word-level reading.

However, a solid conclusion that a causal relationship exists cannot be made based only on this approach, as confound variables such as cognitive maturity and family environment may be the true underlying factors that affect reading performance. As a result, some researchers adopt the experimental or training approach to tackle the causal relationship (e.g., Ball & Blachman, 1991; Lundberg et al., 1988; Rosner, 1971; Wallach & Wallach, 1976; Wise, Ring, & Olson, 1999). In essence, training programs are designed to facilitate phonological awareness and subsequent reading performance is observed. The improved reading performance will then imply that the specific phonological skills that are trained are predictive of reading performance. Several studies adopting this approach showed that prereaders or early readers who received extensive training in phonological awareness developed better reading skills than control children who were not trained (e.g., Rosner, 1971; Wallach & Wallach, 1976). For instance, Rosner (1971) showed that
illiterate first graders who received extensive training in phonemic awareness developed better reading skills than control children who were not trained.

Nevertheless, the experimental approach is criticized as being artificial, because the variables that are manipulated may not be applicable to actual reading settings, and the sole use of these training programs does not exclude the possibility that causality operates in the reverse direction also (Bertelson, 1986). Perhaps the best solution is the use of longitudinal and experimental approach in parallel. The experimental approach better controls for the effects in focus and the correlational/longitudinal approach ensures that the variables one is manipulating in the laboratory are relevant to actual reading.

A classic example of the parallel use of longitudinal and experimental approach is provided by Bradley and Bryant (1983). Their longitudinal study revealed significant correlations (ranged from .44 to .57) between preschoolers’ ability to categorize sameness of sounds when they had not started to read and their reading and spelling ability three years later. These relationships remained strong even when the effects of intelligence and memory were removed. The training study showed that training children in categorizing sounds, together with teaching them letter-sound knowledge, considerably affected reading and spelling performance – the training group was ahead of the control group (trained on conceptual categorization only) by 8-17 months in standardized tests of reading and spelling within a period of 2 years.

The third approach that is adopted in the recent literature, usually in
combination with other approaches, is the use of a statistical testing of causal model, structural equation modeling. This approach is a kind of confirmatory factor analysis that allows construction of a coherent model of overall relations rather than a collection of interpretations of individual measures and their relationships. Typically, a study collects multiple measures on phonological awareness and reading ability, and the structural equation modeling approach is applied to test the consistency of a pre-specified causal model with the observed data, and to describe the causal effects and the amount of unexplained variance (Jöreskog & Sörbom, 1993). Several studies adopted the structural equation approach have shown that phonological awareness causally influences subsequent reading skills (e.g., Tornéus, 1984; Wagner et al., 1997). For example, Tornéus (1984) conducted a longitudinal study where 46 dyslexics and 44 control children with normal reading and spelling ability were recruited and measures including children’s cognitive development, language development (language production and language comprehension), phonological awareness (sound segmentation, sound blending, and segment deletion), reading skills (assessed by a silent reading text), and spelling skill (assessed by a dictation test consisting of 30 phonetically spelled common words) were obtained. The method of LISREL (Jöreskog & Sörbom, 1981) was chosen to construct a coherent model of overall relationships of these measures, which showed that language and cognitive development has a direct impact on phonological awareness which, in turn, has a direct influence on spelling, and that reading is dependent on cognitive development and phonological awareness.
Finally, the comparison between good and poor/dyslexic readers is considered as providing supplementary evidence that phonological skills are crucial to reading success. Research on poor readers or dyslexics (who had comparable intelligence as that of normal readers) has generally shown that deficits in phonological functioning are a major cause of poor reading (e.g., Bradley & Bryant, 1978; Bruck, 1992; Bruck & Treiman, 1990; Catts, 1996; Landerl et al., 1997; Olson et al., 1989; Rozin et al., 1971; Shankweiler, 1999; Stanovich & Siegel, 1994; Vellutino & Scanlon, 1987; Wolf & Bowers, 1999). For example, Rozin et al. (1971) showed that children who had failed in learning to read English could rather easily learn to read the same words represented by logographic Chinese characters. Other research has found that dyslexic children have poorer sensitivity to rhyme and alliteration than younger children matched in reading level, (Bradley & Bryant, 1978; Bruck, 1992) or normal readers of the same age (I. Liberman et al., 1977). In addition, dyslexics have difficulty in reading pseudowords (e.g., *wef, sloshon*) which can only be read by applying grapheme-phoneme correspondence rules (Baddeley, Ellis, Miles, & Lewis, 1982; Frith & Snowling, 1983; Jorm, 1981; Seymour & Porpodas, 1980; Snowling, 1980). Frith (1995) proposes that these deficits in phonological skills have a genetic origin -- brain abnormalities affect areas which control phonological processing. Frith’s proposal has been buttressed by more recent brain imaging findings that brain areas responsible for phonemic analysis (e.g., left inferior frontal region, left inferior temporal region, left superior and middle temporal gyri) are significantly less active for dyslexics than for normal readers in...
reading tasks (Brunswick, McCrory, Price, Frith, & Frith, 1999; Georgiewa et al., 1999; Shaywitz et al., 1998).

In summary, phonological awareness is found to be predictive of reading success. However, several studies indicate that phonological awareness is necessary but not sufficient in enhancing children’s reading skill (see Bus & van-IJzendoorn, 1999 for a meta-analysis of previous findings). They suggest the importance of letter knowledge which is necessary for children to understand that there is a systematic relationship between the spelling patterns of words and their pronunciations (e.g., Ball & Blachman, 1988; Bradley & Bryant, 1983; Byrne & Fielding-Barnsley, 1989; Ehri, 1998; Hatcher, Hulme, & Ellis, 1994; Muter et al., 1997; Tunmer & Hoover, 1992). Muter et al. (1997) further argue that both of these two factors (i.e., phonological awareness and letter knowledge) should act in an interactive fashion to permit good progress in learning to read.

2.6.2 Reading Affects the Development of Phonological Awareness

Support for the view that reading affects the development of phonological awareness mainly comes from poor performance on phonological tasks that has been shown by adult illiterates (Morias, Cary, Algria, & Bertelson, 1979), prereaders (I. Liberman et al., 1974; Wimmer, Landerl, Linortner, & Hummer, 1991), and readers whose (first) written language is nonalphabetic (Cheung, 1999; Holm & Dodd, 1996; Mann, 1986; Read et al., 1986). The rationale behind these studies is that if
children can read words and texts accurately before they can segment words into phonemes, or if the ability to perform phonological awareness tasks is contingent on reading experience or the properties of the written script, it is difficult to argue that this manipulation is a reading prerequisite (Murray, 1998).

Morais et al. (1979) examined the causal status of the relation between phonological awareness and the acquisition of reading skill by studying individuals who came from a poor agricultural community of Portugal. Thirty individuals who had never received training in reading (the illiterate group) and 30 individuals who had learned to read beyond the usual age (the literate control) participated in their study. Two tasks were presented to subjects: Saying words and nonwords without one of their sounds (e.g., purso became urso), and adding sounds to words and nonwords (e.g., uva became chuva). Percentages of correct responses for illiterates on the deleting sounds task were 26% for words and 19% for nonwords, compared with 87% and 73%, respectively, for the literate control subjects. Percentages of correct responses for illiterates on the adding sounds task were 46% for words and 19% for nonwords, compared with 91% and 71% respectively, for the literate controls. These results led Morais et al. to conclude that phonological awareness does not develop automatically without learning to read an alphabetic script and hence may not be a precondition for learning to read and write. However, they pointed out that the absence of explicit knowledge of phonemic segmentation does not automatically imply that segmentation skill is not used at all during speech processing. It is important to distinguish
between the processing of a linguistic unit at an unconscious level and the ease of access to the same unit at a conscious, metalinguistic level.

Read et al. (1986) provided further support that it is learning to read an alphabetic system that allows phonological awareness to develop. They compared two groups of Chinese readers from Mainland China in the same phoneme segmentation task: those who could read an alphabetic system for representing Chinese (i.e. pinyin) and those who could read only the logographic script. Subjects who could read only the logographic characters could not add nor delete individual consonants in spoken Chinese words, whereas alphabetic readers could perform the same tasks readily and accurately. Read et al. concluded that segmentation skill develops in the process of learning to read and write alphabetically but does not develop with cognitive maturation nor nonalphabetic literacy.

Additional support comes from evidence that orthographic knowledge is being used in phonological awareness tasks. Ehri and Wilce (1980) reported that, when fourth-graders were asked to count the number of phonemes in orally presented words, some children report three phonemes for words such as RICH but four phonemes for words such as WITCH. Both words contain three phonemes, but WITCH has one more letter than RICH.

Similar findings were obtained when using pseudowords. Tunmer and Nesdale (1982) adopted a phoneme tapping task (I. Liberman et al., 1974) in which segments of an orally presented word have to be indicated by the number of taps. Stimuli composed of real words and pronounceable pseudowords, with half of the items in each category
containing digraphs (e.g., WITH, MAN, GITH, and ZAN). The task was administered to a sample of kindergarten and first-grade children. Results indicated that beginning readers tended to overshoot on both the real words and the pseudowords containing digraphs. Tunmer and Nesdale suggested that these beginning readers used their developing knowledge of the grapheme-phoneme correspondence rules to generate a graphemic representation of the auditory word and then tapped out the graphemes rather than the phonemes.

These is also evidence showing that, compared to a phonic instruction approach, a whole-word instruction approach delays children's phonological awareness (Alegria, Pignot, & Morais, 1982). Based on these result findings, Ehri (1989) argues that learning to read and to spell facilitates phonological awareness rather than vice versa.

In summary, several empirical studies using adult illiterates or non-alphabetic readers have indicated that phonological awareness, or more specifically, phonemic awareness, is a consequence of reading development.

2.6.3 Reciprocal Relations of Phonological Awareness and Reading

The seemingly contradictory results that phonological awareness is both a predictor and a consequence of reading acquisition lead some researchers to suggest that the relationship between phonological awareness and reading ability is reciprocal (Bertelson, 1986; Burgess & Lonigan, 1998; Ehri & Wilce, 1980; Goswami & Bryant, 1990; Perfetti et
Bertelson (1986) argues that both reading acquisition and phonological awareness are global constructs that involve complicated processes and hence a unidirectional causal relation between them would not be observed. To expect a unidirectional relation, both constructs should be broken down into simpler episodes.

Interestingly, the literature reviewed above has indicated that, studies supporting the notion that phonological awareness is a consequence of reading generally manipulated phonological awareness at the phoneme level, while those supporting the view that phonological awareness enhances reading success manipulated phonological awareness at a more general level, which could be onset-rime or phoneme level. In fact, some researchers have suggested that different levels of phonological awareness entail different relationships with reading acquisition. This speculation is demonstrated clearly in a longitudinal study by Perfetti et al. (1987), where children were tested at four points throughout a year on tasks of reading ability and phoneme blending, deletion and tapping. They found that phonological analysis skill (as measured by the phoneme deletion task) that taps a sophisticated phonemic segmentation ability bears a reciprocal relation with reading: Gains in reading enable gains in deletion which enable further gains in reading. Phonological synthesis skill (as measured by the phoneme blending task) that taps a less sophisticated but more essential phonemic knowledge has a simple, non-reciprocal relationship to reading gains. Perfetti et al. concluded that rudimentary ability to manipulate isolated segments (such as blending
phonemes into syllables) plays a causal role in reading acquisition, which, in turn, plays a causal role in the development of higher level, more sophisticated skill in phoneme manipulation (such as phoneme deletion and tapping).

Similarly, Goswami and Bryant (1990) argue that there are different levels of analysis for spoken words and awareness of these develops at different rates. The gist of their argument lies in the importance of two sub-syllabic units: the onset and the rime. Within each linguistic syllable, the rime comprises the peak (vowel nucleus) and an optional coda (final consonant or consonant cluster), and the onset refers to the consonant or consonant cluster preceding the vowel (if any). To illustrate, the monosyllabic word “strong” consists of an onset /str/ and a rime /ong/, while the monosyllabic word “in” consists of a zero onset and a rime /in/.

Many linguists and psycholinguists have argued that syllables in English and related languages are not just linear sequences of phonemes; rather, they have a hierarchical structure consisting of the onset and the rime (Cairns & Feinstein, 1982; Fowler, Treiman, & Gross, 1993; Fudge, 1969; MacKay, 1972; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). This idea has received support from the findings that adults (Treiman, 1983) and children (Treiman, 1985) found it easier to break up a syllable at the boundary between the onset and the rime than to break up the onset or the rime, and that subjects took longer to search for a target phoneme (e.g., ‘s’) when it was part of a consonant cluster (e.g., ‘s’ in the syllable ‘spa’) than when it was an onset (e.g., ‘s’ in the syllable ‘sap’) (Treiman, 1983). In addition, first graders made 21.9% more errors on
words with less consistent rime units (e.g., *cough*) than words with more consistent rime units (e.g., *game*), while they showed no performance difference in words with high (e.g., *doll*) or low (e.g., *pull*) consistent CV (onset plus vowel) units (Treiman et al., 1995).

Goswami and Bryant suggest that awareness of larger linguistic units such as syllables and onset/rime develops preliterately and is causally related to reading acquisition, while awareness of smaller linguistic units, such as phonemes, develops later and is possibly a consequence of learning to read. Their argument is based on the empirical findings showing that children's sensitivity to rimes (measured by rhyme detection or rhyme oddity task) appears as early as 4 or 5 years of age, before they have learned to read, and is highly predictive of their later success in reading and spelling (Bradley & Bryant, 1978, 1983). Children’s ability to segment words by phonemes, however, appears later (usually after 5 or 6 years of age), possibly as a consequence of learning to read (Fox & Routh, 1976; I. Liberman et al., 1974; Rosner & Simon, 1971). Also, phoneme manipulation is difficult for young children (Calfee et al., 1972; I. Liberman et al., 1974) and illiterate adults (Morais et al., 1979) but not for fluent readers.

Burgess and Lonigan (1998) argued that this bidirectional relation of phonological awareness and reading is present relatively early in the development of reading skills, possibly prior to the onset of formal reading instruction. They conducted a one-year longitudinal study with 115 4- and 5-year-old children. Four phonological awareness tests, namely rhyme oddity detection task, alliteration oddity detection task,
blending task, and deletion task were measured and children’s letter knowledge was used as an index of their pre-reading ability. They found that children’s letter knowledge at time 1 predicts children’s phonological awareness at time 2 and vice versa. Moreover, letter knowledge is a better predictor of phonological awareness skills that involve smaller linguistic units such as phonemes than phonological awareness skills that involve larger linguistic units such as syllables or onsets and rimes.

### 2.7 The Effects of Orthographies on Reading Acquisition

We have seen that phonological awareness can be measured at a number of different levels, namely syllabic, sub-syllabic (onset and rime), and phonemic. Both onset-rime and phonemic awareness are found to be good predictors of English reading development, though there are still disputes over whether onset-rime or phonemic awareness is more important to English reading (Bryant, 1998; Bryant, MacLean, Bradley, & Crossland, 1990; Muter et al., 1997). Does the awareness of the same phonological units predict reading development in different alphabetic scripts? Some recent studies seem to suggest not (e.g., Goswami, Gombert, & de Barrera, 1998; Goswami, Porpodas, & Wheelwright, 1997).

Writing systems differ in how their orthography represents their phonology, which is defined as orthographic depth. Scripts that make close correspondences between graphemes and phonemes are said to have shallow orthographies, whereas scripts that do not have a close
correspondence between graphemes and phonemes are said to have deep orthographies (Sebastian-Galles, 1991). The family of alphabetic writing systems has more or less systematic relationship between letters or letter clusters and their pronunciations. This relationship is highly reliable for orthographically transparent scripts, such as Spanish, German and Italian, where the orthography represents phonology in a direct and unambiguous way, with very consistent mappings from individual graphemes to individual phonemes, and grapheme-phoneme correspondences are easier to detect and use. The English orthography is not very consistent at the grapheme-phoneme level, and is generally regarded as more opaque than other alphabetic scripts (e.g., Paulesu et al., 2000; Rozin & Gleitman, 1977). In English, a grapheme may represent more than one phoneme and, on the contrary, a phoneme can be represented by more than one grapheme. In fact, there are 1120 ways of representing 40 phonemes by different graphemes in English (Paulesu et al., 2000). For example, the grapheme \(c\) represents the phoneme /k/ in \textit{can} and the phoneme /s/ in \textit{city}. On the other hand, the phoneme /k/ can be represented by the graphemes \(k\) (as in \textit{kite}), \(c\) (as in \textit{can}), \(q\) (as in \textit{queen}) or \(ch\) (as in \textit{choir}). In addition, there are many exception words which have irregular spelling-sound correspondences. For example, while \textit{ave} in \textit{cave}, \textit{save}, \textit{gave}, \textit{pave} and \textit{brave} has the same pronunciation, it sounds differently in \textit{have}. A more extreme example is demonstrated by the spelling pattern \textit{ough}, which has different pronunciations in \textit{cough}, \textit{dough}, \textit{tough} and \textit{through}. There are reports that the low consistency of the English orthography lies mainly in the vowels (Treiman et al., 1995). A computational analysis of the
English writing system (Treiman et al., 1995) reveals that the consistency of the initial grapheme (C₁) and the final grapheme (C₂) of English monosyllabic words (having a CVC structure) is rather high, with about 90% words that share the same C₁ (or C₂) have the same pronunciation of the C₁ (or C₂) unit, and each C₁ or C₂ has, on average, 1.5 different pronunciations. On the other hand, the consistency of vowels is much lower, with only about 50% of words that share the same vowel have the same pronunciation of the vowel, and vowels have, on average, 3.3 different pronunciations. In a nutshell, one cannot simply apply grapheme-phoneme correspondences to pronounce exception words correctly but must master knowledge about the whole string.

Interestingly, although the consistency at the level of grapheme-phoneme for English is relatively low compared with other alphabetic systems, the consistency increases at the onset-rime level (Treiman et al., 1995). The same computational analysis as mentioned above shows that VC₂ (which corresponds to the rime of speech) has a more consistent pronunciation than either V or C₁V, with about 80% words that share the same VC₂ have the same pronunciation of the VC₂ unit, and VC₂ has, on average, 1.3 different pronunciations. On the contrary, the consistency of C₁V is much lower, with only about 55% of words that share the same C₁V have the same pronunciation of the C₁V unit, and C₁V has, on average, 1.8 different pronunciations. This finding is consistent with the proposal that an English syllable has a hierarchical structure consisting of the onset and the rime (Cairns & Feinstein, 1982; Fowler et al., 1993; Fudge, 1969; MacKay, 1982; Treiman et al., 1995).
This hierarchical organization of English syllables has been supported by findings of reading acquisition. Goswami and her colleagues (Goswami et al., 1997, 1998) conducted several cross-linguistic studies where children’s nonword reading performance was compared. They generally found that for less-transparent orthographies such as English and French, rime units are functionally more significant than phonemes. On the other hand, in highly transparent orthographies such as Greek and Spanish, children develop orthographic representations that encode individual grapheme-phoneme correspondences, and rime units play a more minor role in these orthographies. Goswami (1999, 2000) suggests that different phonological units predict reading development in different linguistic environments and that the units of phonology predicting reading success in a specific language depend on the way the orthography encodes the phonology.

2.8 Stages of Reading Development: A Review of Theories

Previous research unanimously points to the importance of phonological awareness on alphabetic reading development. Reading theorists generally agree that beginning readers must possess some level of phonological awareness (probably syllabic or rime-onset awareness) before they can learn to read, and learning to read in turn improves their phonological awareness. However, they differ in their views on the nature of phonological awareness that is associated with reading success and the relative importance of phonological awareness on reading success. So far,
several reading development models or theories have been proposed to interpret facts already known about normal reading development as well as developmental reading disorders and to make new predictions.

2.8.1 Stage Models

A variety of stage models of learning to read have been proposed (e.g., Chall, 1983; Ehri, 1998; Frith, 1985; Marsh, Friedman, Welch, & Desberg, 1981; Seymour & MacGregor, 1984). The traditional stage models are essentially descriptive but less explanatory in nature. They share the common view that reading development consists of qualitatively distinct stages and all children pass through the same stages in the same order, irrespective of the orthography that is used. In general, these models specify the cognitive processes or learning strategies underlying reading at each stage and how the processes by which readers acquire higher levels of reading change.

A most influential stage model was proffered by Frith (1985), which suggests that reading development is divided into three stages identified with three strategies used in learning to read, progressing from logographic, alphabetic, to orthographic. During the logographic phase, the “look-and-say” method is predominant and words are mainly identified as unanalyzed whole images. Phonological factors are entirely secondary in a sense that children pronounce the word only after they have recognized it. Next comes the alphabetic stage when the storage of words as unanalyzed images has reached a critical limit and visually
similar words become confused. Children are motivated by the desire to write and through writing, they learn the sounds that each letter represents. The look-and-say method is abandoned and the arbitrary association of selected graphic cues with words is replaced by a more systematic link through letter-sound associations. At this stage, phonemic awareness emerges, and phonological processes and letter order start to influence reading. The acquisition of the alphabetic skills then allows them to read novel and nonsense words.

As reading skills become more automatic, children move on to the final stage when they acquire and utilize orthographic knowledge to identify words. Frith points out that the orthographic strategy is distinguished from the logographic one by being analytic in a systematic way and by being non-visual in the sense that abstract (morphological) units are used to identify words but not salient graphic features; it is distinguished from the alphabetic one by operating in bigger units and by being non-phonological.

Frith asserts that the transitions between stages are abrupt, not smooth and are triggered by developmental factors such as maturation. If this particular developmental process fails, it is likely that the child would not move on to the next step in normal development.

Frith's stage model suffers from a number of limitations (see Snowling, 1998, for a review). First, the mechanisms involved in the transitions between stages are not elaborated. Second, it is contradicted by empirical data indicating that the sequence of reading developmental stages is not universal (e.g., Fletcher-Flinn & Thompson, 2000; Snowling,
Several studies reveal that the reading strategies children use are affected by the teaching instruction that they are exposed to (Johnston & Thompson, 1989) and by children's phonological state at the time when they begin to learn to read (Stuart & Coltheart, 1988). Moreover, orthographic transparency (i.e., how the writing system codes the units of language) has an impact on the developmental sequence (Goswami, 1999; Goswami et al., 1998; Wimmer & Hummer, 1990). For example, if an orthography is highly transparent such as German, beginning readers of this highly transparent orthography adopt an alphabetic stage of decoding without passing through a logographic stage (e.g., Seymour & Elder, 1986; Stuart & Coltheart, 1988; Wimmer & Hummer, 1990).

To take into account of the limitations suffered by Frith's model, some theorists take a different perspective that does not emphasize the qualitative differences between stages. For example, Ehri (1998) identifies four successively emerging phases (pre-alphabetic, partial alphabetic, full alphabetic, and consolidated alphabetic) of reading development in the alphabetic system and provides an account of how one phase transits to another (see Ehri, 1992 for an older version of the sight word reading theory that involves three stages of reading development). According to Ehri, the transition between phases is gradual and continuous and is determined by the degree of involvement of learners' working knowledge of the alphabetic system. Ehri's pre-alphabetic phase is similar to Frith's logographic stage where children make no use of the alphabetic knowledge. When children have acquired low-level phonemic
awareness that enables them to focus on beginning and ending sounds in words, they make partial connections between some of the letters seen in spellings (usually the beginning and/or ending letters) and sounds of words. Children at this partial alphabetic phase have not yet acquired the grapheme-to-phoneme correspondence rules nor the abstract nature of the sounds (phonemes) that are connecting to letters. Although children remember how to read words through this phonetic cue reading, misreading often occurs when other words share the same visual-phonetic cues.

During the full alphabetic phase, children continue to use the alphabetic principle to read words by sight but in a more mature way: Sight words are memorized by forming complete connections between letters and sounds and children no longer make the errors characteristic of phonetic cue reading. Children in this phase are able to read words that they have never seen before by blending letters into a pronunciation. As readers encounter more and more words, decoding skills become automatic during the consolidated alphabetic phase. Readers are able to manipulate multiletter units that may be morphemes, syllables, or subsyllabic units such as onsets and rimes. These larger letter units reduce the memory load involved in storing visual words in memory and hence are favorable for visual word reading. According to this sight word reading theory, phonemic awareness is both a consequence of phonetic cue reading and a prerequisite of the attainment of the orthographic reading skills.

Some other theorists decline the universality of developmental
38 stages among different individuals and orthographies. For example, Stuart and Coltheart (1988) argue that children's pre-literate phonological awareness is crucial to their subsequent reading development. Pre-literate children who are phonologically able (i.e., who can segment an auditory word into its corresponding phonemes) and who have the letter-sound knowledge do not begin reading logographically. Rather, they will apply their phonological skills and letter-sound knowledge to make associations of print and speech based on the first and/or last letter.

2.8.2 Interactive Models

While traditional stage theorists have generally ignored the fact that phonological awareness is a global construct that relates to a number of levels, interactive theorists take into account the fact that phonological awareness and reading ability are not simple constructs but are composites of skills that are highly correlated but differ in the level of difficulty. They conceptualize reading as an interactive development process from the very earliest phases. For example, the restricted interactive model proposed by Perfetti (1991) and the interactive analogy model proposed by Goswami (1993) both postulate that phonological awareness and reading acquisition has a reciprocal relationship. A preliterate child with some rudimentary phonological awareness (such as noticing and producing rhymes) is able to make connections between the knowledge of speech sounds and alphabetic print during the beginning phase of reading acquisition. The connections can be formed at the whole-
word or sub-word level (e.g., syllable, rime-onset, phoneme). As reading progresses, the understanding of the orthographic structure of words will result in an increased understanding of the sound structure, which in turn leads to better understanding of the orthographic structure. Speech-print connections will then be formed at a more refined manner, which finally leads to the acquisition of the grapheme-phoneme correspondence rule and hence the decoding skills. According to Perfetti, decoding is a mechanism that helps increase the size of the mental lexicon by allowing recognition of new words. A child lacking this alphabetic knowledge will evidence problematic reading acquisition.

Goswami particularly emphasizes the importance of rime units and the processes of analogy as having a special status for children who are learning to read in English (although the special status of rime units does not hold for more transparent orthographies such as German). She argues that preliterate phonological knowledge plays an important role in establishing an orthographically-addressable mental lexicon from the earliest phases of development. Awareness of larger phonological units such as syllables and onsets/rimes are acquired earlier, and hence play a more important role to reading development than awareness of smaller units such as phonemes. The associations between the English spoken and writing system start by making rime analogies between the two systems, and children with better onset-rime skills make more rime analogies.

More recently, Goswami (1999, 2000) proposes that the nature of phonological awareness predicting reading development in a particular writing system depends on the phonological structure of the language and,
particularly, how the orthography encodes the phonology. In a very transparent orthography such as German and Spanish, phonemic awareness may play a more important role than in a less transparent orthography such as English (Gombert, Bryant, & Warrick, 1997; Goswami et al., 1998; Wimmer and Goswami, 1994). It is thus likely that the nature of phonological awareness that associates with a very opaque orthography, such as Chinese, may be different from that of alphabetic languages.

2.8.3 The Component Skills Theory

Unlike the above-mentioned theories which provide a detailed description of the processes involved in each developmental stage of learning to read, the component skills theory (e.g., Carr, 1981; LaBerge & Samuels, 1974) provides a more or less general framework for investigating the relations among various cognitive aspects relating to reading development and the mechanisms underlying the developmental changes. It suggests that the mastery of reading depends on establishing an information-processing system that is complex and dynamic in nature and that is characterized by the interaction and cooperation of theoretically isolable component skills such as visual, orthographic, phonological, semantic, syntactic, pragmatic, and prosodic skills (Brown & Haynes, 1985). Unless each of these processes operates properly, nothing else in the system can either.

The information processing system is originally designed for
processing speech and it consists of integrative cognitive processes by which spoken language is processed, comprehended, memorized, produced and used to carry out other acts of thought such as problem solving and decision making (Carr, 1985). To transit from reasonably good listeners to equally good readers, it requires new perceptual processes to be established to extract information from the printed page and to coordinate with already existing integrative processes of comprehension, memory, and thought. These new perceptual processes are highly specialized to deal with the visual domain and they play a central role especially for beginning reading: failure in visual word recognition will lead to failure in reading, and if word recognition is not mastered, little progress toward skilled reading is likely to be made. To understand how these perceptual processes develop and how they affect word recognition, it is important to take account of the differences as well as the similarities between written and spoken language (Carr, 1985). In this way, the perceptual processes involved in processing different languages may be different.

At the very beginning phase of reading, the integrative cognitive processes originally designed for processing speech are used to process reading. But as written language is not a simple manifestation of spoken language and there are some features that are unique to the written language (syntactic constructions, rhetorical devices, and discourse-organizing techniques), additions or modifications to the integrative processes are thus needed to accommodate differences in form and function between written and spoken language (Brown & Haynes, 1985).
These modified integrative skills have to work well with the new perceptual skills, or a reader will be handicapped in reading comprehension.

To account for the changes involved in reading development, component skills theory incorporates the concepts of attention and automaticity. It is a well-known fact that our cognitive capacity is limited and there is more information for processing than our limited capacity can cope with. Attention is generally regarded as the selecting process of information that is of significant relevance and that is within the coping capacity of our limited processing resources (Cherry, 1953; Shiffrin & Schneider, 1977; Treisman, 1960). The more processing effort we devote to one input, the less effort or capacity we have available for processing other inputs. Performance may break down if the attentional demands of the task exceed the performer’s capacity. Researchers distinguish controlled processes, which require attention, from automatic processes, which do not. As practice increases, performance may become automatic, requiring less attentional capacity (Logan, 1979; Shiffrin & Schneider, 1977).

Beginning reading requires attentional resources to be allocated to more fundamental skills involved in word recognition. As reading develops, the focus of attention will shift to higher-level skills involved in sentence and text comprehension (LaBerge & Samuels, 1974; Perfetti & Hagaboam, 1975). In other words, the more fundamental skills such as visual and phonological processing become automatic with practice and consequently less in need of conscious control (Brown & Haynes, 1985).
This automaticity of cognitive processes at word recognition level is essential for comprehending text because if word recognition is slow and capacity-draining, it will adversely affect the integration of text into larger, more meaningful chunks of information (Tunmer & Nesdale, 1985). This speculation gains support by studies showing that good and poor comprehenders of text differ in decoding speed (e.g., Perfetti & Hogaboam, 1975).

In summary, component skills theory postulates mechanisms that could account for the changes involved in reading at different stages. Reading ability can be analyzed in terms of the development and integration of the skill components that comprise it. These skill components are separable, and each skill component can be weak or strong and well or poorly integrated with other components. By modeling reading as an interactive system of these skill components, the component skills theory provides a more comprehensive alternative to single-factor theories of reading ability and disability (Brown & Haynes, 1985; Carr, 1981). It suggests that measures tapping a wide range of reading-related cognitive processes should be administered to each of the subjects in a sample and that the kind of full characterization resulting from component skills analysis is the only way to get an accurate picture of reading ability: how it changes developmentally, and what creates individual differences among readers who are otherwise roughly the same in developmental level (Carr, 1985).
2.9 Summary

A large body of research with alphabets has produced converging evidence for the hypothesis that phonological awareness is associated with, and longitudinally predictive of, reading ability (e.g., Bradley & Bryant, 1983; Burgess & Lonigan, 1998; I. Liberman et al., 1974; Lundberg et al., 1988; Muter & Snowling, 1998; Perfetti et al., 1987; Wagner et al., 1997). Of more interest is that some researchers claim that phonological reading skills provide necessary, although not entirely sufficient, support for the development of good orthographic reading ability. For example, Share and his colleagues (Share, 1995; Share & Jorm, 1987; Share & Stanovich, 1995; see also Ehri, 1998; Goswami, 1993; Perfetti, 1991) have presented a compelling case for the role of phonological reading skills as a critical base for the development of fully specified orthographic representations of words. In this model, emergent skills in phonological decoding, which consist of letter-sound knowledge and a minimal explicit knowledge of sound structure, provide the basis for acquiring accurate orthographic representations of words from the very beginning of the learning process. A basic proposition of their argument is that if children use partial or complete phonological cues to derive an approximate pronunciation for a word in text, and combine this approximate pronunciation with contextual constraints to identify the fully correct pronunciation, the prior attention to individual letters that is involved in alphabetic decoding provides a solid basis for acquisition or refinement of an orthographic representation for the word. Orthographic
representations are acquired by repeated associations of a word’s correct pronunciation with its visual representation. As children’s increasingly developed alphabetic reading skills lead to more detailed analysis of the internal structure of words in print, they begin to acquire increasingly explicit and more fully specified orthographic representations.

This conclusion of the important contributions of phonological processing skills in reading acquisition seems to be important, given that reading, at a first glance, is a visual task. However, an analysis of alphabetic systems suggests the plausibility of the conclusion. The design principle of alphabetic writing systems allows a close relation between the grapheme and the phoneme of the spoken language. Specifically, alphabetic writing follows quasi-regular grapheme-phoneme mapping rules (Plaut, McClelland, Seidenberg, & Patterson, 1996), leading to the salience of phonological processing.

What is the role of phonological processing skills in reading acquisition of an orthographically opaque writing such as Chinese? As reviewed in the previous sections, orthographic transparency has an impact on the developmental pattern of reading acquisition. It is thus likely that reading Chinese entails different cognitive components than those in reading an alphabetic system. In the next chapter, the characteristics of the Chinese writing system will be discussed, and research on reading acquisition using Chinese will be reviewed.
Chapter Three

Previous Research With Chinese

3.1 The Chinese System

As a logographic system, written Chinese uses characters having a square shape as a basic writing unit. Each Chinese character is made up of strokes, which are the smallest structural unit of a character. A stroke has no meaning nor pronunciation. There are 24 distinct strokes (T. Li, 1989). The number of strokes in a character can vary from 1 to 34. For example, the character "一" (meaning one) has one stroke, while the character "磅" (meaning pound) has 15 strokes.

Chinese characters map onto the morpheme (meaning) and cannot be pronounced by recourse to grapheme-phoneme correspondence rules. Thus, a Chinese character has a more direct association with its meaning than a written word in English does (Wang, 1973). The psychological relevance of this salient visual-orthographic property is that the visual-orthographic dimension is an important constituent of the process underlying Chinese reading (Baron & Strawson, 1976; Gleitman, 1985; Jorm & Share, 1983; Perfetti & Tan, 1998; Smith, 1985; Tan et al., 2001).

Although a lack of the grapheme-phoneme correspondence in Chinese makes a fine-grained phonological segmentation at the phoneme level impossible, the Chinese character does map onto a monosyllable, which has traditionally been conceived of as analyzable into two sub-
syllabic units, the onset and the rime. Such a decomposition of the Chinese syllable stems from the practical use of denoting a character’s pronunciation in the Middle Chinese period (roughly during the Sui and Tang dynasties, i.e. A.D. 581-907). Due to the lack of an alphabetic system, linguists in that period adopted a method known as *fanqie* to elucidate how to pronounce a certain character (Baxter, 1992; Halliday, 1981). With the *fanqie* method, the pronunciation of a character is signified by reference to two characters with which one has the same initial consonant as the character being glossed and another shared the same final. For example, the pronunciation of the character 东 (/dong1/, the numeral following the syllable refers to tone) is represented by the combination of the initial of 德 (/de2/) and the final of 工 (/gong1/). This tradition of parsing a Chinese syllable into the initial and the final has been followed in dictionary compiling and character learning over centuries, as well as in the present-day teaching of written Chinese (see introduction to pinyin below). Modern Chinese linguists also follow this traditional conceptual framework and analyze the phonology of modern Chinese in terms of initials and finals rather than the phonemic inventory of consonants and vowels that has been used in analyzing the phonology of alphabetic languages (P. Chen, 1999).

As a tonal language, Chinese uses four different tones (in Mandarin; hereafter Chinese): High level, rising, dipping, and falling.³ These tones are supra-segmental phonological features that change the pitch of the

³ There is an additional “neutral” tone which occurs on unstressed syllables, suffixes, particles and the second syllables of many disyllabic words (Li & Thompson, 1976).
syllable and are lexically contrastive. In the pinyin system, tones are represented by diacritics as follows: “6” (high level tone; e.g., 分, meaning divide), “5” (rising tone; e.g., 坟, meaning grave), “ˇ” (dipping tone; e.g., 粉, meaning powder) and “`” (falling tone; e.g., 愤, meaning angry).

Unlike English, the Chinese syllable has no consonant clusters (i.e. sequences of consonants). As a result, the onset, or the consonantal beginning of a syllable, can only be a single consonant. There are, occasionally, syllables that do not have any onsets. Rimes, or the final part of a syllable excluding the onset, are composed mainly of vowels in Chinese. The only two consonants that occur in the rime of a syllable are the velar nasal /ʃ/ and the alveolar nasal /n/. Chinese has 22 onsets and 37 rimes (C. Li & Thompson, 1981).

Given the small set of onsets and rimes, the number of syllables that can be formed is limited. Not all combinations of initials and finals will give a Chinese syllable, as some are regarded as theoretically impossible (e.g., the combination of /ʃ/ and /o/ is phonotactically impossible in Mandarin), and others are theoretically possible but do not happen to occur (e.g., the combination of /d/ and /uai/ is phonotactically possible but does not occur in Mandarin) (Halliday, 1981). Also, not all syllables have the full range of tones. In fact, only about half of the 814 possible combinations exist, and Chinese has only approximately 1,200 distinct syllables in the present-day usage (when tones are taken into account) (Suen, 1979). Because modern Chinese uses 4,574 characters according to
Xiandai Hanyu Pinlu Cidian [Modern Chinese Frequency Dictionary] (1986), some characters must share one pronunciation. For example, the characters 力 立 粒 例 利 吏 栗 are all pronounced /li4/ (the numeral following the syllable refers to tone). When a syllable is read without context, even a native Chinese speaker would not know which character is referred to. This feature suggests that successful reading in Chinese may depend much on the ability to make appropriate visual distinctions among characters pronounced as homophones. Some researchers further suggest that in the mental representation of Chinese characters, graphic forms of homophonic characters converge on one phonological node, lowering the activation threshold of the phonological node (Tan, Hossain, & Siok, 1996; Tan & Perfetti, 1997). This kind of convergence may lead to phonological information being computed so rapidly that it becomes a constituent of character identification, as assumed by Perfetti and Tan’s (1999) Constituency Model of reading Chinese. Empirical evidence for this assumption has been obtained with a variety of tasks (e.g., Chua, 1999; Perfetti & Zhang, 1995; Tan et al., 1996; Weekes, Chen, & Lin, 1998; Xu, Pollatsek, & Potter, 1999; Ziegler, Tan, Perry, & Montant, 2000). According to the Constituency Model and previous studies of homophones (Tan & Perfetti, 1999), the processing of homophones in Chinese involves both phonological activation of homophonic graphic forms and visual discrimination among these homophones.

Chinese characters may be divided into two categories: simple characters and compound characters. Only a small number of characters are simple ones that cannot be divided into components. More than 80%
of characters are phonetic compounds which are made up of a phonetic radical and a semantic radical (Perfetti & Tan, 1999). In principle, the phonetic radical gives full or partial cues to the pronunciation of the whole character, whereas the semantic radical gives cues to its meaning. However, the validity of the two components differs. By some estimates, only 26.3% of phonetic compounds share a pronunciation identical with that of their phonetic (Fan, Gao, & Ao, 1984). There are no rules for phonetic radicals to specify pronunciations (including tonal information), and phonological information provided by phonetic radicals is insufficient to allow a child to derive pronunciations of unfamiliar characters. Interestingly, although the validity of phonetic radicals in signaling whole characters' pronunciation is low, the radicals' phonology is activated in fluent reading performances, even for characters containing an invalid phonetic (Pollatsek, Tan, & Rayner, 2000).

Semantic radicals tend to have semantic interpretations that are consistent with the semantics of the whole characters (Fan, 1986). In a sense, they give cues to meaning, although they typically offer a general indication concerning the semantic category rather than a precise meaning for the character (Tan, Hossain, & Peng, 1995). They occasionally have, however, no clear semantic relationship with the characters that contain them.

The features of the Chinese writing system introduced above are relevant to Chinese reading acquisition. At some stage, learning to read Chinese must be achieved by rote memory for characters' visual-orthographic components and their associations with corresponding
meanings and pronunciations. This is true for simple characters that include no phonetic radical. In principle, it is also true for phonetic compounds with a phonetic radical, because the phonetic radical is frequently irregular in signaling the pronunciation of whole characters. Indeed, when we take the reliability of phonetic radicals into consideration (Perfetti, Zhang & Berent, 1992), the picture of Chinese reading becomes more complicated. Some phonetic radicals appear in only one Chinese character, while some appear in as much as 26 different characters. Very often, the pronunciations of the characters that contain the same phonetic radical are different from each other. This low reliability, or consistency as some researchers have termed, of phonetic radicals could restrict the derivation of the pronunciation of a character based on the phonetic radical it carries.

Visuo-orthographic processing skills might be dominant at such a stage for several reasons. First, unlike English words that are composed of relatively simple units -- letters, Chinese characters are assembled by unpronounceable strokes in terms of a set of pre-specified sequence rules. At the beginning, it is rather difficult for children to master these rules and assemble strokes into a character. Thus, elaborated visuo-orthographic processing becomes emergent for reading acquisition. Indeed, to acquire stroke assembly rules and memorize characters’ intricate graphic forms for reading, Chinese learners have to perform various exercise tasks including writing. In other words, character writing is used to aid in the mastery of character reading. Second, a number of Chinese characters as logographs have a close association with their
meanings at the visual form level. Language instructors often make use of this feature and focus on visual dimensions of characters during teaching. Third, although the written Chinese characters that children learn at the beginning phase of reading already have corresponding entries in their well-specified auditory mental lexicon, the connection between a written character entry and an auditory lexical entry may be weak and fragile in this stage, because of the extensive homophony in Chinese.

Despite the importance of visual-orthographic knowledge, the role of phonology, including segments and tones, could surface with learning experience. In particular, at a later stage of reading development, children will be able to memorize characters’ visual-orthographic features relatively quickly and, therefore, it becomes possible to allocate more attention resources to characters’ phonological dimensions. In addition, more segmentally homophonic written characters are encountered with learning, which leads discrimination of tonal information to be emergent in helping children to recognize and organize characters sharing the same segments (onsets and rimes) in the mental lexicon.

Nevertheless, the nature of phonological awareness that relates to reading success may be different between Chinese and English. Given the simple structure of a Chinese syllable (which is historically conceived of as consisting of an initial and a final), onsets and rimes, rather than phonemes, are likely to be salient phonological features. It is likely that the sensitivity towards rhymes and alliterations more strongly correlates with Chinese reading success than does the sensitivity towards phonemes. In English, graphemes map onto phonemes of speech, which explains the
finding that letter knowledge and phonemic awareness can most strongly correlate with the development of reading skills.

### 3.2 Previous Research on Learning to Read Chinese

A few studies with Chinese have investigated whether phonological awareness or visual processing is more important to reading acquisition. Huang and Hanley (1995) administered a battery of tasks to 137 8-year-old third-graders from Britain, Hong Kong, and Taiwan. In assessing reading abilities, they asked children to read one hundred unrelated words or Chinese characters aloud. Visual processing skills were measured by a visual form discrimination test that required subjects to select a designated target figure from amongst several choices and a visual paired associates test taken from Wechsler (1987) that required subjects to learn a series of abstract shapes and associate them with a specific color. Phonological awareness was evaluated by two different tasks, an oddity test and a phoneme deletion test. In the oddity test, subjects heard four one-syllable words (e.g., *rot, rod, rock*, and *box* in the English version; or *ba, bo, fei*, and *be* in the Chinese version) and decided which one was the odd word out in terms of its first, middle or final sound. In the phoneme deletion test, subjects told how a certain word would sound if they lost a specific phoneme. Huang and Hanley found that after the effects of IQ and vocabulary skills were statistically partialled out, phonological skills were significantly correlated to reading abilities of the British children but not to reading abilities of the Hong Kong and Taiwan children. In contrast,
visual skills were significantly related to the reading ability of the children from Hong Kong and Taiwan, but not to the reading of the British children.

Huang and Hanley’s result is interesting because it implies that phonological awareness is not a universal predictor of children’s reading ability. Rather, it suggests that the design principles of writing systems impose constraints on the role of phonology: Phonological awareness influences reading acquisition for alphabets that follow quasi-regular grapheme-phoneme correspondence (GPC) rules but does not operate in the same way for logographs that do not abide by GPC rules.

However, other subsequent investigations have reached different conclusions. Hu and Catts (1998) conducted a study with 50 first-graders from Taiwan. Phonological awareness was measured by an oddity task in which half of the trials required children to contrast the stimulus according to the onsets of the words (e.g., bi, ban, hou) and the other half required children to contrast the stimulus words according to the rimes of the words (e.g., ta, po, ma). Visual processing skills were measured by a memory task which consisted of random shapes. Children were required to read 32 Chinese characters as an index of their reading skills. Hu and Catts found that performance on the phonological awareness task, but not performance on the visual task, was highly related to reading skills.

The findings reported by Hu and Catts (1998) seems to contradict Huang and Hanley's (1995) findings. It suggests there is a role for the phonological component in early reading. Interestingly, in another study with 40 first-graders from Taiwan, Huang and Hanley (1997) reported
results in support of Hu and Catts' conclusion. Early phonological skills, as measured by the same oddity and phoneme deletion tests as in their 1995 study, were significantly correlated with later reading ability, but the visual skills showed a nonsignificant correlation with later reading ability.

A study by Ho and Bryant (1997a) seems to have further complicated the picture. They conducted a 4-year longitudinal study to examine the relationship between Chinese children’s visual skills, phonological awareness and their success in reading with one hundred Hong Kong Chinese preschool children (aged 3 years 4 months on average). Visual processing skills were measured by a visual perceptual task. Two phonological tasks, sound detection and partial homophone detection, were used as measures of phonological awareness. In each task, 10 trials of three monosyllabic words (a target word and two choice words) were given to children and they were asked to judge which of the two choices shared some phonological characteristic with the target. In the sound detection task, the target had the same rime and tone as the correct choice (e.g., /hoi2/ /toi2/) but did not rhyme with nor have the same tone as the incorrect choice (e.g., /maau1/). In the partial homophone task, the target and the correct choice shared the same syllable but had different tones (e.g., /jy2/ /jy5/). The incorrect choice shared no such information with the target (e.g., /bo1/). These visual and phonological tasks were conducted within one year after the start of the study. Various tests of Chinese single-character and two-character reading were given in several sessions during the next three years. Results of fixed-order multiple regressions show that visual measures predicted Chinese reading only in
earlier sessions, whereas the phonological measures predicted reading in later sessions. Ho and Bryant concluded that learning to read Chinese progresses from a visual phase to a phonological phase, similar to the developmental pattern in learning to read alphabetic scripts as proposed by Ehri (1992).

A recent cross-sectional study using Hong Kong 3- and 4-year-olds suggests that tasks combining both visual and phonological information are most predictive of Chinese character reading. McBride-Chang and Ho (2000) assessed children's phonological awareness by using a syllable deletion task where children were asked to delete the initial or final syllables of two-syllable words and the initial, middle, or final syllables of three-syllable words. In addition, children's letter naming ability was measured by asking them to name all 26 English letters, presented in a fixed, random order on a sheet of paper. Children's reading ability was measured by using a Chinese character reading tasks. Interestingly, syllable deletion and letter naming were two primary predictors of character recognition. McBride-Chang and Ho argue that letter naming measures an ability of combining visual and speech information together, and suggest that tasks pairing arbitrary visual forms with oral names may be highly predictive of Chinese character acquisition.

The studies introduced above have produced different results. The importance of visual processing skills was demonstrated by Huang and Hanley (1995) but not by Hu and Catts (1998) nor Huang and Hanley (1997). On the other hand, Ho and Bryant (1997a) discovered that visual processing skills predict reading success at an earlier stage (preschool).
and phonological processing skills predict reading success at a later stage (first grade). McBride-Change and Ho (2000) further argue that tasks tapping the ability to combine both visual and phonological skills best predict Chinese reading acquisition. These different patterns of findings could arise for by several reasons. First, their subjects were different in age and reading experience, from preschoolers (McBride-Chang & Ho, 2000; Ho & Bryant, 1997a) to first-graders (Hu & Catts, 1998; Huang & Hanley, 1997) to third-graders (Huang & Hanley, 1995). It is evident that the relationships between various cognitive components and reading performance change with reading experience (Ehri, 1998; Frith, 1985).

Second, the tasks used to measure visual skills and phonological awareness varied across the above studies. Specifically, Ho and Bryant (1997a) adopted a visual task that mainly required subjects to discriminate among figures, whereas Hu and Catts (1998) used a visual task that required subjects to visually memorize figures. Huang and Hanley (1995) used both kind of tasks (though they collapsed the scores of the two tasks into a single measure of visual skills). It is possible that these differential visual tasks tap different visual processing sub-components. Moreover, Huang and Hanley's (1995) and Hu and Catts' (1998) oddity tests had quite different formats. The former requested subjects to pay attention to the initial, middle and final sound differences, and the latter asked subjects to detect onset/rime differences. Huang and Hanley (1995) also asked subjects to perform phoneme deletion, while Ho and Bryant (1997a) asked subjects to check syllabic differences and McBride-Change and Ho (2000) asked subjects to delete syllables. In sum, it seems that Huang and
Hanley's (1995) phonological tasks focused on children's phonemic awareness, whereas Hu and Catts' (1998), Ho and Bryant's (1997a) and McBride-Change and Ho's (2000) tasks centered around syllabic or onset-rime sensitivity. It is likely that, as the Chinese writing maps onto the speech at the syllable level, the sensitivity to the syllabic or onset-rime structure of the spoken language is more important to reading success in Chinese than the sensitivity to the phonemic structure.

Finally, Chinese characters are taught via different methods in Hong Kong and Taiwan, which may have an impact on the centrality of phonological awareness in reading acquisition. Specifically, children in Taiwan learn Zhu-Yin-Fu-Hao during the first 10 weeks of the first grade before they begin to learn Chinese characters. Zhu-Yin-Fu-Hao is a phonetic system devised in 1912, which represents the initial and final sound of characters (Chang, 1981). Zhu-Yin-Fu-Hao adopts 37 symbols which were mostly taken from the ancient Chinese script, where 21 symbols representing various initials, 3 representing medials (the vowel immediately after the initial and before the main vowel), and 13 representing various finals. In fact, Zhu-Yin-Fu-Hao can be regarded as a modification of the fanqie method. The function of Zhu-Yin-Fu-Hao is to help children to form the association of speech sounds and visual symbols (Chinese characters) via a visual modality. In Hong Kong, the majority of children learn to read Chinese characters without first being taught Zhu-Yin-Fu-Hao. In other words, children in Hong Kong learn to recognize Chinese characters based on rote memory without any help from phonetic tools. It is possible that the learning of a phonetic script may facilitate the
development of phonological awareness and a relationship between phonological awareness and reading ability.
Chapter Four

Questions to be Addressed in The Present Research

The review of the previous research indicates that the developmental pattern of Chinese reading acquisition shares some similarities with that of English. In particular, both English and Chinese reading progress from a visual, logographic stage to a phonological stage (Ehri, 1992; Frith, 1985; Ho & Bryant, 1997a), and phonological awareness also plays a role in Chinese beginning reading (Ho & Bryant, 1997a; Hu & Catts, 1998; McBride-Chang & Ho, 2000). These findings are concordant with the hypotheses that there are some universal aspects in reading across all orthographies (Perfetti et al., 1992).

However, linguistic analyses of the Chinese writing system as well as empirical evidence with Chinese suggest that there might be some specialties in reading development across different writing systems. First, because a Chinese visual symbol has more direct association with its meaning than an English word does (Wang, 1973), it is likely that visual-orthographic information plays an important role in Chinese reading (Baron & Strawson, 1976; Gleitman, 1985; Huang & Hanley, 1995; Jorm & Share, 1983; Perfetti & Tan, 1998; Smith, 1985; Tan et al., 2001).

Second, a Chinese character maps onto the syllable but not individual segments, while an English grapheme (letter) has a close connection with a phoneme. This linguistic characteristic of Chinese writing suggests that syllabic awareness plays a more important role than
phonemic awareness in Chinese beginning reading. Besides, linguists have traditionally assumed that phonology of Chinese (syllable) is always analyzable into an initial (onset) and a final (rime), and this tradition of decomposing a Chinese syllable into the initial and the final (evident in the fanqie method) has been adopted in dictionary compiling and character learning over centuries (Baxter, 1992; Halliday, 1981), as well as in modern theories of Chinese phonology (P. Chen, 1999). It is thus likely that onset-rime awareness may also play a part in Chinese reading development. In fact, several studies manipulating phonological awareness at the syllable or onset-rime level (e.g., Ho & Bryant, 1997a; Hu & Catts, 1998; McBride-Chang & Ho, 2000) found a significant relationship between phonological awareness and reading acquisition, while those manipulating at the phoneme level did not (e.g., Huang & Hanley, 1995). These findings are consistent with the theoretical frameworks suggesting that the nature of phonological awareness predicting reading development in a particular writing system depends on the phonological structure of the language and, particularly, how the orthography encodes the phonology (Goswami, 1999).

A major focus of this research is on the nature of phonological awareness for a non-alphabetic language and the developmental pattern of relative contributions of phonological sensitivity and visuo-orthographic processing. Another goal of the present study is to fill out a missing piece of the literature on Chinese reading development. Previous research on Chinese children's phonological awareness recruited subjects from either Taiwan or Hong Kong. However, the majority of Chinese, amounting to
about a quarter of the world's population, reside in Mainland China, but so far there have been no systematic investigations ascertaining the relative importance of phonological awareness and visual-orthographic skills for reading acquisition of Mainland children.

The way Mainland children learn Chinese is different from that of Taiwan and Hong Kong children because, since 1958, an official alphabetic writing system known as Hanyu pinyin has been taught in primary schools, during the first two months in first grade (for about 8 weeks), before children learn to read Chinese characters. Pinyin is essentially a phonemic representation system, using 26 Roman letters. It is used to help children read Chinese characters, usually appearing above the character (see Figure 1). The function of pinyin is similar to that of Zhu-Yin-Fu-Hao in Taiwan, although a sub-syllabic segment is represented by a unique character for the latter while a phoneme is represented by a Roman letter for the former. However, the way pinyin is taught is similar to that of Zhu-Yin-Fu-Hao. The pinyin system is commonly introduced beginning with the names of the 21 consonantal initials, followed by 37 rimes (vowels and nasal finals) (Lehmann, 1975). This analysis of a syllable as containing an onset and a rime reflects the long influence of the traditional Chinese linguistic history – the fanqie rendering. Children are given extensive training in combining these onsets

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4 The 21 onsets used in the pinyin system are b, p, m, f, d, t, n, l, g, k, h, j, q, x, zh, ch, sh, r, z, c and s, and the 37 rimes are i, u, ū, a, o, e, ê, ai, ei, ao, ou, an, en, ang, eng, ong, er, ia, ie, iao, iou, ian, in, iang, ing, iong, ia, iao, iou, ian, in, iang, ing, iong, ua, uo, uai, uei, uan, uen, uang, ueng, üe, üan and ün. These 37 rimes are not necessarily learned as units. As in Zhu-Yin-Fu-Hao, children are told that there are 3 medials (i, u, ū) which could combine with different finals (a, o, e, ê, ai, ei, ao, ou, an, en, ang, eng, ong) to form different rimes (ia, ie, iao, iou, ian, in, iang, ing, iong, ua, uo, uai, uei, uan, uen, uang, ueng, üe, üan and ün).
Figure 1

An illustration of the way pinyin is represented, appearing above Chinese characters. The symbols that appear over pinyin vowels indicate the tone in which the word is spoken.

Xiàoyuán lǐ you sì dà sōngshù.

(There are four big pine trees in the campus.)
and rimes to form meaningful syllables. For example, they learn how to combine /ch/ and /a/, /ch/ and /an/, and /ch/ and /ang/ to form different syllables /cha/, /chan/, and /chang/ in different tones. Children are told that syllables in different tones have different meanings. For example, when the syllable /ma/ has a high level tone, it means mother (/ma1/ ㄕ). When it has a dipping tone, it means horse (/ma3/ ㄕ). Occasionally, a Chinese syllable can be further analyzed as consisting of a medial vowel, the vowel immediately after the initial and before the main vowel. There are 3 medials in Chinese, namely, i, u, ü. Children are given extensive training in combining these onsets, medials, and finals to form meaningful syllables. For example, they learn how to combine the medial /i/ and the final /ong/ to form the rime /iong/, and they learn how to combine the initial /x/ and the rime /iong/ to form the syllable /xiong/ in different tones. When learning nasal finals such as /ong/, children are not told that these sounds can be further segmented into phonemic units (e.g., /o/ and /ng/). Rather, they are told that /ong/ is a unitary phonological element, which can combine with an onset to form a syllable. Thus, through pinyin learning, children become aware of the existence of onsets and rimes in a Chinese syllable. To determine whether learning to read Chinese with the aid of the alphabetic script will lead to the role of phonological awareness and visual-orthographic processing skills being differentially weighted, it is important to investigate reading acquisition with Mainland Chinese children.

In brief, the present research aimed to address the following questions:
(1) What is the relationship between the reading ability of Chinese children and their performance on tests of visual-orthographic skills and phonological awareness? (2) What is the developmental pattern of Chinese reading acquisition? (3) What is the nature of phonological awareness that best relates with Chinese reading? (4) Does pinyin knowledge play a role in Chinese reading development? and (5) Is there a relationship between pinyin knowledge and phonological awareness?
Chapter Five

Study 1: The Cross-Sectional Study

5.1 An Overview

The present study investigated the relationship between the reading ability of Chinese children and their performance on tests of visual-orthographic skills and phonological awareness. To attempt reconcile the discrepant findings reviewed earlier, subjects from grades 1 to 5 were recruited to discover the developmental pattern from a cross-sectional perspective. A comprehensive battery of tests were designed. (See the Method section for a detailed description of these tasks.) In particular, phonological awareness was assessed by the following 4 tasks that varied in linguistic and task complexity: the rhyme-alliteration oddity test, the tone oddity test, the sound blending test, and the sound isolation test. Visual-orthographic processing was measured by two sets of tasks, visual processing tasks and orthographic processing tasks. In this study, the visual form constancy task was adopted to measure visual analysis skills and the visual sequential memory task to estimate visual memory. To examine orthographic processing skills, the component search and the miswriting search tasks were utilized. It is worth noting that the literature on Chinese reading, so far as visual tasks are concerned, tends to look only at visual processing skills. As Frith (1985) has pointed out, the neglecting of the differences between visual/logographic and orthographic
strategies might result in some controversies over the developmental succession of visual and phonological reading strategies.

As noted in the preceding sections, beginning learners of Chinese must acquire some characters by rote memory, even with the help of pinyin. The visual complexity of characters (as estimated by strokes) and their unique square shape should heavily involve visual and spatial recognition processes. Thus, visual processing skills might be crucial to reading success at an early stage of reading development. However, when children have acquired a sizeable number of characters, they may be aware of the fact that certain sub-character components (namely the semantic radicals, phonetic radicals and other orthographic components) appear in many characters and their appearance may be position specific (Y. P. Chen, Allport, & Marshall, 1996). For example, the radical 沙 can only appear on the left side of a character (e.g., 沙 游 汤). This kind of sensitivity to the orthographic structure of Chinese may begin to play a role in reading at a relatively later stage of development. With the development of visual-orthographic analysis skills, children begin to build a strong association between a character's visual graphic form and the pronunciation that has existed in their mental (auditory) lexicon. This association bears resemblance to the association of an English letter (or letter cluster) with its phoneme. Once such an association is established, phonological information may become an important component of reading skills.

In establishing the association of a visual character form and its pronunciation (i.e., syllable), pinyin, by appearing above the character,
serves as a bridge at the earliest phases of learning. In fact, the pinyin system with 26 Roman letters is learnt first (before learning Chinese characters), and leads children to realize that a Chinese syllable can be segmented into onsets and rimes and that Chinese is a tonal language. Imposing pinyin above a character makes children further realize that there is no representation of onsets and rimes in a character. Thus, pinyin as pronounceable alphabetic letters first leads children to map their own visual form (e.g., ma1) to a phonological entry in the spoken mental lexicon. In this sense, it can be inferred that there might be a strong correlation between pinyin knowledge and reading ability at early grades. Acquisition of pinyin knowledge makes explicit segmental and tonal processing of Chinese characters possible (Read et al., 1986). Thus, phonological awareness (as measured by auditory tasks) may be related to the development of children's reading ability. In the present study, children's pinyin knowledge was measured by requiring them to read out 60 syllables written in pinyin. As the pinyin writing follows a letter-phoneme or letter cluster-rime conversion rules, processing of pinyin entails both visual-orthographic as well as phonological components.

Because homophones abound in Chinese, children must learn to discriminate among characters sharing a pronunciation to understand a word or a phrase. Reading out a homophonic character results in the uncertainty of mapping the phonological code onto visual graphic forms - there is a one-to-many correspondence between phonological and graphic form (Perfetti & Tan, 1998). Visual-orthographic processing of the homophone's graphic form allows children to escape from such a
mapping ambiguity. Thus, homophones may be used to examine the role of the combination of visual-orthographic and phonological analyses in predicting reading abilities. In this study, a homophone discrimination task was employed to address this question.

In assessing children's reading ability, two tasks were used: a single-character reading task and a two-character word reading task. These tasks were commonly adopted by previous work on children's reading (Ho & Bryant, 1997a; Hu & Catt, 1998; Huang & Hanley, 1995; McBride-Change & Ho, 2000). In the present study, children's IQ was also measured by using the Chinese version of Raven's Standard Progressive Matrices to partial out any possible influence of intelligence.

5.2 Method

5.2.1 Subjects

One hundred and fifty-four subjects from the Yuquan Primary School in Beijing, China participated in this study. The subjects comprised 37 first graders (mean age = 6 years, 5 months; SD = 3.7 months), 36 second graders (mean age = 7 years, 10 months; SD = 4.4 months), 42 third graders (mean age = 9 years, 1 month; SD = 5.2 months), and 39 fifth graders (mean age = 11 years, 0 month; SD = 3.7 month). According to the class teachers' judgments, all children were of normal intelligence and without any physical handicap. They were native speakers of Putonghua, the official dialect of Mainland China and the language of instruction in school. Children start learning English in grade 4 in Mainland China.
5.2.2 Test Materials and Procedures

The materials consisted of a battery of phonological, visual and orthographic tasks and measures of intelligence, pinyin knowledge and reading achievement. These tasks were similar to those commonly used in the literature and were designed to take account of the characteristics of the Chinese writing system. The phonological, visual and reading tasks were administered individually by trained research assistants in two sessions, each of which took about 30 to 40 minutes. In the first session, children's phonological awareness and visual processing skills were assessed, while in the second their pinyin knowledge and reading ability were measured. The orthographic, homophone discrimination and intelligence tasks were administered in class by class teachers.

I. Phonological Awareness

Children’s phonological awareness was measured individually by the following four tests:

(1) Rhyme-Alliteration Oddity test. Children listened to sets of four syllables. For each set, one of the syllables was the odd one out by virtue of lacking a beginning or ending sound shared by the other three syllables. For example, /duo1/ is the odd one out in the set /wa1/, /wu1/, /duo1/, /wei1/ in terms of the initial sound, and /re4/ is the odd one out in the set /juan4/, /yuan4/, /re4/, /quan4/ in terms of the final sound. This test was similar to Bradley and Bryant’s (1983) and Hu and Catts' (1998) oddity test and was intended to measure children’s onset-rime awareness.

It is interesting to assess Chinese children’s sensitivity to unfamiliar
linguistic structure, because it will help us understand whether phonological awareness develops on the basis of cognitive maturation or needs some special instruction and training. As a result, English stimuli were also used, all having the CVC structure, to see if children could identify the odd one out among unfamiliar syllables. For instance, jeep is the odd one out in the set sad bad jeep had. There were 5 practice items and 10 test items in Chinese. In addition, 1st and 2nd graders received 8 English test items and 3rd and 5th graders received 10 English test items. Half of the items tested children’ sensitivity to rimes and the other half to onsets. The position of the odd word varied systematically in the test. During the practice, feedback was provided to ensure that they understood the test. Also, the experimenter repeated the four words if the child had not given a correct answer. No feedback was provided in the test items. Each word was pronounced with equal emphasis at about 2 second interval during testing. Each correct item received one score and the maximum score was 16 for 1st graders and 20 for other graders. Appendix I shows a sample of the test.

(2) Tone Oddity test. This test had a same format as the rhyme-alliteration oddity test and was intended to measure children’s sensitivity to tone differences. Children listened to sets of four words. For each set, one of the words was the odd one out by virtue of a different tone. There were four practice items for all children. For 1st graders, there were 10 test items. The words in each set of the items shared either the same onset (e.g., /tu3/, /tai4/, /ti4/, /tui4/; /tu3/ is the odd one out) or rime (e.g., /ling2/, /ding1/, /jing1/, /xing1/; /ling2/ is the odd one out). For 2nd, 3rd and 5th
graders, there were 6 additional sets of items, in each of which four words shared no onset nor rime with each other (e.g., /hu1/, /feng1/, /tao1/, /shui3/; /shui3/ is the odd one out). The position of the odd word varied systematically in the test. During the practice, feedback was provided to ensure that they understood the test. The experimenter repeated the four words if the child had not given a correct answer. No feedback was provided in the test items. Each word was pronounced with equal emphasis at about 2 second interval during testing. Each correct item received one score and the maximum score was 10 for 1st graders and 16 for other graders. Appendix I shows a sample of the test.

(3) Sound Isolation test. This test required children to repeat the first, last, or middle sound in a word and was similar to Wallach and Wallach’s (1976) sound isolation test. There were 3 practice items and 24 experimental items (8 items for each position). For the initial and final items, half were Chinese words and the other half were English. For the medial trials, six were Chinese words and two were English words. To illustrate, children had to repeat /b/, /e/, and /i/ when they heard the Chinese words /bang1/, /ke1/, and /xia1/ in the initial, final, or middle trials, respectively. Similarly, they had to repeat /f/, /s/, and /ε/ when they heard the English words fat, bus, and care in the initial, final, or middle trials, respectively. This test was intended to measure children’s phonemic awareness. Each correct item received one score and the maximum score was 24 for all graders. Before the test was conducted, experimenters were given instructions and training on item scoring to ensure that the scoring was consistent and valid across different experimenters. Appendix I
shows a sample of the test.

(4) Sound Blending test. Children listened to isolated segments of sounds and were asked to pronounce the words that resulted when the sounds were blended together. For example, the sounds /h/ and /ao/, or /m/, /i/ and /ao/ were read to children and they were asked to pronounce the word /hao1/ or /miao1/, respectively. Children were requested to make the response in the first tone. There were 10 test items. Each segment was pronounced with equal emphasis at about 1 second interval during testing. Each correct item received one score and the maximum score was 10 for all graders. Appendix I shows a sample of the test.

II. Visual Processing Skills.

The Test of Visual-Perceptual Skills (non-motor) -- Revised (TVPS-R) (Gardner, 1996) was used as a brief and convenient procedure to measure the visual processing skills of children. This is a test standardized in the USA and is suitable for children aged 4 years through 12 years, 11 months. Due to time limitation, only two subtests of TVPS were used in the present study, namely the visual form-constancy and the visual sequential memory subtests. Children were tested individually.

(1) Visual form constancy (VFC). A single visual form (the target) was presented above five other forms on a card. Subjects were asked to find the target among these five forms. The target in these forms might be smaller, bigger, darker, turned, or upside down. There were one practice trial and 16 test trials. If subjects could not give correct answer to the practice trial, they were shown the correct answer with explanation. No
feedback was provided in the test items. Each subject progressed on the subtest until he or she failed four out of five consecutive items. Each correct item received one score and the maximum score was 16 for all graders.

(2) Visual sequential memory (VSM). A card with several figures was presented to the subject for a few seconds (5 seconds for items 1-4, 9 seconds for items 5-8, 12 seconds for items 9-12, and 14 seconds for items 13-16). Then it was taken away and was replaced by a second card. The subject was asked to find the form he or she saw in the first card among the 4 forms shown in the second card. There were one practice trial and 16 test trials. If subjects could not give correct answer to the practice trial, they were shown the correct answer with explanation. No feedback was provided in the test items. Each subject progressed on the subtest until he or she failed three out of four consecutive items. Each correct item received one score and the maximum score was 16 for all graders.

III. Orthographic Processing Skills.

Two tests, administered in the class, were constructed in this section.

(1) Component Search. Subjects were asked to look for a designated orthographic component (口) from among 80 randomly arranged characters (printed on a sheet of paper) that might (e.g., 哦) or might not (e.g., 努) include the designated component. Forty out of 80 characters contained the designated component, and children were requested to circle those characters containing the designated component. This test was
similar to the letter search task used in alphabetic languages (e.g., Mason, 1975) as well as to Chen, Lau, and Yung's (1993) visual analysis task.

Each correct item received one score and the maximum score was 80 for all graders. Appendix II shows a sample of the test.

(2) Miswriting Search. Twenty Chinese characters with their pinyin printed alongside were given to subjects. Ten characters were written correctly and ten were incorrectly by missing one stroke. Subjects were asked to select the incorrect items and to write down the characters in their correct forms. First-graders did not take this test as they had not learned enough characters at the time the test was conducted. Characters were selected from the first year textbook to ensure that students had learned the characters before taking the test. Each correct item received one score and the maximum score was 20 for all graders. Appendix II shows a sample of the test.

IV. Tasks That Involve Both Visual-Orthographic and Phonological Processing

(1) Homophone Discrimination. Subjects were asked to select from among two homophonic characters (e.g., 工 and 公, both pronounced as /gong1/) the one that formed a legal two-character word with another character (e.g., 人 /ren2/). This test was similar to Barker et al.’s (1992) homophone choice task. Although a crucial factor for discriminating the two choice characters in the homophone discrimination task is the orthographic element, previous research on Chinese reading indicated that homophone discrimination and processing are also mediated by
phonological codes (Chen et al., 1993; Tan & Perfetti, 1999). Thus, in this study this task was considered to provoke both orthographic and phonological processing. There were 10 items for 2nd-graders and 10 additional items for 3rd- and 5th-graders. First-graders did not take the test, as they had not learned enough characters at the time the test was conducted. Characters were selected from the first year textbook to ensure that students had learned the characters before taking the test. This test was administered in the class. Each correct item received one score and the maximum score was 10 for 2nd graders and 20 for 3rd and 5th graders. Appendix II shows a sample of the test.

(2) Pinyin Knowledge. Subjects were required to read 60 syllables written in pinyin that were printed on a sheet. All grades were given the same stimuli. Subjects were asked to read the pinyin aloud as quickly and accurately as possible within 1.5 minutes. The time limit was set by asking a good, an average, and a poor reader from each grade (according to teacher rating) who did not participate in this study to read the pinyin aloud and the average time of completion for each grade was taken. This test was administered individually. The number of pinyin syllables that children correctly pronounced was counted. Each correct item received one score and the maximum score was 60 for all graders. Appendix III shows a sample of the test.

V. Reading.

Two tests were devised to assess children’s reading abilities. They were administered individually.
(1) **Single Character Reading.** Subjects were required to read Chinese characters printed on a sheet. There were one hundred characters for 1st-graders and 120 characters for 2nd-, 3rd- and 5th-graders. They were asked to read the characters aloud as quickly and accurately as possible within a time limit. The selection of the characters was based on two resources: (a) *Hanyu Cihui De Tongji Yu Fenxi* [The Statistical Analysis of Chinese Words] (1984), which lists the frequency of words that are used in elementary and high school materials in the Mainland; (b) two sets of primary school textbooks that are used in the Mainland. For 2nd-, 3rd- and 5th-graders, about 80% of characters selected were grade appropriate; the rest 20% appeared in more advanced-level textbooks. For 1st-graders, all the characters had been recently learned.

The time limit was set based on similar criteria as in the pinyin knowledge test. The time limit for all grades was 2 minutes. The number of characters that children correctly identified was counted. Each correct item received one score and the maximum score was 100 for 1st graders and 120 for other graders. Appendix III shows a sample of the test.

(2) **Two-Character Word Reading.** Only 2nd-, 3rd- and 5th-graders took this test. Children were asked to read 60 two-character words aloud as quickly and accurately as possible within a time limit. The words were selected and the time limit was set based on similar criteria as in the character reading test. The time limit for all graders was 1 minute. The number of words children correctly identified was counted. Each correct item received one score and the maximum score was 60 for all graders. Appendix III shows a sample of the test.
VI. Intelligence.

The present study used the Chinese version of Raven’s Standard Progressive Matrices (Zhang & Wang, 1985) as an index of intelligence because it was standardized in the Mainland and could be administered in a group. This is a test of nonverbal problem solving requiring perceptual analysis that is highly correlated with general intelligence. Each correct item received one score and the maximum score was 60 for all graders.

5.3 Results

Descriptive statistics including means and standard deviations for all children on each test are presented in Table 1. Percentage correct scores are reported for these tests. Zero-order correlations between character reading, word reading, pinyin knowledge, Raven and component skills measures for 1st- to 5th-graders are presented in Table 2. The reliability (Cronbach alpha) for the component skills tasks ranged from 0.40 to 0.96.\(^5\)

5.3.1. The Development of Phonological Awareness

Among the four phonological awareness tests, subjects performed the best in sound blending, followed by sound isolation and tone oddity. The rhyme-alliteration oddity test was the most difficult. (See Table 1.)

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\(^5\) The Cronbach reliability coefficients for rhyme-alliteration oddity, tone oddity, sound isolation, sound blending, visual form constancy, visual sequential memory, component search, miswriting search and homophone discrimination were 0.59, 0.78, 0.65, 0.40, 0.78, 0.84, 0.96, 0.51 and 0.40, respectively.
Table 1. Descriptive statistics for all children in the cross-sectional study.

| Grade | Phonological Awareness | | | |
|-------|------------------------|---|---|---|---|
|       | Oddity                 | One Mean (Std) % | Two Mean (Std) % | Three Mean (Std) % | Five Mean (Std) % |
|       | Chinese items          | 51 (18) | 55 (21) | 59 (20) | 69 (20) |
|       | English items          | 47 (22) | 56 (19) | 57 (17) | 75 (14) |
|       | Alliteration           | 44 (22) | 50 (17) | 56 (17) | 67 (16) |
|       | Rhyme                  | 54 (22) | 60 (22) | 60 (20) | 77 (17) |
|       | Tone Awareness         | 65 (23) | 76 (9) | 69 (23) | 81 (18) |
|       | Sound Isolation        | 71 (13) | 76 (10) | 82 (10) | 87 (8) |
|       | Chinese                | 77 (12) | 83 (6) | 95 (6) | 92 (9) |
|       | English                | 62 (20) | 67 (17) | 66 (18) | 82 (12) |
|       | Initial                | 86 (18) | 91 (14) | 88 (16) | 93 (11) |
|       | Middle                 | 70 (17) | 78 (10) | 75 (16) | 74 (15) |
|       | Final                  | 56 (18) | 59 (16) | 83 (20) | 95 (11) |
|       | Chinese Initial        | 88 (19) | 93 (11) | 98 (7) | 95 (10) |
|       | Chinese Middle         | 79 (24) | 95 (9) | 92 (11) | 88 (16) |
|       | Chinese Final          | 78 (20) | 79 (13) | 96 (11) | 92 (15) |
|       | English Initial        | 85 (27) | 90 (20) | 78 (31) | 90 (20) |
|       | English Middle         | 30 (32) | 26 (33) | 45 (37) | 50 (29) |
|       | English Final          | 34 (23) | 40 (25) | 71 (37) | 97 (16) |
|       | Sound Blending         | 98 (4) | 98 (4) | 96 (7) | 95 (9) |
|       | Visual Processing Skills |           |           |           |           |
|       | Visual Form Constancy  | 66 (26) | 61 (18) | 53 (21) | 55 (21) |
|       | Visual Sequential Memory | 60 (20) | 73 (14) | 73 (24) | 78 (21) |
|       | Orthographic Processing Skills |           |           |           |           |
|       | Component Search       | 69 (11) | 85 (14) | 96 (6) | 78 (15) |
|       | Miswriting Search      | -- | 89 (10) | 93 (7) | 92 (6) |
|       | Visual-Orthographic and Phonological Processing Skills |           |           |           |           |
|       | Homophone Discrimination | -- | 92 (10) | 96 (5) | 98 (4) |
|       | Pinyin Reading         | 38 (21) | 42 (15) | 41 (17) | 55 (18) |
|       | Reading Skills         |           |           |           |           |
|       | Character Reading      | 85 (16) | 72 (16) | 70 (15) | 68 (15) |
|       | Word Reading           | -- | 66 (21) | 78 (12) | 76 (17) |
|       | Intelligence (Nonverbal)|           |           |           |           |
|       | Raven – Raw Score      | 48 (18) | 62 (16) | 68 (17) | 75 (15) |
|       | Raven – Percentile1    | 71 (27) | 79 (23) | 76 (25) | 72 (26) |
|       | Demographic Factors    |           |           |           |           |
|       | Age2                   | 77.4 (3.7) | 93.9 (4.4) | 108.8 (5.2) | 131.8 (3.7) |

1 The Raven raw score was compared with the norm and transferred into percentile.
2 In terms of months
Table 2. Zero-order Correlations (r) between Reading Skills, Raven and Component Skills Measures in the Cross-Sectional Study.

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### Character Reading

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### Pinyin Knowledge

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### Raven

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* p<.05  ** p<.01
To test the effect of grade on each test, the data were subjected to One-Way ANOVA analyses. The main effect of grade was significant for rhyme-alliteration oddity \[F(3,150)=16.062, \ p<.001\], tone oddity \[F(3,150)=4.541, \ p<.005\] and sound isolation \[F(3,150)=17.413, \ p<.001\], but not for blending \[F(3,150)=2.008, \ p=.115\]. In general, the higher the grade, the better the performance on all but the blending test. All the four graders did extremely well in sound blending, probably because they were given extensive exercises for this kind of task during pinyin learning. The ceiling effects in the blending task made it less diagnostic for reading abilities.

To examine whether English items in the rhyme-alliteration oddity test were more difficult than Chinese items, the data were subjected to paired-samples t-tests. Interestingly, the main effect of language (Chinese vs. English) was not significant \[t(153)=.063, \ p=.950\]. On the other hand, in the sound isolation test, children's performance of Chinese items was significantly better than their performance of English items \[t(153)=12.565, \ p<.001\]. This was true for children in all grades [all ps<.001].

Several studies using alphabetic languages demonstrate a tendency that alliterations are more difficult to detect than rhymes (e.g., Bradley & Bryant, 1983; Burgess & Lonigan, 1998; Hatcher & Hulme, 1999). To check whether this was true for the present study, the data were subjected to paired-samples t-tests. Performance in detecting alliterations was poorer than in detecting rhymes \[t(153)=4.285, \ p<.001\], although paired comparisons showed that this was true only for 1st, 2nd and 5th graders.
(all ps < .05) but not for 3rd graders (p > .05). This finding is consistent with those using alphabetic languages, and can probably be accounted for by the fact that a rime involves one or more vowels which are perceptually more salient than consonants. Further, this finding suggests that subjects’ performance on the oddity task was not based on overall similarity but on onset and rime differences, and the level of phonological awareness tapped by this task is at the onset-rime but not the syllable level (Treiman, 1988).

Interestingly, the performance on tone oddity was better than that on rhyme-alliteration oddity in all grades. Both tests had the same format except that one tested sensitivity to rhyme/alliteration and one to tone. This result suggests that the detection of rhyme/alliteration differences is more difficult than the detection of tone differences. Paired-samples t-tests showed that the differences between the two tasks were statistically significant for all grades (all ps < .005).

In Chinese, tone is a suprasegmental feature which attaches to the rimes. It is possible that the poor performance on rhyme-alliteration oddity might be due to the presence of alliteration items. To test this possibility, another set of paired-samples t-tests was performed where only the scores of the Chinese rhyming items of the rhyme-alliteration oddity test were compared with the scores of tone oddity. Results showed that the performances on the two tests were significantly different across all graders (all ps < .01), with the performance on tone oddity significantly better than that on Chinese rhyming detection.

In summary, children perform the best in sound blending, followed
by sound isolation, tone detection and alliteration/rhyme detection, and their performance generally improves with age.

5.3.2 Simple Correlations between Various Component Skills and Reading Measures

Among the various component skills measures, only the visual sequential memory scores (VSM) significantly correlated with character reading in grade 1 (r=.392). For second graders, rhyme-alliteration oddity, homophone discrimination and pinyin knowledge significantly correlated with character reading (r=.493, .482, and .521, respectively) whereas rhyme-alliteration oddity, tone oddity, homophone discrimination and pinyin knowledge significantly correlated with word reading (r=.406, .353, .356, and .652, respectively). The two reading measures were significantly correlated (r=.718).

For third graders, homophone discrimination was the only variable that correlated with character reading (r=.423). Homophone discrimination and pinyin knowledge correlated with word reading (r=.579 and .379, respectively) and the two reading measures were correlated (r=.805).

For fifth graders, rhyme-alliteration oddity, tone oddity, homophone discrimination and pinyin knowledge significantly correlated with character reading (r=.451, .352, .519, and .665, respectively) and tone oddity, homophone discrimination and pinyin knowledge significantly correlated with word reading (r=.369, .520, and .478, respectively). The two reading measures were correlated (r=.781).
In summary, visual skills correlated with reading success at early grades, whereas phonological and orthographic skills (i.e., rhyme-alliteration oddity, homophone discrimination and pinyin knowledge) correlated with reading success at higher grades. The variables that correlated with character and word reading did not differ in general, suggesting that the cognitive mechanisms underlying the two processings may be similar.

5.3.3. Simple Correlations between Phonological Awareness and Pinyin Knowledge

Mean reading scores for pinyin ranged from 38% to 55% in this study, indicating this task was demanding even for 5th graders within the time limit that was set. Pinyin knowledge correlated with rhyme-alliteration oddity ($r=.479$, $p<.005$) and sound isolation ($r=.335$, $p<.05$) in grade 1, while it correlated with rhyme-alliteration oddity ($r=.408$, $p<.05$) and sound blending ($r=-.392$, $p<.05$) in grade 2. In grades 3 and 5, tone oddity was a significant correlate of pinyin knowledge ($r=.321$, $p<.05$ and $r=.421$, $p<.01$, respectively) and rhyme-alliteration oddity was marginally correlated with it ($r=.288$, $p=.065$ and $r=.298$, $p=.065$, respectively).

This pattern of results suggests that, in general, oddity was an important correlate of pinyin knowledge in all grades but particularly lower ones. That the relationship between tone awareness and pinyin knowledge surfaces only at a later stage of reading development is

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6 Sound blending negatively correlated with pinyin knowledge for 2nd graders. This might be attributed to its ceiling effects, which make it non-diagnostic.
consistent with our speculation that tonal information becomes important when more characters (homophones) are encountered.

5.3.4. Predicting Character and Word Reading by Using Hierarchical Multiple Regression Analysis

A series of fixed-order hierarchical multiple regressions was conducted to investigate the predictive power of the phonological awareness tests, the visual processing skills tests and the orthographic processing skills tests. Character reading was the criterion variable for 1st-graders whereas character and word reading were two separate criterion variables for 2nd-, 3rd- and 5th-graders. Children’s age and intelligence were entered in the equation as step 1 and step 2, respectively, to control for the variances accounted for by these variables. One of the component skills was then entered as the final step. Table 3 summarizes the results of these analyses.

For grade 1, visual sequential memory (VSM) was the only significant predictor of Chinese character reading, which accounted for 15.4% of variance [$\Delta F=5.946$, $p<.05$].

For grade 2, rhyme-alliteration oddity, visual form constancy (VFC), homophone discrimination and pinyin knowledge were the most powerful predictors in character reading, which respectively accounted for 21.5% [$\Delta F=9.774$, $p<.005$], 11.2% [$\Delta F=4.396$, $p<.05$], 15.0% [$\Delta F=6.188$, $p<.05$] and 24.8% [$\Delta F=11.792$, $p<.005$] of variance. Rhyme-alliteration oddity, VFC and pinyin knowledge were significant predictors in word reading,
Table 3. Summary of Hierarchical Multiple Regressions That Tested the Predictive Power of Various Component Skills Measures On Character and Word Reading After Controlling for Differences in Age and IQ in the Cross-Sectional Study.

<table>
<thead>
<tr>
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<td>.101*</td>
<td>.155**</td>
<td>.456**</td>
<td>.210**</td>
</tr>
</tbody>
</table>

*p<.10  * p<.05  ** p<.01
which respectively accounted for 9.7% $[\Delta F=4.776, p<.05]$, 14.3%
$[\Delta F=7.575, p<.01]$ and 31.2% $[\Delta F=23.257, p<.001]$ of variance.

For grade 3, homophone discrimination and pinyin knowledge were
two significant predictors of both character and word reading, which
respectively accounted for 13.4% $[\Delta F=6.381, p<.05]$ and 10.1%
$[\Delta F=4.595, p<.05]$ of variance in character reading and 31.1%
$[\Delta F=17.987, p<.005]$ and 15.5% $[\Delta F=7.252, p<.05]$ of variance in word
reading.

For grade 5, rhyme-alliteration oddity, homophone discrimination
and pinyin knowledge were the most powerful predictors in character
reading, which accounted for 15.2% $[\Delta F=7.102, p<.05]$, 24.7%
$[\Delta F=13.271, p<.005]$ and 45.6% $[\Delta F=36.040, p<.005]$, respectively, of
variance in character reading. Homophone discrimination and pinyin
knowledge were two powerful predictors in word reading, which
respectively accounted for 23.5% $[\Delta F=12.319, p<.005]$ and 21%
$[\Delta F=10.577, p<.005]$ of variance.

In summary, these data suggest that visual processing skills, in
particular the ability to visually memorize figures, predict reading success
at early grades. This finding is consistent with the hypothesis that, at an
early stage of reading development, learning to read Chinese must be
achieved by rote memory. At a later stage of development when more
homophones are encountered, the ability to make appropriate visual
distinctions among visually similar forms may become important. The
present study lends support to this speculation.
Among the four phonological awareness tasks, only the rhyme-alliteration oddity task bears a significant relationship with character and word reading when the variance of intelligence is partialled out. Specifically, the ability to detect rhymes and alliterations accounts for a significant portion of variance in reading for second- and fifth-graders. This finding provides support to the suggestions that syllabic or onset-rime awareness, rather than phonemic awareness, may be a more meaningful component of phonological awareness in Chinese and that phonological awareness may become strongly correlated with reading skills at a later stage of reading development. One may argue that task complexity might influence the pattern of results in the present study, because onset-rime awareness was measured by the oddity task while phonemic awareness was assessed by the sound isolation task. Previous research, however, suggested that linguistic complexity, but not task complexity, affects subjects’ performance on various phonological awareness tasks (Stahl & Murray, 1994).

The grade 3 results are sometimes anomalous with the general trend of the findings and it is not very clear why this is so.

Pinyin knowledge starts to predict reading success in grade 2 and this influence proceeds to grade 5. It accounts for the largest amount of variance in Chinese reading for most (but first) graders.

5.3.5. Predicting Character and Word Reading with the Effect of Pinyin Knowledge Partialled Out

To investigate the predictive power of component skills in Chinese
reading with the effect of pinyin knowledge partialled out, another series of fixed-order multiple regression analyses was conducted. In these regressions, children’s age and non-verbal intelligence were again entered the equation as step 1 and step 2, respectively. Children's pinyin knowledge was entered as step 3. One of the component skills was then entered as the last step. Character reading was the criterion variable for 1st-graders whereas character and word reading were two separate criterion variables for 2nd-, 3rd- and 5th-graders. Table 4 summarizes the results of these regression analyses.

For 1st-graders, pinyin knowledge did not account for a significant portion of variance in character reading. The only significant predictor of character reading was VSM, which accounted for 15.4% of variance \( [\Delta F=5.765, p<.05] \).

For 2nd-graders, pinyin knowledge accounted for 24.8% of variance in character reading \( [\Delta F=11.792, p<.005] \). Rhyme-alliteration oddity and homophone discrimination accounted for an additional 9.0% \( [\Delta F=4.793, p<.05] \) and 11.3% \( [\Delta F=6.300, p<.05] \) of variance, respectively. Pinyin knowledge accounted for 31.2% of variance in word reading \( [\Delta F=23.257, p<.001] \), and VFC accounted for an additional 7.1% of variance \( [\Delta F=6.121, p<.05] \).

For 3rd-graders, pinyin knowledge accounted for 10.1% of variance in character reading \( [\Delta F=4.595, p<.05] \) and 15.5% of variance in word reading \( [\Delta F=7.252, p<.05] \). Homophone discrimination accounted for an additional 19.6% of variance in word reading \( [\Delta F=11.780, p<.005] \).
Table 4. Summary of Hierarchical Multiple Regressions That Tested the Predictive Power of Pinyin Knowledge and Various Component Skills Measures on Character and Word Reading After Controlling for Differences in Age and IQ in the Cross-Sectional Study.

<table>
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<th>Grade One Word Reading</th>
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</table>

* p<.10  * p<.05  ** p<.01
For 5th-graders, pinyin knowledge accounted for 45.6% of variance in character reading [$\Delta F=36.040, p<.005$] and homophone discrimination accounted for an additional 8.7% of variance [$\Delta F=8.295, p<.01$]. Pinyin knowledge accounted for 21% of variance in word reading [$\Delta F=10.577, p<.005$] and homophone discrimination accounted for an additional 12.7% of variance [$\Delta F=7.605, p<.01$].

In summary, pinyin knowledge and homophone discrimination were two important predictors of Chinese reading. The effects of other component skills dropped when pinyin knowledge entered the regression equation as a predictor variable.

### 5.4 Discussion

The cross-sectional study reports four important findings. First, onset-rime awareness was significantly related to Chinese reading even after the effects of IQ had been partialled out, but phonemic awareness was not. Second, children were as competent in detecting onset-rime differences in English as in Chinese, but not as competent in segmenting phonemes. Third, results of hierarchical multiple regression analyses show that visual skills predicted reading at lower grades while phonological awareness, homophone discrimination and pinyin knowledge predicted reading at higher grades. Finally, pinyin knowledge and phonological awareness (rhyme-alliteration and tone oddity) correlated. These findings will be discussed in the following sections.
5.4.1 The Level of Phonological Awareness that Best Predicts Chinese Reading Development

Among the different levels of phonological awareness that were assessed in this study, onset-rime awareness conveyed a stronger relationship with reading than phonemic awareness when the variance of intelligence was partialled out. Tone awareness correlated with reading and pinyin knowledge at higher grades. These findings deviate from those using alphabetic languages which generally show that both onset-rime and phonemic awareness are important correlates of reading success (see Adams, 1990, for review). However, results of the present study are anticipated given that characters, the basic writing units in Chinese, map onto syllables of the language, and there is no part within a character that encodes individual segments. It is this linguistic nature of written Chinese, along with pinyin knowledge as discussed below, that accounts for the importance of phonological awareness at the onset-rime and syllable levels to Chinese reading (Holm & Dodd, 1996). The present discoveries have been buttressed by previous studies that either failed to show the role of phonemic awareness (Huang & Hanley, 1995) or only demonstrated a relationship between syllabic (Ho & Bryant, 1997a; McBride-Chang & Ho, 2000) or onset-rime processing (Hu & Catts, 1998) and Chinese reading. This finding lends strong support to theoretical frameworks that suggest that the nature of phonological awareness predicting reading development in a particular writing system depends on the phonological structure of the language and, particularly, how the orthography encodes the phonology (Goswami, 1999).
Children in this study were equally competent in detecting alliteration/rhyme differences among both familiar and unfamiliar linguistic structures. This implies that the development of onset-rime awareness does not depend upon reading experience and may not need special instruction and training. On the other hand, the ability to explicitly manipulate sub-syllabic segments, especially deleting or isolating a phonemic segment, of a particular language depends on reading experience of that language. These results agree with Goswami and Bryant's (1990; Goswami, 1999) causal connections theory that syllabic and onset-rime awareness develops before children learn to read while phonemic awareness emerges as a consequence of reading achievement.

Although 5th-graders in this study had learned English since they were in grade 4, there might be a discrepancy in proficiency between English and Chinese, which resulted in a 10% difference between the performance of the two languages. However, learning English does enhance phonemic manipulation, as is reflected by the 16% jump in performance from grade 3 to grade 5, compared with a 5% difference between grades 1 and 2 and a 1% difference between grades 2 and 3.

5.4.2 The Development of Phonological Awareness in Chinese

Children in the present study performed the best in sound blending, followed by sound isolation, tone oddity and rhyme-alliteration oddity. Research using alphabetic languages shows that rhyme/alliteration detection is easier than sound blending and sound isolation (see Adams, 1990, for a review). The discrepant finding in this study might be
accounted for by two reasons. First, all Mainland children receive pinyin training during the first two months in first grade before they learn to read Chinese characters. As pinyin training involves explicit teaching of splitting a syllable into the onset and the rime (and occasionally a medial vowel) and blending these sound segments into a syllable, it is not surprising to find that Mainland children perform well in the sound blending and isolation task even in grade 1. Second, the linguistic structure of a Chinese syllable is simple, unlike an English syllable which may involve initial or final consonant clusters such as "str" in strong and "ngst" in amongst. This makes the tasks of sound blending and isolation relatively easy in Chinese. As Stahl and Murray (1998) have suggested, linguistic complexity should not be ignored when we study the nature of phonological awareness measured by different tasks.

Interestingly, children's performance on tone oddity was better than on rhyme-alliteration oddity (rhyme detection in particular) in all grades. Both tasks share the same format and the linguistic complexity involved is comparable. This finding implies that tone detection is relatively easier than rhyme detection for Mainland children. It is consistent with the findings reported by C. Li and Thompson (1976) which showed that mastery of lexical tones occurs in advance of mastery of segmentals in Taiwan preliterate children. On the other hand, Ho and Bryant (1997b) reported that the performance of Hong Kong kindergarten children in rhyme detection was better than that in tone detection. This may well be because Cantonese (the Chinese dialect spoken in Hong Kong) has six contrastive tones while Mandarin has four, and so tonal detection is more
difficult in Cantonese than in Mandarin.

5.4.3 The Developmental Pattern of Chinese Reading Acquisition

Visual skills predict reading success at lower grades and orthographic and phonological skills predict reading success at higher grades. This finding is in line with that of Ho and Bryant (1997a), suggesting that Chinese reading progresses from a visual phase to a phonological phase, though the onset time of each stage is different in the two studies. Both studies demonstrate that the developmental pattern of Chinese script is similar to that of alphabetic scripts (Ehri, 1998; Frith, 1985). This study further demonstrates that visual and orthographic processing skills entail different relationships with successful reading. It is thus important to distinguish between these two skills in the study of the developmental succession of visual and phonological reading strategies (Frith, 1985).

Importantly, pinyin knowledge predicts reading success starting from grade 2 and this influence proceeds to grade 5. Pinyin knowledge does not correlate with reading at grade 1. Because the 1st graders in this study had just finished the eight-week training in pinyin and started to learn Chinese characters at the time they were tested, they would not have fully familiarized with pinyin during the time the study was conducted. Hence, it is likely that characters were learned independent of pinyin knowledge at that time. Through practice, children become more capable in pronouncing syllables written in pinyin and they are able to read visually unfamiliar characters with the aid of pinyin printed above the
characters. In this way, a strong association between pinyin and Chinese characters is formed and this explains the strong correlation between pinyin knowledge and reading in later grades. The reduced influence of pinyin knowledge on reading in grade 3 might be due to the fact that, starting from grade 3, pinyin is no longer printed above characters in textbooks. This reduction is probably a transient phenomenon as children keep using the pinyin knowledge as a means to encode the pronunciations of characters. The association between pinyin knowledge and reading remains strong through grade 5.

It is noteworthy that when pinyin knowledge enters the regression equation as a predictor variable, the effect of phonological awareness diminishes in grade 2, and becomes nonsignificant in grade 5. This suggests that the effect of pinyin knowledge on reading is more significant and direct than that of phonological awareness.

On the other hand, the ability to discriminate between homophones remains an important predictor of reading success even after the variance in pinyin knowledge has been partialled out. This might be relevant to the important feature of the Chinese language that homophones abound. In modern-day usage, 4,574 characters make up 100% of a 1,800,000-character Chinese corpus, according to *Xiandai Hanyu Pinlu Cidian* [Modern Chinese Frequency Dictionary] (1986). As there are only about 1200 different syllables in Chinese when tones are taken into account, on average about 4 characters share one segmental configuration. Successful reading in Chinese depends much on the ability to make appropriate visual distinctions among characters which are homophones.
5.4.4 The Role of Pinyin on Chinese Reading and Its Relation with Phonological Awareness

Since there is no internal structure in a Chinese character that maps onto sub-syllabic units, the connection between the spoken and written language is established through rote memory at the syllable level. This is unlike alphabetic languages where grapheme-phoneme correspondence rules can be applied. In a sense, a child is able to read a Chinese character only when he has been taught to do so. However, the introduction of pinyin may have changed the way the connection between the speech and the writing is formed. When a child has acquired the pinyin principle, she is able to derive the sounds of characters through pinyin and to match these sounds with the phonological codes that already exist in the mental lexicon. In other words, pinyin knowledge bridges the gap between speech and writing in Chinese and this enables children to derive the meanings of characters that are visually unfamiliar but are auditorily familiar. This pinyin (alphabetic) knowledge plays a role very similar to the grapheme-phoneme correspondence rule in alphabetic languages (see also Harris & Coltheart, 1986, for a similar account). This study has demonstrated the importance and effectiveness of pinyin as a learning tool from a psychological perspective.

Through learning pinyin, Chinese children come to explicitly realize the phonological structure of a Chinese syllable and acquire the ability to split a syllable into its corresponding initial (onset) and final (rime) and blend these sound segments into a syllable. Together with the fact that the
structure of the Chinese syllable is simple, it is thus not surprising to find
that even first graders in our study performed quite well in the Chinese
version of sound isolation and blending tasks, by contrast to the findings
using alphabetic languages where segmentation and blending tasks were
shown to be difficult (see Adams, 1990, for review). In addition, our
results show that pinyin knowledge correlates with phonological skills.
Particularly, oddity correlates with pinyin knowledge in grades 1 and 2
and tone awareness correlates with pinyin knowledge in grades 3 and 5.

It is possible that the sensitivity towards alliterations/rhymes and
tones is a consequence of pinyin knowledge or the relationship between
them is reciprocal. As is suggested in the previous sections, the learning
of pinyin makes children realize that Chinese is a tonal language and that
(22) onsets and (37) rimes are basic phonological components of the
language. Therefore, the mastery of pinyin knowledge makes explicit
segmental and tonal processing of Chinese characters possible. On the
other hand, it is also possible that children who have better skills in
manipulating onsets/rimes and tones can read out pinyin faster. Both skills
are required for developing a well-specified phonological lexicon prior to
reading. In particular, tonal skills are required for disambiguating
meaning in spoken input and segmental skills are required for
representing lexical information in a more parsimonious manner
(Goswami, 1999; C. Li & Thompson, 1976; Metsala & Walley, 1998).
These two possible accounts both explain why oddity and tone awareness
are good correlates of pinyin knowledge and it is likely that phonological
awareness and pinyin knowledge bear a reciprocal relation. The design of
the present study prohibits a resolution of this issue, however. 

In fact, as the data were cross-sectional in nature, it is too early to conclude that pinyin knowledge and the ability to discriminate homophones bear a causal relationship with reading success, nor to conclude that phonological awareness is either a prerequisite or a consequence of pinyin knowledge. To elucidate the causal relationships between these variables, a longitudinal approach, which will be described in the next chapter, was adopted in this research to investigate the causal relationship of these variables.
Chapter 6

Study 2: The Longitudinal Study

6.1 An Overview

The major purpose of this study was to tackle the causal relationship among variables from a longitudinal perspective. Specifically, the nature of the relationships between various component skills and reading, between phonological awareness and pinyin knowledge, and between pinyin knowledge and reading was investigated. To achieve this goal, children's pinyin knowledge and reading ability were measured again one year later. Ideally, children's component skills measures should also be assessed in the longitudinal study so as to tackle any possible reciprocal relationship between these variables and reading. However, due to the scope of the present study as well as time constraint, it was not possible to collect those data.

Another purpose of the present study was to explore the correlations between the reading measures that were used in different grades. As different reading tasks were used in different grades, it may not be justified to compare and contrast the developmental pattern of reading from a cross-sectional perspective. As a result, in the longitudinal study, children were given two sets of reading tasks: One that they had already taken in Study 1, and the other that was taken by other graders in Study 1.
Correlations between these two sets of reading tasks were then obtained.

In addition to hierarchical multiple regression analysis, the structural equation modeling (SEM) approach was used in this study to construct a coherent model of overall relations among various phonological skills, visual-orthographic skills, pinyin knowledge and reading ability. The SEM approach provides a means of testing more complex and specific hypotheses than can be tested by other standard linear models such as ANOVA, multiple regression, and factor analysis (Hoyle, 1995). Unlike multiple regression which only permits specification of direct effects on a single outcome, SEM allows specification of more complex relations among multiple outcomes. Relations between variables in SEM are of three types. First, the association, or correlation, is a nondirectional relation between two variables. Second, the direct effect refers to a directional relation between two variables. Third, the indirect effect is the effect of an independent (exogenous) variable on a dependent (endogenous) variable, through one or more intervening variables.

The gist of SEM is to evaluate the compatibility of an a priori specified model and the observed sample data (Jaccard & Wan, 1996). The chi-square ($\chi^2$) goodness-of-fit test is the most common test of the model where the null hypothesis is that the model fits the population data perfectly. A statistically nonsignificant $\chi^2$ is consistent with a good model fit and suggests that the model can be regarded as credible. A statistically significant chi-square implies imperfect model fit and possible rejection of the model. Note that a good model fit is indicated by inability to reject
the null hypothesis, and this situation is reversed from traditional hypothesis testing situations. Usually, researchers adopt a defensive strategy by consulting fit indexes from multiple classes of indexes.

Under the circumstances that fit indexes point to an unfavorable model fit, the model is either rejected and an alternative model is submitted for testing, or the model is modified. In the latter case, the basis for modification typically is an inspection of the modification indices providing by the LISREL program (Jöreskog & Sörbom, 1993) and adjustments will then be made that result in more favorable indicators of fit.

6.2 Method

6.2.1 Subjects

One hundred and forty-eight children remained from the previous sample of 154 children when they were tested again one year later. The 6 children who were lost had moved out of the school district. A comparison of the 6 dropouts to the remaining 148 children revealed no differences in background variables, component skills measures and reading measures.

In the following sections, 1st-, 2nd-, 3rd-, and 5th-graders in the cross-sectional study will be re-labeled as 2nd-, 3rd-, 4th- and 6th-graders, respectively.
6.2.2 Test Materials and Procedures

The same pinyin knowledge task was used. Reading ability was measured by the following tasks:

1. **Single Character Reading.** Children took the same single character reading test as in Study 1 (this test is labeled as *Character Reading Form A* thereafter). In addition, they took another single character reading test that was grade-appropriate (this test is labeled as *Character Reading Form B* thereafter). To illustrate, 3rd-graders (previously 2nd-graders) took both the 2nd-grade reading test (i.e., Character/Word Reading Form A) as well as the 3rd-grade reading test (Character/Word Reading Form B) in Study 2. As there were no 4th-graders in Study 1, a new character reading task was devised for 4th-graders (previously 3rd-graders). The selection criteria of the characters was the same as that in Study 1. The time limit for all grades was 2 minutes per test. Each correct item received one score and the maximum score was 100 for Character Reading Form A for 2nd graders and 120 for other Character Reading tests. Appendix IV shows a sample of the test.

2. **Two-Character Word Reading.** Similar to the single character reading test, children took both the two-character word reading test that was used in Study 1 (labeled as *Word Reading Form A* thereafter) and another two-character word reading test that was grade-appropriate (labeled as *Word Reading Form B* thereafter). Again, as there were no 4th-graders in Study 1, a new word reading task was devised for 4th-graders (previously 3rd-graders). The selection criteria of the words was the same as that in Study 1. The time limit for all grades was 1.5 minutes.
per test. Each correct item received one score and the maximum score was 60 for both Word Reading Forms A and B for all graders. Appendix IV shows a sample of the test.

These tasks were administered individually by trained research assistants in a single session that took about 30 to 40 minutes.

6.3 Results

Descriptive statistics including means and standard deviations for all children on pinyin knowledge and reading tests are presented in Table 5. Table 6 shows the correlations between various reading measures that were obtained in the two studies.

In general, the correlations among various reading measures were relatively high, ranging from .563 to .913 (see Table 6). The correlations between forms A and B of single character reading were high, ranging from .664 to .872. Similarly, the correlations between forms A and B of word reading were high, ranging from .754 to .913. These findings suggest that, although different reading tasks were used for children in different grades, they measured similar skills and hence it is justified to compare and contrast the developmental pattern of reading from a cross-sectional perspective. Given the high correlations between the various reading tasks, the scores of forms A and B of single character reading obtained in this study were combined as a single measure of single character reading for each grade. By the same token, the scores of forms A and B of word reading were combined as a single measure of word
Table 5. Descriptive statistics of scores in pinyin knowledge and reading for all children in the longitudinal study.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Two Mean (Std) %</th>
<th>Three Mean (Std) %</th>
<th>Four Mean (Std) %</th>
<th>Six Mean (Std) %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pinyin Knowledge</td>
<td>Reading Skills</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Character Reading -- Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Form A</td>
<td>Form B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>72 (18)</td>
<td>58 (23)</td>
<td>65 (17)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86 (16)</td>
<td>57 (23)</td>
<td>75 (18)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75 (18)</td>
<td>55 (18)</td>
<td>67 (16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86 (18)</td>
<td>62 (18)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>73 (17)</td>
<td>42 (16)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>67 (19)</td>
<td>56 (19)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Word Reading -- Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Form A</td>
<td>Form B</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>58 (23)</td>
<td>58 (23)</td>
<td>80 (17)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>84 (20)</td>
<td>75 (14)</td>
<td>84 (14)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>81 (16)</td>
<td>50 (18)</td>
<td>81 (16)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>75 (17)</td>
<td>75 (17)</td>
<td></td>
</tr>
</tbody>
</table>

1 The Raven raw score was compared with the norm and transferred into percentile.
2 In terms of months
Table 6  Zero-Order Correlations between various reading measures obtained in Study 1 and 2.

<table>
<thead>
<tr>
<th>Grade One/Two</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Character Reading -- Form A, Study 1</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Character Reading -- Form A, Study 2</td>
<td>.651**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Character Reading -- Form B, Study 2</td>
<td>.563**</td>
<td>.664**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Word Reading -- Form A, Study 1</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5. Word Reading -- Form A, Study 2</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>6. Word Reading -- Form B, Study 2</td>
<td>.580**</td>
<td>.605**</td>
<td>.721**</td>
<td>--</td>
<td>--</td>
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<table>
<thead>
<tr>
<th>Grade Two/Three</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Character Reading -- Form A, Study 1</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Character Reading -- Form A, Study 2</td>
<td>.706**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Character Reading -- Form B, Study 2</td>
<td>.720**</td>
<td>.872**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Word Reading -- Form A, Study 1</td>
<td>.718**</td>
<td>.664**</td>
<td>.753**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5. Word Reading -- Form A, Study 2</td>
<td>.752**</td>
<td>.845**</td>
<td>.795**</td>
<td>.659**</td>
<td>--</td>
</tr>
<tr>
<td>6. Word Reading -- Form B, Study 2</td>
<td>.748**</td>
<td>.821**</td>
<td>.847**</td>
<td>.773**</td>
<td>.913**</td>
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<table>
<thead>
<tr>
<th>Grade Three/Four</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
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<tbody>
<tr>
<td>1. Character Reading -- Form A, Study 1</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Character Reading -- Form A, Study 2</td>
<td>.731**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Character Reading -- Form B, Study 2</td>
<td>.668**</td>
<td>.790**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Word Reading -- Form A, Study 1</td>
<td>.805**</td>
<td>.729**</td>
<td>.698**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5. Word Reading -- Form A, Study 2</td>
<td>.674**</td>
<td>.832**</td>
<td>.788**</td>
<td>.711**</td>
<td>--</td>
</tr>
<tr>
<td>6. Word Reading -- Form B, Study 2</td>
<td>.601**</td>
<td>.710**</td>
<td>.830**</td>
<td>.673**</td>
<td>.754**</td>
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<table>
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<tr>
<th>Grade Five/Six</th>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Character Reading -- Form A, Study 1</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Character Reading -- Form A, Study 2</td>
<td>.822**</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Character Reading -- Form B, Study 2</td>
<td>.884**</td>
<td>.861**</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Word Reading -- Form A, Study 1</td>
<td>.781**</td>
<td>.786**</td>
<td>.720**</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>5. Word Reading -- Form A, Study 2</td>
<td>.762**</td>
<td>.743**</td>
<td>.736**</td>
<td>.839**</td>
<td>--</td>
</tr>
<tr>
<td>6. Word Reading -- Form B, Study 2</td>
<td>.792**</td>
<td>.815**</td>
<td>.822**</td>
<td>.826**</td>
<td>.903**</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
6.3.1. Simple Correlations between Various Component Skills and Reading Measures

Zero-order correlations between character reading, word reading, pinyin knowledge obtained in this study and various measures obtained in Study 1 are presented in Table 7. Unless otherwise stated, only those correlations that were significant at 0.05 alpha level will be reported in the text.

From Table 7, only sound blending longitudinally correlated with character reading (r=.497) while VSM significantly correlated with word reading (r=.327) for 2nd graders.

For 3rd graders, Raven, rhyme-alliteration oddity, tone oddity and homophone discrimination significantly correlated with character reading (r=.437, .382, .346 and .367, respectively) and word reading (r=.485, .399, .423 and .392 respectively).

For 4th graders, age, Raven and homophone discrimination significantly correlated with character reading (r=-.340, .348 and .629, respectively). Homophone discrimination significantly correlated with word reading ability (r=.584).

For 6th graders, rhyme-alliteration oddity and homophone discrimination significantly correlated with character reading (r=.388 and .560, respectively). Rhyme-alliteration oddity, tone oddity and homophone discrimination correlated with word reading (r=.348, .365 and .597, respectively).
Table 7. Zero-order Correlations (r) between Pinyin Knowledge and Reading Measures Obtained in Study 2 and All Measures Obtained in Study 1.

<table>
<thead>
<tr>
<th>Character Reading in Study 2</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>r</td>
<td>r</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Age</td>
<td>-.128</td>
<td>-.197</td>
<td>-.340*</td>
<td>.111</td>
</tr>
<tr>
<td>Raven</td>
<td>.311*</td>
<td>.437*</td>
<td>.348*</td>
<td>.050</td>
</tr>
<tr>
<td>Oddity</td>
<td>.159</td>
<td>.382*</td>
<td>.214</td>
<td>.388*</td>
</tr>
<tr>
<td>Tone Awareness</td>
<td>.058</td>
<td>.346*</td>
<td>.145</td>
<td>.297</td>
</tr>
<tr>
<td>Sound Isolation</td>
<td>.187</td>
<td>.049</td>
<td>.182</td>
<td>.163</td>
</tr>
<tr>
<td>Sound Blending</td>
<td>.497**</td>
<td>-.225</td>
<td>-.057</td>
<td>-.234</td>
</tr>
<tr>
<td>Visual Form Constancy</td>
<td>-.194</td>
<td>-.245</td>
<td>.104</td>
<td>-.204</td>
</tr>
<tr>
<td>Visual Sequential Memory</td>
<td>.248</td>
<td>.124</td>
<td>.170</td>
<td>.029</td>
</tr>
<tr>
<td>Component Search</td>
<td>.007</td>
<td>.129</td>
<td>-.202</td>
<td>.067</td>
</tr>
<tr>
<td>Miswriting Search</td>
<td>--</td>
<td>-.056</td>
<td>.111</td>
<td>.016</td>
</tr>
<tr>
<td>Homophone Discrimination</td>
<td>--</td>
<td>.367*</td>
<td>.629**</td>
<td>.560**</td>
</tr>
<tr>
<td>Character Reading (S1)</td>
<td>.632**</td>
<td>.737**</td>
<td>.740**</td>
<td>.885**</td>
</tr>
<tr>
<td>Word Reading (S1)</td>
<td>--</td>
<td>.733**</td>
<td>.755**</td>
<td>.780**</td>
</tr>
<tr>
<td>Word Reading (S2)</td>
<td>.717**</td>
<td>.872**</td>
<td>.888**</td>
<td>.828**</td>
</tr>
<tr>
<td>Pinyin Knowledge (S1)</td>
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<td>.663**</td>
<td>.295*</td>
<td>.684**</td>
</tr>
<tr>
<td>Pinyin Knowledge (S2)</td>
<td>.377*</td>
<td>.599**</td>
<td>.588**</td>
<td>.724**</td>
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<table>
<thead>
<tr>
<th>Word Reading in Study 2</th>
<th>Two</th>
<th>Three</th>
<th>Four</th>
<th>Six</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>r</td>
<td>r</td>
<td>r</td>
<td>r</td>
</tr>
<tr>
<td>Age</td>
<td>-.012</td>
<td>-.212</td>
<td>-.215</td>
<td>-.030</td>
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<tr>
<td>Raven</td>
<td>.298*</td>
<td>.485**</td>
<td>.290</td>
<td>.242</td>
</tr>
<tr>
<td>Oddity</td>
<td>.235</td>
<td>.399*</td>
<td>.227</td>
<td>.348*</td>
</tr>
<tr>
<td>Tone Awareness</td>
<td>.244</td>
<td>.423*</td>
<td>.104</td>
<td>.365*</td>
</tr>
<tr>
<td>Sound Isolation</td>
<td>.168</td>
<td>.070</td>
<td>.273</td>
<td>.158</td>
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<tr>
<td>Sound Blending</td>
<td>.262</td>
<td>-.273</td>
<td>-.073</td>
<td>-.098</td>
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<td>Visual Form Constancy</td>
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<td>-.208</td>
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<td>Visual Sequential Memory</td>
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<td>.169</td>
<td>.109</td>
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<tr>
<td>Component Search</td>
<td>.014</td>
<td>.129</td>
<td>-.141</td>
<td>-.022</td>
</tr>
<tr>
<td>Miswriting Search</td>
<td>--</td>
<td>.065</td>
<td>.052</td>
<td>.086</td>
</tr>
<tr>
<td>Homophone Discrimination</td>
<td>--</td>
<td>.392*</td>
<td>.584**</td>
<td>.597**</td>
</tr>
<tr>
<td>Character Reading (S1)</td>
<td>.580**</td>
<td>.767**</td>
<td>.676**</td>
<td>.797**</td>
</tr>
<tr>
<td>Word Reading (S1)</td>
<td>--</td>
<td>.723**</td>
<td>.736**</td>
<td>.853**</td>
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<tr>
<td>Pinyin Knowledge (S1)</td>
<td>.209</td>
<td>.523**</td>
<td>.304*</td>
<td>.550**</td>
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<tr>
<td>Pinyin Knowledge (S2)</td>
<td>.414*</td>
<td>.542**</td>
<td>.604**</td>
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*p<.10  * p<.05  ** p<.01

1S1 refers to Study 1; S2 refers to Study 2
In summary, similar sets of variables longitudinally correlated with character and word reading across all but second grades. Specifically, phonological awareness (i.e., sound blending) correlated with character reading while visual skills (i.e., visual sequential memory) correlated with word reading in second grade. On the other hand, phonological awareness (rhyme-alliteration and tone oddity) and homophone discrimination correlated with both character and word reading at higher grades.

6.3.2. Simple Correlations between Pinyin Knowledge and Reading Measures

A purpose of this study was to investigate the nature of the relationship between pinyin knowledge and reading achievement. It is likely that pinyin knowledge is predictive of reading success or that the two abilities bear a reciprocal relationship. The results of the present study suggest the latter: Pinyin knowledge assessed in Study 1 significantly correlated with reading measures obtained in Study 2, while reading measures obtained in Study 1 significantly correlated with pinyin knowledge assessed in Study 2 in all but second graders (refer to Table 7).

6.3.3. Simple Correlations between Pinyin Knowledge and Phonological Awareness

In this section, the pinyin knowledge obtained in Study 2 was used to study the size of correlations with measures of phonological awareness obtained in Study 1.

Rhyme-alliteration oddity marginally correlated with pinyin
knowledge in grade 2 \((r=.312, p=.060)\) but they had a significant correlation in grades 3, 4 and 6 \((r=.345, .344\) and \(.415\), respectively\). Tone oddity marginally correlated with pinyin knowledge in grade 3 \((r=.304, p=.080)\) and it significantly correlated with pinyin knowledge in grade 6 \((r=.481)\). Surprisingly, sound blending had a negative correlation with pinyin knowledge in grade 3 \((r=-.606)\). As is suggested in Chapter 5, the ceiling effects in the blending task made it less diagnostic for pinyin knowledge and reading abilities.

The significant correlation between phonological awareness (rhyme-alliteration and tone oddity in particular) and reading obtained in Study 1 could suggest that the sensitivity towards alliterations/rhymes and tones is a consequence of pinyin knowledge or that the relationship between them is reciprocal. The present study demonstrates that phonological awareness longitudinally correlates with pinyin knowledge, and implies that the sensitivity towards alliterations/rhymes and tones might enhance children's pinyin knowledge. In addition, it reinforces the hypothesis that onset-rime awareness, rather than phonemic awareness, plays a more important role in Chinese reading development.

6.3.4. Predicting Character and Word Reading by Using Multiple Regression

A series of fixed-order hierarchical multiple regressions were conducted to investigate the predictive power of various component skills as well as pinyin knowledge obtained in Study 1 on reading measures that were obtained in Study 2.
The combined scores of character and word reading were two separate criterion variables. Children’s age and intelligence were entered the equation as step 1 and step 2, respectively, to control for the variances accounted for by these variables. Children's pinyin knowledge obtained in Study 1 was entered as step 3. One of the component skill was then entered as the last step. Table 8 summarizes the results of these regression analyses.

For 2nd-graders, pinyin knowledge did not account for a significant portion of variance in character reading. The only significant predictor of character reading was sound blending, which accounted for 16.3% of variance \( [\Delta F=6.955, p<.05] \). Pinyin knowledge and other component skills did not significantly predict word reading success, however.

For 3rd-graders, pinyin knowledge accounted for 33.2% of variance in character reading \( [\Delta F=21.236, p<.005] \). VFC accounted for an additional 6.8% of variance \( [\Delta F=4.954, p<.05] \). Pinyin knowledge accounted for 17.7% of variance in word reading \( [\Delta F=9.164, p<.005] \), and VFC accounted for an additional 7.2% of variance, which was marginally significant \( [\Delta F=4.147, p=.051] \).

For 4th-graders, pinyin knowledge accounted for 9.9% of variance in character reading \( [\Delta F=5.159, p<.05] \) and 9.9% of variance in word reading \( [\Delta F=4.527, p<.05] \). Homophone discrimination accounted for an additional 16.8% of variance \( [\Delta F=11.274, p<.005] \) and 16.8% of variance \( [\Delta F=9.504, p<.05] \) in character and word reading, respectively.
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* p<.01  * p<.05  ** p<.00  ^1S1 refers to Study 1
For 6th-graders, pinyin knowledge accounted for 45.3% of variance in character reading [$\Delta F=28.392$, $p<.005$] and homophone discrimination accounted for an additional 12.0% of variance [$\Delta F=9.428$, $p<.005$]. Pinyin knowledge accounted for 31.1% of variance in word reading [$\Delta F=16.369$, $p<.005$] and homophone discrimination accounted for an additional 18.0% of variance [$\Delta F=12.871$, $p<.01$].

In summary, pinyin knowledge and homophone discrimination are two most important predictors of Chinese reading in most especially higher grades.

6.3.5. The Use of Structural Equation Modeling (LISREL)

To elucidate the causal relationship among the various component skills and reading ability, the data from both the cross-sectional and longitudinal study were used to test a number of structural equation models by the method of LISREL. As mentioned previously, the structural equation model specifies the causal relationships among the variables and is used to describe the causal effects and the amount of unexplained variance.

The causal relationships that are of major focus in the present study are the relationships between phonological awareness and pinyin knowledge, between phonological awareness/visual-orthographic skills and reading success, and between pinyin knowledge and reading success. Because of the small sample size of each grade, it is impractical to include too many variables in the models. Therefore, the results of multiple regression analyses as were reported in Section 6.2.4 were used as a
guideline to select those variables that entered the regression equations to construct structural equation models. Moreover, only character reading measures obtained in both Study 1 and Study 2 were used as indices of reading success. This practice is justified given that character and word reading measures are highly correlated and similar sets of variables longitudinally correlated with these two reading measures (see Section 6.2.1). Note that in the application of SEM small samples are likely to yield unreliable results, hence the models specified here will be regarded as supplementary but not of major significance.

A priori models for each grade were specified based on the following hypotheses: Tasks measuring phonological awareness and IQ were predictors of pinyin knowledge and reading; visual skills and homophone discrimination were predictors of reading; pinyin knowledge in Study 1 and Study 2 were correlated; reading ability in Study 1 and Study 2 were correlated. The goodness-of-fit between the hypothesized models and the sample data was evaluated with LISREL 8.14 using the sample covariance matrix as input and a maximum likelihood solution. The models are statistically overidentified. A variety of indices of model fit were evaluated. Under the circumstances that fit indexes point to an unfavorable model fit, the model was modified (by adding or removing paths and/or changing the direction of the paths) based on the modification indices providing by the LISREL program and adjustments were made until a favorable fit was achieved. Only the final models will be reported. Figures 2 to 5 list the path diagrams (pictorial representations of structural equation models) for Grades 2 to 6. These path diagrams
were drawn based on the parameter estimates for the structural coefficients provided by the LISREL program.

For Grade 2, fit indexes point to an unfavorable model fit of the a priori model and the model was modified based on the modification indices providing by the LISREL program and adjustments were made until a favorable fit was achieved. The overall chi square test of the final model fit was statistically non-significant ($\chi^2 (15) = 10.32, p=0.80$). The Root Mean Square Error of Approximation (RMSEA) was less than 0.01 and the p value for the test of close fit (RMSEA < 0.05) was 0.85. The Comparative Fit Index was 1.00 and the traditional GFI was 0.93. The standardized root mean square residual was 0.097. The indices uniformly point towards good model fit. Inspection of the residuals and modification indices revealed no significant points of ill-fit in the model. Figure 2 presents the parameter estimates for the structural coefficients.

Standardized coefficients appear on each path, with unstandardized coefficients in parentheses. Causal direction is indicated by straight arrows and correlation is indicated by bi-directional curved arrows. The residuals indicate the proportion of unexplained variance in the endogenous variables (i.e., they are error variances in standardized form). The variables in the model were able to account for approximately 13% of variance in children's reading ability at Time 1 (the cross-sectional study) and 19% of variance in children's reading ability at Time 2 (the longitudinal study). All path coefficients were statistically significant (all $t$s > 2, $p$s < 0.05). Visual sequential memory was the only variable that predicted reading success at Time 1. Rhyme-alliteration oddity predicted
Figure 2
Path Coefficients for Model of Reading Development of Grade 2

- **Oddity**
  - $0.39 (0.47)**
  - 0.45**

- **Pinyin Knowledge at Time 1**
  - 0.36 (0.29)*
  - 0.43 (2.00)**

- **Pinyin Knowledge at Time 2**
  - 0.34 (1.82)*
  - 0.43 (2.00)**
  - 0.88

- **Reading Ability at Time 1**
  - 0.36 (0.29)*
  - 0.45**
  - 0.58**
  - 0.87

- **Reading Ability at Time 2**
  - 0.85

- **Sound Blending**
  - 0.81

- **Visual Sequential Memory**
  - * p<.05
  - ** p<.01
pinyin knowledge at Time 1. Sound blending predicted both reading success and pinyin knowledge at Time 2.

For Grade 3, fit indexes point to an unfavorable model fit of the a priori model and the model was modified based on the modification indices providing by the LISREL program and adjustments were made until a favorable fit was achieved. The overall chi square test of the final model fit was statistically non-significant ($\chi^2 (11) = 4.35, p=0.96$). The Root Mean Square Error of Approximation (RMSEA) was less than 0.01 and the p value for the test of close fit (RMSEA $< 0.05$) was 0.97. The Comparative Fit Index was 1.00 and the traditional GFI was 0.96. The standardized root mean square residual was 0.074. The indices consistently point towards good model fit. Inspection of the residuals and modification indices revealed no significant points of ill-fit in the model. Figure 3 presents the parameter estimates for the structural coefficients. The variables in the model were able to account for approximately 47% of variance in children's reading ability at Time 1 and 58% of variance in children's reading ability at Time 2. All path coefficients were statistically significant (all $t$s $> 2$, $p < 0.05$).

Rhyme-alliteration oddity predicted pinyin knowledge at both Time 1 and Time 2. Homophone discrimination and pinyin knowledge at Time 1 predicted reading success at Time 1. Nonverbal intelligence and pinyin knowledge at both Time 1 and Time 2 predicted reading success at Time 2.

For Grade 4, fit indexes point to an unfavorable model fit of the a priori model and the model was modified based on the modification
Figure 3
Path Coefficients for Model of Reading Development of Grade 3

Oddity

Homophone Discrimination

0.50 (0.46)**
0.28 (0.28)**
0.30 (0.47)**

Pinyin Knowledge at Time 1

Reading Ability at Time 1

0.40 (0.44)**

0.75

0.33 (0.40)*

Pinyin Knowledge at Time 2

Reading Ability at Time 2

0.38 (0.35)**

0.32 (0.35)**

Nonverbal Intelligence

0.88

0.74**

e1
e2
e3
e4

0.53

0.69**

* p<.05
** p<.01
indices providing by the LISREL program and adjustments were made until a favorable fit was achieved. The overall chi square test of the final model fit was statistically non-significant ($\chi^2 (12) =6.02$, $p=0.92$). The Root Mean Square Error of Approximation (RMSEA) was less than 0.01 and the $p$ value for the test of close fit (RMSEA < 0.05) was 0.94. The Comparative Fit Index was 1.00 and the traditional GFI was 0.96. The standardized root mean square residual was 0.092. The indices uniformly point towards good model fit. Inspection of the residuals and modification indices revealed no significant points of ill-fit in the model. Figure 4 presents the parameter estimates for the structural coefficients. The variables in the model were able to account for approximately 17% of variance in children's reading ability at Time 1 and 53% of variance in children's reading ability at Time 2. All path coefficients were statistically significant (all $t$s $>2$, $ps <0.05$). Rhyme-alliteration oddity predicted pinyin knowledge at both Time 1 and Time 2. Homophone discrimination predicted reading success at Time 1, which in turn predicted pinyin knowledge at Time 2. Pinyin knowledge at Time 2 as well as homophone discrimination and nonverbal intelligence predicted reading success at Time 2.

For Grade 6, fit indexes point to an unfavorable model fit of the a priori model and the model was modified based on the modification indices providing by the LISREL program and adjustments were made until a favorable fit was achieved. The overall chi square test of the final model fit was statistically non-significant ($\chi^2 (11) =8.87$, $p=0.63$). The Root Mean Square Error of Approximation (RMSEA) was less than 0.01.
Figure 4

Path Coefficients for Model of Reading Development of Grade 4

Homophone Discrimination  
Nonverbal Intelligence  
Reading Ability at Time 1  
Reading Ability at Time 2  
Pinyin Knowledge at Time 1  
Pinyin Knowledge at Time 2  
Oddity  
Pinyin Knowledge at Time 2

0.41 (1.27)**  
0.19 (0.17)*
0.49 (1.53)***
0.74**
0.32 (0.39)*
0.31 (0.41)*
0.33 (0.41)*
0.83
0.26 (0.22)**
0.79
0.89
0.47
e1 0.89 e2
e3 0.79 e3
e4 0.47 e2

* p<.05  
** p<.01  
*** p<.001
and the p value for the test of close fit (RMSEA < 0.05) was 0.70. The Comparative Fit Index was 1.00 and the traditional GFI was 0.94. The standardized root mean square residual was 0.097. The indices uniformly point towards good model fit. Inspection of the residuals and modification indices revealed no significant points of ill-fit in the model. Figure 5 presents the parameter estimates for the structural coefficients. The variables in the model were able to account for approximately 62% of variance in children's reading ability at Time 1 and 54% of variance in children's reading ability at Time 2. All path coefficients were statistically significant (all ts >2, ps <0.05). Tone oddity predicted pinyin knowledge at both Time 1 and Time 2. Pinyin knowledge at Time 1, homophone discrimination and nonverbal intelligence predicted reading success at Time 1. Pinyin knowledge at Time 1 and homophone discrimination predicted reading success at Time 2, which in turn predicted pinyin knowledge at Time 2.

**6.4 Discussion**

The longitudinal study reported three important findings. First, it consolidates the findings of the cross-sectional study that pinyin knowledge and homophone discrimination are two important predictors of reading success. The effects of visual skills on reading success are rather transient and occur only in first grade, while phonological awareness (or onset-rime and tone awareness) plays mostly an indirect role on reading success via a mediating variable, pinyin knowledge.
Figure 5
Path Coefficients for Model of Reading Development of Grade 6

Nonverbal Intelligence

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<td>Homophone Discrimination</td>
<td>0.39 (1.76)**</td>
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Reading Ability at Time 1

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Reading Ability at Time 2

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Pinyin Knowledge at Time 2

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*p<.05
**p<.01
***p<.001
Second, it shows that phonological awareness and pinyin knowledge bear a causal relationship, with phonological awareness predictive of later pinyin knowledge. Specifically, the ability to detect rhymes and alliterations predicts pinyin knowledge from grade 1 to grade 4, whereas the sensitivity towards tone predicted pinyin knowledge in grades 5 and 6. This finding is consistent with the prediction that tonal sensitivity becomes important at higher grades when more homophones are encountered.

Third, it demonstrates that the relationship between pinyin knowledge and reading success is probably reciprocal in nature. These two variables do not correlate when children have just learned pinyin and begin to learn to read (i.e., in grade 1). Correlation appears once children become more familiar with pinyin principle (grade 2) \( (r=.377, p<.05; \text{ see Table 7}) \). From Figure 2 we can see that the correlation between the two is likely due to a common cause -- sound blending skills. The pinyin principle involves segmenting a syllable into its onset and rime and blending an onset and a rime into a syllable. It is thus understandable that sound blending skills predict both pinyin knowledge and reading success in lower grades. However, when pinyin skills become automatic, it is likely that pinyin is predictive of reading success (grade 3), which in turn is predictive of later pinyin knowledge (grades 4 and 6).
In the last few decades, phonological awareness, together with letter knowledge, has been believed to be one of the most important factors affecting reading in alphabetic languages (Bradley & Bryant, 1983; Chall, 1967; Liberman & Shankweiler, 1979). Phonological awareness is an explicit knowledge of the phonological structure of a language. Some investigations indicate that phonological awareness can be taught and that students who have received training in phonemic awareness have better reading ability than those who have not (e.g., Lundberg et al., 1988). This finding has very important practical implications for alphabetic reading instruction: To improve children’s reading achievement, it is important to enhance children’s phonological awareness.

Does phonological awareness play a similar role in Chinese reading success? A few studies focusing on this issue have produced mixed evidence. While Huang and Hanley (1995) found that phonological awareness does not relate to Chinese reading success, Ho and Bryant (1997a), Hu and Catts (1998) and McBride-Chang and Ho (2000) showed otherwise. Because characters, the basic writing units in Chinese, map onto syllables of the speech, and there is no part within a character that encodes phonemes, it is likely that syllabic or onset-rime awareness, rather than phonemic awareness, is more important to Chinese reading. Interestingly, Huang and Hanley's (1995) phonological tasks manipulated
the phoneme level, while Ho and Bryant's (1997a), Hu and Catts's (1998) and McBride-Change and Ho's (2000) manipulated the onset-rime or syllable level.

The present study provides further support to this hypothesis. First, among the four tasks that were used to assess phonological awareness, rhyme-alliteration oddity, along with tone oddity, is the most important predictor of Chinese reading success, although these skills bear mostly an indirect relationship with reading success via pinyin knowledge. Sound blending shows its influence only at an early stage of reading while sound isolation shows no impact at all. This finding demonstrates that the ability to detect rhymes/alliteration and tone differences are more important predictors of reading success in Chinese than the ability to split or blend phonemic segments. In other words, the nature of phonological awareness that affects Chinese reading appears to be different from that in English.

This finding has one important theoretical implication: To understand the nature of phonological awareness that affects reading acquisition, we must consider how orthography is mapped onto phonology in the written language (Goswami, 1999). Educators and psychologists tend to model language development as universal across languages. Language processing strategies incorporated in their models are presumed to be characteristic of a general human language processing system which is not language-specific. However, several behavioral studies have reported that different strategies may be applied to process different languages (e.g., Seymour & Elder, 1986; Stuart & Coltheart, 1988; Wimmer & Hummer, 1990). Recently, research using
neuroimaging has provided converging evidence for this language-specific hypothesis (e.g., Paulesu et al., 2000; Tan et al., 2001).

For alphabetic languages, the design principle of the writing systems allows a close connection between the grapheme and the phoneme of the spoken language: The unit of speech a grapheme represents is the phoneme, and the number of phonemes represented is the same as that of speech (although this may not be true for orthographically less transparent script such as English). Once a child has acquired this alphabetic knowledge and understood the relation between print and speech, he can apply the knowledge to derive the meanings of words that are visually unfamiliar but exist in his auditory mental lexicon. Therefore, the explicit knowledge of the phonological structure of a language, or phonological awareness, as well as the knowledge of the sounds that letters represent, is crucial to alphabetic reading.

Chinese does not have grapheme-phoneme mapping. Even if a character maps onto the syllable of speech, the mapping does not follow a rule. It is thus unlikely that the awareness of the phonemic structure is an antecedent of successful reading. Rather, the connection between speech and print is established through rote memory. In a sense, a child is able to read a Chinese character only when she has been taught to do so. However, the introduction of pinyin may have changed the way the connection between speech and print is formed.

Pinyin has been used in Mainland China since 1958 as a learning tool to help children learn Chinese characters. It is a phonemic representation system which helps children read Chinese characters by
appearing above the characters. When a child has acquired the pinyin principle, he is able to derive the sounds of the characters through pinyin and to match these sounds with the phonological codes that already exist in the mental lexicon. In other words, pinyin knowledge bridges the gap between speech and writing in Chinese and this enables children to derive the meanings of characters that are visually unfamiliar but are auditorily familiar. Moreover, pinyin helps to transfer a visual character into a phonological code, which helps keep information in short-term and long-term memory. This alphabetic knowledge plays a role very similar to the grapheme-phoneme correspondence rule in alphabetic languages. This study has demonstrated the importance and effectiveness of pinyin as a learning tool from a psychological perspective.

Rhyme-alliteration oddity predicts pinyin knowledge in grades 1 to 4 and tone oddity predicts pinyin knowledge in grades 5 to 6. This suggests that children who are well-equipped with rhyme-alliteration and tonal sensitivity have better pinyin knowledge. An important educational implication that follows is: Improving children's sensitivity towards rhyme/alliteration and tone differences can enhance children's pinyin knowledge, which in turn enhances their reading performance. This issue merits further research.

Pinyin helps the association of speech sounds and visual symbols via a visual modality. However, the present study shows that pinyin knowledge correlates with phonological skill. This suggests that pinyin knowledge can be conceptualized as a skill that involves both visual and phonological processing. Together with the fact that homophone
discrimination also entails these two processes, the present study suggests that processing written Chinese is characterized by a synchronous processing of both visual-orthographic and phonological components at a later stage of development. Investigating either component alone may not reflect the full picture of Chinese reading development. Similar to this idea, McBride-Change and Ho (2000) have argued similarly that "tasks pairing arbitrary visual stimuli with meaningful vocabulary may prove maximally predictive of Chinese character acquisition in children" (p.54).

Conclusion

The results of the present research have suggested that phonological awareness plays a role in Chinese reading acquisition. In addition, visual skills play a role in Chinese reading at an earlier stage of development, while phonological and orthographic skills play a role at later stages of development. These findings are similar to those obtained with alphabetic languages (e.g., Ehri, 1992; Frith, 1985) and are consonant with the hypotheses suggesting that there are some universals for the reading of all orthographies (Perfetti et al., 1992). On the other hand, the study also indicates that onset-rime is a better predictor of Chinese reading than phonemic awareness. This finding differs from that using alphabetic languages which shows that both onset-rime and phonemic awareness are important predictors of reading success. It implies that research on the relationship between phonological awareness and reading of a specific script should consider how orthography maps onto phonology in the written language (Goswami, 1999).
Pinyin reading and homophone discrimination are two major predictors of Chinese reading, especially for second to sixth graders. As argued earlier, these tasks provoke the ability to combine both orthographic and phonological skills together, unlike the component or miswriting search tasks which entail only the orthographic processing. I therefore propose that tasks measuring the synchronous processing of both orthographic and phonological information are better predictors of Chinese reading than tasks tapping either information alone, an idea similar to that proffered recently by McBride-Chang and Ho (2000).

As a final remark, pinyin knowledge seems to play a rather important role in Chinese reading. Specifically, it helps children to form the association of speech sounds and visual characters. However, I do not wish to conclude that children who learn pinyin have better reading ability than those who have not, nor to argue that the pinyin system should be taught to children to enhance their reading performance. These issues warrant further investigation.

In fact, for societies where the writing does not consistently encode speech, learning to read may be a more complicated issue. In the Chinese society, multiple dialects exist, and these Chinese dialects differ from one another quite dramatically. The only script that is used in the Chinese society is hence independent of any particular phonetic manifestation of these dialects (Norman, 1988). This independence leads to the difference in the degree of mapping between speech (dialect) and writing. For the current standard dialect, Putonghua, the distinction between the written literary medium and spoken language is probably not very great, thanks to
a campaign led by the May 4th movement in 1919 which advocated the use of the modern spoken language (based on the Beijing dialect) as the sole basis for written Chinese (Lehmann, 1975). But for other dialects, the difference could be rather big. This discrepancy between the script and speech may induce difficulties on learning to read because a child has to rote memorize a huge set of characters without making reference to the already-existed auditory mental lexicon.

This issue is particularly relevant to the situation in Hong Kong where Chinese (Cantonese) as the medium of instruction has been implemented since 1997 (note that the medium of instruction used to be English for the majority of schools). Most Hong Kong children do not learn Putonghua systematically and hence cannot speak Putonghua, unlike children in Mainland China. They generally have a frustrating feeling that what they speak (in Cantonese) is different from what they read and write. For example, /ngo5 dei6/ (in Cantonese, same below) is the spoken form meaning we, which is represented by the visual form 我们 (pronounced as /ngo5 mun4/) when it appears in written text; /bin1 dou6/ is the spoken form meaning where, which is represented by the visual form 那里 (pronounced as /na5 lœy4/) when it appears in written text. This inconsistency between the way we speak and read/write may create confusion for children when they apply their knowledge obtained from the auditory domain to reading and writing. In fact, there is a claim that Hong Kong children's Chinese language ability is not as good as that Mainland or Taiwan counterparts, although we do not have empirical evidence to support this claim. As many Hong Kong children and teachers
have indicated, learning to read Chinese is painstaking as it involves
tremendous amount of rote memory and writing exercises, and children
have difficulties in reading Chinese texts at home as there is no guidance
on how to pronounce unfamiliar Chinese characters. Without teacher’s or
parents’ help, Hong Kong children cannot know the sounds of newly
encountered characters, unlike Mainland children who can read with the
help of pinyin. This casts doubts on the effectiveness of using Cantonese
as the instruction medium in Hong Kong. One possible way to resolve this
difficulty may be to teach Hong Kong children to learn speak Putonghua.
Further research can investigate whether Hong Kong children who have
learned Putonghua and pinyin have better Chinese reading performance
than children who have not.
Appendix I

A Sample of Phonological Awareness Tests

(语音测试，适用于一、二年级，个人测试)
Phonological Test. For Grades 1 and 2. Individual Test.

姓名:  性别:  出生日期:  年  月  年级:  班
Name:  Sex:  Date of Birth:  Grade:

第一部分
在下列每一道题目里，一共有四个音节，其中三个有共同的声母或韵母，而另一个和其他三个没有共同的地方。我现在读出这四个音节，请你说出哪一个音节和其他三个不一样。

Part 1: In each of the following items, there are four syllables. Three of them have either the same initial or the same final, while the other shares no initial nor final. Now I read out four syllables, please tell me which one is the odd one out.

练习部分！（Practice Trials）

1. juan  yuan  rè  quàn  2. nǐ  bèn  nào  nù
3. chá  jī  jīng  jūn  4. táng  màn  tīe  tāo
5. bee  see  hi  lee

正式mm % 试：（Test Trials）

1. sòng  pà  tàng  suǒ  2. sì  nài  hǎi  kāi
3. wa  wu  duō  wěi  4. yī  hào  lǐng  liǎn
5. dāng  sai  gang  bāng  6. xià  xie  xiān  fāng
7. qian  piào  tiáo  8. fù  gù  kūn  wǔ
9. lái  xiao  yì  10. dài  hài  nai  wang
11. wet  get  bet  sun  12. pī  sak  pat  pop
13. top  yes  tak  tim  14. mip  yip  tip  rat
15. seem  cat  cop  kid  16. sad  bad  jeep  had
17. jam  sing  ram  pam  18. food  fat  week  fog

第二部分
在下列每一道题目里，一共有四个音节，其中三个音的声调是一样的，另外一个的声调和其他三个不一样。我现在读出这四个音节，请你说出哪一个的声调和其他三个不一样。

Part 2: In each of the following items, there are four syllables. Three of them have the same tone, while the other has a different tone. Now I read out four syllables, please tell me which one has a different tone.

练习部分！（Practice Trials）

1. shē  shào  shēn  shì  2. xī  qiào  jiào  biào
3. zhē  chē  gé  rè  4. li  là*  liǎn  luò

正式mm % 试：（Test Trials）

1. xìng  xi  xiao  xian  2. yán  yáng  yu  ya
Part 3: Each (Chinese) syllable consists of an initial and a final. Some syllables contain a medial vowel. For example, the syllable /p/ has an initial p, a medial vowel i, and a final a. Another example, the syllable not has an initial n, a medial vowel o, and a final t. Now I read out a syllable, please tell me what is the initial of this syllable. (Trial item: da)

| 1. bang | 2. chaif | 3. gong | 4. qin | 5. beef | 6. gas | 7. top | 8. fat |

Be. 我现在读出一个音节，请你告诉我这个音节的结尾的部分是什么。 (练习题：ben) Now I read out a syllable, please tell me what is the final of this syllable. (Trial item: ben)

| 1. nan | 2. shai | 3. ke | 4. hao | 5. bus | 6. nut | 7. dad | 8. him |

C. 我现在读出一个音节，请你告诉我这个音节的中间的部分是什么。 (练习题：jue) Now I read out a syllable, please tell me what is the medial of this syllable. (Trial item: jue)

| 1. guai | 2. tuan | 3. xia | 4. huan | 5. qiong | 6. ping | 7. bomb | 8. care |

第四部分

在这一部分，我每次说出一个音节的声母和韵母(或介音)，请你把这几个部分组合成音节，以第一声读出。例如，如果说出 m 和 a，你就应该把这两部分组合起来，说出 ma。如果说出 x—u—e 你则应该说出 xue.

In this section, I will read out several sound segments (initial, final, and/or medial of a syllable). Your task is to blend these sound segments to form a syllable in the first tone. For example, if I read out the sounds m and a, you have to blend them to form the syllable ma. If I read out the sounds x, u, and e, your have to say xue.

下面我们做正式的测验。

| 1. l—ei | 2. h—ao | 3. w—ang | 4. q—u—e | 5. sh—eng | 6. m—i—ao | 7. b—an | 8. c—ai | 9. g—u—ai | 10. zh—ui |
姓名：

性：

生日期：

年月：

班级：

第一部分
在下列每一题题里，一共有四个音节，其中三个有共同的声母或韵母，而另一个和其他三个没有共同的地方。我现在读出这四个音节，请你说出哪一个音节和其他三个不一样。

Part 1: In each of the following items, there are four syllables. Three of them have either the same initial or the same final, while the other shares no initial nor final. Now I read out four syllables, please tell me which one is the odd one out.

练习部分. (Practice Trials)

1. juan yuan rè quan
2. ní ben n&n báo tao
3. chē jī* jīng jūn
4. tang nàng tāo fen
5. bee see hi lee

正式测部分 (Test Trials)

1. sōng pa sāng sù
2. x. nái hù kāi
3. wā wū duō wēi
4. sā liāo lǐng hán
5. dāng sai gang bang
6. xià xie xian fāng
7. quān sai gang tiào
8. sī gu kūn wǔ
9. lǎn pāo pāo tāo
10. dāi hǎi nài wàng
11. get get bet sun
12. pig sak pat pop
13. top yes tak tim
14. mǐp yíp tip rat
15. seem cat cop kid
16. sad bad jeep had
17. jam sing ram pam
18. food fat week fog
19. cups boys tank hats
20. hot hope home boss

第二部分
在下列每一题题里，一共有四个音节，其中三个的声调是相同的，另外一个的声调和其他三个不一样。我现在读出这四个音节，请你说出哪一个的声调和其他三个不一样。

Part 2: In each of the following items, there are four syllables. Three of them have the same tone, while the other has a different tone. Now I read out four syllables, please tell me which one has a different tone.

练习部分. (Practice Trials)

1. shè shào shēn shì
2. nǐ tāo lǎi jīn
3. chē chē gē ré
4. xīn gào dào tāo
5. tu tài tì tu

正式测部分 (Test Trials)

1. xīng xi xīn xián
2. yán yàng you yā
3. hào gào dao tāo
4. fāng fān fēng fēn
5. tu tài tì tu
6. wèn wàng wéi wǎn
第三部分

A. 每一个音节包括声母（开头的部分）和韵母（结尾的部分）。有一些音节还包括介母（中间的部分）。
例如，pi 的开头的部分是 p，结尾的部分是 i；而 jia 的开头的部分是 j，中间的部分是 i，结尾的部分是 a。又例如，not 的开头的部分是 n，中间的部分是 o，结尾的部分是 t。我现在读出“\(\text{da}\)”，请告诉我这个音节的开头的部分是什么。（练习题 - da）

<table>
<thead>
<tr>
<th>1. bang</th>
<th>2. chai</th>
<th>3. guang</th>
<th>4. qin</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. beef</td>
<td>6. gas</td>
<td>7. top</td>
<td>8. fat</td>
</tr>
</tbody>
</table>

Bo **mmwm**— **rWv**> **wWm**— **m**

我读出这个音节的结尾的部分是什么。（练习题 - ben）

M : **ben** Now I read out a syllable, please tell me what is the final of this syllable. —^- (Trial item: ben)

<table>
<thead>
<tr>
<th>1. nan</th>
<th>2. shai</th>
<th>3. kr</th>
<th>4. bab</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. bus</td>
<td>6. nut</td>
<td>7. dad</td>
<td>8. him</td>
</tr>
</tbody>
</table>

C. 我现在读出一个音节，请你告诉我这个音节的中间的部分是什么。（练习题：jue）

Now I read out a syllable, please tell me what is the medial of this syllable. —^- (Trial item: jue)

<table>
<thead>
<tr>
<th>1. gua</th>
<th>2. tuan</th>
<th>3. xia</th>
<th>4. huai</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. qiong</td>
<td>6. ping</td>
<td>7. bomb</td>
<td>8. care</td>
</tr>
</tbody>
</table>

第四部分

在这一部分，我每次说出一个音节的声母和韵母（或介音），请你把这几个部分组合成音节，以第一声读出。例如，如果我说出 m 和 a，你就应该把这两部分组合起来，说出 ma。如果我说出 x—u—e

则应该说出 xue.

In this section, I will read out several sound segments (initial, final, and/or medial of a syllable). Your task is to blend these sound segments to form a syllable in the first tone. For example, if I read out the sounds m and a, you have to blend them to form the syllable ma. If I read out the sounds x, u and e, your have to say xue.

下面我们做正式的测验。

| 1. l—ei | 2. h—ao |
| 3. w—ang | 4. q—u—e |
| 5. sh—eng | 6. m—i—ao |
| 7. b—an | 8. e—ai |
| 9. x—u—ai | 10. zh—ui |
Appendix II

A Sample of Orthographic Tests and the Homophone Discrimination Test

(Orthographic Test. 2nd Grade. Group Test)

<table>
<thead>
<tr>
<th>Name:</th>
<th>Sex:</th>
<th>Date of Birth:</th>
<th>Grade:</th>
</tr>
</thead>
</table>

**Part 1:** In the following section, some characters contain a component "\( \text{口} \)", while some do not. Please read each character carefully, and circle those contain the component "\( \text{口} \)".

<table>
<thead>
<tr>
<th>1.</th>
<th>2.</th>
<th>3.</th>
</tr>
</thead>
<tbody>
<tr>
<td>bl</td>
<td>fāng</td>
<td>( \text{ai} )</td>
</tr>
<tr>
<td>qīu</td>
<td>qīng</td>
<td></td>
</tr>
<tr>
<td>tū</td>
<td>màn</td>
<td></td>
</tr>
<tr>
<td>tài</td>
<td>yǎn</td>
<td></td>
</tr>
<tr>
<td>wù</td>
<td>zhí</td>
<td></td>
</tr>
<tr>
<td>hé</td>
<td>géi</td>
<td></td>
</tr>
<tr>
<td>chu</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Part 2:** In the following section, some characters are written correctly, while some do not. Please read each character carefully, and circle those that are written incorrectly and write down the correct characters.

<table>
<thead>
<tr>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8.</th>
<th>9.</th>
<th>10.</th>
<th>11.</th>
<th>12.</th>
<th>13.</th>
<th>14.</th>
<th>15.</th>
<th>16.</th>
<th>17.</th>
<th>18.</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tr>
</tbody>
</table>

- 区  | 贾  | 破  | 务  | 拟  | 末  | 耳  | 两  | 同  | 称  | 体  | 密  | 词  | 多  | 安  | 做  | 便  |
- 韬  | 价  | 拳  | 梨  | 魔  | 书  | 卷  | 珍  | 书  | 贸  | 份  | 福  | 贡  | 品  | 庭  | 顶  |
- 信  | 信  | 手  | 铁  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  |
- 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  | 早  |
- 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  | 爱  |
- 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  | 冬  |
- 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  | 信  |
- 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  | 开  |
- 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  | 圆  |
- 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  | 镜  |
Part 3: Word combination. In each of the following items, please select from the bracket the character that can form a meaningful two-character words with the character on the left. Please write down the correct number on the blank.

1. ___ X: (① ® ⑤ ®％)
2. ___ H: (① 井 ② 警)
3. ___ ft: (⑥ ⑧ ② 连)
4. ___ 午: (① 夏 ② 下)
5. ___ %: (⑤ m® »)
6. ___ A: (① 公 ② 工)
7. ___ M: (④ ④ ③ M)
8. ___ 处: (① 到 ③ 道)
9. ___ M: (④ Bf ® U)
10. ___ 法: (① 办 ② 半)
姓名： 性别： 出生日期： 年 一 年级： 班
Name: Sex: Date of Birth: Grade:

第一部分 下面的字有的含有部首（或偏旁）“口”，有的不含“口”。请你仔细认读每一个字，并圈出含有“口”的字
Part 1: In the following section, some characters contain a component “口” while some do not. Please read each character carefully, and circle those contain the component “口”.

区 哇 部 户 打 举 另 类 记 恰 末 欧 叫 高 同 堆 体 密
品 多 做 修 么 触 面 没 n 与 词 与

第二部分 下面的字，有的写对了，有的写错了。请把写错的字用 O 圈出来，并把正确的字写在旁边。
Part 2: In the following section, some characters are written correctly, while some do not. Please read each character carefully, and circle those that are written incorrectly and write down the correct characters.

16. hé 和 17. 18. gēi 给 19. chú 出 20. lì 丽
Part 3: Word combination. In each of the following items, please select from the bracket the character that can form a meaningful two-character words with the character on the left. Please write down the correct number on the blank.

1. ___ 热: (① 残 ② 断) 2. ___ 争: (① 豆 ② 斗)
3. ___ 风: (① 寒 ② 含) 4. ___ 对: (① 觉 ② 绝)
5. ___ 欢: (① 洗 ② 喜) 6. ___ 证: (① 保 ② 宝)
7. ___ n: (① 访 ② 缝) 8. ___ 引: (① 西 ② 吸)
9. ___ 度: (⑧ ⑨ X) 10. ___ ifr: (⑧ ⑩ i)
11. ___ X: (① 谋 ② 客) 12. ___ 夕: (① 井 ② 夜)
13. ___ ft: (① 怜 ② 连) 14. ___ 午: (① 夏 ② 下)
15. ___ M: (① 清 ② 青) 16. ___ 人: (① 公 ② 工)
17. ___ 等: (① 乌 ② 屋) 18. ___ 处: (① 到 ② 道)
19. ___ 然: (① 呼 ② 忽) 20. ___ 法: (① 办 ② 半)
Appendix III

A Sample of Reading and Pinyin Knowledge Tests for the Cross-Sectional Study

Part 1: Please read the following characters as fast and accurate as possible.

木 船
气 中 雨 爪 钟 学 我 马 禾
羊 井 甲 虾 鸟 男 妈 解 天 桥
竹 姐 真 和 跑 冷 袋 弟 鱼 空
梅 你 鹅 白 清 爬 吃 往 会 里
船 吹 立 火 十 多 国 星 校

Part 2: Please read the following pinyin syllables as fast and accurate as possible.

wu xì xiang mian snao xie lu hún tiāo ān

hèn fo’ tò’ wàn pou mian pie né niè shuān
阅读测试 (二年级)
Reading Test (2nd Grade)

第一部分 请读出下面的字，读得越快越准确越好。
Part 1: Please read the follow characters as fast and accurate as possible.

第二部分 请读出下面的词，读得越快越准确越好。
Part 2: Please read the follow words as fast and accurate as possible.
Appendix III (Cont'd)
Reading Test (2nd Grade)

第三部分　请你读出下面的拼音，读得越快越准确越好。
Part 3: Please read the follow pinyin syllables as fast and accurate as possible.

wu xi xiang mian snao xie lu hun tiao an
mn mie xu piao rong fan zui chi ceng mm
xuan chong hui dian guo xun jm jia kui seqng
quan mu za xie gen ang chen de kuo cou
hen fo te wan pou mian pie ne nue shuan
tou she qie niang qu ru san pan qiong zen
姓名： 性别： 出生日期： 年 月 年级：
Name: Sex: Date of Birth: Grade:

阅读测试 (三年级)
Reading Test (3rd Grade)

第一部分 请你读出下面的字，读得越快越准确越好。
Part 1: Please read the follow characters as fast and accurate as possible.

```
m  \n  t  t  i  f  i  i  拦  拆
51  7%  $  #  H  H  M  %  甜  相
```

第二部分 请你读出下面的词，读得越快越准确越好。
Part 2: Please read the follow words as fast and accurate as possible.

```
本领 外国 永远 如果 一旁 有趣 名字 仔细 辛苦 决定
明白 长处 事情 秋天 红叶 疼爱 旅行 神气 秘密 浪费
画家 黑夜 31S 喜爱 准备 微风 国国 鲜花 愿意 遗失
山峰 内容 介绍 座位 同意 议论 开水 #14 ttX U 重
社会 保障 乘客 翅膀 海滩 负责 配合 狭窄 见识 清澈
寂寞 接受 买卖 视线 预备 感动 鼓励 精美 欢畅 滋润
```
第三部分　请你读出下面的拼音，读得越快越准确越好。
Part 3: Please read the following pinyin syllables as fast and accurate as possible.

wu xí xiàng mian sào xie lu hím tiáo àn
mì xu piào róng fàn zm chí cèng mm
xuàn chóng huì diàn guò xún jiù jiā km séh
quan niú zu xie gén ang chén de kuo cou
hén fó te wán pòu miàn piè ne ntie shuān
tou she qiè niáng qu ru sān pan qióng zen
第三部分  请你读出下面的拼音，读得越快越准确越好。
Part 3: Please read the following pinyin syllables as fast and accurate as possible.

WU  xi  xiang  mian  shao  xie  lu  hun  tiao  an
nin  mie  xu  piao  rong  fan  zu  chi  ceng  mm
xuan  chong  hm  diah  guo  xun  jiu  jia  kui  seng
quan  niu  za  xie  gen  ang  chen  de  kuou  cou
hen  fo  te  wan  pou  mian  pie  ne  nie  shuan
tou  she  qie  niang  qu  ru  san  pan  qiong  zen
Appendix IV
A Sample of Reading and Pinyin Knowledge Tests for the Longitudinal Study

姓名：
Name:
Sex: Date of Birth:
年级：
Grade:

rag si ft (±*?&),
Reading Test (2nd Grade)

第一部分  请你读出下面的字，读得越快越准确越好。
Part 1: Please read the follow characters as fast and accurate as possible.

木  舟

气  中  雨  爪  亻  学  卫  我  马  禾
羊  井  七  虾  鸟  男  妈  解  天  桥
竹  姐  真  和  跑  冷  蛋  弟  鱼  空
梅  你  鹅  白  清  灼  吃  往  会  里
船  冬  吹  立  火  十  多  国  星  校

m  秋  笔  弓  豆  电  口  爱  爸  前
安  军  阳  护  京  nf  到  草  雪
想  衣  字  坐  有  在  道  扇  fl  高

石  毛  米  土  保  生  旗  做  来  去

第二部分  请你读出下面的字，读得越快越准确越好。
Part 2: Please read the follow characters as fast and accurate as possible.

村  图  温  线  笔  院  院  晴  滴  报  和  M
落  4  题  凤  猜  始  采  功  敢  旗
球  犯  钟  竿  晚  扬  路  响  装
姐  z:  W.  -m  M  乡  互  纸  岁  扇
卖  P|  SE  In  Nl  3l  出  秋  歌  校  东
诚  牛  演  怕  用  值  fl  放  洗  笑
兔  该  面  梯  哭  好  稀  抱  雨  拿
洞  离  翻  爱  搬  拢  补  清  极  慢
事  圆  朋  给  刚  等  明  桥  拿  站
红  形  银  商  角  单  照  调  举  初
iff  fl  际  凶  亩  助  运  移  项  强
移  肉  赞  醒  般  贵  曲  顿  零  背
Part 3: Please read the follow words as fast and accurate as possible.

政治 经验 随便 校园 买卖 休息 听话 背景 题目 游泳
动物 树林 知道 阳光 技术 勇敢 美丽 迟到 回答 空中
欧洲 课堂 身体 蚂蚁 彩虹 镜子 原谅 高兴 早操 开学
本领 翅膀 永远 如果 一旁 有趣 名字 仔细 辛苦 决定
明白 长处 事情 秋天 Infl m% 疼爱 旅行 神气 浪费
画家 黑夜 习惯 喜爱 如果 准备 微风 图画 鲜花 愿意

Part 4: Please read the follow pinyin syllables as fast and accurate as possible.

xùn jia seng xuan chóng hui diǎn guò jiǔ km
mìe xu piào róng fān zm chí cēng miù
hèn fo té wan pou mian pie ne nǐè shuān
tshe qiē qu tou ru san pan mang qióng zen
mian wu xì shào lu hun xie tiao an xiàng
mù còu zà xie gén èng chén quàn de kuò
姓 名：  性 别： 出 生 日 期 ：  年  n  年 级 ：  班
Name:  Sex:  Date of Birth:  Grade:

阅 读 测 试 (三 年 级)
Reading Test (3rd Grade)

第 一 部 分  请 你 读 出 下 面 的 字，读 得 越 快 越 准 确 越 好。
Part 1: Please read the follow characters as fast and accurate as possible.

村 图 温 线 笔 院 晴 报 和 显
落 鸟 题 凤 游 始 采 功 敢 旗
球 犯 钟 幽 晚 整 扬 m m 装
姐 艺 板 省 通 乡 互 纸 岁 扇
卖 织 注 信 退 LB 秋 歌 校 东
诚 牛 演 怕 用 值 淋 放 洗 笑
兔 该 裁 面 条 哭 好 稀 m fii 抬
洞 高 翻 爱 撒 沾 补 清 极 慢
事 团 浪 给 服 等 明 桥 举 站
银 商 角 单 灯 调 举 初
if ^ 际 凶 凑 助 运 随 项 强
移 岗 贤 醒 程 贵 曲 项 零 背

第 二 部 分  请 你 读 出 下 面 的 字，读 得 越 快 越 准 确 越 好。
Part 2: Please read the follow characters as fast and accurate as possible.

m 倒 信 敢 缩 情 箱 甜 起
理 永 昂 # n w 醒 毛 甜 相
坏 浪 谜 货 漫 诞 归 露 平 吵
断 顿 极 段 价 户 算 疲 燃 夹
移 志 沾 事 翻 稀 领 曲 垂 始
神 印 肿 久 落 更 胜 郊 声 演
苗 森 E m i 渔 姿 格 泡 晶
宏 宽 LB fiK 偏 剪 墨 灶 彩
尖 岩 蜂 配 锦 材 n & 舌 轮
杏 凝 仙 盒 治 袜 乖 栏 秋 m
辨 稀 理 凉 人 史 瓦 滑 露 腰
辅 浓 验 蛀 合 典 香 酒 遗 洒
Part 3: Please read the follow words as fast and accurate as possible.

政治  经验  随便  校园  买卖  休息  听话  背景  题目  游泳
动物  树林  知道  阳光  技术  勇敢  美丽  迟到  回答  空中
身体  蚂蚁  彩虹  镜子  原谅  高兴  早操  开学
本领  翅膀  永远  如果  一旁  有趣  名字  仔细  辛苦  决定
明白  长处  事情  秋天  红叶  秘密  疼爱  旅行  神气  浪费
画家  黑夜  习惯  喜爱  如果  准备  微风  图画  鲜花  愿意

Part 4: Please read the follow words as fast and accurate as possible.

本领  外国  永远  如果  一旁  有趣  名字  仔细  辛苦  决定
明白  长处  事情  秋天  红叶  疼爱  旅行  神气  秘密  浪费
画家  黑夜  习惯  喜爱  准备  微风  图画  鲜花  愿意  遗失
山峰  内容  介绍  座位  同意  议论  汗水  材料  作文  沉重
社会  保暖  乘客  翅膀  海滩  负责  配合  狭窄  见识  清澈
寂寞  接受  买卖  视线  感动  预备  鼓励  精美  欢畅  滋润

Part 5: Please read the follow pinyin syllables as fast and accurate as possible.

xun  jia  seng  xuan  chong  nui  dian  guo  jm  kui
nin  mie  xu  piao  rong  fan  zu  chi  ceng  mm
hen  fo  s  wan  pou  mian  pie  ne  nie  shuan
she  que  qu  tou  ru  san  pan  niang  qiong  zen
mian  xi  shab  la  hun  xie  tiao  an  xiang
mu  cou  za  xie  gen  ang  chen  quan  de  kuo
姓名： 性别： 出生日期： 年 月 年级： 班
Name: Sex: Date of Birth: Grade:

阅读测试（四年级）
Reading Test (4th Grade)

第一部分 请你读出下面的字，读得越快越准确越好。
Part 1: Please read the follow characters as fast and accurate as possible.

M 倒 案 敢 经 包 胶 拍 拾
理 永 S 林 园 刚 醒 € ffl 相
坏 浪 迷 话 漫 雅 归 露 平 吵
撕 顾 选 价 户 算 被 热 夹
移 志 担 事 翻 稀 领 曲 垂 起
神 印 肿 久 落 更 胜 郊 聋 演
茁 森 匠 腊 悲 浴 姿 格 ffl 晶
7E 宽 $ 寒 威 剪 墨 堆 彩
尖 岩 蜂 配 镇 hi ni A 舌 轮
沓 液 澄 仙 盒 治 袜 乖 栏 秧 航
辨 稀 理 雅 仁 史 万 滑 露 腰
辅 浓 验 蛙 舍 典 宴 酒 逸 泊

第二部分 请你读出下面的字，读得越快越准确越好。
Part 2: Please read the follow characters as fast and accurate as possible.

柔 砖 早 闹 融 默 凡 轴 弱 盈
征 嘱 置 鹤 拽 淑 妇 峰 痕 豹
邓 器 盟 梦 偶 俊 奋 崖 湿 卸
泊 还 拜 E M k Tn 禽 濑 适 啸
堪 汇 绵 齿 棺 俭 黑 猿 缺 项
牵 揽 颤 触 悉 遨 莹 炼 鹭 额
窝 拳 乖 if 拢 蚊 嵌 t2 磨 铺
履 煤 拦 波 兆 领 漫 警 吊 贼
擒 猿 乘 骡 黏 纹 贱 昂 堡 跨
账 藩 蝶 凹 绿 笛 欣 卧 弥 尚
赠 献 窈 获 徽 隆 悼 赠 弭 鞭
a 尘 居 蹲 调 $ if 击 击 酷
第三部分 请你读出下面的词，读得越快越准确越好。
Part 1: Please read the follow words as fast and accurate as possible.

| 本 | 领 | 外 | 国 | 永 | 远 | 果 | 如果 | — | 一 | 旁 | 有 | 趣 | 名 | 字 | 仔 | 细 | 辛 | 苦 | 决 | 定 |
| — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — | — |
| 明 | 白 | — | 事 | 情 | 秋 | 天 | 红 | 叶 | 疼 | 爱 | 旅 | 行 | 无 | 气 | m | 密 | 浪 | 费 |
| 画 | 家 | 黑 | 夜 | 习 | 惯 | 喜 | 爱 | 准 | 备 | 微 | 风 | 图 | 画 | 鲜 | 花 | 愿 | m | 遗 | 失 |
| 山 | 峰 | 内 | 容 | 介 | 绍 | 座 | 位 | 同 | 意 | 议 | 论 | 汗 | 水 | 材 | 料 | 作 | 文 | 沉 | 重 |
| 社 | 会 | 保 | 暖 | 乘 | 客 | 翅 | 膀 | 海 | 滩 | 负 | 任 | 配 | 合 | 狭 | 窄 | 见 | 识 | 清 | 澈 |
| 寂 | 寞 | 接 | 受 | 买 | 卖 | 视 | 线 | 预 | 备 | 感 | 动 | 鼓 | 励 | 精 | 美 | 欢 | 畅 | 滋 | 润 |

第四部分 请你读出下面的词，读得越快越准确越好。
Part 1: Please read the follow words as fast and accurate as possible.

| 咀 | 嚼 | 熙 | 撒 | 展 | 览 | 迅 | 速 | 槽 | 蹋 | 继 | 续 | 介 | 绍 | 环 | 罗 | 堆 | 积 | 鹅 | 鹅 |
| 声 | 声 | 委 | 屈 | 朴 | 素 | 贫 | 穷 | 欢 | 腾 | ma | ma | & | 嘱 | 咐 | 眼 | 睛 | 懒 | 惰 |
| 咳 | 嗽 | 芙 | 蓉 | 狭 | 窄 | 肿 | 胀 | 葡 | 萄 | 便 | 便 | 研 | 究 | 端 | 详 | 贷 | 妾 | 贸 | 易 |
| 挖 | 掘 | 谣 | 言 | 漂 | 浮 | 巡 | 回 | 恐 | 怖 | 湖 | 畔 | 伶 | 剌 | 堤 | 堤 | 扫 | 荡 | 养 | 育 |
| 设 | 备 | 损 | 烂 | 飞 | 越 | 智 | 慧 | 背 | 诵 | 踏 | 踏 | 黯 | 然 | 炸 | 弹 | 空 | 洞 | 避 | 避 |
| 深 | 情 | 无 | 限 | 难 | 题 | 激 | 励 | 慷 | 慨 | 纠 | 缠 | 驱 | 逐 | 牺 | 牲 | 鞠 | 躬 | 蓠 | 蓋 |

第五部分 请你读出下面的拼音，读得越快越准确越好。
Part 1: Please read the follow pinyin syllables as fast and accurate as possible.

| xun | jia | seng | xuan | cnong | hm | dian | guo | jm | kui |
| nin | mie | xu | piao | rong | fan | zui | cni | ceng | mm |
| hen | fo | te | wan | pou | mian | pie | ne | nue | shuan |
| she | qie | qu | tou | ru | san | pan | niang | qiong | zen |
| mian | wu | xi | shao | lu | hun | xie | tiao | an | xiang |
| niu | cou | za | xie | gen | ang | chen | quan | de | kuo |
阅读测试 (六年级)
Reading Test (6th Grade)

第一部分 请你读出下面的字，读得越快越准确越好。
Part 1: Please read the follow characters as fast and accurate as possible.

第二部分 请你读出下面的字，读得越快越准确越好。
Part 2: Please read the follow characters as fast and accurate as possible.
Part 3: Please read the follow words as fast and accurate as possible.

暴露 承担 惩罚 赛跑 麦田 飘浮 贫婪 巡回 废料 杂志
苏醒 贸易 掌声 剧烈 局势 潮味 管家 端详 避免 携要
桌子 规模 恐怖 起程 温柔 隐免 览展 喜悦 寒气 谦盲
悬殊 晦微 乐观 飞荡 养育 踏跃 设备 满烂 飞越 队员
抄写 背诵 黯然 化石 空洞 爽朗 优胜 原始 音调 无限
深情 情形 难题 锦鸡 克服 巨浪 漂浮 恐怖 简要 冷清

Part 4: Please read the follow words as fast and accurate as possible.

洪亮 控制 慷慨 昼夜 神秘 疏乏 巅新 消耗 咆哮 狡猾
坚毅 惺忪 呻吟 慈祥 录获 择交 凭据 投降 纯洁 拼扎
僵硬 威胁 慷厚 翡翠 鳞峋 屏障 峰峦 妒忌 殴误 mm
批评 道歉 击溃 淌流 疏浮 惨不懂 懊悔 疲惫 沸腾 蔓延
搜索 抄削 凋零 戈壁 咨询 歼灭 掌谈 崎岖 摊圆 放肆
管辖 淋博 淋散 气魄 急情 紊乱 崇高 哭泣 突兀 灌输

Part 5: Please read the follow pinyin syllables as fast and accurate as possible.

xùn jiā sēng xǔn chōng huǐ diān guō jǔ kǔ
mǐn mìe xī piāo róng fān zuǐ chí cēng mm
hèn fó té wān pōu miàn piě ne niiē shuā
she qie qu tou ru san pan niang qióng zen
mian wu xī shàō lú hún xie tiǎo àn xiàng
niǔ còu zǎ xīqù gēn làng chēn quàn de kuò