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Development and validation of a new Mandarin tone identification test

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ABSTRACT

Objectives: The objectives of this study were to develop a new Mandarin tone identification test (MTIT) to assess the Mandarin tone identification ability of children with hearing impairment (HI) and at age around 7 years; and to evaluate the reliability and sensitivity of the MTIT.
Methods: The word materials to be used in the MTIT were developed in Phase I. Monosyllables were chosen to represent the daily repertoire of young children and to avoid the influence of co-articulation and intonation. Each test stimulus set contained four words, with one target, one containing contrastive tone, and two unrelated distracters. All words were depicted using simple pictures, and the test targets in quiet or in noise were presented using recorded stimuli on a custom software. Phase II evaluated the reliability and sensitivity of the MTIT. Participants were 50 normal-hearing native-Mandarin speakers around 7 years of age.
Results: In Phase I, the MTIT was developed as described above. The final test consists of 51 words that are within the vocabulary repertoire of children aged 7 years. In Phase II, with the Mandarin tone identification scores collected from 50 children, the repeated measure ANOVA showed a significant main effect of S/N on MTIT performance ($p < 0.001$). Pairwise comparisons revealed a significant difference in performance across the five S/N conditions ($p < 0.01$) when S/N varied from −30 to −10 dB. Cronbach's alpha at −15 dB S/N was 0.66, suggesting satisfactory internal consistency reliability. A paired-samples t-test showed that there was no significant difference between the test–retest scores across the five S/N conditions ($p > 0.05$).
Conclusions: Compared with the available Mandarin tone identification tools, MTIT systematically evaluated the tone identification performance in noisy environment for normal hearing children at age around 7 years. Results also showed satisfactory internal consistency reliability, good test–retest reliability and good sensitivity. In the near future, MTIT could be used to evaluate tone perception ability of children with hearing impairment and help to design hearing rehabilitation strategies for this population at the age critical for their language learning.
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1. Introduction

A quarter of the world languages are tonal [1]. Mandarin is a tonal language spoken by 53.1% of people in China [2,3]. In a tonal language, pitch level changes denote the meaning of the word. However, there is a lack of a validated tool to examine lexical perception in children. Based on the various patterns of the fundamental frequency (F0), Mandarin tones are classified into Tone 1 (high level), Tone 2 (mid-rising), Tone 3 (mid-falling-rising), and Tone 4 (high-falling) [4,5]. For example, the syllable/mA/ expressed with the four tones would mean 'mother', 'hemp', 'horse', and 'reproach', respectively. The consonants and vowels could be combined into 417 syllables without tone. These 417 syllables are combined with the four tones into 1302 different syllables. As many Chinese characters have the same pronunciation, these 1302 syllables could represent more than 6763 Chinese characters [6]. Thus, lexical tone plays an important role in sentence perception, especially in challenging listening conditions [7]. In quiet, Feng et al. [8] found that tone serves as a redundant

Abbreviations: F0, fundamental frequency; HI, hearing impairment; H-NTLA, Hiskey-Nebraska Test of Learning Aptitude; ICC, intra-class correlation; MTIT, Mandarin tone identification test; NH, normal-hearing; S/N, signal to noise ratio; SSN, speech spectrum shaped noise.

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cue for the meaning of the Mandarin sentence. Mok and Wong [9] also found that lexical tones did not remarkably influence speech perception in quiet. However, the situation is completely different in noisy environment. Chen et al. [7] showed that, although tone contours were not important in sentence perception in quiet, their importance increased in noise. Wang et al. [10] and Xu et al. [11] reported similar findings.

1.1. Tone perception in children with hearing impairment

As reported in the Second National Disabled Sample Survey, Mainland China, a typical developing country has around 20 million people exhibiting hearing impairment (HI) as the sole disability [12]. Among them, there were 1.37 million hearing-impaired children and 23,000 babies born with hearing impairment per year [13]. These children may have a delayed or impaired speech perception development [14]. Mandarin tone perception ability in children with cochlear implants was reportedly poor, ranging from 67% correct to 73% correct in quiet environment [15,16]. Little is known about tone perception ability in Mandarin-speaking children with hearing aids. Previous research found that Mandarin-Chinese tones 2 and 3 are more difficult to discriminate than other tone contrasts, not only by adults with HI but also those with NH [17,18]. Lee et al. [19] found that native-Cantonese speaking children with profound HI have difficulties discriminating some tone pairs, possibly due to the small differences in F0 onset values and F0 contour. To our knowledge, little has been done to examine the tone perception ability of Mandarin-speaking children with HI, especially in noise.

1.2. Mandarin tone perception test

In order to evaluate the tone perception ability of children with HI, a standardized Mandarin tone perception test material is needed. To date, there are three existing tone perception test materials: (1) the Mandarin early speech perception test (MESP) [18], (2) the Mandarin pediatric lexical tone and disyllabic-word picture identification test in noise (MAPPID-N) [20], and (3) the set of standard and method for evaluation of hearing-impaired children's hearing and speech ability [21]. However, these test materials have some limitations. Table 1 compares the Mandarin tone identification test (MTIT) material developed in the current study to these three tests. First, these tests are mostly conducted in quiet and, therefore, are not expected to reflect the performance in real life situations (e.g., nurseries or classroom) where noise is eminently present. This is particularly important to note because speech understanding in noise is more challenging, particularly for children with HI [22,23]. Second, there is no carrier phrase to draw children's attention to listen and respond. Although a verbal prompt from the examiner could be used, the administration of the test would become more cumbersome. Third, there are few items in these tests, yielding uncertain practice effects, particularly when repeated measures of the same test is being used, such as in a longitudinal study. Finally, but more importantly, the psychometric properties of these tests were not evaluated.

The development of the MTIT considered the importance of reliability, validity and sensitivity. Test materials were developed in Phase I, and the reliability and sensitivity of the MTIT were evaluated in Phase II. This research was approved by the Human Research Ethics Committee, the University of Hong Kong. Informed consent was obtained from the parents or the participants.

2. Phase I: development of the test material

2.1. Method

2.1.1. Materials and equipment

To ensure that the test is a valid measure for the pediatric population, care was taken in the selection of test materials. First, vocabulary within the daily repertoire of children aged 7 or above was selected. Second, words that are familiar to young children [20,24] were used, because previous study showed that the error rate in tone perception test is closely related to the familiarity of the words [25]. Third, monosyllables were used because they are very common in Chinese. They are preferred in a tone identification test because it will be difficult to come up with disyllabic or multisyllabic distractors that differ only in tones. In addition, co-articulation in disyllabic or multisyllabic words would result in modification of the tones (referred to as tone sandhi), especially for words in Tone 2 and Tone 3 [26]. In such case, the first syllable would become a neutral when it is followed by another stressed syllable. In other words, the first syllable will be weakly stressed. Furthermore, the tone of a word may be changed with the intonation of the sentence, so that the identification of the tone could be difficult [27,28]. With the above concerns in mind and as we targeted to test school-age children, monosyllabic words that are representative of the vocabulary repertoire of a 7 year old child were used in this study.

A pointing response mode and pictorial representation of the items were chosen in order to allow the test to be performed among children with HI and/or difficulty to accurately articulate the response. Colored illustrations have been found to successfully

Table 1
Materials to evaluate Mandarin tone perception.

	MESP [18]	MAPPID-N [20]	Sun's (2009)	MTIT (current study)
Target age	2–5 years	4–9 years	3 years and above	7 years and above
Presentation	2 picture plates; male recorded voice	2 × 2 picture plates; male recorded voice	2 picture plates; live voice	2 × 2 picture plates; male recorded voice
Number of different test stimuli	48 different stimuli	24 different stimuli, repeated twice	4 different stimuli	51 different stimuli, 9 stimuli repeated twice
Number of test items	48	48	12	60
Distracters	1 test item and 1 tone contrast as distractor	1 test item and 3 syllable-related distracters (3 distracters have same syllable as the test item but with different tones)	1 test item and 1 tone contrast as distractor	1 test item and 1 tone contrast as distractor plus 2 unrelated distracters
Carrier phrase	No	No	Yes	Yes
Test condition(s)	Quiet	Quiet and adjustable *S*/*N*	Quiet	Quiet and noise at 5 *S*/*N*s
Evaluation of psychometric properties	No	No	No	Test–retest reliability, internal consistency reliability, sensitivity

Note: MTIT = Mandarin tone identification test, MESP = Mandarin early speech perception test. MAPPID-N = the Mandarin pediatric lexical tone and disyllabic-word picture identification test in noise, Sun's (2009) = the set of standard and method for evaluation of hearing-impaired children's hearing and speech ability.

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