Clinical Focus

Validation of the Chinese Sound Test: Auditory Performance of Hearing Aid Users

Yu-Chen Hung, a Ya-Jung Lee, a and Li-Chiun Tsai a

Purpose: The Chinese Sound Test (Hung, Lin, Tsai, & Lee, 2016) has been recently developed as a modified version of the Ling Six-Sound Test (Ling, 2012). By incorporating Chinese speech sounds, this test should be able to estimate whether the listener can hear across the Chinese speech spectrum. To establish the clinical validity of the test, this study examined the relationship between the aided audiometric thresholds and the distance thresholds.

Method: Sixty children with bilateral hearing aids were recruited. The aided sound-field thresholds at 250, 500, 1000, 2000, 4000, and 6000 Hz were compared with the distance thresholds of six sounds, /u, ə, a, i, tɕʰ, and s/, which encompass the entire Chinese speech frequency range from low to high.

Results: Partial correlation and stepwise regression analyses revealed that the Chinese testing sounds are frequency specific and that the audibility of each sound could be predicted by a specific frequency threshold.

Conclusions: The results confirm the validity of the Chinese Sound Test, indicating that the testing sounds can be reliably used to assess the perception of frequency-specific information. Crucially, these data also demonstrate that the Chinese Sound Test is a useful tool to identify red flags of poor auditory access in daily environment to monitor device malfunctions and possible hearing fluctuations.

Consistent and adequate auditory access to speech sounds plays a crucial role in the successful development of hearing and speech abilities. The evaluation of standard audiological parameters, such as pure-tone audiogram, speech awareness thresholds, and speech recognition thresholds, can help determine children’s hearing levels and provide information on the adequacy of hearing aid fittings. In addition to formal hearing assessments, caregivers are recommended to monitor children’s daily hearing status because regular listening checks are crucial for the early identification of sudden changes in hearing. Amplification malfunction is one of the most common factors that hinder proper auditory access in pediatric patients (Elfenbein, Bentler, Davis, & Niebuhr, 1988). For example, low battery may lead to intermittent, distorted, or unclear sound, whereas a depleted battery or blockage in the receiver tube may cause a hearing aid to receive no sound at all. Because children are often unable to adequately express what and how they hear, it is important for caregivers to closely monitor the hearing quality of the devices, so that they can quickly identify and troubleshoot problems when they arise. In addition to device-related problems, pathological factors may cause changes in hearing. For example, hearing fluctuations have been commonly reported in pediatric populations, particularly in children with large vestibular aqueduct syndrome, auditory neuropathy spectrum, or middle ear infection (Lai & Shiao, 2004; Rance et al., 1999; Starr et al., 1998). Fluctuations are defined by a constant threshold change in hearing, either an improvement or reduction, with a threshold variation of ≥ 10 dB HL at three or more frequencies in at least one ear (Simninger & Oba, 2001). Moreover, there is another type of hearing loss called progressive hearing loss, with which the hearing ability worsens gradually over time. Progressive hearing loss is frequently identified in children with cytomegalovirus infections or deafness-causing mutations in GJB2 or mtDNA 12s rRnA genes (for an overview, see Barreira-Nielsen et al., 2016). Because appropriate and adequate amplification plays a crucial role in hearing and speech development, detailed monitoring of the auditory performance of children with fluctuating or/and progressive hearing loss is essential. Once a decline in hearing ability...
is observed, medical care is vital for preventing any further hearing loss. However, after detecting hearing reduction or improvement, hearing devices should be adjusted promptly to ensure optimal auditory access.

The most widely used screening test for detecting hearing fluctuations and poor auditory access in English-speaking regions is the Ling Six-Sound Test (Ling, 1976, 2002), which comprises six phonemes from low to high frequencies: /m, u, a, i, f, and s/. To provide a highly accurate diagnosis, several modified versions of the Ling Six-Sound Test have been developed for non–American English speakers in order to incorporate their native speech sounds, such as the Australian English Sound Test (Agung, Purdy, & Kitamura, 2005) and the Chinese Sound Test (Hung, Lin, Tsai, & Lee, 2016; Hung & Ma, 2016). In the Australian version, /u/ was replaced with /ə/ because /s/ is lower in frequency than /u/ in the Australian accent. As for a completely different language from English, the Chinese version has six testing sounds, namely /u, ə, a, i, te⁵/, and /s/, which were selected on the basis of their acoustic–phonetic characteristics, acquisition age, and interspeaker articulatory stabilities. Consistent with previous findings (Hillenbrand, Getty, Clark, & Wheeler, 1995; Johnson, 1997; Jongman, Wayland, & Wong, 2000; Stoel-Gammon, Williams, & Buder, 1994; Zee & Lee, 2001), Hung et al. (2016) showed that, although different languages may share the same phonemes, the corresponding phonetic realizations may differ between languages. For example, the average spectral concentration of the Chinese /s/ sound was found to be approximately 9000 Hz, generally higher than the English /s/, which concentrates at approximately 8000 Hz. This finding highlights the need to adapt the Ling Six-Sound Test for other languages, especially because speech-related frequency specificity is its core assessment target. Furthermore, because the /f/ sound does not exist in the Chinese phoneme inventory, it is difficult for monolingually raised Chinese speakers to accurately articulate the sound within the intended testing frequency range (e.g., Best & Strange, 1992; Bradlow, Pisoni, Akahane-Yamada, & Tohkura, 1997). Therefore, the Chinese /te⁵/ was selected to replace the nonnative English sound in order to assess the audibility of Chinese sounds with mid–high frequencies. A frequency comparison between the speech sounds in the Ling Six-Sound Test and Chinese Sound Test is provided in Table 1.

Although speech materials vary between languages, the assessment procedure is identical for these tests. The distinct aspects of auditory performance can be evaluated through tasks requiring different auditory skills. To ensure optimal hearing quality, identification tasks are often used, in which listeners are instructed to repeat a test sound they hear. These results can help audiologists validate and fine-tune hearing aid fittings. By contrast, detection tasks can be used to monitor auditory access to speech sounds because such tasks probe an individual’s sound awareness (Ling, 2012; Madell, 2008; Tye-Murray, 2015). Unlike identification tasks, detection tasks can be performed at near-threshold levels; therefore, detection is a more sensitive method for identifying hearing fluctuations (Tye-Murray, 2015). To determine the detection ability, examiners randomly present testing sounds at a conversational level. By maintaining the same vocal effort, examiners increase their distance from listeners until the listeners are unable to detect the sounds. This maximal distance signifies listeners’ detection thresholds. Moreover, because the testing sounds are frequency specific, any inconsistent response to a particular sound may indicate hearing difficulties in the corresponding frequency region. For example, if the listener’s maximal detection distance of /s/ or /f/ decreases drastically, the examiner should be alert to a sudden drop in high frequencies. Because sound intensity decreases with increasing distance from the sound source, such tests can provide distance thresholds as the screening procedures can be performed in a silent environment without additional audiological equipment.

Although the Ling Six-Sound Test and the Chinese Sound Test have high face validity and have been extensively used in therapy sessions and home settings because of their simplicity (Hung & Ma, 2016; Ling, 2012; Smiley, Martin, & Lance, 2004), according to our review of the relevant literature, these tests are yet to be validated. To the best of our knowledge, the only relevant work in the literature was dedicated to the development of a calibrated version of the Ling Six-Sound Test for evaluating aided detection thresholds (Glista, Scollie, Moodie, & Easwar, 2014; Scollie et al., 2012). However, this evaluation procedure was designed to be performed in a sound-proof booth with prerecorded speech materials, meaning the results cannot be directly applied for use in domestic environments.

### Table 1. Phonetic properties of the testing sounds in the Ling Six-Sound Test and Chinese Speech Sound Test.

<table>
<thead>
<tr>
<th>Ling Six-Sound Test</th>
<th>/u/</th>
<th>/a/</th>
<th>/i/</th>
<th>/m/</th>
<th>/f/</th>
<th>/s/</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Hz)</td>
<td>459</td>
<td>936</td>
<td>437</td>
<td>250–350</td>
<td>4500</td>
<td>8000</td>
</tr>
<tr>
<td>F2 (Hz)</td>
<td>1105</td>
<td>1551</td>
<td>2761</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chinese Sound Test</th>
<th>/u/</th>
<th>/ə/</th>
<th>/a/</th>
<th>/i/</th>
<th>/t̂e⁵/</th>
<th>/s/</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 (Hz)</td>
<td>464</td>
<td>627</td>
<td>873</td>
<td>453</td>
<td>6622</td>
<td>8998</td>
</tr>
<tr>
<td>F2 (Hz)</td>
<td>968</td>
<td>1456</td>
<td>1564</td>
<td>2624</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. This table is adapted with permission from Hung et al. (2016). F1 = first formant; F2 = second formant.
Furthermore, whether such hearing screening tools, capitalizing on distance variations and related testing sounds, can provide frequency-specific information analogous to audiometric tests remains unexplored. Therefore, this study investigated the correlation between frequency-specific hearing thresholds in intensity (i.e., dB HL) and distance (i.e., meters). Notably, we examined whether intensity thresholds can efficiently predict the distance thresholds. To this end, correlation tests were performed to examine the relationship between aided audiometric thresholds and distance thresholds of the Chinese testing sounds. Furthermore, stepwise regression analyses were performed to identify which frequency thresholds were accurate predictors of speech sound detection performance. The present findings can help professionals and caregivers accurately interpret the Chinese Sound Test results.

Method

Participants

In total, 60 children (31 girls and 29 boys) with pre-lingual, bilateral sensorineural or mixed hearing loss and aged between 2.5 and 11.2 years (mean age = 4.7 years) were recruited. Two participants were excluded from the analysis due to fussiness. All participants were regular users of binaural air conduction hearing aids. The unaided better-ear pure-tone averages ranged from 28 to 108 dB HL (mean = 68.3 dB HL). All children were enrolled in early intervention programs through oral communication, and their native language was Taiwanese Mandarin, a variant of Standard Mandarin with a Taiwanese accent. The mean age of first matching for hearing aids was 2 years (0.2–5.2 years), and the average duration of hearing aid use was 2.7 years (0.3–7 years). All participants wore nonlinear digital hearing aids with amplitude compression, and 26 of them used nonlinear frequency compression. To minimize the unwanted effects of specific technical settings, other smart hearing features such as directional microphones and noise reduction were deactivated during the test. No participants reported any motor, cognitive, or sociopsychological deficits. Prior to the study, the procedures and ethical concerns were explained to participants’ parents and caregivers, and subsequently signed consent forms were obtained.

Audiology Evaluation

Prior to the Chinese Sound Test, all participants completed a standard audiological evaluation performed by audiologists, in which their aided sound-field thresholds were measured (250, 500, 1000, 4000, and 6000 Hz) by using warble-tone or narrowband noise stimuli with the Hughson–Westlake technique (Hughson & Westlake, 1944). Because most of the hearing aids tested in this study provided rather insufficient gains above 6000 Hz and our participants were mostly preschoolers (n = 47), who have short attention spans, the 8000-Hz measurement was excluded in order to complete the audiogram within the time limit.

All audiometric threshold measurements were conducted using a Grason-Stadler model 61 (GSI 61) audiometer. Testing was executed in a soundproof booth with loudspeakers (GSI high-performance speakers) located 1 m to the left and right of the seated participant at a 45° azimuth approximately 1 m above the floor. Figure 1 shows participants’ hearing thresholds.

Detection Distance Evaluation

Materials

In this study, six phonemes from the Chinese Sound Test were used, namely /u, a, i, tei, and s/, encompassing the entire Chinese speech spectrum. The Chinese Sound Test was administered by directing the live voice of a 25-year-old female tester to avoid any potential effects induced by different talker characteristics (Robinson, 2011). The average fundamental frequency of the talker was 224 Hz. Table 2 presents the talker’s acoustic features of each testing sound. The speech material for the talker’s acoustic analysis was collected separately in a soundproof booth by using Praat (Version 5.3.85; Boersma & Weenink, 2012) at a sampling rate of 44,100 Hz. The谈者 produced each sound three times in isolation. The first two formants of vowels were calculated using Praat, and the center of gravity of the spectrum of consonants was obtained with Time–Frequency Analysis for 32-bit Windows (TF32; Milenkovic, 2004).

The detection thresholds were measured under aided conditions for both the audiological and detection distance evaluations. There were two reasons for this. First, the participants’ degree of hearing loss varied from mild to profound; it is difficult for individuals with more severe hearing loss to perceive speech without wearing hearing aids, even when the speaker is very close (Anderson & Matkin, 2007). Second, in addition to unaided testing conditions, the Ling Six-Sound Test and Chinese Sound Test are often used to monitor hearing aids or cochlear implant function to ensure optimal amplification (Lin & Hung, 2017; Ling, 2012). The knowledge gained from comparisons between aided thresholds could therefore be directly applied to the care of individual’s hearing. However, future work on unaided testing conditions is required to verify the Chinese Sound Test for users with milder hearing loss.

Procedure

Speech sound tests are commonly administered with live voice either at home or in clinical settings. To improve the test reliability, it is important to accurately articulate the sounds with a consistent vocal effort. Accurate sound production ensures that the correct frequency range is being assessed (e.g., the /u/ sound for the lower frequencies), because the acoustic properties of sound vary with the manner of articulation (Ladefoged, 1993). Maintaining the same vocal effort is equally important. These conditions render distance as the only factor affecting the loudness of sound.
To ensure the quality of phoneme presentation, the tester was required to practice stabilizing her speaking level during the production of the six Chinese speech sounds by monitoring it on the audiometer’s volume unit meter (GSI 61) and Praat. Prior to each session, the tester rehearsed and calibrated her speaking intensity with a digital sound level meter (TES-1351B, TES Electrical Electronic Corp.) to maintain the loudness of her voice at a conversational level (60–70 dBA). In an attempt to maintain the same vocal effort over the course of testing, the tester placed her fingers gently on her throat to feel the vibration during the production of the voiced sounds. The hearing assessments were performed in a silent room (13 [length] × 4.5 [width] m). The environmental settings were unchanged throughout the experiment; for example, the air conditioner was always switched off to avoid unwanted noise. The ambient noise level was maintained at approximately 40 dBA.

The participants were seated with their backs to the tester (see Figure 2). To assess their awareness to the presented sounds, the participants were instructed to raise their hand and say “yes.” A modified Hughson–Westlake technique (Hughson & Westlake, 1944) was adopted during the assessment. The tester always started the assessment at a 5-m distance from the participants. If the presented sound was audible, the tester would decrease the intensity by stepping backward at 1-m distances until the participants did not respond (the maximum detection range was 12.5 m). The absence of any response to the presented sounds indicated that the intensity was too low to be audible, following which the tester would step forward in 0.5-m distances until a response was obtained. By adjusting the distance, the tester would eventually obtain the detection threshold in distance (meters) for each sound. The threshold was determined when there were two out of three responses. To avoid false positive responses, the interval between each sound was varied to ensure that the participants could not predict the presentation rate of sounds and had to rely on their hearing ability to provide responses.

Six testing lists of randomly ordered six sounds were generated. The distribution of lists was counterbalanced across the participants. The detection thresholds were documented for each sound. Each sound represents a specific frequency range, presumably resulting in distinct maximum detection distances. The assessment session was completed.

Table 2. Average (standard deviation) frequency values of the testing sounds.

<table>
<thead>
<tr>
<th>(Hz)</th>
<th>/u/</th>
<th>/ə/</th>
<th>/a/</th>
<th>/i/</th>
<th>(Hz)</th>
<th>/tɕʰ/</th>
<th>/s/</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>306 (56)</td>
<td>539 (16)</td>
<td>933 (28)</td>
<td>379 (10)</td>
<td>Central gravity</td>
<td>8247 (100)</td>
<td>9177 (143)</td>
</tr>
<tr>
<td>F2</td>
<td>542 (22)</td>
<td>1529 (21)</td>
<td>1553 (16)</td>
<td>2505 (404)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. The formant frequency values (F1 and F2) and central gravity values for consonants were measured using Praat (Version 5.3.85; Boersma & Weenink, 2012) and Time–Frequency Analysis for 32-bit Windows (Milenkovic, 2004), respectively. F1 = first formant; F2 = second formant.
in approximately 15 min. All participants received a small gift after test completion.

Results

Figure 3 presents the detection (distance) thresholds for each sound and participant. Because chronological and hearing ages influence hearing-related performance (Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; Yoshinaga-Itano, 2003), these two variables were partialled for calculating the correlation coefficients between the magnitude of the aided audiometric thresholds (dB HL, six frequencies) and the aided Chinese Sound Test distance thresholds (meter, six sounds). Table 3 presents the partial correlation coefficients. As shown in Table 3, significant negative partial correlations were observed for /u/ and 1000 Hz ($p = .027$); /l/ and 250, 500, 1000, and 2000 Hz (all $ps \leq .029$); /a/ and 250, 500, 1000, and 2000 Hz (all $ps \leq .037$); /i/ and 250 and 1000 Hz (all $ps \leq .030$); and /s/ and 6000 and 8000 Hz (all $ps \leq .038$). A marginal negative correlation was observed between /u/ and 250 Hz ($p = .058$) as well as /te$/ and 6000 Hz ($p = .058$). In addition, the current results showed that the strength of the relationships was moderate (all $r$ values were between $-0.5$ and $-0.3$), which might have resulted from the relatively low variability in the aided conditions with a narrow range of threshold values (Goodwin & Leech, 2006). However, the observed weaker relationships may imply the presence of other unidentified factors accounting for speech sound detection, which must be clarified in future research.
Stepwise regression analyses were conducted to investigate whether the aided distance thresholds of the testing sounds can be predicted by the aided audiometric thresholds at specific frequencies. An individual stepwise regression was performed for each testing sound. The independent variables of each model were the same, namely the audiometric thresholds at each frequency (i.e., 250, 500, 1000, 2000, 4000, and 6000 Hz). The results (see Table 4) showed that, in the low-frequency range, hearing thresholds at 250 and 500 Hz were the highest contributors to the auditory performance of /u/ and /ə/, respectively. In the mid-frequency range, hearing thresholds at 1000 Hz contributed significantly to the prediction of detection results of /u/ and /ə/. Finally, hearing thresholds at 6000 Hz were the strongest predictors of the performance of high-frequency sounds, /tɕʰ/ and /s/.

Altogether, the present data demonstrated that the testing sounds are frequency specific and their detection distances can be predicted by audiometric thresholds at certain frequencies.

### Discussion

Although speech sound tests, such as the Ling Six-Sound Test and the Chinese Sound Test, have been widely used by parents and clinicians, the empirical relationship

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**Table 3.** Partial correlation coefficients for audiometric thresholds and Chinese Sound Test distance thresholds after partialing for chronological and hearing ages.

<table>
<thead>
<tr>
<th>Testing sounds</th>
<th>Audimetric thresholds (Hz)</th>
<th>250</th>
<th>500</th>
<th>1000</th>
<th>2000</th>
<th>4000</th>
<th>6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>/u/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.310</td>
<td>−.298</td>
<td>−.358</td>
<td>−.180</td>
<td>−.156</td>
<td>−.149</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.058*</td>
<td>.069</td>
<td>.027*</td>
<td>.278</td>
<td>.349</td>
<td>.371</td>
</tr>
<tr>
<td>/ə/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.371</td>
<td>−.484</td>
<td>−.436</td>
<td>−.355</td>
<td>−.208</td>
<td>−.160</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.022*</td>
<td>.002**</td>
<td>.006**</td>
<td>.029*</td>
<td>.210</td>
<td>.338</td>
</tr>
<tr>
<td>/a/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.485</td>
<td>−.406</td>
<td>−.437</td>
<td>−.339</td>
<td>−.262</td>
<td>−.155</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.002**</td>
<td>.011*</td>
<td>.006**</td>
<td>.037*</td>
<td>.112</td>
<td>.354</td>
</tr>
<tr>
<td>/i/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.442</td>
<td>−.188</td>
<td>−.353</td>
<td>−.284</td>
<td>−.223</td>
<td>−.133</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.005**</td>
<td>.258</td>
<td>.030*</td>
<td>.084</td>
<td>.178</td>
<td>.425</td>
</tr>
<tr>
<td>/tɕʰ/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.277</td>
<td>−.068</td>
<td>−.081</td>
<td>−.058</td>
<td>−.243</td>
<td>−.310</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.092</td>
<td>.687</td>
<td>.631</td>
<td>.728</td>
<td>.141</td>
<td>.058*</td>
</tr>
<tr>
<td>/s/</td>
<td>r&lt;sub&gt;partial&lt;/sub&gt;</td>
<td>−.270</td>
<td>−.155</td>
<td>−.118</td>
<td>−.186</td>
<td>−.338</td>
<td>−.383</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>.102</td>
<td>.353</td>
<td>.482</td>
<td>.263</td>
<td>.038*</td>
<td>.018*</td>
</tr>
</tbody>
</table>

*p < .05. **p < .01. *p < .06.

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**Table 4.** Stepwise regression analyses for the prediction of audiometric thresholds in the Chinese Sound Test.

<table>
<thead>
<tr>
<th>Testing sounds and step</th>
<th>Independent variables (Hz)</th>
<th>R&lt;sup&gt;2&lt;/sup&gt;</th>
<th>p</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/u/</td>
<td>1</td>
<td>.13</td>
<td>.022</td>
<td>−.356</td>
</tr>
<tr>
<td>/a/</td>
<td>1</td>
<td>.22</td>
<td>.002</td>
<td>−.465</td>
</tr>
<tr>
<td>/i/</td>
<td>1</td>
<td>.20</td>
<td>.004</td>
<td>−.441</td>
</tr>
<tr>
<td>/tɕʰ/</td>
<td>1</td>
<td>.19</td>
<td>.005</td>
<td>−.432</td>
</tr>
<tr>
<td>/s/</td>
<td>1</td>
<td>.12</td>
<td>.025</td>
<td>−.350</td>
</tr>
<tr>
<td>/tɕʰ/</td>
<td>1</td>
<td>.15</td>
<td>.011</td>
<td>−.392</td>
</tr>
</tbody>
</table>
between the distance and aided audiological thresholds remains unexamined, increasing the challenges in the accurate interpretation of test results. Therefore, this study compared the aided distance thresholds of the Chinese Sound Test to the aided audiological thresholds at each frequency. The data revealed that the detection (distance) thresholds for vowels were significantly correlated with the audiological thresholds at low to mid–high frequencies, whereas those for consonants were strongly correlated with the hearing thresholds at high frequencies. Notably, the present correlation analyses indicated that phoneme detection may not rely solely upon the acoustic cues delivered by the first two formants or the peak energy region, and the adjacent frequencies may also contribute to sound audibility (see Tables 2 and 3). For example, a significant correlation was found between /u/ and the hearing threshold at 1000 Hz, although the first two formants of Mandarin /u/ are generally located below 1000 Hz. However, this assumption regarding the essential components in detecting speech sound must be confirmed by further information on detection thresholds at formant frequencies. Nevertheless, examiners should be aware of this possibility when deriving clinical implications from test results.

Furthermore, the stepwise regression analyses demonstrated that the performance of each testing sound can only be accounted for by a specific pure-tone hearing threshold, thus emphasizing the frequency specificity of each sound; this provides empirical evidence that could aid testers in interpreting the results of the Chinese Sound Test. The results revealed that the threshold at 1000 Hz contributed the most to detecting the sound /s/, confirming the relevance of the first two formants. The detection of /s/ and /s/ were only determined by the first formant, namely 250 and 500 Hz, respectively, which is consistent with a previous finding, which indicated that sound detection typically requires fewer acoustic cues than sound identification (Boothroyd, 2008; Monahan & Idsardi, 2010). Apart from the core formants, the data indicated that adjacent frequencies might play a crucial role in detecting certain sounds. For example, the audibility of sound /u/ was most accounted for by the threshold at 1000 Hz, slightly higher than the first two formants. Similarly, the performance of consonants /t/ and /l/ was mostly predicted by the hearing thresholds at 6000 Hz. Nevertheless, because the aided sound-field thresholds at 8000 Hz were not obtained during the preset audiology evaluation, additional studies are warranted to examine whether the hearing thresholds at 8000 Hz are stronger predictors of the testing results of /t/ and /l/.

Overall, the present data provide an overview of the auditory performance of children with hearing aids in the Chinese Sound Test, demonstrating that the testing sounds can be reliably used to assess the perception of frequency-specific information, as well as to assist clinicians and caregivers in obtaining information on children’s auditory status, monitoring device malfunctions, and possible hearing fluctuations.

Finally, to achieve higher test reliability, testers should exercise caution in the following areas: (a) maintaining the same vocal effort while presenting consonants, even when the intensity appears softer to the tester; (b) maintaining the same environmental setting to ensure that the signal-to-noise ratio stays more or less the same in every test; and (c) obtaining the baseline performance, such as the establishment of detection distance thresholds after the hearing aids are fitted. If the distance threshold of a certain sound differs from the baseline performance, the tester should note a possible hearing change. If the hearing problem persists after troubleshooting is conducted for the hearing aid and possible causes such as wax blockage are excluded, an audiological evaluation may be in order.

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References


