The Importance of Phonological Processing in English- and Mandarin-speaking Emergent and Fluent Readers

by

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Dedication

For my mother and father.

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To make up for the length of my dissertation, I will try to be as succinct as possible here without diminishing the importance of these acknowledgements. First, I would like to acknowledge and thank my dissertation advisor, chair, and mentor; Twila Tardif, without whom, my dissertation and my horizons would be a lot narrower. I would like to thank her for her infinite faith, relentless encouragement, compassionate role-modeling and demanding tutelage. Professionally, she opened up different fields of research, and personally, different worlds. Secondly, I would like to thank my committee members for their flexibility and keen insights. Next, I would like to thank the research assistants in the US and in China, as well as the participating students and families, without whom there would be no data. In general, I would like to thank the Psychology department, Rackham, and the University as a whole for the wealth of opportunities provided and the funding I received. Having worked for several years before returning to graduate school, I was constantly amazed that I was to be paid to study and do research. Finally, I would like to acknowledge my family for providing humor, perspective, and support throughout this process, my dissertation 'partners-in-crime' for the many different ways they have helped, Bill Gehring, for offering professional and political counsel, and of course, Lee Newman for serving as a constant sounding board, remarkable brainstormer, invaluable writing coach, late-night snack-maker, and for all things good.

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Chapter 1: Introduction: The Components of Reading in English and Mandarin Chinese

The importance of reading to modern society is enormous. Within industrialized nations, the expectation of (and demand for) literacy is omnipresent. At one extreme, most commerce is founded on written communication, ensuring that only those who can read and write are the main recipients of the revenue generated (Snow, 2002). At the other extreme, reading skill is necessary for successful navigation of the most basic requirements of everyday life, from following street signs, to using a phone card, reading a bus schedule, or finding the correct address (e.g., Whitehurst & Lonigan, 2002). And there are, of course, all the activities and tasks that fall in between, including many of the products of technological advancement such as computers, text messaging, the internet, e-mail and e-commerce (Snow, 2002).

The effects of the divide between the literate and the illiterate are divisive and widespread. Those who are illiterate not only have a smaller portion of societal resources available to them, but they often pass on these disadvantages to their children (e.g., Whitehurst & Lonigan, 2002). Children with illiterate or even semi-literate parents live in conditions that are marked by poverty, with fewer educational resources (fewer books in the home, no extra-curricular activities, poorer school districts, etc.) and poorer quality parental input (less child-parent communication, no parental reading or homework helping behaviors) to name just a few (e.g., McBride-Chang, 2004; Whitehurst & Lonigan, 2002). Although literacy does not eliminate poverty and disadvantage, the expectation of literacy is often linked to valued resources within a society (McBride-Chang, 2004). Ideally, for many, becoming literate could be a means to equalize what circumstance has dictated to be unequal.

Unfortunately, this is not happening. Comparisons within countries reveal that the poor and disadvantaged still disproportionately represent those who are illiterate (Snow, 2002). One reason for this is inequity in schooling. However, even in the US, where schooling is mandatory and public education free, nearly one quarter of adult Americans are functionally illiterate (Adams, Treiman, & Pressley, 1998). The majority of these individuals are from low-income families with a recent immigration history (Snow, 2002), and the minority who are not, will soon become the disenfranchised and disadvantaged (Landgraf, 2005). Why, when education is mandated and free for all, are nearly 40% of U.S. 4th graders and 30% of U.S. 8th graders below the cutoff for basic-level performance in reading, a statistic unchanged in the last ten years (NAEP, 2000)? The numbers point to a failure in reading education despite the "No Child Left Behind Act" and demand an improved understanding of the processes involved in learning to read. In the face of the continuing illiteracy epidemic, identifying early foundations of later reading achievement has become a critical research priority with broad-reaching social, economic, and political ramifications nationally and internationally.

Hints on Pronunciation for Foreigners
…A moth is not a moth in mother
Nor both in bother, broth in brother,
And here is not a match for there
Nor dear and fear for bear and pear,
And then there's dose and rose and lose—
Just look them up – and good and choose,
And cork and work and card and ward,
And font and front and word and sword,
And do and go and thwart and cart –
Come, come, I've hardly made a start!
A dreadful language? Man alive.
I'd mastered it when I was five.

(An anonymous letter published in the
London Sunday Times, Jan 3, 1965.
Chomsky, 1970- cited in Adams, 1990)

The Relationship between Phonological Awareness and Reading

Reading is not a unitary skill (Adams, 1990). Instead, learning to read involves many cognitive and linguistic skills that develop during childhood. A large and diverse group of factors has been found to predict children's reading abilities in the early school years: age, IQ, receptive and expressive oral language abilities (including phonological, lexical/semantic, and syntactic components), speech perception, phonological awareness, morphological awareness, speed of processing, awareness of print principles, and a variety of familial background and literacy home environment measures (e.g., Adams, 1990; Burgess, 2002; Christian, Morrison, & Bryant, 1998; Schatschneider, Fletcher, Francis & Carlson, Foorman, 2004; Share, Jorm, Maclean, & Matthews, 1984; Whitehurst & Lonigan, 1998). These skills are commonly aggregated into four distinct emergent literacy domains: phonological processing, print knowledge, oral language, and home literacy (Whitehurst & Lonigan, 2002) and collectively have been found to explain nearly 80% of the variance in early child reading (Share et al., 1984). "Children with more of these emergent literacy skills appear to profit more from reading instruction, learn to read sooner, and read better than do children with less emergent literacy skills." (Anthony, Lonigan, Burgess, Driscoll, Phillips, & Cantor, 2002, p66).

Within these domains, phonological processing, or "the use of phonological information (i.e., the sounds of one's language) in processing written and oral language" (Lonigan, Burgess, Anthony, & Barker, 1998, p294), has been identified as a very strong correlate of reading ability (e.g., Coltheart, 1983; McBride-Chang, 1996, 2004; Scarborough, Dobrich, & Hager, 1991; Stahl & Murray, 1994; Torgesen, Wagner, & Rashotte, 1994). However, phonological processing itself also encompasses a large spectrum of skills, leading many researchers to view it as composed of three separate constructs: phonological awareness (identification and manipulation of sound units), phonological working memory (storage of sound units), and phonological rapid access (speed of processing of and access to sound units) (Wagner & Torgesen, 1987; Wagner, Torgesen, Laughon, Simmons & Rashotte, 1993; Wagner, Torgesen, & Rashotte, 1994). Each of these three abilities has been found to contribute unique variance to individual differences in emergent reading, suggesting distinct and separable underlying skills (Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wagner, Torgesen, Rashotte, Hecht, Barker, Burgess, Donahue, & Garon, 1997; Wimmer, Mayringer, & Landerl, 2000). However, longitudinal and cross-sectional studies have repeatedly isolated phonological awareness as the most discriminating predictor of reading ability in English-speaking children (e.g., Bradley & Bryant, 1983; de Jong & van der Leij, 1999; Liberman, Shankweiler, & Liberman, 1989), explaining more than 50% of the variance in later reading ability (e.g., Lonigan, Burgess, & Anthony, 2000) even when controlling for age, IQ, and vocabulary (Bowey, 1994; Snowling & Hulme, 1993; Wagner & Torgesen 1987). This finding has lead many to claim that phonological awareness is the most important causal factor of reading ability (e.g., Adams, 1990; Bradley & Bryant, 1983; Bryant, Maclean, Bradley & Crossland, 1990; Chaney, 1998; Stanovich, 1993; Torgesen et al., 1994; but see Castles & Coltheart, 2004).

Because of the primacy of phonological awareness in predicting reading outcomes, many researchers have endorsed this skill as the key to learning to read and a panacea to remediating reading difficulties (e.g., Adams, 1990; Stanovich, 1993a, 1993b; Torgesen et al., 1994). In the U.S., this endorsement has become embodied in both legislation and practice, with policymakers including phonemic awareness as one of the 'big 5' components of reading development (National Reading Panel, 2000; Snow, Burns, & Griffin, 1998). However, this endorsement may be premature as it is still not clear exactly *which* phonological skills are critical for reading or exactly *how* they are related to reading (Castles & Coltheart, 2004).

Which Phonological Skills are Related to Reading?

Phonological awareness is formally defined as "the ability to perceive and manipulate sounds of spoken words" (Goswami & Ziegler, 2005, p78). The simplicity of the definition belies the complexity of the concept. Cognitively there is a large difference between tasks requiring perception and tasks requiring manipulation (e.g., Cheour, Paavo, Kraus, 2000; Coch, Grossi, Coffey-Corina, Holcomb, & Neville, 2002). Linguistically, there is a large difference between processing "sounds" in one's native language and processing "sounds" composed of unfamiliar phonological information (e.g., Werker & Tees, 1984). Moreover, cognitively and linguistically there are large differences in the skills required to process sound units of differing sizes (e.g., Anthony & Lonigan, 2004). So, exactly which of these skills are related to reading ability?

Paradigms intended to measure phonological awareness are as variable as the concept is complex. Just a partial list of tasks used to measure phonological awareness includes asking children to: monitor and correct speech errors (Elbro, Petersen, Borstrom, 1998), identify words based on partial acoustic information (e.g., Metsala, 1997), identify words preceded by primes with partial acoustic information (e.g., Bouda & Pennington, 2006), select the odd-word out of a list based on some sound criteria (Hatcher & Hulme, 1999), judge the similarity of word pairs containing different degrees of phonological overlap (e.g., Burgess, 1999), segment words by counting out the parts (e.g., Hoien, Lundberg, Stanovich, & Bjaalid, 1995), remove or switch specific sounds in the word (e.g., Wagner et al., 1997), and blend sounds to produce words and nonwords (e.g., Burgess & Lonigan, 1998). However, correcting a puppet who mispronounces the word, "garbage" (e.g., Elbro, et al., 1998) requires a host of skills, skills that may or may not be required in a task requiring the child to "Say cat without the /k/" (e.g., Wagner et al., 1997). Thus, both the imprecision of the definition and the wide variability in tasks do little to improve our understanding of *which* phonological skills are related to reading.

In the current paper I focus on three task-specific dimensions of phonological awareness, (i) the level of processing, (ii) the type of phonological information, and (iii) the linguistic-level of analysis (i.e., *linguistic grain size*). My focus on these task-specific dimensions is not because I am interested in the tasks per se, but because associated with each of these is an ongoing theoretical debate about the specific nature of the relationship between phonological awareness and reading. In the next section, I review these debates and propose a study designed specifically to adjudicate among the differing theoretical positions and provide insight into *which* phonological skills predict reading and *how* they are related.

How is Phonological Awareness Related to Reading?

i) Is the relationship between phonological awareness and reading specific to the level of processing?

Recently, the term phonological sensitivity replaced the term phonological awareness (Stanovich, 1987; Stanovich, 1992) broadening the definition to include everything from tasks of perceptual processing (the ability to perceive and discriminate sounds in words) to measures of metalinguistic awareness (the ability to manipulate sounds in words; Burgess, 2002; McBride-Chang, 2004). This broadening in definition served to obscure two important distinctions in the construct, (i) the type of task demand and (ii) the level of processing, distinctions that may reflect important conceptual differences in the relationship between phonological skills and reading.

Discriminating /ba/ from /pa/ or /bɑɪl/ from /paɪl/ is not the same type of skill as the removing the /p/ sound in the word 'spoil' (Savage, Blair, & Rvachew, 2006; Ziegler & Goswami, 2005). The former is a measure of sensory-level sensitivity that requires implicit perceptual discrimination of phonetic or phonological features at any linguistic level. The latter measures a more cognitive complex sensitivity involving the explicit and conscious ability to identify, remove, and reconstruct the sounds in a word at any linguistic level. Distinguishing /ba/ from /pa/ or /bɑɪl/ from /paɪl/ requires the recognition of shared phonological segments and is an automatic and unconscious part of speech processing whereas removing the /p/ sound in the word 'spoil'requires the identification and production of shared phonological segments as a conscious, effortful process

(Goswami, 2002, p112). Gombert (1992) distinguished between skills that occur spontaneously versus those that are based on (i) systematically represented knowledge and (ii) that require intentional application and called these two types of skills, epilinguistic and metalinguistic processes. This classification corresponds to both a difference in task demand (implicit versus explicit) and a differences in level of processing (perception versus cognition). Although research has not often differentiated between the two (typically measuring sensory-level sensitivity with implicit tasks and higher-order cognitive sensitivity with explicit tasks), there exists both conceptual and empirical support for Gombert's (1992) dissociation.

Proponents of low-level processing (e.g., Johnston, 1993; Liberman, 1998; Spregner-Charolles, Cole, Lacert, & Serniclaes, 2000; Tallal, Miller, Fitch, 1993) suggest that there are individual differences in sensory processing that relate to differences in reading ability whereas proponents of higher-order awareness argue that there are differences in metacognitive phonological abilities perhaps specific to phonological assembly (Bryant, Nunes, & Bindman 1998; Bradley & Bryant, 1983; Gough & Turner, 1986; Liberman, Shankweiler & Liberman, 1989). Interestingly, most research has found that measures of phonological sensitivity do not predict unique variance in reading ability in adults, nor do they predict emergent reading ability in children beyond measures of phonological awareness (McBride-Chang, 1996; McBride-Chang, 2004; Muter, Hulme, Snowling, & Stevenson, 2004; Scarborough, 1990, 1991 but see Burgess, 2002). Moreover, regardless of whether phonological sensitivity is conceptualized as general sound processing (as measured through tone discrimination and ordering tasks) or a speech-specific component (as measured through speech discrimination and sound judgment tasks), there is limited and conflicting evidence that sensory-driven phonological deficits cause reading impairment (see Rosen, 2003 for an overview, although also see Banai & Ahissar, 2006; Breier, Fletcher, Denton, & Gray, 2004; Habib, 2003) or that measures of phonological sensitivity predict unique variance in reading ability (Hulme, Hatcher, Nation, Brown, Adams, & Stuart, 2002; Hulslander, Talcott, Witton, DeFries, Pennington, Wadsworth, Willcutt, & Olson, 2004; Marshall, Snowling & Baily, 2001; Mody 2003; Muter, Hulme, Snowling & Taylor, 1998; although see Burgess, 2002; McBride-Chang, 1995). Instead, for English speakers, the relationship between phonological sensitivity and reading appears to be mediated by measures of phonological awareness (e.g., Boets, Wouters, Wieringen, & Ghesquiere, 2006; Cooper, Roth, Speece, Schatschneider, 2002; McBride-Chang, 1996; McBride-Chang, Wagner, & Chang, 1997). It may be premature however, to overlook the contribution of phonological sensitivity, as it is not yet clear whether this skill may be more important for predicting reading (i) in younger children and (ii) in children learning languages other than English.

There is some evidence that when phonological sensitivity is measured in younger children (preschool-aged or younger) there are stronger longitudinal relationships with later reading ability than have been reported in older children and adults. The most dramatic example of this is a longitudinal study tracking children from infancy though second grade conducted by Molfese and colleagues (Molfese, Molfese, Modgline, 2001). In this study, Molfese et al. (2001) found signature patterns of brain activation in newborns in response to native contrasts (i.e., bi – gi) that were significantly related to reading differences 8-years later. In another longitudinal study, Scarborough (1990, 1991) found that early pronunciation differences (in particular, errors on consonants) in two-year-olds were related to later phonological skills and differences in reading ability at age 5. In general, although there are many fewer studies investigating reading predictors in children preschool-aged or younger (e.g., Lonigan, Burgess, & Anthony, & Barker, 1998), there is weak support that sensitivity in these younger children (i.e., discriminating word pairs with differing amounts of phonological overlap, e.g., Molfese et al., 2001) is related to later reading levels (e.g., Burgess, 1999).

It is also possible that measures of phonological sensitivity may be important in predicting reading in languages other than English. A recent year-long study of predictors of reading in two small samples of native and non-native English-speaking first-graders found that both phonological sensitivity (measured by word discrimination, i.e., /pæt/ versus /bæt/) and phonological awareness predicted unique variance in reading ability in both groups at the end of the year (Chiappe, Glaeser, & Ferko, 2007). However, sensitivity in the non-native sample (comprised entirely of native Korean-speaking children) explained nearly 45% of the variance in reading growth, compared to only 8.4% in the native English-speaking group (Chiappe et al., 2007). Because of the potential importance in distinguishing between sensitivity and awareness across development and in languages other than English, this dissertation treats phonological sensitivity and phonological awareness as separable and meaningfully dissociable constructs and labels them accordingly. Specifically, I adopt Gombert's (1992) terminology and refer to implicit, sensory-level phonological skills as measures of sensitivity or epilinguistic measures of sensitivity compared to measures of awareness or metalinguistic measures of awareness. This qualification is to recognize the possibility that low-level phonological sensitivity when measured behaviorally may be insensitive to differences found when measured neurally (e.g., Bonte, Poelmans, & Blomert, 2007). Thus, the terminology of low-level sensitivity that is often adopted in the literature (and that would be so convenient to adopt here) may not truly reflect sensory-based sensitivity at the neural level. In order not to overstate the findings as a consequency of an overally-general term, I take care to use the term epilinguistic sensitivity to refer to implict behavioral measures of sensory-level phonological skills and to contrast epilinguistic sensitivity with metalinguistic awareness (i.e. explicit behavioral measures of higher-order phonological sensitivity). Thus, the levels of processing that this dissertation is designed to measure (i) are not designed to disentangle task and level effects, and (ii) are underspecified relative to neurophysiological examinations of levels of processing.

ii) Is the relationship between phonological awareness and reading specific to language-experience?

One commonality in tasks used to measure phonological awareness is that each involves a child's ability to process phonological information in the absence of graphemic information. Based on this, research has explored whether a critical component of phonological awareness lies specifically in the storage of phonological information. There are two bodies of literature that speak to this question.

The speech-specific hypothesis (Liberman, 1998) argues that differences in reading ability may stem from differences in the encoding of speech units. This approach underscores that speech is not an "acoustic alphabet" (Studdert-Kennedy, 2002). According to this perspective, the ability to parse a word into its constituent phonemes relies heavily on an individual's intact categorical perception because of the high amounts of coarticulation within a spoken word,. Although infants are born with the ability to perceive the phonetic contrasts of any language (Kuhl, 1985; Kuhl, Stevens, Hayashi, Deguchi, Kiritani, & Iverson, 2006), the speech-specific approach suggests that there may be gradations in this ability or, that with development some infants fail to tune or consolidate their phonemic categories (e.g., Bates Devescovi, & Wulfeck, 2001). Thus, the speech-specific hypothesis proposes that without proper fine-tuning, a child's phonological representations may remain under- or poorly specified which could lead to difficulties in acquiring alphabetic insight and learning to read (e.g., Liberman, 1989).

Similarly, the lexical restructuring hypothesis (e.g., Metsala, 1997; Walley, 1993; Garlock, Walley & Metsala, 2001) proposes that a child's earliest words are not composed of fully-specified, phonemically-bound sound representations, but rather may be stored and retrieved as "a holistic pattern of interacting elements, variously described as gestures, features, or articulatory routines" (Ferguson & Farwell, 1975; Menyuk & Menn, 1979). However, proponents of this approach argue that it is the lexical properties of vocabulary growth (i.e., frequency and size) that affect the degree of segmentation of the phonological representations (Walley, Metsala, & Garlock, 2003). From either perspective, the degree of specification or the well-formedness (Fowler, 1991) of a child's phonological representations will influence both their level of phonological sensitivity and awareness and their developing reading ability (Elbro, 1996; Elbro, et al., 1998)

There is evidence, albeit limited (e.g., Blomert, Mitterer, Paffin, 2004), that individual differences in phonological representations in children (whether measured by a standard gating paradigm[1]; e.g., Metsala, 1997; Elliott, Sholl, Grant, & Hammer, 1990; or a pronunciation task; Elbro, et al., 1998; Foy & Mann, 2001; Wesseling & Reitsma, 2001) are related to reading ability (e.g., Garlock, Walley, & Metsala, Wesseling & Reitsma, 2001; Griffiths & Snowling, 2001; Metsala, 1997). However, an interesting

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[1] The forward gating paradigm is designed to assess subjects' word recognition abilities from the auditory presentation of partial acoustic-phonetic input. Participants are initially given the first 100ms (100 – 150ms range) of acoustic-phonetic input of a word and are asked to identify the word. Subsequently, segments of acoustic-phonetic input is added systematically (usually in gates of 50ms) until the participants hear the entire word. At each additional gate, participants are also asked to rate their confidence (Walley, 1993).

question becomes what happens in fluent readers? It seems that in older children and adults, phonemic categories are well-established for their native language (e.g., Vitevitch & Luce, 1999, Vitevitch, Luce, Pisoni, & Auer, 1999). Moreover, the more ingrained one becomes in making discriminations important for one's native language, the harder it becomes to make discriminations in a non-native languages, a process that begins even in infancy (e.g., Kuhl et al., 2006). Thus, an interesting set of questions is, if the degree of phonemic specification is a causal component in reading ability (i) are there differences in the predictivity of phonological skills in emergent readers, decoding child readers, and skilled adult readers that may shadow the refinement and specification of phonological representations in these three groups, and (ii) are these phonological skills tied to the phonemes and lexical representations in one's native language, or is it a more global phonological skill independent of one's phonological inventory and mental lexicon that is important for reading? This dissertation attempts to answer these questions through an examination of the relationship between reading ability and two types of phonological processing measures (an epilinguistic sensitivity task requiring discriminations between native and non-native syllables with differing amounts of phonological overlap and a metalinguistic phonological awareness task) measured at three separate levels of reading proficiency - in younger children, older children, and adults.

iii) Is the relationship between phonological skills and reading specific to linguistic grain size?

A large portion of the research investigating phonological awareness and reading has focused on this question of linguistic grain size (i.e., the syllable, the onset-rime, or the phoneme). This research attempts to establish *which* linguistic level is *the* level at which awareness is necessary in order to learn to read. Cross-sectional and longitudinal studies with English-speaking children and children speaking a variety of different languages (primarily Indo-European) have shown a relationship between each linguistic level measured and reading ability: the syllable (e.g., Badian, 1998; Cossu, Shankweiler, Liberman, Katz, & Tola, 1988; Elbro et al., 1998, McBride-Chang & Ho, 2000); the onset-rime (de Jong & van der Leij, 2003; Ho & Bryant, 1997; Maclean, Bryant, & Bradley, 1987); and the phoneme (e.g., Hoien, et al., 1995; Wagner et al., 1994, 1997), making it hard to isolate a single level as critical to reading. However, research has also found differences in these relationships depending on the child's age, reading ability and the language learned.

Preschool aged children with little to no reading ability demonstrate poor phoneme-level awareness (e.g., Adams 1990; Bryant et al., 1990; Wagner & Torgesen, 1987) as do adults with no alphabetic training (i.e., illiterate adults, e.g., Morais, Cary, Alegria, & Bertelson, 1979; or adults learning nonalphabetic languages, e.g., Read, Zhang, Nie, & Ding, 1986). In fact, it has been suggested phonemes are not a psychological reality (e.g., Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967 cited in Lonigan et al., 1998) and that phoneme-level awareness can only develop as a result of literacy training (e.g., Morais, 1991, Scarborough et al, 1998; although see Hulme, 2002). Instead, in younger children measures of syllable (Adams et al., 1998; Lonigan, Burgess, & Anthony, 2000; McBride-Chang & Kail, 2002; Morais, 2003) and onset-rime (Bryant et al., 1990; Burgess & Lonigan, 1998; Carroll & Snowling, 2001; Maclean, et al., 1987) awareness are strong predictors of later phonological skills and reading ability whereas measures of phoneme-level awareness are less related or not at all related to later reading ability (Anthony & Lonigan, 2004). In contrast, in older, school-aged children, phoneme-level awareness is the strongest predictor of reading ability (e.g., Hulme, Hatcher, Nation, Adams, Brown, & Stuart, 2002; Muter, Hulme, Snowling & Taylor, 1998; Stuart, 1995; Wagner et al., 1994, 1997), beyond measures of syllable (e.g., Elbro, et al., 1998) and onset-rime level awareness (e.g., Duncan, Seymour, & Hill, 1997; Stuart, 1995; Hulme et al., 2002; Muter et al., 1998; Stuart, 1995 although see Bryant, 2002). Thus, there appears a developmental continuum in children's level of awareness and the relationship of that level of awareness with reading ability across different linguistic grain sizes (e.g., Burgess & Lonigan, 1998).

The Developmental Perspective. According to a developmental approach this trajectory is a product of task demands and not the linguistic unit being measured (e.g., Anthony & Lonigan, 2004). The search is not for the key level at which awareness is necessary in order to learn to read. Instead, phonological awareness should be conceptualized as "a unitary construct that varies on a continuum of complexity from preschool through at least second grade" (e.g., Anthony & Lonigan, 2004). This claim is supported by the fact that there is a high degree of interrelatedness between the measures of phonological skill at differing linguistic levels (e.g., de Jong & van der Leij, 1999; Lonigan et al., 1998, 2000; Wagner et al., 1997) and that in confirmatory factor analyses, research has found phonological awareness tasks often load on a single factor (Lonigan et al., 2000; Schatschneider, Francis, Foorman, Fletcher, & Mehta, 1999; Stahl & Murray, 1994; Wagner & Torgesen, 1987 although see Goswami & Bryant, 1990 and Muter et al., 1998). Thus, phonological awareness is argued to be a single construct that is related to reading ability independent of linguistic grain size, but that shows developmental differences in awareness of the linguistic grains sizes due to the accessibility of these linguistic units pre- and post alphabetic literacy. From this perspective, the important question then is, "not what type of phonological sensitivity is most important for literacy but which measures of phonological sensitivity are developmentally appropriate for the particular child" (Anthony & Lonigan, p53, 2004).

Language-Specific Perspective. A second (although not always separate) approach interested in linguistic grain size reflects a larger underlying question as to whether or not the importance of phonological awareness stems from the linguistic and orthographic properties of the language learned. Proponents of a language-specific relationship between phonological awareness and reading argue that the linguistic grain size (or *granularity*) at which phonology is mapped to orthography in a particular language, the *consistency* of this mapping, and the *availability* of this linguistic level in spoken language are the three critical determinants of the type of phonological awareness that is important in learning to read and the strength of the relationship between phonological awareness and reading ability in any language (e.g., Goswami, 1999; Ziegler & Goswami, 2005).

English is an alphabetic language that uses letters to represent the phonemes of the language. Furthermore, although the mappings are not always one to one between the letters and the sounds (e.g., c = /s/ i.e., city or /k/ i.e., cat) or between the sounds and the letters (e.g., /eɪ/ = ate or eight), there are inductive regularities in the phoneme-grapheme relations (Ziegler & Goswami, 2005). Proponents of the language-specific approach propose that these sound-script properties of English are what underlie the strong relationship between phonological awareness and reading in English-speaking children. Although English maps at the level of the phoneme and thus phoneme-level awareness is important, proponents of a language-specific approach also suggest that good onset-rime skills can also exploit regularities in the system at the level of the onset-rime that are not captured in a direct one-to-one mapping at the level of the phoneme (Goswami, 1999; Treiman, Mullennix, Bijeljac-Babic, & Richmond-Welty, 1995). Thus sensitivity to subsyllabic and phonemic divisions within words are both important precursors to gaining alphabetic insight, a proposal with strong empirical support (e.g., Bryant et al, 1998, Bryant, 2002; Muter et al., 1998).

Although research in English speakers has provided some support of a language-specific relationship between phonological awareness and reading, cross-cultural comparisons provide the perfect platform for comparison and a stronger test of whether the relationship between phonological awareness and reading is a product of the ways in which written orthographies map to the spoken language and the consistency of this mapping. To date, research on languages other than English has revealed at least some language-specific patterns in the development of phonological awareness and the strength of its relationship with reading ability (e.g., Ziegler & Goswami, 2005). First, the syllable structure of a language has been shown to influence phonological development and its relationship with reading ability (Seymour et al., 2003; Treiman & Weatherston, 1997). Specifically, in a cross-linguistic comparison of English and 12 other European languages, Seymour and colleagues (2003) found that children who learned languages with simple syllable structures (no consonant clusters or multi-letter grapheme-phoneme correspondences) like Finnish, were faster and more accurate at reading a list of simple nonwords than children who learned languages with complex syllable structures, like English. The authors of this study proposed that complex syllable structure in a language may serve to obscure the level of the phoneme (Seymour et al., 2003). However, other researchers have argued that syllabic complexity makes phonemes more salient (Caravolas & Bruck, 1993; Durgunoglu, & Oney, 1999). Cheung et al. (2001) proposed that the performance differences they observed on phonological awareness tasks between English- and Mandarin-speaking children were due to the existence of initial consonant clusters in English but not Mandarin (Cheung, Chen, Lai, Wong & Hills, 2001). Thus, the language-specific view argues that languages differ in whether their spoken features serve to highlight (or obscure) phonological features important for reading and it is this *availability* of these features that is related to the development of phonological awareness and its relationship with reading within a language.

Second, there is evidence that the *consistency* of the sound-symbol mappings in a language influence the rate of development of phonological awareness and the strength of the relationship between phonological awareness and reading. For example, in Spanish, a language with a highly regular sound-symbol system, phoneme-level awareness develops earlier and is related to reading ability for a shorter period of time, than in French, a language with a higher degree of spelling inconsistencies, or English, a language with a higher degree of spelling and pronunciation inconsistencies (e.g., Goswami, Gombert, & de Barrera, 1998). In Hebrew, a language where only partial phonological information can be retrieved from the orthography (Bendror, Bentin & Frost, 1995), phoneme-level awareness develops slowly (Levin & Korat, 1993) and is related to reading late in elementary school. This pattern of late development of phoneme awareness and its relations to reading at later, rather than earlier stages of reading, is even stronger in Arabic, a language with an even more opaque orthography (e.g., Ibrahim, Eviatar, & Aharon-Peretz, 2007).

Last, there is a small, but growing body of research demonstrating an effect of the *granularity* (or the level at which sounds are mapped to symbols) in an orthography and the development and predictivity of phonological awareness in reading. Nonalphabetic languages provide the only naturalistic test of the role of linguistic grain size in reading. Early research done in nonalphabetic languages such as Chinese (Read, et al., 1986) provided strong support for the language-specific approach by showing that without alphabetic training, Asian adults demonstrated very low-levels of phonological awareness, but normal levels of reading ability. Furthermore, more recent research has suggested that alphabetic training in nonalphabetic languages does increase phonological awareness and strengthens the relationship between phonological awareness and reading ability (Hu & Catts, 1998).

On the other hand, there are also arguments against the language-specific approach. First, there is evidence of differences in the rate and development of phonological awareness in languages with common structural properties (Demont & Gombert, 1996; Harris & Giannouli, 1999). For example, in a comparison of studies examining phoneme and syllable awareness in different languages, French children's phoneme-level awareness was significantly lower than English-speaking children in both kindergarten and in first grade, although we consider the languages structurally similar (Demont & Gombert, 1996; Liberman et al., 1974 cited in Ziegler & Goswami, 2005). Furthermore, there are a growing number of studies where phonological skills are strongly predictive of reading ability regardless of orthography, whether transparent, i.e., Italian, (Cossu et al., 1988), opaque, i.e., Arabic (e.g., Abu-Rabia & Taha, 2006), or somewhere in-between, i.e., English, (e.g., Wagner et al., 1997). For example, Mann (1986) found that older Japanese children could perform phoneme-level manipulations despite learning a language without an explicit mapping at the level of the phoneme (although see Goetry, Urbain, Morais, & Kolinsky, 2005). Thus, although orthographies vary in how they encode phonological information (Shu, Anderson & Wu, 2000), the constancy of this relationship cross-linguistically implies a degree of language-independence or a general underlying cognitive mechanism linking phonological skills and reading ability (Comeau et al., 1999 as cited in McBride-Chang, 2004). Thus, research remains divided over the importance of linguistic grain size in phonological awareness and reading.

Both the developmental and the language-specific approaches to the question of linguistic grain size provide testable claims. It may be that different levels of awareness develop at different rates, that different levels of awareness are needed depending on the language, that different levels of awareness develop at different rates in different languages, and/or that they predict reading at different stages. A strong test for these questions is to compare reading models in beginner and more fluent readers cross-culturally. Furthermore, as detailed above, a strong test for each of the questions posed, (i) which level of processing, (ii) the importance of one's language experience, or (iii) the role of linguistic grain size, is cross-cultural comparison. However, the choice of the cultures to be compared should not be arbitrary. It is important to compare languages that are maximally different in linguistic and orthographic structures and in the mapping between these two domains so that the effects of language and development can be teased apart in models of reading.

Much of the existing cross-cultural research has compared English speakers with other Indo-European languages (e.g., Wimmer et al., 2000) and languages with alphabetic orthographies (e.g., Seymour et al., 2003) and made claims about the role of phonological processing cross-culturally. However, comparatively little research has been conducted in nonalphabetic languages, where the mapping between sound and symbols does not occur at the level of the phoneme, like in English, and thus the connection between phonological awareness (and in particular, phoneme-level awareness) is not as straight forward. In the current study, I compare English to Mandarin Chinese because the structural properties of spoken and written Mandarin Chinese and the mapping between these two are uniquely suited to provide one of the strongest possible contrasts to an alphabetic language like English.

A Comparison of the Structure of Spoken and Written Language for English and Mandarin Chinese

English and Mandarin Chinese differ in structural properties at both the spoken and written level as well as in the mapping between these levels. At the spoken level, English and Mandarin have similar phonological inventories (sharing 15 consonants sounds and 11 surface vowel sounds, Duanmu, personal communication, April 20, 2007), but different syllabic inventories. In Mandarin, there are only 1200-1300 syllables (400 without tone) compared to roughly 15,000 syllables in English (Shu & Anderson, 1999). Syllable structure in Mandarin is constrained to (CG)VX and consonant clusters do not exist (Duanmu, 2000). All syllables contain a consonant onset (although sometimes this is dropped) followed by a rime containing a nuclear vowel, and additional optional vowels and/or an optional consonant (Anderson, Li, Shu, & Wu, 2003). Within this structure, there are only two viable consonants for syllable final position, /n/ and /ŋ/ and in total, there are only 21 onsets, 36 rimes, and 4 tones that can be used to create valid Mandarin syllables (Anderson et al., 2003). Taken together, these syllabic restrictions produce the high degree of homophony that characterizes Mandarin. Thus, a single toned syllable often has multiple meanings (Packard, 2000). For example, the toned syllable *mǎ* can appear as several different words/characters: a horse (馬), morphine (嗎), a name of a river (溤), a mammoth (獁), agate (瑪), a weight; number; yard; pile; stack (碼), or an ant (螞). Phonological information may be less informative for Mandarin speakers than for English speakers due to differences in spoken language structure (Tan et al., 2005).

Orthographic factors are also important. The Chinese writing system represents an interesting contrast to an alphabetic system like English (Perfetti et al., 2005). In Chinese, characters represent syllables and morphemes rather than individual phonemes, giving the language a morpho-syllabic structure rather than an alphabetic structure (McBride-Chang, 2004; Ramsey, 1987). In addition, the consistency of the Mandarin Chinese sound-symbol mapping is fairly opaque. Roughly 80% of characters are semantic-phonetic compounds, and thus contain a component signaling meaning and a component signaling pronunciation which vary in the reliability with which they represent this information (Perfetti, Zhang, & Berant, 1992; Shu, 2003; Shu & Anderson, 1999; Shu, Chen, Anderson, Wu & Xuan, 2003). The semantic component cues the meaning (but not sound) of over 80% of characters providing important categorical information (e.g., in the character 林 / lín/ (forest)[2], the semantic component is 木 /mù/ (tree)) (Shu et al., 2003; Tan & Perfetti, 1998). In contrast, the phonetic component cues the pronunciation in less than 40% of compound characters (Ni, 1982 and Zhou, 1978 cited Shu et al., 2003). Moreover, even when it does provide a cue, it often provides only partial information about the pronunciation of the character (Zhou, 1978 cited in Feldman & Siok, 1999). For example, in the character 煤 /méi/ the phonetic 某 /mǒu/ shares the pronunciation of the onset of the character, but not the rime. There are only about 200 semantic components and 800 phonetics in Chinese (Ho & Bryant, 1997), thus not only is the semantic component a more reliable cue for word meaning, there are many fewer to be learned.

One additional and potentially important feature typifying Chinese spoken and written language is the high level of morphological compounding that now exists in Mandarin (Packard, 2000; Ramsey, 1987). In all languages, morphemes, the smallest units of meaningful speech (Sternberg, 2003), are manipulated in regular speech to

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[2] The pinyin and pronunciation of the character is enclosed in back slashes. The meaning of the character is enclosed in parentheses.

produce any number of different lexical transformations: changes in inflection (adding "s" to change "cat" to "cats"), in derivation (adding an "er" to change "bat" to "batter"), and in compounding (add "sun" to "light" to produce a new word, "sunlight"). Languages differ in the extent to which they use specific types of morpheme changes. For example, in English, inflectional and derivational morphology are the most common ways to manipulate and transform words, but there is some compounding morphology as well. In contrast, in Mandarin, although once considered an analytic language (due to the large portion of morphologically simple words and limited use of inflectional and derivational morphology; Matthews, 1991), morphological compounding has become increasingly common (Packard, 2000; Ramsey, 1987). Today, nearly 80% of all Mandarin words are polymorphemic (Taft, Liu, & Zhu, 1999).

In addition, there are interesting and important regularities in the sound-symbol relations of morphological compounds in Mandarin. Compound words are composed of two or more individual characters, each with its own sound and meaning as a single character. However, unlike the components of compound characters (the phonetic and the semantic components described above), the characters in the compound word are almost always pronounced the same as in the individual characters whereas the same cannot be said for the relationship between the meaning in of the individual characters in compound characteres (Hoosain, 1991; Hu & Catts, 1998). Thus, phonological information in Chinese may be a reliable guide to pronunciation depending on the level of analysis (phoneme versus syllable).

The Relationship between the Structural Properties of Chinese and Phonological Skills in Chinese Reading.

Based on the overall structural properties of Chinese, phonological awareness should not be particularly important for learning to read in Chinese and in fact, some have claimed it is "a skill that does <u>not</u> develop with cognitive maturation, non-alphabetic literacy, or exposure to a language rich in rhymes and other segmental contrast" (Read et al., p2). However, more recent research has suggested phonological awareness is not only relevant for predicting reading in Chinese, but is equally as important for predicting reading ability in Chinese as in English (e.g., McBride-Chang & Kail, 2002). Although this is surprising in light of the structural properties of Chinese, a closer analysis reveals a surprising number of regularities in the conversion of sounds to symbols in Mandarin Chinese; regularities that are particularly salient in the characters that children first learn; regularities that have led some researchers to suggest that learning to read in Chinese requires gaining insight into the *phonetic principle*, the system behind the orthography-phonology correspondence of Chinese script (Ho & Bryant, 1997a; Chen, Shu, Wu, & Anderson, 2003), a similar task to what is required for English-readers of gaining *alphabetic insight* into principles of mapping for the English script.

The Relationship between the Phonetic Principle and Chinese Reading

School Chinese is a corpus of 2,570 characters used to teach reading in all schools in Beijing (and several other regions; Shu & Anderson, 1999). Shu & Anderson's (1999) analysis of these characters demonstrates important inductive patterns in the phonetic component of characters that children first learn: (i) patterns in *regularity* (a concept that reflects the degree of congruence between the phonetic component and the overarching pronunciation of the compound) and (ii) patterns in *consistency* (a concept that measures how regular a component is across all the different characters in which it is used).[3] In School Chinese, the pronunciation of the compound character can be deduced from full or partial information (i.e., in the compound character 忙 /máŋ/ the phonetic 亡 /wáŋ/ provides information about the rime) included in the phonetic in roughly 75% of all compound characters. Not only does the phonetic in these become more *regular* between 1st and 6th grade (Shu et al., 2003), but the *consistency* is improved in these characters relative to later-learned material. Thus, the characters children first learn in elementary

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[3] In different characters, the regularity of the same phonetic component may vary. For example, the compound character for partner, 伴, contains a regular phonetic, 半, which accurately cues the pronunciation of this compound character /bàn/. However, the phonetic 半 also appears in the compound character 判, but only partially cues the pronunciation of this character, /pàn/. Researchers discuss this relationship in terms of the consistency of the phonetic in relation to its family (all characters incorporating the designated phonetic component) and calculate a phonetic's consistency from the ratio of the number of characters in the family with identical pronunciations to the total number of characters in the family, weighted by frequency (frequency is inversely linked to phonetic regularity; Shu et al., 2003).

school contain highly informative phonetic components, a feature that may signal to the beginning reader a system for how to learn new words.

There is evidence that children are sensitive to differences in the regularity and consistency of the phonetic and use this information in learning to read (e.g., Shu & Anderson, 1999). Children in first through sixth grade read regular characters faster and more accurately than irregular characters and read regular unfamiliar characters better than irregular unfamiliar characters, suggesting that children not only are aware of the role of regularity, but that they use this information to help read less familiar words (Ho & Bryant, 1997a; Shu, Anderson, & Wu, 2000). Children also appear sensitive to the regularity of the partial information contained in the phonetic. First, second and fourth graders are able to both read and learn significantly more regular characters than tone-different characters and more tone-different characters than irregular characters (Anderson, Li, Ku, Shu, & Wu, 2003; He, Wang, & Anderson, 2005; Ho & Bryant, 1997a). Moreover, children also appear attuned to differences in the consistency of characters and use this information judiciously to help learn new words (Shu, Wu, & Zhou, 2000; Tzeng, Zhong, Hung, & Lee, 1995).

Furthermore, these insights into the usefulness of the phonetic depend on reading level. Poor readers make more semantic and visual errors during reading than better readers who make more phonologically based errors (Chan & Siegel, 2001). Moreover, when poor readers do try to use the phonetic component for information, they demonstrate insensitivity to the types of regularity treating semiregular phonetics as informative as regular phonetics (Anderson, Li, Ku, Shu, & Wu, 2003). In contrast, good readers are better at weighting decisions in pseudocharacter reading based on the consistency of a phonetic (Tzeng et al., 1995) and score higher on pseudoword reading measures and phonological processing measures than poor readers (Chan & Siegel, 2001). In sum, children are sensitive to the regularity and consistency of the phonetic component in compounds, and their level of sensitivity is related to reading proficiency (Chan & Siegel, 2001; Shu et al., 2000; Tzeng et al., 1995).

Thus, although the structural properties of the Chinese script do not reveal an easy or obvious system of mapping between the sounds and symbols of the language (e.g., Shu, et al., 2003), there are in fact some systematic regularities between the phonological information in a character and its pronunciation, particularly in the words that children first learn. Furthermore, the degree to which children perceive and utilize these regularities is intimately related to their reading development. However, these regularities of the Chinese orthography, although more than what has often assumed to be available in nonalphabetic languages (e.g., Shu & Anderson, 1999), are still different from alphabetic languages in important and meaningful ways, ways that speak specifically to the role of phonological awareness in reading.

Based on these differences, I hypothesize that if the relationship between phonological awareness and reading is language-specific, then based on both the spoken and written structures of Chinese one would predict a weaker relationship between phonological awareness and reading ability in Chinese than in English. Furthermore, because the phonetic component represents a complete sound syllable if there is a language-specific relationship between phonological awareness and reading, it should be restricted to the syllable level of representation. Alternatively, because of the high degree of morphological compounding and the consistency of the semantic component in compound characters, one would expect to see a strong relationship between morphological awareness and reading ability in Chinese but not in English. These are testable claims that speak to the validity of the language-specific hypothesis.

Summary

In the reading literature, discussions of (i) level of processing, (ii) type of phonological information, and (iii) linguistic grain size subserve important theoretical debates centered on *which* phonological skills relate to reading and *how* they relate to reading. The goal of my dissertation is to use a cross-cultural developmental design to gain insight into these questions. To do this, I adopt a two-pronged approach. First, I examine whether the phonological mechanisms of reading are actually the same across linguistic systems as suggested by Zhou and Marslen-Wilson (1999), or whether they differ depending on the language learned by comparing reading models for English- and Mandarin speakers. Second, I examine whether the phonological mechanisms of reading are actually the same across developmental levels by comparing reading models for two groups of child readers, younger 'emergent' readers and older 'decoding' readers with adult skilled readers.[4] In these comparisons, I focus specifically on the relationship between phonological awareness and reading, and what a cross-cultural developmental approach can do to provide insight into the three questions outlined in the introduction: Is the relationship between phonological awareness and reading specific (i) to a level of processing (ii) to language experience and (iii) to linguistic grain size? Investigating these questions by comparing two languages (English and Mandarin Chinese) and three developmental levels (emergent, decoding, and fluent) provides a unique opportunity to investigate *which* phonological skills are critical to reading and *how* they are related to reading.

Outline of Chapters

The organization of my dissertation is as follows. In the introduction, I have made the argument for a cross-linguistic developmental comparison between English and Mandarin Chinese as a means for exploring the underlying mechanisms of reading development. In **Chapter 2**, I discuss the role of phonological and morphological variables in predicting emergent reading ability in English and Mandarin-speaking children. In the introduction, I outline similarities and differences in the phonological and morphological correlates of reading ability in English- and Mandarin-speaking children. I then discuss the limitations of the existing research and propose a study designed to circumvent these existing problems in order to test the three questions outlined in the introduction. In this study, I compare the performance of two groups of monolingual English- and Mandarin-speaking children, young *emergent* readers and older *decoding* readers, on a series of reading and reading-related measures (including phonological and morphological processing skills).

In **Chapter 3**, I discuss the role of phonological and morphological processing in predicting fluent reading in English- and Mandarin-speaking adults. In the introduction, I highlight evidence of phonological mediation in reading for both Chinese and English fluent readers but also evidence of neurophysiological differences in the processing of

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[4] In this paper, I divide child readers into a younger and older group. This division is based on grade level (a point justified in chapter 2). For the sake of simplicity however, I will refer to the younger children as younger ‘emergent’ readers, and the older children as older ‘decoding’ readers. This nomenclature is imprecise, particularly given the choice of grade as a divider, but is necessary for ensuring clarity in the following discussions.

phonological information between Chinese and English fluent readers. I then motivate the comparison for using adult readers by highlighting ways in which child and adult readers may differ in their ability to process and use phonological information in reading. I follow with a discussion of the results of an experiment, parallel in design to that of Chapter 2, where I compare the performance of English- and Mandarin-speaking fluent readers on a series of reading and reading-related measures (including phonological and morphological processing skills).

In **Chapter 4**, I first provide an overview and comparison of the results from Study 1 and Study 2. In this overview, I highlight how the results address the three questions proposed in the introduction, namely, is the relationship between phonological awareness: (i) specific to level of processing, (ii) specific to language-experience, or (iii) specific to linguistic grain size. I then take a figurative step back, and position these findings in the larger context of the reading acquisition literature. From this position, I discuss the dual impacts of language learned (English, Mandarin) and level of reader (emergent child, decoding child, skilled adult), and the interaction between these two dimensions on the models of reading explored. I conclude with a proposal about language-general, language-specific and developmental mechanisms of reading and propose several future ‘next steps’ for improving our understanding of the role of phonological awareness in reading.

Chapter 2: Similarities and Differences in the Predictors of Reading Acquisition in English- and Mandarin-speaking Emergent Readers.

Although few researchers have conducted cross-cultural comparisons of the predictors of reading in Chinese and English-speaking children (Holm & Dodd, 1996; Huang & Hanley, 1994; McBride-Chang, Bialystok, Chong, & Li, 2004; McBride-Chang, Cho, Liu, Wagner, Shu, Zhou, Cheuk, & Muse, 2005; McBride-Chang & Kail, 2002; McBride-Chang, Tardif, Cho, Shu, Fletcher, Stokes, Wong, & Leung, submitted), most existing research on the predictors of reading in Chinese children has studied the factors known to be important for English speakers (e.g., Ho & Bryant, 1997b; Read et al., 1986). Importantly, phonological awareness (at the level of the syllable and onset-rime) has been found to be among one of the strongest predictors of reading ability for Chinese children and demonstrates a developmental trend specific to the size of the linguistic unit being measured as found for English-speaking children (e.g., Ho & Bryant, 1997a). Furthermore, individual differences in phonological working memory (Ho, 1997; Hu & Catts, 1998; So & Siegel, 1997) and rapid naming (Ho & Lai, 2000; Hu & Catts, 1998; McBride-Chang & Ho, 2000) have been shown to be related to individual differences in reading ability as well. And, like for English speaker, measures of speech perception are related to phonological awareness, but not directly to reading ability (McBride-Chang & Ho, 2000; McBride-Chang, Shu, Tardif, Fletcher, Stokes, Wong, & Leung, 2006). Even though the spoken language and written scripts of English and Chinese are dramatically different, the reading models for the two languages appear very similar. However, there are also important ways in which the role of phonological information differs for Chinese readers compared to English readers (e.g., McBride-Chang & Cho, et al., 2005), leading some researchers to suggest that, “Although the underlying mechanisms for sublexical processing in logographic and alphabetic languages are essentially the same, we believe that the application or the performance of these mechanisms varies according to the structural properties of different writing systems" (Zhou & Marslen-Wilson, 1999 p. 830). Examining this hypothesis in light of cross-linguistic data that speak to both language-specific and more general aspects of phonological processing will help elucidate the role of phonological processing in predicting reading ability.

In the current study, I compare the phonological correlates of reading ability in younger *emergent* and older *decoding* English and Mandarin readers in order to explore whether the mechanisms of reading are the same across linguistic systems and across early development. Specifically, I propose to investigate how the structural properties of a language and the level of reading proficiency may differentially influence (i) the existence, and (ii) the expression of the underlying mechanisms of reading ability in three ways. First, I test whether low-level phonological sensitivity has any role independent of higher-level phonological sensitivity (i.e., phonological awareness) in predicting reading ability in. In addition, I examine whether this relationship might depend on an individual's specific language experience (i.e., processing phonemes in one's native language) or whether it can extend to the processing of any speech sounds. Last, I explore whether the relationship between phonological awareness and reading depends on linguistic grain size. Comparing these two languages at two different levels of reading proficiency provides a unique opportunity to investigate *which* phonological skills are critical to reading and *how* they are related to reading.

Similarities in the Predictors of Chinese Reading

In the past decade, there have been significant advances in identifying the linguistic levels of phonological awareness that *are* and *are not* important for predicting reading in Chinese-speakers. Given the morpho-syllabic structure of Chinese, a handful of studies have examined the role of phonological awareness in Chinese readers at the level of the syllable (e.g., McBride-Chang & Ho, 2005). In these studies, both cross-sectional (McBride-Chang & Ho, 2000) and longitudinal designs (McBride-Chang & Ho, 2005; Chow et al., 2005) have found syllable awareness to be the strongest predictor of character reading, predicting up to 20% of the variance in character recognition in 3- to 6-year olds even after controlling for other phonological measures, vocabulary and nonverbal IQ.

Researchers have also investigated awareness at the level of the onset-rime (Siok & Fletcher, 2001). In cross-sectional (Chen, Anderson, Li, Hao, Wu, & Shu, 2004; So & Siegel, 1997) and longitudinal analyses (Ho & Bryant, 1997a, Ho & Bryant, 1997b; Hu & Catts, 1998), onset-rime awareness predicted reading ability in children ages 3 – 8 years-old in even after controlling for other phonological processing skills, vocabulary, and nonverbal IQ. This suggests that the heightened orthographic consistency of the phonetic at the level of the onset-rime may be an important and useful analytic tool in learning to read (Leong, Cheng, & Tan, 2005).

Little research has explored phoneme-level awareness in Chinese children. There is no obvious theoretical relationship between phoneme-level awareness and reading ability given the linguistic structure of Mandarin and Cantonese and the morpheme-level mapping of Chinese script (e.g., McBride-Chang, Cho, et al., 2005). In fact, research in adult readers has demonstrated that phoneme level awareness is nearly inaccessible to Chinese adults without explicit training in a phonemic coding system like pinyin[5] (Read et al., 1986) and is not related to individual differences in reading ability (Holm & Dodd, 1996). Only five studies (Huang & Hanley, 1994; 1997; Leong, Cheng & Tan, 2005; Shu et al., submitted; Siok & Fletcher, 2001) have ever even measured phoneme awareness in children. Although children appear to be able to perform initial, medial, and final manipulations as demonstrated by above-chance performance on either sound isolation or phoneme elision, their ability to do these manipulations is weakly related to reading ability (if at all, e.g., Huang & Hanley, 1997; Shu et al., submitted), particularly when compared to measures of syllable or onset-rime elision (e.g., Siok & Fletcher, 2001).

Differences in the Predictors of Chinese Reading

Although there are strong parallels to English readers, there are also important ways in which the role of phonological information differs for Chinese readers compared to English readers. First, performance on phonological awareness tasks is generally lower in Chinese readers than in English readers (e.g., Ho & Bryant, 1997; McBride-

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[5] Pinyin is a Romanization of the Chinese phonology using alphabetic letters and is used to provide a phonemic-coding system to help with reading instruction (Duanmu, 2000; Ramsey, 1987).

Chang, Bialystok, et al., 2004, but see McBride-Chang & Kail, 2002) and does not relate to reading as strongly as for English readers, particularly when measured at the level of the onset-rime (e.g., McBride-Chang, Bialystok, et al., 2004). Furthermore, some argue that the relationship between phonological awareness and reading is highly dependent on the alphabetic training that some[6] Chinese children receive in kindergarten (e.g., Holm & Dodd, 1996; Hu & Catts, 1998; Huang & Hanley, 1994, 1997; McBride-Chang, Bailystok, et al., 2004; Read et al., 1986).

Research has found that training in pinyin appears to improve awareness at the level of the onset and rime, and even at the level of the phoneme (e.g., Chen et al., 2004; Huang & Hanley, 1997; Leong, et al., 2005; Siok & Fletcher, 2001) and that this training may either improve the relationship between phonological awareness and reading ability (Holm & Dodd, 1996; McBride, Bialystok et al., 2004; Siok & Fletcher, 2001) or fully mediate the relationship (e.g., Leong et al., 2005). Furthermore, there is neurophysiological evidence showing that character and picture naming activate similar brain substrates, areas that are not associated with the translation of orthography to phonology for alphabetic readers (i.e., the left supra-marginal gyrus; Tang, Zhou, Weng, Ma, & Li, 2001) whereas pinyin reading activates a different area of the brain (i.e., the inferior parietal cortex; Chen, Fu, Iversen, Smith & Matthews, 2002). These results suggest that the relationship demonstrated between phonological awareness and reading ability in Chinese readers (e.g., Shu et al., 2007) may be in a large part explained by knowledge of pinyin. And as such, phonological awareness may not play as important a role in learning to read Chinese (beyond reflecting the particular features of literacy instruction specific to different regions of the country) as in English.

Recent research has also highlighted two other skills (rapid naming and morphological construction) as potentially more potent predictors of reading ability and disability in Chinese children than phonological awareness (Ho, 2005; Penney, Leung, Chang, Meng & McBride-Chang, 2005; Shu, McBride-Chang, Wu, & Liu, 2006). In Chinese children, rapid naming, also considered a component of phonological processing (Wagner & Torgesen, 1987), is sometimes a stronger predictor of reading ability and

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[6] In Hong Kong, pinyin instruction is not used, and reading is taught through exclusively through the look-and-say method (McBride-Chang, 2004).

disability than measures of phonological awareness (Ho, Chan, Tsang, & Lee, 2002; Ho, Chan, Tsang, & Luan, 2004; Ho, 2005, although see Shu et al., submitted; Chow et al., 2005; McBride-Chang & Ho, 2005). Although it is not clear exactly which cognitive skills underlie rapid naming, some research suggests that visual processing may be a critical component (Stainthorp, 2005). Specifically, the visual complexity of characters (relative to letters) may tap abstract visual mapping abilities and make this measure a particularly potent predictor of character identification in Chinese and a component that is impaired in reading disabled (McBride-Chang & Shu, 2006).

Morphological awareness (the understanding that words represent individual meanings and that individual characters and syllables represent individual morphemes) has also emerged as an important predictor of reading outcomes in Chinese children (McBride-Chang, Shu et al., submitted; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu & Anderson, 1997; Shu & McBride-Chang, 2006; Shu et al., 2006, Shu et al., submitted). In a recent two-year longitudinal study of 232 Hong Kong children (mean age at T1 = 26 months; McBride-Chang, Shu, et al. submitted), morphological processing was a unique predictor of emergent reading skills even after controlling for low-level phonological sensitivity (measured by an articulation test of consonant phonology), phonological awareness (at the level of the syllable), speeded naming, speed of processing and vocabulary (McBride-Chang, Shu et al., submitted). Similarly, a path analysis conducted on data from reading-disabled Chinese fifth and sixth graders identified the construct of morphological awareness as the strongest correlate of a variety of literacy-related skills (Shu et al., 2006). Mandarin orthography is considered morphosyllabic, and thus, it is not surprising that morphological awareness tasks have proven to be more predictive of reading ability in Mandarin than measures of phonological awareness (McBride-Chang et al., 2003; McBride-Chang, Cho, et al., 2005). However, less is known about the relative role of morphological awareness as compared to phonological awareness in predicting reading in English-speaking children (e.g., McBride-Chang et al., 2003; although see Carlisle 1996, 2000, 2003; Deacon & Kirby, 2004).

In a recent cross-cultural study comparing Mandarin-, Cantonese-, Korean-, and English-speaking second graders, measures of phonological awareness and morphological structure awareness were similarly associated with one another and vocabulary across languages, but showed significantly different relationships with reading ability depending on the language learned (McBride-Chang, Cho, et al., 2005). In Chinese readers, morphological awareness showed significant relations with reading (β=.27, p<.001 for Mandarin speakers and β=.23, p<.05 for Cantonese-speakers) but not phonological awareness (β=.16 for Mandarin speakers and β=.18 for Cantonese-speakers); whereas in English speaker, the inverse was true, β=.42, p<.001 for phonological awareness and β=-.06 for morphological awareness. The authors concluded that although phonological and morphological information may be important for language development in both cultures, the usefulness of these measures as predictors of reading ability may depend heavily on the sound-symbol mappings of the particular language.

Limitations of Current Research

Thus, there are both similarities and differences in the way in which phonological skills appear related to Chinese and English emergent reading skill. However, existing research on the predictors of reading in Chinese has several major limitations, limitations that restrict the interpretability of these findings and limit the claims that can be made about the mechanisms of reading cross-culturally.

First, there is limited cross-cultural research exploring the predictors of reading in English- and Chinese-speaking children (Holm & Dodd, 1996; Huang & Hanley, 1994; McBride-Chang, Bialystok et al., 2004; McBride-Chang, Cho et al., 2005; McBride-Chang & Kail, 2002; McBride-Chang, Shu et al., 2003; McBride-Chang, Tardif, et al., submitted). Moreover, in the cross-cultural studies that do exist, many have used different measures to assess similar constructs across the languages being compared (e.g., McBride-Chang, Cho, et al., 2005; McBride-Chang, Shu et al., 2003; McBride-Chang, Tardif, et al., submitted). In defense of this approach, researchers have argued that the tests are designed to measure identical constructs but are modified to be sensible within each language and culture. For example, McBride-Chang et al. (2005) used different measures of morphological ability, phonological awareness, vocabulary and reading in the four different language groups in their sample (English, Korean, Cantonese, and Mandarin). Not only did these tests differ in the number of items, but also in the demands of the task (i.e., phoneme awareness was measured in English and Korean children, whereas only syllable and onset-level awareness were measured in the Chinese readers). Although I acknowledge the importance of using measures that are appropriate cross-culturally, it is not possible to make definitive conclusions about the cross-cultural correlates of reading unless the measures that are administered are identical. Much of the research comparing the predictors of reading for English- and Chinese-speaking (Mandarin or Cantonese) children has found differences in way phonological and morphological variables are related to reading, a finding that suggests that structural differences in the languages may place different pressures on the mechanisms of reading development. However, it is difficult to interpret these findings based on the difference in the measures used for the English and Chinese children in these studies. Thus, an important next step in cross-cultural research on the predictors of reading in English and Chinese is to use measures that are tightly controlled in their cross-cultural comparability.

Furthermore, there are limitations in the existing within-culture research on Chinese reading as well. Given the dearth of cross-cultural work in English and Chinese readers, the majority of information on the cross-cultural predictors of reading has been drawn from research exploring reading development in Chinese readers and comparing the results with existing research on English-speaking children (e.g., Ho & Bryant, 1997b). However, a large portion of this research has not systematically controlled for exposure to English in the Chinese readers (e.g., Chang & Siegel, 2001; Chow, et al., 2005; Ho & Bryant, 1997b; Huang & Hanley, 1994; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005; Siok & Fletcher, 2001; So & Siegel, 1997). One reason is because much of the reading research has been conducted in Hong Kong, using Cantonese-speaking children (e.g., Chan & Siegel, 2001; Chow, et al., 2005; Ho & Bryant, 1997b; McBride-Chang & Ho, 2000; McBride-Chang, & Ho, 2005; So & Siegel, 1997). However, children in Hong Kong learn English in kindergarten, and thus typically the children tested all have received formal English instruction. There is evidence that learning an alphabetic language may help develop phoneme-level awareness (e.g., Holm & Dodd, 1996; Morais, et al., 1979; Read et al., 1986). Furthermore, there is evidence of transfer of phonological skills in bilinguals (e.g., Bialystok, Majumder, & Martin, 2003) and of heightened phonological sensitivity and awareness that are hypothesized to be due to the demands of learning two languages (e.g., Chen et al., 2004). Therefore, research using bilingual Chinese children does not provide a pure test of the role of phonological awareness in reading in nonalphabetic languages, and the conclusions that have been made must be interpreted carefully.

A second limitation of existing within culture research in Chinese children (although not a limitation for studies using Cantonese-speaking children) is that most research on the predictors of reading have not controlled for knowledge of pinyin (e.g., Huang & Hanley, 1994; Shu et al., submitted; although see Siok & Fletcher, 2001). However, as noted earlier, research has found that training in pinyin may influence the development of phonological awareness (e.g., Chen et al., 2004; Huang & Hanley, 1997; Leong et al., 2005; Siok & Fletcher, 2001) and may mediate the relationship between phonological awareness and reading ability (Holm & Dodd, 1996; Leong et al., 2005; McBride, Bialystok et al., 2004; Siok & Fletcher, 2001). Studies that do not control for the influence of pinyin contain an important confound that limits the conclusions that can be drawn about the predictors of reading in nonalphabetic orthographies in these studies as well.

A final limitation of existing research on Chinese children is that little to no research has investigated developmental changes in children as they begin formal reading training (although see Ho & Bryant, 1997a). Although there have been several cross-sectional studies exploring reading across a range of ages (e.g., Leong, et al., 2005; Siok & Fletcher, 2001; So & Siegel, 1997)[7] and a handful of longitudinal studies investigating the changes in the predictors of reading over time (e.g., Chow, et al., 2005; Hu & Catts, 1998; McBride-Chang & Ho, 2005), relatively little research has systematically documented the changes in phonological processing over time. A notable exception is the study by Ho & Bryant (1997a) which demonstrated a developmental trajectory in phonological awareness from awareness of coarser grained linguistic distinctions (successfully discriminating word pairs that shared only the onset) to finer grain linguistic distinctions (successfully discriminating homophones differing in tone only) similar to that demonstrated in English-speaking children (e.g., Anthony & Lonigan, 2004).

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[7] For example, So & Siegel (1997) included first through fourth grade children, Siok & Fletcher (2001) used first through fifth grade children, Leong, and colleagues (2005) tested fourth and fifth graders.

Furthermore, these authors showed that different levels of awareness were related to reading differently across development, as seen for English children as well (e.g., for a review see Castles & Coltheart, 2004). However, no research has built upon or extended these findings. Thus, an important question in the current study is whether phonological skills develop over time similarly in English and Mandarin-speaking children and if so, whether there is a corresponding development in the relationship between phonological awareness and reading in these two languages.

In the current study I explore the predictors of reading in 4 – 8-year-old monolingual English- and Mandarin-speaking children first learning to read. I investigate the effect of language and reading level on the relative contributions of both epilinguistic and metalinguistic phonological skills (sensitivity and awareness, working memory and rapid naming), morphological construction, and verbal and nonverbal IQ in predicting reading ability in English and Chinese children. In this examination, I am particularly interested whether the relationship between phonological awareness and reading is specific to (ii) the level of processing, (ii) one's language experience, and (iii) the linguistic grain size. Thus, I explore (i) whether the same phonological constructs (sensitivity and awareness) predict reading in English and Mandarin and in beginning and more fluent readers, (ii) whether the role of phonological sensitivity in reading depends on measuring known words from an individual's native language or can it extend to words composed of familiar phonological information but from any language, and (iii) what role syllable and phoneme-awareness play in predicting reading for children at different reading levels (emergent vs. decoding) learning two very different languages (English and Mandarin). Through a cross-cultural developmental approach, I hope to gain insight into *which* phonological skills predict reading and *how* these skills predict reading.

Method

Subjects

140 children (69 English speakers, 71 Mandarin speakers) participated in the current study. All participants were reported to be native-speakers of English or Mandarin, with normal or corrected-to-normal vision and no history of language, hearing,

or reading impairments and no history of exposure to the opposite language (Chinese for English speakers and English for Mandarin speakers)[8]. Participants were between 4- and 8-years-of-age, and all were enrolled in preschool or elementary school in the U.S. or in China (although several participants in the U.S. were being homeschooled at a grade-appropriate level).

75 English-speaking children were recruited from the Developmental Subject Pool, a recruitment list housed in Michigan's psychology department. The list is comprised of families with young children who have expressed interest in participating in research. Of the original 75 recruited, six participants were not included in the analyses: four for failure to meet the screening criteria (due to exposure to an Asian language, a history of a speech disorder or developmental delays) and two who refused to participate once the study had commenced. All children included in the analyses were reported to be native English speakers. Two of the children included were also reported to have additional exposure to Spanish in the household. Although information on race and ethnicity was not formally recorded, the majority of the children participating were of European-American descent. The mean age of the remaining 69 English-speaking participants was 79 months (range 52 – 108 months) and 55% were female. At the time of testing, 9% of the sample was in preschool, 35% in kindergarten, 19% in first, 32% in second, and 3 participants were in third grade.

75 Mandarin-speaking children were recruited directly from a local preschool and primary school in downtown Beijing. Of the 75 children with permission to participate, eight were reported to have learned a dialect of Mandarin as their first language.[9] All eight were included in the current analyses as the dialects learned were all from provinces in Northern China (inner China north of the Yangtze River) and are considered variants of northern Mandarin (Ramsey, 1987). Four children were excluded from the analyses, two whose native language was not Mandarin (one Korean, one Mongolian) and two identified as having a history of developmental delays. All children were of the ethnic majority in mainland China, Han Chinese. No participants had any formal instruction in English because English is not introduced into the curriculum in mainland China until

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[8] As reported by the child caregiver.

[9] Dialects from the provinces of Anhui, Henan, Shanxi, and Hebei.

fourth grade (e.g., Leong et al., 2005), but two participants were reported to have had some exposure to English (reported as spoken in the home 1% or less of the time). The mean age of the remaining 71 Mandarin-speaking participants was 73 months (range 49 – 102 months). 41% of the participants were in their second year of kindergarten called middle kindergarten[10], and 59% were enrolled in first grade.

In the U.S. sample, the children and families participating were representative of a small Midwestern academic community. The Chinese sample was recruited from an area and school serving primarily working class families. The mean levels of maternal education were significantly different between the two samples. Mothers in Beijing had a mean of 9-12 years of education with roughly 35% of the sample having less than 12 years of education total, whereas mothers in Ann Arbor had on average 16 years of education and no mother participating reported having less than 12 years of total education. Family income and parental education have been found to affect behavioral (Li & Rao, 2000; McBride-Chang, 2004; Morrison, Bachman, & Connor, 2005) and neurophysiological (Noble, Wolmetz, Ochs, Farah, & McCandliss, 2006) correlates of reading, and reading outcomes themselves. However, in the current sample maternal education was not significantly correlated with any of the measures collected within each sample (except for the English-speaking children's performance on Digits backward). Therefore, I do not use this variable to control for environmental differences in any further analyses.

Procedure

In the current study, I examined the relationship between phonological sensitivity measured in a phonological same/different judgment task and reading ability measured by a battery of standardized reading and reading-related tasks. Children were tested in a typical laboratory testing room in a single session lasting 2 to 2.5 hours. Two formal breaks were built into the testing in order to avoid fatigue. However, additional breaks were encouraged if the child showed signs of tiring or inattention.

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[10] In mainland China, there are three years of kindergarten, lower kindergarten starts when a child turns three. Lower and middle kindergarten are analogous to what is called preschool in the U.S. Upper kindergarten corresponds to the U.S. kindergarten.

After giving assent, children were seated in a comfortable chair in front of a computer monitor and were asked to wear a set of high-quality, sound-canceling headphones. For the phonological sensitivity task (the same/different judgment task), participants were told that they would be listening to pairs of words, some of which might be unfamiliar, and were to decide whether the word pairs sounded exactly the same or different. They were told to respond "Yes" if the words sounded exactly the same and "No" if the words sounded different.[11] The experimenter used the serial response box to record the child's response. Participants were monitored during the practice block (8 trials) to ensure comprehension, and received corrective feedback if necessary. Corrective feedback was continued into the testing blocks for one child who got over ½ the practice trials wrong. Feedback was stopped when the child got five consecutive trials correct in the first block of the task. The 5 blocks of trials were self-paced and children were given the option to take a break at the completion of each block (after 24 trials).

At the completion of the phonological judment task, children were asked to participate in a series of activities measuring letter, sound, and word knowledge. The behavioral battery measures were administered either in front of the computer or across from the experimenter at a table in the same testing room.

Materials

Phonological sensitivity task. To measure epilinguistic phonological sensitivity, we created a phonological discrimination task using a same/different judgment paradigm. In our design, we used stimuli that were consonant-vowel (CV) in structure such that the onset and rime corresponded to single phonemes (treating diphthongs, triphthongs and glide+phoneme combinations as single phonemes). We also varied the position of phonological overlap, creating word pairs that overlapped either in the onset (e.g., bye/bow) or in the rime position (e.g., bye/pie). For English speakers, contrasts in word initial position are easier to discriminate than word final position due to the hypothesized

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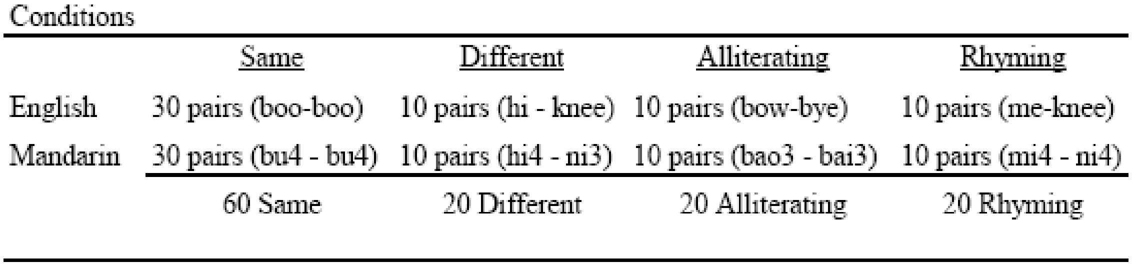
[11] Some children decided to say, "Same" and "Different" of their own accord. However, the nature of the responses was not considered relevant as all experimenters were asked to record a response as soon as they could distinguish a response, a decision that could be made based on the first phoneme for either Yes/No or Same/Different responses.

salience of the initial position (Treiman, Tincoff, Rodriguez, Mouzaki, & Francis, 1998) and researchers have found a relationship between reading and the ability to process information in differing positions within the word and with differing degrees of phonological overlap (e.g., Metsala, 1999; Treiman & Zukowski, 1996; Walley, Metsala, & Garlock, 2003). In addition, we used both native and non-native words that were identical in phonetic structure, but were represented and pronounced as complete words within each language (e.g., bye/ bái). Research has explored the relationship between speech perception and reading (e.g., McBride-Chang, 1996), and the relationship of language-experience in speech perception (e.g., Werker & Tees, 1984), but has never combined this exploration. It is possible that the relationship between phonological sensitivity and reading ability is specific to the phonological information in one's lexicon, a proposal with support from research showing a relationship between the degree of specification of one's phonological representations and reading ability (e.g., Elbro, et al., 1998; Metsala, 1997; Garlock, Walley, & Metsala, 2001; Fowler, 1991). Alternatively, the relationship may be specific to a more general sound processing (e.g., McArthur & Bishop, 2001) or processing of any phonological information.

Table 2.1 Phonological sensitivity task design: 2 (native/nonnative) x 4 (Same, Different, Alliterating, Rhyming)



Conditions	Same	Different	Alliterating	Rhyming
English	30 pairs (boo-boo)	10 pairs (hi - knee)	10 pairs (bow-bye)	10 pairs (me-knee)
Mandarin	30 pairs (bu4 - bu4)	10 pairs (hi4 - ni3)	10 pairs (bao3 - bai3)	10 pairs (mi4 - ni4)
	60 Same	20 Different	20 Alliterating	20 Rhyming

For the phonological judgment task, each target word was preceded by one of four types of mono-morphemic (syllabic) prime words[12]: Same, Different, Alliterating, and Rhyming (shown in Table 2.1). For Same pairs, the prime and target were the identical stimulus. For the Different condition, the prime was selected to be maximally different

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[12] Although not a formal priming paradigm, the task design is more easily explained by referring to the first word as a prime and the second as the target word. Similarly, in the results, I discuss "priming effects". These effects are differences in the speed and accuracy in judgment that appear related to the preceding word, thus fitting the canonical understanding of a priming effect, although not generated by a traditional priming paradigm.

from the target. Specifically, Different primes had no overlapping phonemes (initial, medial, or final) with the targets. All Mandarin Different pairs also had different tones. Alliterating primes shared the onset of the target, but differed in the rime. Rhyming primes shared the rime unit of the target and differed in the onset. Tone was held constant across these two types of pairs. Although primes were one of four types- Same, Different, Alliterating, and Rhyming, responses required only a “same” or “different” judgment. In order to control for response bias, participants heard an equal number of “same” (60 Same) and “different” (20 Alliterating, 20 Rhyming, and 20 Different) word pairs.

For cross-linguistic comparability, only syllables that were CV in structure and composed of phonemes common to both languages were used. The word list for English and Mandarin was identical except Mandarin words had tones (e.g., bye/ bái or bye/ bǎi) as would be expected in order for the syllables to be meaningful words in Mandarin. Although participants were not explicitly told that they would be hearing words in a non-native language[13], each subject heard an equal number of trials in both their native and non-native language and to the extent possible, word pairs were matched between the languages such that each participant heard the identical word pair in his/her native and non-native language (i.e., bye-pie/bái-pái). In total, 60 of the prime-target word pairs were presented in English and 60 in Mandarin (see Appendix A).

To avoid potential speaker-effects, all stimuli were spoken by two English and Mandarin female bilinguals, one a native English speaker, the other a native Mandarin speaker. At least 5 tokens of each stimulus word were recorded on a DAT recorder at a sampling rate of 44 kHZ in a sound-attenuating room. The digitized stimuli were converted with 16-bit resolution and a bandpass filter with a boundary of 120 kHZ was applied. Each stimulus was stored in a separate file and edited for precise onset time to maximize synchronization with the behavioral (E-Prime) data collection system. Final stimuli were selected based on independent ratings of the stimuli by several native speakers for each language (rating only for their native language). The speaker-type of the word tokens (native or nonnative) was counterbalanced. During the experiment,

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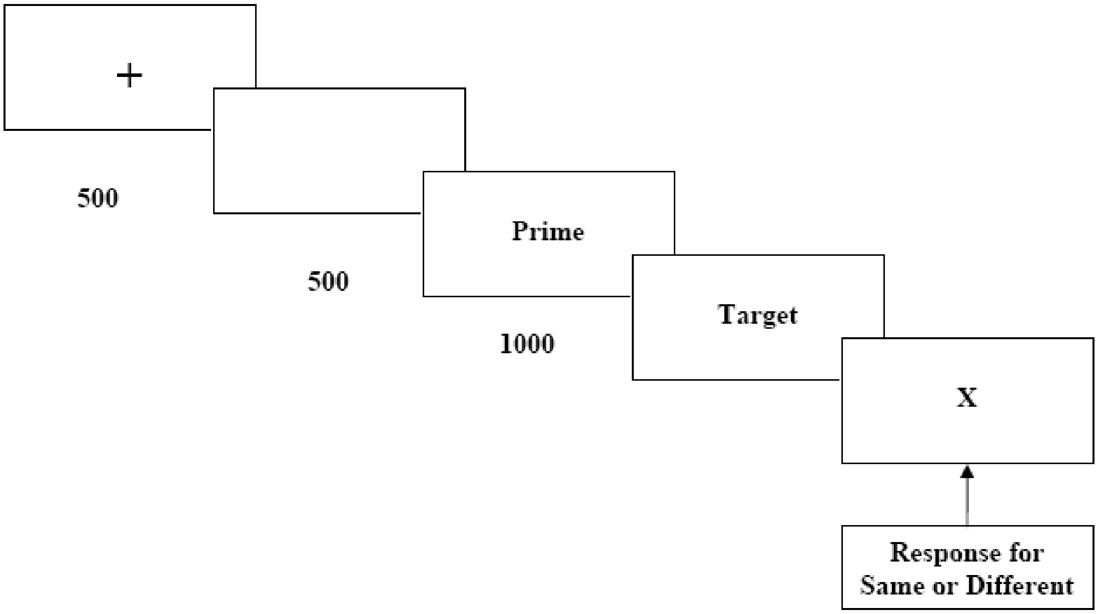
[13] They were told that they would be hearing words, some of which would be familiar and some which wouldn’t.

stimuli were presented binaurally over JVC noise-canceling headphones at a comfortable listening level (average 60 dB SL).

Stimuli were selected to be equal in word length and phonetic complexity across prime and target and across language and pair type. The final stimuli selected had a mean length of 690msec (English primes = 755msec, targets = 739msec; Mandarin primes = 633msec, targets = 634msec). Mean acoustical duration was not significantly different between prime and target, *F(1, 224)*=.22 or between pair type (Same, Different, Alliterating, and Rhyming), *F(3, 224)*=.77. Mean acoustical duration was significantly different between languages, *F(1, 224)*= 24.33, p<.001, but there were no 2- or 3-way interactions. The mean length of English stimuli was 747msec (range 409 – 1001msec), and the Mandarin stimuli was 635msec (range 382 – 885msec). However, we did not expect any differences to affect the primary predictions since all participants heard all stimuli.

Figure 2.1 Design of auditory same/different judgment paradigm.



Stimuli were presented in 5 blocks of 24 trials each, and one practice block of 8 trials, for a total of 128 trials. As shown in Figure 2.1, each trial started with a fixation cross on the screen for 500msec followed by a blank screen for 500msec. This was followed by the auditory prime and then the target. SOA was 1000msec.[14] At the offset of the target (range 382 – 1001msec), a blank screen with a red ‘X’ appeared. Subjects were instructed to make a same/different judgment for each word pair as quickly as possible. Maximum response time was set at 5000msec, but trials advanced as soon as a response was made.

Within a block, pair type varied across the task in a pseudorandom order such that no more than 3 ‘same’ and 3’ different’ responses occurred in succession (limiting pair types to 3 Same pairs and 3 Different, Alliterating, or Rhyming pairs in a row). Each block had a total of 12 ‘same’ and 12 ‘different’ responses (12 Same, 4 Different, 4 Alliterating, 4 Rhyming). The order of blocks was counterbalanced across participants.

Reading-related battery. We administered one measure of reading ability and a series of tasks measuring phonological awareness, speed of processing, phonological memory, morphological construction, vocabulary and nonverbal IQ, all skills important for explaining individual differences in reading in English and Chinese (e.g., McBride-Chang & Kail, 2002; Torgesen et al., 1997). Most measures were selected from standardized assessment tests for English speaker, The Woodcock Johnson Psychoeducational Battery – Revised: Tests of Achievement (Woodcock and Mather, 1989) and the Wechsler Adult Intelligence Tests (Wechsler, 1981), and were adapted for administration in Chinese. The adaptation of materials involved either direct translation of culturally-appropriate measures (e.g., block design, digit span or rapid naming) or the creation of analogous, culturally-relevant measures, tightly controlled for comparability (e.g., elision). All modifications are noted in the following descriptions and included in the Appendices (D – K). Two measures (single word reading and vocabulary) had existing semi-standardized forms in Chinese that were parallel in design (but not parallel in items) to the English versions. For nearly all measures, accuracy and reaction times were collected by the experimenter using the E-Prime serial response box.

Alphabet Letter Sound Knowledge. Knowledge of letter sounds is a strong predictor of reading ability in English (e.g., Adams, 1990; Chall, 1967; Share et al., 1984) and knowledge of letter names has been shown to be related to reading in Chinese

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[14] One sound file, pie.wav, was longer than 1 second. This file was automatically truncated by E-Prime when played in the prime position. The net result of the truncation was a loss of 14msec of dead space at the end of one token repeated 4 times over the entire experiment.

(McBride-Chang & Ho, 2000). Although Chinese does not have an alphabetic orthography, it has been hypothesized that knowledge of letter sounds may be an important predictor for Chinese children because the ability to learn the arbitrary mappings between letters and sounds is a skill that may be parallel to learning the relatively arbitrary mappings between sounds and characters (McBride-Chang, 2004). Furthermore, children living in mainland China learn the pinyin sounds associated with letters (McBride-Chang, Bialystok, et al., 2004) and knowing pinyin may be indirectly helpful in learning to read because pinyin is used as a bridge to character recognition in primary school (e.g., McBride-Chang & Kail, 2002).

In the current study, knowledge of the sounds of letters was assessed for 22 letters and letter pairs for English and Mandarin speakers. Vowels were removed due to high-variability in pronunciation in both languages and the letter ‘x’ was removed because it is a difficult phoneme to pronounce in English. The letter pairs ‘ch’ (English phoneme /ʧ/ and Mandarin phoneme /tʂʰ/) and ‘sh’ (English phoneme /ʃ/ and Mandarin phoneme /ʂ/) were added as they are phonemes that are represented in the pinyin alphabet and are important sound combinations in both Mandarin and English. There was only one letter that differed between the stimuli for the English- and Mandarin-speaking samples. The letter ‘v’ was replaced in the stimuli for the Chinese children with the letter pair ‘zh’ (Mandarin phoneme /tʂ/) because ‘v’ is not used in pinyin and in English ‘zh’ is not a viable letter pair.

Children were instructed to name the sound of each letter/letter pair presented individually on the computer screen as quickly as possible. The stimuli were visually-presented letters in black uppercase or lowercase[15] Times New Roman font, centered on a white screen. A total score of 22 points was possible, and the task had a reliability of α=.90 for the American children and α=.99 for the Chinese children.

Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). We administered two subtests, elision and rapid naming, from Wagner et al.’s

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[15] For the English, the stimuli were in uppercase letters because the letters children first learn are in uppercase. Pinyin uses lowercase letters, so the Chinese children were tested using lowercase letters.

Comprehensive Test of Phonological Processing (CTOPP). Because the tasks are designed for English-speaking, we adapted the materials for administration in Chinese.

i) Elision. The elision task measured the participant's ability to remove initial, final, or medial phonemes (or phoneme clusters) and syllables from words. The chart in Appendix B shows the structure of the English and Mandarin versions of the test and examples of each type of item. We made several modifications to the original CTOPP version. First, we added nonwords because Mandarin elision tasks are typically composed to produce nonwords, whereas the English do not (which may be one reason for the performance differential between languages; e.g., Shu et al., 2006). Second, we added medial deletions and deletions from consonant clusters. However, given the phonemic structure of Mandarin, there were no cluster deletions for the Mandarin version. Thus, the maximum score differs between languages (67 English, 54 Chinese). The reliability of this measure was α=.98 for English-speaking children and α=.97 for Mandarin-speaking children.

ii) Rapid Object Naming. The rapid object naming task measured a participant's speed in naming a series of objects. Six different pictures (pencil/qiānbǐ (鉛筆)[16], rainbow/ cǎihóng(彩虹), fish/yú(魚), monkey/hóuzi(猴子), boat/chuán(船), and apple/ píngguǒ(蘋果)) were used. Three substitutions (replacing star, key, and chair) were made to the items used on the original CTOPP version to balance word difficulty and number of syllables across languages. Objects were represented by simple but colorful pictures presented on a white background. 36 objects randomly arranged into 4 rows and 9 columns were presented on the page. Two alternate forms, each with 36 random-ordered stimuli, were administered. The total score was the sum of the reaction times for each form. The reliability of this task was α=.87 for English-speaking children and α=.85 for Mandarin-speaking children.

ii) Rapid Digit Naming. The rapid digit naming task measured the speed with which the participant named a series of digits printed on a page. This task is the exact subtest from the CTOPP. 36 digits (2, 3, 4, 5, 7, 8) in a 4x9 arrangement were presented on a page. Two alternate forms, each with 36 random-ordered stimuli, were

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[16] The pinyin is listed first, followed by the character in parenthesis.

administered. The total score was the sum of the reaction times for each form. The reliability of this task was α=.96 for English-speaking children and α=.92 for Mandarin-speaking children.

Morphological Construction. Recently, measures of morphological compounding have been shown to be very strong predictors of reading ability for Chinese-speaking children in both cross-sectional and longitudinal designs (e.g., McBride 2003, McBride-Chang, Cho, et al., 2005; McBride-Chang, Shu et al., submitted), and have been found to relate to vocabulary development in English-speaking children (McBride-Chang, Bialystok, et al., 2004) and to reading development in older children in alphabetic orthographies (Casalis & Louis-Alexandre, 2000). In the current study, we used a modification of a morphological construction task provided by McBride-Chang and colleagues (2003, 2006) to assess children's ability to manipulate morphemes in compound words. For the child administration, we used two different testing formats.

i) Morphological Construction- Production. This is a task of compounding morphology that measures the child's ability to manipulate morphemes in compound words. For each trial, children heard sentences such as, "A tree that grows apples is called an *appletree.* What would you call a tree that grows bread*?*" Children were required to use the morpheme cues to create new compound words such that the correct response in this example would be '*breadtree'*. The task was composed of 16 items (items 14 – 30 on the adult task, see Chapter 3): 8 requiring word-initial substitutions (i.e., blackboard-greenboard) and 8 requiring word-final substitutions (i.e., handbag-handpot). This task had a maximum score of 16 points and reliability was α=.80 for U.S. participants and α=.81 for Chinese participants.

ii) Morphological Construction - Reception. This task was designed to measure the child's morphological comprehension and was modeled after McBride-Chang et al.'s (2006) morphological awareness task. For this task, the first 14 items from the adult version (items 1-14) were transformed into a receptive task using a forced-choice picture format. For example, a child would hear the prompt, "A fish that has a nose that looks like a sword is called a swordfish. Where's the picture of a gunfish?" The child was then required to choose the correct picture from a set of four simple but colorful hand-drawings. One of the four choices was a drawing of the target response (gunfish) and the remaining three responses were distractors. Two of the distractors were selected randomly to represent cues from the prompt (i.e., fish, sword, swordfish, or gun) and the third was a picture picked randomly from the total pool of drawings for the other trials (i.e., snowman or snowcat). The location of the different picture types in the four quadrants of the page varied randomly across the task. 7 items required word-initial substitutions (i.e., swordfish-gunfish) and 7 items required word-final substitutions (i.e., snowman-snowcat) for a total score of 14 points. The task had a reliability of α=.54 for U.S. children and α=.50 for Chinese children.

The Wechsler Intelligence Scale for Children (WWPSI-R)-(Wechsler, 1989). This battery contains measures designed to cover a range of general intellectual measures for ages, 3 – 7.5 years. In the current study, we administered two of the subtests without any changes to the standardized versions: block design as a measure of nonverbal IQ and vocabulary, as a measure of verbal IQ.

i) Block design. The block design task required participants to recreate various block formations within a specific time-period. Participants were given 4 blocks that were either all red or all white on a side or were half red and half white on a side and were asked to create designs that were either modeled by the experimenter or in a task booklet. Administration and scoring in both languages followed the instructions in the WWPSI-R testing manual (Wechsler, 1981). Of the 14 possible trials, items 1 – 7 were scored as 0, 1 or 2 points each and items 8 – 14 were scored as 0- 4 points each based on the participant’s accuracy and time to completion. Testing was stopped when the participant failed three consecutive trials. The task had a maximum score of 68 and a reliability of α=.79 for English and α=.85 for Chinese.

ii) Vocabulary. For English speakers, the vocabulary subtest of the Wechsler Intelligence Tests (*WWPSI-R,* Wechsler, 1981) required participants to define 25 words of increasing conceptual difficulty. Responses were recorded by hand and scored by two independent testers based on the standardized scoring instructions of the Wechsler Intelligence Tests (*WWPSI-R,* Wechsler, 1981). The first three items were scored 0 for incorrect or 1 for correct and the remaining responses were scored 0 (incorrect), 1 (partially correct), or 2 (correct). Any inconsistencies in scoring were resolved by the primary investigator. Testing was discontinued when a participant got six or more consecutive items wrong. The task had a total possible score of 47 points and a reliability of α=.83.

The Mandarin-version of the vocabulary task was roughly comparable in word difficulty (word complexity and frequency) to the English version. For Mandarin speakers, the task required participants to define thirty-two words of increasing conceptual difficulty. The words were from the vocabulary subtest of the Hong Kong Stanford Binet Intelligence Scale (Thorndike, Hagen, & Sattler, 1986) and were adapted for Mandarin speakers. Responses were recorded by hand and scored by three independent scorers. Each response was scored 0 (incorrect), 1 (partially correct), or 2 (correct) based on the standardized scoring instructions of the Stanford Binet Intelligence Scale (Thorndike et al., 1986) for a total maximum score of 64 points. Testing was discontinued when a score of 0 was obtained on 6 or more consecutive items. The task had a reliability of α=.87.

Memory for Digits. The memory for digits task from the *Wechsler Adult Intelligence Tests (WAIS-R); Wechsler, 1981)* measured the child's ability to recall a list of digits in serial order. This task was composed of two separate measures: Digits Forward and Digits Backward. Digits Forward had 16 trials that required the participant to repeat a series of numbers that increased in length over the trials from 2 to 9 digits, for a maximum score of 16 points. The reliability of this measure was α=.62 for English and α=.82 for Chinese. Digits Backward had 14 trials that required the participant to repeat a series of numbers that increased in length over the trials from 2 to 8 digits, backwards, or in reverse order, for a maximum score of 14 points. The reliability of this measure was α=.68 for English and α=.76 for Chinese. Administration and scoring in both languages followed the standard protocol of the WAIS-R (*Wechsler, 1981).* Testing ceased when the discontinue criterion (two failures in a row on trials of the same length) was met.

Wide Range Achievement Test 3 (WRAT 3; Wilkinson, 1993)-Single Word Reading. For English speakers, we administered the standardized reading subtest of the WRAT 3, which required participants to read 42 words of increasing difficulty for a maximum score of 42 points. The reliability of this measure was α=.92.

For Mandarin speakers there is no standardized test of word reading in mainland China. So, for Mandarin speakers, we administered a single character reading test that has been used in several other studies of reading ability of children in mainland China (e.g., Shu et al., in press; Shu et al., submitted). The test was composed of 120 characters selected from language textbooks used in primary school in Beijing (Shu, Chen, Anderson, Wu, & Xuan, 2003). 20 items were chosen for each grade level, first through sixth. The first 20 items that were selected to be representative of first grade reading were also chosen to be orally familiar to kindergarten children (formal reading instruction doesn't begin until first grade). Administration of the Chinese single-character-reading test was modeled after the English version and had a reliability of α=.99.

Results

The results section is divided into four parts. In the first section I review the results of the phonological sensitivity task and explore differences in the performance between English- and Mandarin-speaking children. In the second section I discuss the results for the behavioral battery and examine whether the relationships among the measures in the battery replicate those found in existing literature. In the third section, I test whether the relationship between the phonological sensitivity task and the reading and reading-related measures depends on age or language learned. In the last section, I compare reading models for English- and Mandarin-speaking children, and explicitly test three questions about the role of phonological sensitivity and awareness in predicting reading for Mandarin-speaking children.

Phonological Sensitivity Task

Accuracy. Children's performance on the phonological sensitivity task ranged from 81 – 94% accurate across all conditions as shown in Table 2.2. In a repeated measures analysis of variance, we measured the effect of location of testing (Michigan or Beijing) as a between-subjects factor, age-at-testing as a covariate, and prime type (Same, Different, Alliterating, and Rhyming) and language (native or nonnative) as within-subjects factors. There was no effect of location of testing, $F(1, 135)=1.21$, but the covariate, age-at-testing, was significant, $F(1, 135)=23.00$, $p<.001$. Younger children were less accurate than older children, but there were no significant interactions with age.

Thus, the pattern of performance was the same across ages, but the younger participants made more errors.

Language type (native, nonnative) was not a significant within-subjects effect, but there was a significant effect of prime type, $F(3, 404)=4.87$, $p<.01$. Specifically, performance in the rhyming condition was significantly worse than the other three conditions and performance in the Alliterating condition was significantly worse than the Different condition, test of mean differences Bonferroni-adjusted, $p\text{s}<.01$. Overall, children demonstrated the greatest difficulty detecting differences in rhyming pairs with an average 10 point drop in accuracy compared to performance in the other conditions. Interestingly, performance in the Alliterating condition was also significantly worse relative to the two other conditions where a ‘different’ decision was required (Different and Rhyming). However, the mean difference between Alliterating (M=.91) and Different (M=.93) was much smaller than that between Rhyming (M=.83) and the two other “different” conditions. Thus, the two prime types with partial phonological overlap (Alliterating and Rhyming) were processed less effectively than prime types with no phonological overlap (i.e., Different). However, for both English and Mandarin speakers the effect was much stronger when the phonological overlap was in the rime unit than in the onset.

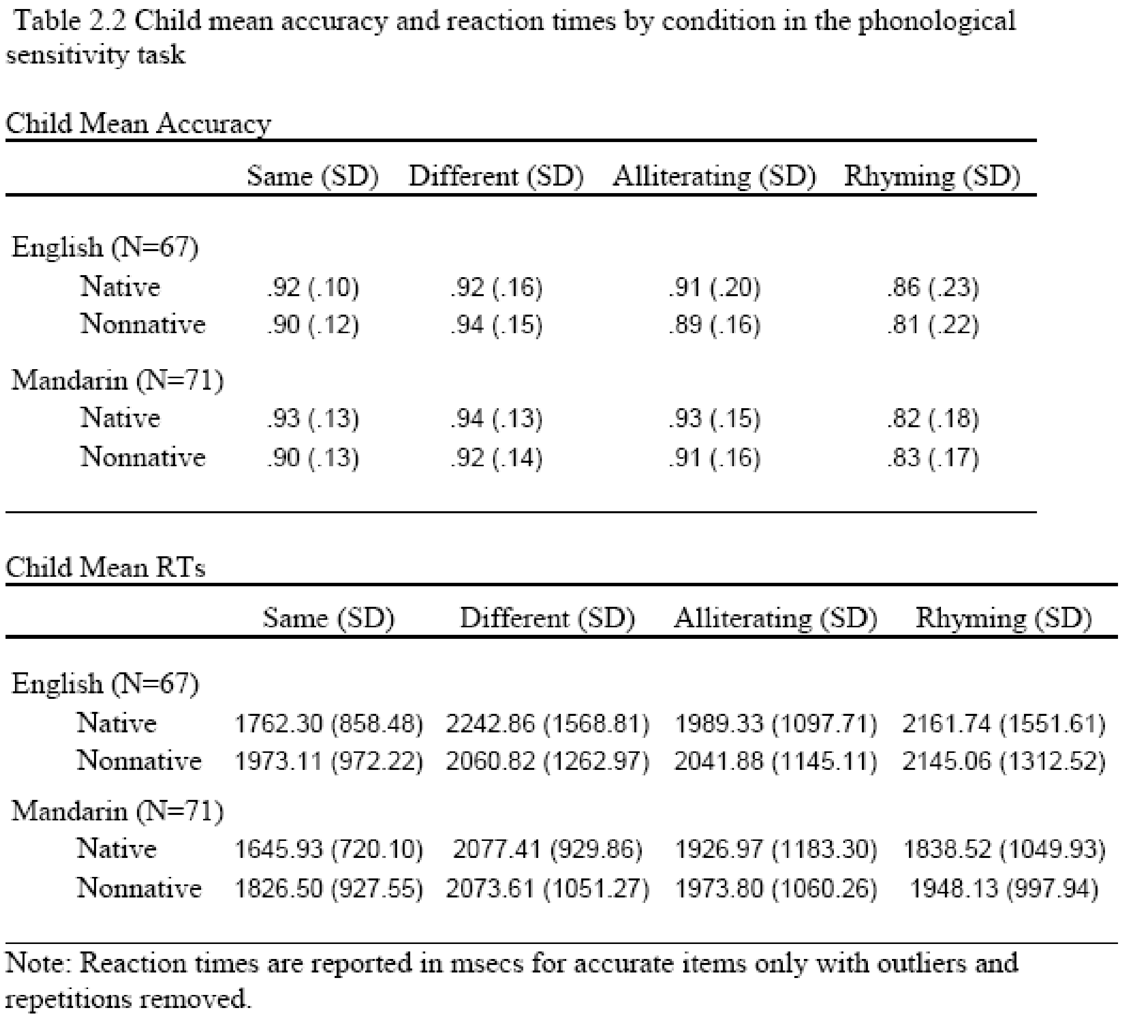

Table 2.2 Child mean accuracy and reaction times by condition in the phonological sensitivity task

Child Mean Accuracy

	Same (SD)	Different (SD)	Alliterating (SD)	Rhyming (SD)
English (N=67)				
Native	.92 (.10)	.92 (.16)	.91 (.20)	.86 (.23)
Nonnative	.90 (.12)	.94 (.15)	.89 (.16)	.81 (.22)
Mandarin (N=71)				
Native	.93 (.13)	.94 (.13)	.93 (.15)	.82 (.18)
Nonnative	.90 (.13)	.92 (.14)	.91 (.16)	.83 (.17)

Child Mean RTs

	Same (SD)	Different (SD)	Alliterating (SD)	Rhyming (SD)
English (N=67)				
Native	1762.30 (858.48)	2242.86 (1568.81)	1989.33 (1097.71)	2161.74 (1551.61)
Nonnative	1973.11 (972.22)	2060.82 (1262.97)	2041.88 (1145.11)	2145.06 (1312.52)
Mandarin (N=71)				
Native	1645.93 (720.10)	2077.41 (929.86)	1926.97 (1183.30)	1838.52 (1049.93)
Nonnative	1826.50 (927.55)	2073.61 (1051.27)	1973.80 (1060.26)	1948.13 (997.94)

Note: Reaction times are reported in msecs for accurate items only with outliers and repetitions removed.

There are several non-intuitive elements to this finding. First, the task demands suggest that alliterating pairs should be more difficult to process because they require the participant to change his initial response bias from 'same' (shared onset) to 'different' (nonshared rime). What's more, research has shown that consonants are more important to lexical specification than vowels (Nazzi & New, 2007) and the word initial position is more salient (Treiman et al., 1998) in language processing. Thus, a change in a consonant in the word initial position (between rhyming pairs) should be more salient than a change in the vowel structure at the end of a word (between alliterating pairs). Last, existing research in fact shows that children find detecting alliterations harder than detecting rhymes in oddball tasks (where children are required to identify the word that didn't sound like the other words in a series- i.e., pin, win, *sit*, fin; e.g., Bradly & Bryant, 1983; Burgess & Lonigan, 1998; Hatcher & Hulme, 1999).[17]

On the other hand, the consonant initial position demonstrates a higher degree of co-articulation with the following sound (in this case a vowel) than the vowel final position, making it more difficult to parse successfully. Furthermore, this co-articulation effect may be exacerbated in the current stimuli because in the rhyming word pairs there were several minimal contrasts whereas there were none in the alliterating pairs. Lastly, in research there is evidence that dyslexics show less impairment to rhyming pairs than normals, whereas they demonstrate equal impairment to alliterating pairs (Desroches, Joannisse, & Robertson, 2006). This suggests that there may be something unique and important about the rhyme position and reading ability. In sum, it is interesting and noteworthy that both English and Mandarin speakers demonstrate greater rhyming interference than alliterating interference and this finding merits further investigation.

Although there were no significant two-way interactions in the repeated measures ANOVA, there was a significant three-way interaction between location of testing, language, and prime type, $F(3, 405)=4.09, p<.01$. The interaction appeared to be located in a significant difference between English and Mandarin-speaking children's performance in the Rhyming condition for native word pairs compared to non-native word pairs. A post-hoc test of means revealed a significant difference between native and non-native words pairs in the Rhyming condition for English-speaking children, Bonferroni-adjusted $p<.01$, but not for Mandarin-speaking children. English children showed a slight advantage for familiar rhymes ($M=.86$) compared to unfamiliar rhyming word pairs ($M=.81$) whereas Chinese children performed equally on familiar and unfamiliar rhyming word pairs ($M=.82-.83$). Although these differences are small, they are worthy of explanation because they speak to some of the fundamental issues under investigation.

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[17] However, these tasks are different not only in the demand characteristics (it is easier to say something sounds the same or not, than to decide what word doesn't sound the same) but also in the training. In the Bradley and Bryant (1983) oddity task format that is also used in Lonigan and colleagues work and in Hatcher and Hulme's (1999) paper, the child is trained using nursery rhymes, a training that may easily prime the child in detecting rhymes.

One possible explanation may be that the nature of lexical representations for English and Mandarin speakers differs. The level at which phonological information is stored in lexical representations has been shown to influence processing of information at this level (e.g., Tan & Perfetti, 1998; Zhou & Marslen-Wilson, 1999). In English-speaking children's lexicons there are a larger proportion of rime neighbors (words that differ in the onset) than onset neighbors (words that differ in the rime) or onset-vowel neighbors (words that differ in the final) (e.g., Baayen, Piepenrock & van Rijn, 1993 cited in Ziegler & Goswami, 2005) suggesting that the phonological characteristics of English support lexical encoding of phonological information at the level of the rime (Ziegler & Goswami, 2005). Thus, the difference in accuracy when comparing familiar rhyming words and unfamiliar rhyming words may be that English-speaking children can access the rime unit in familiar words more readily because this is the linguistic level that at which known words are stored. Unfamiliar words, even when composed of the same phonological information, do not have lexical representations, and thus, children may process these words less efficiently. In contrast, the reason that Chinese children process both familiar and unfamiliar words pairs equally may be because lexical representations for Chinese children are not represented at the level of the rime, thus there may be no advantage for familiar rhymes. To date, there is no existing work that explores the role of the onset-rime in lexical representations in Chinese.

Alternatively, English-speaking children may process native and non-native rhyme pairs differently than Mandarin speakers because of differences in familiarity with the non-native language. Although for Chinese children in mainland China formal training in English doesn't begin in school until fourth grade (e.g., Lao & Rao, 2000), it is probable given the greater degree of English exposure (on television, billboards, airports, etc.) in Beijing compared to Mandarin exposure in Ann Arbor, that Chinese children are exposed to more English words than English children are exposed to Mandarin Chinese words. Thus, the difference in performance between native and non-native pairs for English-speaking children may be a product of task difficulty and not due to intrinsic properties of their phonological representations.

Reaction Times. Reaction times were computed for each subject based on correct responses with outliers[18] removed (Table 2). 12% (2049) of the trials were inaccurate for the English sample (19,653 trials across 69 participants) and 3% (614) were outliers. For the Chinese sample (22,496 total trials across 75 participants) 10% were inaccurate responses and only 10 trials were outliers. Interestingly, both groups showed extremely few response times greater than 2 SD's above the mean. One reason for this may be because of the high variability in reaction times within each condition seen in both groups.

A repeated measures analysis of variance in the phonological sensitivity task was performed on reaction times with location of testing (Michigan, Beijing) as a between subjects-factor, age-at-testing as a covariate, and prime type (Same, Different, Alliterating, and Rhyming) and language (native, nonnative) as within-subjects factors. There was a marginally significant effect of location of testing, $F(1, 135)=3.53$, $p<.10$, and a highly significant effect of the covariate, age-at-testing, $F(1, 135)=23.20$, $p<.001$. Younger children responded more slowly than older children and English-speaking children responded more slowly than Mandarin-speaking children. Surprisingly, there were no within-subject effects for the language condition (native, nonnative) or pair type (Same, Different, Alliterating, Rhyming) and there were no significant interactions.

It is important to note here that (unlike in the adult study) child participants did not respond manually in this task. Instead, experimenters recorded the verbal responses of children as quickly as possible using the serial response box. Thus, these results for reaction times must be interpreted carefully. In particular, the lack of within-subjects effects raises a red flag. The one consistent finding across the accuracy and reaction time findings for the adults (see Results, Chapter 3) and the accuracy results for the children is a highly significant effect of prime type. The lack of a significant effect of prime type suggests a high degree of variability within the conditions that may obscure patterns across the conditions (a finding echoed earlier when reporting the outliers). Furthermore, the direction of the main effect of location is unexpected. In the adult study, Mandarin speakers were notably slower than English speakers during pilot testing and the removal

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[18] Any response greater than 2SD's above the mean or less than 50msec.

of outliers in the adult reaction time data pointed to Chinese participants as being on whole, consistently slower and more cautious than U.S. participants. It is of course possible that the reverse effect is found in Chinese and U.S. children, but it is also possible that these effects were due to other, more spurious causes.

Specifically, it is possible that the two main effects of age and location of testing reflect differences in the experimenter's responsiveness and not true differences within the sample of children tested. Informally, several testers mentioned that some children were prone to self-correction, and thus, the tester purposefully waited a brief period after the child gave a response. Younger children may have been more likely to change their answers, which could provide an external explanation for the significant age-of-testing effect independent of the test itself. Thus, what appears to be a difference between samples may only be a difference between experimenters. Because of these potential confounds in the reaction time data; I will only include the accuracy data in further analyses.

Behavioral Battery

Descriptive statistics for measures in the behavioral battery are shown in Table 2.3. With a few exceptions, all measures demonstrated good distributions and relatively high and consistent alphas (α = .76 - .99) across both samples[19]. The morphological reception task was close to ceiling for the English sample (*M*=12.76, *SD*=1.39) which may explain the low reliability in this sample (α = .54). However, the reliability in the Chinese sample was also low for this task, (α = .50), even though performance in the Chinese sample was skewed but not at ceiling (*M*=10.49, *SD*=1.85). Thus, it is possible that this task is not in fact a reliable measure of the underlying construct of morphological ability and therefore, I do not use it further in the analyses. In contrast, the morphological production task demonstrated good distributions both for English

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[19] There is no formally established rule for acceptable, marginal or unacceptable levels of internal consistency. In general, in the reading literature levels of reliability of α = .70 or higher are considered to be acceptable (Nunnally and Bernstein, 1994). However, interpretation of these levels depends on the test itself, the number of items, the quality of the items, the homogeneity of the group being tested, and the application or proposed use/purpose of the test. Thus, in my dissertation, I apply the 'rule-of-thumb' commonly used in the literature, with minor adjustments depending on the nature of the task itself that are noted accordingly.

(*M*=10.23, *SD*=3.34) and Chinese (*M*=10.94, *SD*=3.26) and good reliability for both samples (α =.80 for English and α =.81 for Chinese).

Digit span forwards also demonstrated a lower than expected reliability for the U.S. sample (α =.62), but not for the Chinese sample (α =.82). Statistically the performance of the English speakers was less variable than performance of the Mandarin speakers. For example, the range for the Digit Forwards task was only 0 – 9 items for the English speaker, but 2 – 15 items for the Mandarin speakers. Furthermore, nearly 70% of the English speakers got between 6 – 8 items correct. In the Mandarin speakers, the greatest concentration of scores was between 9 and 11 points, and constituted only 24% of the sample. Thus, the lower reliability levels for English speakers in the Digits Forward measure may be due to restricted variability in performance.

As shown in the analysis of variance results in Table 2.3, English- and Mandarin-speaking participants performed differently on several measures that are typically found to predict individual differences in reading. Specifically, English speakers knew significantly more letters than the Mandarin speakers, *F*(1, 134)=15.76, *p*<.001 and were faster in the object naming task than Mandarin speakers, *F*(1,130)= 19.25, *p*<.001. In China, children do not learn pinyin until the third year of kindergarten (McBride-Chang, Bialystok et al., 2004). Thus, nearly half the Chinese sample had not yet learned the sounds associated with the letters. In fact, when the participants are divided by age, the difference in letter sound knowledge in older children (shown in Table 2.5) switches direction (*M*=19.54 for English speakers and *M*=20.71 for Mandarin speakers).

Table 2.3 Descriptives for child performance on reading-related measures by language group.

	English-speakers			Mandarin-speakers			Eng vs. Mand
Measures	N	Mean (SD)	α	N	Mean (SD)	α	ANOVA
Age	69	79.18 (12.96)		71	73.49 (16.09)		F(1, 139)= 5.30*
Alphabet Sounds [22][a]	63	17.60 (4.64)	.90	71	11.99 (10.34)	.99	F(1, 134)= 15.76***
Digits Forward [16]	63	6.13 (1.67)	.62	71	8.76 (2.94)	.82	F(1,134)= 39.29***
Digits Backward [14]	60	3.53 (1.53)	.68	71	3.03 (1.99)	.76	F(1, 131)= 2.58
Elision Total [67, 54]	62	31.73/51% (17.21)	.98	71	22.27/41% (15.07)	.97	N/A
Morph Rec [14]	63	12.76 (1.39)	.54	71	10.49 (1.85)	.50	F(1, 134)= 63.16***
Morph Prod [16]	62	10.23 (3.34)	.80	71	10.94 (3.26)	.81	F(1, 133)= 1.57
Rapid Digits [72]	58	25.44 (18.16)	. 96	71	29.27 (13.98)	.92	F(1, 129)= 1.83
Rapid Objects [72]	59	35.78 (10.95)	.87	71	47.04 (16.97)	.85	F(1, 130)= 19.25***
Reading [42, 120]	54	9.91/24% (7.77)	.92	61	37.82/32% (29.00)	.99	N/A
Vocabulary [25, 32]	58	27.26/58% (6.83)	.83	67	14.28/22% (7.71)	.87	N/A
Nonverbal IQ [14]	64	30.53 (7.21)	.79	71	26.28 (8.24)	.85	F(1, 135)= 10.07**
Sound Sensitivity [128]	67	.89 (.13)	.95	71	.90 (.12)	.96	F(1, 138)=.02

Note: All data are presented as raw scores. RTs were computed only for accurate items with outliers and repetitions removed. Sound Sensitivity = mean accuracy averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).

[a]: number of items for each task are presented in brackets- where total differs by sample, we reported as [English, Mandarin].

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

The reason for the difference in rapid object naming between the two groups is not as obvious. It is possible that because different object names were used for the two groups there were differences in the frequency or familiarity of the names (although we controlled for the syllabic complexity and length), differences that may have made the English names easier to retrieve than the Chinese names. Interestingly, there was a similar difference between language groups on the test of rapid object naming in adults (see Results, chapter 3). In order to correct for this difference, I computed standardized totals for the rapid object and rapid digit tasks within each sample and then averaged the scores to create a composite score for rapid naming.

The Mandarin-speaking children scored significantly better than the English speakers on the nonverbal IQ measure, $F(1, 135)=10.07, p<.01$, and on the Digits Forward task, $F(1, 134)=39.29, p<.001$ (see Table 2.3). The difference between Mandarin- and English speakers in nonverbal IQ may reflect an underlying IQ difference between the two groups or it may be a byproduct of the nonverbal IQ measure used. Block design is a task that has a heavy visual component that may tap skills that develop more strongly in Mandarin-speaking children due to the visual complexity of the character system and the commensurate demands on visual sensitivity (McBride-Chang, Chow, Zhong, Burgess, & Hayward, 2005). The difference between language groups on the test of digit span was also found for adults (see Results, Chapter 3). Chinese participants may perform better on the Digits Forward test because Chinese number names are shorter than English number names (Miller, Smith, Zhu, & Zhang, 1995).[20] Again, because of the significant difference in performance between English- and Mandarin-speaking children on the Digits Forward task in the current study, I created a composite score for Digit Span computed from standardized scores for Digits Forward and Digits Backward in each sample.

Differences in performance for the elision, single-word/character-reading, and vocabulary tests could not be tested because the measures were not identical for the two samples. However, when performance is compared using percentages, the two samples

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[20] Compare phonemes for English: one (3 phonemes), two (2), three (3), four (3), five (3), six (4), seven (4), eight (2), nine (3) and Chinese: yi (1 phoneme), èr (2), sān (3), sì (2), wǔ (2), liù (3), qī (2), bā (2), jiǔ (3).

appeared to perform relatively similarly on the elision task (51% accurate for U.S., 41% accurate for Chinese) and reading test (24% accurate for U.S. and 32% accurate for Chinese), with the differences being in the direction predicted by previous research (McBride-Chang & Kail, 2002). In contrast, the samples showed a dramatic difference in performance on the vocabulary test, with the Chinese children correctly identifying less than 25% of the vocabulary words, where the English-speaking children correctly defined more than 60% of the words. Despite the fact that both tests are from well-known standardized batteries (the Hong Kong Stanford Binet; Thorndike, et al., 1986, adapted for Mandarin, and for English the Wechsler Intelligence Tests- WPPSI-R; Wechsler, 1981), it is extremely difficult to control for difficulty levels of vocabulary items across languages. Thus, the difference may be because the Mandarin version of the Stanford Binet was harder than the English vocabulary subtest of the WPPSI (Wechsler, 1981). Or, it is possible that the Chinese children had an overall lower vocabulary level. Vocabulary development is strongly influenced by caregiver income and education levels (Morrison, Bachman, & Connor, 2005) and thus this performance difference may be due to differences between the samples in demographics. An alternative explanation may be due to differences in testing fatigue. The vocabulary test was the last measure administered and the Chinese children may have been more fatigued by the end of testing than the U.S. children for several reasons. First, testing was administered during the school day in China, whereas the majority of testing in the U.S. was administered on the weekends. Furthermore, the type of mandatory breaks that the U.S. and Chinese children had, differed. For each break, U.S. participants played a game where they won a prize, whereas at the request of the school principal, the Chinese children stayed seated and chatted with the experimenter. Last of all, the Chinese children were better behaved than the U.S. participants and appeared to maintain attention for longer and thus were given fewer additional breaks. For these reasons, it is likely that the Chinese children were more fatigued by the time the vocabulary test was administered than the U.S. children, a difference exacerbated by the fact the questions were open-ended, a response type that is markedly effortful.

The last difference between the groups was in age, $F(1,139)=5.30$, $p<.05$. The English-speaking sample was on average 5½ months older ($M=79.18$) than the

Mandarin-speaking group (*M*=73.49) and ranged in grade-level from pre-kindergarten (4-year-olds) to third-grade (8-year-olds) whereas the Chinese sample only contained children in kindergarten (4- and 5-year-olds) and first grade (6- to 8-year-olds). I subdivided the samples into a younger and older group in order to explore whether the performance differences on the behavioral battery between the English- and Mandarin speakers were a product of age. To create the groups, I selected grade-level as the dividing point instead of age because reading and reading-related skills show strong schooling effects, often greater than age effects (e.g., Morrison, Griffith, & Frazier, 1997; Morrison, Smith, & Dow-Ehrensberger, 1995). Thus, the *younger* group was composed of American children in preschool and kindergarten and Chinese children in their second year of kindergarten. Both the American and Chinese children in this group had not received any formal instruction in reading. The *older* group was composed of children first grade or older in the U.S. and children in first grade in China. At the time of testing, both U.S. and Chinese children in the older group had been exposed to formal reading instruction for at least 3 months. In the U.S., reading-related skills such as letter knowledge and concepts of print are introduced in kindergarten (and in some preschools) but formal reading instruction does not begin until first grade (McBride-Chang, 2004; McBride-Chang, Bialystock et al., 2004; McBride-Chang & Kail, 2002). Similarly, in Beijing, training in pinyin begins in the third year of kindergarten and formal reading instruction begins in the first grade of primary school (Li & Roa, 2000). Thus, although the groups were divided by grade, the split was aligned with differences in reading instruction (and, by proxy, reading levels). The younger children had not yet received any formal reading instruction whereas all the children in the older group had at least three months of formal reading instruction. Although this split does not match up exactly with a reader/nonreader divide (English- and Mandarin-speaking younger children identified 12-13% of the words correctly on the reading task), it does produce interesting, and meaningful differences in the results. For the purpose of clarity, we refer to the younger group, as *emergent* readers, and the older group (who averaged above 30% accuracy in reading), as *decoding* readers, a labeling convention that is aligned with the division.

The younger group included 30 English-speaking children ranging in age from 52 – 75 months, with a mean age of 66.89 months (*SD*=6.66) and 30 Mandarin-speaking children ranging in age from 49 – 63 months with a mean age 55.88 months (*SD*=3.52). In this group, the Chinese children were significantly younger than the American children, $F(1, 59)=64.06$, $p<.001$. In the older group, there were 39 English-speaking children ranging in age from 73 – 108 months with a mean age of 88.64 months (*SD*=7.46) and 41 Mandarin-speaking children ranging in age from 75 – 102 months with a mean age of 86.38 months (*SD*=6.41). In the older group there was no significant difference in age between the U.S. and Chinese children, $F(1, 79)=2.12$.

In Table 2.4 and 2.5, descriptive statistics for measures in the behavioral battery are shown for the older and younger groups separately. With this division, the reliability is decreased in measures which now demonstrate floor effects (i.e., digit span backwards for the younger English-speaking children) and ceiling effects (i.e., alphabet sounds for the older Mandarin-speaking children). However, this division improves the comparability of the older group as there is now no significant difference between nonverbal IQ for English and Mandarin speakers in this group. However, there continues to be a difference between English and Mandarin speakers in both older and younger groups on Alphabet Sound Knowledge, Digits Forward, and Rapid Object Naming. The low reliability and continued difference in performance between English- and Mandarin-speaking children on the digit span tasks proves problematic, particularly as these tasks are the only measures of phonological working memory collected in the current study. Thus, interpretations about the role of phonological working memory must be made with caution. Phonological sensitivity and awareness, rapid naming, morphological production, and vocabulary generally showed good distributions and reliabilities across the groups.[21] Because these are the measures with the greatest relevance to the questions posed in the introduction, most of the subsequent analyses will focus on these measures.

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[21] Two exceptions to this are the reliability of morphological production for the younger Chinese children and vocabulary for the older English-speaking children.

Table 2.4 Descriptives for *younger* children: Performance on reading-related measures

	English-speakers			Mandarin-speakers			English vs Mandarin
Measures	N	Mean (SD)	α	N	Mean (SD)	α	ANOVA
Age	30	66.89 (6.66)		30	55.88 (3.52)		F(1, 59)= 64.06***
Alphabet Sounds [22][a]	26	14.85 (5.38)	.91	30	.07(.25)	.04	F(1, 55)= 226.53***
Digits Forward [16]	26	5.19 (1.81)	.66	30	6.90(2.22)	.65	F(1, 54)= 9.76**
Digits Backward [14]	23	2.78 (1.20)	.55	30	1.67(1.56)	.69	F(1, 51)= 8.06**
Elision Total [67, 54]	26	19.96 / *30%* (13.79)	.97	30	9.70 / *18%* (6.04)	.90	N/A
Morph Prod [16]	25	8.48 (3.68)	.83	30	9.40 (2.72)	.65	F(1, 54)= 1.13
Rapid Digits [72]	23	35.71 (23.26)	.95	30	41.32 (12.92)	.83	F(1, 52)= 1.25
Rapid Objects [72]	24	42.96 (10.86)	.76	30	59.17(17.37)	.78	F(1, 53)= 15.89***
Reading [42, 120]	25	5.04 / *12%* (6.09)	.91	26	15.23 / *13%* (13.88)	.98	N/A
Vocabulary [25, 32]	22	21.64 / *46%* (5.55)	.83	29	10.66 / *17%* (6.07)	.82	N/A
Nonverbal IQ [14]	27	27.74 (7.79)	.81	30	19.70 (6.52)	.81	F(1, 56)= 17.97***
Sound Sensitivity [128]	29	.86 (.16)	.96	30	.85 (.13)	.95	F(1, 57)= .07

Note: All data are presented as raw scores. RTs were computed only for accurate items with outliers and repetitions removed. Sound Sensitivity = mean accuracy averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).

[a]: number of items for each task are presented in brackets- where total differs by sample, we reported as [English, Mandarin].

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

Table 2.5 Descriptives for *older* children: Performance on reading-related measures

	English-speakers			Mandarin-speakers			English vs. Mandarin
Measures	N	Mean (SD)	α	N	Mean (SD)	α	ANOVA
Age	39	88.64 (7.46)		41	86.38 (6.41)		F(1, 79)= 2.12
Alphabet Sounds [22][a]	37	19.54 (2.77)	.80	41	20. 71 (1.58)	.50	F(1, 78)= 5.33**
Digits Forward [16]	37	6.78 (1.20)	.37	41	10.12 (2.66)	.81	F(1, 78)= 49.22***
Digits Backward [14]	37	4.00 (1.55)	.67	41	4.02 (1.65)	.66	F(1, 78)= .01
Elision Total [67, 54]	36	40.22 / *60%* (14.26)	.96	41	31.46 / *58%* (12.87)	.96	N/A
Morph Prod [16]	37	11.41 (2.51)	.69	41	12.07(3.17)	.87	F(1, 78)= 1.05
Rapid Digits [72]	35	18.70 (9.21)	.94	41	20.45 (5.72)	.87	F(1, 75)= 1.03
Rapid Objects [72]	35	30.86 (7.97)	.90	41	38.16 (9.70)	.73	F(1, 75)= 12.54***
Reading [42, 120]	29	14.10 / *34%* (6.56)	.84	35	54.60 / *46%* (25.73)	.98	N/A
Vocabulary [25, 32]	36	30.69 / *65%* (5.05)	.65	38	17.05 / *27%* (7.75)	.87	N/A
Nonverbal IQ [14]	37	32.57(6.09)	.72	41	31.10 (5.64)	.71	F(1, 78)= 1.22
Sound Sensitivity [128]	38	.92 (.10)	.92	41	.93 (.11)	.96	F(1, 80)= .22

Note: All data are presented as raw scores. RTs were computed only for accurate items with outliers and repetitions removed. Sound Sensitivity = mean accuracy averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).

[a]: number of items for each task are presented in brackets- where total differs by sample, we reported as [English, Mandarin].

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

Relationships among the reading and reading-related measures.

Younger children. The simple correlations in Table 2.6 show the relationships among the measures of the behavioral battery for English- and Mandarin-speaking younger children. For English speakers, there were significant correlations among measures of phonological processing and reading that replicate those found in previous studies (e.g., Lonigan et al., 1998; Torgesen et al., 1997; Wagner et al., 1997). Specifically, measures of phonological awareness (elision and alphabet knowledge) were significantly correlated with each other, r=.67, p<.001, and with measures of phonological working memory (measured by a composite of the standardized scores for digit span forwards and backwards), alphabet knowledge, r=.67, p<.001, and elision, r=.57, p<.001, but none of the three was significantly correlated with rapid naming (measured by a composite of the standardized scores for rapid naming objects and digits). Furthermore, all phonological processing measures with the exception of working memory and sensitivity[22] were significantly correlated with single-word-reading. Morphological production showed strong relationships with alphabet knowledge (r=.54, p<.01), digit span (r=.65, p<.01), and elision (r=.71, p<.001), but a weak relationship with reading, r=.35, p<.10. Unlike existing research (e.g., McBride-Chang, Cho et al., 2005), our measure of vocabulary showed only a marginally significant relationship with reading, r=.39, p<.10, and no relationships with either phonological awareness or morphological construction for the English-speaking younger children.

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[22] I created a general measure of sound sensitivity by collapsing across all conditions in the phonological sensitivity task (native/non-native and Same/Different/Alliterating/Rhyming) discussed more fully in the following section.

Table 2.6 Simple correlations for *younger* children: Sound sensitivity, reading, and reading-related measures
English-speakers above the diagonal, Mandarin-speakers below the diagonal

	English-speakers (N= 30)								
	1	2	3	4	5	6	7	8	9
1. Alphabet Sounds	—	.67***	.67***	.54**	-.27	.51**	.19	.58**	.44*
2. Digit Span Total	.08	—	.57**	.65**	-.25	.30	.23	.45*	.28
3. Elision	-.23	.17	—	.71***	-.26	.61**	-.12	.56**	.29
4. Morph Production	-.14	.29	.22	—	-.08	.35†	-.04	.39*	.47*
5. Rapid Naming Total	.34†	-.28	-.34	.01	—	-.41*	.22	-.57**	.07
6. Single Word Reading	-.09	-.02	.41*	.26	-.34†	—	-.39†	.36†	.13
7. Vocabulary	-.17	.06	.02	.21	.03	.40*	—	-.18	.03
8. Nonverbal IQ	.22	.06	.08	-.13	.02	.25	.44*	—	.31
9. Sound Sensitivity (Acc)	.23	.42*	.43*	.11	-.37*	.26	.16	.27	—

Mandarin-speakers (N=30)

Note: Digit Span (forwards/backwards) and Rapid Naming (object/digit) were combined using means of standardized scores.
Sound Sensitivity (Acc) = mean accuracy averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
†p<.10, *p<.05, **p<.01, ***p<.001

The simple correlations for younger Mandarin-speaking children revealed many fewer relationships among the measures of the behavioral battery than for the younger English-speaking children. Phonological sensitivity was significantly correlated with the three traditional measures of phonological processing, elision, digit span, and rapid naming, although these measures themselves were not correlated. Only rapid naming (measured by a composite of the standardized scores for rapid naming objects and digits) and elision were significantly correlated with single-character-reading (elision, $r=.41$, $p<.05$ and rapid naming, $r=-.34$, $p<.10$). Furthermore, vocabulary was also significantly correlated with single-character-reading, $r=.40$, $p<.05$, and vocabulary and nonverbal IQ were related, $r=.44$, $p<.05$. Of interest, given the current literature suggesting a unique and perhaps more powerful role of morphological processing in predicting character reading ability than standard phonological measures (e.g., McBride et al., 2003), there was no relationship in the current group between morphological production and any variable measured, most importantly, reading.

Older children. Table 2.7 shows the simple correlations for older Mandarin- and English-speaking children. For older English-speaking children, the relationships among phonological processing measures and reading mirror findings in the existing literature (Wagner, et al., 1994) and in the younger children in the current study. Specifically, phonological awareness (measured by alphabet knowledge and elision), working memory (measured by a composite of the standardized scores for digit span forwards and backwards) and rapid naming (measured by a composite of the standardized scores for rapid naming objects and digits) were all significantly inter-correlated, whereas phonological sensitivity was only related to elision. In addition, elision continued to be correlated with single-word-reading, ($r=.51$, $p<.01$) and digit span was now correlated as well, $r=.48$, $p<.01$. Rapid naming showed a marginally significant relationship with reading, $r=-.36$, $p<.10$. Unlike for younger English-speaking children, in older more fluent readers the measure of alphabet sound knowledge was no longer predictive of reading ability (but most likely due to ceiling effects; e.g., Bus and van IJzendoorn, 1999; Wagner et al., 1997), and the contribution of morphological production to reading ability was lower than in younger children, $r=.33$, $p<.10$.

Table 2.7 Simple correlations for *older* children: Sound sensitivity, reading, and reading-related measures English-speakers above the diagonal, Mandarin-speakers below the diagonal

	English-speakers (N=39)								
	1	2	3	4	5	6	7	8	9
1. Alphabet Sounds	—	.33*	.58***	.28†	-.61***	.22	.29	.34*	-.11
2. Digit Span Total	.23	—	.45**	.20	-.45**	.48**	.38*	.36*	.00
3. Elision	.26†	.46**	—	.42**	-.52**	.51**	.45**	.30†	.34*
4. Morph Production	.08	.59***	.35*	—	-.38*	.33†	.35*	.06	.21
5. Rapid Naming Total	-.06	-.57***	-.35*	-.22	—	-.36†	-.20	-.38*	.05
6. Single Word Reading	.12	.49**	.54***	.40*	-.59***	—	.26	-.02	-.09
7. Vocabulary	-.15	.31*	.34*	.57***	-.28†	.44**	—	.41**	.17
8. Nonverbal IQ	.22	.32*	.38*	.48**	-.16	.35*	.51***	—	.12
9. Sound Sensitivity (Acc)	.19	.46**	.33*	.34*	-.30†	.43**	.29†	.31*	—
	Mandarin-speakers (N=41)								

Note: Digit Span (forwards/backwards) and Rapid Naming (object/digit) were combined using means of standardized scores.
Sound Sensitivity (Acc) = mean accuracy averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
†p<.10, *p<.05, **p<.01, ***p<.001

The simple correlations for older Mandarin-speaking children appear more similar to the correlations for older English-speaking children than to the correlations for younger Mandarin-speaking children. Specifically, measures of phonological processing, sensitivity, elision, digit span, and rapid naming, were all significantly intercorrelated at levels of r=.30, p<.10 or higher and were significantly correlated with single-character-reading at levels of r=.43, p<.01 or higher. Like in older English-speaking children, morphological production was related to reading ability, r=.40, p<.05. However, unlike older English readers, nonverbal IQ and vocabulary were significantly related to seven of the nine measures collected in the behavioral battery, and both were related to single-character-reading, r=.44, p<.01 and r=.35, p<.05, respectively

What is the role of phonological sensitivity in predicting reading in English and Mandarin speakers?

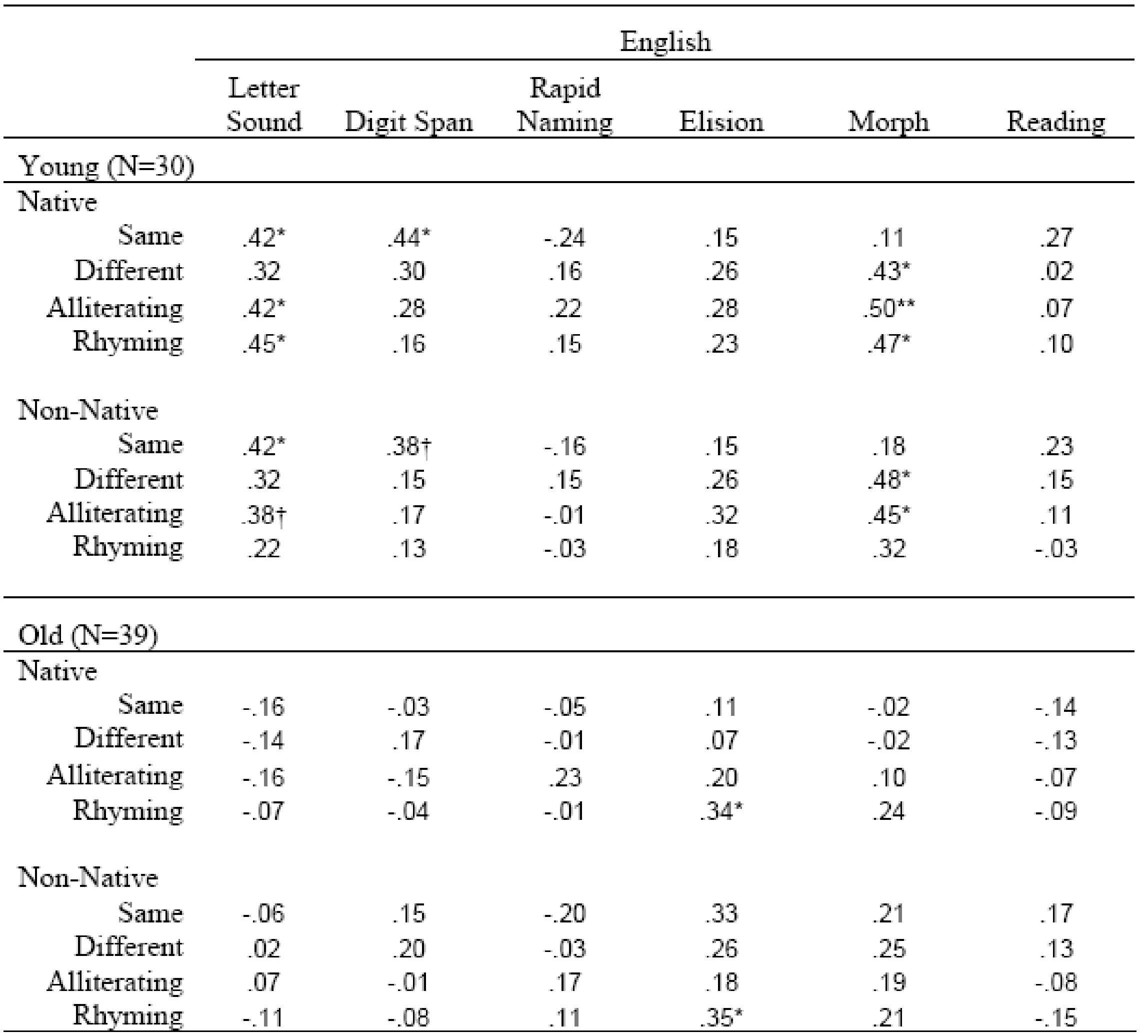
In the next section, I explore the role of phonological sensitivity in predicting reading ability depending on the language learned and level of reading development. First, I created a general measure of sound sensitivity by collapsing across all conditions in the phonological sensitivity task (native/non-native and Same/Different/Alliterating/Rhyming) and examined the correlations of this measure with the measures in the behavioral battery as shown in line 9, Table 2.6 and 2.7. Although there were no significant differences in general sound sensitivity between English- and Mandarin-speaking children in either the younger, F(1, 57)=.07, or older groups, F(1, 80)=.22, there were interesting and potentially meaningful differences in the relationship between the generalized measure of phonological sensitivity and the other reading and reading-related measures within each age and language group.

For young English speakers, general sound sensitivity was significantly correlated with one of the measures of phonological awareness (alphabet sound knowledge), r=.44, p<.05, and with morphological production, r=.47, p<.05. For older children, general sensitivity was significantly correlated with the other measure of phonological awareness (elision), r=.34, p<.05, but not with any other measures. The commonality among these tasks, phonological sensitivity, phonological awareness (alphabet knowledge and elision) and morphological production, may be the ability to detect and process differences in sounds. However, overall phonological sensitivity was not related to reading ability in either the younger or older group of English-speaking children, a finding with implications for understanding the role of phonological awareness in reading.

The results for the Mandarin-speaking children are notably different. For young Mandarin-speaking children, general sound sensitivity was correlated with the three constructs of phonological processing, digit span (r=.42, p<.10), elision (r=.43, p<.05), and rapid naming (r=-.37, p<.05). In older Mandarin-speaking children, general sound sensitivity was significantly correlated with all measures except alphabet sound knowledge. The continued relationship between phonological sensitivity and the measures of phonological processing suggests a shared phonological component among the measures specific to processing sounds, but does not clarify what type of shared component. Furthermore, the relationship between general sound sensitivity and reading in the older children may suggest a change in the role of phonological sensitivity that is coincident with the advent of learning to read. Although I am not able to test the directionality of the relationship, the developmental shift may suggest that an increase in phonological sensitivity is a product of beginning to learn to read, although not a result of specific emergent training (e.g., training in pinyin), as the relationship between alphabet knowledge and phonological sensitivity is not significant, r=.19.

Thus, low-level phonological sensitivity is related to reading and reading-related skills differently depending on the language learned and the level of reading development (or grade). In order to clarify the nature of this difference, it is important to determine whether the relationship between phonological sensitivity and reading skills might depend on either the linguistic grain size measured or on the type of phonological information being processed. To test this, I examined the relationship between the specific conditions of the phonological sensitivity task (Same, Different, Rhyming, Alliterating and Native/Nonnative) and the measures of phonological processing, morphological production, and reading in the behavioral battery. In doing so, I was specifically interested in two types of patterns. First, did the type of contrast (Same, Different, Alliterating, Rhyming) required in the phonological sensitivity task affect the strength of the relationship with the measures in the behavioral battery? Second, did the familiarity of the words, whether native or non-native words, relate to reading and reading-related measures differently?

Table 2.8 Simple correlations of reading and reading-related measures with phonological sensitivity by condition for *English*-speaking children



	English					
	Letter Sound	Digit Span	Rapid Naming	Elision	Morph	Reading
Young (N=30)						
Native						
Same	.42*	.44*	-.24	.15	.11	.27
Different	.32	.30	.16	.26	.43*	.02
Alliterating	.42*	.28	.22	.28	.50**	.07
Rhyming	.45*	.16	.15	.23	.47*	.10
Non-Native						
Same	.42*	.38†	-.16	.15	.18	.23
Different	.32	.15	.15	.26	.48*	.15
Alliterating	.38†	.17	-.01	.32	.45*	.11
Rhyming	.22	.13	-.03	.18	.32	-.03
Old (N=39)						
Native						
Same	-.16	-.03	-.05	.11	-.02	-.14
Different	-.14	.17	-.01	.07	-.02	-.13
Alliterating	-.16	-.15	.23	.20	.10	-.07
Rhyming	-.07	-.04	-.01	.34*	.24	-.09
Non-Native						
Same	-.06	.15	-.20	.33	.21	.17
Different	.02	.20	-.03	.26	.25	.13
Alliterating	.07	-.01	.17	.18	.19	-.08
Rhyming	-.11	-.08	.11	.35*	.21	-.15

†p<.10, *p<.05, **p<.01, ***p<.001

In Table 2.8 and 2.9, simple correlations for the conditions of the phonological sensitivity task with the reading and reading-related measures are shown divided by grade level. For younger English speakers, there was no clear pattern in the correlations between alphabet sound knowledge and the conditions of the phonological sensitivity task. In contrast, the morphological production task correlated only with conditions in the sensitivity task that involved comparisons of different phonological information (Different, Alliterating, or Rhyming). In older English-speaking children, this relationship was reduced even further, such that the only significant correlation that remained was between the Rhyming conditions and elision. Thus, for the morphological and phonological measures, the relationship with phonological sensitivity appeared to be related to the conditions in the phonological sensitivity task where there were differences in the amount of overlapping phonological information, but not differences in the familiarity of the information (i.e., native or non-native word pairs), or in the position of the overlapping information (i.e., relating just to pairs with differences in the onset or just to pairs with differences in the rime position).

In English-speaking children, there appeared to be a shared component among measures of low- and higher-level phonological awareness and morphological construction that was specific to the detection of differences in phonological information. This shared component appeared unrelated to the linguistic level of analysis because it was correlated with both syllable level manipulations in the younger children (i.e., morphological construction) and phoneme-level awareness (i.e., the second part of the elision task, $r=.32$, $p<.05$) in the older children. It also appeared unrelated to the level of processing, as the relationship bridged epilinguistic sensitivity and metalinguistic awareness. And, lastly, the relationship appeared unrelated to the type of language contrast. There was no difference in the correlations between the native and non-native word pairs in the phonological sensitivity task with the higher metalinguistic skills (i.e., phonological awareness and morphological construction). Thus, the 'shared component' was unrelated (i) to the specific linguistic unit of analysis, (ii) to the level of processing (whether an epilinguistic or metalinguistic skill; Stuart, 2005), and (iii) to the type of language contrast (native or nonnative). However, it is important to emphasize that this 'shared component' did *not* relate to reading ability. Phonological sensitivity when measured as an overall mean accuracy, or when divided by condition, demonstrated no relationship with reading in the emergent or decoding English-speaking children.

In comparison, for Mandarin-speaking children the relationship between reading and reading-related measures and low-level phonological sensitivity did not appear to differ depending on the condition of the sensitivity task. For younger Mandarin speakers, there was no obvious pattern in the way the conditions of the phonological sensitivity task correlated with digit span, rapid naming, or elision. In older Mandarin speakers, nearly all conditions of the phonological sensitivity task correlated with the measures of the behavioral battery, particularly for digit span and reading. Thus, the degree of phonological overlap (full overlap in the Same pairs, partial in the Alliterating and Rhyming pairs), the position of overlap (in word initial or final position), and the familiarity of the phonological information (native or nonnative) had no effect on the relationship between low-level sensitivity and reading and reading-related measures in the Mandarin-speaking children.

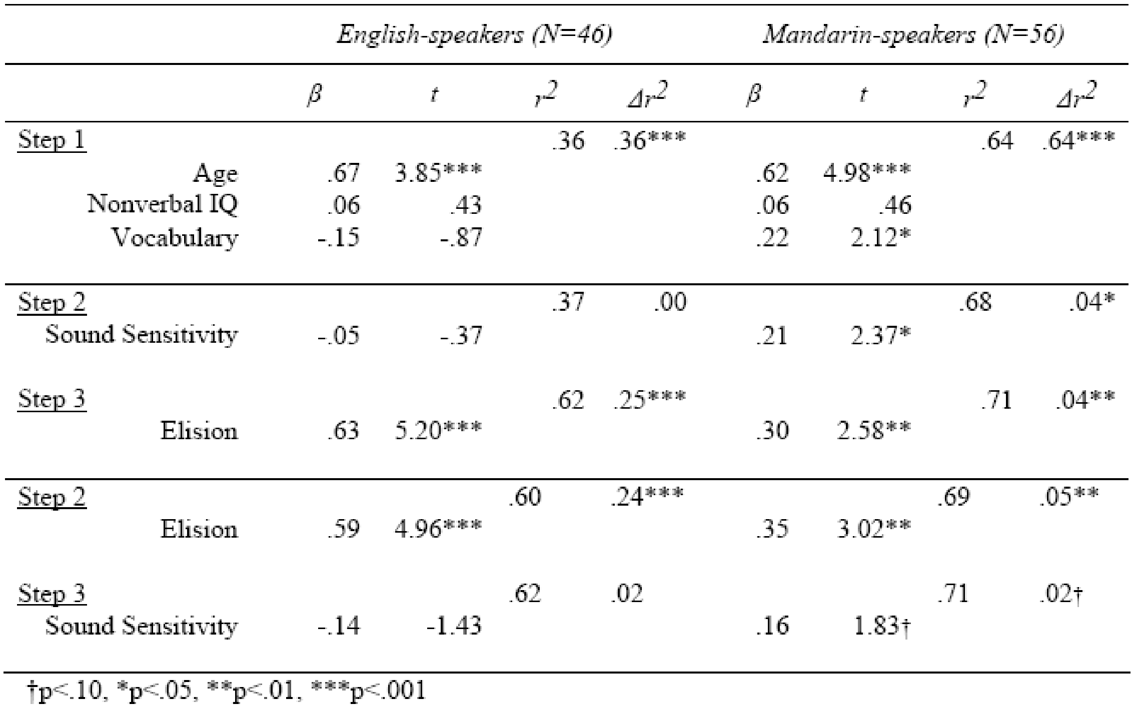
These results validate the interpretation that in Mandarin speakers, general sound sensitivity is related to reading and reading-related measures, whereas in English-speaking children, specific sensitivity to differences in sounds is related to metalinguistic awareness but not to reading ability. However, the relationship between phonological sensitivity and reading was only demonstrated in older Mandarin-speaking children, children who had begun receiving formal reading instruction. Thus, these results suggest that the influence of phonological sensitivity on emergent reading skills depends on the language being learned and on the level of reading development (or grade level). Next, I examined the nature of the relationship between phonological sensitivity, awareness, and reading using stepwise linear regressions.

Table 2.9 Simple correlations of reading and reading-related measures with phonological sensitivity by condition for *Mandarin*-speaking children

	Mandarin					
	Letter Sound	Digit Span	Rapid Naming	Elision	Morph	Reading
Young (N=30)						
Native						
Same	.18	.23	-.21	.34†	.18	.14
Different	.16	.14	-.21	.39*	-.11	.21
Alliterating	.18	.44*	-.46**	.43*	.18	.31
Rhyming	.31†	.59***	-.18	.17	.23	.08
Non-Native						
Same	.14	.27	-.43*	.31†	.29	.26
Different	.14	.39*	-.39*	.43*	.01	.22
Alliterating	.25	.30	-.35†	.34†	.03	.37†
Rhyming	.08	.21	-.13	.26	-.09	.03
Old (N=41)						
Native						
Same	.24	.42**	-.27	.42**	.31*	.42**
Different	.07	.35*	-.31*	.11	.26†	.37*
Alliterating	.21	.45**	-.26†	.21	.38**	.44**
Rhyming	.13	.37*	-.33*	.25	.26†	.41**
Non-Native						
Same	.21	.36*	-.27†	.32*	.22	.42**
Different	.10	.42**	-.27†	.26†	.31*	.42**
Alliterating	.18	.37*	-.19	.34*	.33*	.35*
Rhyming	.21	.50***	-.23	.41**	.35*	.32†

†p<.10, *p<.05, **p<.01, ***p<.001

Table 2.10 Stepwise regression comparing the relationship of phonological sensitivity to phonological awareness in predicting single-word reading in children



	English-speakers (N=46)				*Mandarin-speakers (N=56)*			
	β	*t*	r^2	Δr^2	*β*	*t*	r^2	Δr^2
Step 1			.36	.36***			.64	.64***
Age	.67	3.85***			.62	4.98***		
Nonverbal IQ	.06	.43			.06	.46		
Vocabulary	-.15	-.87			.22	2.12*		
Step 2			.37	.00			.68	.04*
Sound Sensitivity	-.05	-.37			.21	2.37*		
Step 3			.62	.25***			.71	.04**
Elision	.63	5.20***			.30	2.58**		
Step 2			.60	.24***			.69	.05**
Elision	.59	4.96***			.35	3.02**		
Step 3			.62	.02			.71	.02†
Sound Sensitivity	-.14	-1.43			.16	1.83†		

†p<.10, *p<.05, **p<.01, ***p<.001

Existing research is not clear about the role phonological sensitivity may play in predicting reading in languages other than English (e.g., Chiappe et al., 2007; McBride-Chang & Ho, 2000). Research on English speakers demonstrates that the relationship between phonological sensitivity and reading is indirect, and is mediated by higher-order measures of phonological awareness (e.g., McBride-Chang, 1996). However, there is limited, but suggestive research that suggests that low-level sensitivity may be a more important predictor in nonalphabetic orthographies (e.g., Chiappe et al., 2007). In order to test whether phonological sensitivity and phonological awareness are dissociable constructs in the current sample of English and Mandarin speakers, I conducted a stepwise regression where I alternated the order of entry of phonological sensitivity and phonological awareness in order to test the unique contribution of each to reading ability.

In Table 2.10, the results show that after controlling for age, nonverbal IQ, and vocabulary, general phonological sensitivity was a significant predictor that explained an additional 4% of the variance in single-character reading for the Mandarin-speaking children, but did not improve the fit of the reading model for English-speaking children.

When elision was entered after phonological sensitivity, it continued to be a unique and significant predictor of individual differences in reading in both English and Mandarin speakers. However, when these steps were switched and general phonological sensitivity was entered in the final step after phonological awareness, it continued to be related to single-character reading for Mandarin speakers (β=.16, p<.10) explaining an additional 2% variance in reading ability, and was unrelated to reading for English-speaking children.

These results echo findings from a recent year-long study of native and non-native English-speaking children which showed that low-level phonological sensitivity in the non-native sample (comprised entirely of native Korean-speaking children) explained nearly 45% of the variance in reading growth, compared to only 8.4% in the native English-speaking group (Chiappe et al., 2007). Although not as dramatic this, the current results do provide support for the proposal that phonological sensitivity may be a dissociable and distinct construct of phonological processing that predicts reading in different orthographies, particularly character-based orthographies. However, the current study further suggests that the importance of this variable for predicting reading may only develop in tandem with formal reading instruction, a point to which I return later in this chapter.

What is the role of phonological awareness in predicting reading in English- and Mandarin-speaking children?

Next, I explore the role of phonological awareness in predicting reading ability and how this may depend on the language learned and the level of reading skill. In a fixed regression with all reading-related variables included, phonological awareness was the only significant predictor of reading ability in both English and Mandarin speakers, β=.49, p<.01 and β=.30, p<.05 respectively. As highlighted in Chapter 1, the importance of phonological awareness for predicting reading in English speakers is uncontested (e.g., Castle & Coltheart, 2004); however, the precise nature of the relationship between phonological awareness and reading (namely does it depend on the linguistic grain size; e.g., Ziegler & Goswami, 2005, 2006) is still under debate (e.g., see Bryant, 2002 vs. Hulme, 2002). Furthermore, the importance of phonological awareness for Chinese readers is unclear and has recently come under question (e.g., McBride-

Chang, Cho et al., 2005). Comparing the role of phonological awareness in English and Chinese emergent readers will provide insight into the specific nature of the relationship between phonological awareness and reading. In the next section, a series of analyses was conducted that were designed to (i) explore the contribution of phonological awareness relative to other important predictors of Chinese reading (i.e., morphological awareness and rapid naming), (ii) examine the relationships between phonological awareness, knowledge of pinyin/alphabet sounds, and reading ability, and (iii) identify specific features of phonological awareness (i.e., the type of deletions required, whether syllable or phoneme, and the position of the deletions required, initial, medial, or final) that predict reading in English and Mandarin speakers.

For the first set of analyses, two stepwise regressions were performed, one comparing the relative contributions of morphological production and phonological awareness to predicting reading ability (shown in Table 2.11) and the other comparing the relative contributions of rapid naming and phonological awareness to predicting reading ability (shown in Table 2.12). In both models, I alternated the entry of the two target variables in order to measure the unique contribution of each after controlling for the other.

Table 2.11 Stepwise regression comparing the relationship of morphological production to phonological awareness in predicting single-word reading in children

	English-speakers (N=46)				*Mandarin-speakers (N=56)*			
	β	*t*	r^2	Δr^2	*β*	*t*	r^2	Δr^2
<u>Step 1</u>			.43	.43			.68	.68
Age	.44	2.31*			.43	3.36***		
Vocabulary	-.06	-.38			.24	2.58**		
Rapid Naming	-.33	-2.32*			-.29	-2.40*		
<u>Step 2</u>			.49	.06*			.68	0
Morphological Production	.26	2.15*			.10	.99		
<u>Step 3</u>			.61	.12***			.72	.04*
Phonological Awareness	.51	3.54***			.29	2.52*		
<u>Step 2</u>			.61	.18***			.72	.04**
Phonological Awareness	.53	4.34***			.31	2.71**		
<u>Step 3</u>			.61	0			.72	0
Morphological Production	.03	.20			.05	.48		

†p<.10, *p<.05, **p<.01, ***p<.001

As shown in Table 2.11, after controlling for age, vocabulary, and rapid naming, morphological production was significantly related to reading ability for English-speaking children, β=.26, p<.05, but not for Mandarin speakers, β=.10. When phonological awareness was entered in the third step, it was uniquely predictive of reading for both English and Mandarin speakers, β=.51, p<.001 and β=.29, p<.05, respectively. However, when morphological production was entered in the last step, it did not explain any additional variance in reading ability in either English or Mandarin speakers. These findings replicate the research for English-speaking children but not for Mandarin speakers.

In English speakers, morphological and phonological factors are highly correlated (Carlisle, 1995) and it is expected that morphology will play a small (if any) role in reading (Fowler & Liberman, 1995). In particular, morphological compounding is not as common in English as in Mandarin Chinese (e.g., Packard, 2000), and the combinatorial principles of morphology are not as transparent and thus not as productive in English as in Chinese (McBride-Chang, Shu et al., 2006). For example, in English, knowing the word *under* can help learn the meaning of the word *underwater* and *underdeveloped*, but provides little insight into more opaque words such as *understand*. And, the inverse is often true as well. Knowing the word *know* does not help one pronounce the word *knowledgeable* (McBride-Chang, Shu et al., 2006). In contrast, there are several reasons why morphological awareness should be important in reading for Mandarin speakers. First, most words are compound words, and the phonological transparency of these words is high (although the semantic transparency is not as high) (e.g., McBride-Chang, Tardif, et al., submitted). Furthermore, in Mandarin Chinese, inflectional and derivational morphemes are added directly to the root morpheme in an agglutinative process that highlights the combinatorial power of individual morphemes. Lastly, in Mandarin Chinese, the characters map directly to the morpheme as compared to English where this mapping occurs at the phoneme. Thus, there are strong structural arguments for a more important role of morphological awareness in learning to read in Chinese than in English.

However, for Mandarin-speaking children in the current study, morphological ability is not related to reading ability beyond measures of vocabulary, rapid naming, and phonological awareness. These findings contradict recent research highlighting the importance of morphological skills in predicting unique variance in Chinese reading (e.g., McBride-Chang, et al., 2003; McBride-Chang, Cho, et al., 2005; Shu et al., submitted). One possible explanation for the discrepancy between the current results and those in the recent literature may be due to specific features of the design, a point to which I return below.

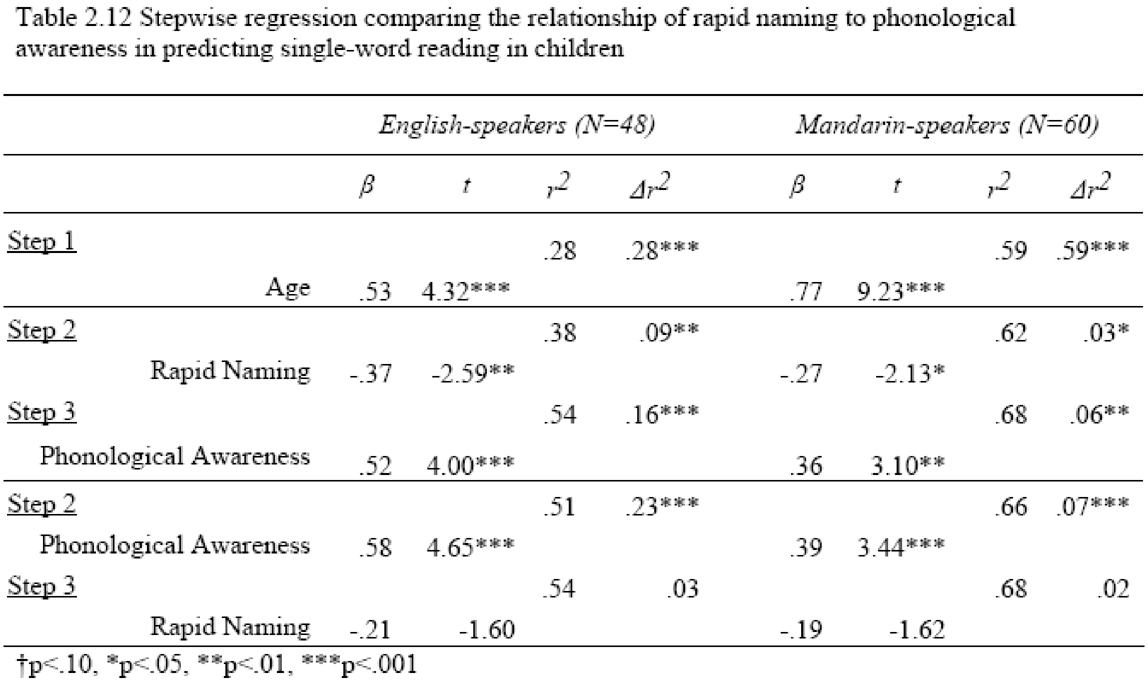


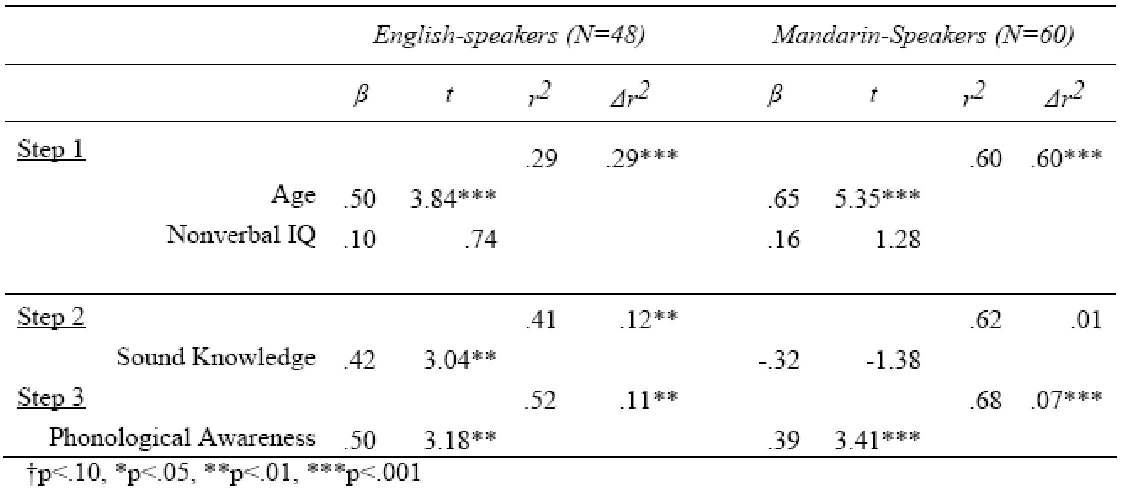
Table 2.12 Stepwise regression comparing the relationship of rapid naming to phonological awareness in predicting single-word reading in children

	English-speakers (N=48)				*Mandarin-speakers (N=60)*			
	β	t	r^2	Δr^2	β	t	r^2	Δr^2
Step 1			.28	.28***			.59	.59***
Age	.53	4.32***			.77	9.23***		
Step 2			.38	.09**			.62	.03*
Rapid Naming	-.37	-2.59**			-.27	-2.13*		
Step 3			.54	.16***			.68	.06**
Phonological Awareness	.52	4.00***			.36	3.10**		
Step 2			.51	.23***			.66	.07***
Phonological Awareness	.58	4.65***			.39	3.44***		
Step 3			.54	.03			.68	.02
Rapid Naming	-.21	-1.60			-.19	-1.62		

†p<.10, *p<.05, **p<.01, ***p<.001

Recent research has also identified rapid naming as a particularly important predictor of reading ability (Hu & Catts, 1998) and more often reading disability (Ho, Chan, Tsang, & Lee, 2004) in Chinese children. As shown in Table 2.12, when rapid naming is entered in the regression after controlling for age, it is uniquely predictive of reading ability for both English, β=-.37, *p*<.01, and Mandarin speakers, β=-.27, *p*<.05. However, when rapid naming is entered in the last step of the regression after phonological awareness, it is no longer predictive of reading ability in either sample. These findings replicate the research for English speakers (e.g., Torgesen et al., 1997; Wagner et al., 1997), but demonstrate that in this sample of Mandarin-speaking children, phonological awareness was a stronger predictor of reading ability than rapid naming unlike in some of the existing research on Chinese children (e.g., Ho, 2005).

Table 2.13 Stepwise regression comparing the relationship of alphabet knowledge to phonological awareness in predicting single-word reading in children



	English-speakers (N=48)				*Mandarin-Speakers (N=60)*			
	β	*t*	r^2	Δr^2	*β*	*t*	r^2	Δr^2
<u>Step 1</u>			.29	.29***			.60	.60***
Age	.50	3.84***			.65	5.35***		
Nonverbal IQ	.10	.74			.16	1.28		
<u>Step 2</u>			.41	.12**			.62	.01
Sound Knowledge	.42	3.04**			-.32	-1.38		
<u>Step 3</u>			.52	.11**			.68	.07***
Phonological Awareness	.50	3.18**			.39	3.41***		

†p<.10, *p<.05, **p<.01, ***p<.001

One reason for the importance of phonological awareness in the current sample of Chinese children may be due to familiarity with pinyin. Mandarin-speaking children in the older group had learned pinyin and thus, the importance of phonological awareness for predicting reading in the Chinese children may be explained in part by this newly acquired skill. In order to test whether knowledge of pinyin mediated the relationship between phonological awareness and reading for Mandarin speakers, I used a stepwise regression with reading as the dependent variable, and entered the measure of letter sound knowledge in step 2 and elision in step 3 (shown in Table 2.13). In step 2, letter sound knowledge did not explain any additional variance in Mandarin speakers, β=-.32, but was significantly related to reading in English speaker, β=.42, *p*<.01. In step 3, elision explained significant variance in both samples (11% for English speakers and 7% for Mandarin speakers). Thus, in the current study, elision was uniquely predictive of reading ability in Chinese children even after controlling for knowledge of pinyin, a skill which was thoroughly (and surprisingly, e.g., see Huang & Hanley, 1997) unrelated to reading ability.

Another reason for the potency of phonological awareness in predicting reading in our sample of Mandarin speakers may be due to the specific measure of phonological awareness that we created. Prior research has argued that tasks requiring phoneme-level elision (particularly final and medial deletions) are not important for Chinese readers because (i) they don't predict reading (e.g., Siok & Fletcher, 2001), (ii) Chinese readers tend to perform remarkably poorly on them (Read et al., 1986), and (iii) they are not 'sensible' given the structural properties of the sound-symbol mappings of Chinese (McBride-Chang et al., 2004). In fact, the majority of cross-cultural research has either used measures of phonological awareness that differ for English and Mandarin speakers (McBride-Chang, Bialystok et al., 2004; McBride-Chang, Cho et al., 2005) or used only tasks that measure syllable (e.g., Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005) and onset (initial phoneme) deletions (e.g., McBride-Chang, Bialystok, et al. 2004; Read et al., 1986).

In the current study, we attempted to create closely related forms of the elision task for both the English and Chinese version of the test by including the same type of deletions, initial, medial, and final (although there were slight differences in the total number of types for each version). More importantly, we also tried to use deletions of the same level of difficulty, particularly for the medial deletions. In Chinese, medial deletions can only be created by deleting a phoneme (i.e., 请说踹(chuai4)/ tş^{hw} ai/, 但不说出 a.= *chui4*)[23] from a diphthong or triphthong, or a phoneme (i.e., 请说暖(nuan3) /n^{w}an/, 但不说出 a. = *nun3*) or glide (i.e., 请说春(chun1)/tş^{hw}ən/, 但不说出 u.= *chen1*) from a glide-vowel combination because of the structural constraints of the language.

These types of deletions are particularly challenging and so care was taken in the modification of the elision task to include deletions of this type in the English version as well. Thus, for the English version I have coded for two different types of medial phoneme deletions (shown in Table 2.14). The first type includes easier deletions, where a medial phoneme is removed typically at a syllable boundary (i.e., say faster /fæstɜː /without saying /s/ = /*fætɜː*/) or in the interior portion of an onset cluster (say snail /sneɪl / without saying /n/ =/ *seɪl/*) or a final cluster (say silk /sɪlk/ without saying /l/ = /sɪk/). The second type includes more difficult deletions of interior cluster deletions, where a glide is removed (quarrel /kwɔːrəl/without saying /w/ = /kɔːrəl/) or an affricate is split (say box /bɒks/ without saying /k/ = / bɒs/).

Table 2.14 shows the performance for each type of deletion reported as a raw score and as a percentage for the older and younger groups of English and Mandarin

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[23] For the target word in this item the pinyin is reported in parentheses, the IPA in backslash marks and the correct answer in pinyin and italics after the equal's sign.

speakers. In order to compare performance across English and Mandarin speakers, I first performed a simple ANOVA using the percent correct for each level of the elision task. These results show that younger English and Mandarin speakers performed differently on all three types of phoneme deletions, and older English and Mandarin speakers performed differently on initial and medial deletions, but not final deletions. In contrast, for syllable deletions, younger and older English- and Mandarin performed differently only on the medial deletions, *F(1,*59)=-4.77, *p*<.05 and *F(1,*79)=13.27, *p*<.001 respectively. In order to explore these differences more fully, I examined the role of the position of the deletion (initial, medial[24], or final) and the level of deletion (syllable or phoneme) together with location of testing (Michigan or Beijing) and age group (younger or older) in an omnibus repeated measures ANOVA using percent accurate. However, this resulted in a significant 4-way interaction, *F*(2, 262)=10.13, *p*<.001 and made interpretations particularly complex. Thus, I simplified the repeated measures ANOVA to examine differences within the younger and older groups separately.

For the younger children, there was a significant effect of level (syllable or phoneme), *F*(1, 55)=113.63, *p*<.001 for both groups of speakers. Overall, syllables were easier to process than phonemes, a finding with support in both the literature on English and Chinese readers (e.g., Siok & Fletcher, 2001; Wagner & Torgesen, 1987). Furthermore, there was a significant effect of position (initial, final, or medial) for both groups of speakers, *F*(2, 110)= 126.12, *p*<.001, with medial deletions proving to be significantly harder than initial and final deletions, post-hoc Bonferroni-adjusted means, *p*s<.001. In addition, younger Mandarin-speaking children performed at floor on the phoneme elision task, and thus there was a significant interaction between level and language, F(1, 55)=3.94, *p*<.05. There was also a significant interaction between position and language, F(2, 110) = 11.75*, p*<.001, but this was most likely due to the poor performance on phonemes by the Mandarin.

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[24] Using the more difficult medial deletions (medial2), the common type of medial deletion task across languages.

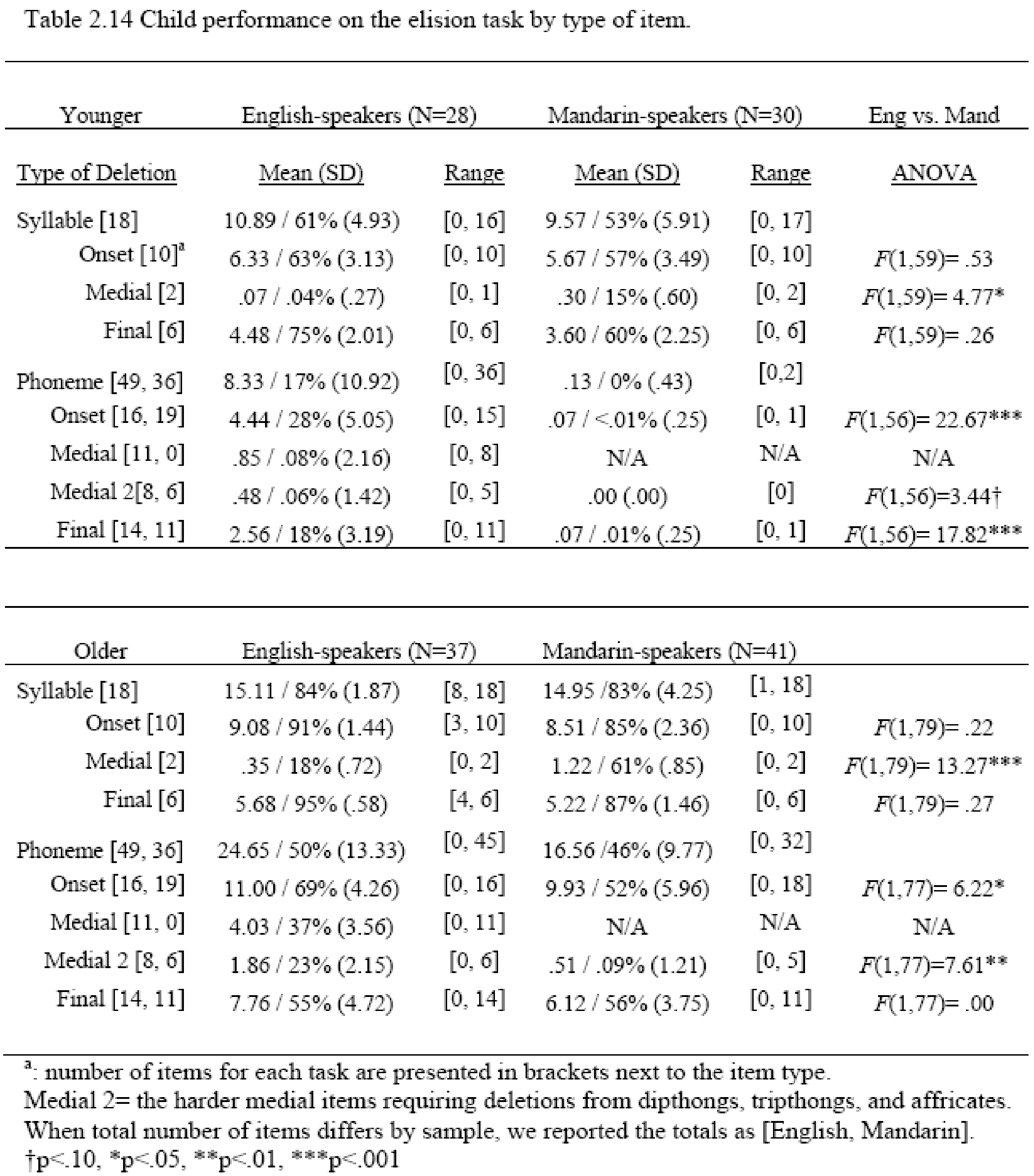


Table 2.14 Child performance on the elision task by type of item.

Younger	English-speakers (N=28)		Mandarin-speakers (N=30)		Eng vs. Mand
Type of Deletion	Mean (SD)	Range	Mean (SD)	Range	ANOVA
Syllable [18]	10.89 / 61% (4.93)	[0, 16]	9.57 / 53% (5.91)	[0, 17]	
Onset [10][a]	6.33 / 63% (3.13)	[0, 10]	5.67 / 57% (3.49)	[0, 10]	*F*(1,59)= .53
Medial [2]	.07 / .04% (.27)	[0, 1]	.30 / 15% (.60)	[0, 2]	*F*(1,59)= 4.77*
Final [6]	4.48 / 75% (2.01)	[0, 6]	3.60 / 60% (2.25)	[0, 6]	*F*(1,59)= .26
Phoneme [49, 36]	8.33 / 17% (10.92)	[0, 36]	.13 / 0% (.43)	[0,2]	
Onset [16, 19]	4.44 / 28% (5.05)	[0, 15]	.07 / <.01% (.25)	[0, 1]	*F*(1,56)= 22.67***
Medial [11, 0]	.85 / .08% (2.16)	[0, 8]	N/A	N/A	N/A
Medial 2[8, 6]	.48 / .06% (1.42)	[0, 5]	.00 (.00)	[0]	*F*(1,56)=3.44†
Final [14, 11]	2.56 / 18% (3.19)	[0, 11]	.07 / .01% (.25)	[0, 1]	*F*(1,56)= 17.82***

Older	English-speakers (N=37)		Mandarin-speakers (N=41)		
Syllable [18]	15.11 / 84% (1.87)	[8, 18]	14.95 /83% (4.25)	[1, 18]	
Onset [10]	9.08 / 91% (1.44)	[3, 10]	8.51 / 85% (2.36)	[0, 10]	*F*(1,79)= .22
Medial [2]	.35 / 18% (.72)	[0, 2]	1.22 / 61% (.85)	[0, 2]	*F*(1,79)= 13.27***
Final [6]	5.68 / 95% (.58)	[4, 6]	5.22 / 87% (1.46)	[0, 6]	*F*(1,79)= .27
Phoneme [49, 36]	24.65 / 50% (13.33)	[0, 45]	16.56 /46% (9.77)	[0, 32]	
Onset [16, 19]	11.00 / 69% (4.26)	[0, 16]	9.93 / 52% (5.96)	[0, 18]	*F*(1,77)= 6.22*
Medial [11, 0]	4.03 / 37% (3.56)	[0, 11]	N/A	N/A	N/A
Medial 2 [8, 6]	1.86 / 23% (2.15)	[0, 6]	.51 / .09% (1.21)	[0, 5]	*F*(1,77)=7.61**
Final [14, 11]	7.76 / 55% (4.72)	[0, 14]	6.12 / 56% (3.75)	[0, 11]	*F*(1,77)= .00

[a]: number of items for each task are presented in brackets next to the item type.
Medial 2= the harder medial items requiring deletions from dipthongs, tripthongs, and affricates.
When total number of items differs by sample, we reported the totals as [English, Mandarin].
†p<.10, *p<.05, **p<.01, ***p<.001

In the older children, there was no overall difference in performance on the elision task between the English and Mandarin speakers, *F*=.001. For both groups of speakers, there was a significant effect of level (syllable or phoneme), *F*(1, 76)=119.13, *p*<.001. Overall, syllables were easier to process than phonemes, *M*=72.68 and *M*=43.98, respectively, a finding identical to the results for the younger children. Furthermore, like for younger children, there was a significant effect of position (initial, final, or medial) for both groups of older children, *F*(2, 152)= 328.81, *p*<.001, with medial deletions being significantly harder than initial and final deletions, post-hoc Bonferroni-adjusted means, ps<.001.

However, there were also important differences between the performance of the two samples of older children. First, older Mandarin-speaking children performed significantly better on the syllable task than English-speaking children (M=77.70 and M=67.66, respectively), a finding that seemed to be located in a dramatic difference in performance on the medial syllable deletions. Furthermore, although there was no difference in overall performance on the phoneme task between the groups, there was a difference in the pattern of performance on phoneme elisions between English- and Mandarin-speaking older children. Mandarin speakers showed a significant effect of position only for the medial position, post-hoc Bonferroni-adjusted means, ps<.001, whereas English speakers showed a significant difference across all positions in the phoneme elision task, post-hoc Bonferroni-adjusted means, ps<.001.

In sum, there are clear commonalities in performance on the elision task across language and across developmental groups. Overall, children demonstrated an advantage in processing syllables compared to phonemes, a finding with support in both the literatures on reading in English and Chinese (e.g., Siok & Fletcher, 2001; Wagner & Torgesen, 1987) and had more difficulty processing medial deletions relative to initial or final deletions. Although medial deletions have been shown to be more difficult, there is also research that suggests that initial and final word position differ in their level of difficulty (Treiman et al., 1998), a finding not supported in the current study.

There are also interesting differences in the performance of English and Mandarin speakers that may suggest differences in the way each group processes phonological information. First, younger Mandarin-speaking children were at floor on the phoneme task, whereas younger English speakers were not. The cause of this difference is difficult to determine given the age, IQ, and vocabulary differences between the English and Mandarin speakers in the younger group. However, this is an interesting finding, in light of evidence for a bidirectional relationship between phonological awareness and reading in English speakers (e.g., Burgess & Lonigan, 1998) and suggestion that phoneme-level awareness can only develop with the onset of reading in alphabetic languages (e.g., Ziegler & Goswami, 2005). A second finding is a difference in the effect of position (initial, medial, or final) between the two language samples. Mandarin speakers performed similarly on the initial and final position items regardless of whether syllables or phonemes, whereas the older English children demonstrated this effect only for the syllable items. It is tempting to attribute this effect to task difficulty, i.e., the more difficult the task for a particular child, the most likely there will be a graded effect of position (medial harder than final, final harder than initial; as suggested by Treiman et al., 1998). However, this interpretation weakens given that Mandarin speakers performed worse than English speakers on nearly every type of elision item with the exception of syllable medial deletions.

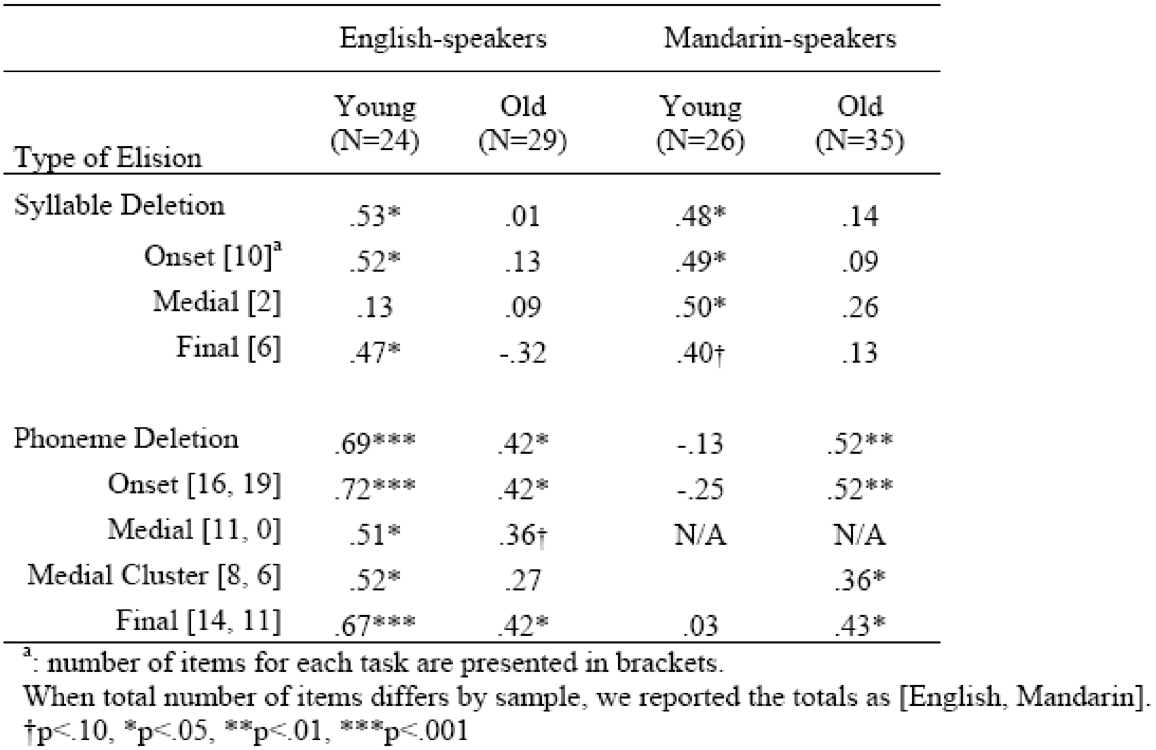
The next question I investigated was whether performance on the different types of elision items related to overall differences in the correlation between the item type and reading ability. Table 2.15 shows the correlations between single word/character reading and the type of deletion required in the elision task after controlling for vocabulary knowledge. Syllable deletions were significantly correlated with reading for both English- and Mandarin-speaking children in the young group (overall syllable correlation for younger English, r=.53, p<.05 and for younger Chinese, r=.48, p<.05), but not in the older group. Phoneme deletions were significantly correlated for younger and older English speaker, overall phoneme correlation r=.69, p<.001 and r=.42, p<.05, respectively. In contrast, young Mandarin speakers demonstrated no significant correlations for phoneme elision, a finding most likely due to floor performance. However, like the English-speaking children, older Mandarin speakers demonstrated strong correlations between all types of phoneme deletions and single-character reading (overall phoneme correlation, r=.52, p<.01).

These findings demonstrate several expected and unexpected outcomes. First, syllable awareness was related to reading only in the younger children, independent of language spoken. This result finds support in much of the research on English-speaking children (e.g., Wagner & Torgesen, 1987). However, there are important implications of these findings for explaining the results from studies in Chinese reading. The majority of research exploring phonological awareness in Chinese reading has used only tasks of syllable-level elision to measure phonological awareness, which may explain the lower levels of phonological awareness in this work compared to the current study as well as the increased importance of morphological awareness. One possible reason that phonological awareness was a stronger predictor of reading than morphological awareness or rapid naming in the current study may be due to the use of syllable and phoneme deletions in our phonological awareness task.

Second, it is interesting, and somewhat surprising that the correlation between phonological awareness and reading is weaker in the older English-speaking children compared to the younger English-speaking children . It has been argued that there is a strong bidirectional relationship between the development of phoneme-level awareness and reading ability in alphabetic languages, English in particular (Ehri & Wilce, 1980; Perfetti Beck, Bell, & Hughes, 1987; Burgess & Lonigan, 1998). And, although research has shown that phoneme level awareness can be demonstrated in prereaders (e.g., Lonigan et al., 2000) and that the relationship between phoneme-level awareness and reading is not time-locked precisely to the onset of reading instruction, rarely has research shown a decrease in the predictive power of phonological awareness as children begin formal reading instruction (e.g., Wagner et al, 1997; Torgesen et al., 1997). Although not a longitudinal design, the results from the current study for the younger and older English speakers are suggestive of an attenuation in predictive power and accordingly draw into question the use of a grade-level split and the associated assumption that the younger group were 'emergent' readers, and the older 'more fluent'. Furthermore, the lower predictivity of phonological awareness in the older English-speaking children relative to the younger children is to the inverse of the pattern observed for the Chinese readers, where there is no relationship in the younger children and a very strong relationship in the older children.

Overall, the item analysis confirms that older Mandarin-speaking children do have phoneme-level awareness, and that this awareness is significantly correlated with character recognition. However, one explanation for the importance of emerging phoneme-level awareness in this older population of Mandarin-speaking children may be the pinyin training that the older sample received a year earlier. In Table 2.16, partial correlations are reported for elision (by item type) and reading controlling for knowledge of letter sounds and vocabulary. It is striking that the relationship between the type of phoneme deletion and reading ability is barely affected by controlling for letter sound knowledge in the Mandarin-speaking children while the relationships for the English speakers are significantly attenuated (due to the high correlation in English speakers between the elision and alphabet sounds task, *p*<.001*)*. Clearly, the demonstrated phoneme-level sensitivity in the current Mandarin-speaking sample and the demonstrated relationship between this sensitivity and reading cannot be a product purely of knowledge of pinyin (as often argued, see Read et al., 1986).

Table 2.15 Partial correlations between type of elision item and child reading, controlling for vocabulary



	English-speakers		Mandarin-speakers	
Type of Elision	Young (N=24)	Old (N=29)	Young (N=26)	Old (N=35)
Syllable Deletion	.53*	.01	.48*	.14
Onset [10][a]	.52*	.13	.49*	.09
Medial [2]	.13	.09	.50*	.26
Final [6]	.47*	-.32	.40†	.13
Phoneme Deletion	.69***	.42*	-.13	.52**
Onset [16, 19]	.72***	.42*	-.25	.52**
Medial [11, 0]	.51*	.36†	N/A	N/A
Medial Cluster [8, 6]	.52*	.27		.36*
Final [14, 11]	.67***	.42*	.03	.43*

[a]: number of items for each task are presented in brackets.
When total number of items differs by sample, we reported the totals as [English, Mandarin].
†p<.10, *p<.05, **p<.01, ***p<.001

Thus, this item analysis of the phonological awareness task demonstrates that, (i) syllable-level deletions only are related to reading in younger emergent readers, but not older decoding readers, (ii) that phoneme-level awareness is present in older Mandarin speakers, and is related to reading in this sample as well, and that (iii) the phoneme-specific relationship in the older Mandarin speakers is not due to the influence of pinyin training. Chinese research has found a relationship between phonological awareness and reading, but a stronger relationship between morphological production and reading (e.g., McBride-Chang, Cho et al., 2005). The current results suggest that these findings are *not* due to the intrinsic properties of the language and its sound-symbol relations, but may be due to the limited way in which phonological awareness has been conceived of and measured in studies with Chinese children.

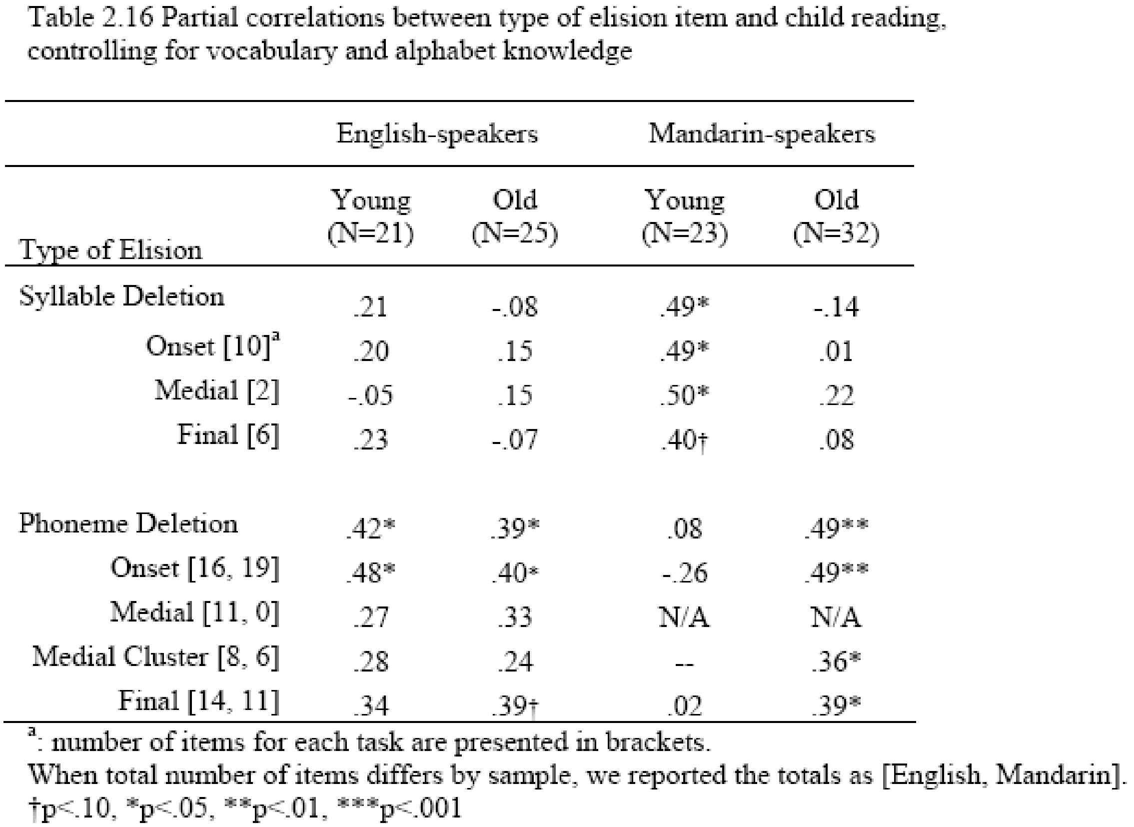


Table 2.16 Partial correlations between type of elision item and child reading, controlling for vocabulary and alphabet knowledge

	English-speakers		Mandarin-speakers	
Type of Elision	Young (N=21)	Old (N=25)	Young (N=23)	Old (N=32)
Syllable Deletion	.21	-.08	.49*	-.14
Onset [10][a]	.20	.15	.49*	.01
Medial [2]	-.05	.15	.50*	.22
Final [6]	.23	-.07	.40†	.08
Phoneme Deletion	.42*	.39*	.08	.49**
Onset [16, 19]	.48*	.40*	-.26	.49**
Medial [11, 0]	.27	.33	N/A	N/A
Medial Cluster [8, 6]	.28	.24	--	.36*
Final [14, 11]	.34	.39†	.02	.39*

[a]: number of items for each task are presented in brackets.
When total number of items differs by sample, we reported the totals as [English, Mandarin].
†p<.10, *p<.05, **p<.01, ***p<.001

In the current study, phonological awareness was the strongest predictor of reading for both Mandarin- and English-speaking emergent readers. In order to gain understanding of the nature of this relationship, I investigated three questions tailored to provide insight into the role of phonological awareness across language systems and across different levels of reading development. First, I explored whether the relationship between phonological awareness and reading ability was specific to the level of processing. Interestingly, phonological sensitivity predicted unique variance beyond measures of phonological awareness, however only in older Mandarin-speaking children. This suggests that low-level phonological sensitivity may be an important and dissociable construct from higher-level phonological awareness in nonalphabetic orthographies, but that the importance of this skill for predicting reading may depend on the age and reading level.

The second question I examined was whether the relationship between phonological sensitivity and reading was specific to an individual's language experience. The results demonstrated that for both English- and Mandarin speakers, the native/non-native condition made no difference to the relationship between low-level phonological sensitivity and reading, or reading-related skills. Although unrelated to reading, there was evidence that Mandarin speakers are able to process non-native contrasts better than English speakers, a finding that I suggest may be due to exposure differences or to underlying differences in spoken word processing (e.g., Chen & Shu, 2001).

The third question I examined was the way in which phonological awareness was related to reading ability across the two samples, first by comparing performance between phonological awareness and the other related reading tasks, and second, by comparing performance within the phonological awareness task. In the current study, neither morphological production or rapid naming improved the fit of the reading model for English- or Mandarin speakers beyond measures of phonological awareness. This is surprising, in light of recent research (e.g., McBride-Chang, Cho et al., 2005). However, I suggest that one reason for the potency of phonological awareness in the current study may be due to specific features of the task design, a suggestion with support from the within-task analysis.

We designed a phonological awareness test that measured both syllable- and phoneme-level skills. Although existing research has argued against using phoneme-level measures with Chinese readers (e.g., McBride-Chang, Cho, et al., 2005), the results from the current study suggest otherwise. First, older Mandarin-speaking children were able to perform phoneme-level deletions, and these deletions are strongly related with reading ability. Also, although there were differences in performance on the phonological awareness task between English and Mandarin speakers (i.e., younger Mandarin speakers perform at floor, and older Mandarin speakers demonstrate a different pattern in performance across the position of deletion, initial, medial or final), both syllable and phoneme level awareness was related to reading in English and Chinese.

Furthermore, the item-analysis revealed a potential confound in research exploring phonological awareness in Chinese readers. In the current study, syllable level awareness was related to reading ability in younger English- and Mandarin-speaking children, but not in older children. Much of the research on the predictors of reading in Chinese children has relied on syllable awareness tasks alone (Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005 although see McBride-Chang, Bialystok, et al., 2004). It is possible that the recent importance of morphological awareness relative to phonological awareness may be due to the poor predictive power of syllable awareness in older children, as demonstrated in the current study, and not implicit differences in the relative importance of these two skills. In sum, these analyses have identified several unique and interesting findings that provide insight into *which* phonological skills are related to reading with important implications for how phonological skills relate to reading.

Discussion

In the current study, I tested English- and Mandarin-speaking children on a battery of reading and reading-related measures with the goal of comparing reading models for the two groups using tasks that were either identical or that were carefully adapted for cross-cultural comparability. To date, most cross-cultural research comparing English and Chinese readers has used measures that are similar, but not identical (e.g., McBride-Chang, Cho et al., 2005; McBride-Chang, Shu, et al., 2003). The results from the current study suggest that it is in fact possible to devise identical or close-to-identical tasks that appear effective as measures of reading-related constructs in both cultures.

The reading-related tasks in the behavioral battery generally demonstrated good distributions and high reliability in both samples of children. This is particularly noteworthy in the test of elision. Existing English-Chinese comparative research has only tested syllable elision (Chow et al., 2005; McBride-Chang, Cho et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005; McBride-Chang & Kail, 2002) or onset-rime elision (McBride-Chang, Bialystok, et al., 2004; Read et al., 1986), and many researchers have argued for the inappropriateness of phoneme-level testing for Chinese participants (McBride-Chang, Shu et al., submitted; Read et al., 1986; Siok & Fletcher, 2001). Nonetheless, in the syllable and phoneme elision task that we administered, not only did both samples of children show good distributions and comparable reliabilities, but the older Mandarin-speaking children were able to perform phoneme-level deletions and this ability was related to reading.

The relationships among the reading-related measures also support the cross-cultural validity of the adaptations made. For all children except the younger Mandarin-speaking children, the measures of phonological processing were strongly intercorrelated, as has been found in existing research in English (e.g., Torgesen, et al., 1994) and in a few studies with Chinese children (McBride-Chang & Ho, 2005; Shu et al., submitted). Furthermore, the measure of morphological compounding demonstrated strong correlations with measures of phonological processing in younger and older children (but not the young Mandarin speakers), and was correlated with vocabulary in the older children, as seen in the literature (Carlisle, 1995; McBride-Chang, Cho et al., 2005; McBride-Chang, Shu et al., submitted). In addition, the amount of variance explained in reading ability was nearly comparable between the two samples, 75% for Mandarin-speaking children and nearly 65% for the English speaker. Not only do these numbers replicate and even surpass levels found in the research (Hu & Catts, 1998; Lonigan et al., 2000, So & Siegel, 1997; Shu et al., submitted), but they clearly demonstrate the efficacy of these measures in explaining individual differences in reading ability. Thus, the measures we modified (i) showed good distribution within groups, (ii) comparable performance levels between groups, and (iii) were equally successful at explaining variance in reading ability for both samples. These results suggest that it is in fact possible to devise effective measures of reading-related skills in English and Chinese children when controlling for cross-cultural comparability.

In the current study I compared reading models for children beginning to read in two different orthographies, English and Mandarin Chinese. In the analyses, I tested the relative contribution of four predictors of reading: phonological sensitivity, phonological awareness, morphological construction, and rapid naming, with particular attention to better understanding the role and contribution of phonological awareness in Mandarin-speaking children. Specifically, I tested the three questions outlined in the introduction. Namely, is the relationship between phonological awareness and reading specific to (i) level of processing, (ii) language experience, and (iii) linguistic grain size? Next, I report the results to these questions, and follow with a developmental and cross-cultural framing of these results.

Although I reported the results for both Mandarin- and English speakers, I was explicitly testing questions specific to the literature on the predictors of reading in Chinese children. Thus, in the next two sections I focus the interpretation on the results for the Mandarin-speaking children in order to highlight language-specific predictors of reading. However, the overarching goal of this study was to explore language and developmental differences in the underlying mechanisms of reading acquisition. Therefore, in the final two sections I discuss the results in terms of the overall importance and levels of phonological awareness predictive of reading in younger (emergent) and older (decoding) readers.

Level of Phonological Processing that Predicts Reading

Some research suggests that, although epilinguistic sensitivity has only an indirect relationship with reading in English speakers, that in other languages, particularly languages with character scripts, it may be a more important skill for predicting reading. However, previous research in nonalphabetic orthographies has rarely combined measures of sensitivity and awareness in the same study. Interestingly, however, there have been a wide-range of tasks used to measure phonological awareness in Mandarin speakers, ranging from more epilinguistic tasks requiring detection or discrimination (using paired comparisons or an oddball design; Chan & Siegel, 2001; Chen et al., 2004; Ho & Bryant, 1997; Hu & Catts, 1998; Siok & Fletcher, 2001; So & Siegel, 1997) to metalinguistic measures requiring sound manipulation (Chow et al., 2005; Hu & Catts, 1998; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005; Siok & Fletcher, 2001; Shu et al., submitted). Although there appears to be a relationship between reading and phonological knowledge in Chinese children regardless of the task demands, I propose that these differences in the level of processing may reveal meaningfully different relationships with reading when compared in the same study.

In the current study, I demonstrate a significant dissociation between the measure of phonological sensitivity and the measure of phonological awareness in predicting reading ability for Mandarin-speaking children, but not in English speakers. In English speakers, phonological sensitivity was related to other tasks requiring sound and syllable discrimination (letter sound knowledge, elision, and morphological compounding) but was unrelated to reading ability. I suggested that the shared variance among these measures may be due to a reliance on the ability to distinguish differences in sounds (even though morphological awareness requires morpheme-level awareness, there is still a phonological component to the task). Specifically, based on the structure of the phonological sensitivity task, what appeared to be the common component across these related measures was *not* specific to the level of processing (i.e., sensitivity and awareness were related) or the position of phonological overlap (i.e., Alliterating and Rhyming pairs were equally as related to phonological awareness and morphological production) or to type of phonological information (i.e., native and non-native word pairs did not show different patterns of correlation with phonological and morphological processing skills), but seemed specific only to the degree of phonological overlap (i.e., only Different, Alliterating, and Rhyming word pairs demonstrated this relationship).

Existing literature on English speakers supports this finding and shows that sensitivity does not predict emergent reading ability in children beyond measures of phonological awareness (McBride-Chang, 1996; McBride-Chang, 2004; Muter, Hulme, Snowling, & Stevenson, 2004; Scarborough, 1990, 1991). However, the current juxtaposition (of sensitivity to sound differences in the phonological sensitivity task compared to the ability to manipulate phonemes and morphemes in the other two tasks) underscores the fact that what *is* predictive of reading in English speakers is unrelated to discriminating differences in sounds.

For Mandarin speakers, all conditions of the phonological sensitivity task were highly related to measures of phonological processing, morphological compounding, and reading ability (only in the older children). Furthermore, in the stepwise regression, I found that after controlling for phonological awareness, phonological sensitivity was still marginally predictive of reading ability in the Mandarin-speaking children, but not English speakers. These results suggest that not only is epilinguistic sensitivity related to individual differences in reading ability in Chinese, but that this skill is a distinct, and meaningfully dissociable construction of phonological processing.

To date, only one study has measured both phonological sensitivity and awareness in Chinese children (using a speech discrimination task and a task of syllable deletion, e.g., Ho & Bryant, 2000). This study found that the relationship between phonological sensitivity and reading was mediated by the measure of syllable awareness. In contrast, a recent year-long study of predictors of reading in two small samples of native and non-native English-speaking first graders found that both phonological sensitivity and higher-order measures of phonological awareness predicted unique variance in reading ability in both groups at the end of the year (Chiappe et al., 2007). However, phonological sensitivity in the non-native sample (comprised entirely of native Korean-speaking children) explained nearly 45% of the variance in reading growth, compared to only 8.4% in the native English-speaking group (Chiappe et al., 2007). The current findings offer further support that depending on language learned, phonological sensitivity may serve as an important construct of phonological processing that is distinct from phonological awareness. However, further research is needed to understand *why* general sound sensitivity may be more important for reading in languages other than English.

There is a theoretical divide as to whether individual differences in reading in English speakers stem from differences in the degree of specification of an individual's phonological representations (e.g., Fowler, 1991; Metsala, et al., 2003; Elbro et al., 1998). In the introduction, I proposed that an important test of the phonological representation hypothesis (e.g., Walley, 1993) is to examine whether the relationship between phonological awareness and reading is specific to processing of familiar compared to unfamiliar (or nonnative) phonological information. This test should, in theory, also have provided insight into why phonological sensitivity is a unique predictor of reading in the current Mandarin-speaking sample.

Analysis of the conditions of the phonological sensitivity task revealed that processing of native versus non-native word pairs did not show any difference in correlation with reading or reading-related variables. This suggests strong evidence against the phonological representation hypothesis. Namely, the relationship between phonological processing and reading does not appear specific to one's existing phonological representations. However, there were several issues in the task design that limit the interpretability of this finding.

The current design did not provide a direct test of the phonological representation hypothesis for two reasons. First, I did not explore the impact of language-experience in metalinguistic phonological awareness. Thus, conclusions can only be drawn for the relationship of epilinguistic sensitivity and reading, a relationship that is predictably absent in the English speakers (e.g., McBride-Chang, 1996). Furthermore, in the phonological sensitivity task, we created native and non-native word pairs that shared similar phonological information, but differed in lexicality, (i.e., native words were familiar words in the child's lexicon and non-native were unfamiliar words). Thus, in fact, we measured an effect of lexicality, as opposed to an effect of language-experience.

A stronger test of the question of whether language-experience is important in phonological processing (and a direct test of the phonological representations hypothesis) would be to create words pairs from phonological information familiar to one language, but not familiar to another. The current contrast between Mandarin and English affords the perfect opportunity to do this. For example, the English word /vɛrɪ/ is composed of phonemes and phonological combinations that are not used in Mandarin. The word /tʂu/ begins with a phoneme combination that is unfamiliar in the word initial position. It would be interesting to extend the current findings by exploring the role of native and non-native word pairs composed word pairs with words like this as a window into the role of phonological representation in predicting differences in reading ability.

The Role of Phonological Awareness in Predicting Chinese Reading Development

In the current sample, phonological awareness (elision) was the strongest predictor of reading ability for English- and Mandarin-speaking children, $\beta=.49$, $p<.01$ and $\beta=.30$, $p<.05$, respectively. Although this finding is strongly aligned with nearly all existing research on English speakers, the results for the Mandarin speakers were unexpected. Thus, a series of analyses were performed with the intention of unpacking the relationship between phonological awareness and reading ability, first by exploring the relationship between phonological awareness, reading, and two other predictors identified as important in the reading research, rapid naming and morphological construction, and second by examining the specific features of the phonological awareness task itself.

In the first set of analyses, a series of stepwise regressions compared the relative contribution of phonological awareness, morphological construction, and rapid naming in predicting unique variance in reading ability. These analyses revealed that in both English- and Mandarin-speaking children, rapid naming and morphological production contributed no additional variance to reading after controlling for phonological awareness. Although at first glance these findings seem surprising in light of the most recent research findings for Chinese children (e.g., McBride, Cho et al., 2005; McBride, Shu et al., 2003; Shu et al., submitted), when considered against the backdrop of all the research on the components of Chinese reading from the last decade, these results are better aligned.

First of all, rapid naming has been found to be more strongly related to reading disability (e.g., Ho & Lai, 2000; Ho, Chan, Tsang, & Lee, 2002; Penney, et al., 2005) than to reading ability (e.g., Chow et al., 2005; McBride-Chang & Ho, 2005, although see Shu et al., submitted). In Chinese, existing studies that demonstrate a unique contribution of rapid naming, often show attenuation of this skill when controlling for other predictors Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Kail, 2002) and when examined longitudinally (McBride-Chang, & Burgess, 2005; McBride-Chang & Ho, 2005). Thus, the lack of support for a unique role of rapid naming in the current sample matches existing research.

Secondly, the finding that morphological construction was not a significant predictor of reading ability in Mandarin-speaking children fits existing research better than expected. Recent research has argued for the primacy of this measure (morphological compounding) in predicting reading above measures of phonological awareness in similarly-aged Cantonese-speaking and Mandarin-speaking children (e.g., McBride-Chang, Cho et al., 2005). However, to date, there are only five studies that include measures of both phonological and morphological knowledge (McBride-Chang, Cho et al., 2005; McBride-Chang, Shu, et al., 2003; Shu et al., 2006; Shu et al., submitted). In these studies, although morphological awareness demonstrates a unique relationship with reading after controlling for phonological awareness (a finding that in itself is important), the actual additional variance explained by morphological awareness varies significantly from 1.5% of the variance (McBride-Chang, Shu et al., submitted) to close to 10% (e.g., McBride-Chang, Shu, et al., 2003). Furthermore, in the current study, the variance explained by morphological knowledge may be low due to the additional measures included in my study that have not been used in prior research. In particular, the phoneme deletion items on the phonological awareness tasks showed a strong contribution to reading in older Mandarin-speaking children relative to the contribution of syllable awareness (the level of awareness typically measured in Chinese reading studies; e.g., McBride-Chang & Ho, 2005).

Third, the primacy of phonological awareness for predicting reading in the current study does in fact have substantial support in the existing research. Although there has a been a recent burgeoning of interest in morphological awareness, there has been a strong and steady demonstration of the importance of phonological awareness across nearly all the literature on Chinese emergent readers (e.g., McBride-Chang, Shu et al., 2003, submitted). However, these studies have also argued that the importance of phonological awareness depends on way it is measured (i.e., syllable level and onset-level deletions were predictive, where phoneme level deletions were not; e.g., Siok & Fletcher, 2001). Thus, what is surprising in the current study is not the potency of the phonological awareness predictor, but the relationship of phoneme-level awareness and reading.

Is the relationship between phonological awareness and reading specific to linguistic grain size?

It has long been argued that phoneme-level awareness is not only extremely difficult for individuals without some form of alphabetic training (e.g., Morais, Alegria, & Content, 1987; Read et al., 1986; Sholes, 2005), but completely unrelated to predicting reading in nonalphabetic orthographies (e.g., Siok & Fletcher, 2001; Shu et al., submitted; McBride-Chang, Cho, et al., 2005). In the current study, an item-analysis of the phonological awareness task revealed several important findings about the relationship between phoneme-level awareness and reading ability in Chinese. First, younger Mandarin-speaking children performed at floor on the phoneme items, and their performance was not related to levels of reading. In contrast, older Mandarin speakers performed similarly (although not identically) to older English-speaking children, and their performance was significantly correlated with reading, even after controlling for knowledge of pinyin. These findings suggest that phoneme-level awareness is an important and interesting construct in reading acquisition in Chinese that may develop only with the onset of reading instruction.

There was a second, embedded finding, a finding that suggests the cause behind the differences in reading models between the current sample, and those found in recent research (e.g., McBride-Chang, Shu et al., 2006). The item-analysis revealed that syllable level awareness was only related to reading in the younger emergent readers (ages 4-6 years) but not the older decoding readers in both samples. Because most research on Chinese reading has assumed that phoneme-level awareness is irrelevant (McBride-Chang, Cho et al., 2005), too difficult (e.g., Read et al., 1986), and/or unrelated to reading in Chinese children (e.g., Siok & Fletcher, 2001), the majority of Chinese reading research has used either syllable or onset-rime manipulations for a measure of phonological awareness (e.g., McBride-Chang & Ho, 2000, 2005). However, the current findings suggest that syllable level awareness is not a strong developmental correlate of reading in either English or Chinese orthographies, whereas phoneme-level awareness proved a strong developmental correlate of reading in both samples.

Because this was the first time that a relationship between true phoneme-level awareness (not just onset- deletions) and reading has been found even though there have been six studies that have measured some form of phoneme awareness in Chinese readers (including phoneme initial deletions, e.g., Read et al., 1986; Siok & Fletcher, 2001; Huang & Hanley, 1994; 1997; Leong et al., 2005; and Shu et al., submitted), interpretations must proceed with caution. Among these six studies, only two used a similar test of phoneme elision in children readers (Huang & Hanley, 1997; Shu et al., submitted) and only one (Shu et al., submitted) also included medial deletions. It is nontrivial that the Shu et al., (submitted) study did not find a significant relationship between measures of phoneme deletion and reading in a similarly aged-group of Mandarin-speaking children. However, the authors of this study do not break-down the comparisons by phoneme type nor provide information about children's performance across the phoneme types, so it is difficult to identify the source(s) of difference. Nonetheless, the discrepancy in results between the current study and that of Shu et al., (submitted) suggests a need for further research and caution in the current interpretations.

Considering the phoneme – reading relationship in Mandarin-readers more closely, it is important to explore several possible explanations. In chapter 1, I outlined a divide in the literature over whether the connection between phonological awareness and reading is specific to development or to language learned, or to both. Unfortunately, the current results do not provide unambiguous support to help adjudicate among these competing approaches.

It could be argued that because Mandarin speakers demonstrate phoneme-level awareness and this awareness is related to reading in a *nonalphabetic* orthography, that these results alone provide convincing evidence against a language-specific interpretation. However, there was an important developmental effect in the results that tempers this strong interpretation. Young Mandarin-speaking children performed at floor on the phoneme-level items whereas the younger English-speaking children demonstrated higher levels of phoneme-level awareness, and this awareness was strongly related to reading ability. It is possible that this language difference is due to differences between the samples that are unrelated to the question at hand (i.e., differences in nonverbal IQ or age). However, the similar performance on the syllable elision items between these two groups argues against this interpretation. Instead, this difference suggests possible support for a language-specific interpretation. Moreover, there is some evidence that the structural properties of Mandarin Chinese do facilitate phoneme-level awareness.

In Mandarin Chinese, the onset and final consonant in CVC structured words both correspond to a single phoneme. It is possible that this structure of the spoken language draws attention to the level of the phoneme in ways that affect phonological awareness (e.g., Seymour et al., 2003, although see Cheung et al., 2001). Furthermore, because there are only two possible phonemes in the consonant final position, awareness of these phonemes may precede and possibly scaffold awareness of phonemes in other positions. Durgunoglu's (2006) found that Turkish kindergartners demonstrated greater final phoneme awareness than English children due (according to the author) to the high degree of single-phoneme morphemic suffixes in Turkish (see also Durgunoglu & Oney, 1999). A similar argument could be made for the structural properties of Mandarin Chinese.

An alternative possibility specific to the structure of Mandarin Chinese is that the use of tone heightens phoneme-level awareness. Several studies have used tone discrimination as a measure of phonological awareness (Chan & Siegel, 2001; Li, Anderson, Nagy, & Zhang, 2002; So & Siegel, 1997) and have found significant relationships with reading ability. Moreover, in a few of these studies, children demonstrated a developmental trajectory in awareness from larger unit comparison to smaller unit comparisons (e.g., Ho & Bryant, 1997a, 1997b), similar to that found in English (e.g., Anthony & Lonigan, 2004). In Chinese, the ability to discriminate word pairs that differ in rime and tone precedes the ability to discriminate word pairs that differ in tone only (e.g., Ho & Bryant, 1997a) whereas in English awareness moves from the syllable to the phoneme (e.g., Lonigan & Burgess, 2002). Thus, tone awareness may facilitate phoneme-level awareness, and thus may mediate the connection between phoneme-level awareness and reading in the current study. However, this evidence does not explain *why* heightened phoneme awareness would be related to reading in a nonalphabetic script.

There is another important effect in the findings that further complicates the interpretation. The onset of phoneme-awareness and its relationship with reading is coincident with the onset of formal reading training. Some research on the development of phonological awareness in English-speaking children has argued that true phoneme-level awareness does not develop until formal training in alphabetic literacy (e.g., Scarborough, et al., 1998). It is possible, that the onset of phoneme-awareness in the older Mandarin-speaking children occurs for this very same reason. Thus, phoneme-level awareness develops with the onset of formal literacy training even in nonalphabetic orthographies.

Thus, there are several possible interpretations for the current results. But in order to make definitive claims about the linguistic level of analysis important in phonological awareness further research is needed to (i) replicate our finding of a relationship between phoneme-level awareness and reading in Chinese children, (ii) explore possible regularities of the *sound-symbol* mappings (as opposed to in the structure of the language) in Mandarin Chinese that may happen at the level of tone or the single phoneme, and (iii) examine the impact of formal reading training on the development of phoneme-level awareness in Mandarin-speaking children.

Developmental Changes in Reading Ability

Although not longitudinal by design, the current study allows for a modest exploration of developmental effects in the comparison of the younger and older groups of English- and Mandarin-speaking children (although recognizing that these comparisons involve different samples of children). In the English-speaking children, there was a developmental sequence in the correlations between reading and phonological and morphological variables going from awareness of larger linguistic units (i.e., morphological compounding and syllable awareness) to awareness of smaller linguistic units (i.e., phoneme awareness) similar to that found in the literature (Lonigan, Burgess, Anthony, & Barker; Stuart, 2005). However, there was also a 'reverse' in the developmental trend such that the relationships between phonological awareness and working memory and reading were lower in the older children than in the younger group although the relationship between rapid naming and reading was stronger in the older children compared to the younger children. Most research to date has shown strong relationships between phonological skills and reading through 4th grade (e.g., Torgesen et al., 1997), with some of the highest relationships emerging in first and second grade (e.g., Wagner et al, 1994). Although the current design is cross-sectional, and so developmental discussions must be made cautiously, the findings suggest that the English-speaking sample was not representative of the samples typically measured in research on English-speaking children. One difference may be due to the reading measure selected, which was not the standard measure of decoding typically used, such as the Letter-Word or Word Attack subtest of the Woodcock Johnson (Woodcock et al., 1989). Alternatively, the current sample may be representative of more fluent (older) readers who show attenuation in the importance of phonological awareness, and who often show a commensurate increase in the importance of rapid naming in predicting reading fluency (e.g., Georgiou, Parrila, & Kirby, 2006; de Jong & van der Leij, 1999; although see Torgesen et al., 1997). Given this, interpretations about the developmental changes in the English-speaking children, and comparisons between the English- and Mandarin-speaking samples must be made with care.

In the Chinese readers, there was some evidence of a developmental trajectory in awareness from larger grained syllable level awareness to smaller grained phoneme level awareness that was even more pronounced than in the English speakers. The younger Mandarin-speaking children were able to perform syllable-level deletions but not phoneme-level deletions, and this ability was related to differences in reading.

Furthermore, the measure of general sound sensitivity was related to phonological processing skills in younger Mandarin speakers but not reading, whereas in older Mandarin speakers, low-level phonological sensitivity was specifically related to reading. These two examples demonstrate continuity in the development of phonological skills, but an important discontinuity in the relationship between these skills and reading ability.

Low-level phonological sensitivity and phoneme-level awareness are only related to reading in older Mandarin speakers, after the onset of formal reading change. Thus, in Mandarin speakers, there may be a change in the model of reading that occurs coincident with the reading instruction (although the change does not appear specific to learning pinyin). An important next question is to examine whether formal reading instruction produces such a change and to highlight differences between instruction in the U.S. and Chinese schools in support.

It is possible that the current developmental difference between reading models for English and Mandarin-speaking children may be a product of two important educational differences between reading instruction in the U.S. and in Beijing. First, reading instruction in the U.S. has primarily adopted a phonics-based approach to teaching reading (e.g., Siegler, 1998), whereas, in mainland China, reading educators do use an analytic approach, but this approach focuses only on dissecting characters into meaning based components and properties as opposed to sound (e.g., Shu et al., submitted). Furthermore, in American preschools and kindergartens, there is a high level of training in preliteracy skills, such as learning the letter names and sounds of the alphabet, familiarizing children with the spelling of their name and other common objects, and introducing children into a print-rich environment in the classroom (e.g., McBride-Chang, 2004; Morrison et al., 2004). In contrast, in Beijing, teaching of reading or writing in the preschools has been prohibited since 1956 (Li & Rao, 2000) and pinyin training starts only in the last year of kindergarten, one year after the grade of the current younger Chinese children.

Based on these differences, early phoneme-level (and possibly onset-rime) awareness may be initially irrelevant for learning to read in Chinese given the holistic approach to reading. Having insight into the components of the characters and their combinability can only come once the child has learned enough characters to detect a pattern in the regularity and consistency of the phonetic components. Thus, higher levels of phonological awareness may aid in the process of reading only once the child has a large enough pool of characters from which to draw insights. There is some support for this idea in existing research that shows evidence of a bidirectional relationship between phonological awareness and reading ability (Chow, et al., 2005; McBride-Chang & Ho, 2005). What would be interesting and a potential next step is to determine how many characters a child needs to know before s/he can begin to apply analytic strategies to learning to read.

Conclusion

In the current study, I compare reading models in young emergent and older decoding English- and Mandarin-speaking children. The goal of this comparison is to explore whether the same constructs predict reading in two contrasting orthographies and whether the same constructs predict reading in beginning and more skilled child readers? Specifically, I am interested in the effect of language and development on the relationship between phonological awareness and reading ability. Thus, in the current study I explore whether the relationship between phonological awareness is specific to (i) a level of processing, (ii) one's language experience, and (iii) to the linguistic unit of analysis.

The current study provides some interesting and novel findings related to these three questions. First, the current study offers support for a dissociation between levels of processing that is relevant for Mandarin speakers, but not English speaker. Low-level phonological sensitivity is predictive of reading beyond measures of awareness in older Mandarin speakers, but not in English speakers. Future research is needed to explore what aspects of the structure of Mandarin Chinese can explain the importance of low-level sensitivity in beginning readers. Second, language experience does not seem important to the relationship between low-level phonological sensitivity and reading. Although English and Mandarin speakers demonstrated slightly different effects of native and non-native word pairs on processing, these effects were not related to reading ability. However, as noted in the discussion, the task design was not suited to test for differences in underlying phonological representations, a difficulty that needs to be resolved in future research. Third, the importance of phoneme elision in both English and Chinese reading suggests a need for improved measures of phonological awareness tasks in research on Chinese readers, and further investigation into the properties of Mandarin Chinese. Why is phoneme-level awareness as important for predicting reading in older Mandarin-speaking children as for English speakers? Last, appeared to be a developmental trend in the results, although I could not test for this explicitly. The significant relationships between phonological sensitivity and phoneme-level awareness and reading only emerge in Mandarin speakers after the onset of formal training. It is possible that the process of learning to read itself is what causes these relationships. However, future research is needed to disentangle this effect.

Thus, the current study reveals interesting and unexpected similarities and differences between the phonological skills that predict reading in English and Mandarin speakers across early reading development. This study is the first to compare both phonological processing and morphological construction measures in a monolingual English- and Mandarin-speaking group of beginner and more able readers. This study was designed to extend earlier cross-cultural work of McBride-Chang & Kail (2002) titled, "Cross-cultural Similarities in the Predictors of Reading Acquisition" by including a comparison on phonological processing measures and morphological construction. Remarkably, even with the inclusion of morphological construction, the results were extremely similar to McBride-Chang and colleagues' who concluded, "Despite diversities of culture, language, and orthography to be learned, models of early reading development were remarkably similar across cultures and first and second language orthographies." (McBride-Chang & Kail, 2002, p1392). Before moving into Study 2, I would like to echo this sentiment here.

Although there are enormous differences between the spoken and written properties of English and Chinese, and the mapping between these two systems, although there are large differences in the culture and educational climate in the U.S. and China (e.g., Stevenson, Lee, & Stigler, 1986), although there were even within-sample differences in age, reading, and reading-related skills, there were strong, and often surprising, similarities in the predictors of reading across English- and Mandarin-speaking emergent readers. Although the results do not definitively resolve the three questions posed in the introduction, I think it is important to emphasize that our results do suggest an unusual number of similarities in the mechanisms of reading across two dramatically different cultures, a finding that does speak to there being very strong universal aspects of reading ability. An interesting next question and good test of the universality of the current findings is whether these relationships are similar in fluent English and Mandarin speakers. Are the mechanisms of reading the same in skilled readers?

Chapter 3: Dissociating Phonological Sensitivity from Phonological Awareness in English- and Mandarin-speaking Adult Readers.

In the field of psychology, research on skilled reading has one of the longest research histories of any topic. In fact, the roots of much of today's reading research can be found as far back as the early 1900's (e.g., Huey, 1908, 1968). Historically, however, the questions and methods of investigation used to understand skilled reading differ from those used to understand emergent reading (as discussed in Chapter 2). For one, the research question in skilled and emergent reading differs. Research on emergent reading focuses nearly exclusively on how children learn to decode, whereas in skilled readers, the interest is in reading fluency and comprehension (e.g., Jackson, 2005). The primary reason for this shift in attention is that decoding is a mastery variable; and it is argued that once a certain threshold of decoding proficiency is achieved, individual differences in decoding become less important for determining reading outcomes (as measured by fluency and comprehension; e.g., Jackson, Fuchs, van der Broek, Espin, & Deno, 2003). Thus, much of the research on skilled reading focuses on either comprehension or fluency but not individual differences in decoding.[25]

Within this framework, there is a growing body of correlational research that investigates the component skills of reading comprehension in adults (e.g., Daneman & Carpenter, 1980) and in older children (for a review see Cain & Oakhill, 2004, Oakhill & Cain, 2004). Although there are methodological parallels between this research and the research on emergent reading, the mechanisms investigated typically have few if any areas of overlap (i.e., recent research on individual differences in comprehension in children has focused on the role of phonological working memory, general knowledge, and inference-making skills; see Cain & Oakhill, 2007).

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[25] In this paper, I will use *reading* and *decoding* synonymously and when referring to fluency or comprehension, will do so explicitly.

Another reason for the lack alignment between research on skilled and emergent reading is methodological. Although there is research investigating component skills of single word reading (*decoding)*, this research has often been experimentally-based and grounded in an information-processing context (e.g., Baddeley, Logie, Nimmo-Smith, & Bereton, 1985). For example, historically skilled reading research has focused[26] on the role of automaticity (e.g., LaBerge & Samuels, 1974), information encapsulation and modularity (e.g., Perfetti & McCutchen, 1987; Stanovich, 1986); "obligatory" versus "intentionless" processing (e.g., Kahneman & Treisman, 1984), attentional limitations (LaBerge & Samuels, 1974) and selective filtering (e.g., Treisman, 1964), visual search (e.g., Palmer, MacLeod, Hunt & Davidson, 1985), and effects of lexicality (e.g., Reicher, 1969) in single word reading. In contrast, research on emergent reading has primarily used correlational methods to identify the components of decoding, focusing primarily on phonological processing skills, and has explored questions of causation through longitudinal and training studies (e.g., for a review see Swanson, Trainin, Necoechea, & Hammill, 2003).

The majority of the single word reading research with skilled adult readers can be aggregated into three domains: "(a) processes analyzing the visual aspects of individual words and sentences, (b) processes integrating information presented at different points in text, and (c) processes relating information in a text to general world knowledge" (Palmer, et al., 1985, p59). Although interesting, the breadth and depth of these domains exceed the scope of the current paper. Furthermore, although many of the topics are related to the components identified in emergent readers (i.e., visual search, speed of processing, effects of lexicality) and could be used to inform the current comparison, for the sake of parsimony, I will only focus on one body of experimental research specifically related to the processing of phonological information in visual word recognition.

In the current study, I propose to investigate the phonological and morphological correlates of reading ability in English- and Mandarin-speaking fluent adult readers. Based on evidence discussed below showing (i) a role of phonological information in skilled reading, (ii) differences in processing of this information between English and

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[26] (among many other topics)

Mandarin speakers, and (iii) developmental change in cortical organization specific to processing of phonological information, I propose that an investigation into *which* measures of phonological and morphological processing are related to skilled reading and *how* they are related depending on the language learned, is an important and theoretically interesting, next step.

Evidence of phonological mediation in single word reading in Chinese and English

Research on visual word recognition in skilled adult readers has a long and productive history both in alphabetic and nonalphabetic orthographies (e.g., for a review, see Frost, 1998; Zhou & Marslen-Wilson, 1999). The task of this type of research is to determine the relationships among orthography, phonology, and semantics in lexical access within a particular language (e.g., Seidenberg & McClelland, 1989). In English speakers, research examining the relationships among orthography, phonology, and semantics in visual word recognition has evidenced a pendulum-like swing between theories of a dual-route in lexical access (e.g., Coltheart, 1980; Coltheart, Curtis, Attkins, & Haller, 1993) and those of a parallel processing single route (e.g., Seidenberg & McClellan, 1989). Beyond representational and computational differences in these models (e.g., Perry, Ziegler, & Zorzi, 2007), the main distinction is whether access to phonological information is a default procedure in reading (i.e., the single route; Seidenberg & McClellan, 1989) or whether phonological information is encoded in one route to lexical access, but can be circumvented in the second (and third) routes to lexical access (i.e., dual-route theory and dual-route-model; Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001). This debate highlights a point integral to the current research. If there are two routes to lexical access, one through a phonological recoding of the graphemes, and the other a direct route to the semantic representation, what is the role of these two routes in skilled reading? Clearly, a heavy reliance is placed on the grapho-phoneme conversion route in beginning readers, and in skilled readers facing new, novel, or nonwords, but what role do phonological skills play in fluent skilled readers under normal reading conditions and how do these skills contribute to reading success?

Research on lexical access in Chinese has revealed a similar theoretical divide concerning the relationship of phonological information in visual word recognition. General phonological processing at both sublexical and lexical levels of representation has been shown to play an important role for Mandarin- and Cantonese- fluent readers (e.g., Tan & Perfetti, 1998). Chinese readers show phonological facilitation/interference in masked priming (e.g., Zhou, Marslen-Wilson, Taft, & Shu, 1999), backward masking (Tan, Hoosain, & Peng, 1995; Tan, Hoosain, & Siok, 1996), primed naming (e.g., Zhou & Marlsen-Wilson, 1999a, 1999b, 2000; Perfetti & Tan, 1998), lexical decision (e.g., Zhou & Marlsen-Wilson, 2000; Zhou et al., 1999), semantic and phonological judgments (e.g., Perfetti & Zhang, 1995), character reading (Zhou & Marlsen-Wilson, 1999a, 1999b); sentence reading (e.g., Zhang & Perfetti, 1993), and standard word recognition tasks (e.g., Tan & Perfetti, 1998). This research has shown that Chinese adults independently process the information of the phonetic component (although primarily in low-frequency compounds) and the phonological information of the whole compound in reading (Zhang, Perfetti, & Yang, 1999; Zhou & Marslen-Wilson, 1999a, 1999b). However, there is disagreement as to whether phonology mediates lexical access or whether phonology is a byproduct of lexical access (e.g., Perfetti & Zhang, 1995; Perfetti & Tan, 1998, 1999; Tan & Perfetti, 1997; Zhou & Marlsen-Wilson, 2000). Some research has shown that phonology is activated earlier (Perfetti & Tan, 1998; Perfetti, & Zhang, 1995) than semantics and has strong effects on lexical access (Tan & Perfetti, 1997), whereas others (Chen & Shu, 2001; Cho & Chen, 1999; Feng, Miller, Shu, & Zhang, 2001; Shen & Forster, 1999; Wong & Chen, 1999; Zhou & Marslen-Wilson, 2000) have found no evidence for early phonological activation. In fact, some research has found that there is significant phonologically mediated priming only when the primes are *regular* and *consistent* characters (the features of the relationship between the phonetic and the compound character discussed in Chapter 1; Zhou et al., 1999), a finding that makes sense given the lack of "feedback consistency" between phonology and orthography in Chinese characters (Stone, Vanhoy, & van Orden, 1997). Furthermore, some research has found that there is significantly mediated semantic priming that precedes phonological mediated priming (e.g., Feldman & Siok, 1999; Ho, Ng & Ng, 2003), a finding claimed to better align with the structural properties of Mandarin Chinese, i.e., the high reliability of the semantic component in compound characters, and the high levels of morphological compounding (e.g., Packard, 2000; Shu & Anderson, 1999).

Thus, although the canonical measures of phonological processing skills assessed in emergent readers are not often measured in skilled adult readers (e.g., although see Cunningham, Stanovich, & Wilson, 1990; Jackson, 2005; Perfetti & Hart, 1999; Sabatini, 2002), there is evidence that phonological skills are important in skilled reading in both English and Mandarin speakers. However, existing behavioral and computational accounts of reading suggest that the specific role of phonological information in reading may depend upon the language learned (e.g., Seidenberg & McClelland, 1989; Zhou & Marslen-Wilson, 1999). Thus, a comparison between English and Chinese skilled readers may provide insight into similarities and differences in the role of phonological information in reading for these two languages.

Evidence of cortical differences in processing phonological information in English and Chinese

Recent research in cognitive neuroscience has identified neural correlates of language-specific similarities and differences in skilled readers. In a meta-analysis of 25 studies exploring the neural correlates of skilled reading in alphabetic and nonalphabetic languages, Bolger, Perfetti, & Schneider (2005) found that writing systems all use a common cortical network in visual word recognition that encompasses three distinct areas[27]. In this meta-analysis, not only did these areas demonstrate similar activation, but localization within the areas was nearly identical across all studies. This strong uniformity in activation and localization suggested “a gateway region that is highly generalized for orthographic form processing” (Bolger et al., p102). However, the meta-analysis also pointed to language-specific divergences in the results specific to the language tested. In particular, the nine imaging studies on Chinese reading found slight differences in activation from the studies with alphabetic, Indo-European languages, differences believed to derive from differences in linguistic and orthographic structures. Specifically, there were three areas identified that demonstrated different patterns and levels of activation during word reading for English and Chinese readers, two of which are known to be linked to differences in role of phonological information for Chinese readers compared to alphabetic readers (Bolger et al., 2005; Booth, Burman, Meyer,

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[27] For the interested reader, the areas are: the left superior posterior temporal gyrus, the left inferior frontal gyrus, and the left occipitotemporal region (or the Visual Word Form, VWF, area).

Gitelman, Parrish, & Messulam, 2004; Gandour, Wong, Lowe, Dzemidzic, Satthamnuwong, Tong, & Li, 2002; Tan, Spinks, Eden, Perfetti, & Siok, 2005; Temple, Deutsch, Poldrack, Miller, Tallal, Merzenich, & Gabrieli, 2003).[28] Thus there appear neural and behavioral similarities and differences in the role of phonological information in skilled reading that depend on the language learned. Comparing skilled reading in English and Chinese will allow us to determine whether the same skills predict reading across these two languages in adult readers, or whether the weight placed upon specific skills may differ depending on the script-specific knowledge required by the writing system as well as by the particular ways in which written orthographies map to the spoken language (e.g., Shu & Anderson, 1999).

There is also evidence of similarities and differences in the role of phonological information in reading that depend on the level of reading skill or reading proficiency. Adult skilled reading represents the model of fluent reading towards which a beginner child reading is moving. However, it is not completely clear whether adult readers approach the task of reading by employing similar mechanisms as children or whether to the same extent as children.

Evidence of behavioral and cortical differences in processing phonological information in beginner child readers and skilled adult readers

Phonological awareness is tightly associated with gaining insight into the alphabetic principle, but the role of phonological awareness once that insight has been acquired or mastered is not as clear. Little research has investigated the importance of phonological awareness in skilled readers (e.g., Allyn & Burt, 1998; Loureiro, Braga, Souza, Filho, Queiroz, & Dellatolas, 2004; Meyer, Wood, Hart, & Felton, 1998; Pratt & Brady, 1988; Scarborough, et al., 1998). It is assumed that once phonological awareness

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[28] Again, for the interested reader, the three areas demonstrating different patterns and levels of activation during word reading are the superior temporal gyrus, the inferior frontal gyrus/dorsal-lateral frontal region, and the right occipitotemporal cortex. Furthermore, in the superior temporal gyrus, the activation in the Chinese studies was more anterior compared to a more posterior activation for alphabetic languages, a finding that aligns with the anterior (temporoparietal boundary) regions being dedicated more to speech comprehension, and the posterior (perisylvian, Heschl's gyrus and planum temporale) regions being dedicated more to grapho-phonic conversion (e.g., Booth et al, 2005; Bolger, Perfetti, & Schneider, 2005). Second, in the inferior frontal gyrus, the Chinese participants demonstrated an increase in anterior activation from the posterior region of the IFG that may be associated with processing of tonal information (e.g., Tan et al., 2005; Gandour et al., 2002) or may be specific to the synchronous processing of phonological and semantic information in lexical access (Perfetti et al., 2005).

is acquired, the ability to discriminate and manipulate phonemes will continue to be developed and refined naturally through the reading process. Furthermore, there is some support for this assumption showing that adults are close to ceiling on a variety of phonological awareness tasks (i.e., phoneme counting/deletion, e.g., Bruck, 1992).

However, there is also evidence that skilled readers demonstrate surprisingly low levels of phonemic awareness (e.g., Scarborough, et al., 1998; Scholes, 1993). In fact, as highlighted by Scarborough et al., (1998), in an early study exploring phonological awareness from kindergarten through 12th grade (Calfee, Lindamood, & Lindamood, 1973), performance on phonological awareness tasks among skilled 12th grade readers dropped to levels seen in the second and fourth graders (58% - 69% correct). These results coupled with evidence that illiterate and neoliterate adults enrolled in adult literacy training demonstrate continuing impairments in phonological skills when compared to reading-matched children (Greenberg, Ehri, & Perin, 1997) and show a bias towards relying on orthographic strategies over phonological strategies in word reading (Greenberg, et al., 1997) can be interpreted to suggest that either adults 'lose' phoneme awareness as fluency skills are acquired or, that there is a critical period in childhood only during which phonological awareness can develop (Perfetti, 2005).

On the other hand, the adult performance may depend heavily on the nature of the task. Adults may demonstrate more orthographic interference in phoneme tasks where there is an inconsistent phoneme-grapheme mapping than children who don't have the same level of grapheme familiarity (e.g., Ehri & Wilce, 1980; Frost & Katz, 1989; Gombert, 1996). In the current study, we often saw evidence of this on the elision task. For example, in response to the item "Say apple without the /l/", more adults than children would respond, /æppə/, a finding showing a reliance on orthographic structure over phonological information to aid in processing. Thus, there is evidence that the mechanisms of reading in skilled adult readers may differ from the mechanisms of reading in the emergent child reader, particularly relative to the processing of phonological information. Furthermore, there is neural support for these findings.

Learning to read and write in childhood produces morphological differences in brain structure and organization, and that these changes may disproportionately affect phonological processing (Castro-Caldas, Petersson, Reis, Stone-Elander, & Ingvar, 1998). Neural organization for emergent reading appears more diffuse and less localized than the neural organization of adult readers. During reading acquisition, a shift is observable in the visual word form area (Brown, Lugar, Coalson, Miezin, Petersen, et al., 2005; Shaywitz, Shaywitz, Blachman, Pugh, Fullbright et al., 2004; Shaywitcz, Shaywitz, Pugh Mencl, Fullbright et al. 2002; Schlaggar, Brown, Lugar, Visscher, Miezin, et al., 2002), much of which appears linked to an increase in the ability and efficiency with which the reader processes phonological information. Experiments using neuroimaging techniques such as fMRI (functional magnetic resonance imaging) show that children activate phonological information later and less automatically than adults during reading (Booth, Perfetti, & MacWhinney, 1999). These results demonstrate a restructuring of functional brain organization with development and reading (Sandak, Mencl, Frost, & Push, 2004; Schlaggar & McCandliss, 2007) that may suggest different mechanisms of reading for beginning child readers and skilled adult readers.

In sum, there is evidence of important commonalities in the mechanisms of reading across language and across reading level as well as behavioral and neural differences across language and reading level, many of which appear specific to differences in the processing of phonological information. Although little existing research has investigated the component skills of reading in adult fluent readers (e.g., Vellutino, Tunmer, Jaccard, & Chen, 2007; Jackson, 2005), I believe that it is an interesting and relevant question. The immediate goal of early reading is to become a proficient decoder. Thus, in order to understand the steps necessary for achieving this, it is important to identify the profile of a skilled reader within the same framework (i.e., word decoding) as the emergent reader. A comparison of skilled English and Chinese readers within the same framework as that used for emergent readers (described in Chapter 2) will provide invaluable insights into the mechanisms of reading across language and across development.

In this chapter, I investigate the role of phonological and morphological skills in predicting individual differences in English- and Mandarin-speaking fluent adult readers. Specifically, I propose to explore whether the relationship between phonological awareness and reading depends on the level of reading skill and the language learned by examining the three questions outlined in the introduction: Is the relationship between phonological awareness and reading specific to (i) level of processing, (ii) language experience, or (iii) linguistic grain size? Using hierarchical linear regressions, I investigate the relative contributions of both low- and high-level phonological skills (sensitivity and awareness, working memory and rapid naming), morphological construction, and verbal and nonverbal IQ to reading ability in English and Chinese adults. First, I explore (i) whether the same phonological constructs (low-level sensitivity and high-level awareness) predict reading in English and Mandarin in skilled adult readers. I extend this analysis by examining (ii) whether the role of phonological sensitivity in reading depends on measuring known words from an individual's native language or whether it can extend to words composed of familiar phonological information but from any language. Finally, I compare (iii) whether syllable and phoneme-awareness predict reading similarly in skilled adult readers from two very different language backgrounds (English and Mandarin Chinese). Through comparing English- and Mandarin-speaking skilled adult readers using the same framework as for emergent child readers, I hope to gain important insights into *which* phonological skills predict reading and *how* these skills predict reading across languages and across development.

Method

Subjects

94 adults (67 English speakers, 27 Mandarin speakers) participated in the current study. All were right-handed, native-speakers of English and Mandarin, respectively, with normal or corrected-to-normal vision. Participants reported no history of language, speech, hearing, or reading impairments and no exposure[29] to the opposite language (Mandarin for English speakers and English for Mandarin speakers). Testing was conducted in parallel psychology labs at two sites, one at the University of Michigan in Ann Arbor and the other at Beijing Normal University in Beijing, China.

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[29] Due to the difficulty of finding Chinese students with no exposure to English, we adopted a specific criterion that accepted no- to limited-exposure to English for the Chinese participants.

67 English-speaking undergraduates at the University of Michigan were recruited from the psychology subject pool. The mean age of the participants was 19 yrs. (range 18-22½) with a female-biased gender split (56% female). Although race and ethnicity were not recorded, the majority of participants were of European-American descent. Subjects received course credit upon successful completion of the experiment. 8 participants (of the original 75) were excluded for failure to meet the screening criteria (as either non-native English speakers or with a history of exposure to Asian languages).

27 Mandarin-speaking students at Beijing Normal University were recruited through advertisements posted around campus and word-of-mouth. The mean age of the sample was 22 years (range 18½-28½) and was predominantly female (85% female). Although race and ethnicity were not recorded, the majority of participants were Han Chinese, the ethnic majority of mainland China. Participants were paid 60RMB (approximately $8) upon successful completion of the experiment.

Existing research on reading in Chinese adults and children has not controlled for amount, degree, and/or length of exposure to English (e.g., Chow et al., 2005; Holm & Dodd, 1996; McBride-Chang, Bialystok, et al., 2004; McBride-Chang & Ho, 2005). However, learning to speak and read in English, may, as described earlier, draw attention to the phonemic properties of words in a way that the Chinese script does not (e.g., Cheung et al., 2001; Huang & Hanley, 1994; Read et al., 1986). Furthermore, there is evidence of transfer of phonological skills in bilinguals (e.g., Bialystok, Majumder, & Martin, 2003) and of heightened phonological sensitivity and awareness that are hypothesized to be due to the demands of learning two languages (e.g., Chen et al., 2004). Thus, cross-linguistic (Chinese/English) research on reading would ideally include only Chinese participants having no prior training in English. Unfortunately, it is difficult to find Chinese adults who have not had any exposure to English or English instruction. The education system in Hong Kong provides bilingual instruction in English and Chinese from kindergarten (McBride-Chang & Kail, 2002). University instruction is often conducted in English as well, and most commerce and industry has a bilingual component (McBride-Chang, 2004; McBride-Chang & Kail, 2002). In mainland China and Taiwan, although there is less bilingualism, education in English has been included in the primary and secondary school curriculum as an instructional class after the adoption of the People's Republic of China Compulsory Education Law in 1986 (known informally as the Law on Nine-Year Compulsory Education). What's more, English is one of the most commonly taken second-language courses in major universities with most university students logging roughly 3,000 hours studying English over the 4-years (Chinese Education and Research Network, 2005).

Because I am interested in determining language-specific aspects of reading, I was vigilant about the degree of second language exposure in our participants, particularly for the Mandarin speakers. Thus, we tested only Mandarin speakers with little to no exposure to English and English speakers with no exposure to Mandarin, or to any Asian language. To determine this, all participants were asked a series of screening questions to determine the individual's language status, such as: (i) "What is your native language? If not Mandarin/English, at what age did you start speaking Mandarin/English?"; (ii) "What other languages do you speak?"; (iii) "What is your fluency level/how long have you been speaking each of these languages?"; (iv) "Where were your born (city/region & country)?"; (v) "Have you ever lived abroad? If so, where and for how long?" It was difficult to recruit Chinese-speakers with absolutely no exposure to English. Despite extensive recruiting efforts to find students with high school foreign language experiences that did not include English, of the original 32 individuals who met our initial recruiting (no high school English instruction) criteria, 3 were excluded from the analyses who reported studying English formally as a second language in the University and an additional 2 were excluded who were non-native Mandarin speakers. In the 27 remaining participants, 3 reported minimal exposure (<=1 year) to English but were included after determining there was no significant difference in the results with or without them.

Procedure

In the current study I examined the relationship between phonological sensitivity measured in a same/different judgment task and reading ability measured by a battery of standardized reading and reading-related tasks in skilled adult readers. Administration of the testing session was identical to that described for children (see Methods, Chapter 2), except for two modifications. First, adults were tested in a single session lasting 1 to 1.5 hours without any formal breaks. Second, for the phonological sensitivity task, children were asked to respond aloud whereas adults were asked to respond manually. In the adult study, participants were asked to place their pointer and middle fingers over the correct response keys on an E-Prime serial response box. If the pairs sounded the same, participants were told to press the 'same' button (labeled 'same' in green on the response box). If pairs sounded different, participants were told to press the button labeled 'different' (labeled 'different' in red on the response box). All participants used their right hand to respond, but assignment of the keys was counterbalanced, with half the subjects using their pointer finger to respond to 'same' cues.

Materials

Phonological sensitivity task. To measure phonological sensitivity, we used the same phonological judgment task as described for the child participants. In the current study, the task was identical except the adult stimuli included a few changes to the pairings used for the children (see appendix C). Overall, the adult stimuli had a mean length of 716msec. The English stimuli had a mean length of 753msec (range 515 – 1001msec), the Mandarin stimuli had a mean length of 679msec (range 412 – 885msec). Mean acoustical duration was not significantly different between prime and target, *F(1, 224)*=1.23 or between pair type (Same, Different, Alliterating, and Rhyming), *F=(3, 224)*=.11. Mean acoustical duration was significantly different between languages, *F(1, 224)*= 11.37, p<.001, but there were no 2- or 3-way interactions. However, we did not expect any differences to affect our predictions since all participants heard all stimuli.[30]

Reading-related battery. We administered two measures of reading ability and a series of tasks measuring phonological awareness, speed of processing, phonological memory, morphological construction, vocabulary and nonverbal IQ, all skills important for explaining individual differences in reading in English and Chinese (e.g., McBride-Chang & Kail, 2002; Torgesen et al., 1997). Here we only provide a description of measures that were not used in the child behavioral battery (see Table 3.1 for a comparison of measures used in the child and adult studies, Study 1 and Study 2,

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[30] Like for the child stimuli, the SOA in the design was 1000msec. However, one sound file, pie.wav, was longer than 1 second. This file was automatically truncated by E-Prime when played in the prime position. The net result of the truncation was a loss of 14msec of dead space at the end of one token repeated three times across the experiment.

respectively).

Table 3.1 A comparison of the measures used in the behavioral battery

	English		Mandarin	
	Children	Adults	Children	Adults
Alphabet Sound[a]	X		X	
Digit Span Forwards	X	X	X	X
Digit Span Backwards	X	X	X	X
Rapid Naming Digits	X	X	X	X
Rapid Naming Objects	X	X	X	X
Elision[a]	X	X	X	X
Morphological Production[b]	X	X	X	X
Morphological Reception[b]	X		X	
Single-Word/Character Reading[a]	X	X	X	X
Nonverbal Iq[b]	X	X	X	X
Vocabulary[ab]	X	X	X	X
Phonological Sensitivity (Accuracy)	X	X	X	X
Phonological Sensitivity	X	X	X	X

[a]= measures that differ between English- and Mandarin-speakers
[b]= measures that differ between children and adults

One major change between the child and the adult study was that in the adult study nearly all measures (except for the nonverbal IQ, vocabulary, and reading fluency tasks) were adapted for computer administration using the E-Prime programming software (Psychology Software Tools Inc., Pittsburgh, PA, USA; www.pstnet.com/eprime) so that both accuracy and reaction times could be collected. Inaccurate responses were recorded manually by the experimenter. Speed was digitally recorded and retimed for any coughs or other extraneous sounds that might have erroneously been recorded as a response.

Comprehensive test of phonological processing (Wagner, Torgesen, & Rashotte, 1999). We administered two subtests, elision and rapid naming from Wagner et al.'s Comprehensive Test of Phonological Processing (CTOPP).

i) Elision. The elision task measured the participant's ability to remove initial, final, or medial phonemes (or phoneme clusters) and syllables from words. The reliability of this measure was α=.75 for English and α=.62 for Chinese.

ii) Rapid Object Naming. The rapid object naming task measured a participant's speed in naming a series of objects. The reliability of this measure was α=.84 for English and α=.87 for Chinese.

ii) Rapid Digit Naming. The rapid digit naming task measured the speed with which the participant named a series of digits printed on a page. The reliability of this measure was α=.93 for English and α=.92 for Chinese.

Morphological Construction. The adult version of the morphological construction task used the identical items from the child version of the test (see Methods, Chapter 2), but administered these items only using the *production* format not the *reception* format (i.e., selecting one picture from a page of four that fits the prompt). Namely, participants were required to generate novel compound words from a prompt for 30 construction items, 14 items requiring word-initial substitutions (i.e., swordfish-gunfish), and 16 items requiring word-final substitutions (i.e., mailbox-mailtray). There was a maximum score of 30 points. The reliability of this measure was α=.57 for English and α=.67 for Chinese.

The Wechsler adult intelligence tests, WAIS-R,(Wechsler, 1981). This battery contains measures designed to cover a range of general intellectual measures for ages 16 – 74 years. In the current study, we administered three of the subtests, memory for digits, block design, and vocabulary without any changes to the standardized versions.

i) Memory for Digits. The memory for digits task measured the participant's ability to recall a list of digits in serial order. The reliability of Digits Forward was α=.71 for English and α=.42 for Chinese and Digits Backward was α=.72 for English and α=.77 for Chinese.

ii) Block Design. The block design task required participants to recreate various block formations modeled in the task booklet within a specific time-period using 9 blocks that were white on one side and red-and-white on the other side. Administration and scoring in both languages followed the instructions in the WAIS-R (Wechsler, 1981) testing manual. Of the 14 possible trials, items 1 – 7 were scored as 0, 1 or 2 points each and items 8 – 14 were scored as 0- 4 points each based on the participant's accuracy and time to completion for a maximum score of 68. Testing was stopped when the participant failed three consecutive trials. The reliability of this measure was α=.55 for English and α=.75 for Chinese.

iii) Vocabulary. For English speakers, the vocabulary subtest of the Wechsler Intelligence Tests (WAIS-R) required participants to define thirty-three words increasing in conceptual difficulty. Each response was scored 0, 1, or 2, based on the standardized scoring instructions of the Wechsler Intelligence Tests (WAIS-R) for a total maximum score of 66 points. Responses were recorded by hand and scored by two independent scorers. Any inconsistencies in scoring were resolved by the primary investigator. Testing was discontinued when a score of 0 was obtained on 6 or more consecutive items. The task had a reliability of α=.63.

The Mandarin-version of the vocabulary task was roughly comparable in word difficulty (word complexity and frequency) to the English version. For Mandarin speakers, the vocabulary task required participants to define thirty-five words increasing in conceptual difficulty. Thirty-two of the words were based on the Hong Kong version of the vocabulary subtest of the Stanford Binet Intelligence Scale et al., 1986), adapted for Mandarin speakers that was administered to the Chinese children (see Methods, Chapter 2). An additional three words were selected by Professor Shu, a Chinese co-author, to equate for difficulty between the English and Chinese versions of the test. Responses were recorded by hand and scored by three independent scorers. Each response was scored 0, 1, or 2, based on the standardized scoring instructions of the Stanford Binet Intelligence Scale (Thorndike et al., 1986) and based on the dictionary definitions for the additional 3 words, for a total maximum score of 70 points. Testing was discontinued when a score of 0 was obtained on 6 or more consecutive items. The task had a reliability of α=.78.

The Woodcock Johnson Psychoeducational Battery – Revised: Tests of Achievement (Woodcock & Mather, 1989)

i) Fluency subtest. The Fluency subtest is a three-minute timed test that required participants to answer ‘yes’ or ‘no’ to verify the validity of each of 98 sentences. All items on the English task were from the standardized Woodcock Johnson Achievement Battery (Woodcock & Mather, 1989). In adapting the task for Mandarin, several changes were made. First, items requiring the ordering of alphabet knowledge were modified to reflect ordering in a non-alphabetic domain (for example, the item, “The letter “C” is the last letter of the alphabet" was changed in Mandarin to "The meal for dinner comes before the meal for lunch"). Secondly, several items were changed to ensure comparability of meaning (for example, the item, "Oranges can be used to make juice for breakfast" was changed in Mandarin to "(Soy) Beans can be used to make soymilk"). No discontinue criterion was used, and for both groups the total score was the sum of the correct items (answered within 3-minutes) for a maximum score of 98. The reliability of this measure was α=.96 for English and α=.94 for Chinese.

Wide Range Achievement Test 3 (WRAT 3) (Wilkinson, 1993)--Single Word/Character Reading. For English speakers, we administered the standardized reading subtest of the WRAT 3, which required participants to read 42 words of increasing difficulty for a maximum score of 42 points. The reliability of this test was α=.63 for English. For Mandarin speakers, we used the Chinese Single Character Reading Test, a common measure of reading ability in children in China (e.g., Shu et al., submitted.). The reliability of this measure was α=.81 for Chinese.

Results

The results section is divided into four parts. In the first section I review the results of the phonological sensitivity task and explore differences in the performance between English- and Mandarin-speaking adults. In the second section I discuss the results for the behavioral battery and examine whether the relationships among the measures in the battery align with the findings in the literature on children. In the third section, I test the three questions outlined in the introduction. Namely, I explore whether the relationship between phonological awareness and reading depends on (i) level of processing, (ii) language experience, and/or (iii) linguistic grain size. Last, I compare the overall model of skilled reading for English- and Mandarin-speaking adults.

Table 3.2 Adult mean accuracy and reaction times by condition in the phonological sensitivity task.

Adult Mean Accuracy

	Same (SD)	Different (SD)	Alliterating (SD)	Rhyming (SD)
English (N=63)				
Native	0.99 (.02)	1.00 (.01)	0.98 (.07)	0.87 (.32)
Nonnative	0.99 (.02)	1.00 (.02)	0.99 (.03)	0.86 (.29)
Mandarin (N=27)				
Native	0.97 (.05)	1.00 (.02)	0.99 (.03)	0.95 (.07)
Nonnative	0.98 (.03)	1.00 (.00)	1.00 (.00)	0.97 (.06)

Adult Mean RTs

	Same (SD)	Different (SD)	Alliterating (SD)	Rhyming (SD)
English (N=63)				
Native	303.44 (90.94)	291.51 (83.34)	280.09 (77.75)	307.48 (78.17)
Nonnative	300.71 (75.46)	330.45 (90.91)	307.67 (91.11)	344.41 (102.28)
Mandarin (N=27)				
Native	357.09 (115.76)	344.99 (101.45)	315.68 (88.51)	348.03 (110.28)
Nonnative	336.47 (93.01)	312.08 (91.17)	325.67 (81.41)	354.60 (117.06)

Note: Reaction times are reported in msecs for accurate items only with outliers and repetitions removed.

Phonological Sensitivity Task

Accuracy. Overall, mean accuracy was near ceiling for all conditions ranging from 97 – 100% accurate except for the Rhyming condition. A repeated measures analysis of variance with location of testing (Michigan, Beijing) as a between-subjects factor and prime[31] type (Same, Different, Alliterating, Rhyming) and language (native, nonnative) as within-subjects factors, revealed no significant main effect of location, $F(1, 88)= 2.08$. However, there was a significant effect of prime type, $F(3,264)=7.75$, $p<.001$,

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[31] As noted in the Chapter 2, the phonological sensitivity task is not a canonical priming task. However, the structure does conform to a priming task structure, and thus for the sake of simplicity I have labeled the auditory stimuli, prime and target, respectively. Furthermore, the results demonstrate that the relationship between prime and target was significant, and thus, I later discuss the results in terms of ‘priming effects’.

confirming poorer performance in the Rhyming condition compared to other conditions, as shown in Table 3.2. In addition, there was a significant interaction between location and prime type, F (3, 264) = 3.09, p<.05 such that English speakers (M=.87) performed worse in the Rhyming condition than the Mandarin speakers (M=.96).

Reaction times. Reaction times were computed for each subject based on correct responses with outliers[32] removed (about 10% of the trials for both groups). 5% (903) of the trials for the English sample (18,516 total trials across 67 participants) were inaccurate and slightly less than 5% (889) of the responses were outliers. For the Chinese sample (8,192 total trials across 27 participants), only 3% (248) were inaccurate responses and roughly 7% (586) of the trials were outliers. Interestingly, there appears to be a reversal in the speed/accuracy trade-off between cultures that was also reflected in the overall reaction times, with the English participants showing a 15-30msec trend towards faster reaction times across all conditions. Because of a marginally significant difference in overall processing speed, F(1, 81)=3.31, p<.10, and because I was primarily interested in differences in patterns of response based on the degree or amount of phonological overlap as opposed to overall differences in reaction time, I used the Same condition as the baseline and compared each of the additional conditions to the Same condition.

Priming effects for targets assessed against the baseline (Same) condition[33] are displayed in Figure 3.1. A repeated measures analysis of variance was performed on reaction times (relative to the baseline) with location of testing (Michigan, Beijing) as a between-subjects factor and prime type (Different, Alliterating, Rhyming) and language (native, nonnative) as within-subjects factors. When individual response times in the Same condition were subtracted from response times in each condition, Mandarin and English-speaking participants were generally similar in the speed with which they processed the different prime-target pairs overall. However, there was a significant effect of native versus non-native language F(1,81)=9.53, p<.005 with native stimuli

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[32] Outliers were considered reaction times 2SDs above the mean within the condition and any response <50msec.

[33] Reaction times shown are relative to the baseline (Same) such that positive bars represent times faster than the baseline and negative-going bars represent times slower than the baseline.

(*M*=17.06) showing significantly faster processing than non-native *(M*=-6.81). In addition, there was a highly significant effect of prime type *F*(2, 162)=15.08, *p*<.001. Rhyming stimuli showed significantly slower responses than either Different or Alliterating conditions, in a post-hoc test of means, Bonferroni-adjusted p<.01. In contrast, Alliterating stimuli showed significantly faster responses than either the Different or Rhyming conditions, in a post-hoc test of means, Bonferroni-adjusted p<.05. Thus, there appears to be a facilitative effect of shared onset but an inhibitory effect of shared rime on speed of processing in the current phonological discrimination task across both languages.

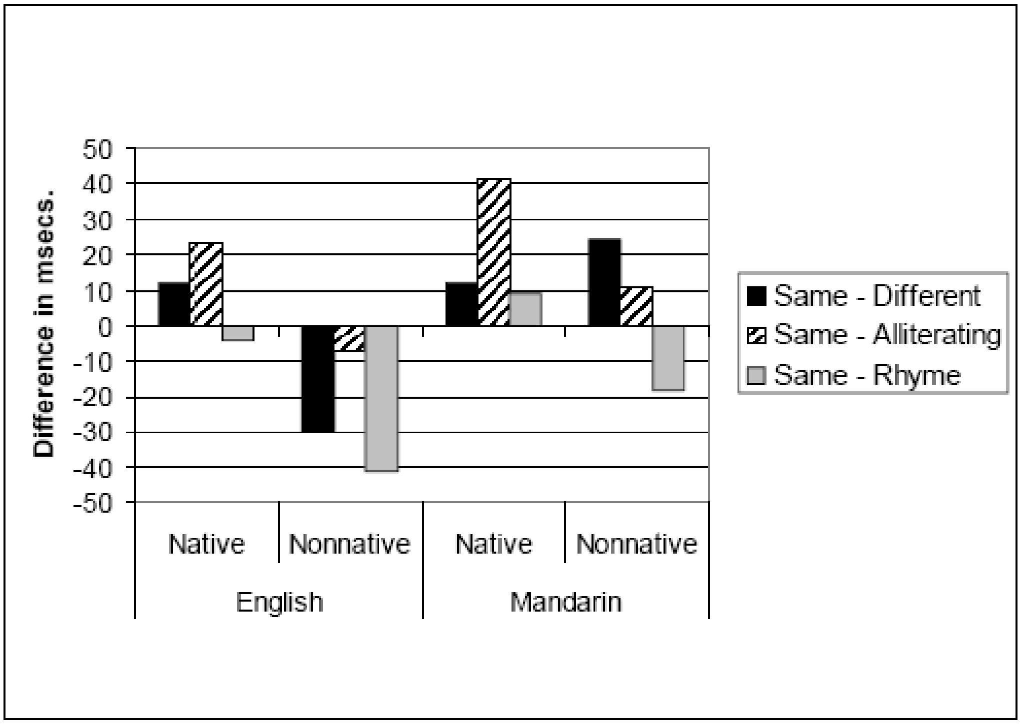

Figure 3.1 English- and Chinese Adult RTs in the Phonological Sensitivity Task for each Condition Relative to Baseline (Same).

Although there were no significant 2-way interactions, there was a significant 3-way interaction between location of testing, native/non-native language, and condition, *F*(2,162)=3.15, *p*<.05. One possible interpretation of this finding is due to a difference in processing of native and non-native stimuli between the English- and Mandarin-speaking adults. English participants performance in the non-native condition was significantly different from performance in the native condition on all three pair types, Different, Alliterating, and Rhyming, post-hoc test of means, bonferroni-adjusted, *p*s<.05, whereas for Mandarin speakers the Alliterating pair was the only condition in which there was a significant difference between the native and non-native condition, post-hoc test of means, bonferroni-adjusted, *p*s<.05. The 3-way interaction appeared to be specifically located in a difference between English and Mandarin speakers in processing of native and non-native Different word pairs, post-hoc test of means, Bonferroni-adjusted, p<.001. English speakers were slower to respond to Different word pairs in the non-native condition (*M=-23.89)* than in the native condition (*M=14.71)*, or than Mandarin speakers in either the native (*M=12.09)* or non-native (*M*=24.39) conditions. This result may be due to differences in language exposure. Specifically, the Mandarin speakers in our study had a higher-level of exposure to English, than the English speakers to Mandarin Chinese. This level of exposure may have affected the familiarity of the stimuli, and subsequently the response times. If this is the case, however, why aren't there between-subjects differences in processing of Rhyming stimuli in the native and non-native condition?

One possible explanation is that the effect of exposure/familiarity that the Mandarin speakers demonstrated may have been canceled out by an effect of difficulty. Specifically, levels of accuracy differed across Different, Alliterating, and Rhyming conditions, with the Different condition appearing the easiest with both English and Mandarin speakers demonstrating perfect discrimination (100% accuracy) in this condition only. So although English speakers were slower to respond to the non-native stimuli overall, the existence of phonological overlap increased the difficulty and possibly neutralized the benefits of familiarity for the Mandarin speakers. Thus, there were no significant differences between performance on native and non-native word pairs in the Alliterating and Rhyming conditions between English and Mandarin speakers.

Behavioral Battery

Descriptive statistics for measures in the behavioral battery for the English and Mandarin-speaking samples are shown in Table 3.3. With a few exceptions, all measures demonstrated good distributions and relatively high and consistent alphas (α = .70-96) suggesting the efficacy of these measures for adults and for the two different language samples. However, the morphological construction task demonstrated low-reliabilities[34] (English α= .57 and Chinese α= .67) and performance was close to ceiling in both groups (*M*=28.7, *SD*=1.6 for English, and *M*=28, *SD*=2.1 for Chinese). In the Chinese sample, digit-span forwards was close to ceiling, (*M*=14.5, *SD*=1.2). Furthermore, in the English sample, the reliabilities for single-word reading (α = .63), vocabulary (α = .63), and blocks were lower than anticipated (α = .55), particularly given that these were standardized measures. It is possible that the version of these measures used for the English-speaking participants, particularly single-word reading and vocabulary, were not reliable measures of the constructs proposed. However, it is equally as possible that the English-speaking sample was more homogenous than the Chinese sample (the participants were primarily first and second year undergraduates at Michigan whereas the Chinese participants were both undergraduate and graduate students spanning a larger range in education level and age), and thus there was not enough variability in performance to establish reliability across the items in each measure.

Although there was no difference in nonverbal IQ, English- and Mandarin-speaking participants performed differently on several of the measures that are typically found to predict individual differences in reading as shown in Table 3.3. Specifically, Mandarin speakers were better on working memory measures F=(1, 93)= 64.00 (forwards) $p<.001$, 6.82 (backwards) $p<.01$, and faster in rapid naming of digits F= (1, 93)=10.28, $p<.01$. These three measures all involve digits, and thus the differences observed may be an artifact of language (number names [1-10] are all single-syllable words in Mandarin, but not in English, see p53, footnote #20), and not intrinsic processing differences. In contrast, English speakers were slightly faster on rapid naming of objects, $F(1,92)=5.14$, $p<.05$, another possible language artifact. It is interesting that the differences in the performance of the Mandarin-and English-speaking adults mirrored the direction and type of differences in the Mandarin- and English-speaking children. Although this does not clarify whether the differences are a product of task demands or a language-specific task superiority, it does suggest strong continuity in the constructs across development.

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[34] Again, as discussed in Chapter 2, a common rule of thumb is that reliabilities above .70 are considered acceptable (Nunnally and Bernstein, 1994).

Table 3.3 Descriptives for adult performance on reading-related measures by language group

	English Adults			Chinese Adults			Eng vs. Mand
Measures	N	Mean (SD)	α	N	Mean (SD)	α	ANOVA F(1,94)
Digits Forwards [16][a]	67	11.03 (2.12)	.71	27	14.52 (1.22)	.42	64.00***
Digits Backwards [14]	67	7.58 (2.17)	.72	27	8.96 (2.67)	.77	6.82**
Elision [66, 54]	66	54.61 / 82% (5.12)	.75	27	43.30/ *80%* (5.44)	.62	N/A
Morphological Construction [30]	67	28.67 (1.58)	.57	27	28.04 (2.10)	.67	2.54
Rapid Digits [72]	67	24.30 (5.01)	.93	27	20.86 (4.42)	.92	10.28**
Rapid Objects [72]	66	40.87 (6.74)	.84	27	44.43 (6.07)	.87	5.14*
Single Word Reading [42, 120]	67	33.63 / *80%* (2.67)	.63	27	115.67 / *96%* (4.26)	.81	N/A
Reading Fluency [98]	67	91.42 (9.70)	.96	27	81.41 (10.15)	.94	19.96***
Vocabulary [33, 35]	65	47.42 / 72% (5.76)	.63	27	52.44 / 75% (4.90)	.78	N/A
Nonverbal IQ [14]	67	47.70 (8.29)	.55	27	47.33 (11.19)	.75	.03
Sound Sensitivity (RTs)	63	308.00 (73.82)	.94	27	336.83 (88.53)	.96	3.31

Note: All data are presented as raw scores. RTs were computed only for accurate items with outliers and repetitions removed. Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).

[a] : number of items for each task are presented in brackets- where total differs by sample, I reported at [English, Mandarin]

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

Differences in performance for the elision, single-word/character-reading, and vocabulary tests could not be tested because the measures were not identical for the two samples. However, when performance is compared using percentages, the two samples appeared to perform relatively similarly on the elision task (82% accurate for U.S., 80% accurate for Chinese) and the vocabulary test (72% accurate for U.S. and 75% accurate for Chinese). In contrast, the samples showed a large difference in performance on the reading test, (80% accurate for the U.S. and 96% accurate for the Chinese). The Chinese version of the single-character reading test was designed for administration in a child sample (e.g., Shu et al., submitted) and thus, performance was skewed for the Chinese adult readers. Therefore, interpretations of the data for the Chinese speakers must be made with caution, particularly when interpreting null effects, as performance on the reading test did not demonstrate the desired distributions.

In contrast, the English reading test is a well-known standardized reading measure designed for ages 5 – 75 years. However, performance on this task showed a small range of variability (SD=2.67) and a lower reliability than desired, α=.63 even though accuracy was not at ceiling. Thus, although the English sample's performance was better distributed than the Chinese participants and was no doubt a better measure of reading ability overall, interpretations must still be made with caution and must be validated whenever possible with the other reading measure, reading fluency. However, the outcome of these restricted ranges and close-to-ceiling performance would at the worst underestimate the potential effects in the current study. Thus, the implication of these methodological complications is restricted to the interpretation of null findings, as opposed to the interpretation of significant findings.

The simple correlations in Table 3.4 show relationships between measures of phonological processing and reading that replicate those found in previous studies with children (e.g., Wagner & Torgesen, 1987; McBride & Ho, 2000). Specifically, for English speakers the components of phonological processing were significantly correlated with one another and were significantly correlated with single word reading (elision, r=.39, p<.001, and digit span, r=.50, p<.001, except rapid naming, r=.07). Vocabulary was correlated with single word reading, r=.29, p<.05, and with reading fluency, r=.36, p<.01. The relationship between vocabulary and reading is one found in previous research in children (McBride-Chang, 2004) and offers tentative support for the validity of the vocabulary measure in the current sample regardless of its low level of reliability. Similarly, single word reading and reading fluency were positively correlated (r=.29, p<.05), a finding that supports the reliability of single word reading as a construct measuring reading. Interestingly, unlike prior research, nonverbal IQ was not related to any of the other reading-related skills, although this may be a product of the restricted variability and low reliability of the nonverbal IQ measure in the English-speaking sample.

As predicted due to differences in the sound-symbol relations in Mandarin Chinese, there were fewer significant relationships among reading-related variables for the Mandarin speakers. Nonetheless, components of phonological processing, elision and digit span were correlated, r=.48, p<.01. In addition, vocabulary was correlated with single word reading, r=.57, p<.01, but not reading fluency. However, unlike existing research in children (e.g., Ho & Lai, 2000) and the current findings in Study 1, morphological construction and rapid naming were unrelated to all measures of phonological processing, reading, and even vocabulary.

Performance on the morphological production task was close to ceiling in both the English- and Mandarin-speaking adults, a result which may explain its lack of predictive power. However, the finding that the rapid naming composite was unrelated to any other measure collected, is surprising. In particular, it is interesting that the rapid naming task was unrelated to reading in both the English- and Mandarin-speaking adults, although it was significantly related to reading in the children (younger and older English, r= -.41 and r=-.36 and younger and older Chinese, r=-.34 and r=-.59). It could be that although rapid naming is a strong predictor of reading fluency in skilled adult readers and in impaired adult readers (e.g., Sabatini, 2002; Miller, Miller, Bloom, Jones, Lindstrom, Craggs, Garcia-Barrera, Semrud-Clikeman, Gilger, & Hynd, 2006) its relationship with decoding attenuates over development. Some support for this has been found in older child readers (e.g., Torgesen et al., 1997; Wolf, 1986 although see Meyer, Wood, Hart, & Felton, 1998). If this is the case, it further supports the claim that decoding and fluency are separable constructs, particularly in skilled readers.

Table 3.4 Simple correlations of sound sensitivity, reading, and reading-related measures for adults: English-speakers above the diagonal, Mandarin-speakers below the diagonal

	English-Speakers (N=67)								
	1	2	3	4	5	6	7	8	9
1. Digit Span Total	—	.35**	-.05	-.27*	.50***	.12	.15	-.03	-.09
2. Elision	.48**	—	.14	-.01	.39***	.14	.10	.06	-.13
3. Morph Construction	.04	.07	—	.09	.21	.08	.21	.22	-.11
4. Rapid Naming Total	-.25	-.03	.10	—	.07	-.20	-.13	.06	.34**
5. Single Word Reading	-.04	.24	.08	.21	—	.18	.29*	.00	.09
6. Fluency	.24	-.03	.06	-.27	20	—	.36**	.03	-.01
7. Vocabulary	.08	.06	-.01	.17	.57**	.37	—	.16	-.14
8. Nonverbal IQ	.38*	.22	-.04	.03	.10	.42*	.39*	—	.02
9. Sound Sensitivity (RTs)	.06	.05	-.33	-.12	-.62***	-.40*	-.33	-.27	—
	Mandarin-Speakers (N=27)								

Note: Digit Span (forwards/backwards) and Rapid Naming (object/digit) were combined using means of standardized scores. Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
*p<.05, **p<.01, ***p<.001.

Is the relationship between phonological awareness and reading specific to level of processing?

Research on English speakers suggests that the relationship between epilinguistic measures of phonological sensitivity and reading is indirect, and is mediated by metalinguistic measures of phonological awareness (e.g., McBride-Chang, 1996). However, there is limited, but suggestive research that phonological sensitivity may be a more important predictor in languages other than English, particularly those with nonalphabetic orthographies (e.g., Chiappe et al., 2007). Study 1 provided support of this language effect, showing that phonological sensitivity contributed unique variance to explaining reading ability in the older Mandarin speakers beyond measures of awareness. These findings suggest that the importance of phonological sensitivity in predicting reading ability may depend both on the language learned and on the level of reading proficiency. To test this proposal, I next examine the relationship between an epilinguistic measure of phonological sensitivity and reading in a sample of English- and Mandarin-speaking skilled adult readers by performing two types of analyses.

First, I collapsed across all conditions in the phonological sensitivity task (Native/Non-native and Same/Different/Alliterating/Rhyme) and produced a measure of generalized phonological sensitivity (averaged reaction times; see line 9 in Table 4). Although there was no significant difference between English and Mandarin speakers performance on this task, $F(1,4)=.06$, there were interesting and meaningful differences in the relationships between phonological sensitivity and the other reading and reading-related measures within each group. For English speakers, the general measure of phonological sensitivity was related to rapid naming, $r=.34$, $p<.01$, but not reading. Given that these were the only two measures where performance was based exclusively on reaction time, this is an expected relationship. In contrast, for Mandarin speakers, the general phonological sensitivity measure was strongly related to both reading measures, single word reading $r=-.62$, $p<.001$and fluency $r=-.40$, $p<.05$. Mandarin speakers who were faster on discriminating word pairs were better readers.

The results for the English speakers are aligned with existing research (e.g., McBride-Chang, 1996) and the results from Study 1 showing no relationship between phonological sensitivity and reading ability in English-speaking children. The results for the Mandarin-speaking adults also extend the findings for the older Mandarin-speaking children in Study 1 demonstrating a very strong overall relationship between general phonological sensitivity and reading ability for Mandarin speakers. However, there were two differences between the correlations of the phonological sensitivity task and reading in Mandarin-speaking children and adults.

First of all, phonological sensitivity was related only to single-character reading and fluency, in the adult readers, whereas in the Mandarin-speaking children, the sensitivity task also showed relationships with phonological processing skills. Secondly, the relationship between phonological sensitivity and reading ability in the Mandarin-speaking children only appeared to come online with the onset of formal reading instruction and did not explain nearly as much unique variance in single-character reading as in the adults ($\Delta r^2 = .02$ in children and .26 in adults). The strengthening of the relationship between phonological sensitivity and reading ability in skilled adult readers compared to decoding child readers suggests that the relationship may be specific to some feature of the automatization of decoding.

Although there is a strong relationship between general sound sensitivity and reading ability in Mandarin-speaking adults, it is possible that this relationship could be mediated by individual differences in phonological awareness as suggested in the literature for English-speaking children (e.g., McBride-Chang, 1996). Although this was not the case in the results for Mandarin-speaking children in Study 1, I next tested the mediation question in two stepwise regressions where I varied the order in which I entered the different types of phonological measures for Mandarin-speaking adults. In Model 1, phonological sensitivity was entered as the last step, and the phonological processing measures (elision, rapid naming, and working memory) were entered simultaneously in the previous step. In Model 2, phonological sensitivity was entered in the earlier step and the phonological processing measures were entered in the last step.

Table 3.5 Linear regression equations predicting single word reading in adult English-speakers.

Phonological Sensitivity entered after Phonological Awareness

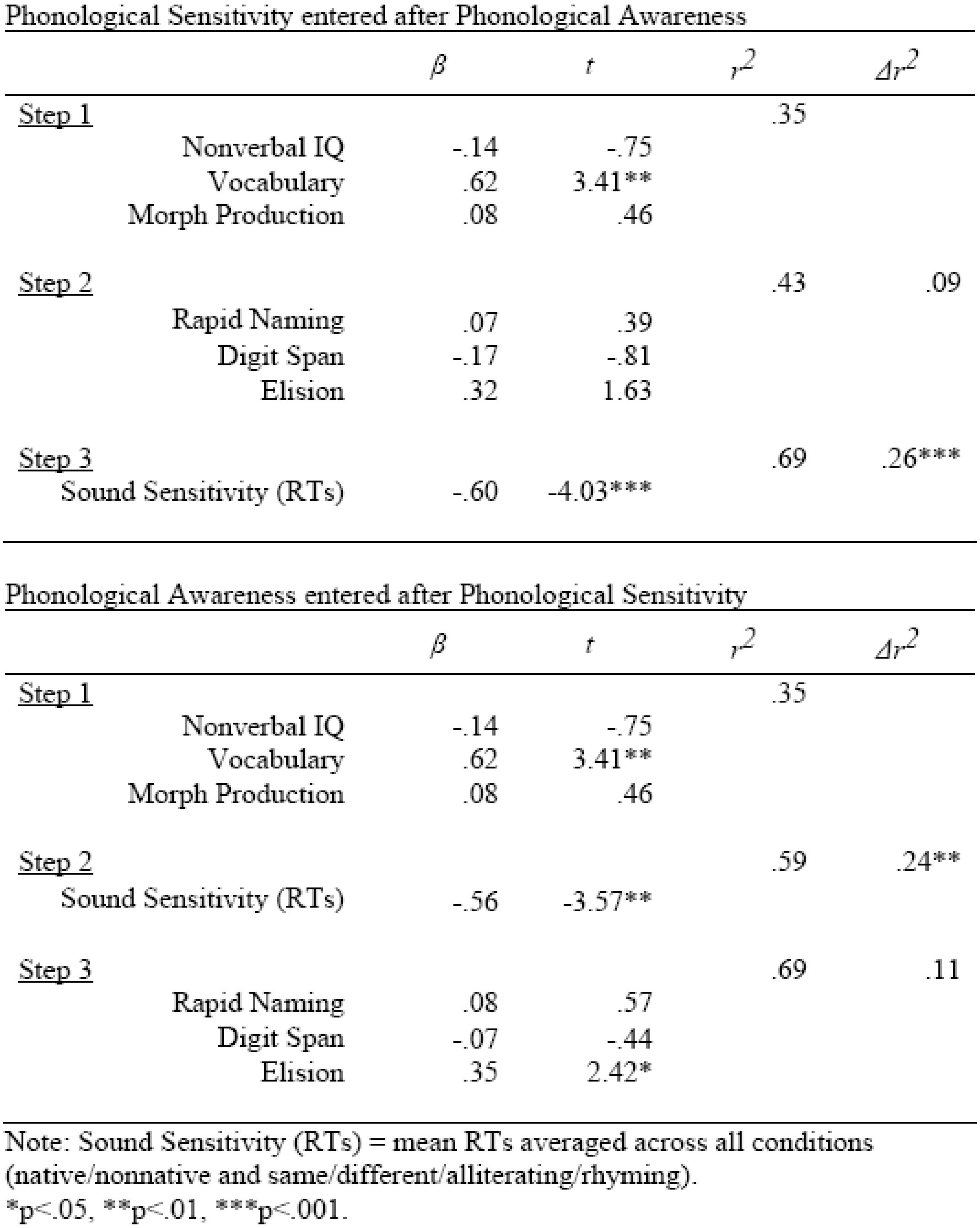
	β	t	r^2	Δr^2
Step 1			.14	
Nonverbal IQ	-.17	-1.30		
Vocabulary	.30	2.31*		
Morph Production	.18	1.41		
Step 2			.47	.33***
Rapid Naming	.30	2.78**		
Digit Span	.50	4.43***		
Elision	.17	1.60		
Step 3			.47	.00
Sound Sensitivity (RTs)	.05	.47		

Phonological Awareness entered after Phonological Sensitivity

	β	t	r^2	Δr^2
Step 1			.14	
Nonverbal IQ	-.17	-1.30		
Vocabulary	.30	2.31*		
Morph Production	.18	1.41		
Step 2			.15	.01
Sound Sensitivity (RTs)	.11	.90		
Step 3			.47	.32***
Rapid Naming	.27	2.23*		
Digit Span	.50	4.36***		
Elision	.18	1.64		

Note: Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
*p<.05, **p<.01, ***p<.001.

Table 3.6 Linear regression equations predicting single word reading ability in adult Mandarin-speakers



Phonological Sensitivity entered after Phonological Awareness

	β	t	r^2	Δr^2
Step 1			.35	
Nonverbal IQ	-.14	-.75		
Vocabulary	.62	3.41**		
Morph Production	.08	.46		
Step 2			.43	.09
Rapid Naming	.07	.39		
Digit Span	-.17	-.81		
Elision	.32	1.63		
Step 3			.69	.26***
Sound Sensitivity (RTs)	-.60	-4.03***		

Phonological Awareness entered after Phonological Sensitivity

	β	t	r^2	Δr^2
Step 1			.35	
Nonverbal IQ	-.14	-.75		
Vocabulary	.62	3.41**		
Morph Production	.08	.46		
Step 2			.59	.24**
Sound Sensitivity (RTs)	-.56	-3.57**		
Step 3			.69	.11
Rapid Naming	.08	.57		
Digit Span	-.07	-.44		
Elision	.35	2.42*		

Note: Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
*p<.05, **p<.01, ***p<.001.

In Table 3.5, the hierarchical linear regression results for single word reading for English-speaking adults are presented for Model 1 and Model 2. For English speakers, 33% of the variance in single word reading was predicted by measures of rapid naming, working memory, and phonological awareness. In contrast, phonological sensitivity did not improve the fit of the model. In Model 2, when elision, digit span, and rapid naming are entered after phonological sensitivity (and verbal and nonverbal IQ and morphological construction), two of the three measures each contribute unique variance to explaining differences in single word reading for English speakers, rapid naming, β=.27, p<.05, digit span, β=.50, p<.001, but not elision, although marginally, β=.18. In contrast, in Model 1 when phonological sensitivity is entered as the last step after elision, digit span, and rapid naming, the sensitivity measure did not contribute unique variance to explaining individual differences in single word reading. Again, these findings are aligned with the reading literature (e.g. McBride-Chang, 1996; Muter et al., 2004) and with the results for English-speaking children in Study 1. Phonological sensitivity does not appear to contribute unique variance to explaining reading ability in English-speaking adults beyond measures of phonological processing.

In Table 3.6, the hierarchical linear regression results for single character reading for Mandarin-speaking adults present a different story. For Mandarin speakers, only 9% of the variance in single character reading was explained by the measures of working memory, rapid naming, and phonological awareness. However, phonological sensitivity improved the model fit significantly, explaining 26% additional variance in the reading variable. As suggested by these findings, in Model 1 when phonological sensitivity was entered last in the stepwise regression, it was highly predictive of single word reading, (β=-.60, p<.001), even after controlling for elision, rapid naming, digit span, and verbal and nonverbal IQ and morphological construction. In Model 2 when elision, rapid naming and digit span were entered last in the equation, rapid naming and digit span were not predictive of single word reading. Interestingly, elision was predictive even after the measure of phonological sensitivity was accounted for, β=.35, p<.05.

Phonological sensitivity contributes unique variance in older Mandarin-speaking children (see Study 1) and in Mandarin-speaking adults (Study 2), suggesting a unique and dissociable role for epilinguistic sensitivity separate from metalinguistic awareness, working memory, and rapid naming. Furthermore, the importance of phonological sensitivity in Mandarin speakers appears to be restricted to more fluent readers (i.e., older children with some literacy training and adults). In order to examine whether the relationship between sensivity and reading ability in proficient adult readers is specific to the degree of fluency, I next conducted two stepwise regressions predicting reading fluency where (like above) I alternated the order of entry of sensitivity and the other phonological processing measures, elision, working memory, and rapid naming.

In Table 3.7, the hierarchical linear regression results for reading fluency for English-speaking adults are shown and in Table 3.8 the linear regression results for reading fluency for Mandarin-speaking adults are shown. It is notable, that none of the phonological variables, not sensitivity, awareness, working memory, or rapid naming, contributed unique variance to explaining differences in reading fluency for either the English- or Mandarin-speaking groups. These results suggest that the importance of phonological sensitivity in beginning and more fluent Mandarin-speaking readers is not due to an effect of fluency.

Alternatively, it is possible that in Mandarin speakers the seeming "increase"[35] in the relationship between phonological sensitivity and reading coincident with an increase in reading proficiency can be explained by decoding automaticity but not reading fluency per se, a distinction to my knowledge not researched in the reading literature. In order to test this possibility, I conducted a third series of stepwise regressions parallel to those represented in Tables 3.5 – 3.7 where I used decoding reaction time (the average speed of response per item on the single-word-reading task, with outliers and inaccuracies removed) as the dependent variable. The results suggest that there is indeed an important distinction between the current measures of decoding fluency and reading fluency, a distinction that is meaningfully related to the relationship between phonological sensitivity and reading ability. In English-speakers, only rapid naming was significantly related to decoding fluency, $\beta=.29$, $p<.05$. In Mandarin-speakers, rapid naming also was significantly related to decoding fluency, $\beta=.38$, $p<.05$, when entered in the last step with working memory and elision after phonological sensitivity. However, phonological sensitivity was significantly predictive of decoding fluency as well, $\beta=.52$, $p<.05$, when

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[35] This is not a longitudinal study so any claims of growth or attenuation over time are made with the implicit understanding that the suggestive longitudinal trends may be completely due to differences in samples, and so I urge the reader to read these alternative suggestions with this understanding constantly in mind.

itself entered in the last step. These results offer support for the validity of the finding of a relationship between phonological sensitivity and reading in the Mandarin-speaking adults and argue against a spurious effect due either to the small sample or the near-ceiling performance in accuracy on the single-word-reading task. Furthermore, these results offer support for the ‘automaticity’ explanation proposed above, although revealing an interesting, and potentially informative distinction between decoding automaticity and reading fluency. An interesting next step would be to explore the role of specific properties of Mandarin Chinese that may account for the language-specific relationship between sensitivity and reading or the specific properties of reading development and decoding fluency but not reading fluency that produce the suggested strengthening of the relationship between sensitivity and reading ability in Mandarin speakers.

Table 3.7 Linear regression equations predicting reading fluency in adult English-speakers.

Phonological Sensitivity entered after Phonological Awareness

	β	t	r^2	Δr^2
Step 1			.13*	
Nonverbal IQ	-.02	-.16		
Vocabulary	.27	2.87**		
Morph Production	-.01	-.09		
Step 2			.15	.02
Rapid Naming	-.11	-.80		
Digit Span	-.00	-.02		
Elision	.08	.59		
Step 3			.16	.01
Sound Sensitivity (RTs)	.08	.58		

Phonological Awareness entered after Phonological Sensitivity

	β	t	r^2	Δr^2
Step 1			.13*	
Nonverbal IQ	-.02	-.16		
Vocabulary	.37	2.87**		
Morph Production	-.01	-.09		
Step 2			.13	.00
Sound Sensitivity (RTs)	.01	.07		
Step 3			.46	.02
Rapid Naming	-.15	-.97		
Digit Span	-.01	-.06		
Elision	.09	.66		

Note: Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
*$p<.05$, **$p<.01$, ***$p<.001$.

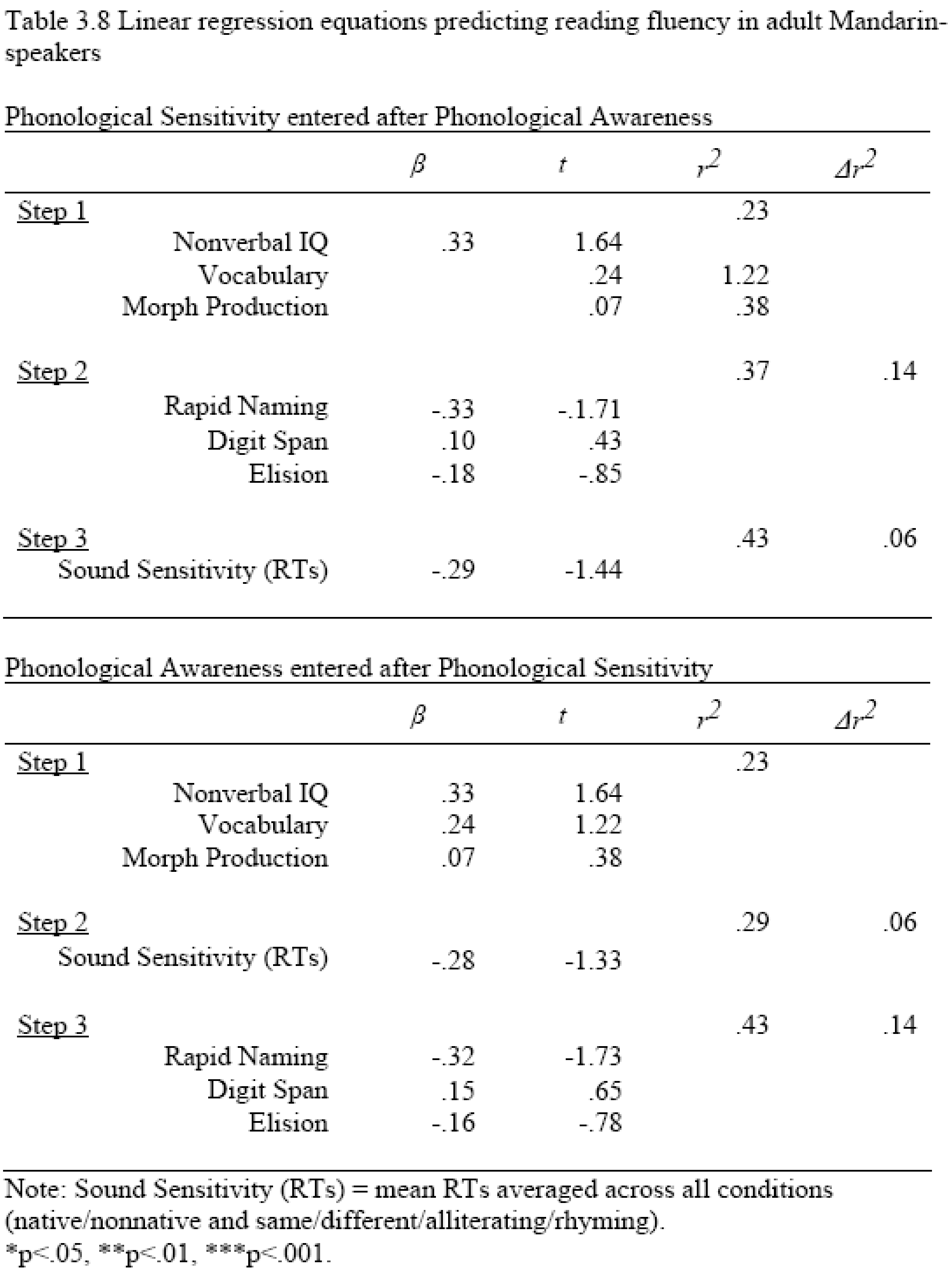


Table 3.8 Linear regression equations predicting reading fluency in adult Mandarin-speakers

Phonological Sensitivity entered after Phonological Awareness

	β	t	r^2	Δr^2
Step 1			.23	
Nonverbal IQ	.33	1.64		
Vocabulary		.24	1.22	
Morph Production		.07	.38	
Step 2			.37	.14
Rapid Naming	-.33	-.1.71		
Digit Span	.10	.43		
Elision	-.18	-.85		
Step 3			.43	.06
Sound Sensitivity (RTs)	-.29	-1.44		

Phonological Awareness entered after Phonological Sensitivity

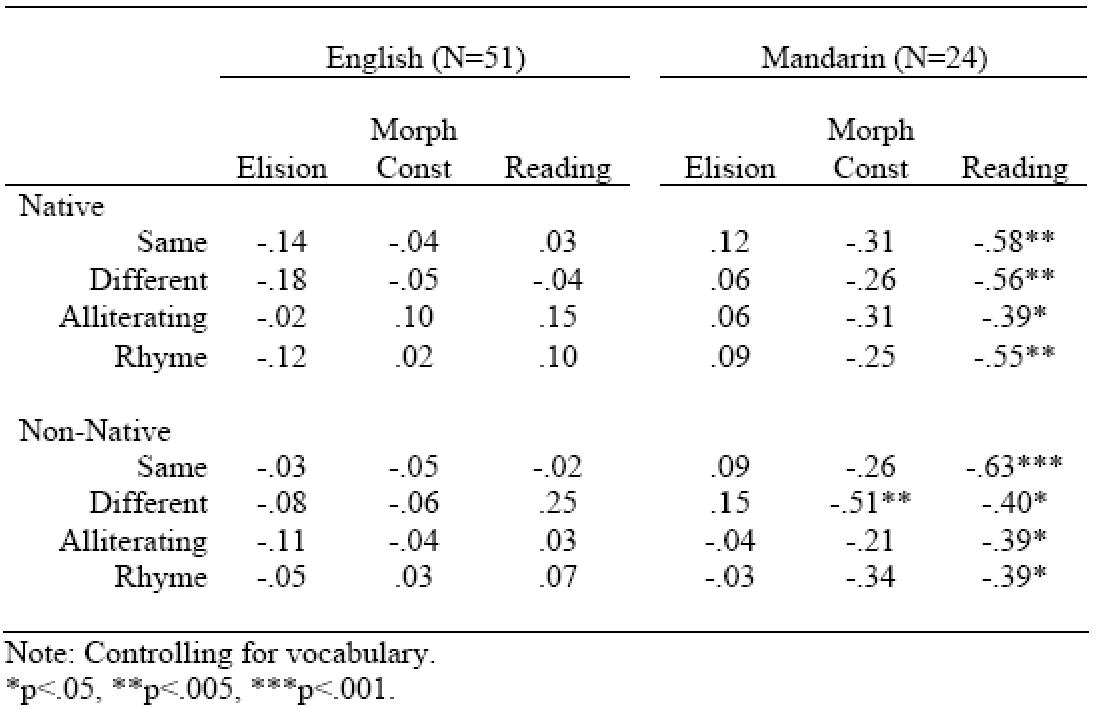
	β	t	r^2	Δr^2
Step 1			.23	
Nonverbal IQ	.33	1.64		
Vocabulary	.24	1.22		
Morph Production	.07	.38		
Step 2			.29	.06
Sound Sensitivity (RTs)	-.28	-1.33		
Step 3			.43	.14
Rapid Naming	-.32	-1.73		
Digit Span	.15	.65		
Elision	-.16	-.78		

Note: Sound Sensitivity (RTs) = mean RTs averaged across all conditions (native/nonnative and same/different/alliterating/rhyming).
$*p<.05$, $**p<.01$, $***p<.001$.

Is the relationship between phonological awareness and reading specific to language learned?

The word pairs in the phonological sensitivity task were designed to test the importance of three contrasts: What is the effect of (i) the degree of overlap (i.e., Rhyming word pairs contain more phonological overlap than Different word pairs), (ii) the position of overlap (i.e., in the Alliterating word pairs, the overlap of phonological information is in the word initial position), and (iii) the familiarity of the word pairs (i.e., native and non-native words) in the relationship between the phonological sensitivity task and reading ability. Table 3.9 presents the correlations between the conditions of the sound sensitivity task and elision, morphological production, and single word reading after controlling for vocabulary (as a proxy for verbal IQ). For English speakers, there were no significant relationships between any of the conditions of the sound sensitivity task and reading and reading-related measures. In contrast, the Mandarin speakers demonstrated strong correlations between all conditions of the phonological sensitivity task and single word reading. Thus, there was no effect of any contrast on the relationship between low-level phonological sensitivity and reading ability, suggesting that it was a general sound sensitivity that was related to reading ability in the Mandarin-speaking participants.

Table 3.9 Simple correlations of reading and reading-related measures with phonological sensitivity (Overall RTs) by condition for adults



	English (N=51)			Mandarin (N=24)		
	Elision	Morph Const	Reading	Elision	Morph Const	Reading
Native						
Same	-.14	-.04	.03	.12	-.31	-.58**
Different	-.18	-.05	-.04	.06	-.26	-.56**
Alliterating	-.02	.10	.15	.06	-.31	-.39*
Rhyme	-.12	.02	.10	.09	-.25	-.55**
Non-Native						
Same	-.03	-.05	-.02	.09	-.26	-.63***
Different	-.08	-.06	.25	.15	-.51**	-.40*
Alliterating	-.11	-.04	.03	-.04	-.21	-.39*
Rhyme	-.05	.03	.07	-.03	-.34	-.39*

Note: Controlling for vocabulary.
*p<.05, **p<.005, ***p<.001.

In the Chapter 1, I proposed to test whether the relationship between phonological sensitivity and reading ability was specific to language experience by exploring whether processing sounds that were familiar compared to sounds that were not familiar would produce measurable differences in the relationship between phonological processing and reading ability. I suggested that this comparison would provide an interesting test of the phonological representation hypothesis (Walley, 1993), a theory that argues that the degree of well-formedness of an individual's underlying phonological representations is the causal mechanism beneath the relationship between phonological awareness and reading. Unfortunately, as noted in Study 1, the task design of the phonological sensitivity task did not allow for the appropriate comparisons to test the representation hypothesis, i.e., processing of familiar phonological information compared to processing of unfamiliar phonological information. Instead, the design used native and non-native word pairs that shared similar phonological information, but differed in lexicality, (i.e., native words were familiar words in the adult's lexicon and non-native were unfamiliar words) and thus tested the effect of lexicality, as opposed to the effect of language-experience.

In the current study, it is interesting, albeit not a good test of the phonological representation hypothesis (Walley, 1993), that the relationship between sound sensitivity and reading did not differ for processing of native versus non-native word pairs in the Mandarin-speaking adults. The lack of an effect of lexicality suggests that it is possible that the phonolgical judgment task is indeed a measure of low-level sensitivity at a sensory level. Alternatively, as noted earlier, Mandarin-speaking adults were less impaired processing non-native word pairs than English-speaking adults, a result similar to that found in the performance of the Mandarin-speaking children in Study 1. It is possible that Mandarin speakers (both children and adults) were processing the spoken word pairs at a sublexical level only, and thus not only didn't evidence a difference in lexicality in the performance on the phonological sensitivity task itself, but also did not demonstrate a differential relationship of word type (native/nonnative) and reading ability. Neuroimaging techniques are uniquely suited for teasing apart questions specific to level of processing, such as this. A future study of interest may be to compare neural components of processing of phonological sensitivity between English- and Mandarin-speaking adults to further explore differences in levels of processing and the relationship between these different levels of processing and reading ability across cultures.

Is the relationship between phonological awareness and reading specific to linguistic grain size?

The stepwise regressions (shown above) testing the contribution of phonological sensitivity and phonological awareness revealed that measures of phonological awareness were uniquely predictive of reading ability beyond measures of phonological processing and phonological sensitivity in Mandarin-speaking adults but not English-speaking adults. This result for the English-speaking adults is aligned with existing research suggesting attenuation in the predictive power of phonological awareness over time (e.g., Scarborough et al., 1998). In contrast, the continued predictive power of phonological awareness for Mandarin-speaking adults was unexpected given the literature (e.g., Read et al., 1986), but consistent with the results for older Mandarin-speaking children in Study 1. One reason for the potency of phonological awareness in predicting reading in our sample of Mandarin speakers may be due to the specific measure of phonological awareness that we created.

Prior research has argued that tasks requiring phoneme-level elision (particularly final and medial deletions) are not important for Chinese readers because (i) they don't predict reading (e.g., Siok & Fletcher, 2001), (ii) Chinese readers tend to perform remarkably poorly on them (Read et al., 1986), and (iii) they are not 'sensible' given the structural properties of the sound-symbol mappings of Chinese (McBride-Chang et al., 2004). In fact, the majority of cross-cultural research has either used measures of phonological awareness that differ for English and Mandarin speakers (McBride-Chang, Bialystok et al., 2004; McBride-Chang, Cho et al., 2005) or used only tasks that measure syllable (e.g., Chow et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang & Ho, 2005) and onset (initial phoneme) deletions (e.g., McBride-Chang, Bialystok, et al. 2004; Read et al., 1986). However, in the current study, we created an elision task designed to be tightly aligned across the English and Chinese versions using syllable and phoneme level deletions (as detailed in Study 1). In order to better understand the relationship between phonological awareness and reading demonstrated in the current sample of Mandarin-speaking adults, I conducted two types of analyses. First, I compared the performance of the English- and Mandarin-speaking adults on the different items of the phonological awareness task. Second, I compared the relationship between performance on the items of the phonological awareness task with reading ability in both language groups.

Table 3.10 shows the performance for each type of deletion reported as a raw score and as a percentage for English- and Mandarin-speaking adults. In order to compare performance across English and Mandarin speakers, I first performed a simple ANOVA using the percent correct for each level of the elision task. These results show that English- and Mandarin-speaking adults performed differently on four of the six types of item deletions. In order to explore these differences more fully, I examined the role of the position of the deletion (initial, medial[36], or final) and the level of deletion (syllable or phoneme) together with location of testing (Michigan or Beijing) in an omnibus repeated measures ANOVA using percent accurate.

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[36] Using the more difficult medial deletions (medial2), the common type of medial deletion task across languages.

Table 3.10 Adult performance on the elision task by type of item.

English-speakers (N=60)

Type of Elision	Mean (SD)	Range	ANOVA	*r*
Syllable [18]	16.83 / *94%* (1.08)	[13, 18]		.19
Onset [10][a]	9.78 / *98%* (.52)	[7, 10]	$F(1, 91)=.37$	.02
Medial [2]	1.12 / *56%* (.82)	[0, 2]	$F(1, 91)=.30.69$***	.26*
Final [6]	5.91 / *99%* (.29)	[5, 6]	$F(1, 91)=4.18$*	-.06
Phoneme [49, 36]	37.77 / *77%* (4.49)	[24, 26]		.40***
Onset [16, 19]	14.34 / *90%* (1.45)	[11, 16]	$F(1, 89)=27.21$***	.45***
Medial [11, 0]	8.09 / *74%* (2.49)	[0, 11]	N/A	.47***
Medial 2[8, 6]	3.08 / *39%* (1.68)	[0, 8]	$F(1, 89)=16.50$***	.11
Final [14, 11]	12.23 / *87%* (1.68)	[7, 14]	$F(1, 89)=3.50$	-.17

Mandarin-speakers (N=24)

Syllable [18]	17.41 / *97%* (1.25)	[12, 18]		-.06
Onset [10][a]	9.70 / *97%* (.72)	[7, 10]		.01
Medial [2]	2.00 / *100%* (.00)	[0, 2]		N/A
Final [6]	5.70 / *95%* (.67)	[5, 6]		.00
Phoneme [49, 36]	25.89 / *72%* (5.06)	[12, 32]		.28
Onset [16, 19]	14.72 / *77%* (2.25)	[11, 16]		.01
Medial [11, 0]	N/A	N/A		N/A
Medial 2 [8, 6]	3.71 / *62%* (1.71)	[0, 8]		.09
Final [14, 11]	9.12 / *83%* (1.68)	[7, 14]		.13

[a]: number of items for each task are presented in brackets next to the item type.
Medial 2= the harder medial items requiring deletions from dipthongs, tripthongs, and affricates.
Where item number differs by sample, we reported as [English, Mandarin].
Reported partial correlations controlling for vocabulary knowledge.

The repeated measures ANOVA revealed a significant effect of location of testing, $F(1, 84)=11.46$, $p<.001$. A post-hoc test of means showed that overall Mandarin speakers performed better than English speakers (M= 77.98 and M=85.77, respectively). However, the difference appeared to be located in the near-ceiling performance on syllable awareness items of the Mandarin speakers, scores that were significantly (12%) higher than those of the English speakers, $p<.001$ Bonferroni adjusted. Mandarin speakers also performed better overall (but not significantly) on the phoneme deletion items, M= 71.81 for Chinese and M=74.50 for English, although much of the difference was due differences in the medial phoneme position. There was also a significant effect of level (syllable and phoneme), $F(1, 84)=124.81$, $p<.001$ and a significant effect of position (initial, medial, or final), $F(1, 84)=77.20$, $p<.001$. Post-hoc test of means revealed that for adults syllable awareness was easier than phoneme awareness and medial deletions were significantly harder than initial or final deletions, $ps<.001$, Bonferroni adjusted. These results are similar to the findings for Mandarin- and English-speaking children who also showed an overall effect of type and position, with syllables being easier than phonemes, and medial position deletions being harder than onset or final deletions. Thus, there is consistency across development suggesting a universal degree of difficulty in type (syllable or phoneme) and position (initial, medial, and final) of phonological deletions.

In the Mandarin- and English-speaking adults, there was also a significant 3-way interaction between location of testing, level of elision and position of deletion, $F(2, 168)=236.17$, $p<.001$. A post-hoc test of means revealed that the interaction appeared to be located in the Chinese adults' performance on the syllable task. Both English and Mandarin speakers demonstrated a significant effect of the medial position in the phoneme task, and the English-speaking adults demonstrated an identical effect in the syllable task, but the Chinese adults did not demonstrate any significant differences between positions of the items, a fact that could be ascribed to the near-ceiling performance of this group on syllable deletions. Thus, the repeated measures ANOVA revealed that although Mandarin speakers demonstrated significantly higher performance overall on the syllable items, and higher, but not significantly higher performance on the phoneme items than the English speakers, the pattern of performance for these two groups was the same on the phoneme elisions items. The next question I investigated was whether the pattern of performance on the items was related to reading depending on the type or position of the deletion in both samples.

Table 3.10 also shows the correlations between the item type and reading after controlling for vocabulary. In Mandarin speakers, there were no significant relationships between the syllable or phoneme deletion items and reading. In contrast, phoneme initial and phoneme and syllable medial deletions were significantly related to performance in the English-speaking adults. Thus, there appears to be a different relationship between phonological awareness and reading depending on language learned. Although Mandarin- and English-speaking adults perform similarly on the phoneme deletions, their performance is differentially related to reading ability.

To date, little research has explored phonological awareness in English-speaking adults (e.g., ref) or Mandarin-speaking adults (e.g., Holm & Dodd, 1996; Read et al., 1986), and the few studies that have, have found inconsistent results suggesting that phonological awareness may not be relevant or even accessible in skilled adult readers in either language. However, the current results provide interesting insight into similarities and differences between English- and Mandarin-speaking adults on measures of phonological awareness and the relationship between phonological awareness and reading ability.

First, it is interesting that both syllable and phoneme-level deletions are correlated with reading ability in English-speaking adults. Thus, it is clear that English-speaking skilled readers can in fact perform phonological awareness tasks (contrary to some research, e.g., Scholes, 1995) and that individual differences in ability to perform these tasks is significantly related to individual differences in reading ability. However, as noted in the stepwise regression (see Table 3.5), phonological awareness is not a unique predictor of reading ability in English-speaking adults after controlling for other measures of phonological processing. This finding suggests that although phonological awareness is correlated with reading, other measures of phonological processing (working memory and rapid naming) are more important in predicting unique variance in skilled readers than phonological awareness. In sum, contrary to some claims in existing research (e.g., Scarborough, et al., 1998), English-speaking adults exhibit both syllable and phoneme-level awareness and this awareness is related to reading, just not as strongly as other measures of phonological processing.

Second, it is interesting that Chinese adults are able to perform syllable and phoneme elisions, and at levels higher than English-speaking adults (although primarily on syllable level items and on phoneme medial items). However, the Chinese adults' item-level performance is unrelated to reading ability. This contradicts the results of the stepwise regression (see Table 3.6) demonstrating that phonological awareness emerges as a significant predictor of reading after controlling for phonological sensitivity. One explanation for the lack of predictive power at the item-level may be due to the small sample size and the small number of items in each condition. I repeated the stepwise regression, controlling for measures of nonverbal and verbal IQ, phonological processing and low-level sensitivity, and entered the average score on all phoneme-level items and the average score on the syllable items. These analyses revealed that phoneme-level awareness was a unique predictor of reading ability, $\beta=.64$, $p<.05$, whereas syllable level awareness was not. These findings suggest that indeed phoneme-level awareness continues to be a predictive component skill in Chinese adults. Furthermore, these findings suggest developmental continuity in the role of phonological awareness and reading ability from older Mandarin-speaking children to skilled adult readers. However, like for the English-speaking children and adults, it appears that the relationship between phonological awareness and reading may be weakened over development coincident with a strengthening of other variables in skilled readers (i.e., phonological sensitivity in Mandarin-speaking adults and phonological working memory and rapid naming in English-speaking adults).

The results presented here demonstrate interesting and somewhat unexpected findings regarding the role of phonological processing skills in skilled adult readers. In the introduction of this chapter, I proposed to investigate the components identified as important in emergent reading, in a sample of skilled adult English- and Mandarin-speaking readers. I argued that although an atypical research question, there was enough evidence that i) phonological skills are important in fluent reading, ii) the importance of these skills may differ depending on language learned, and iii) depending on the level of reading proficiency to merit the current investigation in skilled adult readers. Furthermore, I proposed that the only way to truly understand the development of reading is to compare models of reading across development. In order to achieve this goal, I proposed to investigate three questions tailored to provide insight into the role of phonological awareness across language systems and across different levels of reading development. First, I explored whether the relationship between phonological awareness and reading ability was specific to the level of processing. Interestingly, phonological sensitivity predicted unique variance beyond measures of phonological awareness, only in Mandarin-speaking adults. Furthermore, this finding demonstrated a potential continuity and possible strengthening of the relationship first evidenced in the older Mandarin-speaking children, a trend possibly explained by an increase in decoding fluency, but not overall reading fluency. These findings suggest that low-level phonological sensitivity may be an important and dissociable construct from higher-level phonological awareness in nonalphabetic orthographies, but that the importance of this skill for predicting reading may depend on the age and reading level. Future research is needed however to understand *why* there are both language and reading level effects on the relationship between phonological sensitivity and reading.

The second question I examined was whether the relationship between phonological sensitivity and reading was specific to an individual's language experience. The results demonstrated that for Mandarin speakers the native/non-native condition made no difference to the relationship between low-level phonological sensitivity and reading (there was no relationship between any measures of the phonological sensitivity task and reading in English-speaking adults). Although unrelated to reading, there was evidence that Mandarin speakers are able to process non-native contrasts better than English speaker, a finding that I suggest may be due to exposure differences or to underlying differences in spoken word processing (e.g., Chen & Shu, 2001).

The third question I examined was the way in which phonological awareness was related to reading ability across the two samples by comparing performance on the items in the phonological awareness task. We designed a phonological awareness test that measured both syllable- and phoneme-level skills. Although existing research has argued against using phoneme awareness tasks with English and Mandarin skilled adult readers (e.g., Scarborough et al., 1998; McBride-Chang, Cho, et al, 2005), the results from the current study suggest otherwise. First, both English- and Mandarin-speaking adults were able to perform phoneme and syllable-level deletions, although performance varied significantly by position of the deletion and by language group. Furthermore, in English speakers, the position and type of phoneme deletion was significantly related to reading, although overall phonological awareness was not related to reading ability after controlling for other phonological processing measures. In Mandarin speakers, there was no relationship between the specific types of items on the elision task and reading ability, although there was a significant relationship between overall phoneme-level deletions and reading ability after controlling for measures of phonological processing. In sum, these analyses have identified several unique and interesting findings that provide insight into *which* phonological skills are related to reading and potentially *how* they are related to reading.

Discussion

In the current study I explored the role of phonological processing in predicting performance differences in English- and Mandarin-speaking adult fluent readers. Few studies investigate phonological predictors of reading in adults, and particularly not in proficient adult readers. Primarily this is because interest lies in identifying measures that predict emergent reading ability, particularly at the decoding level (but see Cain & Oakhill, 2007). However, a second reason for overlooking adults is that many of the measures used with children have limited, if any, predictive power for adults (e.g., Scarborough et al., 1998), although this may be a byproduct of ceiling effects (e.g., Bus and van IJzendoorn, 1999; Wagner et al., 1997). Our data suggest that it is in fact possible to devise effective measures of reading-related skills in both English- and Mandarin-speaking adult populations.

With a few exceptions, the measures I administered did not demonstrate ceiling effects even in a highly educated and extremely literate sample, and showed moderate to good alpha levels suggesting the validity of the changes I made. This is particularly notable for the elision task where the items that were most strongly correlated with single-word reading for English-readers were those we added to increase the difficulty of the measure (medial and cluster deletions). Furthermore, the descriptive results of the behavioral battery demonstrated either general congruence between the samples in performance (e.g., blocks) or performance differences in the direction anticipated due to linguistic differences in the stimuli (e.g., digit span and rapid digit-naming). The measures also demonstrated within sample intercorrelations predicted by the literature (e.g., McBride-Chang & Ho, 2000; Wagner & Torgesen, 1987). For example, the phonological processing items were moderately to highly intercorrelated and vocabulary was related to reading for both languages.

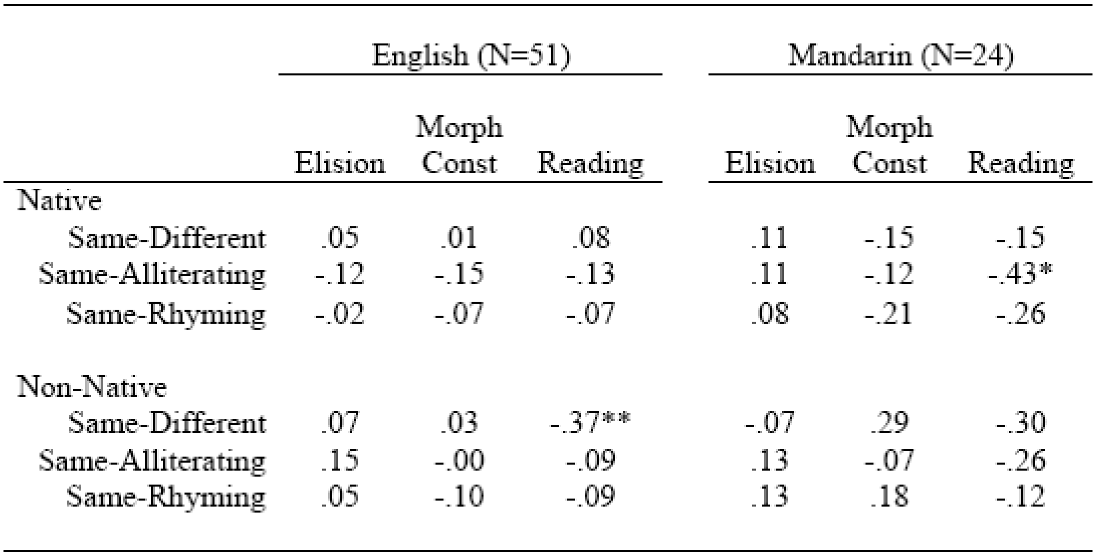
Since the overarching goal of our paper was to identify similarities and differences in the models of reading for English and Chinese adults, I turn now to focus on three questions. First, 'Are the phonological processes of reading the same across different linguistic and orthographic systems?' Specifically, I examined the three questions outlined in the introduction: Is the relation between phonological awareness and reading specific to i) level of processing, ii) language experience, and iii) linguistic grain size. I then take a step back and compare reading models across languages. To do this I ask, 'Are the processes of reading in fluent readers the same across different linguistic and orthographic systems?' When I explored these questions in two languages with different sound-symbol relationships, I found both expected and unexpected answers.

Is the relationship between phonological awareness and reading specific to level of processing?

There are important differences in the relative contributions of phonological sensitivity and awareness to predicting reading in English- and Mandarin-speaking skilled adult readers. In English speakers, measures of phonological sensitivity (whether measured as a general sensitivity or sensitivity by condition) were unrelated to reading or reading-related measures, except for rapid naming. Furthermore, in a stepwise regression predicting reading where entry of phonological processing skills and phonological sensitivity were alternated, neither phonological sensitivity nor phonological awareness significantly improved the fit of the model beyond the contributions of phonological working memory and rapid naming. In fact, phonological sensitivity and awareness combined explained only an additional 2% of the variance in single-word reading for English-speaking adults.

In contrast, in Mandarin-speaking adults, both phonological sensitivity and phonological awareness contributed unique variance to single-word-reading, explaining nearly 35% of the variance in the decoding measure. In simple correlations, phonological awareness was significantly correlated with digit span (r=.48), and showed a strong, but not significant relationship (r=.24) with single-character-reading. However, when entered into the stepwise regression, phonological awareness became a significant predictor after entering phonological sensitivity into the model. This suggests that phonological awareness (as measured by our elision task) is a weakly-related predictor of reading that shares error variance with phonological sensitivity for Mandarin-speaking adults. Not only does this underscore the importance of measuring both low- and high-level sensitivity, but it also suggests an independent role of phonological sensitivity and higher-level phonological awareness, an independence that should not be overlooked particularly when testing in different languages.

Table 3.11 Simple correlations of reading and reading-related measures with phonological sensitivity (Difference in RTs) by condition for adults



	English (N=51)			Mandarin (N=24)		
	Elision	Morph Const	Reading	Elision	Morph Const	Reading
Native						
Same-Different	.05	.01	.08	.11	-.15	-.15
Same-Alliterating	-.12	-.15	-.13	.11	-.12	-.43*
Same-Rhyming	-.02	-.07	-.07	.08	-.21	-.26
Non-Native						
Same-Different	.07	.03	-.37**	-.07	.29	-.30
Same-Alliterating	.15	-.00	-.09	.13	-.07	-.26
Same-Rhyming	.05	-.10	-.09	.13	.18	-.12

Note: Controlling for vocabulary.
*p<.05, **p<.01, ***p<.001

In contrast to phonological awareness, the role of phonological sensitivity in predicting fluent reading in Mandarin speakers is strong. In the current study, measures of phonological sensitivity (overall sound sensitivity and sensitivity by condition) were the strongest predictors of individual differences in single-character reading, showing extremely high correlations and explaining nearly 25% of the overall variance. Furthermore, the relationship in the Chinese sample was not limited to the condition; prime type (Same, Different, Alliterating, or Rhyming) or native vs. non-native. For Mandarin readers, all pair types were significantly correlated with reading. Interestingly, the Rhyming and Alliterating conditions showed weaker correlations than the Same and

Different conditions with reading. Table 3.11 presents the correlations between single word reading and reaction times relative to baseline (Same) in the phonological sensitivity task. It is notable that the power of the relationship between the conditions of the phonological sensitivity task and reading is attenuated when compared to a baseline, suggesting that the baseline performance is the driver in the relationship and not the different patterns in performance specific to the degree of phonological overlap. This finding suggests that the current phonological sensitivity task may in fact measure a very general ability to discriminate sounds without any specific relationship to a level of awareness of the segmented components of a syllable, a skill that in general has seemed relatively unimportant in both the literatures on English and Chinese reading ability, and that appears irrelevant to predicting reading in adult fluent English-speaking readers in the current study. These findings then raise the question, 'What is it about a general ability to discriminate sounds that appears so important for Chinese readers in the current study, but not for English readers?'

Is the relationship between phonological awareness and reading specific to language learned?

In the current study, the low-level phonological sensitivity task produced surprising, but theoretically intriguing results. For English speaker, neither measures of low-level sensitivity of native or non-native word pairs were related to single word reading. Given the research on reading development, it is not surprising that sensitivity did not contribute to predicting reading ability beyond measures of awareness, but it is surprising that there was no relationship at all between phonological sensitivity and reading alone. Unlike the current findings, when measuring phonological sensitivity in isolation, both cross-sectional and longitudinal studies with English-speaking children demonstrate a correlation with reading ability (Hulme et al., 2002; McBride-Chang, 1995; Muter et al., 1998; Scarborough, 1990, 1991).

In contrast for Mandarin-readers, both native and non-native words (composed of familiar phonemes) were significantly correlated with reading. Researchers have suggested that measures of low-level phonological sensitivity may be tapping the degree of specificity or well-formedness of a child's phonological representations (Fowler, 1991; Swan & Goswami, 1997). Many children who demonstrate difficulty reading are those children who demonstrate poor low-level phonological sensitivity, and may therefore have poorly-formed phonological representations (e.g., Elbro, 1996; Elbro, et al., 1998; Elbro, Nielsen, & Peterson, 1994; Morais, 2003; Walley et al., 2003; Wesseling & Reitsma, 2001; although see Foy & Mann, 2001). However, unfortunately, the final design of the phonological sensitivity task precluded a strong test of the phonological representation hypothesis.

Is the relationship between phonological awareness and reading specific to linguistic grain size?

It has long been argued that phoneme-level awareness is not only extremely difficult for individuals without some form of alphabetic training (e.g., Morais, Alegria, & Content, 1987; Read et al., 1986; Scholes, 2005), but completely unrelated to predicting reading in nonalphabetic orthographies (e.g., Siok & Fletcher, 2001; Shu et al., submitted; McBride-Chang, Cho, et al., 2005). In the current study, an item-analysis of the phonological awareness task revealed several important findings about the relationship between phoneme-level awareness and reading ability in Chinese.

The item analysis confirms that (i) Mandarin-speaking skilled adult readers demonstrate phoneme-level awareness, and (ii) that this awareness is similar to that demonstrated by English-speaking skilled adult readers. However, whereas phoneme-level awareness was correlated with reading in English speakers, there was no significant relationship between phoneme-level awareness at an item level and reading ability in Mandarin speakers. Nonetheless, an additional stepwise regression demonstrated that the lack of correlation between the phoneme items and reading in Mandarin may be due to a lack of power. In the stepwise regression, average phoneme-level awareness in Mandarin-speaking skilled adult readers was significantly related to reading ability. These findings suggest that phoneme-level awareness is an important and interesting construct even in skilled reading that demonstrates important similarities and differences across languages and across development.

Are the processes of reading in fluent readers the same across different linguistic and orthographic systems?

In the current study, I compared reading models for adult English and Mandarin speakers. In these models, I tested the relative contribution of a series of skills shown in the literature to be related to reading ability (phonological sensitivity, phonological awareness, working memory, rapid naming, morphological awareness, and verbal and nonverbal IQ). Overall, the reading models I tested fit relatively well, explaining 40% of the variance in reading ability for English speakers and nearly 60% of the variance for Mandarin speakers. Not only did the models fit within a language, but the amount of variance explained is roughly equivalent across languages and is comparable to what has been found in the research for both English and Chinese children (Wagner et al., 1997; Chow et al., 2005). However, there are important differences between languages in the composition of the models.

For English-speaking adults, phonological processing skills as measured by tests of elision, digit span and rapid naming explained 33% of the variance in reading ability even after controlling for morphological construction, verbal and nonverbal IQ. Some research has suggested that the predictive power of phonological awareness is limited to children and further, that this skill may be inaccessible for adults (e.g., Scarborough et al., 1998). Our data show a weaker relationship in the predictive power of phonological awareness for reading relative to that found in the literature for children, but argue against omitting this variable as a factor in adult reading studies of decoding. In the current sample of fluent English-speaking adult readers, measures of phonological awareness showed high correlations with phonological processing measures and reading ability, and a marginally significant relationship with reading after controlling for other phonological processing measures ($\beta=1.64$, $p=.11$). Interestingly, rapid naming and digit span were stronger predictors of reading ability than phonological awareness (although demonstrating comparable distributional features and reliability). This finding may be related to both age-specific (e.g., Baltes, 1997; Kail, 1991; Siegler, 1998) and fluency-related (e.g., Ardila, Ostrosky-Solis, & Mendoza, 2000; Ardila, Rosselli, & Rosas, 1989; Petersson, Reis, & Ingvar, 2001) changes in overall cognitive processing and how these manifest in reading ability.

In the Chinese sample, measures of phonological sensitivity and phonological processing explained roughly 35% of the variance in single-word reading. This result is generally comparable to, if not higher than, the standard models for Chinese emergent readers (Leong et al., 2005; McBride-Chang & Ho, 2005). However, this is where the similarity with existing research ends. In the current Chinese sample, both rapid naming and morphological construction, measures found to be highly predictive of reading ability and disability in Chinese (e.g., McBride-Chang & Ho, 2005; McBride-Chang et al., 2005), were uncorrelated with fluent reading and failed to significantly improve the fit of the reading models in the current study. Instead, measures of phonological sensitivity and phonological awareness predicted unique variance in reading ability in this adult sample after controlling for other phonological processing skills, morphological construction, verbal and nonverbal IQ. The majority of the explanatory power in the reading model (26% of the variance) was derived from phonological sensitivity, a measure that when investigated in Mandarin emergent readers generally shows no predictive power beyond measures of awareness (e.g., Leong et al., 2005; McBride-Chang & Ho, 2000; McBride-Chang et al., 1997; Scarborough et al., 1998). However, our current findings also suggest a role of phoneme elision in predicting reading for Chinese-speaking adults that emerges only when simultaneously controlling for a general sound sensitivity. When phonological awareness was entered alone, in the last step of the regression model, it explained nearly 9% of the variance in single word reading after controlling for all other reading-related measures.

These results are striking for both what they show and what they do not show. As predicted for adult readers, the models of reading appear similar cross-linguistically, but the weight of the predictors varies systematically depending on the language (see Zhou & Marslen-Wilson, 1999a, 1999b). However, the importance of the phonological predictors for Mandarin-readers is unexpected and noteworthy. In particular, the sound-symbol mappings of Mandarin Chinese do not suggest an obvious need for ‘a sensitivity to and awareness of the sounds within a word’ in order to learn to read. What’s more, the contribution of measures of phonological sensitivity and awareness to emergent reading is often eclipsed by measures of morphological construction (e.g., McBride & Shu, 2006). Thus, our findings suggest a hitherto unexpected importance of phonological information in predicting adult fluent reading in Chinese.

Conclusion

The results from our analyses demonstrate that it is possible to find interesting, meaningful, and possibly theoretically important findings in adult proficient readers. In the current study, phonological sensitivity and phonological awareness were strongly predictive of reading differences for Chinese readers, whereas for English readers, higher-level components of phonological processing (working memory and rapid naming) were the only predictors of reading ability. It is possible that there are specific aspects about the way in which sounds map to symbols in these two languages that demand these different relationships. However, given that this was an unexpected finding, our current study is not designed to address this question. Regardless, our data do suggest a role for phonological sensitivity in traditional measures of phonological processing that should not be overlooked, particularly when testing in different languages, where, like Chinese, sensitivity may play a more important role than it does for English. Furthermore, the dependence of phonological awareness on sensitivity underscores the importance of dissociating sensitivity from awareness as independent constructs for predicting reading. Given these results, I advocate for a more language-universal conceptualization of phonological processing containing four skills: phonological sensitivity, awareness, working memory, and rapid processing.

Chapter 4: General Discussion

In the introduction, I proposed using a cross-cultural developmental design to explore *which* components of phonological awareness were related to reading in order to gain insight into *how* phonological awareness was related to reading. This design required comparing reading models across languages and across development. In both the child and adult studies, I was specifically interested in exploring three questions: (i) Is the relationship between phonological awareness and reading ability specific to the level of processing, (ii) Is the relationship between phonological awareness and reading ability specific to language-experience, and (iii) Is the relationship between phonological awareness and reading ability specific to the linguistic grain size? In the next section, I briefly review the major findings specific to each of these questions and then proceed to compare models highlighting the specific effects of language and development on the underlying mechanisms of reading. I then situate these findings in the context of existing research and larger research questions and end with a few suggestions for future directions.

Summary of Results

In my dissertation, I present findings from two studies, one with 4- to 8 year-old children and the other with college-age adults in the U.S. and in China. In total, roughly 250 English- and Mandarin-speaking children and adults participated in our two-part study designed to assess reading and reading-related measures. The first part of the study used an epilinguistic task of phonological judgment to measure the importance of differences in phonological sensitivity by comparing accuracy and speed of processing of familiar and unfamiliar (native, nonnative) word pairs with differing degrees and positions of phonological overlap (Same, Different, Alliterating, and Rhyming). The second part used an adapted battery of measures selected as good predictors of reading in both English and Mandarin children (e.g., Wagner et al., 1997; McBride-Chang, Cho et al., 2005), to explore differences in the phonological and morphological correlates of reading ability across languages and development.

Overall, the results serve to replicate and extend existing research on the cross-cultural predictors of reading ability in English and Chinese (e.g., McBride-Chang & Kail, 2002; McBride-Chang, Cho et al., 2005). First of all, the measures we adapted generally (i) had good distributions within groups, (ii) showed similar performance across groups, and (iii) replicated the correlations found in existing research (e.g., Wagner et al., 1994; McBride-Chang & Kail, 2002). Thus, the tasks used appear to be good measures of the underlying constructs proposed. The noted exception to this is the measure of Digit Span which showed lower reliabilities in the English- and Mandarin-speaking children than anticipated and the receptive task of Morphological Construction which I did not use for any analyses also due to low reliabilities in both samples of children.

Collectively, the battery of measures we administered explained nearly 65% of the variance in reading ability in English-speaking children and nearly 75% of the variance in Mandarin-speaking children, proportions comparable (e.g., Lonigan, Burgess, & Anthony, 2000), and even higher than those typically found in the research (e.g., see Wagner & Torgesen, 1987), particularly for Mandarin-speaking children (e.g., McBride-Chang & Ho, 2005; Chow et al., 2005). Little research has explored the components of reading accuracy in fluent readers however; the variables in the reading model for the English-speaking adults explained nearly 50% of the variance and nearly 70% of the variance for Mandarin-speaking adults. Although there is a slight drop in these numbers compared to the children, the amount of variance explained in adults using measures that (i) are typically only used in children, and (ii) have been argued to be inaccessible to fluent readers (i.e., elision; e.g., Scarborough et al., 1998) is significant. These data suggest that individual differences in decoding persist across development, and in general reading performance in skilled adult readers can be explained by some of the same factors that explain individual differences in children. This finding sheds light on possible similarities in the mechanisms of reading in both beginning readers and in skilled readers, a point to which I return below.

In each study, the results were tailored to address the three specific questions raised in Chapter 1. Below, I review the results for each of these questions.

Is the relationship between phonological awareness and reading specific to the level of processing?

Prior research provides mixed evidence for the role of phonological sensitivity in predicting reading ability across development (e.g., Molfese et al., 2001) and across alphabetic and nonalphabetic languages (e.g., Chiappe et al., 2007). Thus, in the current work, I examined whether measures of phonological sensitivity would contribute to reading independent of measures of phonological awareness depending on the language or the level of reading ability. In concert with existing literature, I found that there was no relationship between the current measure of phonological sensitivity and reading ability in English-speaking children or adults (e.g., McBride-Chang, 1996). In English-speaking adults, the measure of sensitivity was unrelated to any of the measures of reading ability, except for rapid naming, a measure which shared a speeded component. However, in English-speaking children, the measure of sensitivity was significantly correlated with the measures of metalinguistic skills, i.e., alphabet sound knowledge, morphological construction, and elision. Moreover, there was a developmental shift in this relationship such that sensitivity was related to the larger-unit metalinguistic skills in the younger children (i.e., alphabet knowledge and morphological construction) and smaller-unit metalinguistic skills in the older children (i.e., elision), a shift that mirrors that seen in the literature with phonological awareness (e.g., Anthony & Lonigan, 2004). These findings suggest that the commonality among these tasks is sensitivity to differences in sound, or the parts of words (whether at the syllable, onset-rime, or phoneme level). Interestingly, this sensitivity, although clearly associated with phonological awareness and processing of phonological information, is not related to reading ability. Thus, in English speakers there is no evidence that epilinguistic measures of sensitivity are important in beginning or in skilled readers.

In stark contrast, general sensitivity contributed unique variance to explaining differences in reading ability in older Mandarin-speaking children and skilled adult Mandarin-readers beyond measures of phonological awareness. There are three elements to this finding that are noteworthy. First, it is interesting that this phonological sensitivity was not specific to discrimination of particular sound segments (i.e., Alliterating vs.

Rhyming), but appeared to be a more general sensitivity to phonological information as a whole. This was demonstrated in the consistent relationships between reading ability and all conditions of the sensitivity task for both the older Mandarin-speaking children and adults. This suggestion receives further support from the finding that in Mandarin-speaking adults, the relationships between the task conditions and reading ability were attenuated when the reaction times were subtracted from a baseline (the Same condition).

Second of all, there appears to be an interesting developmental relationship. The relationship between phonological sensitivity and reading only came online after formal reading instruction had started, in the older Mandarin-speaking children, suggesting that the process of learning to read in Chinese may impact a child's phonological sensitivity in important and meaningful ways. Existing research has demonstrated a bidirectional relationship between phonological awareness and reading in English (e.g., Burgess & Lonigan, 1998) and in Chinese readers (i.e., Huang & Hanley, 1997), but research has not yet tested the directionality of the relationship with phonological sensitivity. Moreover, the relationship between sensitivity and reading in Mandarin speakers appeared to 'strengthen' over development, such that in Mandarin-speaking adults, this variable alone accounted for 26% of the variance in single-character-reading, and was the single strongest predictor of individual differences in the reading model. In order to investigate whether the *suggested* developmental effect was in fact associated with an increase in automaticity of reading, I conducted a series of additional stepwise regressions specifically testing this in the adult sample of Mandarin speakers. Of interest, I found that phonological sensitivity was uniquely predictive of differerences in decoding speed, but not of differences in reading fluency. This finding has little precedent in the research, and thus at this point is but suggestive of a potential dissociation between single-word decoding fluency and reading fluency (a task which required speeded sentence verification). However, the specificity of the relationship between phonological sensitivity and decoding points to one interesting potential avenue for future research. An important question that comes out of this finding is what is it about acquiring decoding fluency that heightens the importance of phonological sensitivity in predicting reading ability in Mandarin Chinese?

Is the relationship between phonological awareness and reading specific to language experience?

In the literature on emergent reading in English-speakers, one approach has argued that the relationship between phonological awareness and reading lies in the degree of specification of an individual's phonological representations (e.g., Fowler, 1991; Metsala, et al., 2003; Elbro et al., 1998). In this dissertation, I proposed that an important test of this hypothesis was to examine whether the relationship between phonological awareness and reading is specific to processing of familiar compared to unfamiliar (or nonnative) phonological information. To test this question, I examined whether processing of native and non-native word pairs in the phonological sensitivity task would be differentially related to reading ability. The results showed that there was no demonstrated effect of language experience (i.e., native vs. non-native pairs did not differ in predictability) in the relationship between phonological sensitivity and reading ability across the U.S. and Chinese sample or across development. First of all, there was no relationship between phonological sensitivity and reading for either English-speaking children or adults. Furthermore, although there was a significant relationship between phonological sensitivity and reading ability beyond measures of phonological awareness in both older Mandarin-speaking children and skilled adult readers the relationship was consistent across native and nonnative pairs. These findings suggest that the relationship between phonological sensitivity and reading ability is not specific to one's phonological representations, at least in nonalphabetic orthographies.

However, this finding should be interpreted with caution. First, the phonological sensitivity task was only related to reading for older Mandarin-speaking children and adults. Thus, the conclusions about *reading* can only be drawn for these two samples of participants. Furthermore, the current design did not directly answer the proposed question for two reasons. First, I did not explore the impact of language-experience in phonological awareness tasks. Thus, conclusions can only be drawn for the relationship of sensitivity and reading, a relationship that is predictably absent in the English speakers (e.g., McBride-Chang, 1996). Second of all, in the phonological sensitivity task, we created native and non-native word pairs that shared similar phonological information, but differed in lexicality (i.e., native contrasts involved familiar words in the child's lexicon and non-native contrasts involved unfamiliar words). Thus, in fact, we measured an effect of lexicality, as opposed to an effect of language-experience per se. A stronger test of the phonological representation hypothesis (e.g., Walley, 1993) would be to create words pairs from phonological information familiar to one language, but not familiar to another. The current contrast between Mandarin and English affords the perfect opportunity to do this. For example, the English word /vɛrɪ/ is composed of phonemes and phonological combinations that are not used in Mandarin. The word /tʂu/ begins with a phoneme combination that is unfamiliar in the word initial position. It would be interesting to extend the current findings by exploring the role of native and non-native word pairs composed of words like this.

There was nonetheless, an interesting difference (unrelated to reading) in the processing of native and non-native pairs in the phonological sensitivity task between the English- and Mandarin-speaking children and adults that may provide insight in the underlying mechanisms used to perform this task. Overall, Mandarin speakers demonstrated less difficulty processing non-native pairs than the English speakers, a finding common across younger and older children and adults. Specifically, English-speaking children performed significantly worse on non-native Rhyming pairs than native Rhyming pairs whereas Mandarin-speaking children did not differ in their processing of native versus non-native Rhyming pairs. Similarly, English-speaking adults demonstrated a significant difference in processing of native and non-native stimuli in all three conditions (Different, Alliterating, and Rhyming), whereas the Mandarin speakers only demonstrated a difference in processing native and non-native stimuli in the Alliteration condition. Furthermore, there was a significant difference between Mandarin- and English-speakers in the difference between processing native and nonnative word pairs in the Different condition.

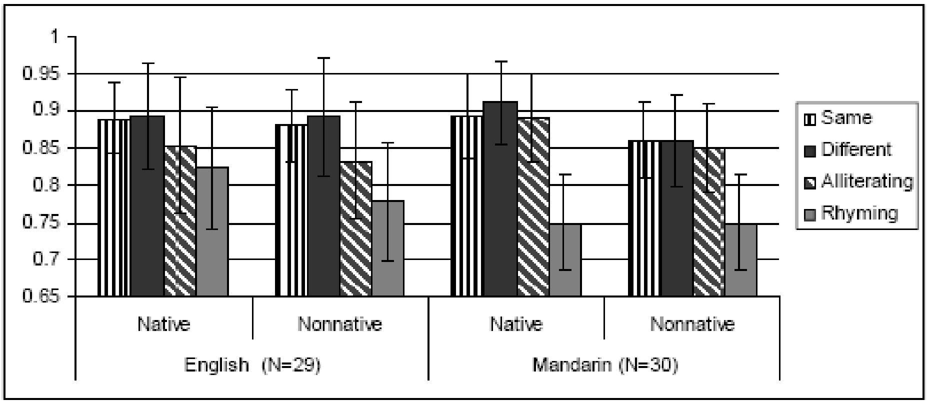
The overall slight advantage demonstrated by the Mandarin speakers when processing non-native word pairs is highlighted in Figure 4.1 where accuracy on the phonological sensitivity task by condition is presented for all four samples (although in Study 3, I report RTs for the adults due to near ceiling levels in accuracy). In this figure, one can see that performance on the native and non-native Rhyming pairs was more consistent in the Mandarin speakers than in the English speakers across development, and in fact, the Mandarin speakers sometimes showed an advantage in processing of Rhyming pairs. The most likely explanation of this finding is a difference in exposure to the non-native language. In Beijing, there is a much greater degree of English-print in the environment (whether on TV, on billboards, in stores or online). In contrast, in Ann Arbor, it is rare to see or hear any Chinese, beyond specialty cable stations, specialty food stores, and in the airport.

An alternative explanation, albeit it hypothetical, is that there was a difference in the manner in which Mandarin and English speakers performed the phonological sensitivity task (either consciously or unconsciously). Although there was no main effect of location of testing (US or Beijing) for the children using accuracy or for the adults using reaction times, this may not preclude different strategies or different mechanisms of processing. One possible (unconscious) processing difference could be that Mandarin speakers were relying on sublexical routes of processing and therefore did not demonstrate effects of lexicality, whereas, English speakers were relying on lexical routes of processing, and therefore demonstrated impaired performance for nonlexical items composed of familiar phonological information.

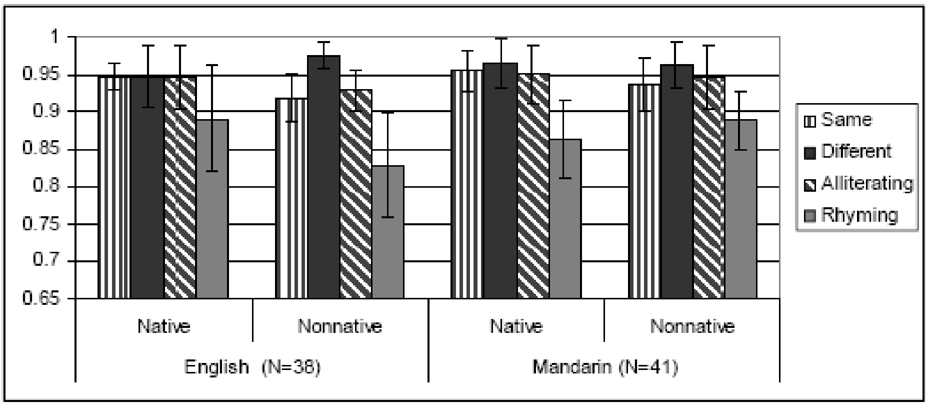
The current study provides preliminary evidence in support of the hypothesis that English and Mandarin participants may have processed the task differently. Specifically, in the adult study, when reaction times for each condition were considered relative to baseline (Same), English and Mandarin speakers demonstrated facilitative effects of Alliterating pairs and inhibitory effects of Rhyming pairs. However, in the non-native condition, English speakers failed to demonstrate these facilitative effects for the Alliterating condition whereas the Mandarin speakers maintained the effect. This could be because the English-speakers performance on the Alliterating conditions relied on lexical level support, in the form of facilitation from primed lexical candidates, and thus, the nonnative condition could not demonstrate the same facilitation from form priming due to the lack of suitable (native) lexical candidates. This finding, although speculative, suggests that Mandarin and English-speakers may have relied on different cognitive strategies and systems in processing the phonological sensitivity task, an explanation that suggests a possible reason for the primacy of phonological sensitivity in explaining reading differences in Mandarin-speaking participants, but not English-speaking participants.

However, there is not enough evidence in the current study to further substantiate this line of reasoning. Nonetheless, given the dramatic difference in the predictive power of the phonological sensitivity task for the two languages (English and Mandarin), a next step would be to examine (i) whether there are processing differences across the samples through a design that counterbalanced differences (native/nonnative) in lexicality with differences (native/nonnative) in phonological properties or even phonotactic properties (as these are shown to be processed exclusively at a sublexical level in both English and Mandarin speakers; e.g., Vitevitch & Luce, 1998, 1999; Marslen-Wilson, 1999) and (ii) to examine which of these conditions (if any) would correlate with reading ability, specifically decoding automaticity as compared to reading fluency.

Younger Children's Accuracy on the Phonological Sensitivity Task



Older Children's Accuracy on the Phonological Sensitivity Task



Adult Accuracy on the Phonological Sensitivity Task

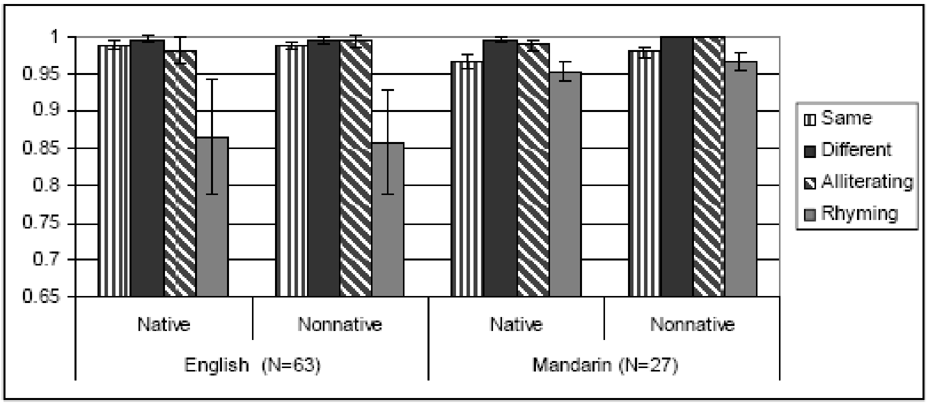


Figure 4.1. A comparison of accuracy on the conditions in the phonological sensitivity across English- and Mandarin-speaking children and adults.

Is the relationship between phonological awareness and reading specific to linguistic grain size?

One of the largest sources of dissension in research on reading in children is whether the linguistic grain size is important in the relationship between phonological awareness and reading (e.g., Goswami et al., 1990, Lonigan et al., 2004). One approach argues that the grain size that is relevant to reading will depend completely on the linguistic and orthographic properties of a language (Ziegler & Goswami, 2005). In fact, Goswami and colleagues (1990, 2005, 2006) have proposed a theory of psycholinguistic grain size that posits that there are three dimensions of a language that are important for determining the rate and manner in which reading develops, the *availability*, the *consistency*, and *granularity*. Each of these three dimensions refers specifically to the way in which a linguistic grain size is or is not privileged in a language (i.e., availability refers to the accessibility of the linguistic grain size in the spoken language that is important for the sound-symbol mappings; Ziegler & Goswami, 2005), and these three dimensions may vary by language and orthographic system.

A second approach argues that phonological awareness develops on a continuum, from an awareness of larger linguistic units (i.e., syllables) that are easily accessed without training to an awareness of smaller linguistic units (i.e., phonemes) that are difficult to access without explicit training (e.g., McBride-Chang, 2004). What is important then in predicting reading is not the linguistic grain size per say, but instead the level of development at which a child is tested (e.g., Lonigan, et al, 2004). Performance differences that appear related to the type of linguistic grain size are in fact a product of the task demands (and possibly the corresponding floor effects associated with age-inappropriate task demands; e.g., Bus, & van IJzendoorn, 1999). The strong interpretation of this theory is that *all* children, regardless of language learned, will at some point acquire awareness at *all* linguistic levels.

In the current study, I examined the effects of single word reading accuracy and the effects of language in the development of phonological awareness and in the relationship between phonological awareness and reading. Although we collected three tasks that required manipulation of sound information at varying linguistic levels: The morphological construction task required syllable-level manipulations (although the syllables were morphemes), the elision task required syllable and phoneme manipulations, and the phonological sensitivity task required onset-rime manipulations (although these also corresponded to phonemes because the words used were (C)V in structure), only the elision task can provide a within-task comparison of the different levels of linguistic grain size and whether there is an effect of development or an effect of language on the relationship between the linguistic unit investigated and reading ability.

In the results, I first explored differences in performance on the phonological awareness task specific to the type of elision (syllable, phoneme) and the position of elision (initial, medial, final) across language and across development. After adapting the elision task from the Comprehensive Test of Phonological Processing (CTOPP, Wagner, Torgesen, & Rashotte, 1997) for administration in an older population and for administration in Mandarin Chinese, the modified test had 18 syllable deletions and 49 and 36 phoneme deletions in the English and Mandarin versions, respectively. Using repeated measures ANOVAs for the child and adult data, I examined the effects of type of deletion (syllable, phoneme) and position of deletion (initial, medial, and final) across the younger and older participants.

As expected, in both Mandarin- and English-speaking children and adults, the type of deletion and the position of deletion showed significant within-subjects effects. For all participants, syllable elision was easier than phoneme elision, a finding that replicates existing research (e.g., McBride-Chang, 2004; Castles & Coltheart, 2004). In addition, medial deletions resulted in significantly poorer performance than initial or final deletions, but initial and final did not show consistent differences in performance. It comes as no surprise that medial deletions are markedly harder than initial and final position deletions; however, it was striking that there was no difference in position otherwise, particularly given the research that has suggested that the salience of initial and final positions is different (e.g., Treiman et al., 1998).

However, there are also several main findings showing both a language effect and an effect of development on performance in the phonological awareness task. First, there appeared to be a developmental effect in the children's performance across all types of elision. In a repeated measures ANOVA, the younger children performed significantly worse than the older children, $p<.01$ Bonferroni adjusted, a trend that continued when comparing the older children to the adults (although not tested statistically). The direction of the performance difference was consistent across all conditions, both for the type of item (syllable or phoneme) and the position of the deletion (initial, medial, and final), $p<.001$, and was in the direction expected (e.g., Anthony & Lonigan, 2004). Research has suggested that awareness of phonological information moves from larger linguistic grain sizes (i.e., syllable) to smaller sizes (i.e., phoneme; e.g., Burgess and Lonigan, 2003; Castles & Coltheart, 2004). In the current study, I replicate this finding and extend it to children learning to speak in a nonalphabetic language.

Across ages, there was an interesting effect of language. Overall, Mandarin speakers performed better on syllable deletions than English speakers, a finding that in each sample appeared to derive from a difference in performance in the syllable medial position. This is particularly striking in the adult data, where Mandarin speakers were 100% accurate on the medial syllable deletions, whereas the English speakers were just a little above change (56%). Research has shown that Mandarin-speaking children seem to be better than same-age English-speaking children on syllable-level deletions (e.g., McBride-Chang & Kail, 2002) but, in the present research, this trend has been found to continue in adults. Given that there were only two items of this type, interpretation is limited. However, one possibility is that the increasing predominance of morphological compounding in Mandarin may explain this difference, particularly the existence of both two and three morpheme compounds in Chinese children's early vocabulary.

There also seems to be a language by development interaction in the phoneme level manipulations. Young Mandarin speakers were unable to complete any phoneme deletions whereas once formal reading instruction has begun older Mandarin-speaking children demonstrated a significant growth in their phoneme level awareness. However, even with this growth, there continues to be differences in the pattern of performance across the different positions (initial, medial, and final) between the English- and Mandarin-speaking older children. These findings suggest that phonological awareness may develop later in Mandarin-speaking children (a finding coincident with the onset of reading training) and that this development may be different from the English speakers in the type of position effects demonstrated.

In contrast, Mandarin-speaking adults outperformed English-speaking adults on the syllable and phoneme deletions, a finding that was primarily due to the near-ceiling performance of the Mandarin speakers, although Mandarin-speakers also performed better (although not significantly) on the phoneme elision items. However, performance within the phoneme elision tasks (across initial, medial, and final) was not significantly different between English- and Mandarin-speakers, a somewhat surprising finding given the comparatively high levels of phoneme medial awareness demonstrated by the Mandarin-speakers. Thus, the important points in this series of analyses were (i) Mandarin- and English-speaking adults can perform syllable and phoneme-level awareness tasks, and (ii) their performance appears similar across the different types of phoneme elision items. However, a striking difference between the two language samples and across development was the pattern of correlations between the elision items and reading.

The pattern of correlations between syllable and elision items reveals both language and developmental differences. In children, syllable level awareness was correlated with reading ability only in the younger group of English- and Mandarin-speaking children. Phoneme level awareness was correlated with reading in younger and older English-speaking children but only in the older Mandarin-speaking children even after controlling for vocabulary and alphabet knowledge. Thus, there may be a developmental trajectory in the linguistic level that relates to reading across the languages. However, the relationship between phoneme-level awareness and reading appears to come online later in the Mandarin speakers

It is possible that this developmental difference between English and Mandarin-speaking children may be a product of two important educational differences between reading instruction in the U.S. and in Beijing. First, reading instruction in the U.S. has primarily adopted a phonics-based approach to teaching reading (e.g., Siegler, 1998), whereas, in mainland China, reading educators do use an analytic approach, but this approach focuses only on dissecting characters into meaning based components and properties as opposed to sound (e.g., Shu et al., submitted). Furthermore, in American preschools and kindergartens, there is a high level of training in preliteracy skills, such as learning the letter names and sounds of the alphabet, familiarizing children with the spelling of their name and other common objects, and introducing children into a print-rich environment in the classroom (e.g., McBride-Chang, 2004; Morrison et al., 2004). In contrast, in Beijing, teaching of reading or writing in the preschools has been prohibited since 1956 (Li & Rao, 2000) and pinyin training starts only in the last year of kindergarten, one year after the grade of the current younger Chinese children. Thus, the reason that syllable awareness in young Chinese children is related to reading ability, but that phoneme (and possibly onset-rime) awareness do not develop until later and are not correlated with reading until once reading instruction has started, may be solely due to instructional practices and properties of Chinese schooling and differences in home literacy environments. Having insight into the sound components of the characters and their combinability can only come once the child has learned enough characters to detect a pattern in the regularity and consistency of the phonetic components. Thus, higher levels of phonological awareness may aid in the process of reading only once the child has a large enough pool of characters from which to draw insights. There is some support for this idea in existing research that shows evidence of a bidirectional relationship between phonological awareness and reading ability (Chow, et al., 2005; McBride-Chang & Ho, 2005). What would be interesting and a potential next step is to determine how many characters a child needs to know before s/he can begin to apply analytic strategies to learning to read.

The correlations for the adults demonstrated a continued relationship between syllable and phoneme awareness and reading for English speakers, whereas there were no significant correlations across any of the items in the Mandarin-speaking group. This finding was not aligned with the regression results in Chapter 3 which found that phonological awareness was a significant predictor of reading differences in Mandarin-speaking adults, but not in English-speaking adults. However, there are two reasons for the difference. First, phonological awareness is related to reading ability in English-speaking adults, as demonstrated by the overall task and item-specific correlations. However, when considered within the larger framework of the reading model for English speakers, the importance of phonological awareness is eclipsed by a stronger contribution of phonological working memory and rapid naming. Second of all, for the Mandarin-speakers it appeared that the lack of item-specific correlations may have been due to a lack of power. When average phoneme-elision performance was entered in a stepwise regression after other measures of phonological processing, it was uniquely predictive of reading ability in Mandarin-speakers. Thus, interpretations of the role of phonological awareness in Mandarin-speaking adults must be made with care.

It appears that phoneme-level awareness develops later in Mandarin speakers but still demonstrates the same correlations with reading in Mandarin-speaking children as in English-speaking children, even though there are slight differences in the patterns in performance across the item types for English and Mandarin speakers. However, in adults, although both English and Mandarin speakers demonstrate similar performance in the ability to perform phoneme elisions, the skill was related to reading in English speakers but not in Mandarin speakers. Thus, our data show both an effect of language and an effect of development, and an interaction between these two.

These findings are interesting and important for several reasons. First, both older Mandarin-speaking children and adults demonstrate phoneme-level awareness. Furthermore, this awareness is related to reading only in the Mandarin-speaking older children (although this may be due to a lack of power for the adult item-analysis). This finding is surprising as all research on Chinese reading has argued against the importance of phoneme-level awareness in Chinese(e.g., McBride-Chang, Cho, et al, 2005), and the few studies that have measured phoneme-level awareness have not shown a significant relationship with reading ability in Mandarin- (Shu et al., submitted) or Cantonese-speaking children (e.g., Siok & Fletcher, 2001; Huang & Hanley, 1997). Furthermore, the present findings provide support for a developmental story in the acquisition of awareness and the relationship between awareness and reading ability. Finally, the present findings also provide tentative evidence against a strong version of the psycholinguistic grain size argument. Mandarin Chinese is a morphosyllabic script. Given the properties of availability, consistency, and granularity of spoken and written Chinese, and in the mapping between these two, it is very difficult to conceptualize how the structure of the language could necessitate phoneme-level awareness. However, future research is needed to (i) replicate these findings, and (ii) to investigate how or why awareness at the level of the phoneme may be important in learning to read Chinese given specific orthographic or linguistic features of the language, or features of the sound-symbol mappings between these two systems.

In the general introduction, I proposed to examine these three questions in order to gain insight into *which* phonological skills predict reading and *how* these skills might be related. The larger goal behind these questions was to understand the similarities and differences between the mechanisms of reading across two dramatically different language systems, and two dramatically different reading levels. Thus, next I discuss a comparison of reading models across culture and development.

Comparison of Reading Models across Language and across Development

Figure 4.2 shows the standardized beta weights for the phonological and morphological measures when predicting single word reading (decoding) after controlling for verbal and nonverbal IQ and age (in the child data). English speakers are represented on the left, and Mandarin speakers on the right, and adult scores are in brackets [ ]. Although this representation obscures a lot of the interesting, but nuanced findings discussed above, it does reveal very clear effects of language and development.

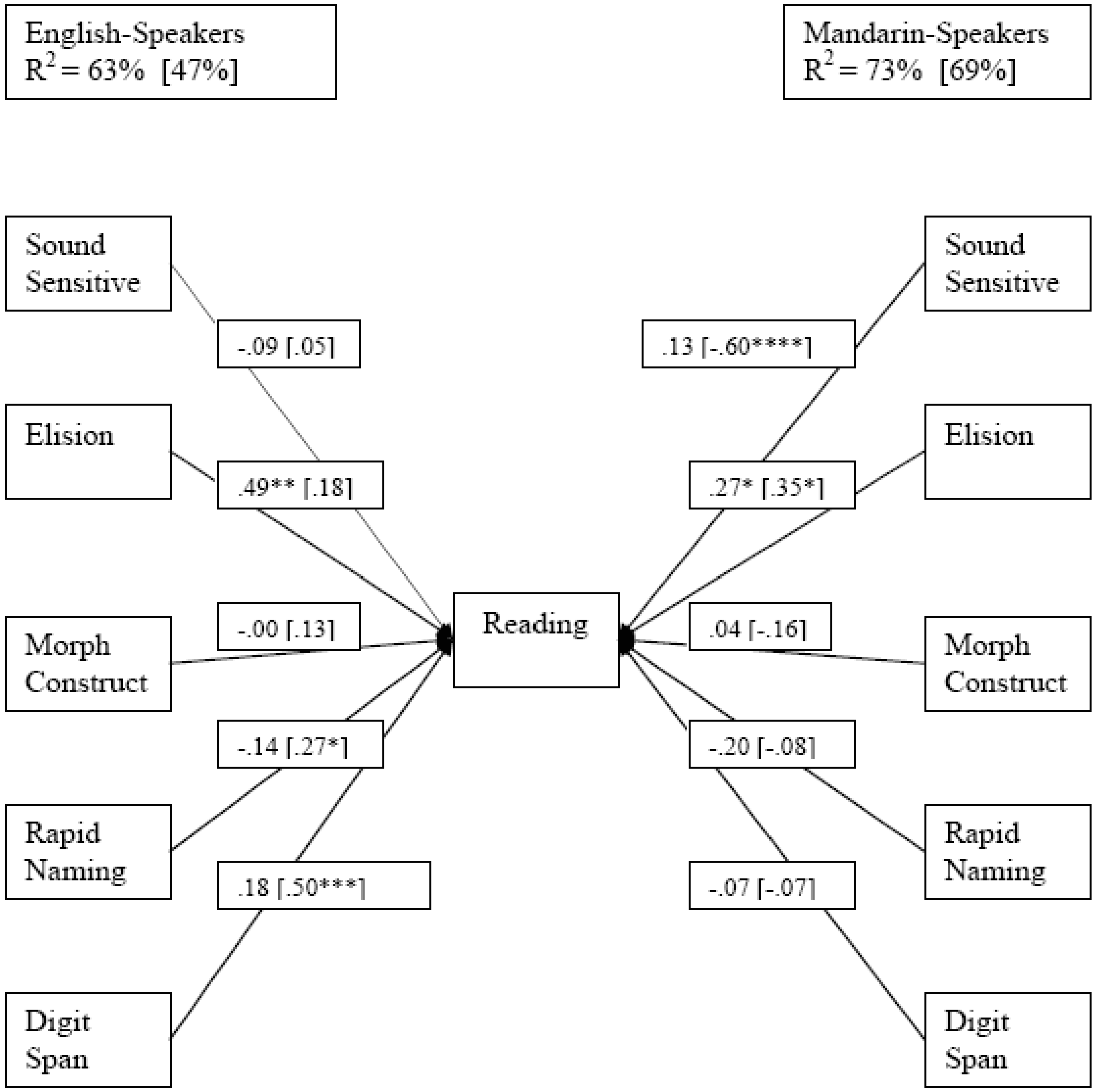
Specifically, the phonological predictors of reading appear to differ for English readers of different ages and ability levels. On the one hand, phonological processing skills prove core constructs in predicting individual differences in reading in both beginner and skilled reading systems, suggesting important developmental continuity in the underlying mechanisms of reading. On the other hand, there are theoretically important differences in the relative contributions of these variables over time. In English-speaking children, as has been shown innumerable times in the literature, phonological awareness was found to be the single strongest predictor of reading ability even after controlling for nonverbal IQ, verbal IQ, and other phonological processing skills, explaining roughly 10% of the variance in reading in the current sample of children. In contrast, although phonological awareness was correlated with reading in English-speaking adults, digit span and rapid naming were the only two unique predictors of reading, explaining close to 30% of the variance in reading ability. Thus, as has been previously suggested, the importance of phonological awareness may differ depending on the level of development (Wagner et al., 1997), despite the fact that this is not due to ceiling effects in performance in the task. Of note, in skilled adult readers the importance of phonological working memory and speed of processing was stronger than phonological awareness in predicting decoding ability. This is interesting because (i) little research has examined the relationship between the components of phonological processing and decoding in skilled adult readers, and (ii) previous work investigating the components of phonological processing in older more fluent readers, has demonstrated a weakening of the contribution of rapid naming with increased fluency, (e.g., Torgesen, et al., 1997). Of further interest, when phonological working memory is left out of the regression, the overall variance explained was significantly reduced and the importance of rapid naming was weakened, $p<.05$, but phonological awareness became a significant predictor of individual differences in skilled English-speaking readers, $p<.05$. Thus, in the current sample of skilled adult English-speaking readers, phonological working memory serves an unexpectedly powerful role. The change in the relationship between phonological awareness, decoding, and phonological working memory is one that should be explored further. Although phonological working memory has been shown to play a large role in explaining differences in reading comprehension (e.g., Cain & Oakhill, 2004; Oakhill & Cain, 2004), I know of no existing research demonstrating an importance of phonological working memory in decoding skills in English-speaking adults.

In contrast, the role of phonological processing in predicting reading for Mandarin-speakers appeared to change with age and reading ability in the strength but not the pattern of relationships. In Mandarin-speaking children in the current study, phonological awareness was the strongest predictor of reading ability even when compared with morphological processing and rapid naming, two skills highlighted as important components of reading in Chinese (e.g., McBride-Chang et al., 2003; Ho, 2005). As discussed, this is different from previous studies (e.g., McBride-Chang, Cho et al., 2005; McBride-Chang, Shu, et al., 2006) but, one reason for the heightened potency of phonological awareness in the current sample of Mandarin-speaking children may be due to the use of phoneme elision items on this task. Prior research has used primarily syllable (e.g. McBride-Chang & Ho, 2005) or onset deletions (e.g., Ho & Bryant, 1997), but not phoneme-level deletions.

The current study also showed that although younger and older Mandarin-speaking children can perform syllable level deletions, the potency of this type of elision as a predictor of reading was limited. In contrast, phoneme-level deletions demonstrated stronger relations with reading in the older Mandarin-speaking children than syllable level deletions, and even stronger relationships than demonstrated in the older English-speaking children. Furthermore, phonological awareness was significantly related to reading ability in Mandarin-speaking adults, although not at an item-level. And, like in children, the predictive power of this relationship stemmed from a relationship between phoneme-level deletions and reading ability as demonstrated by a stepwise regression that showed overall phoneme-level awareness was uniquely predictive of reading ability after measures of phonological processing and sensitivity. This suggests continuity in the role of phonological awareness as an important predictor of reading ability in Mandarin-speaking children and adults.

The relationship between phonological sensitivity and reading ability in Mandarin speakers similarly seemed to demonstrate developmental growth and continuity. In Mandarin-speaking children, phonological sensitivity contributed unique variance beyond measures of phonological awareness to reading ability (although not in the full regression) suggesting that the skill is both an important predictor of reading and is distinct from phonological awareness. Furthermore, this relationship only came online with the onset of formal reading training, thus demonstrating a possible effect of literacy training or schooling. However, once online, the importance of this skill appeared to increase over time, such that in Mandarin-speaking adults, differences in phonological sensitivity explained 26% of the variance in reading ability.

Figure 4.2. Model of reading for English- and Mandarin-speaking children and adults.



Note: βs from a fixed-order regression are reported controlling for (age- child only), nonverbal IQ, and vocabulary.
Adult βs in [ ].
*<.05, **<.01, ***<.001

There are two important findings in these data that need to be underscored. First, phonological awareness is a potent predictor that was able to be measured in Mandarin-speaking adults and children, and that demonstrated a powerful relationship with reading in older Mandarin-speaking children, a relationship that in large part seemed to stem from the phoneme elision items. The late onset of the relationship in Chinese children (only observed in the older Chinese children who had commenced literacy training) and the continued importance of phonological awareness in Chinese adult readers may be somewhat analogous to research in opaque alphabetic orthographies showing a later onset and more protracted development of the relationship between phonological awareness and reading (e.g., Abu-Rabia & Taha, 2006). Furthermore, as noted in Chapter 1, the ability to use the regularity and consistency of the phonetic component in reading compound characters continues to show individual differences even in college students (e.g., Ho & Bryant, 1997b), which may in part explain the continued relationship between phonological awareness and reading in adults.

Alternatively, it may be that the relationship between phoneme-level awareness and reading observed in both alphabetic and nonalphabetic systems is purely a product of instruction and schooling. In the current study, the seeming developmental difference in the relationship between phoneme-level awareness and reading ability in English- and Mandarin-speaking children may be a product of different instructional climates and home literacy environments. An important next step in the current study is to explore the causes behind the different role of phonological awareness for English and Mandarin-speaking emergent readers.

Second, the role of phonological sensitivity in predicting reading in older Mandarin-speaking children and skilled adult readers is important. The role of phonological sensitivity in reading has little support in previous research on English-speaking children (e.g. McBride-Chang, 1996). This finding was replicated in the current sample of English-speaking children and adults. However, phonological sensitivity demonstrated a unique influence on reading development distinct from phonological awareness, offering support for the claim that phonological sensitivity may be a more important construct in nonalphabetic orthographies, and suggesting that the conceptualization of phonological processing my need to be reconfigured to include a component of low-level phonological sensitivity.

Limitations

There are of course limitations in this dissertation, both methodological and theoretical, that restrict the strength and scope of my interpretations. First, I have reported correlational research only. Thus, any relationships I have called predictive reflect associations or uniquely shared variance only and are not predictive in a causal sense. Furthermore, all discussions of developmental changes, are made lightly, and with the understanding that the comparison across age groups involves *different* samples and outcomes may be related to differences in samples and importantly not differences in development.

Furthermore, the results for the adult study in particular must be interpreted with care. Because it is difficult to find adult Mandarin-speakers without ANY knowledge of English, the data collection efforts in Beijing lagged behind the US efforts for the adult study, resulting in a large discrepancy in sample size between the two groups, and an unfortunately small sample of Mandarin-speaking adults (n=27). The smallness of this sample could easily lead to non-replicable results and the high number of analyses conducted on this sample to spurious relationships. Furthermore, in both the English- and Mandarin-speaking adults, there were distributional problems with the primary dependent variable, single-word-reading. For these reasons, wherever possible, I attempted to replicate and validate the results using slightly different outcome measures (i.e. speed of decoding and/or fluency). However, one of the most important next steps is clearly to replicate these findings in a larger sample of Mandarin-speaking adults with a stronger measure of reading ability in both English and Chinese.

A third limitation is the cross-cultural comparability of the adapted measures. Although all efforts were made to create identitical tests for the two samples, linguistic differences made this impossible for certain measures (i.e. phonological awareness, single-word-reading, vocabulary). Unfortunately, these measures also happen to be the measures in which I have the greatest interest. Differences in the current study compared to existing research may be due to potential inequalities in the adaptation of the measures for cross-cultural administration. Although certainly an improvement when compared to the few existing studies that do compare performance between Chinese and English, there is still room for improvement with the goal of creating identical cross-linguistic measures.

One of the largest and most theoretically compromising limitations in the current dissertation and its design is the lack of cross-cultural environmental controls. In the current dissertation, I draw conclusions about cross-cultural similarities and differences with attention only to linguistic and orthographic differences between English and Chinese and little acknowledgement of the wide-array of confounding environmental differences. However, there are certainly more than a host of other cross-cultural differences, many of which have been shown to be intimately related to reading development (e.g., classroom teaching style, Foorman, Francis, Fletcher, Schatschneider, & Mehta, 1998; home environment, Whitehurst & Lonigan, 1998; socioeconomic status, Snow et al, 1998, just to name a few), that could potentially explain the results as well.

As a quick demonstration of the potential impact of environmental factors on reading, I next review a seminal comparative study conducted in the early 1980's exploring cross-cultural differences in academic achievement comparing Americans, Japanese and Chinese students on a battery of different sociocultural and cognitive measures (Stevenson, Lee, Stigler, Hsu, & Kitamura, 1990). In this study, Harold Stevenson and colleagues (e.g. Stevenson, Lee & Stigler, 1986) established that even on culturally equalized academic measures, the Japanese and Chinese constantly outperform Americans due to a host of environmental differences. One environmental difference of particular interest for the current dissertation is the impact of differences in school structure between the American and Asian education systems on academic outcomes, and reading in particular.

Stevenson and colleagues (1990) found dramatic and meaningful differences between American and Asian cultures in the percent of time children spend in school, on academic tasks, with a teacher, and on homework differences that were directly correlated with the difference in academic achievement in reading and math across all of the elementary school. First of all, American children are in school fewer days and for fewer hours than both Chinese and Japanese students (Stevenson, Lee & Stigler, 1986). Secondly, Americans spend much less time than Japanese and Chinese students learning. This is a product of difference in time spent doing academic tasks, particularly math, and differences in teacher instruction. In first grade, Americans spent close to 70% of their time during a week on academic activities compared to the 85-90% of time spent in Japanese and Chinese cultures (Stevenson, Lee & Stigler, 1986). In addition, teachers play a different role in the classroom for the different cultures. First, children in America spend 50% of their time in a classroom without a teacher, while this only occurs 10% of the time in China or Japan (Stevenson, Lee & Stigler, 1986). Although the teacher is in the room, American students are receiving direct instruction only 20% of the time compared to 33% and 58% of time that Japanese and Chinese respectively spend receiving tutelage (Stevenson, Lee & Stigler, 1986). All told, children in the US receive direct instruction from a teacher only 6 of the 30 hours a week they spend in school compared to the 12 hours that Japanese receive instruction and the 26 hours for the Chinese (Stevenson, Lee & Stigler, 1986). Last of all, the differences in time spent on task in school are mirrored in the amount of time spent on homework outside of school. In first grade, US children spend on average about 14 minutes a day on homework compared to the 37 and 77 minutes Japanese and Chinese spend on their homework (Stevenson, Lee & Stigler, 1986). By fifth grade, American children are spending on average 46 minutes a day on homework compared to 57 and 114 minutes of the Japanese and Chinese students (Stevenson, Lee, & Stigler, 1986).

It is clear that the structure of a school has a far-reaching impact on achievement both directly and indirectly. Directly, children are spending more time on academic learning. Indirectly, this increase in time and commitment to school impacts the students' and parents' views about the role of school. And, this is just one aspect of the environment that could explain differences in academic outcomes across cultures. However, there are many more socio-cultural differences that may affect the rate and nature of the development of reading ability. Using Brofenbrenner's ecological model as a template, McBride-Chang (2004) has written eloquently about all the possible spheres of difference in cross-cultural comparative research, including macrosystem differences (i.e. attitudes about education, income levels), exosystem differences (i.e., school structures) to microsystem differences (home literacy environment). Clearly, the current study has done little to catalog differences in these separate spheres or to even control these potential differences. One large question then is whether the current results can be explained by socio-cultural effects beyond linguistic and orthographic differences?

Here I argue that the results of my dissertation overwhelming highlight the parallels between the predictors of reading ability across two dramatically different cultures and thus obviate the need for a discussion of socio-cultural impact. However, I also acknowledge that there certainly are cultural effects in the results. Earlier in this discussion, I discuss the possibility of a development by language interaction in the performance on the phonological awareness task and the late-emerging relationship between phonological sensitivity and awareness with reading ability in Mandarin-speaking children. It is possible that the later onset of the observed relationship with reading in the Mandarin-sample is due largely to difference in literacy practices both within the home and within the school, instead of linguistic and orthographic features as proposed. Overall, Chinese society is less focused on children adopting an analytic approach to reading compared to American society. Not only is there an institutional de-emphasis on character decomposition and analytic strategies in reading, but there is also clearly less time spent on preliteracy activities focusing on phonological awareness, such as training in letter names and sounds, given the character-based spelling system. Thus, it is possible and theoretically interesting that if what I called a developmental difference in the relationship between phonological awareness and reading was little more than a reflection of differences in educational practices. As noted above, I think this is an important and interesting next step.

General Discussion and Future Directions

The present dissertation both replicates and extends existing research on the predictors of reading in several important ways. First, I demonstrate that exploring the mechanisms of reading (accuracy) in adult readers is not only a viable task, but one that leads to the types of insights similar to those gained from exploring the same measure in children but with different conclusions about the relative roles of the predictors. An important next step is to explore whether these individual differences in adult readers are important for predicting long term academic or professional success (e.g., Jackson, 2005). Clearly, differences in beginner readers have an impact on long-term academic outcomes, but once children reach a threshold of competency, it has been assumed (i.e., Gough & Tumner's Simple View of Reading, 1986), that individual differences in decoding are unimportant to comprehension or fluency. The present research suggests that this conclusion is unwarranted.

Second, exploration of adult performance can be used to better understand the development of the mechanisms of reading with increased fluency. Phonological skills are of continued importance in explaining differences across development, but the relative importance of the particular skills shifts with changes in proficiency. An interesting study would be to explore when and where that shift occurs and/or if it is simply a gradual process of change. Much research has assumed that a threshold of decoding skill is needed in order to scaffold additional learning (e.g., Gough & Tumner, 1986); however, it would be interesting to test this assumption by matching presumed threshold levels with shifts in predictive skills.

Third, I demonstrate interesting and important differences in reading development across alphabetic and nonalphabetic orthographies. This is the first study to explore the phonological and morphological predictors of reading in English- and Mandarin-speaking emergent and fluent readers. Thus, the results are largely exploratory because there is (i) a small and inconsistent literature on the components of reading in Chinese, (ii) a practically nonexistent literature on cross-cultural predictors of reading in English- and Mandarin-speaking children (with the exception of Huang & Hanley, 1997; McBride-Chang & Kail, 2002, McBride-Chang, Cho et al., 2005) and adults (Read et al., 1986; Huang & Hanley, 1994; Holm & Dodd, 1996), and (iii) no literature on the cross-cultural predictors of reading in monolingual Chinese and English children as in the current study. Nonetheless, the results of the current study build on previous cross-cultural studies (e.g., McBride-Chang & Kail, 2002) comparing English- and Cantonese-speaking children on a similar battery of phonological measures and present important caveats for other cross-cultural studies of English and Mandarin-speaking children (e.g., McBride-Chang, Cho, et al., 2005) that have explored the relationship between phonological and morphological variables and reading ability.

Moreover, the current studies provide preliminary support that phonological sensitivity and phonological awareness are distinct and dissociable predictors of reading in nonalphabetic languages. Existing research (McBride-Chang, 1996) on English speakers has provided strong, but not unequivocal evidence that low-level measures of phonological sensitivity are unrelated to reading ability, a finding replicated in the current study. However, research on Chinese readers has failed to be systematic in distinguishing between low- and high-level measures of sensitivity and awareness in research, and reading studies rarely test both (although see McBride-Chang & Ho, 2000). Thus, the current study sets an important precedent for including multiple measures of phonological processing skills, particularly in nonalphabetic languages.

Finally, the current studies demonstrate that the importance of phonological awareness is not restricted to syllable or onset-rime level awareness in Mandarin-speakers. Not only do both older children and adults demonstrate the ability to perform phoneme-level deletions, but this ability is correlated with reading ability in emergent Mandarin readers. The parallels between English- and Mandarin-speaking children suggest that phoneme level awareness develops later in speakers of nonalphabetic orthographies, but is possibly as important in predicting individual differences in reading ability.

Overall then, this study has made several significant advances to the understanding of the components of reading. First, the current research extends existing cross-cultural work and demonstrates both important similarities and differences in the models of reading in alphabetic and nonalphabetic languages. Second, the current research extends existing developmental work by studying skilled adult readers within the framework used for emergent readers. Through this comparison, both continuities and discontinuitites in the predictors of reading ability across development have been identified. Last, the combination of a cross-cultural developmental study demonstrates important language by development interactions. By comparing two languages (English and Mandarin Chinese) and three developmental levels (emergent, decoding, and fluent), the current study provides insights into *which* phonological skills are critical to reading and *how* they are related to reading.

The current dissertation highlights interesting and potentially important questions that address specific limitations in the existing literature and important next steps. However, it also serves to highlight a few overall limitations in current approaches used in reading research that may restrict our understanding of the mechanisms of reading across languages and across development. First, there is little research that systematically compares reading performance in alphabet and nonalphabetic languages. Not only does more research in this area need to be conducted, but this research should be more careful, (i) in cataloguing the actual linguistic and orthographic differences between the comparison languages, (ii) in designing the measures to be used cross-culturally, (iii) in controlling bilingualism and exposure to the languages being contrasted, and (iv) in controlling for environmental and socio-cultural factors that may affect the interpretation of the study. Second, existing research on decoding has been limited to studying emergent and beginning readers. However, my results suggest that not only are there individual differences in decoding ability in fluent readers, but that there may be continuity in the development of decoding across time. The mechanisms of reading in fluent readers may serve as the ‘final state’ of emergent reading. Thus, perhaps more research should be addressed at delineating this final state. Overall, I believe that the findings in this dissertation not only are provocative and merit further investigation but also suggest a potential need for a shift in the current approaches used to investigate the phonological predictors of emergent reading.

Appendices

Appendix A. List of pairs used in the child version of the phonological sensitivity task

English		Mandarin	
Different	Same	Different	Same
cow-do	boo-boo	hua1-bai2	bai2-bai2
hi-doe	bow-bow	tu4-bai3	bai3-bai3
bye-low	bye-bye	kao3-du4	bao3-bao3
hi-may	cow-cow	nu3-hai4	dou4-dou4
bow-neigh	do-do	pu3-hai4	du4-du4
neigh-pie	do-do	wei4-kao3	hai2-hai2
way-pooh	doe-doe	lei4-mai2	hao3-hao3
show-pow	hey-hey	lou4-mai3	hei1-hei1
pooh-way	hi-hi	kou3-mu4	hua1-hua1
how-way	hi-hi	pai2-shou4	kao3-kao3
	how-how		kao3-kao3
bow-boo	knee-knee	bai3-bao3	kou3-kou3
doe-do	lay-lay	du4-dou4	lei4-lei4
hey-hi	low-low	hei1-hua1	lou4-lou4
low-lay	may-may	kao3-kou3	mai2-mai2
my-me	me-me	mu4-mei4	mai3-mai3
knee-neigh	my-my	mai3-mi3	mei4-mei4
pie-pooh	neigh-neigh	ni3-nu3	mi3-mi3
pie-pow	neigh-neigh	pao3-pu3	ni3-ni3
two -toe	pie-pie	shou3-shu3	nu3-nu3
way-why	pie-pie	wai4-wei4	pai2-pai2
	pooh-pooh		pao3-pao3
pooh-do	pooh-pooh	mai2-hai2	pu3-pu3
toe-doe	pow-pow	wei1-hei1	pu4-pu4
may-hey	show-show	hao3-kao3	pu4-pu4
cow-how	toe-toe	mei4-lei4	shou3-shou3
me-knee	two -two	dou4-lou4	shu3-shu3
show-low	way-way	mi3-ni3	tou4-tou4
why-my	way-way	bai2-pai2	wai4-wai4
lay-neigh	why-why	bao3-pao3	wei1-wei1
hi-pie		shou4-tou4	
boo-two		pu4-tu4	

Appendix B. A comparison by language of the types of items on the elision task

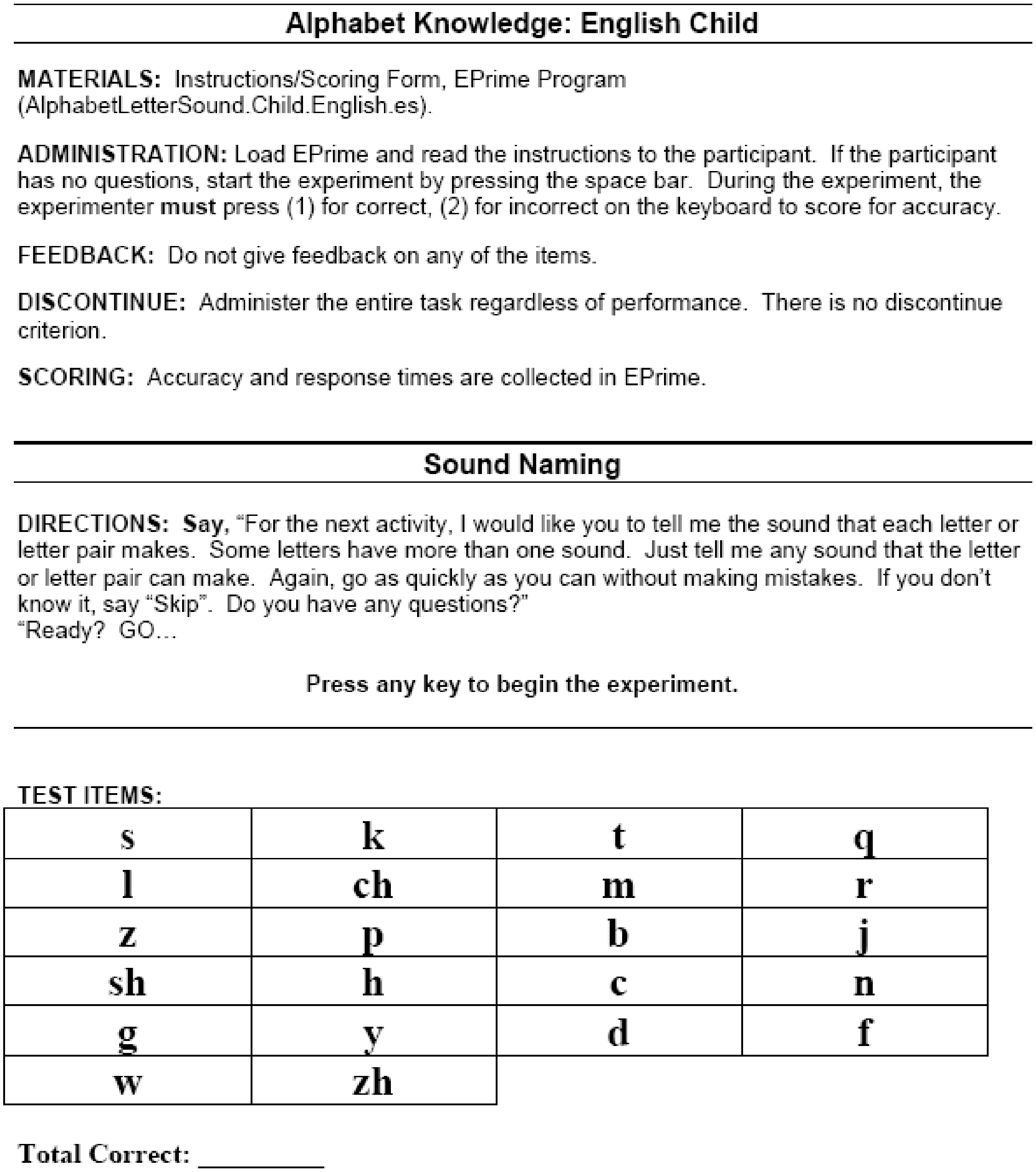
3-syllable	Initial	Say strawberry without saying 'straw'.
	Final	Say butterfly without saying 'fly'.
	Medial	Say forgotten without saying 'got'.
Phoneme Deletions		
1-syllable	Initial	Say cup without saying /k/.
	Final	Say time without saying /m/.
	Medial	Say tiger without saying /g/.
	Final Clusters	Say box without saying /k/.
2-syllable	Initial	Say finish without saying /f/.
	Final	Say cracker without saying /r/.
	Medial	Say winter without saying /t/.
	Medial Difficult	Say quarrel without saying /w/.

Mandarin		Example
Syllable Deletions		
2-syllable	Initial	请说面条(mian4tiao2)，但不说出面(mian4)=tiao2
	Final	请说茶壶(cha2hu2)，但不说出壶(hu2)= cha2.
3-syllable	Initial	请说红颜色(hong2yan2se4)，但不说出红(hong2)= yan2se4
	Final	请说汽车站(qi4che1zhan4)，但不说出站(zhan4)= qi4che1.
	Medial	请说大门口(da4men2kou3)，但不说出门(men2)= da4kou3.
Phoneme Deletions		
1-syllable	Initial	请说福(fu2)，但不说出f= wu2.
	Final	请说肯(ken3)，但不说出en3= ke1.
	Medial	请说暖(nuan3) /n^{w}an/, 但不说出 a.nun3

Appendix C. List of pairs used in the adult version of the phonological sensitivity task

English		Mandarin	
Different	Same	Different	Same
boo-way	boo-boo	dou4 - bai3	bai2 - bai2
bye-how	boo-boo	pao3 - bu4	bai3 - bai3
cow-pie	bow-bow	mi3- du4	bai3 - bai3
hey-do	bye-bye	wei4 - hai2	bao3 - bao3
may-pow	cow-cow	tou4 - mai2	bu4 - bu4
me-hi	do-do	bai2 - mei4	dou4 - dou4
pie-low	doe-doe	hai4 - ni3	dou4 - dou4
show-lay	hey-hey	tu4 - pao3	du4 - du4
toe-knee	hey-hey	hei1 - shou4	hai2 - hai2
way-two	hi-hi	hai3 - wei1	hai3 - hai3
	hi-hi		hai4 - hai4
boo-bow	how-how	bao3 - bai3	hao3 - hao3
doe-do	knee-knee	bu4 - bai3	hei1 - hei1
how-hi	knee-knee	bu4 - bao3	hei1 - hei1
hey-how	lay-lay	dou4 - du4	kao3 - kao3
low-lay	low-low	hai4 - hao3	mai2 - mai2
pooh-pie	may-may	hao3 - hai4	mai2 - mai2
pow-pie	me-me	hei1 - hai3	mai3 - mai3
pooh-pow	my-my	mai2 - mei4	mei4 - mei4
two-toe	pie-pie	mi3 - mai3	mi3 - mi3
why-way	pooh-pooh	pu4 - pao3	mi3 - mi3
	pow-pow		ni3- ni3
two-boo	pow-pow	kao3 - bao3	pai2 - pai2
pow-bow	show-show	tu4 - bu4	pao3 - pao3
how-cow	toe-toe	bai2 - hai2	pu4 - pu4
bye-hi	toe-toe	pai2 - mai2	shou4 - shou4
me-knee	two-two	wei4 - mei4	tou4 - tou4
way-may	way-way	mi3 - ni3	tu4 - tu4
pie-my	way-way	hao3 - pao3	wei1 - wei1
do-pooh	why-why	du4 - pu4	wei4 - wei4
show-toe		shou4 - tou4	
hey-way		hei1 - wei1	

Appendices D. Adapted Measures Alphabet Knowledge – English Child



Alphabet Knowledge: English Child

MATERIALS: Instructions/Scoring Form, EPrime Program (AlphabetLetterSound.Child.English.es).

ADMINISTRATION: Load EPrime and read the instructions to the participant. If the participant has no questions, start the experiment by pressing the space bar. During the experiment, the experimenter **must** press (1) for correct, (2) for incorrect on the keyboard to score for accuracy.

FEEDBACK: Do not give feedback on any of the items.

DISCONTINUE: Administer the entire task regardless of performance. There is no discontinue criterion.

SCORING: Accuracy and response times are collected in EPrime.

Sound Naming

DIRECTIONS: **Say,** "For the next activity, I would like you to tell me the sound that each letter or letter pair makes. Some letters have more than one sound. Just tell me any sound that the letter or letter pair can make. Again, go as quickly as you can without making mistakes. If you don't know it, say "Skip". Do you have any questions?"
"Ready? GO…

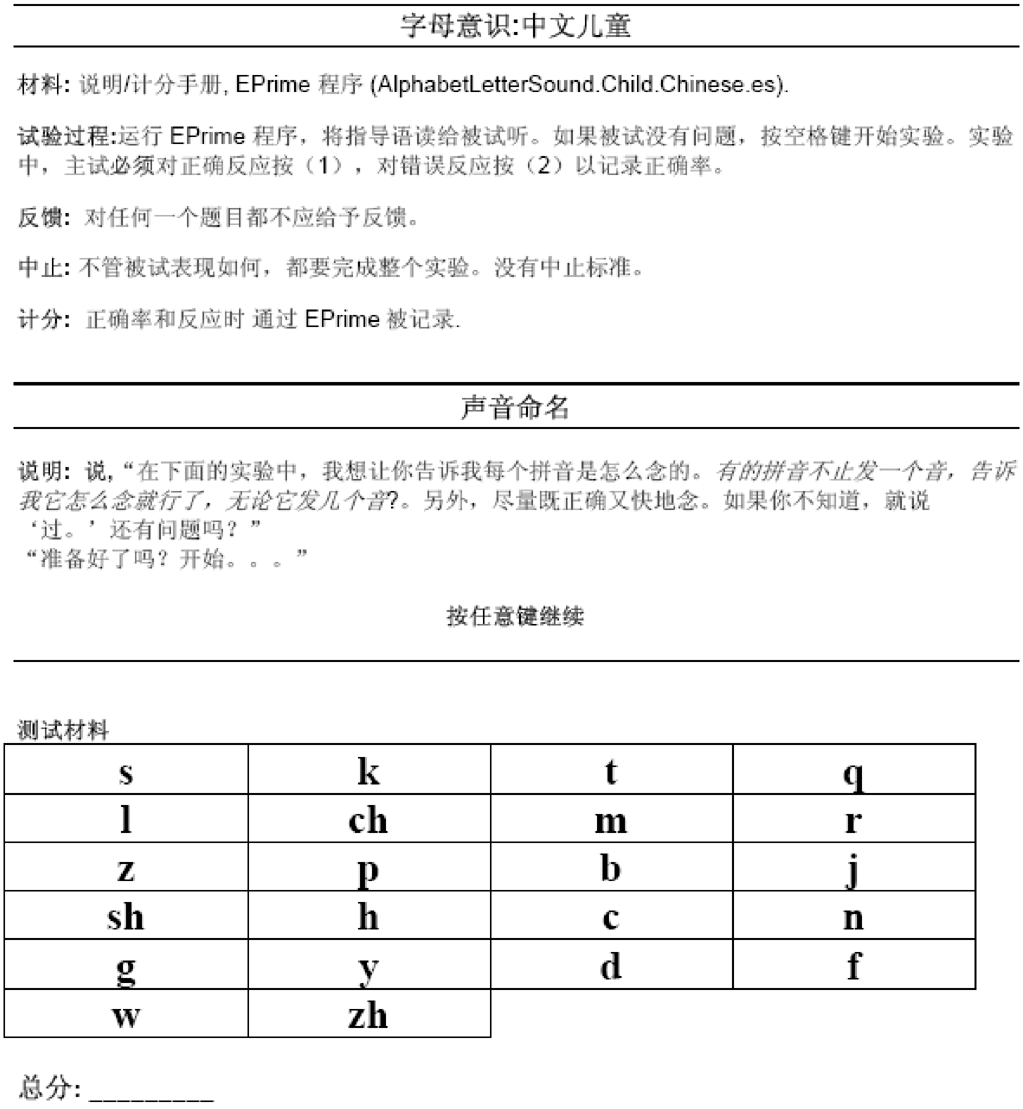
Press any key to begin the experiment.

TEST ITEMS:

s	**k**	**t**	**q**
l	**ch**	**m**	**r**
z	**p**	**b**	**j**
sh	**h**	**c**	**n**
g	**y**	**d**	**f**
w	**zh**		

Total Correct: __________

Appendices E. Adapted Measures Alphabet Knowledge –Chinese Child



字母意识:中文儿童

材料: 说明/计分手册, EPrime 程序 (AlphabetLetterSound.Child.Chinese.es).

试验过程:运行 EPrime 程序，将指导语读给被试听。如果被试没有问题，按空格键开始实验。实验中，主试**必须**对正确反应按（1），对错误反应按（2）以记录正确率。

反馈: 对任何一个题目都不应给予反馈。

中止: 不管被试表现如何，都要完成整个实验。没有中止标准。

计分: 正确率和反应时 通过 EPrime 被记录.

声音命名

说明: 说,“在下面的实验中，我想让你告诉我每个拼音是怎么念的。*有的拼音不止发一个音，告诉我它怎么念就行了，无论它发几个音*?。另外，尽量既正确又快地念。如果你不知道，就说‘过。’还有问题吗？”
“准备好了吗？开始。。。”

按任意键继续

测试材料

s	**k**	**t**	**q**
l	**ch**	**m**	**r**
z	**p**	**b**	**j**
sh	**h**	**c**	**n**
g	**y**	**d**	**f**
w	**zh**		

总分: _________

Appendices F. Adapted Measures Elision – English

Elision: English Adult

MATERIALS: Eprime File: Elision.es

ADMINISTRATION: Load EPrime and ask the participant to listen to the instructions. After each subject response, the experimenter **must** press (1) for correct, (2) for incorrect on the response box.

DISCONTINUE: Administer the entire section regardless of performance.

SCORING: Accuracy and response times are collected in EPrime.

EXPERIMENTER WILL SAY, "For the next activity, you're going play a word game."

AUDIO INSTRUCTIONS (Participant will hear when experiment starts): "For the next activity, we're going to play a word game. Please respond whenever you hear a beep and see an 'X' on the screen."

SECTION 1

PRACTICE ITEMS:	Correct Response
a. Say *toothbrush*. Now say *toothbrush* without saying *tooth*.	**Brush**
b. Say *airplane*. Now say *airplane* without saying *plane*.	**Air**
c. Say *doughnut*. Now say *doughnut* without saying *dough*.	**Nut**

TEST ITEMS: Feedback Given		**Score (1/0)**
1. Say *popcorn* without saying *corn*.	**Pop**	______
2. Say *baseball* without saying *base*.	**Ball**	______
3. Say *butterfly* without saying *fly*.	**Butter**	______

REMAINING TEST ITEMS: No Feedback Given		
4. Say *sandwich* without saying *sand*.	**Which**	______
5. Say *donkey* without saying */don/*.	**Key**	______
6. Say *strawberry* without saying *straw*.	**Berry**	______
7. Say *ugliness* without saying */ness/*.	**Ugly**	______
8. Say *unpleasant* without saying */un/*.	**Pleasant**	______
9. Say *meow* without saying *me*.	**Ow**	______
10. Say *banana* without saying */ba/*.	**Nana**	______
11. Say *bicycle* without saying *bi*.	**Cycle**	______
12. Say *spider* without saying */der/*.	**Spy**	______
13. Say *coffee* without saying */ee/*.	**Cough**	______
14. Say *hamburger* without saying */burg/*.	**Hammer**	______
15. Say *forgotten* without saying *got*.	**Foreign**	______

SECTION 2

AUDIO INSTRUCTIONS (Participant will hear): "Okay, now let's try some where we take away smaller parts of the words."

Feedback is Given

	Correct Response
a. Say *cup*. Now say *cup* without saying /k/	**Up**
b. Say *meet*. Now say *meet* without saying /t/.	**Me**
c. Say *farm* without saying /f/.	**Arm**

TEST ITEMS: Feedback Given

		Score (1/0)
16. Say *bold* without saying /b/.	**Old**	______
17. Say *mat* without saying /m/.	**At**	______
18. Say *good* without saying /g/.	**Ood**	______

REMAINING TEST ITEMS: No Feedback Given

19. Say *tan* without saying /t/.	**An**	______
20. Say *mike* without saying /k/.	**My**	______
21. Say *time* without saying /m/.	**Tie**	______
22. Say *tiger* without saying /g/.	**Tire**	______
23. Say *powder* without saying /d/.	**Power**	______
24. Say *winter* without saying /t/.	**Winner**	______
25. Say *snail* without saying /n/.	**Sail**	______
26. Say *faster* without saying /s/.	**Fatter**	______
27. Say *sling* without saying /s/.	**Ling**	______
28. Say *driver* without saying /v/.	**Dryer**	______
29. Say *silk* without saying /l/.	**Sick**	______
30. Say *flame* without saying /f/.	**Lame**	______
31. Say *strain* without saying /str/.	**Ain**	______
32. Say *split* without saying /s/.	**Plit**	______
33. Say *fixed* without saying /k/.	**Fist**	______
34. Say *finish* without saying /f/.	**Inish**	______
35. Say *deer* without saying /d/.	**Ear**	______
36. Say *penny* without saying /p/.	**Any**	______
37. Say *hurt* without saying /h/.	**Urt**	______
38. Say *then* without saying /th/.	**En**	______

SECTION 3

39. Say *yum* without saying /m/.	**Yu**	______
40. Say *light* without saying /t/.	**Lie**	______
41. Say *brown* without saying /n/.	**Brow**	______
42. Say *touch* without saying /ch/.	**Tuh**	______
43. Say *sprinkler* without saying /n/.	**Sprikler**	______
44. Say *yogurt* without saying /g/.	**Yourt**	______
45. Say *throw* without saying /th/.	**Row**	______
46. Say *pumpkin* without saying /m/.	**Pupkin**	______
47. Say *quarrel* without saying /w/.	**Coral/Karl**	______
48. Say *squish* without saying /k/.	**Swish**	______
49. Say *squirrel* without saying /k/.	**Swirl**	______
50. Say *examine* without saying /k/.	**Esamine**	______
51. Say *kitchen* without saying /ch/.	**Kitten**	______
52. Say *box* without saying /k/.	**Boss**	______
53. Say *which* without saying /t/.	**Wish**	______
54. Say *lunch* without saying /ch/.	**Lun**	______
55. Say *ground* without saying /nd/.	**Grou**	______
56. Say *listen* without saying /en/.	**Lis**	______
57. Say *fast* without saying /st/.	**Fa**	______
58. Say *apple* without saying /el/.	**App**	______
59. Say *cracker* without saying /er/.	**Crack**	______
60. Say *first* without saying /st/.	**Fur**	______
61. Say *taste* without saying /s/.	**Tate**	______

Total Raw Score ______

Appendices G. Adapted Measures Elision – Chinese

Elision: 中文成年人

材料： Eprime 文件：Elision.es

执行：启动 EPrime，并让被试听指示。在每次被试反应之后，实验人员**必须**在反应盒上给正确答案按（1）键，给错误答案按（2）键。

终止测试：执行第 1 和 2 部分，不管被试表现如何。如果被试在第 3 部分连续答错 3 道题，就停止测试。在键盘上按下 control-shift。EPrime 会停止并记下数据。

打分：EPrime 会纪录准确性和反应时间。

实验者说明：“在下一系列活动中，您需要用麦克风对问题进行反应。请大声清楚的进行反应，并直接对着麦克风说话。并且，在您思考反应的时候，尽量避免说其他的东西，譬如“阿，嗯”之类的，因为计算机会将那个识别为回答。您有任何问题么？”

录音说明（被试会听到）：“下面的活动中，我们将玩一个文字游戏。”

第 1 部分

练习题目：给予反馈	**正确答案**
a. 请说衣服(yi1fu). 请说衣服，但不说出衣.	**fu2**
b. 请说茶壶(cha2hu2). 请说茶壶，但不说出壶.	**cha2**
c. 请说面条(mian4tiao2). 请说面条，但不说出面.	**tiao2**

测试题目：给予反馈		**分数 (1/10)**
1. 请说白饭(bai2fan4)，但不说出饭.	**bai2**	______
2. 请说面包(mian4bao1)，但不说出面.	**bao1**	______
3. 请说电脑(dian4nao3)，但不说出脑.	**dian4**	______
剩下的测试题目：不给予反馈		
4. 请说鲨鱼(sha1yu2)，但不说出鲨.	**yu2**	______
5. 请说炸药(za4yao4)，但不说出炸.	**yao4**	______
6. 请说黑皮鞋(hei1pi2xie2)nw，但不说出黑.	**pi2xie2**	______
7. 请说汽车站(qi4che1zhan4)，但不说出站.	**qi4che1**	______
8. 请说红颜色(hong2yan2se4)nw，但不说出红.	**yan2se4**	______
9. 请说西瓜(shuo1gua1)nw，但不说出西.	**gua1**	______
10. 请说班主任(ban1zhu3ren4)，但不说出班.	**zhu3ren4**	______
11. 请说暖水壶(nuan3shui3hu2)nw，但不说出暖.	**shui3hu2**	______
12. 请说可爱(ke3ai4)，但不说出爱.	**ke3**	______
13. 请说大门口(da4men2kou3)nw，但不说出门.	**da4kou3**	______
14. 请说红绿灯(hong2lu4deng1)，但不说出绿.	**hong2deng1**	______
15. 请说垃圾桶(la1ji1tong3)nw，但不说出桶	**la1ji1**	______

第 2 部分

录音说明（被试会听到）：“好，现在我们试着将拿掉这些词的部分缩小一点。”

练习题目：给予反馈

	正确答案
a. 请说壮(zhuang4). 请说壮，但不说出 zhu1.	**ang4**

b. 请说关(guan1)．请说关，但不说出an1．	**gu1**
c. 请说顿(dun4)，但不说出en4．	**du1**

测试题目：给予反馈		**Score (1/10)**
16. 请说福(fu2)，但不说出f.	**wu2**	_____
17. 请说低(di1)，但不说出d.	**yi1**	_____
18. 请说灯(deng1)，但不说出d.	**eng1**	_____

剩下的测试题目：不给予反馈

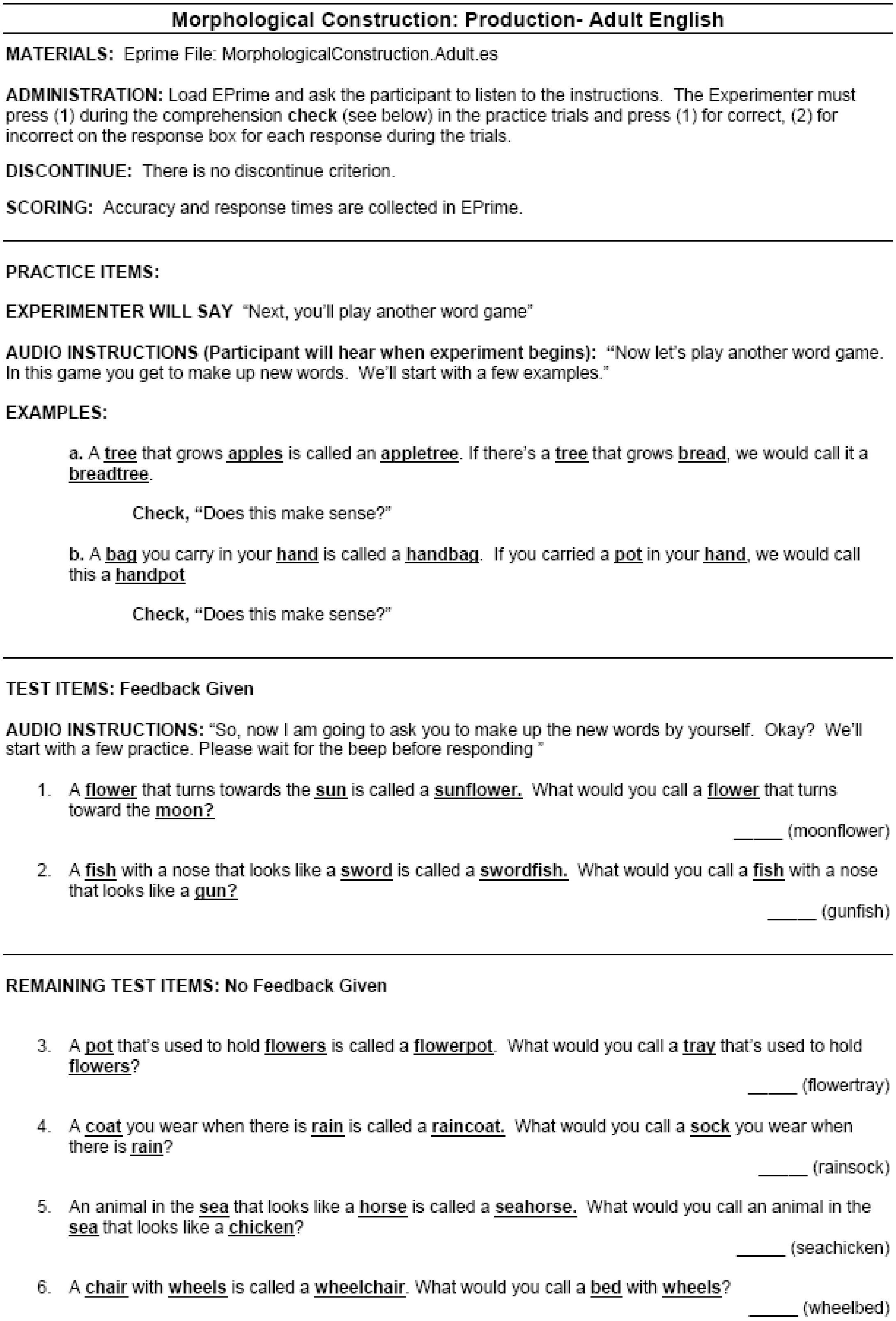
19. 请说先(xian1)，但不说出x.	**yan1**	_____
20. 请说哲(zhe2)，但不说出zh.	**e2**	_____
21. 请说熊(xiong2)，但不说出xi.	**ong2**	_____
22. 请说肯(ken3)，但不说出en3.	**ke1**	_____
23. 请说转(zhuan3)，但不说出zh.	**wan3**	_____
24. 请说抢(qiang3)，但不说出qi.	**ang3**	_____
25. 请说晒(shia4)，但不说出sh.	**ai4**	_____
26. 请说坡(po1)，但不说出p.	**o2**	_____
27. 请说蝶(die2)，但不说出d.	**ye2**	_____
28. 请说垛(duo3)，但不说出d.	**wo3**	_____
29. 请说偷(tou1)，但不说出t.	**ou1**	_____
30. 请说超(chao1)，但不说出ch.	**ao1**	_____

第 3 部分

31. 请说热(re4)，但不说出e4.	**r**	_____
32. 请说新(xin1)，但不说出n.	**xi1**	_____
33. 请说卢(lu4)，但不说出u2.	**l**	_____
34. 请说顺(shun4)，但不说出sh.	**wen4**	_____
35. 请说戳(chuo1)，但不说出ch.	**wo1**	_____
36. 请说传(chuan2)，但不说出ch.	**wan2**	_____
37. 请说闯(chuang3)，但不说出ch.	**wang2**	_____
38. 请说三(san1)，但不说出an1.	**si1**	_____
39. 请说打(da3)，但不说出a3.	**d**	_____
40. 请说副(fu4)，但不说出u4.	**f**	_____
41. 请说踢(ti1)，但不说出yi1.	**t**	_____
42. 请说风(feng1)，但不说出eng1.	**fo1**	_____
43. 请说面(mian4)，但不说出a.	**min4**	_____
44. 请说转(zhuan4)，但不说出a.	**zhun4**	_____
45. 请说暖(nuan3)，但不说出a.	**nun3**	_____
46. 请说踹(chuai4)，但不说出a.	**chui4**	_____
47. 请说春(chun1)，但不说出u.	**chen1**	_____
48. 请说峦(luan4)，但不说出a.	**lun2**	_____

合计分数 _____

Appendices H. Adapted Measures Morphological Construction – Adult



Morphological Construction: Production- Adult English

MATERIALS: Eprime File: MorphologicalConstruction.Adult.es

ADMINISTRATION: Load EPrime and ask the participant to listen to the instructions. The Experimenter must press (1) during the comprehension **check** (see below) in the practice trials and press (1) for correct, (2) for incorrect on the response box for each response during the trials.

DISCONTINUE: There is no discontinue criterion.

SCORING: Accuracy and response times are collected in EPrime.

PRACTICE ITEMS:

EXPERIMENTER WILL SAY "Next, you'll play another word game"

AUDIO INSTRUCTIONS (Participant will hear when experiment begins): "Now let's play another word game. In this game you get to make up new words. We'll start with a few examples."

EXAMPLES:

a. A **tree** that grows **apples** is called an **appletree**. If there's a **tree** that grows **bread**, we would call it a **breadtree**.

Check, "Does this make sense?"

b. A **bag** you carry in your **hand** is called a **handbag**. If you carried a **pot** in your **hand**, we would call this a **handpot**

Check, "Does this make sense?"

TEST ITEMS: Feedback Given

AUDIO INSTRUCTIONS: "So, now I am going to ask you to make up the new words by yourself. Okay? We'll start with a few practice. Please wait for the beep before responding "

1. A **flower** that turns towards the **sun** is called a **sunflower.** What would you call a **flower** that turns toward the **moon?**
   _____ (moonflower)
2. A **fish** with a nose that looks like a **sword** is called a **swordfish.** What would you call a **fish** with a nose that looks like a **gun?**
   _____ (gunfish)

REMAINING TEST ITEMS: No Feedback Given

3. A **pot** that's used to hold **flowers** is called a **flowerpot**. What would you call a **tray** that's used to hold **flowers**?
   _____ (flowertray)
4. A **coat** you wear when there is **rain** is called a **raincoat.** What would you call a **sock** you wear when there is **rain**?
   _____ (rainsock)
5. An animal in the **sea** that looks like a **horse** is called a **seahorse.** What would you call an animal in the **sea** that looks like a **chicken**?
   _____ (seachicken)
6. A **chair** with **wheels** is called a **wheelchair**. What would you call a **bed** with **wheels**?
   _____ (wheelbed)

7. A **cage** that holds a **bird** is called a **birdcage**. What would you call a **cage** that holds a **snake**?
_____ (snakecage)

8. A **ring** you wear in your **ear is** called an **earring**. What would you call a **ring** you wear on your **back**?
_____ (backring)

9. A **knob** on a **door** is called a **doorknob.** What would you call a **knob** on a **window**
_____ (windowknob)

10. A **fish** that is **gold** is called a **goldfish**. What would you call a **fish** that is **black**?
_____ (blackfish)

11. A **box** used to hold **mail** is called a **mailbox.** What would you call a **bowl** used to hold **mail**?
_____ (mailbowl)

12. A **man** made out of **snow** is called a **snowman.** What would you call a **cat** made out of **snow**?
_____ (snowcat)

13. A **gown** you wear at **night** is called a **nightgown**. What would you call a **gown** you wear to **study**?
_____ (studygown)

14. A **snake** with a **rattle on its tail** is called a **rattlesnake**. What would you call a **horse** with a **rattle on its tail**?
_____ (rattlehorse)

15. The **light** on the **tail** of a car is called a **taillight.** What would you call the **door** on the **tail** of a car?
_____ (taildoor)

16. The game where you throw a **ball** into a **basket** is called basketball. What would you call a game where you throw a **shoe** into a **basket**?
_____ (basketshoe)

17. **Paper** that covers the wall is called **wallpaper.** What would you call **cloth** that covers the **wall**?
_____ (wallcloth)

18. The **room** where you wash is called the **washroom.** What would you call a **house** where you **wash**?
_____ (washhouse)

19. An **ache** in your **head** is called a **headache**. What would you call an **itch** in your **head**?
_____ (headitch)

20. A **print** made by a **foot** is called a **footprint**. What would you call a **print** made by a **nose**?
_____ (noseprint)

21. A **board** that is **black** is called a **blackboard.** What would you call a **board** that is **green**?
_____ (greenboard)

22. A **flower** that is **wild** is called a **wildflower.** What would you call a **lake** that is **wild**?
_____ (wildlake)

23. A **ball** made out of **snow** is called a **snowball**. What would you call a **ball** made out of **mud**?
_____ (mudball)

24. A **cloth** you put over the table is called a **tablecloth.** What would you call a **paper** you put over the **table**?
_____ (tablepaper)

25. A glass used to hold **wine** is called a **wineglass**. What would you call a **glass** used to hold **oil**?
_____ (oilglass)

26. A **yard** on the **back** of a house is called a **backyard**. What would you call a **yard** on the **side** of a house?
_____ (sideyard)

27. The **light** of the **moon** is called **moonlight.** What would you call the **light** of a **tree**?
_____ (treelight)

28. A **clip** for holding **paper** is called a **paperclip**. What would you call a **band** for holding **paper**?
_____ (paperband)

29. A **bird** that is **blue** is called a **bluebird**. What would you call a **bird** that is **white**?
_____ (whitebird)

30. The **shore** by the **sea** is called the **seashore.** What would you call the **shore** by a **pond**?
_____ (pondshore)

Total Raw Score _____

Appendices I. Adapted Measures Morphological Reception – Child

Morphological Construction: Reception- English Child

MATERIALS: Instruction/Stimuli Sheet

ADMINISTRATION: Follow the instructions in the stimuli sheet.

DISCONTINUE: Complete the entire task regardless of subject performance.

FEEDBACK: Give feedback on the practice item and test items 1-3.

SCORING: 0-incorrect, 1-correct. The total score is the total number of items correct.

DIRECTIONS:
Say to the child, **"Here are some pictures. When I say the name of something you show me where it is okay? Some of them might sound silly, but that's okay. Just show me which one you think it is.**

EXAMPLES:

Say: "A **flower** that turns towards the **sun** is called a **sunflower.** If I asked you for a picture that shows a **moonflower**, you would point to this picture." Point to the picture with the *moonflower*.

Say, "Does this make sense?"

TEST ITEM: Provide feedback.

Say, "Now, you'll try some. Remember just point to the picture that I say." **Score (0/1)**

1. A **fish** with a nose that looks like a **sword** is called a **swordfish.** Where's the picture of a **gunfish?** ________
   If correct say, "That's right. Let's try the next one."
   If incorrect say, "That's not quite right. This picture, (Point to the *gunfish*) shows a **gunfish**.

2. Where's the picture of a **flowertray**?
3. Where's the picture of a **rainsock?**

REMAINING TEST ITEMS: Provide no feedback on the remaining items.

4. Where's the picture of a **seachicken?**
5. Where's the picture of a **wheelbed?**
6. Where's the picture of a **snakecage?**
7. Where's the picture of a **backring?**
8. Where's the picture of a **windowknob?**
9. Where's the picture of a **blackfish**?
10. Where's the picture of a **mailbowl**?
11. Where's the picture of a **snowcat**?
12. Where's the picture of a **daygown?**
13. Where's the picture of a **rattlehorse?**
14. Where's the picture a **taildoor?**

Appendices J. Adapted Measures Morphological Production – Child

Morphological Construction: Production- Child English

MATERIALS: MorphologicalProduction.Child.English.es, instructions

ADMINISTRATION: Load EPrime and read instructions to the child. Press any key to begin the experiment after giving the instructions. After each subject response, the experimenter **must** press (1) for correct, (2) for incorrect on the keyboard.

DISCONTINUE: There is no discontinue criterion.

FEEDBACK: Give feedback only on practice item and test items 1-3.

SCORING: Accuracy and response times are collected in EPrime. If the subject gives answer other than the standard answer, please write down the response of the child for future reference.

PRACTICE ITEM:

EXPERIMENTER WILL SAY "Now let's play another word game. In this game you get to make up new words.

EXAMPLES:

a. A **tree** that grows **apples** is called an **appletree**. If there's a **tree** that grows **bread**, we would call it a **breadtree**.

Say, "Does this make sense?"

****Press the '1' key**

TEST ITEMS: Feedback Given

1. A **bag** you carry in your **hand** is called a **handbag**. What would you call a **pot** you carry in your **hand**?
_____ (handpot)

If correct say, "That's right. Let's try the next one."
If incorrect say, "That's not quite right. You would call a **pot** that you carry in your **hand**, a **handpot.**

2. The game where you throw a **ball** into a **basket** is called basketball. What would you call a game where you throw a **shoe** into a **basket**?
_____ (basketshoe)

If incorrect say, "That's not quite right. You would call a game where you throw a **shoe** into a **basket**, is called **basketshoe.**

3. **Paper** that covers the wall is called **wallpaper.** What would you call **cloth** that covers the **wall**?
_____ (wallcloth)

If incorrect say, "That's not quite right. You would call a **cloth** that covers the **wall** a **wallcloth.**

REMAINING TEST ITEMS: Provide no feedback on the remaining items.

4. The **room** where you wash is called the **washroom.** What would you call a **house** where you **wash**?
_____ (washhouse)

5. An **ache** in your **head** is called a **headache**. What would you call an **itch** in your **head**?
_____ (headitch)

6. A **print** made by a **foot** is called a **footprint**. What would you call a **print** made by a **nose**?

_____ (noseprint)

7. A **board** that is **black** is called a **blackboard.** What would you call a **board** that is **green**?
_____ (greenboard)

8. A **flower** that is **wild** is called a **wildflower.** What would you call a **lake** that is **wild**?
_____ (wildlake)

9. A **ball** made out of **snow** is called a **snowball**. What would you call a **ball** made out of **mud**?
_____ (mudball)

10. A **cloth** you put over the table is called a **tablecloth.** What would you call a **paper** you put over the **table**?
_____ (tablepaper)

11. A glass used to hold **wine** is called a **wineglass**. What would you call a **glass** used to hold **oil**?
_____ (oilglass)

12. A **yard** on the **back** of a house is called a **backyard**. What would you call a **yard** on the **side** of a house?
_____ (sideyard)

13. The **light** of the **moon** is called **moonlight.** What would you call the **light** of a **tree**?
_____ (treelight)

14. A **clip** for holding **paper** is called a **paperclip**. What would you call a **band** for holding **paper**?
_____ (paperband)

15. A **bird** that is **blue** is called a **bluebird**. What would you call a **bird** that is **white**?
_____ (whitebird)

16. The **shore** by the **sea** is called the **seashore.** What would you call the **shore** by a **pond**?
_____ (pondshore)

Total Raw Score _____

Appendices K. Adapted Measures Fluency – Chinese Adult

测试题目

1 苹果是可以吃的。 是 否
2 老鼠会飞。 是 否
3 狗有五条腿。 是 否
4 帽子是戴在手上的。 是 否
5 书有书页。 是 否
6 鱼有两只手与两条腿。 是 否
7 B是一个数字。 是 否
8 戒指是圆的。 是 否
9 母鸡可以下蛋。 是 否
10 人用眼睛看东西。 是 否
11 车是在天上飞的。 是 否
12 很多人都喜欢玩游戏。 是 否
13 有些天太阳是绿色的。 是 否
14 蚂蚁很小。 是 否
15 有些农民种小麦。 是 否
16 蝌蚪长大之后是青蛙。 是 否
17 电话薄里有很多数字。 是 否
18 晚饭是午饭的前面的一餐。 是 否
19 月亮在天上。 是 否
20 勺子是用来吃东西的。 是 否
21 人们可以用收音机听音乐。 是 否
22 屋顶在房子的顶端。 是 否
23 大象是小动物。 是 否
24 一只野兔有两只耳朵。 是 否
25 一个男孩可以穿衬衫。 是 否
26 很多植物都有绿色的叶子。 是 否
27 人们喜欢用笔吃米饭。 是 否
28 用一副牌可以玩游戏。 是 否
29 午饭时早饭之后的一餐。 是 否
30 钥匙可以打开门上的锁。 是 否
31 人们可以用火柴点蜡烛。 是 否
32 有些自行车有两个轮子。 是 否
33 飞机有翅膀。 是 否
34 游泳池总是装满了气球。 是 否
35 一只杯子可以是满的。 是 否
36 人们在寄信之前把邮票贴在信封上。 是 否
37 A是英文的字母。 是 否
38 玻璃掉在地上会碎。 是 否

39 夏天的天气总是下雪。 是 否

40 一个箱子可以由木头做成。 是 否

41 小宝宝可能想要瓶子。 是 否

42 一个孩子可以躲在杯子里面。 是 否

43 一只牛可以由花做出蜂蜜。 是 否

44 烤箱里面可能会很热。 是 否

45 星期日是一周里的第三天。 是 否

46 所有的蜘蛛都只有两条腿。 是 否

47 很多猫和狗都穿长裤。 是 否

48 大豆可以用来做早餐的豆浆。 是 否

49 一幅画可以挂在墙上。 是 否

50 多数人感到悲伤的时候都在笑。 是 否

51 大海有很多水。 是 否

52 牛常坐校车上学。 是 否

53 有些学生在学校写故事。 是 否

54 很多植物都长在园中。 是 否

55 水池可以装水。 是 否

56 马一般活在水下。 是 否

57 所有的女孩都有蓝眼睛和黑色的头发。 是 否

58 有些人在冬天穿大衣。 是 否

59 一本字典里有很多字。 是 否

60 小孩的年龄都不一样。 是 否

61 多数人在睡觉前都在他们的枕头里面装满石头。 是 否

62 多数蛇都从树中飞过。 是 否

63 铺床的时候要用耙子。 是 否

64 轿车一般比公共汽车要大。 是 否

65 市动物园里面有很多不同的动物。 是 否

66 有些人喜欢在湖里钓鱼。 是 否

67 五月份是一年里最后的一个月。 是 否

68 一只闹钟早上可以把你叫醒。 是 否

69 一只装满砖块的袋子很轻。 是 否

70 人们可以通过工作来赚钱。 是 否

71 一支坏的笔可能漏墨水。 是 否

72 狮子饿了的时候一般会吃纸。 是 否

73 人们把车停在烟囱上面。 是 否

74 苍蝇比马大。 是 否

75 儿童和大人的体重和身高一样。 是 否

76 咖啡和茶都能在早上供应。 是 否

77 很多人头上都长厚厚的叶子。 是 否

78 有些家庭里有好几个孩子。 是 否

79 鸟咆哮声和狗一样。 是 否

80 钢琴的键一般都被漆成红色和绿色。 是 否

81 很多人都把身份证装在皮夹或钱包里。 是 否

82 牙医能在脚的问题上帮助你。 是 否

83 斑马的身上没有条纹。 是 否

84 水管工人可能会补管道。 是 否

85 有些人喜欢周末去滑雪。 是 否

86 老师是一个教书的人。 是 否

87 地毯应该放在天花板上。 是 否

88 手提箱可以用来装一只大象。 是 否

89 糖品尝时总是苦的。 是 否

90 电扇可以产生凉风。 是 否

91 一个成年人可以购买一栋代售的住宅。 是 否

92 在很多国家公园里面都能找到漫游的恐龙。 是 否

93 人们为了可以骑猫会把鞍放在它上面。 是 否

94 一位科学家也许在实验室工作。 是 否

95 一个儿童也许会喜欢一出有趣的木偶戏。 是 否

96 在马戏团你也许能看见一个杂技演员走在拉紧的钢索上。 是 否

97 马一般在车库睡觉。 是 否

98 在公共图书馆里一般能找到很多种参考书。 是 否

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