Empirical Article

Reading Strategies of Chinese Students With Severe to Profound Hearing Loss

Ka Yan Cheung*1, Man Tak Leung2, Bradley McPherson1
1University of Hong Kong
2Hong Kong Polytechnic University

Received August 29, 2012; revisions received January 17, 2013; accepted January 30, 2013

The present study investigated the significance of auditory discrimination and the use of phonological and orthographic codes during the course of reading development in Chinese students who are deaf or hard of hearing (D/HH). In this study, the reading behaviors of D/HH students in 2 tasks—a task on auditory perception of onset rime and a synonym decision task—were compared with those of their chronological age-matched and reading level (RL)-matched controls. Cross-group comparison of the performances of participants in the task on auditory perception suggests that poor auditory discrimination ability may be a possible cause of reading problems for D/HH students. In addition, results of the synonym decision task reveal that D/HH students with poor reading ability demonstrate a significantly greater preference for orthographic rather than phonological information, when compared with the D/HH students with good reading ability and their RL-matched controls. Implications for future studies and educational planning are discussed.

Reading problems have been reported to be a continuing deficit concomitant with hearing loss (HL), not only in individuals reading in alphabetical languages (Allen, 1994; Engel-Eldar & Rosenhouse, 2000; Moores, 2006; Tye-Murray & Clark, 1998) but also in people reading in nonalphabetical languages such as Chinese (Jiang & Ling, 2007; Lin & Li, 1987; Liu, 2003). In addition, reading problems in people with HL often are not effectively alleviated over time (Allen, 1994; Conrad, 1979; Wauters, van Bon, & Tellings, 2006). To treat reading problems found in students who are deaf or hard of hearing (D/HH), it is important to know more about the effects of HL on reading acquisition.

For preschool children, learning to read can be a process that involves matching novel visual symbols (orthographic codes) to sounds (phonological codes) that they have already heard (Ziegler & Goswami, 2005). Reading acquisition, therefore, might imply learning a system of mapping between the orthographic codes and phonological codes in a language. This system has been termed phonological recoding (Frost, 1988; Frost & Kampf, 1993; Ziegler & Goswami, 2005). Beginning readers with normal hearing should have developed basic mental phonological representations of their own native language that ensure effective utilization of phonological recoding and hence successful reading acquisition (Elbro & Pallesen, 2002; Perfetti, 1992). Therefore, auditory information is considered an important building block for the development of phonological representation. In a study on the audiometric configurations of students in special schools for the D/HH, around 75% of students perceived low-frequency sounds better than high-frequency sounds (Yuen & McPherson, 2002). Therefore, people with HL might have difficulties in perceiving high-frequency phonemes (such as fricatives) and suprasegmental features (such as aspiration). In other words, HL leads not only to a decrease in the intensity of speech input but also to a
distortion, or even the absence, of certain phonological codes in a language. It is predicted that poor auditory discrimination will lead to repeated exposures to distorted phonemes or even unavailability of certain phonological codes and will further result in the establishment of a poorly defined phonological representation. Empirically, auditory discrimination ability has been found to be significantly correlated with phonological awareness, which is considered a reflection of one’s phonological representations (Ziegler & Goswami, 2005), when complex verbal abilities and verbal short-term memory are controlled (McBride-Chang, 1995; Nittouer, 1996). It is also well documented that phonological awareness is a predictive indicator of reading ability (Boscardin, Muthen, Francis, & Baker, 2008; Bryant, Bradley, MacLean, & Crossland, 1989; Kim, Kim, & Lee, 2007; Li & Shu, 2009; Wagner, Torgesen, & Rashotte, 1994). Therefore, it is reasonable to suggest that poor auditory discrimination will lead to reading problems and there are experimental findings showing that auditory discrimination ability is a good predictor of reading success (Bond & Dijkstra, 1967; Hurford, Darrow, Edwards, Howerton, Mote, & Schaaf, 1993; Hurford, Schaaf, Bunce, Blaich, & Moore, 1994; Stevenson & Newman, 1986). The above postulation is, theoretically, supported by the psycholinguistic grain-size theory (PGST), which proposes three main problems of phonological recoding in children (Ziegler & Goswami, 2005). According to the PGST, the unavailability of certain phonological codes (also referred to as the “availability problem”) in early years of literacy hampers the mapping between graphemes and phonemes and this further affects reading development. However, despite the above empirical and theoretical support, some students with HL have been reported to achieve good reading ability (Conrad, 1979; DiFrancesca, 1972; Harris & Moreno, 2004, 2006; Marschark & Harris, 1996; Traxler, 2000). There are two possible explanations. First, some D/HH students are able to establish a well-defined phonological representation and overcome the availability problem by optimizing their residual hearing. Second, phonological recoding might not be the sole access route for retrieval of meaning from the mental lexicon. Typically, even individuals with severe to profound HL are reported to have some residual hearing (Foust & Gengel, 1973; Lamoré, Verweij, & Brocaar, 1985). There are low-frequency acoustic features in speech that help those with HL to discriminate between phonemes, even though their speech perception might be hampered by difficulties in perceiving high-frequency phonemes (Denes & Pinson, 1993; Fry, 1987). For example, plosives are distinctive from fricatives because of the presence of an interruption in air stream and affricates are distinctive from fricatives because of the presence of noise of appreciable duration. Furthermore, experimental results indicate that accurate speech recognition may be achieved even when acoustic signals are largely distorted. Shannon, Zeng, Kamath, Wygonski, and Ekidel (1995) and Shannon, Zeng, and Wygonski (1998) have shown that listeners were able to complete speech sound-recognition tasks with high accuracy even when the spectral information of the speech sound was reduced to only two broad noise bands. Therefore, theoretically, it is possible for an individual with HL to build up a well-defined phonological representation and be more ready to make use of phonological codes in a language and hence achieve good reading ability.

In addition to residual hearing, good D/HH readers may also need to make use of the orthographic information in words during lexical access. With regard to the phonology and orthography of most languages, two conditions make use of lexical orthographic information necessary. First, the disambiguation of groups of homophones such as “bark” [bæk] (outmost layer of wooden plants)” and “barque” [bɑːk] (a sailing vessel with three or more masts)” by phonological recoding or grapheme–phoneme conversion alone will only result in more than one phonological lexical entry to the mental lexicon. Therefore, one might have to make use of additional information from larger-grain-size orthographic structures (whole word) rather than the smaller-grain-size orthographic structures (graphemes). Second, the inconsistencies in the grapheme–phoneme correspondences found in languages with deep orthography will make the pronunciation of many words unpredictable by simple grapheme to phoneme conversion and, consequently, enhance the necessity of using orthographic information.
Empirically, experimental findings show that speakers, both with and without normal hearing, of alphabetic languages make use of lexical orthographic information in semantic categorization tasks (Hanson, 1989; Jared, McRae, & Seidenberg, 1990; Jared & Seidenberg, 1991; Nation & Cocksey, 2009). For example, Nation and Cocksey (2009) have investigated whether English-speaking young children make use of orthographic information in words when they participate in a semantic categorization task. In the task, the participants were asked to decide whether a briefly presented word belonged to a specific category. Findings show that children often confuse stimuli with similar orthographic information, like “ship” and “hip.” In addition, it would take children a longer time to decide that the word “ship” did not belong to the category of body parts.

Similar findings were obtained from experiments working on D/HH students. In a lexical decision task, English-speaking D/HH college students were asked to confirm whether pairs of briefly presented stimuli were word or nonword items (Hanson & Fowler, 1987). In the experiment, pairs of words that were orthographically and phonologically similar yielded the shortest response time. The response time for pairs of words that were orthographically similar but phonologically different was shorter than that for pairs of words that were orthographically and phonologically different. D/HH students were found to make use of both lexical phonological information and orthographic information. In addition, simultaneous use of both phonological and orthographic information created a synergistic effect in word processing for the D/HH participants.

Overall, the aforementioned findings support the theory that orthographic information is used in the word processing of alphabetic languages. In comparison with English D/HH students, Chinese-speaking D/HH students should be more prone to making use of lexical orthographic information. In Chinese, homophone density is much higher than that in English. According to the Oxford Advanced Learners’ Dictionary of Current English (Hornby, 1989), around 4% (2,814 in 70,637 words) of English words are homophones (Higgins, 1995). On the other hand, according to the Modern Chinese Dictionary (Institute of Linguistics, 1985), 55% of the monosyllabic words in Chinese have five or more homophones (Li & Yip, 1998). The fact that homophones have more than one orthographic correspondence hampers reading development and this is referred to as the “consistency problem” in PGST. Furthermore, in Chinese, there are more words than syllables and there are more syllables than rimes. The necessity of learning more words than syllables will again slow reading acquisition and this constraint is referred to as the “granularity problem” in PGST. Theoretically, Chinese readers will be more prone to using orthographic access and may take longer to develop a mature reading ability.

There are empirical findings showing that Chinese speakers, both with and without normal hearing, make use of lexical orthographic information. Using Chinese integrated characters and compound characters, Leck, Wekes, and Chen (1995) investigated the relative significance of lexical orthographic and lexical phonological information in the reading process of Chinese adults. Similar to the results of the experiment by Nation and Cocksey, they found that both orthographic and phonological types of information are important in lexical processing.

Making use of a priming task, Feng and Fang (2003) investigated the use of phonological, orthographic, and semantic information by Chinese D/HH students who had no auditory experience and were studying in Grade 6. When the stimulus onset asynchrony (SOA) was short (i.e., SOA = 50 ms), stimuli that had similar semantic and phonological characteristics as the targets yielded the shortest response latencies. When the SOA was 300 ms, stimuli that were phonetically similar to the targets yielded the shortest response latencies. When the SOA was 600 ms, stimuli that were identical to or orthographically similar to the target yielded the shortest latencies in D/HH participants. Overall, phonological information was used by D/HH participants, but the D/HH students preferred semantic and orthographic information over phonological information.

If readers with and without normal hearing make use of orthographic information in words during reading, will good D/HH readers, who have deficits in auditory discrimination, also develop a stronger reliance on lexical orthographic information?

In order to answer the above question, an experiment investigating the preference of D/HH students...
for orthographic and phonological information in a reading task is recommended. However, owing to the covarying relationship between orthographic and phonological information in English words (the word “ship” is both orthographically and phonologically similar to the word “hip”), we could not determine whether the participants in this type of study used orthographic or phonological information during lexical access (Leck, Weekes, & Chen, 1995). In contrast with alphabetical words, Chinese characters may serve as better stimuli for experiments investigating the specific contribution of orthographic and phonological information during lexical access. In Chinese, the orthographic structure of characters is considered to be composed of three visually divided layers. The three layers, from small to large size, are strokes (⿵, 丶, 丿), logographemes (⿵, 亠, 丂), and radicals (⿵, 虫, 象; Han, Zhang, Shu, & Bi, 2007; Su, 1994). At the stroke layer, strokes are arranged in different arbitrary spatial relationships to form different characters. At the stroke layer, orthographic units do not correspond to any phoneme in Chinese and provide no clues to the pronunciation of characters. Logographemes are defined as the basic unit of writing (Lui, Leung, Law, & Fung, 2010). Logographemes do not necessarily carry semantic and phonological information. In the database of logographemes created by Lui, Leung, Law, and Fung (2010), only 84 out of 249 logographemes are stand-alone characters carrying sounds and meaning and they may or may not be phonetic radicals. Again, they do not necessarily hint at the pronunciation of other characters. However, there are orthographic units on the radical layer that give indications of the pronunciation of Chinese characters. These orthographic units are referred to as phonetic radicals. Phonetic radicals and semantic radicals, which make up around 70% of Chinese characters, are components of phonetic compounds. For example, “蝴” is an example of a phonetic compound. In the character “蝴” (pronunciation:/wu⁴/, meaning: “butterfly”), “蝴” (pronunciation:/wu⁴/, meaning: “a surname”) is the phonetic radical, which provides orthographic cues of the character’s pronunciation. Furthermore, “虫” (pronunciation:/tsʰun⁴/, meaning: “insect”) is the semantic radical, which provides orthographic cues of the character’s meaning or the character’s semantic attributes. Around two third of phonetic compounds are rhyme neighbors of their phonetic radicals (Zhou & Marslen-Wilson, 1997) and around 80% of semantic radicals provide categorical information of their phonetic compounds (Shu, Chen, Anderson, Wu, & Xuan, 2003). As a result, both phonetic and semantic radicals provide clues to the pronunciation and meaning of characters, but the clues may not be reliable or confirmatory. Unlike English, the phonological information in Chinese characters does not necessarily covary with the orthographic information. Thus, there are Chinese homographs with totally different phonological structures, for example, “易,” Cantonese pronunciation: [ji⁴]; and “易,” Cantonese pronunciation: [zik⁴]; in addition, there are also Chinese homophones with totally different orthographic features, for example, “刀,” Cantonese pronunciation: [dou¹] and “都,” Cantonese pronunciation: [dou¹]. With reference to the lexical orthographic and phonological information in Chinese characters mentioned above, it is possible for us to choose appropriate distracters and stimuli for word-processing tasks without involving the confounding variables found in alphabetic languages. For example, choosing the less-reliable or opaque semantic radicals would provide distracters that are orthographically similar to but semantically different from the stimuli. Moreover, avoidance of phonetic radicals would enable the choice of distracters that are phonologically similar to but orthographically different from the stimuli. Therefore, Chinese characters are the ideal stimuli for these kinds of experiments.

In summary, both optimal use of residual hearing and the use of orthographic information are hypothesized to be important in the overall reading achievement of students with severe to profound HL. In order to investigate the significance of residual hearing and orthographic information, the first question to answer is the following: “Is auditory discrimination ability causally related to reading ability in D/HH students?” If auditory discrimination is a possible cause of reading problems in D/HH students, it is necessary to investigate whether the effect of auditory discrimination in reading achievement will be manifested in the reading behavior of good and poor D/HH readers and in their chronological age (CA)–matched and reading level (RL)–matched controls. Therefore, the second question to substantiate is “Does better auditory
discrimination allow CA- and RL-matched controls to demonstrate stronger preference for phonological to orthographic information when compared with D/HH participants?” If the answer to the second question is “yes,” the third question should be “Are D/HH participants prone to using orthographic information during reading?” Finally, in order to confirm whether it is the stronger preference for phonological distracters or orthographic distracters that leads to better reading performance, the fourth question should be “Do good and poor D/HH readers demonstrate a difference in their preference for phonological and orthographic information in a reading task?” By answering the above four questions, the relative significance of residual hearing and orthographic information in the reading success of D/HH students can be established.

As mentioned above, previous studies have demonstrated that reading ability and auditory discrimination abilities are correlated (Hurford et al., 1994; Stevenson & Newman, 1986). However, neither regression analysis nor a single cross-group comparison between D/HH participants and CA-matched participants can serve as sufficient evidence of a causal relationship between the two abilities. In comparison with the D/HH participants, the better auditory discrimination found in CA participants can be a cause of better reading ability found in CA participants, or it may simply be a consequence of CA participants’ better exposure to reading materials, or CA participants’ better reading skills (Goswami & Bryant, 1989). Only if the auditory discrimination ability of both CA- and RL-matched participants is found to be significantly better than that of D/HH participants can the possibility of better auditory discrimination as a consequence of better reading experience or better reading ability be ruled out. Therefore, the present study employs a CA/RL dual cross-group comparisons paradigm.

As noted, the existence of a causal relationship between auditory discrimination and reading ability should be manifested in the reading behavior of D/HH participants. However, such a causal relationship does not rule out the positive contribution of orthographic information in reading. Therefore, to gain a more comprehensive picture of how D/HH students make use of different kinds of lexical information in characters, it is important to investigate how D/HH participants employ the available orthographic and phonological information during reading. Similar to the relationship between auditory discrimination and reading ability, the relationship between reading ability and stronger preference for phonological information in relation to orthographic information can be further delineated by comparing the preference pattern of D/HH participants with their RL- and CA-matched controls. Moreover, the observation of changes in the preference for different lexical information as demonstrated by D/HH participants with different reading abilities should provide further insight into the relative importance of different lexical information during different stages of reading development in D/HH participants.

Experiment One

Task on Auditory Perception of Onset Rime

In order to test the hypothesis that good auditory discrimination is the basis for the development of reading ability of D/HH participants and answer Question 1 of this study, it is necessary to determine the speech unit that is important for early literacy development. Considering that phonological awareness is a well-recognized factor for reading success and that onset-rime awareness is a kind of crosslinguistic phonological contrast normally acquired in the early years (Anthony & Lonigan, 2004; Ziegler & Goswami, 2005), the auditory perceptual awareness of onset rime (APOR) is a possible prerequisite for reading success. Therefore, in the present experiment, the relationship between reading ability and auditory discrimination ability for onset-rime contrasts was studied.

Methods

In the task on APOR (TAPOR), the participants were asked to decide whether two monosyllabic stimuli, which were presented from a loudspeaker, were homophones or rhyming syllables. Monosyllabic stimuli were created by combining three groups of initial consonants—namely, velar consonants, alveolar consonants, and bilabial consonants—combined with the Cantonese tone one vowel /a/. Each monosyllabic
stimulus was paired with either a syllable with identical phonetic structure or a syllable that rhymed with it. Examples of the stimuli included homophonic pairs [“/tsai/ vs. /tsai/”] and rhyming pairs [“/tsai/ vs. /sa/”] (rhyming stimuli with the same articulation placement) or [“/tsai/ vs. /ma/”] (rhyming stimuli with different articulation placements). Two stimuli were presented consecutively from a loudspeaker at an intensity level comfortably audible for an adult with normal hearing. All participants had to listen to the stimuli and record their decision on a formal answer sheet. The number of phonologically identical pairs was balanced with the number of rhyming pairs, and the presentation of stimuli was randomized.

Participants

Thirty-four students with average hearing threshold more than 70 dB HL at 500, 1,000, 2,000, and 4,000 Hz in the better ear were recruited. In order to maintain some homogeneity in the amplification status of participants with HL, only participants with programmable or digital hearing aids were recruited. Among the D/HH participants, 91.1% of the hearing aids were provided through a Hong Kong Government support scheme.

According to the results of the administered Hong Kong graded Chinese character naming test (HKGCNT; Leung, Cheng-Lai, & Kwan, 2008), among the 34 D/HH participants, 10 participants had Grade 1 (G1) reading level, 12 participants had Grade 2 (G2) reading level, and 12 participants had Grade 6 (G6) reading level. The averages and the standard deviations (SDs) of the ages in the three groups of D/HH participants were as follows: G1—average: 15.58, SD: 3.01; G2—average: 15.76, SD: 2.23; and G6—average: 14.15, SD: 1.08. Among the three subgroups of D/HH participants, D/HH_G2 was the oldest and D/HH_G6 was the youngest subgroup. The averages and the SDs of the hearing thresholds of the three groups of D/HH participants were as follows: G1—average: 94.32 dB HL, SD: 13.68; G2—average: 89.86 dB HL, SD: 8.73; and G6—average: 81.4, SD: 7.18. Three groups of RL control participants, who had an average hearing threshold ≤ 25 dB HL at 500, 1,000, 2,000, and 4,000 Hz in the better ear and with G1, G2, and G6 reading abilities, were recruited. There were 30 participants in each subgroup of RL controls and the mean ages of the G1, G2, and G6 subgroups were 6.5, 7.42, and 11.67, respectively.

In addition to the RL and D/HH participants, CA controls who had an average hearing threshold ≤ 25 dB HL at 500, 1,000, 2,000, and 4,000 Hz in the better ear were recruited to allow CA/RL cross-group comparisons. As noted, the reading ability of D/HH students could not be improved over time, and the chronological age ranges of the G1, G2, and G6 subgroups of the D/HH participants were large and similar to each other (D/HH_G1: 11–18.83 years; D/HH_G2: 11.08–19.17 years; and D/HH_G6: 11.67–18 years). Direct matching between the three subgroups of D/HH participants with the three subgroups of CA controls was comparable to the matching between 34 D/HH participants with 34 CA controls with a similar age range and SD. Therefore, 34 CA controls with a mean age of 15.23 years (SD: 1.78) were recruited.

The participants with HL were recruited from two special schools for D/HH students. The RL and CA controls were recruited from two mainstream primary schools and one mainstream secondary school.

In order to avoid any potential confounding factors, all participants were required to attain at least a standard score ≥ 85 in Raven progressive matrices (Raven, 1995). They used Cantonese as their mother tongue or had at least 6 years of experience in using Cantonese as their main language for communication in school, and their academic performance was considered to be average or above in their own school.

The experiments were completed in two separate sessions. In the first session, Raven progressive matrices and TAPOR were conducted with groups of eight students. In the second session, the HKGCNT was individually administered. In the first session, the participants were allowed 5 min of rest between tests. A longer break, lasting 20 min, was given between the two assessment sessions.

Statistical Analysis

Correlation and regression analyses were conducted to identify any correlational relationship between auditory discrimination and reading ability. Mann–Whitney U
tests were conducted to compare the performance of D/HH participants, CA controls, and RL controls in TAPOR.

Results

As noted, onset-rime awareness is a type of phonological contrast acquired before formal literacy and the average percentage accuracy achieved by all the CA and RL controls was >90% (RL_G1: 95.21%, SD: 5.17; RL_G2: 94.69%, SD: 5.48; RL_G6: 98.54%, SD: 2.13; and CA_Gp: 98.34%, SD: 2.04); moreover, a ceiling effect was noted. All the D/HH participants were found to have poorer performance (D/HH_G1: 60.94%, SD: 0.15; D/HH_G2: 76.05%, SD: 0.12; D/HH_G6: 88.28%, SD: 0.19). Among the D/HH participants, the scores in TAPOR increased across the subgroups from G1 to G6. In addition, the SD in TAPOR was minimal in each subgroup, reflecting similar performances of all the D/HH participants in each subgroup (see Table 1).

A Kruskal–Wallis test was conducted to determine any significant differences among the subgroups of D/HH and RL participants. Results showed that the performances of all the subgroups of D/HH and RL participants were significantly different from each other (D/HH: p value < .001; RL group: p value = .007).

Correlation analyses were performed to investigate the relationship between auditory perception of onset rime and reading ability. Because only the data set from the D/HH participants followed a normal distribution, Pearson correlation analyses were conducted to investigate the relationship between auditory perceptual ability and reading ability for this comparison. Spearman correlation analysis was conducted to investigate the correlation between auditory perceptual ability and reading ability in RL and CA controls. Because a ceiling effect was observed in RL and CA controls, results of the analyses showed that auditory perceptual ability correlated with reading ability only in the D/HH subgroups (D/HH group: r = .703, p value < .001; RL group: r = .141, p value = .186; CA group: r = .087, p value = .624).

In order to investigate the predictive power of auditory perceptual ability on the reading ability in D/HH participants, zero-order correlations were derived. The results of zero-order correlations between reading ability and a number of variables, namely, age, nonverbal intelligence, hearing threshold, and APOR, showed that only hearing threshold and TAPOR results were significantly correlated with the participants’ reading ability: \( r_{\text{hearing threshold}} = -0.388, p \text{ value} = .012; r_{\text{TAPOR}} = .703, p \text{ value} < .001 \) (Table 2). As a result, the contributions of TAPOR and hearing threshold to reading success were further analyzed.

To test the unique association of auditory discrimination ability with reading ability, linear stepwise regression analysis was conducted. Results of linear stepwise regression analyses showed that \( R^2 \) of APOR awareness was much larger than that of hearing threshold (\( R^2 \) of auditory discrimination = .494 and \( R^2 \) of hearing threshold was .151). Although hearing threshold accounted for 15% of the variance in participants’ reading ability, the auditory discrimination ability of the participants accounted for 49% of the variance in participants’ reading ability (p value < .001), when the effects of age, nonverbal intelligence, and hearing threshold were controlled (Table 3). Rather than hearing threshold, APOR contrasts were significantly correlated with the reading ability of D/HH participants.

To investigate a possible causal relationship between APOR and reading ability, the performance of the D/HH participants was compared with that of their RL- and CA-matched controls. Mann–Whitney U tests were carried out to obtain cross-group comparisons. All the cross-group comparisons between D/HH participants and their CA and RL controls were found to be significantly different (D/HH_G1 vs. RL_G1:

### Table 1: Performances of D/HH participants and the RL and CA controls in TAPOR

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>60.94%</td>
<td>76.05%</td>
<td>88.28%</td>
<td>95.21%</td>
<td>94.69%</td>
<td>98.54%</td>
<td>98.34%</td>
</tr>
<tr>
<td>SD = 0.15</td>
<td>SD = 0.12</td>
<td>SD = 0.19</td>
<td>SD = 5.17</td>
<td>SD = 5.48</td>
<td>SD = 2.13</td>
<td>SD = 2.04</td>
</tr>
</tbody>
</table>

*Note.* D/HH, participants who are deaf or hard of hearing; G, grade; RL, reading level–matched controls; CA, chronological age–matched controls; TAPOR, task on auditory perceptual ability.
$p$ value < .01; D/HH_G2 vs. RL_G2: $p$ value < .01; D/HH_G6 vs. RL_G6: $p$ value < .01; D/HH_G1,2,6 vs. CA_Gp, $p$ value < .01). As noted, the average score of D/HH participants was lower than those of the CA and RL controls. Thus, results of all the analyses showed that the performances of D/HH participants in TAPOR were significantly poorer than those of their CA and RL controls.

Discussion

As expected, results of correlation and regression analyses showed that auditory discrimination ability of the D/HH participants accounted for 49% of the variance in the participants’ reading ability when the effects of age, nonverbal intelligence, and hearing threshold were controlled (Table 3). Concomitant factors, such as cognitive skills and even hearing threshold, were not found to be the most important contributors to reading problems in D/HH participants. To determine a potential causal relationship between auditory discrimination and reading achievement, the remaining concern of this experiment was to rule out the fact that auditory discrimination might only be an ability covarying with reading ability. Results of CA/RL dual cross-group comparison revealed the most important finding of this experiment. The auditory discrimination ability of D/HH participants was not only found to be significantly poorer than that of their CA controls but was also worse than their younger, cognitively less-mature RL controls. Additionally, the same phenomenon was repeated across the G1, G2, and G6 subgroups of D/HH participants and their controls. Because a significant difference in the auditory discrimination ability between D/HH participants and RL controls was found, the hypothesis that better auditory discrimination was just a consequence of better reading skills could be ruled out. In conclusion, the results suggest that poorer APOR awareness might contribute to reading difficulties in D/HH participants with G1, G2, and even G6 reading abilities.

In order to investigate whether auditory discrimination ability and reading ability are necessarily associated with hearing threshold, four stem-and-leaf plots—which show the distribution of scores achieved by different types of D/HH participants in HKGCNT and TAPOR—were plotted (Figures 1–4). In Figure 1, there are two D/HH participants with profound HL but high HKGCNT scores (>110) and there are five D/HH participants with profound HL but high TAPOR scores (higher than the average score obtained by D/HH participants [75.83%]). In Figure 2, there are four

### Table 2  Correlation between age, nonverbal intelligence, hearing threshold, auditory perceptual ability, and reading ability

<table>
<thead>
<tr>
<th></th>
<th>HKGCNT</th>
<th>Age</th>
<th>Raven</th>
<th>Hearing</th>
<th>TAPOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKGCNT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>.062</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Raven</td>
<td>.162</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Hearing</td>
<td>—.388*</td>
<td>.398**</td>
<td>—.146</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>TAPOR</td>
<td>.703***</td>
<td>—.287*</td>
<td>.210</td>
<td>—.415</td>
<td>—</td>
</tr>
</tbody>
</table>

Note. $N = 34$; Raven, Raven progressive matrices; TAPOR, task on auditory perceptual ability; HKGCNT, Hong Kong graded Chinese character naming test; Hearing, average hearing thresholds at 500, 1,000, and 2,000 Hz. *$p < .05$, **$p < .01$, ***$p < .001$.

### Table 3  Stepwise linear regression explaining variance in reading ability

<table>
<thead>
<tr>
<th>HKGCNT Results</th>
<th>Beta In</th>
<th>$t$</th>
<th>$R^2$</th>
<th>$R^2$ change</th>
</tr>
</thead>
<tbody>
<tr>
<td>HKGCNT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.152</td>
<td>1.164</td>
<td>.004</td>
<td>—</td>
</tr>
<tr>
<td>Raven</td>
<td>0.015</td>
<td>0.112</td>
<td>.0262</td>
<td>—</td>
</tr>
<tr>
<td>Hearing</td>
<td>−0.117</td>
<td>−0.839</td>
<td>.151*</td>
<td>—</td>
</tr>
<tr>
<td>TAPOR</td>
<td>1.079</td>
<td>5.586</td>
<td>.494***</td>
<td>.494</td>
</tr>
</tbody>
</table>

Note. $N = 34$; Raven, Raven progressive matrices; TAPOR, task on auditory perceptual ability; HKGCNT, Hong Kong graded Chinese character naming test; Beta In, slope of the regression line; $t$, results of $t$ statistics. *$p < .05$, **$p < .01$, ***$p < .001$. 

Downloaded from https://academic.oup.com/jdsde/article-abstract/18/3/312/367321 by guest on 21 February 2019
D/HH participants with severe HL but low HKGCNT scores (<70) and six D/HH participants with severe HL but low TAPOR scores (lower than the average score obtained by D/HH participants). However, as shown in Figures 3 and 4, none of the D/HH participants could achieve a HKGCNT score higher than 100 if their TAPOR scores were lower than the overall average TAPOR score obtained by the D/HH participants. Similar to the regression analysis results, the stem-and-leaf plots show that, in comparison with hearing threshold, auditory discrimination ability is a better predictive indicator of reading ability in D/HH participants. Further interpretation from the stem-and-leaf plots suggests that auditory discrimination and hearing ability are not necessarily associated. Some of the participants with profound HL might have either fully utilized their residual hearing or developed other reading strategies, such as the use of orthographic information, thereby attaining a better–than–expected reading level. As noted, the availability problem
encountered by D/HH students might be overcome by the use of residual hearing. Optimal use of residual hearing may make the phonological units, which were once unavailable, audible, and a resulting well-defined phonological representation may foster the development of phonological awareness and facilitate efficient phonological recoding. Ultimately, adequate auditory discrimination may facilitate reading development.

Overall, the results of TAPOR gave a positive answer to the first question of this study, “Is auditory discrimination ability causally related to reading ability in D/HH students?” In addition, the results appear to support the predictions evolved from one of the reading acquisition constraints—the availability problem—developed in PGST (Ziegler & Goswami, 2005).

Although the significance of auditory discrimination ability was confirmed by the TAPOR findings, the results did not rule out a significant role of orthographic information in reading. In order to determine how D/HH readers make use of lexical orthographic information in a word-reading task and to investigate whether the significance of auditory discrimination is manifested in the reading behavior of good and poor D/HH readers, the relative importance of phonological and orthographic information at different stages of reading development in D/HH participants and in CA and RL controls was investigated. As a result, a study involving a synonym decision task was conducted.

Experiment Two

Synonym Decision Task

In order to answer Questions 2, 3, and 4, a reading task probing the use of lexical orthographic and phonological information in D/HH students, as well as RL and CA controls, was devised. The design of the second experiment was modified from a synonym decision task (SDT) suggested by Leung (2005).

Methods

In this character-reading task, monosyllabic Chinese words were chosen such that the multiple effects of lexical orthographic and phonological information from different syllables in a multisyllabic word could be avoided. In the task, participants were presented with 24 multiple-choice questions. In each question, they were asked to find the synonym of a stimulus character (e.g., 睹, /tou²/, meaning: see) from among a set of five characters. Among the five choices, there was one target character (e.g., 見, /kin³/, meaning: see; research code: target) and four distracters. Among the four distracters, two were orthographically similar to the stimulus, and the other two were phonologically similar to the stimulus. Between the two orthographically similar distracters (o_dis), one shared the same logographeme as the stimulus (e.g., 煮, /tsy²/, meaning: cook, research code: o_logo) and the other shared the same semantic radical as the target stimulus (e.g., 眠, /min⁴/, meaning: sleep, research code: o_seman). In addition, between the two phonologically similar distracters (p_dis), one was a homophone of the target stimulus (e.g., 島, /tou²/, meaning: island, research code: p_homo) and the other was a word rhyming with the target stimulus (e.g., 土, /tʰou²/, meaning: soil, research code: p_rhyme). As noted, in order to avoid the confounding factor found in alphabetic written languages, the covarying relationship between the phonological and orthographic information in characters was manipulated in such a way that only phonological or orthographical information in the stimuli varied at any one time (Table 4). In order to foster the use of reading strategies and minimize the effect of uneven lexical frequencies, all the stimuli in the experiment were low-frequency words to G1 and G2 students. The average occurrence frequency of the stimuli was 6.13 per million characters (Leung & Lee, 2002). The targets and distracters were middle-frequency words for G1 and G2 students (Leung & Lee, 2002). (For G1 students, middle frequency was considered to be 12.26 to 55.16 per million characters. For G2 students, middle frequency was considered to be 18.39 to 79.67 per million characters.) In the experiment, all the stimuli and choices were presented on a formal testing paper and the participants were asked to guess and circle the synonym of a stimulus.

Participants

The same participants as TAPOR were recruited in the SDT. The task was conducted 20 min after the HKGCNT (Leung et al., 2008).
Statistical Analysis

Similar to the cross-group comparison paradigm suggested in TAPOR, in order to investigate a possible cause of reading problems in D/HH participants, crosstab chi-square tests were conducted to test for any significant differences in the number of choices chosen by D/HH participants and their CA- and RL-matched controls.

Results

The overall percentage of accurate responses and distracters chosen by different groups of participants in the SDT experiment are shown in Table 5. From Table 5, it is noted that CA controls achieved an average percentage of correct identification >85% and a ceiling effect was noted. In addition, across the subgroups of D/HH participants and RL controls, the percentage of accuracy increased gradually with grade progression.

Regarding the ratios between different kinds of distracters chosen by the participants, it was found that the ratios of “o_dis” to “p_dis” in D/HH participants decreased across groups (D/HH_G1: 4.59, D/HH_G2: 1.61, and D/HH_G6: 1.08), whereas the same ratio was relatively stable in the RL participants (RL_G1: 1.81, RL_G2: 1.23, and RL_G6: 2.24). Across all the subgroups of D/HH and RL participants, a preference for orthographic distracters over phonological distracters was found. In comparison with the RL participants, the preference for orthographic distracters was stronger in D/HH. In addition, it was found that the G1 subgroup of D/HH participants was most prone to choosing orthographic distracters.

To determine the possible differences in the use of phonological and orthographic information between D/HH participants and their RL and CA controls, crosstab chi-square tests were undertaken. Results showed that the G1 subgroup of D/HH participants

Table 4  Examples of stimuli and choices in Synonym Decision Task

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Orthographical distracters (O_dis)</th>
<th>Phonological distracters (P_dis)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Same logographeme&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Same semantic radical&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>D: O+P−&lt;sup&gt;b&lt;/sup&gt;</td>
<td>D: O+P−&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>(o_logo)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>(o_seman)&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>睹: /tou/; (see)</td>
<td>D: O+P−&lt;sup&gt;b&lt;/sup&gt;</td>
<td>D: O+P−&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>塗: /tou/; (spread)</td>
<td>o_logo, orthographic distracters with the same semantic radical as the stimulus; o_seman, orthographic distracters with the same logographeme as the stimulus; p_homo, phonological distracters that are homophonic to the stimulus; p_rhyme, phonological distracters that rhyme with the stimulus; syn, synonym.</td>
<td></td>
</tr>
</tbody>
</table>

Table 5  Overall percentage of synonyms and distracters chosen by D/HH and RL participants

<table>
<thead>
<tr>
<th>Grade</th>
<th>Hearing</th>
<th>Choices</th>
<th>SD of accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>o_seman</td>
<td>o_logo</td>
</tr>
<tr>
<td>G1</td>
<td>D/HH</td>
<td>42.5%</td>
<td>30.0%</td>
</tr>
<tr>
<td></td>
<td>RL</td>
<td>27.8%</td>
<td>25.3%</td>
</tr>
<tr>
<td>G2</td>
<td>D/HH</td>
<td>20.3%</td>
<td>13.3%</td>
</tr>
<tr>
<td></td>
<td>RL</td>
<td>16.7%</td>
<td>19.2%</td>
</tr>
<tr>
<td>G6</td>
<td>D/HH</td>
<td>8.3%</td>
<td>1.4%</td>
</tr>
<tr>
<td></td>
<td>RL</td>
<td>6.9%</td>
<td>0.7%</td>
</tr>
<tr>
<td>All</td>
<td>CA</td>
<td>0.37%</td>
<td>2.76%</td>
</tr>
</tbody>
</table>

Note. SD, standard deviation. Abbreviations as in Table 1 and Table 4.<br><sup>a</sup>Cells with the largest percentage of targets or distracters.
chose fewer phonological distracters (D/HH: 15.8%; RL: 29.4%), more orthographic distracters (D/HH: 72.5%; RL: 53.1%), and fewer synonyms (D/HH: 11.7%; RL: 17.5%) than the G1 subgroup of RL controls (χ² (df) = 30.61 (4); p value < .001). Again, in comparison with the G2 subgroup of RL controls, D/HH participants chose fewer phonological distracters (D/HH: 22.2%; RL: 29.1%) and more synonyms (D/HH: 42%; RL: 35%), but their tendency to choose orthographic distracters was similar (D/HH: 35.8%; RL: 35.9%; χ² (df) = 10.47 (4); p value < .001). Finally, the G6 subgroup of D/HH participants chose more orthographic distracters (D/HH: 9.7%; RL: 7.6%), more phonological distracters (D/HH: 9%; RL: 3.4%), and less synonyms (D/HH: 81.3%; RL: 89%) than their RL controls, who chose only a few distracters (χ² (df) = 24.94 (4); p value < .001). A ceiling effect was observed in CA controls (CA controls: 94.6%). The number of distracters chosen by the CA controls was close to zero and thus cross-group comparisons between the performances of D/HH and CA participants could not be done. Generally, in comparison with the RL controls, D/HH participants demonstrated stronger preference for orthographic distracters and a weaker preference for phonological distracters. D/HH participants with G1 reading ability appeared to be more prone to using orthographic distracters compared with their RL controls.

In order to test whether good D/HH readers (G6 reading ability) and poor D/HH readers (G1 and G2 reading abilities) demonstrated a difference in their preference for phonological and orthographic information in a reading task, the total numbers of different kinds of choices made by D/HH participants with G6 reading ability were compared with those of D/HH participants with G1 and G2 reading abilities. As expected, across the G1–G6 subgroups, the total number of orthographic distracters decreased (G1: 72.5%; G2: 35.8%; and G6: 9.7%), whereas the total number of synonyms increased (G1: 11.7%; G2: 42%; and G6: 81.3%). Interestingly, the total number of phonological distracters was found to increase across the subgroups G1–G2 and then decreased again across the G2 and G6 subgroups. The latter subgroup chose only a few phonological distracters (G1: 15.8%; G2: 22.2%; and G6: 9.0%). Crosstab chi-square tests were undertaken to investigate whether the distribution of the types of choices found in the G1, G2, and G6 subgroups of D/HH participants were significantly different from each other. Results of the statistical analysis showed that the differences as listed above were significant (G1,2,6, χ² (df) = 294.513 (4), p value < .001).

Discussion

The results of cross-group comparisons and the ratios of orthographic distracters to phonological distracters demonstrated three phenomena. First, in comparison with the significant correlation between reading and phonological processing skills found in D/HH participants using an alphabetic language (Dillon & Pisoni, 2006), almost all the participants with and without normal hearing showed a preference for orthographic distracters over phonological distracters, and the ratio of orthographic distracters to phonological distracters was particularly strong in the G1 subgroup of D/HH participants when compared with all the other subgroups of both RL controls and D/HH participants. The strong preference for orthographic over phonological information appears to be a temporary reading behavior demonstrated by D/HH participants with G1 reading ability. Only D/HH participants with G1 reading ability were particularly prone to making use of orthographic distracters. Second, the D/HH participants’ preference for phonological compared with orthographic distracters was always found to be weaker than that of the G1 and G2 groups of RL controls. A causal relationship between reading problems and a weak preference to making use of lexical phonological information could be confirmed if the data set from the CA controls could be statistically analyzed. However, a ceiling effect was observed for CA controls and a dual cross-group comparison could not be completed. Third, by comparing the change in the use of lexical phonological and orthographic information across the subgroups of D/HH participants and RL controls, it was found that the temporary increase in the use of phonological information across the G1 to G2 subgroups appears to be a unique reading behavior demonstrated by D/HH participants.
Another interesting finding, which was beyond the scope of this study, was that the preferences for both types of distracters as demonstrated by D/HH participants with G6 reading ability was stronger than that of their RL controls. The RL controls were found to have significantly better ability to detect a synonym even when the reading abilities of the participants were controlled. The results suggest that the RL controls may have developed reading strategies other than those considered in this experiment.

Conclusion

Regarding the first question of this study, “Is auditory discrimination ability causally related to reading ability in D/HH students?,” results of TAPOR show that auditory discrimination ability correlates significantly with reading ability in D/HH participants. Results of regression analysis further showed that good D/HH readers usually had relatively better auditory discrimination ability than poor D/HH readers when the effects of age, nonverbal intelligence, and hearing threshold are controlled. In addition, results of stem-and-leaf analysis on the performances of D/HH participants with severe and profound hearing loss in TAPOR showed that auditory discrimination does not necessarily covary with hearing threshold.

Results of dual cross-group comparisons provided evidence that auditory discrimination ability is not a covarying factor of reading ability. Because the results of cross-group comparison show that the auditory discrimination abilities of D/HH participants with G1, G2, and G6 reading abilities were significantly worse than those of their RL and CA controls, the analysis lends support to the claim that poor auditory discrimination ability is a causal factor for reading difficulties in D/HH students with G1, G2, and G6 reading abilities.

In response to the second question of this study, “Does better auditory discrimination allow CA- and RL-matched controls to demonstrate stronger preference for phonological to orthographic information?,” the results of SDT give us further insights. In SDT, results of crosstab chi-square tests between the D/HH participants and their RL controls did show that D/HH participants with G1 and G2 reading abilities chose significantly fewer phonological distracters than the RL controls. In comparison with the RL controls, results of cross-group comparison suggested that the D/HH participants’ poor reading ability did not result from impoverished reading exposures but might have originated from a poorer tendency to make use of phonological information. However, a ceiling effect was found in CA controls, and some of the cell values from the CA data set were close to zero. Consequently, a crosstab chi-square test could not be completed and the significance of phonological preference could not be statistically confirmed.

Regarding the third question of this study, “Are D/HH students prone to using orthographic information during reading?,” results of a crosstab chi-square test showed that the D/HH participants with G1 reading ability chose significantly more orthographic distracters than their RL controls. D/HH participants with G2 reading ability were found to have a similar preference for orthographic information as their RL controls. It seems that the very strong preference for orthographic information is a transient reading strategy used by D/HH participants with G1 reading ability. Once the phonological strategy is mastered, the strong preference for orthographic distracters diminishes.

Relating to the last question of this study, “Do good and poor D/HH readers demonstrate a difference in their preference for phonological and orthographic information in a reading task?,” results of a crosstab chi-square test showed that the G1 subgroup of D/HH participants choose significantly more orthographic distracters than the G2 subgroup and that the G2 subgroup choose significantly more orthographic distracters than the G6 subgroups of D/HH participants, who have the best reading ability. A more interesting pattern is that the total number of phonological distracters chosen was found to increase from the G1 to G2 subgroups and then the accuracy scores hit ceiling in the G6 subgroup, where only a few distracters were chosen. In comparison with the progressively decreasing pattern for the use of phonological distracters in RL controls, the sudden increase in the use of phonological information in the G2 subgroup of D/HH participants was a unique pattern found in D/HH participants. With reference to the reading level of D/HH participants; if we rearrange the order of occurrence of findings obtained in D/HH participants, the sudden increase in the use of...
phonological distracters found in D/HH participants might not be a simple chance event. In this study, D/HH participants with G1 reading ability were found to have poor auditory discrimination and to demonstrate a very strong preference for orthographic information. The D/HH participants with G2 reading ability were found to have made significant progress in auditory discrimination and demonstrated an increase in the use of phonological distracters. These findings suggest that their particularly strong preference for orthographic distracters was a consequence of the relatively poor auditory discrimination ability found in D/HH participants with G1 reading ability. In addition, the marked increase in the use of phonological information in the G2 subgroup was related to the significant progress in auditory discrimination ability found across the G1 to G2 subgroups of D/HH participants. This may suggest that using orthographic information in preference to phonological information is a less-functional strategy. When auditory discrimination improves and phonological units are available, the preference for orthographic information diminishes. However, whether it is the use of a less-functional strategy or the unavailability of a phonological strategy that causes reading problems in D/HH remains to be clarified.

Overall, the answers to the four questions posed by this experiment appear to be empirical manifestations of the psycholinguistic grain-size theory in the reading development of Chinese-speaking children. First, the overall preference for orthographic distracters over phonological distracters found in all the RL and D/HH participants might be a language-specific reading behavior. As noted, Chinese is a language with an abundance of homophones and deep orthography (Hoosain, 1991). Phonological recoding is more reliable at large grain-size level, for example, at logographeme and radical levels. Therefore, as noted in this experiment, beginning readers show an overall preference for information from the macroorthographic structure of Chinese characters. This might be a manifestation of both the granularity problem and the consistency problem posited in PGST. Second, the relatively weak preference for phonological information found in the G1 subgroup of D/HH participants might be a behavioral manifestation of the availability problem hypothesized in PGST. Overall, the three kinds of developmental constraints as defined in PGST are crosslinguistic phenomena. However, according to the “availability problem,” “consistency problem,” and “granularity problem,” the specific kinds of phonological codes (syllables, onset rime, and phonemes), which need to be acquired before formal literacy, and the grain-size levels of the orthographic codes (stroke, logographeme, radicals, or word), on which the most reliable phonological recoding would take place, may vary from language to language. The whole picture of reading development exemplifies the interactive effects of individual characteristics and the linguistic properties of a language on individual reading development.

Clinical Implications

As suggested by the results of TAPOR in this study, auditory discrimination ability and hearing threshold were not necessarily associated, and a deficit in APOR awareness is a possible cause of reading problems in Chinese-speaking D/HH students. Therefore, APOR contrast should be one of the foci of literacy programs for Chinese-speaking D/HH children. Regarding the reading rehabilitation of D/HH children speaking in other languages, the phonological units that are emphasized in the training should be developmentally significant in their own right. Further exploration on this issue is needed.

Regarding the SDT results, in order to overcome the consistency and granularity problems brought about by the deep orthography of Chinese, the G1 subgroup of D/HH participants were found to show a strong preference for orthographic information from logographemes and radicals but not for phonological information. Therefore, an early reading-rehabilitation program for Chinese-speaking D/HH children should focus on the awareness and use of lexical orthographic information. Again, the importance of orthographic information in the reading rehabilitation for D/HH children using other languages is yet to be explored.

Implications for Further Studies

In this study, results of TAPOR suggest that poor APOR awareness is a causal factor for reading problems in Chinese-speaking D/HH students when the effects
of age, nonverbal intelligence, and hearing threshold were controlled. Because aided threshold may also affect one’s auditory discrimination (Walden & Kasten, 1976), in addition to the factors included in the regression analysis of this study, it would be best to also consider the effect of aided threshold on reading ability in future studies.

Additionally, in this study, the claim that a weaker preference for phonological information is a possible cause of reading difficulties in D/HH participants was not confirmed. As a follow-up to this study, it would be valuable to compare the use of orthographic and phonological information in a reading task by groups of D/HH participants of different reading levels (G1–G6) with their CA- and RL-matched controls. In order to avoid the ceiling effect found in this study, response latencies instead of accuracy counts in lexical decision tasks are recommended for future studies (Leck et al., 1995). Furthermore, in order to avoid the grammatical function effects of characters in word processing, it would be useful to balance the total number of nouns, verbs, adverbs, or adjectives involved in the task.

Notes

1. For the sake of homogeneity in the language background of participants with hearing loss, all the D/HH participants were recruited from the only two schools for the deaf present in Hong Kong. However, among the 54 students from these two special schools who agreed to participate in the study, 20 either failed to achieve G1 reading level or the nonverbal intelligence test (standard score: 285). Consequently, they were excluded from the experiment.

2. Hearing threshold seems to be negatively correlated with reading ability because an increase in hearing threshold means a decrease in hearing ability. Hearing ability should actually be positively correlated with reading ability.

Conflict of Interest

No conflicts of interest were reported.

Acknowledgments

We would like to express our deepest gratitude to all the academic staff and research assistants from the Division of Speech and Hearing Sciences, The University of Hong Kong. Our thanks also go to the principals of all the schools that participated in this research study.

References


Leung, M. T., & Lee, W. Y. (2002). *Hong Kong Corpus of primary school characters (HKCPSC)*. Hong Kong: University of Hong Kong.


