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Concurrent Correlates of Chinese Word Recognition in Deaf and Hard-of-Hearing Children

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Abstract

The aim of this study was to explore the relative contributions of phonological, semantic radical, and morphological awareness to Chinese word recognition in deaf and hard-of-hearing (DHH) children. Measures of word recognition, general intelligence, phonological, semantic radical, and morphological awareness were administered to 32 DHH and 35 hearing children in Hong Kong. Hierarchical regression analyses showed that tone, semantic radical, and morphological awareness made independent contributions to word recognition in DHH children after the effects of age and intelligence were statistically controlled for. Semantic radical and morphological awareness was found to explain significantly more variance than tone awareness in predicting word recognition in DHH children. This study has replicated previous evidence regarding the importance of semantic radical and morphological awareness in Chinese word recognition in hearing children and extended its significance to DHH children.

The overarching goal of this study is to investigate the relative contributions of phonological, semantic radical, and morphological awareness to Chinese word recognition in deaf and hard-of-hearing (DHH) children. Although much effort has been put into literacy education for DHH children in recent decades, the reading performance of these children remains significantly worse than that of hearing children (Spencer & Marschark, 2010). National surveys in the United States demonstrated that the average DHH students who graduated from high schools had reading competence at the fourth grade level only (Traxler, 2000). Similar findings are also shown in DHH children who learn different languages and writing systems in different educational contexts, including Chinese (Yang, 2008), Dutch (Hermans, Ormel, & Knors, 2010), and Spanish (Alvarado, Puente, & Herrera, 2008). The situation has been improving with technological advancement, such as, improvements in hearing devices and early intervention, but it is still considered as far from satisfactory (Geers & Hayes, 2011; Spencer & Tomblin, 2009).

Consistent research evidence shows that the reading outcomes of hearing children are strongly associated with their language skills (e.g., Bradley & Bryant, 1983; Bryant & Bradley, 1985; Goswami & Bryant, 1990; Ho & Bryant, 1997; Hulme & Snowling, 1994; McBride-Chang & Ho, 2000; Stanovich, Cunningham, & Cramer, 1984). A meta-analysis (Mayberry, del Giudice, & Lieberman, 2011) on literacy learning of DHH children presents similar findings that the language abilities of DHH children predicted 35% of the variance in their reading performance. The reduced access to the auditory foundation for the print-sound correspondences in reading contributes to the poor performance of reading in DHH children. Some studies showed that children with moderately severe to profound hearing loss did not have comparable levels of speech perception with hearing children even if they were supported with hearing aids (HA; e.g., Harkins & Bakke, 2011). Intensive oral instruction also does not appear to solve the problem (Conrad, 1979; Meadow, 2005; Seyfried & Kricos, 1989). The poorer quality of speech perception of DHH children may lead to a lower level of phonological awareness that hampers their reading development (e.g., Colin, Magnan, Ecallé, & Leybaert, 2007; Geers, 2003).

There are two issues that remain unexplored. First, the nature of phonological awareness and its relationship with reading depends on the phonological structure and other characteristics
in the writing system (Perfetti, 2011; Perfetti, Liu, & Tan, 2005; Ziegler & Goswami, 2005). It is not clear whether similar findings could be replicated in DHH children who are exposed to nonalphabetic writing systems. Second, it might be less difficult for DHH children to encode and retrieve the meanings of Chinese words than English words (Hoosain, 1991; Nagy & Anderson, 1998). According to Hoosain (1992, p. 115), the “meanings of the constituents of polymorphemic Chinese words are more manifest than often is the case with constituents of multimorphemic English words.” The Lexical Constituency Model (Perfetti et al., 2005) also suggests that phonological awareness may be less important than semantic-related factors, such as, semantic radical, and morphological awareness in Chinese reading. To address these unexplored areas, this study aimed at investigating the relative roles of these variables in Chinese word recognition in DHH children. In the next section, we begin with a general description of the Chinese language and its writing system because some readers may not be familiar with them.

Characteristics of the Spoken Language in Chinese

Chinese characters are basically monosyllabic, such as, “米” (meaning “rice”) in Cantonese (the main language spoken by people in Hong Kong and the participants in this study). The Chinese language has a simpler syllabic structure in comparison to English. For instance, consonant clusters, which are common in English, do not exist in the Chinese spoken language. Ninety-eight percentage of all Cantonese syllables have simple CV (consonant-vowel) and consonant-vowel-consonant (CVC) structures (Wong, 1984).

Another phonological feature in Chinese that is distinct from English is that Chinese is a tonal language. Tone is a suprasegmental feature that is associated with a syllable. In Chinese (both Mandarin and Cantonese), each syllable can be linked to multiple tones. The lexical tone in Cantonese has six major variations (Chao, 1947; Hashimoto-Yue, 1972) and a change in tone involves a change in the meaning of a syllable. For instance, changes in meanings for the Cantonese syllable /jù/ can be created by tone contrasts—/jù1/ (shirt), /jù2/ (chair), /jù3/ (first character of Italy), /jù4/ (son), /jù5/ (ear), /jù6/ (two). Thus, people cannot discern the meaning of a word in the absence of tonal information.

Although the meanings of some words that share the same syllable can be disambiguated when the tonal information is available, there remain a large number of homophones in the Chinese spoken language. Many monosyllabic words are associated with the same tone (Li, Anderson, Nagy, & Zhang, 2002) and these homophones can represent multiple meanings. For example, the Cantonese tonal syllable /sam1/ can represent different words that have different meanings—“heart,” “deep,” and “forest,” whereas the syllable /zung1/ can represent even more words that refer to “centre,” “clock,” “loyalty,” “ending,” and “ancestor.” Thus, the pervasiveness of homophony in the Chinese language renders the pronunciation of words unreliable and inefficient for meaning retrieval. Hence, readers have to make use of other cues in the written script or/and language in order to disambiguate the meanings of identical tonal syllables, for example, (a) the written forms of the words or/and (b) the morphological characteristics of the Chinese language that offers contextual information for efficient lexical retrieval.

Characteristics of the Writing System in Chinese

The basic units of the Chinese orthography are called “characters.” Each character is composed of strokes organized in an imaginary square. The Chinese writing system can be thought of as a hierarchical system that is built up from strokes, radicals, characters, to words. A majority (80-90%) of Chinese characters are called “compound characters” that are formed by semantic and phonetic radicals (Zhu, 1987).

A semantic radical serves to convey some information about the meaning of its host character. Some semantic radicals are free-standing characters that can occur on their own, whereas some can only exist as a bound form within characters. For example, the character 鬼 (tree) consists of the semantic radical 木 (wood), which is a character on its own, while the semantic radical 手 (hand) in the character 採 (to pick) is not an independent character. It is important for one to discern which part of a character is the semantic radical by referring to its relative location to other components within a character. Some components can only serve as a semantic radical at its “legal position.” For example, “木” (tree) has to be either on the left side, for example, 松 (pine) or at the bottom, for example, 鸦 (firewood) of a character in order to function as a semantic radical. Similarly, the component 鳥 (bird) can only be a semantic radical when it is positioned on the right side within a character, for example, 鴿 (duck), 鴻 (goose), 鴯 (pigeon), and 鴦 (crow).

The identification of a semantic radical may be more difficult in some characters that have a more complicated structure. For example, the character 椰 (coconut) is composed of the semantic radical 木 (wood) and the phonetic radical 鴉je4. But it can also be decomposed into three parts, including 木 (wood), 耳 (ear), and 銃, whereas both 木 (wood) and 耳 (ear) are semantic radicals that are commonly used. If a person mistakes 鳥 (ear) as the semantic radical, s/he may erroneously guess that the character 椰 (coconut) is related to “ear.” Therefore, the knowledge of how different parts within a character come together to form a constituent component, for example, as a semantic radical, contributes to the identification of the meaning of a Chinese character.

Although semantic radicals can indicate the broad semantic category that a character belongs to, the semantic relationship between a semantic radical and its host character is not always transparent. Some of the meanings of the characters are directly related to their semantic radicals, for example, 吱 (bite), 耳 (ear), 叫 (shout), 喝 (sing), 喝 (drink) have the same semantic radical "口" which means “mouth.” The meanings of these characters have a close relationship with the meaning(s) that can be inferred from the semantic radical. If a child encounters a new character with this semantic radical, s/he or he would have some ideas about the semantic properties of the character. However, some characters’ meanings are totally not related to their radicals’ meanings. For example, although the character 嗅 (smell) has the semantic radical “mouth,” its meaning has nothing to do with “mouth.” Thus, semantic radicals may help readers understand the meaning of a character, but they are not always reliable.

A phonetic radical provides cues to the pronunciation of its host character. For example, a reader can derive the pronunciation of 雲 [maɪ] from its phonetic radical 音 [maɪ]. On the basis of some linguistic analyses of Mandarin (e.g., Shu, Chen, Anderson, Wu, & Xuan, 2003; Zhou, 1980; Zhu, 1987), the predictive accuracy of the pronunciation of a compound character from its phonetic radical is not high—nearly 40%. The inclusion of tonal information into the analyses showed that the accuracy rate dropped to 23-26%. Although similar analyses on Cantonese are not available in the literature, the predictive accuracy of phonetic radicals is expected to be low as well in Cantonese because it has even more tones than Mandarin. Thus, the role of phonetic radicals in Chinese word recognition will not be the focus of this study.
Connections Between the Chinese Language and Its Writing System

Another way through which readers may escape from the pervasive homophony in Chinese is to rely on the morphological characteristics of the language that offers contextual information for efficient lexical retrieval. The Chinese writing system is sometimes referred to as a logographic system, but some linguists and researchers have argued that it is more accurate to describe it as a morphemic system (e.g., Leong, 1973) or morphosyllabic system (Mattingly, 1999). Instead of corresponding to phonemes as in English, the basic written units in Chinese (i.e., characters) may serve as guidance for children to understand and generate new words.

Morphemes, words, and compounds in Chinese

A morpheme is defined as the smallest meaningful unit in a spoken language (Packard, 2000), which may or may not occur on their own. In Chinese, a word can be represented by one morpheme or formed by combining two or more morphemes. Approximately 65% of the Chinese words are disyllabic compounds with two morphemes, whereas around 10% are three-morpheme trisyllabic compounds (Sun, Sun, Huang, Li, & Xing, 1996). According to Tang (1989), there are several ways to form compounds in Chinese and most compounds consist of two or more root morphemes (the definition of root morphemes in compounds in Chinese is essentially the same as that in English, i.e., the primary lexical unit of a word). For example, in a “subject-predicate construction,” the former root/morpheme in a given compound is a subject and the latter morpheme states the subject (e.g., 烹饪 [tinnitus], 吃 (eat) is considered as the subject and 嘴 (to buzz) is the predicate that states the subject). In a “modifier-head construction,” the former morpheme modifies the meaning of the latter morpheme in a given compound (e.g., 冰箱 [ice + container = refrigerator]). In a “verb-object construction,” the former morpheme expresses an action and the latter morpheme is the object of the action (e.g., 煮饭 [cook + rice = cooking]). These examples illustrate that most of the words in Chinese are semantically transparent insofar as the meanings of constituent roots/morphemes contribute to the meaning of a compound directly. Thus, children who learn to read Chinese could take the advantage of the analytic and systematic nature of word building to understand new concepts and create new words.

Morphological awareness in Chinese

Morphological awareness in Chinese has been conceptualized and measured in various ways in different studies. It can be generally defined as the knowledge of the word structures in compound words and the meanings of constituent morphemes in the words (e.g., Li et al., 2002; McBride-Chang, Shu, Zhou, Wat, & Wagner, 2003; Shu, McBride-Chang, Wu, & Liu, 2006; Wu et al., 2009). Tasks that measure “morphemic structure awareness” and “homophone awareness” are often used to assess children’s morphological awareness in Chinese.

“Morphemic structure awareness” refers to an understanding of the rules for compound word formation. For example, “right headedness” is a common rule in Chinese word formation, by which the second/right morpheme in a compound word specifies the category of the word, and the first morpheme modifies the meaning of the second morpheme. An example can be illustrated in a two-morpheme compound word 教室 (classroom) in Chinese. The second morpheme 教 means “room,” whereas the first morpheme 室 means “room,” whereas the first morpheme 教 (teach) signifies that the word refers to a room for teaching. A similar example can be found in the English word “classroom” where the morpheme “class” modifies the meaning of “room.” In a three-morpheme compound word 長頭駝 (giraffe), the middle morpheme 頭 refers to the concept “neck.” The first morpheme 長 (long) modifies the meaning of 頭 (neck) by indicating that the neck is a long neck. The final morpheme 駝 means “deer,” and the two morphemes on the left-hand side of 駝 modifies its meaning to show that it is a deer with a long neck, that is, giraffe. To measure children’s awareness of morphemic structure in the language, researchers would ask questions, such as, “If we see the sun rising in the morning, we call that a sunrise (yat6 ceot1). What should we call the phenomenon of the moon rising?” (e.g., McBride-Chang et al., 2003). If a child understands the underlying principle of word formation in Chinese, s/he will get the correct answer, that is, “moonrise” /yeu6 ceot1/. Because “moonrise” is not a real word in Chinese, children have to base on their knowledge of morphemic structure to arrive at the correct answer. The ability to reflect on and manipulate the structure of a compound word may serve as guidance for children to understand and generate new words.

“Homophone awareness” refers to ability to distinguish different meanings of homophonic words. To measure homophone awareness in children, researchers would present disyllabic words that share one homophonic syllable to children and ask them to determine whether the homophones in the words represent morphemes that have the same meaning or different meanings. For example, /fu3/ is a homophone in /fu3 zi2/ (trousers) and /fu3 yau5/ (rich), but they are different morphemes. A person has to identify the meaning of a morpheme by referring to another morpheme within the word. In our study, morphological awareness was operationally defined as an individual’s ability to identify the meaning of morphemes that share the same pronunciation, that is, homophone awareness.

Research Evidence in Hearing Children and the Lexical Constituency Model

The significant contributions of phonological awareness to Chinese word reading in hearing children have been demonstrated in both cross-sectional studies (e.g., Hu & Catts, 1998; McBride-Chang & Ho, 2000; Siek & Fletcher, 2001) and in longitudinal studies (e.g., Chow, McBride-Chang, & Burgess, 2005; Ho & Bryant, 1997; McBride-Chang & Ho, 2005). Semantic radicals appear to be important in the reading development of hearing children in Chinese, although little evidence is available in the literature (e.g., Ho, Ng, & Ng, 2003; Nagy et al., 2002; Shu & Anderson, 1997). As for morphological awareness, consistent evidence shows that it has positive contributions to hearing children’s success in learning to read (e.g., Chen, Hao, Geva, Zhu, & Shu, 2009; Ku & Anderson, 2003; McBride-Chang et al., 2003, 2005, 2011; Shu et al., 2006; Tong, McBride-Chang, Shu, & Wong, 2009; Tong et al., 2011; Wang, Cheng, & Chen, 2006; Wong, Kidd, Ho, & Au, 2010). Thus, all of these factors may foster the reading development in hearing children, but which is relatively more important? The Lexical Constituency Model (Perfetti et al., 2005) may provide some insight into this question.

According to this model, both semantic and phonological connections to orthography are available and can be accessed in parallel. Perfetti et al. (2005) argue that word identification in Chinese is less likely to be mediated by phonological information compared with English. Perfetti and Tan (1998) conducted a primed
naming experiment with Chinese participants who were presented with a prime character followed by a target character at different stimulus onset asynchronies (SOA). They manipulated the types of the primes used, including graphic primes (visually similar to the target but not phonologically nor semantically similar); phonological primes (homophones with no shared radicals and no visual similarity); semantic primes (related in meaning without phonological or visual similarity); and unrelated primes (as a baseline for comparison of the strength of priming effects). The SOA between prime and target onset was also manipulated—43, 57, 85, and 115 milliseconds (ms). Perfetti and Tan (1998) found that phonological priming effects did not occur at a faster time point than did graphic priming effects. In contrast, phonological priming effects always happened before graphic priming effects in alphabetic reading, such as, English (Perfetti et al., 2005). This finding suggests that phonological information is not activated before lexical access in Chinese, even though the task requires participants to name a character.

Chen and Shu (2001) attempted to replicate the priming study (Perfetti & Tan, 1998) with both Mandarin-speaking and Cantonese-speaking participants. Similar to Perfetti and Tan (1998), they found that phonological priming effects appeared relatively late and it did not take place before graphic priming. More importantly, they found that strong semantic priming effects occurred very early. Accordingly, Chen and Shu (2001) argue that (a) phonological activation does not play a crucial role in Chinese character recognition (similar findings were also reported in Chen, Flores D’Arcais, & Cheung, 1995; Chen & Juola, 1982; Shen & Forster, 1999; Wong & Chen, 1999), and (b) semantic activation appears very early during lexical access in Chinese character recognition.

Perfetti et al. (2005) proposed two reasons to explain the differences in the time course of phonological activation. The first reason is that the large number of homophones in Chinese makes the pronounciation of the character not “adequately constraining” (p. 56). In other words, the use of phonology is not efficient for word identification in Chinese. The second reason lies in the role of radicals in the Chinese writing system. In English, letters and words are at two distinct levels. Letters are represented at the orthographic level and they are the constituents of a word. In Chinese, radicals are represented at the orthography level, but their relationships to words are not equivalent to that between letters to words in English. This is because some of the radicals themselves are also standalone characters. These radicals may (a) act as a cue to meaning or pronunciation at the sublexical level and (b) contribute to the word identification process at the word level. Thus, Perfetti et al. (2005) argue that the word identification process in Chinese is less mediated by phonology than in English, and one can conceptualize phonology as a constituent of a word, which participates with the orthography and semantics in constraining the word identification process in Chinese, but it is not an “instrument to meaning” (p. 56). According to this model, phonology is involved in the word identification process in Chinese, but its role may not be as important as that in English. Other factors, such as, awareness of the connection between written forms and meaning, that is, semantic radical awareness, may also play a crucial role in word identification. In a more recent review paper, Perfetti, Cao, and Booth (2013) added that “Chinese often requires multiple characters to be encoded (as morphemes) on the way to word identification, the process may allow more complex interactions with context-level factors” (p. 10). Accordingly, successful word recognition in Chinese may also depend on one’s sensitivity to the morphological relationship between characters in a polymorphemic word context, that is, morphological awareness.

Some correlational and longitudinal studies have also shown that morphological awareness has a stronger predictive power than phonological awareness to Chinese word recognition in hearing children (e.g., Chen & Shu, 2001; Kuo & Anderson, 2006; McBride-Chang et al., 2003; Perfetti, 2011, Shu et al., 2006).

The Lexical Constituency Model and research may be helpful for researchers and educators to understand how DHH children learn to read Chinese. Because these children have poorer speech perception, their access to phonological information and its representation must be compromised to a certain extent. It is not reasonable to expect DHH children to rely predominantly on phonological information to identify words efficiently. If semantic information is more important than phonological information in lexical access and they are visually available, it is possible that some of these children who are able to make use of any of these semantic-related cues could have fewer problems in learning to read Chinese.

Phonological Awareness and Reading in DHH Children: Research Evidence

Compared with the research on reading of hearing individuals, very little research has been done with the DHH population. Fairly inconsistent findings regarding the connection between phonological awareness and reading have been reported for DHH children.

Johnson and Goswami (2010) investigated the phonological awareness skills of children who received cochlear implants (CI) before 3.2 years of age, children who received implants after 3.8 years of age, and comparison groups of deaf children who used HA and hearing children matched with reading age. They found that rhyme awareness, speech-reading, and vocabulary were positively associated with reading ability, whereas the three groups of deaf children did not differ from each other in either phonological awareness or reading ability.

Dillon, de Jong, and Pisoni (2012) examined the phonological awareness skills and reading ability among profoundly deaf children who received CI. The children were aged between 6–14 years old. They found that nearly 75% of the children had performance at or above the level of their hearing counterparts on the phonological awareness and reading tasks. Performance on phonological awareness was strongly correlated with reading scores and the correlations remained significant after demographic variables, such as, the age at testing and speech perception skills were controlled for.

Easterbrooks, Lederberg, Miller, Bergeron, and Connor (2008) examined a wide range of phonological skills, including syllable, rhyme, and alliteration awareness skills in a group of deaf children with moderate to profound hearing loss who were aged between 3–6 years old. All of these children wore HA or received CI. They found that phonological skills that were measured at the start of a school year were associated with word reading skills at the end of the school year.

Geers (2003) investigated 181 DHH children between 8–10 years old who had 4–6 years of CI experience. Phonological awareness was measured with a rime task in which children were presented with a set of words that were similar to each other either orthographically or phonologically. They were asked to judge whether the words sound like or not. After controlling for the effects of children and family characteristics, she found that reading competence was significantly associated with children’s rime awareness.

Colin et al. (2007) examined rhyme judgment and rhyme generation abilities in a group of deaf pre-readers who were educated through Cued Speech. They found that phonological skills that were measured in kindergarten remained significant in predicting children’s
ability to read in the first grade, after age and nonverbal intelligence were controlled for. Dyer, MacSweeney, Szczerbinski, Green, and Campbell (2003) also demonstrated that rime awareness contributed to reading in 72 DHH children aged around 7 years. Longitudinal evidence is also available to support phonological awareness as a prerequisite for DHH children’s reading development. For example, Harris and Beech (1998) examined whether rime-onset awareness predicted longitudinally on the reading ability of 24 5-year-old children with severe/profound hearing loss. Children were shown with three pictures and asked to show which of the two pictures (e.g., bed, pen) had a name similar to the target picture (red). They found that the deaf children’s performance in this oddity task were significantly associated with their reading progress.

Some studies have shown no significant association between phonological awareness and literacy in DHH children. For example, Izzo (2002) investigated the concurrent relationship between phonemic awareness and reading ability in 29 DHH children of primary school age. In the study, independent variables were age, phonemic awareness, and sign language ability. Phonemic awareness was measured with a word-to-word matching task in which children were presented with four items and they had to select the two items sharing the same target sound (i.e., initial, medial, or final). Sign language performance of children were videotaped and evaluated by independent sign language raters. Reading ability was measured by a retelling task in which children were asked to read a story written in English and retell it in sign language. Their performance in story retelling was videotaped and evaluated based on criteria regarding, such as, setting, characters, theme, plot episodes, resolution, and sequential order. Izzo (2002) found that sign language ability was significantly correlated with reading ability, whereas phonemic awareness did not contribute significantly to the variance in reading ability. However, severe floor effects were observed in Izzo’s study that may preclude a significant association. Kyle and Harris (2006) showed that phonological awareness was significantly correlated with DHH children’s reading ability. They also found that degree of hearing loss strongly correlated with reading and phonological awareness. After controlling for the influence of hearing loss on reading statistically, they found that only speech-reading skills and productive vocabulary remained significantly associated with reading competence. The findings from these studies called into question regarding the independent role of phonological awareness in the reading development in DHH children.

The evidence regarding the relationship between phonological awareness and reading in DHH children has been equivocal. The diverse characteristics of the DHH children in previous studies may contribute to the discrepant findings and render definitive conclusions difficult. And no study has been conducted with DHH children who read Chinese to examine whether the findings from previous studies are replicable in a different culture. This type of study is warranted because different features in a spoken language and its corresponding writing system may modulate the role of phonological awareness in reading. For example, as predicted by the Lexical Constituency Model, semantic-related factors, such as, morphological awareness may be more important than phonological awareness for DHH children to read Chinese.

Morphological Awareness and Reading in DHH Children: Research Evidence

Scant attention has been paid to the role of morphological awareness in the reading development in DHH children. Gaustad (1986) showed that young DHH children were aware of and could manipulate basic English morphology. Gaustad, Kelly, Payne, and Lylak (2002) found that DHH college and middle school students could segment words into morphemes, and assign meanings to both derivational and inflectional morphemes. These students performed at a comparable level with hearing students on tasks that required them to split and give meanings to words that contain one inflectional or derivational affix (Gaustad & Kelly, 2004). Van Hoogmoed, Verhoeven, Schreuder, and Knoors (2011) also showed that Dutch DHH adults did not differ from hearing adults in morphological processing, suggesting that DHH learners are prepared to work with morphological elements in print.

Regarding the association between morphological knowledge and reading in DHH readers, Kelly (1993) found that skilled DHH readers recognized the function words and inflections appearing in passages more accurately and quickly than did poor readers. Hanson (1993) showed that DHH college students memorized the meanings of pseudoword pairs that were derivationally related (e.g., ralp vs. ralpify) more accurately than that of pseudoword pairs that did share any semantic relationship. Nunes, Burman, Evans, and Bell (2010) showed that suffix spelling made an independent contribution to reading comprehension in deaf children. Nunes et al. (2010) also argue that explicit training on morphology gives DHH children an additional sublexical basis for word identification. They conducted an intervention study in which profoundly deaf children were randomly assigned into a morphology-training group or a control group. The intervention group consisted of computer-supported exercises to enhance children’s awareness of morphemes and grammar, games that children could practice working with morphemes and storybooks so that children could learn in context. They found that children in the intervention group made significantly more progress than children in the control group—they were more aware of morphemes in words and performed significantly better in reading comprehension. This study demonstrated that morphology training was effective in fostering growth in deaf children’s use of morphology and reading ability, suggesting the importance of morphological awareness in DHH children’s reading development.

Present Study

Two issues have emerged from this review of empirical literature. First, the evidence regarding the connection between phonological awareness and word reading in DHH children is mixed. Whether phonological awareness is associated with Chinese word recognition in DHH children is also unclear. Second, no previous study has attempted to address whether semantic radical and morphological awareness are more important than phonological awareness in Chinese word recognition in DHH children. Thus, this study aimed at examining the relative contributions of phonological, semantic radical, and morphological awareness to Chinese word recognition in DHH children in Hong Kong. We also aimed at testing whether the same prediction model of Chinese reading applied to both DHH and hearing children. On the basis of the Lexical Constituency Model, the analysis of the characteristics of Chinese language and writing system, and previous research, this study had the following hypotheses:

1. DHH children have poorer performance in word recognition than hearing children.
2. Phonological awareness makes an independent contribution to Chinese word recognition beyond age, intelligence, and demographic factors in DHH and hearing children.
3. Both semantic radical and morphological awareness make independent contributions to Chinese word recognition beyond age, intelligence, and demographic factors in DHH and hearing children.

4. Both semantic radical and morphological awareness make independent contributions to Chinese word recognition beyond phonological awareness in both DHH and hearing children.

Method

Participants

DHH children

A total of 32 DHH children participated in this study. They ranged in age from 7.89 to 11.64 years old with a mean age of 9.77 years (SD = 1.06 years). Twenty of them were female (62.5%), whereas 12 (37.5%) were male. The criteria for inclusion were that all DHH children (a) had hearing loss before the age of 2 years; (b) had a moderate to profound hear loss; (c) had intelligence within the range accepted as normal for their ages, (d) did not have specific learning disabilities, Attention Deficit and Hyperactivity Disorders (ADHD), or any neurological disorders; (e) were Cantonese speakers. The child and demographic characteristics of the DHH children are presented in Tables 1 and 2. According to parents’ reports, all DHH children were deaf at birth. All children reported using their hearing device regularly. Cantonese is the L1 of 29 DHH children in this study and the remaining three children have both Cantonese and Hong Kong Sign Language as their L1 because they have deaf parents.

Some information about the language exposure of the DHH children is provided as follows. Cantonese is one of the spoken forms of the Chinese language and it is predominantly used in everyday life in Hong Kong, which is not formally taught in schools. Because some of the Cantonese words do not have their equivalent written forms and some of the written forms are not standardized nor officially recognized in Hong Kong, “written Cantonese” is not encouraged in Hong Kong. Therefore, written Chinese that is based on Mandarin grammar is formally taught in schools since kindergarten. Children also start to learn English (both spoken and written) in kindergarten. Some of the children start learning Mandarin (one form of the Chinese language) since primary school. In our study, all children have Cantonese as their L1, learnt English (both and written) and written Chinese since kindergarten, and learnt Mandarin since primary one.

The majority of DHH children in Hong Kong attend mainstream schools and only a small number of DHH children study in schools that are specialized for DHH children (Tang, Lam, & Yiu, 2014). In mainstream schools, DHH children have to rely on their residual hearing with the support of hearing device to learn. Most of the mainstream schools do not have specialist units for DHH children, so there is no access to Hong Kong Sign language in most of the schools in Hong Kong. DHH children have to learn sign language from other sources, such as community centers for deaf people and/or parents (who are also deaf in most cases). According to parents’ reports, 29 children have been exposed to sign language and used it and three did not.

Because we had to rely on the oral responses of DHH children for some of the tasks, we had to ensure that the words produced by those children were to a certain extent understandable by an adult experimenter. We constructed a task for speech intelligibility in our study. On the basis of the Hong Kong Lexical Lists for Primary Learning (Hong Kong Education Bureau, 2013), 30 disyllabic compounds in Key Stage I (Grade 1 to 3) were chosen.

The participating DHH children were shown these written words with pictures that corresponded to the meanings of the words and they were asked to repeat each one for tape recording. Two individuals (one adult male and one adult female) who were blind to the target word acted as independent judges, who listened to the tape and identified the word that they thought the children had spoken. The speech intelligibility of children was determined by the average number of correct identification between the judges. All of the children in this study had satisfactory speech intelligibility (correct identification rate ≥80%).

Hearing children

A total of 35 hearing children participated in this study. The age of hearing children was matched to that of the DHH children in this study. They ranged in age from 7.74 to 11.87 years old with a mean age of 9.37 years (SD = 0.95 years). Analysis of variance (ANOVA) showed no significant difference in age between DHH and hearing children, F (1, 65) = 2.30, p = .05. Thirteen of the hearing children were female (37.14%), whereas 22 (62.86%) were male. All of them had intelligence within the range accepted as normal for their ages, and had no specific learning disabilities, ADHD, or any neurological disorders. Tables 1 and 2 present some of the characteristics and demographic information of the hearing and DHH children, respectively.

Measures

Chinese word recognition

On the basis of the Hong Kong Lexical Lists for Primary Learning (Hong Kong Education Bureau, 2013), we constructed a word recognition task for this study. All Chinese words were disyllabic compounds. Disyllabic words were chosen because 60–70% of Chinese words fall into this category (Sun et al., 1996). In this task, children were shown a word and four pictures. They were then asked to point to a picture that corresponded to the meaning of the word. The four pictures contained (a) the correct answer, (b) a phonological distracter (a picture that corresponded to a disyllabic compound sharing the same syllable with the first character of the target word), (c) a semantic distracter (a picture that corresponded to a disyllabic compound with a meaning related to the target word), and (d) an unrelated distracter (a picture that corresponded to a disyllabic compound that did not resemble the target word neither phonologically nor semantically). We presented the testing materials to DHH children in both oral and sign languages to ensure that they understood the task requirements. The focus of this word recognition task was to test children’s ability to identify the meanings of the words, so it did not require children to pronounce the words.

A pilot test was conducted with 30 children (aged 8–9 years old) to select the most appropriate items for the main study. The piloting procedure was applied to all nonstandardized measures used in this study. We next present a description of the pilot study. Disyllabic compounds were selected from the Hong Kong Lexical Lists for Primary Learning (Hong Kong Education Bureau, 2013). According to the corpus, there are 4,914 words and 4,792 words in Key Stage I (Grade 1 to 3) and Key Stage II (Grade 4 to 6) respectively. One hundred words from this corpus were chosen for the pilot test, of which 50 words from each of the two key stages. After the pilot, we performed an item analysis (Crocker & Algina, 1986; Gronlund & Linn, 1990; Pedhazur & Schmelkin, 1991; Sax, 1989; Thorndike, Cunningham, Thurlow, & Hagen, 1991) to confirm whether the words had an appropriate level of difficulty. Different types of compounds were included in the pilot study, but we chose the word stimuli
in the main study on the basis of the item analysis, rather than types of compounds.

The p index was determined by the proportion of children who answered individual items correctly. An easier item would have a higher p index (Wood, 1960). According to Thompson and Levitov (1985), “items tend to improve test reliability when the percentage of students who correctly answer the item is halfway between the percentage expected to correctly answer if pure guessing governed responses and the percentage (100%) who would correctly answer if everyone knew the answer.” (pp. 164–165). For example, an optimal difficulty for a multiple-choice question (four choices) is halfway between the percentage of pure guess (i.e., 25%) and 100%, that is, \(\frac{25\% + (100\% − 25\%)}{2}\) = roughly 63%.

The d index measured the discriminating power of items. It compared the number of people with high test scores who correctly answered an item with the number of people with low scores who got a correct answer for the same item. If an item has a high discriminating power between high and low scorers, there should be more people in the top-scoring group who answer the item correctly. According to Wiersma and Jurs (1990),
the $d$ index was computed as follows. The children were divided into three groups on the basis of their performance on the task as a whole—an upper group with 27% who had the highest scores, a lower group with 27% who had the lowest scores, and a middle group consisting of the rest 46%. The $d$ index was calculated by the number of people in the upper group who got the right answer minus the number of people in the lower group who got the right answer, divided by the number of people in the largest of the two groups. According to Ebel and Fristie (1986), items with a $d$ index 0.3-0.39 are considered as good items, 0.4 or above as very good.

On the basis of the $p$ and $d$ indexes, we included 50 words in the word recognition task in the main study. Of these 50 items, 15 were easy items, 20 had moderate difficulty, and 15 were difficult. All items, except the easy items, had a $d$ index over 0.3. The items were arranged from the easiest words at the beginning to the most difficult ones toward the end of the test. The internal consistency of this task is satisfactory (hearing: $\alpha = 0.88$; DHH: $\alpha = 0.82$).

**Phonological awareness**

Picture-based oddity tasks were adapted from previous studies (e.g., Harris & Beech, 1998; Ho & Bryant, 1997) to measure children's phonological awareness. Thirty items in each of the following subtests were piloted with 30 children (aged 8–9 years old). Similar to the word recognition task, items used in the main study were selected on the basis of the results from the pilot study.

Onset awareness: Prior work on Chinese word reading in hearing children showed that onset awareness was significantly associated with children's reading ability (e.g., Ho & Bryant, 1997), this aspect of phonological awareness was assessed in this study. In this test, children were presented with three monosyllabic words in Cantonese, along with pictures to ease their memory load. For example, in one item, children were given /maa5/ (horse), /teon5/ (shield), /mong5/ (net). The tone of the three syllables in each trial was identical, whereas the rimes of the three syllables were different. Two target syllables shared the same onset. Children were asked to identify which two monosyllabic words that shared the same onset in each trial by pointing to the picture that they thought was the correct answer. There were 12 trials in the main study. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements. The internal consistency of this task was satisfactory only for DHH children ($\alpha = 0.70$) because of the ceiling effect in the hearing group.

Tone awareness: Similar to onset awareness, prior work on Chinese word reading in hearing children showed that tone awareness was significantly related to children's reading ability (e.g., McBride-Chang et al., 2008b), it was assessed in this study as another construct in phonological awareness. In this task, children were presented with three monosyllabic words in Cantonese, along with pictures to ease their memory load. For example, in one item, children were given /bou3/ (cloth), /cou2/ (grass), /tou3/ (rabbit). The rime of the three syllables in each trial was identical, whereas the onsets of the three syllables were different. Two target syllables shared the same tone. Children were asked to identify which two monosyllabic words shared the same tone in each trial. There were 12 trials in the main study. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements. The internal consistency of this task was satisfactory (hearing: $\alpha = 0.70$; DHH: $\alpha = 0.72$).

**Radical awareness**

Two radical awareness tasks, which were shown to be significantly associated with Chinese word reading in hearing children, were adapted from previous studies (e.g., Ho, Ng & Ng, 2003) to measure children's awareness of semantic and phonetic radicals of Chinese characters. Tasks that involve pseudoword judgment were used because this type of task had the strongest associations with reading among other tasks measuring orthographic awareness in previous studies (e.g., Ho, Ng, & Ng, 2003). Forty items in each of the following subtests were piloted with 30 children (aged 8–9 years old). Items used in the main study were selected on the basis of the results from the pilot study.

Semantic radical awareness task: In this task, children were shown a pseudo-character next to four pictures. The children were required to circle the picture that might be related to the meaning of the pseudo-character. Each pseudo-character, for example, “$\frac{4}{5}$” contained a semantic radical “$\frac{1}{5}$” and a phonetic radical “$\frac{1}{7}$”. Children were tested on how well they were able to identify the semantic radical and use this information to infer the meaning of the pseudo-character. Pseudo-characters were used instead of real characters because if real characters were used, children might rely on their knowledge of the actual meanings of the characters to complete the tasks. Pseudo-characters prompted children to make their decisions according to their awareness of the components within each character. All pseudo-characters were checked against a Chinese dictionary to confirm they were not real characters and all semantic radicals used in the task were familiar to children at their grade levels (Leung & Lee, 2002). The frequency of the number of characters that share the same semantic radicals, semantic transparency of the radical, types of semantic radicals (bound vs. free), and the relative position of each radical within a character (left-right or top-down) were taken into consideration when the stimuli were constructed. There were 19 trials in the main study. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements. The internal consistency of this task was satisfactory (hearing: $\alpha = 0.80$; DHH: $\alpha = 0.77$).

Phonetic radical awareness task: Pseudo-characters were created the same way as in the semantic radical awareness task. In this task, children were shown one pseudo-character (e.g., $\frac{4}{5}$) and three options, each of which being a real character (e.g., $\frac{1}{5}$, $\frac{6}{5}$, $\frac{8}{5}$). They were then asked to circle one character among these three options that might share similar pronunciation with the pseudo-character. They did not have to read the characters aloud. Children were tested how well they were able to identify the phonetic radical and use this information to guess the pronunciation of the pseudo-character. There were 18 trials in the main study. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements. The internal consistency of this task was satisfactory (hearing: $\alpha = 0.83$; DHH: $\alpha = 0.77$).

**Morphological awareness**

According to Carlisle (2000), “morphological awareness, as it contributes to reading, must have as its basis the ability to parse words...
and analyse constituent morphemes for the purpose of constructing meaning” (p. 170). Thus, two tasks were adapted from previous studies (e.g., Shu et al., 2006) to measure children’s skills in morpheme identification and production, which were significantly associated with children’s performance (e.g., McBride-Chang et al., 2003; Shu et al., 2006). The tasks were administered orally in the absence of print so that reading does not confound with language in the tasks. Thirty items in each of the following subtests were piloted with 30 children (aged 8–9 years old). Although words were not presented visually to the children, their written forms were checked against the Hong Kong Corpus of Primary School Chinese (Leung & Lee, 2002) to confirm whether they were familiar to the children at their grade levels.

Morpheme identification: This task measured children’s competence to distinguish the meanings of morphemes among homophones. In each trial, the experimenter faced the children and spoke two disyllabic words to the children in Cantonese with pictures. Children were not likely to recognize the words simply by lip-reading because the lips do not convey tonal information, which is very important in Cantonese. The experimenters faced the children and did not cover their mouths while presenting the words so that the children could hear the words clearly. The two disyllabic words had an identical syllable at the same position. The target syllable was not only identical in sound but also in written form, for example, a shared syllable /hek3/ in 吃飯/hek3 faan6/ (eat rice) and 吃驚/hek3 ging1/ (shocked). In this example, the two syllables sound identical in both words, but their meanings are different. Children were asked to judge whether the identical syllable across both words had the same or different meaning(s). There were 20 trials in the main study. In half of the items, the meanings of the identical syllable across two words were the same, whereas they were different in another half. This task was employed to measure children’s knowledge about that syllables sharing identical pronunciation can carry different meanings, depending on the word context. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements.

Morpheme construction: In each trial, the experimenter faced the children and spoke a disyllabic word to the children in Cantonese. Children were then asked to construct two words with a target morpheme and respond orally. One of these words had to contain a morpheme that had the same meaning as the target morpheme, whereas another word had to contain a morpheme that had a different meaning. However, both morphemes had to be identical in pronunciation. For example, the researcher gave a word 飛機/fei1 gei1/ (plane), children were asked to construct a word with the morpheme /gei1/ in which /gei1/ had the same meaning as it did in 飛機/fei1 gei1/ (the /gei1/ here means “machine”). One example of correct answers was 電視機/din6 si6 gei1/ (television). In the same trial, the children were also required to produce a word that consisted of the morpheme /gei1/ which had a different meaning from that in 飛機/fei1 gei1/. An example was 機會/gei1 wu6/ (chance). This task was also used to assess children’s knowledge about that syllables sharing identical pronunciation can represent words that carry different meanings, depending on the word context. There were 16 trials in the main study. We presented the testing materials to DHH children in both oral and sign languages and conducted two practice trials with all children to ensure that they understood the task requirements. The internal consistency of this task was satisfactory (hearing, $\alpha = 0.76$; DHH: $\alpha = 0.74$).

Nonverbal intelligence
We measured Children’s nonverbal intelligence with Raven’s Standard Progressive Matrices (Raven, Raven, & Court, 2003) in order to partial out any potential influence of general reasoning ability on reading performance. It is a standardized test including five sets of 12 items each. Each item involves a target matrix with a missing piece. Children were asked to choose, from six to eight choices, the best figure to complete the target matrix. One mark was given for the correct answer for each item.

Demographic variables
Demographic information of the children was reported from parents in a questionnaire regarding the degree of hearing loss of DHH children, types of hearing device used, age of fitting CI/using HA, the starting age of hearing loss, types of schools attended, whether and how the children acquire sign language, parents’ hearing status, and parental highest education level.

Procedure
All children were recruited through mainstream primary schools and nonprofit voluntary associations in Hong Kong. Consent forms were sent to parents to seek for their agreement for their children to participate in this study. All measures were administered to each child individually. We used both oral and sign languages consecutively to ensure that the DHH children understand the instructions of all tasks. They were given instructions in Cantonese first, and then in Hong Kong Sign Language (this procedure was applied to all DHH children even though three of them did not know sign language). Sign language was only used in task explanation, but not used in stimuli presentation. The orders of administration of these three tasks were counterbalanced across participants.

Results

Preliminary Analyses

Mean differences of demographic variables between DHH and hearing children.

The means and standard deviations in each of the measures are displayed separately for DHH and hearing children in Table 3. ANOVA was used to assess the mean differences in continuous variables between DHH and hearing children. As for demographic variables, there were no significant differences in age and nonverbal intelligence between DHH and hearing children, respectively (age: $F (1, 65) = 2.30, p > .05$; nonverbal intelligence: $F (1, 65) = 0.23, p > .05$). Chi-squared tests were used to assess the mean differences in categorical variables between the groups. There was a significant difference in paternal ($\chi^2 (2) = 9.77, p < .05$) but not in maternal education ($\chi^2 (2) = 5.69, p > .05$) between DHH and hearing children. The paternal educational level of hearing children was higher than that of DHH children. No significant gender difference was found between the groups, $\chi^2 (1) = 0.038, p > .05$.

Associations between demographic variables and word recognition in DHH and hearing children.

To assess the associations of demographic variables and word recognition in DHH and hearing children, we conducted ANOVA for demographic variables that were categorical and bivariate correlation for variables that were continuous. As for hearing children, no significant differences in word recognition were found between gender, $F (1, 33) = 0.507, p > .05$. Neither paternal educational level, $F (2, 29) = 2.57, p > .05$, nor maternal
Table 3. Means, standard deviations, and F tests for differences between hearing and DHH children for individual measures

<table>
<thead>
<tr>
<th>Measure</th>
<th>Hearing (n = 35)</th>
<th>DHH (n = 32)</th>
<th>F (1, 65)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese word recognition (50)</td>
<td>34.57 (3.62)</td>
<td>34.34 (4.96)</td>
<td>0.05</td>
</tr>
<tr>
<td>Age in years</td>
<td>9.37 (0.95)</td>
<td>9.77 (1.06)</td>
<td>2.30</td>
</tr>
<tr>
<td>Nonverbal intelligence (60)</td>
<td>37.51 (4.15)</td>
<td>38.13 (6.08)</td>
<td>0.23</td>
</tr>
<tr>
<td>Onset awareness (12)</td>
<td>11.23 (0.91)</td>
<td>9.63 (1.31)</td>
<td>0.23</td>
</tr>
<tr>
<td>Tone awareness (12)</td>
<td>11.06 (0.87)</td>
<td>7.09 (1.38)</td>
<td>201.7**</td>
</tr>
<tr>
<td>Semantic radical awareness (19)</td>
<td>15.23 (2.13)</td>
<td>14.94 (2.20)</td>
<td>0.30</td>
</tr>
<tr>
<td>Phonetic radical awareness (18)</td>
<td>14.57 (1.67)</td>
<td>14.44 (1.37)</td>
<td>0.13</td>
</tr>
<tr>
<td>Morpheme identification (20)</td>
<td>13.40 (1.85)</td>
<td>13.13 (1.64)</td>
<td>0.41</td>
</tr>
<tr>
<td>Morpheme construction (32)</td>
<td>23.66 (1.83)</td>
<td>23.44 (1.50)</td>
<td>0.29</td>
</tr>
</tbody>
</table>

Note. Numbers in parentheses represent the maximum score for each measure. DHH, deaf and hard-of-hearing.
*p < .001.

Mean differences of word recognition between DHH and hearing children

Previous research showed that the reduced ability to represent phonological information in DHH children may render them less able to read (e.g., Dyer et al., 2003; Geers, 2003). Are the significant differences in onset and tone awareness between the groups reflected in their performance in word recognition? Contrary to the first hypothesis of this study, there was no significant difference in this word recognition task (identifying the meanings of words by pointing to pictures) between DHH and hearing children, as indicated in Table 3.

Mean differences of word recognition between DHH and hearing children

As shown in Table 3, significant mean differences were found in onset and tone awareness between the groups. Hearing children scored significantly higher than DHH children in these two measures. However, DHH children did not differ significantly from their hearing counterparts in all measures of morphological awareness, that is, semantic radical awareness, morpheme identification, and morpheme construction. Because ANOVA assumes the variances in different samples are equal, Levene's test was used to evaluate whether the present data violated this assumption. Among all of the measures, the variance of tone awareness in DHH children was significantly different from that in hearing children, F(1, 65) = 2.84, p < .05. Hence, Kruskal–Wallis test was used to evaluate the mean difference between the groups for this measure, which indicated similar result that hearing children scored significantly higher than DHH children in tone awareness (p < .05).

Main Analyses—Hypotheses Testing

Mean differences of word recognition between DHH and hearing children

To test the hypotheses regarding the relative contributions of phonological awareness and semantic-related factors (e.g., semantic radical and morphological awareness) in word recognition in DHH and hearing children, we firstly conducted bivariate correlations to investigate the interrelationships among the variables. Second, we carried out hierarchical regression analyses to test the independent roles of these variables in predicting word recognition. As indicated in Table 4, tone awareness was significantly associated with word recognition in DHH children, but onset awareness was not. As for hearing children, both tasks on tone...
Associations among tasks purportedly measuring the same construct are also presented in the correlation matrix as shown in Table 4. There was a significant correlation between onset and tone awareness in DHH children, but it was not found in hearing children. The modest correlation \( r = .36 \) between the two measures in DHH children suggested that these two measures were associated but distinct. The null relationship between these two tasks in hearing children may be due to the fact that the scores of onset awareness reached the ceiling in hearing children—nearly 74% of hearing children scored 11 or above out of 12 in the onset awareness task, whereas 73% of them scored 11 or above out of 12 in the tone awareness task.

A modest and significant association was also found for the tasks measuring radical awareness in both DHH \( r = .37 \) and hearing children \( r = .42 \). The fact that they were significant but not highly correlated suggested that these tasks might be tapping different but related aspects of radical awareness. The correlation between morpheme identification and morpheme construction was only significant in hearing children \( r = .40 \), but not in DHH children \( r = .26 \), indicating that these two skills were more related to each other in hearing than in DHH children.

In order to test whether the three semantic-related measures (i.e., semantic radical awareness, morpheme identification, and morpheme construction) could be combined into one single construct for further analyses, we conducted a principal component analysis. As shown in Table 4, semantic radical awareness had no significant correlation with morpheme construction for both groups. As for the two tasks measuring morphological awareness, they were only significantly correlated in the hearing children. Further, Bartlett’s test of sphericity was not significant for both DHH \( \chi^2 = 3.87, p > .05 \) and hearing samples \( \chi^2 = 6.94, p > .05 \), suggesting that the correlations were not sufficiently large for a principal component analysis. Therefore, the scores of the three semantic-related tasks were not combined for further analyses.

**Independent contributions of variables to word recognition**
To assess the unique contributions of phonological, semantic radical, and morphological awareness to Chinese word recognition, we included variables that were significantly correlated with word recognition in the two groups respectively in hierarchical regression equations. All regression models in both DHH and hearing groups had age and nonverbal IQ being entered first, followed by phonological awareness/semantic radical/ morphological awareness. Although age was not significantly associated with word recognition in DHH children in this study, it was included in the first step because (a) some researchers (e.g., Kail & Hall, 1994; McBride-Chang & Kall, 2002) have argued that age is a fundamental predictor of all tasks related to cognitive development; and (b) age was significantly correlated with IQ, which had a significant correlation with word recognition in DHH children.

To analyze the degree to which phonological awareness contributed to word recognition in DHH children, we entered age and IQ at Step 1 and tone awareness at Step 2 in the regression model. Hierarchical regression equations showed that tone awareness was a significant predictor of word recognition in DHH children \( (\beta = .35, p < .05) \), after the effects of age and nonverbal IQ were controlled for. Another regression analysis was conducted to investigate whether morphological awareness made independent contributions to word reading in DHH children beyond age and nonverbal IQ. It indicates that semantic radical awareness \( (\beta = .32, p < .05) \), morpheme identification \( (\beta = .37, p < .001) \), and morpheme construction \( (\beta = .51, p < .01) \), predicted significant unique variance in word recognition, after the effects of age and nonverbal IQ were controlled for.

Table 4 shows the relative contributions of phonological, semantic radical, and morphological awareness to word recognition in DHH children. It indicates that all three semantic-related tasks, including semantic radical awareness \( (\beta = .30,\)

### Table 4. Bivariate correlations among age, IQ, predictors, and word recognition separately for DHH and hearing children

<table>
<thead>
<tr>
<th>Measure</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>DHH children ( n = 32 )</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Word recognition</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Age</td>
<td>0.24</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Nonverbal IQ</td>
<td>0.36*</td>
<td>0.36*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Onset awareness</td>
<td>0.23</td>
<td>0.32</td>
<td>0.27</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Tone awareness</td>
<td>0.39*</td>
<td>0.11</td>
<td>0.10</td>
<td>0.36*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Semantic radical</td>
<td>0.46*</td>
<td>0.07</td>
<td>0.34</td>
<td>-0.11</td>
<td>0.16</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Phonetic radical</td>
<td>0.25</td>
<td>-0.04</td>
<td>0.18</td>
<td>0.02</td>
<td>0.13</td>
<td>0.37*</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Morpheme identification</td>
<td>0.48*</td>
<td>0.34</td>
<td>0.44*</td>
<td>0.19</td>
<td>0.02</td>
<td>0.15</td>
<td>0.15</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>9. Morpheme construction</td>
<td>0.59**</td>
<td>0.50*</td>
<td>0.39*</td>
<td>0.22</td>
<td>0.35*</td>
<td>0.22</td>
<td>-0.13</td>
<td>0.26</td>
<td>1.00</td>
</tr>
</tbody>
</table>

| Hearing children \( n = 35 \) | | | | | | | | | |
| 1. Word recognition | 1.00 | | | | | | | | |
| 2. Age | 0.49* | 1.00 | | | | | | | |
| 3. Nonverbal IQ | 0.35* | 0.51* | 1.00 | | | | | | |
| 4. Onset awareness | 0.17 | -0.09 | 0.01 | 1.00 | | | | | |
| 5. Tone awareness | 0.28 | 0.08 | 0.07 | 0.09 | 1.00 | | | | |
| 6. Semantic radical | 0.43* | 0.34* | 0.27 | -0.04 | 0.13 | 1.00 | | | |
| 7. Phonetic radical | 0.30 | 0.35* | 0.26 | -0.01 | 0.32 | 0.42* | 1.00 | | |
| 8. Morpheme identification | 0.50* | 0.17 | 0.19 | 0.01 | 0.22 | 0.01 | 0.24 | 1.00 | |
| 9. Morpheme construction | 0.65** | 0.43* | 0.24 | 0.01 | 0.29 | 0.19 | 0.24 | 0.40* | 1.00 |

**Note.** DHH = deaf and hard-of-hearing.

*p < .05. *p < .01. *p < .001.
Differences in Word Recognition Between DHH and Hearing Children

The first hypothesis of this study was that DHH children performed worse than hearing children in word recognition. Contrary to this hypothesis, we found no difference between DHH and hearing children in word recognition. Three factors that might contribute to the null difference were explored, including (a) the nature of the word recognition task, (b) the contribution of technological advancement in HA, and (c) the influence of the Chinese language and writing system.

The word recognition task required children to identify the meaning of words and point to a corresponding picture.

Table 6. Hierarchical multiple regressions predicting Chinese word recognition for hearing children (n = 35)

<table>
<thead>
<tr>
<th>Steps</th>
<th>Variables</th>
<th>$\beta$</th>
<th>t</th>
<th>$R^2$</th>
<th>$\Delta R^2$</th>
<th>Adjusted $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Age</td>
<td>0.42*</td>
<td>2.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nonverbal intelligence</td>
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<td>0.77</td>
<td>0.25</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Age</td>
<td>0.14</td>
<td>0.98</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Nonverbal intelligence</td>
<td>0.05</td>
<td>0.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semantic radical awareness</td>
<td>0.28*</td>
<td>2.31</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Morpheme identification</td>
<td>0.30*</td>
<td>2.41</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Morpheme production</td>
<td>0.40**</td>
<td>2.95</td>
<td>0.62</td>
<td>0.37**</td>
<td>0.55</td>
</tr>
</tbody>
</table>

Note: DHH = deaf and hard-of-hearing

*p < .05. **p < .01.
The task does not require phonological specification of words, which is a typical weakness for DHH children. Thus, DHH children may be less disadvantaged in their performance because of the nature of the task. Similar nonsignificant findings were also reported by a series of studies conducted by Miller (2004a, 2004b, 2005, 2007) in which DHH children were asked to categorize the meanings of words without the need to read them aloud. However, other studies (e.g., Harris & Beech, 1998) that also used tasks that did not require children to represent phonological information of words (e.g., selecting words that go with a picture, filling sentences with an appropriate word) showed significant findings: DHH children had poorer performance in word recognition than hearing children. Thus, the nature of the task itself may not be sufficient enough to explain the nonsignificant difference in word recognition between DHH and hearing children in this study.

Another contributing factor to the comparable levels of word recognition performance between DHH and hearing children may stem from the improvements in technology, early identification, and availability of professionals that may facilitate DHH children in perceiving auditory information and learning spoken languages. DHH children belong to a very heterogeneous group in which there is a considerable variation in literacy-related performance. Although most research shows that DHH individuals across ages were less accurate and slower than hearing individuals in phonological awareness (e.g., Dyer et al., 2003; Hanson & Fowler, 1987; LaSasso, Crain, & Leybaert, 2003; Leybaert & Alegria, 1993), there is wide variation across different studies in the levels of phonological awareness in DHH children. Some studies reported very low levels of awareness in DHH children (e.g., Harris & Beech, 1998; Izzo, 2002), whereas some demonstrated relatively higher levels of awareness. For example, Harris and Beech (1998) showed that most of their 5-year-old participants performed below or around chance levels on a picture-based task of rime judgment. Miller (1997) found that older DHH children performed above chance level on a similar task. Sterne and Goswami (2000) also found that DHH children performed above chance level on a homophone-matching task.

Consistent with the findings in past research, the DHH children in this study performed significantly poorer than their hearing counterparts in both phonological tasks, but most of them performed above chance level. One contributing factor to the DHH children’s comparatively higher level of phonological awareness may come from a variety of support that enhances their access to the phonological representations of the languages, which would provide some advantages in word recognition (Easterbrooks et al., 2008; Geers & Hayes, 2011). For example, Spencer, Tomblin, and Gantz (1997) found that 50% of the DHH children who were fitted with CI in their study attained a reading level much closer to their hearing counterparts. However, past research and the present study involve participants who may represent different parts of the spectrum in the population, so they may vary considerably in individual abilities. Thus, more research is needed to evaluate the influence of environmental support on phonological awareness and reading.

The third factor that may contribute to the comparable levels of word recognition between DHH and hearing children is the influence of the Chinese language and its writing system. According to the Lexical Constituency Model, word identification in Chinese is less mediated by phonological awareness compared with English, whereas semantic-related factors play a more important role in the word identification process in Chinese. In our study, we found a significant difference in phonological awareness between DHH and hearing children, but it seems that the lower level of DHH children in phonological awareness did not translate to lower word recognition ability because, contrary to our hypothesis, we did not find significant difference in word recognition between the groups. No significant differences were also observed for either semantic radical or morphological awareness between two groups. On the basis of the Lexical Constituency Model, DHH children may acquire the knowledge about semantic radicals and morphological characteristics of Chinese that renders them less disadvantaged in word recognition, especially when the task did not require explicit phonological representations of words. In other words, DHH children may rely on semantic-related cues to identify the meanings of words, and this ability may compensate for their disadvantaged phonological awareness in the word identification process.

**Phonological Awareness and Chinese Word Recognition**

The second hypothesis of this study was to examine the contentious issue of whether phonological awareness is important for reading in DHH children. In support of our hypothesis, findings from hierarchical regression analyses showed that tone awareness accounted for significant amount of variance in word recognition in DHH children, even after the effects of age and nonverbal IQ were controlled for. This finding is also consistent with previous findings that tone awareness was significantly linked to Chinese word reading in hearing children. For example, Shu, Peng, and McBride-Chang (2008) showed that tone awareness explained a significant amount of variance in Chinese character recognition of preschoolers. Tone awareness was also significantly associated with both Chinese character and word reading in older children studying Grade 5 (Sleg & Fletcher, 2001). Tone processing ability was also one of the cognitive abilities that could significantly distinguish dyslexic children from age-matched non-dyslexic children (Cheung et al., 2009) and kindergarten children at risk for dyslexia from those who were not at risk (McBride-Chang et al., 2008a). In this study, we showed that tone awareness was also important for DHH children to read Chinese.

However, onset awareness was not significantly associated with Chinese word recognition in DHH children. This finding is buttressed by some previous findings that phonemic awareness (Huang & Hanley, 1995) or onset awareness (McBride-Chang, Bialystok, Chong, & Li, 2004; McBride-Chang et al., 2008b) did not make unique contribution to Chinese word reading in hearing children. Evidence also shows that tone awareness is more important than onset awareness in Chinese character recognition (McBride-Chang et al., 2004, 2008b). The linguistic nature of written Chinese may explain why tone awareness assumes a more prominent role than onset awareness in Chinese word identification. The basic unit of Chinese, that is, the character, maps onto syllables of the language, and there is no clue available within the character that helps individuals encode the fine-grained segments of the syllable. Although tone is not explicitly marked in characters, it is an integral part of syllable processing (Duanmu, 2006), which was a strong predictor of Chinese reading among other phonological awareness skills (e.g., McBride-Chang et al., 2004, 2008b, Shu et al., 2008). An individual who reads a Chinese character does not necessarily encode its onset, but s/he must be aware of the whole syllable and its tone.
children. The reason for this lack of relationship is likely to be that a high proportion of children were at ceiling on both onset and tone awareness tasks, thereby resulting in a limited variability among this group of children on their scores of phonological awareness. One factor that may account for the ceiling effect was the age of the hearing participants (mean age around 9–10 years old). Age is always associated with children’s reading experience. Some studies showed that the relationships between cognitive skills and reading performance change with reading experience (Ehri, 1992; Frith, 1985). In Hong Kong, all children started reading both Chinese and English since kindergarten. Learning to read one more alphabetic script may foster children’s development of all aspects of phonological awareness with age, which may contribute to the ceiling effect observed in this study. Most of the research that demonstrated a significant relationship between phonological awareness and Chinese reading in Hong Kong was conducted with hearing children at a younger age only, but not with children older than 8 years old (e.g., Ho & Bryant, 1997, McBride-Chang & Ho, 2000; McBride-Chang et al., 2008b). Another factor that may contribute to the ceiling effect is related to the type of tasks that were used to assess phonological awareness. Oddity tasks were used to measure onset and tone awareness in this study. Some researchers have argued that tasks that require children to produce an answer on their own have a higher discriminating power between good and poor readers than forced-choice tasks (Siok & Fletcher, 2001). The oddity tasks employed in this study may be too easy for the hearing children at their age. Thus, the relationship between phonological awareness and reading in older hearing children has to be reevaluated with more difficult tasks, for example, production tasks, in the future.

In summary, this study showed that phonological awareness was also important for DHH children to identify Chinese words. Relative to onset awareness, the findings revealed that tone awareness was a more crucial aspect of phonological awareness that predicted Chinese word recognition in DHH children, in which it made an independent contribution to word recognition beyond age and IQ.

Semantic-Related Variables and Chinese Word Recognition

The third and fourth hypotheses of this study concern the independent contributions of semantic radical and morphological awareness to Chinese word recognition in DHH and hearing children. Because most of the Chinese characters consist of semantic radicals, the sensitivity to their functions is important for readers to recognize characters’ meanings and learn new words. Consistent with the hypothesis and previous findings (e.g., Cheung, Chan, & Chong, 2007; Ho, Ng, & Ng, 2003), semantic radical awareness was significantly associated with word recognition in both DHH and hearing children in this study. We also showed that it made independent contribution to word recognition in DHH children, beyond the influence of phonological awareness, age, and IQ.

The prevalence of homophones in the Chinese language may be one of the reasons that make another semantic-related variable, that is, morphological awareness a particularly strong variable that is associated with children’s reading performance in both our study and previous studies. Past research in alphabetic scripts (e.g., McBride-Chang, Manis, Seidenberg, Custodio, & Doi, 1993; Sprenger-Charolles, Siegel, & Bechennec, 1998) has shown that children’s awareness of spellings of homophones is connected with reading competence. Li et al. (2002) also demonstrated that Chinese children’s sensitivity to different meanings of homophones predicted word recognition. It has been argued that this ability may be more strongly associated with reading in Chinese than in languages, such as, Spanish or English, in which homophones do not abound. In our study, the first task of morphological awareness required the children to make judgments about whether two identical syllables share the same meaning in a word context, whereas the second task required the children to produce words that represent the same and different meanings of individual morphemes. Both tasks could not be completed on the basis of the pronunciations because the syllables are identical. Thus, the children have to be sensitive to the meanings of individual morphemes in order to obtain the correct answers. Consistent with previous research with hearing children (e.g., McBride-Chang et al., 2003; Shu et al., 2006), the findings from this study highlighted the importance of morphological awareness in Chinese word recognition of DHH children.

Findings from McBride-Chang et al.’s (2003) study suggested that morpheme identification skills might be useful only for beginning readers to read. They found that it had significant predictions of Chinese character recognition in the kindergarten sample only, but not in children in the second grade. In contrast to this finding, we found that morpheme identification accounted for a significant amount of variance in word recognition consistently in both DHH and hearing children who were, on average, third graders. McBride-Chang et al. (2003) proposed that one reason behind their nonsignificant finding was the task being too easy for second graders in their sample. The items in our study may be more difficult for the participants because the written forms of the homophonic words were also identical, whereas the items used in McBride-Chang et al. (2003) study were not. The design of our task was adapted from Shu et al. (2006) in which they demonstrated significant associations between morpheme identification and Chinese word recognition in both dyslexic and nondyslexic children who were older in age (Grade 5 and 6). In short, our study replicated the findings that morpheme identification is an important skill to read in Chinese in a group of older hearing children and extended its relevance to Chinese word recognition in DHH children.

Our findings underscore the importance of semantic-related factors in Chinese word recognition of DHH children. Semantic radical and morphological awareness were significantly associated with word recognition. They also made unique contributions to word recognition beyond the influence of age, IQ, demographic variables, and phonological awareness in both DHH and hearing children. This finding suggests that semantic-related factors were more important than phonological awareness in Chinese word reading in children.

Limitations and Future Directions

Although this study has addressed a gap in the literature as no studies have been done on DHH children’s reading development in Chinese, it has limitations regarding the design and sample as well as the coverage of important skills that may be related to reading development.

First, we cannot establish causal relationships between variables in this cross-sectional study. For example, morphological awareness may be a precursor of reading development, but it is also likely to be a consequence of reading experience. Longitudinal studies would be the next step to examine the temporal relation among variables. Some studies showed that the role of morphological knowledge increases while that of phonological awareness
decreases with age (e.g., Carlisle, 2000; Mahony, Singson, & Mann, 2000). There was a significant shift in importance from phonological to morphological awareness around 9–10 years old. In this study, we showed that morphological awareness explained significantly more variance than phonological awareness in word recognition for children whose age was around 9–10 years. Future work with a longitudinal design would help in answering questions regarding the development of phonological and morphological awareness in DHH children and their connections with reading development. Further, training studies in which children are randomly assigned into different teaching conditions (e.g., Nunes et al., 2010) would also help in ascertaining whether the development of various knowledge results in improved performance in reading across different groups of children. Second, the sample of this study is another aspect that merits cautious interpretations of the findings. All of the DHH children who participated in this study have functional hearing and speech ability. The results have to be interpreted in the context that a large proportion of the DHH children in our study have a considerable level of residual hearing. Future research should include a comprehensive test for the speech perception abilities of DHH children and examine how profoundly deaf children approach the task of Chinese word recognition. As for DHH children who have limited functional hearing, the ways through which they learn to read a language may not be the same. Some researchers have argued that these children might resort to more visual and kinesthetic ways to develop representations of printed words (Wang, Trezek, Luckner, & Paul, 2008). This would be an interesting area worth exploring in the future. One of the potential predictors that may affect the reading performance of DHH children with limited functional hearing is speech-reading ability. Speech-reading provides visual clues for these children to access to the phonology of the spoken language (Beal-Alvarez, Lederberg, & Easterbrooks, 2012; Johnson & Goswami, 2010; Kyle & Harris, 2006). Some studies have demonstrated high correlations between reading and speech-reading in DHH readers (e.g., Arnold & Kopsel, 1996; Harris & Moreno, 2006). For instance, Arnold and Kopsel (1996) revealed that speech-reading was the only significant variable correlated with the reading ability of orally educated DHH children who had severe and profound hearing loss. Harris and Moreno (2006) showed that speech-reading was the only skill that could be used to identify all DHH children who were good readers. There is a gap regarding the role of speech-reading in Chinese reading in the literature and it awaits more studies in the future. It is speculated that speech-reading may not be a significant predictor of DHH’s reading competence in Chinese because it is a tonal language, together with the pervasiveness of homophony.

The second visual-based strategy that DHH children may use to map printed words to their meanings is sign language (Siedlecki, Votaw, Bonvillian, & Jordan, 1990). The knowledge of signing of some children may have an impact on their acquisition of Chinese vocabulary. The iconicity in sign language may also facilitate concept learning because they may help children link form with meaning more efficiently. Some studies showed that a higher proficiency in sign language was significantly associated with better reading performance (e.g., Chamberlain & Mayberry, 2008; Hermans, Knoors, Ormel, & Verhoeven, 2008; Padden & Ramsey, 2006), whereas some studies did not find such a relationship (e.g., Mayer & Akamatsu, 2011; Moores & Sweet, 1990). A review of DHH children’s reading (Goldin-Meadow & Mayberry, 2001) concludes that signing skills may not guarantee better reading. Some researchers (e.g., Hermans et al., 2010; Mayer & Leigh, 2010) have argued that only when the linguistic characteristics and cognitive underpinnings between two languages are similar to each other that the skills in the sign system could be transferred to understandings of the written form of a different language. The role of sign language in enhancing DHH children’s development of literacy is also subject to the type of language domains or skills that the assessment focuses on. Very little research has been conducted to examine the relation between sign language and word recognition. Future research is needed to develop a reliable and comprehensive assessment tool to assess DHH children’s sign language proficiency for Chinese children and to investigate how sign language relates to reading development.

Conclusion

To conclude, this study provides some evidence regarding the contributions of phonological, semantic radical, and morphological awareness to Chinese word recognition in DHH children. The DHH children in our study performed at a comparable level with hearing children in word recognition, whereas it should be noted that their ability to do so does not necessarily translate to their performance in reading comprehension and fluency. We argued that DHH children who read Chinese might rely more on the information provided by the semantic radicals and morphemes in the word context than phonological information to recognize the meanings of words. In support with our hypotheses, we found that phonological, semantic radical, and morphological awareness made independent contributions to Chinese word recognition in DHH children beyond age, general intelligence, and demographic factors. Relative to phonological awareness, semantic radical and morphological awareness explained significantly more variance in word recognition in both DHH and hearing children. While we replicated findings regarding the importance of semantic radical and morphological awareness in the reading development in hearing children, we also demonstrated its relevance to DHH children who read Chinese. Despite several limitations, this study may offer some new and exciting directions for research in the future.

Conflicts of Interest

No conflicts of interest were reported.

References


