Original Article

The Cantonese Hearing in Noise Test for Children

Trends in Hearing
Volume 23: 1–9
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DOI: 10.1177/2331216519837128
journals.sagepub.com/home/tia
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Abstract

The aim of this study was to develop a children's version of the Cantonese Hearing in Noise Test (CHINT-C). This was accomplished in two stages. First, a total of 120 sentences understood by children aged 6-7 years were selected from the original pool of CHINT sentences and were grouped into 12 lists, each containing 10 sentences composed of 10 characters. Following this, 260 primary and secondary school children, with ages ranging from 6 to 17 years, and 21 adults of age 18 or older were administered the CHINT-C to determine its reliability/validity, normative data, and age-specific correction factors. The result showed good interlist reliability, and test–retest reliability for the CHINT-C. The speech perception skills assessed using the CHINT-C do not reach adult level until after 11-13 years of age. Correction factors were established that could be used to determine age-specific norms for the evaluation of speech intelligibility of children in various sound fields.

Keywords

speech perception, Cantonese, Hearing in Noise Test, children

Date received: 12 April 2018; revised: 9 January 2019; accepted: 14 February 2019

Introduction

Cantonese is spoken by more than 40 million people globally (Bauer & Benedict, 1997). It is a tonal language, where information is distinguished by variations in the pattern of fundamental frequency, with all root words being monosyllabic and lexically meaningful. There are 18 vowels, 19 consonants, and more than 40% of the words are of the consonant–vowel type (Knight, 1997). Cantonese has nine tones, with the first six being basic tones: high-level, mid-level, low-level, high-rising, low-rising, and low-falling. The remaining three are *entering* tones (i.e., high-enter, mid-enter, and low-enter) that have the same pitch levels as high-level, low-level, and low-falling tones, respectively, but are shorter in duration. In addition, syllables with these entering tones are closed by one of the final stop consonants (i.e., /p, t, and k/; Fok Chan, 1974).

Despite its wide usage, there is no standardized tool for the assessment of sentence perception in school-age Cantonese-speaking children. The development of a children's version of the Cantonese Hearing in Noise Test (CHINT-C) would facilitate the evaluation of speech comprehension in children speaking the language, possibly leading to a better understanding of speech perception in Cantonese individuals in the future.

Adaptation From the Adult Version of the CHINT

Soli and Wong (2008) reported normative data for the Hearing in Noise Test (HINT) for adults in 14 languages, including Cantonese. These language modules of the HINT were developed using the same paradigm as the English HINT (Nilsson, Soli, & Sullivan, 1994; Soli & Wong, 2008). Sentences used as test stimuli in the HINT are phonetically balanced across lists and are appropriate for use in adults with a literacy level as low as the first grade. The HINT measures speech reception thresholds (SRTs), which are defined as the signal-to-noise ratios (SNRs) for 50% of the sentences to be

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accurately repeated. The SRTs are obtained in four test conditions: quiet, noise from the front (NF), noise from the right (NR), and noise from the left (NL). SRTs can be obtained within the sound field, or under headphones, with head-related transfer functions (HRTFs) applied to simulate noise from different azimuths. The adult version of the CHINT was previously found to have good inter-list reliability and within-list reliability (Wong, Ho, Chua, & Soli, 2007a).

A child adaptation of the HINT has been created for several languages (e.g., American English, Canadian French, and Norwegian). These children's versions of the HINT were formed from a subset of the adult sentences that were repeated correctly by children between 5 and 6 years of age. These sentences were sorted subsequently to form 10-sentence lists. The same paradigm was used in the present study. The above-mentioned children's versions of the HINT have exhibited good list equivalence and test–retest reliability (Vaillancourt, Laroche, Giguère, & Soli, 2008).

Norming and the Effects of Maturation

It is necessary to obtain norms in children because the auditory system matures over time, improving the ability to understand speech, particularly in noise (Boothroyd, 1997; Elliott et al., 1979; Elliott, Longinotti, Meyer, Raz, & Zucker, 1981; Fior, 1972; Hall III, Grose, Buss, & Dev, 2002; Hnath-Chisolm, Laipply, & Boothroyd, 1998; Jerger, Jerger, & Lewis, 1981; Neuman & Hochberg, 1983; Papso & Blood, 1989). Previous studies conducted to determine norms in children have employed various test materials, such as sentences (e.g., Eisenberg, Shannon, Schaefer Martinez, Wygonski, & Boothroyd, 2000; Fallon, Trehub, & Schneider, 2000) and monosyllables (e.g., Elliott et al., 1979). These studies have found that children tend to reach adult-like performance by 10 to 13 years of age. This maturation effect likely reflects ongoing auditory system development. For instance, the configuration of the cochlea is very adult-like by the end of the second trimester, and the brainstem reaches a mature state, with neurofilament expression reflected in the marginal layer of the auditory cortex during the perinatal period. In early childhood (i.e., 6 months to 5 years), there is progressive maturation of thalamocortical afferents to the deeper cortical layers. During late childhood (5–12 years), maturation of the superficial cortical layer results in the ability to process more complex auditory stimuli (Moore, 2002; Moore & Linthicum, 2007). These physiological changes suggest that the ability to perceive speech continues to improve over childhood. As such, for a test to be used appropriately, normative data should be obtained across ages. In addition, the information gained from obtaining these norms would also inform the developmental trajectories of children and verify that the test can discriminate between these developmental changes.

Age-Specific Correction Factors for Children With Normal Hearing

For HINT materials to be administered under headphones (rather than in the sound field), HRTFs must be applied to simulate the same frequency response for speech that would be produced in the sound field. However, HRTFs differ between children and adults (Fels, Buthmann, & Vorländer, 2004). Specifically, adult HRTFs do not account for the smaller ear and head size in children. Currently, HRTFs for children are unavailable, making the presentation of HINT material to children under headphones impossible. Therefore, until HRTFs for children of different ages become available, the testing of children must be conducted within the sound field. However, results obtained in the sound field are often influenced by room acoustics (i.e., reverberation time, reflections, and objects acting as obstacles to sound propagation; Vaillancourt et al., 2008). A small change in these room acoustic parameters could strongly influence HINT scores, thereby requiring age-specific norms for each sound field. This would be difficult to accomplish in most laboratories or clinics considering the fact that a large number of children of various ages would be required to establish sound field-specific normative values. Nilsson, Soli, and Gelnett (1996) proposed that a single set of age-specific correction factors relative to adult performance be used to allow comparison across different sound fields. These correction factors can be used to derive children's norms for a specific sound field in five steps, as described in Vaillancourt et al. (2008), for the testing of Canadian French-speaking children:

Step 1: obtain the mean adult SRT in Sound Field A
Step 2: obtain age-specific mean SRTs in Sound Field A
Step 3: calculate age-specific correction factors, which are the differences between values from Step 1 and Step 2
Step 4: obtain the mean adult SRT in Sound Field B
Step 5: calculate age-specific norms for Sound Field B, which are the sums of values from Steps 3 and 4

In this study, steps 1 through 3 were performed to generate correction factors for each age-group. Steps 4 and 5 can be repeated for all other sound fields to derive age-specific norms for each sound field. The current study yielded a single set of age-specific correction factors, as only one sound field (i.e., Sound Field A) was used for testing. These correction factors should be obtained in all four listening conditions (i.e., quiet, NF, NR, and NL) because when the speech and noise sources are spatially separated, the reverberation from each source in the sound field can change the interaural time and level differences associated with each source (Soli & Wong, 2008), resulting in compromised spatial unmasking ability of the binaural auditory system. As a result, the SRTs in conditions with spatial separation would be elevated and not reflect the actual performance.

In summary, the current study aimed to develop a children's version of the CHINT in two stages. In the first stage, sentences were selected from the adult version of the CHINT to form lists that were phonetically balanced. In the second stage, these lists were used to obtain normative data and age-specific correction factors. The response variability, reliability, and validity of these lists were also examined in this stage.

Methods

Stage 1: Sentence Selection and List Creation

Nine children, aged 6 to 7 years, participated in Stage 1. They were recruited from schools at the median performance standard in Hong Kong. All participants spoke Cantonese as their first language and had attended schools that instructed in Cantonese the age of three onwards. They had bilateral hearing thresholds at 20 dB HL or better at 500, 1k, 2k, and 4k Hz. Findings from otoscopic examinations, tympanometry, and medical histories were negative for outer- or middle-ear pathologies. Tympanometry was conducted to screen for middle ear pathologies, with normative values from Wong, Au, and Wan (2008) used to define normal middle ear function among participants. Pure-tone audiometry was conducted using the procedures described in the ANSI/ASA S3.21-2004 (R2009) standard (American National Standards Institute/Acoustical Society of America, 2009). Learning difficulties or developmental problems were not reported.

Sentences for the CHINT-C were generated from the adult CHINT corpus of 240 sentences. To ensure that the sentences used were appropriate for the assessment of children aged 6 years or older, the CHINT sentences for the children's version were selected in three phases, with three children in each phase. First, three children listened to all 240 of the adult sentences in the NF condition at an SNR of −4 dB, with noise set at 65 dB A. Sentences that could not be comprehended or repeated correctly by at least two of the three children were excluded. The remaining sentences were presented to the second group of three children in the same noise condition as in the first phase, and those that could not be repeated correctly by any of the three children were discarded. The selected sentences were subsequently presented to the remaining three children to ensure that these sentences could be repeated correctly by children in this age range. At the end of this process, 120 sentences with the highest intelligibility were retained. These 120 sentences were then grouped using a trial-and-error procedure into 12 lists composed of 10 sentences each, with equal phonemic class and tone distributions across the lists.

Stage 2: Examining Reliability/Validity, and Obtaining Normative Data, and Age-Specific Correction Factors

A total of 260 primary and secondary school children, ranging in age from 6 to 17 years (106 girls, 154 boys) participated in Stage 2. There were approximately 21 (ranging from 18 to 22 years) participants in each age-group. In addition, there were 21 adults of age 18 or older. The participant selection criteria were the same as those in Stage 1. The sample size was determined based on the mean difference in the NF SRT between 6- and 9-year-olds for the English (i.e., 0.7 dB) and French (i.e., 1.1 dB) versions of the HINT for children (Vaillancourt et al., 2008). The calculation suggested that the sample size should be 21, with an assumed effect size of 1.0 dB, standard deviation (SD) = 1, and power set at 90% (Myhrum, Tvete, Heldahl, Moen, & Soli, 2016).

A steady-state speech-spectrum-shaped noise was created to match the long-term frequency spectrum of the targeted sentences. Next, SRTs were obtained in children as well as young adults in the four test conditions: speech in quiet, and speech in noise originating from 0° (NF), 90° (NR), and 270° (NL) azimuths. The SRTs from the NR and NL conditions were averaged to yield results for noise side (NS). While the SRTs in the quiet conditions were measured in dB A, the SRTs measured in noise were expressed in dB SNR. These values were compared across age groups.

The 12 lists created in Stage 1 were administered using an adaptive test procedure, according to a previously published HINT paradigm (Wong & Soli, 2005). All participants were given two practice lists, one in the quiet condition, and another in the NF condition, in order to familiarize them with the task. Each participant was then given all 12 sentence lists in the four listening conditions, with each listening condition containing three threshold measurements using three sentence lists. A Latin square design was used to ensure that each sentence list was administered in each condition an equal number of times. Participants were instructed to listen carefully and repeat aloud whatever they heard.

For testing in quiet, the procedure began with the first sentence being presented at 20 dB A, and the sentence presentation level was increased in 4-dB steps until the participants repeated all words in the sentence correctly. The presentation level was then lowered by 4 dB after a correct repetition of the entire sentence or raised after an incorrect response. The four SNRs used to present the first four sentences were averaged and used as the starting presentation level for the fifth sentence. Thereafter, the adaptive procedure proceeded in 2-dB steps to the eleventh sentence. Although an eleventh sentence was not presented, the HINT program would calculate the SNR that would have been used to present this sentence, based on results from the tenth sentence. For testing in noise, the noise level was fixed at 65 dB A, while the intensity levels of the sentences were adaptively adjusted according to the participant's responses. Sentences were initially presented at −5 dB SNR. The same adaptive procedures used in the quiet condition were followed to obtain the SRTs in noise. The HINT program was used to control signal levels, randomize the presentation order of sentences within each sentence list, record the responses to each sentence, and calculate the SRTs for each list.

Stages 1 and 2 were administered in an audiometric test booth in the Speech, Language, and Hearing Clinic at the University of Hong Kong. Loudspeakers were placed 1.0 m away from the center of participants' heads. The study protocol was approved by the Human Research Ethics Committee for Non-Clinical Faculties of the University of Hong Kong. Written informed consent was obtained from both parents and participants prior to testing.

Results

Stage 1: Sentence Selection and List Creation

The sentence selection protocol resulted in the CHINT-C consisting of 12 lists, composed of 10 sentences each. In addition, each sentence was composed of 10 characters. The phoneme class distributions of all the lists were within ±2.5% of the mean distribution for the entire set of sentences. Further, the first six Cantonese tones for each list were within ±2.5% of the average proportion of each tone across the lists. These distributions are comparable with those reported by Wong and Soli (2005) for the adult version of the CHINT. Sentence lists and English translation are provided in online Appendix 1.

Stage 2: Examining Reliability/Validity, and Obtaining Normative Data and Age-Specific Correction Factors

Interlist reliability, test–retest reliability, and within-list variability. To measure interlist reliability, the deviations between SRTs obtained using a single list and mean SRTs obtained using three lists in each listening condition were calculated for each individual. The results are shown in Figure 1. The SRTs in each test condition were typically within 1 dB of the individual overall mean calculated using the three SRTs. Therefore, good interlist reliability was established (Wong & Soli, 2005).

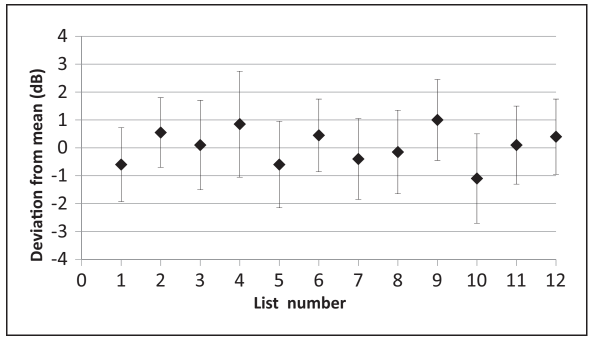

Figure 1. Deviation of mean speech reception thresholds obtained using individual lists compared with the overall within-subjects mean.

Table 1. Standard Deviations of Speech Reception Thresholds Difference Scores From Repeated Measurements Using Different Lists and 95% Confidence Intervals in the quiet, Noise Front, Noise Right, and Noise Left.

Test condition	*SD*	95% Confidence intervals
Quiet (dB A)	1.7	2.3
Noise front (dB SNR)	1.6	2.2
Noise right (dB SNR)	1.2	1.7
Noise left (dB S/R) (dB SNR)	1.7	2.4

Note. SNR = signal-to-noise ratio.

The test-retest reliability of the SRT measures was estimated from the SDs of repeated SRTs within participants (Nilsson et al., 1994; Plomp & Mimpen, 1979). Based on data in all of the noise conditions, the within-subjects SDs of repeated measurements, σ_w, was calculated according to the following formula (Vaillancourt et al., 2008):

$$\sigma_w = \sqrt{\frac{\sum_{i=1}^{n}\sum_{j=1}^{k}(x_{i,j}-\mu_i)^2}{n(k-1)}}$$

where x_{ij} is the jth threshold of the ith subject, μ_i is the mean of the thresholds provided by the ith subject, k is the number of trials ($k = 3$ for test and retest), and n is the number of subjects. The 95% confidence intervals, estimated as the region bounded by ±1.96 SDs of the difference scores divided by $\sqrt{2}$ for a two-tailed test, are also shown. The results are listed in Table 1. The confidence intervals obtained in the present study suggest that SRTs can be accurately measured within ±2.4 dB in repeated measurements with 95% confidence.

Within-list variability was calculated as a function of the average deviation of the presentation levels of the fifth through the eleventh sentence from the SRT of each list. Mean within-list variability in SRT measurement was 1.8 dB ($SD = 0.5$) in quiet, 1.7 dB ($SD = 0.4$) in NF, 1.8 dB ($SD = 0.5$) in NR, and 1.8 dB ($SD = 0.4$) in NL conditions across all age groups. The overall variability was 1.8 dB ($SD = 0.5$), and approximately 91% of the obtained SRTs were associated with a variability of 2.5 dB or less. These results show that the SRTs could be obtained reliably, because the mean SNR was calculated using presentation levels from the fifth to the eleventh sentences for each list. Overall, good interlist reliability, test–retest reliability, and variability were obtained with the CHINT-C.

Normative data. The mean SRTs observed are shown in Figure 2. General trends indicate that both SRTs and directional advantage (DA) improve with age.

A mixed-design analysis of variance with test condition as a repeated-measure variable and age as between-subjects variable was used to examine the effects of test condition and age on SRTs. The results revealed significant effects of test condition, $F(3, 900) = 17549.2$, $p < .001$, and age, $F(12, 300) = 26.1$, $p < .001$; and significant interaction between these variables, $F(36, 900) = 10.1$, $p < .001$. In addition, there were significant differences in within-subjects contrasts between the SRTs obtained in most test conditions ($p < .001$), as expected, except between the NR and NL conditions. Therefore, results from NR and NL conditions were combined into an NS SRT for future comparisons.

To further examine age effects on SRTs, results from one-way analysis of variance were examined in each test condition. Significant effects of age on SRT values were noted in all test conditions: quiet, $F(12, 300) = 8.8$, $p < .001$; NF, $F(12, 300) = 18.4$, $p < .001$; and NS, $F(12, 300) = 46.1$, $p < .001$. Results from the post-hoc Tukey honest significant difference analysis are shown in Table 2. In the quiet condition, children aged 8 to 12 years performed significantly poorer compared to the adults. Further, in the NF condition, children younger than 11 years of age performed significantly poorer compared to the adults. In addition, in the NS condition, children younger than 13 years of age performed significantly poorer compared to the adults. These results suggest that the SRTs approximate adult values at about 13 years of age and older in the quiet and NS conditions and at about 11 years of age or older in the NF condition.

Age-specific correction factors. To understand how the child norms deviated from the adult norms, the SRT

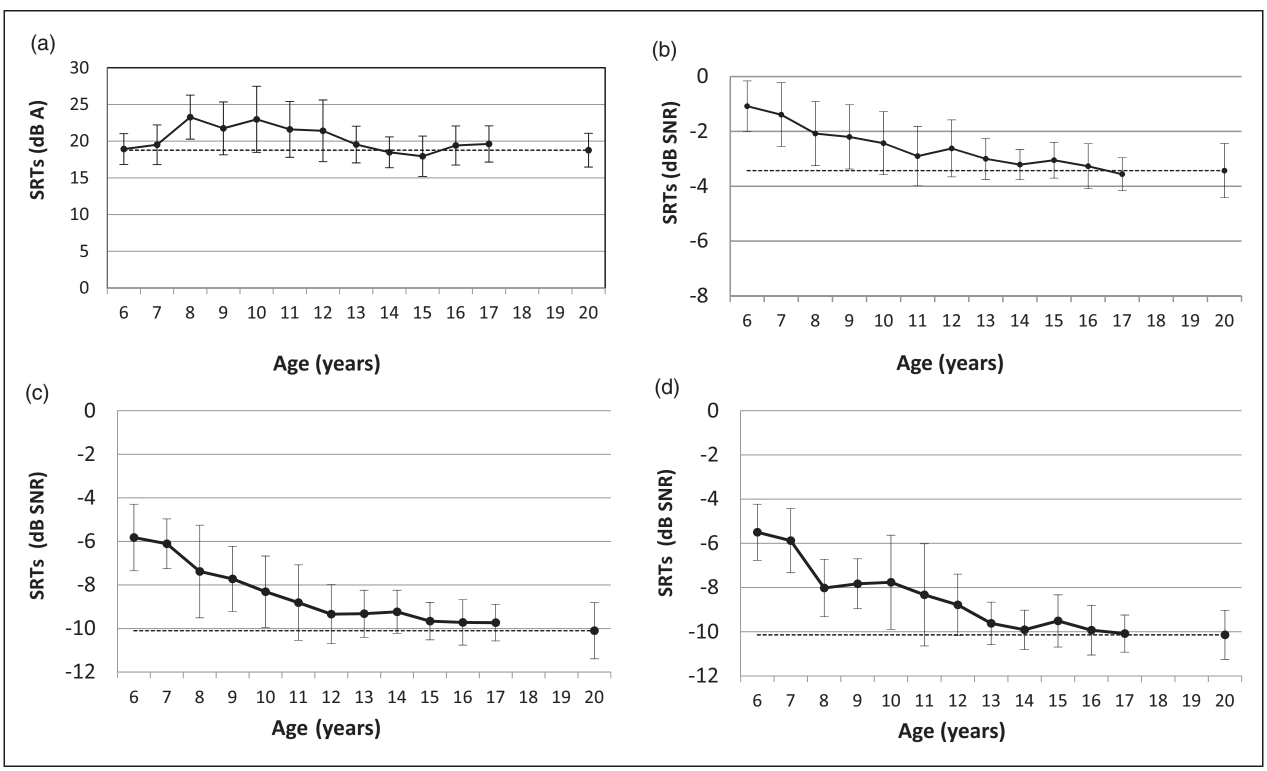

Figure 2. SRTs across age groups in children aged 6 to 17 years and adults shown as "age 20" and dotted lines in the quiet (a), noise front (b), noise right (c), and noise left (d) conditions. The SRTs obtained using the children's version of the Cantonese HINT. Error bars represent standard deviations of the measurements.
SRTs = speech reception thresholds; SNR = signal-to-noise ratio.

Table 2. Post-hoc Tukey Honest Significant Difference Analysis on the Deviation of Speech Reception Thresholds (SRTs) From Adult Norms Across Age Groups in the quiet (Upper), Noise Front (Middle), and Noise Side Conditions (Lower).

Quiet	8	9	10	11	12	13	14	15	16	17	Adults
6	*+		*+	*+	*+						
7	*+		*+	*+							
8						*–	*–	*–	*–	*–	*–
9								*–			*–
10						*–	*–	*–	*–	*–	*–
11							*–	*–			*–
12							*–	*–			*–
13											
14											
15											
16											
17											

Note. Cells with "*+" show younger age groups that performed significantly better when compared with the intersected older age groups. Cells with "*–" represent younger age groups that significantly underperformed when compared with the intersected older age groups. The shaded area shows the age range where SRTs were not significantly different from adult norms.
*$p < .05$.

Table 3. Age-Specific Correction Factors (dB) for the Hearing in Noise Test (HINT) in English (E), Canadian French (F), and Cantonese (C), and the Differences in Values Among the Three Languages.

	Quiet (dQ) ($y = 4.22 - 0.22x$)					Noise front (dNF) ($y = 3.18 - 0.2x$)					Noise side (dNS) ($y = 6.04 - 0.38x$)				
Age	English	French	Cantonese	Difference between C and E*	Difference between C and F*	English	French	Cantonese	Difference between C and E	Difference between C and E	English	French	Cantonese	Difference between C and E	Difference between C and F
6	10.1	7.2	2.9	−7.2	−4.3	2.4	2.3	2.0	−0.4	−0.3	4.3	4.4	3.8	−0.5	−0.6
7	7.4	6.3	2.7	−4.7	−3.6	2.2	1.9	1.8	−0.4	−0.1	3.7	3.9	3.4	−0.3	−0.5
8	5.2	5.3	2.5	−2.7	−2.8	1.9	1.5	1.6	−0.3	0.1	3.1	3.3	3	−0.1	−0.3
9	3.5	4.2	2.2	−1.3	−2	1.7	1.2	1.4	−0.3	0.2	2.6	2.7	2.6	0.0	−0.1
10	2.3	3.1	2.0	−0.3	−1.1	1.5	1.0	1.3	−0.3	0.2	2.1	2.1	2.2	0.1	0.1
11	1.4	1.9	1.8	0.4	−0.1	1.3	0.9	1.0	−0.3	0.1	1.6	1.5	1.9	0.3	0.4
12	0.8	0.7	1.6	0.8	0.88	1.1	0.8	0.8	−0.3	−0.0	1.2	0.9	1.5	0.3	0.6

Note. Difference between C and E: difference in correction factors between the Cantonese and English (Nilsson et al., 1996) version of the HINT. Difference between C and F: difference in correction factors between Cantonese and Canadian French (Vaillancourt et al., 2008) version of the HINT. Estimated linear regression equations used to predict correction factors for the children's version of the Cantonese Hearing in Noise Test are listed in the brackets next to the test conditions with "*x*" representing age and "*y*" representing the correction factor. dQ = deviation in quiet condition; dNF = deviation in noise front condition; dNS = deviation in noise side condition.

difference from adult norms in children up to 12 years of age were calculated as deviation in the quiet condition (dQ), deviation in noise front condition (dNF), and deviation in noise side condition (dNS) values. Linear regression was used to relate each deviation to age. R^2 values were .16, .90, and .90 for quiet, NF, and NS conditions, respectively. The estimated linear regression equations in the form of "$y = c + \beta x$" (shown near the test condition at the top of each panel in Table 3) were used to predict dQ, dNF, and dNS values in children of 6 to 12 years of age. The parameters "c" and "β" were estimated regression coefficients, and "x" and "y" represented age and correction factors, respectively. For example, if we use these linear regression equations (Table 3) to predict age-specific correction factors for Cantonese-speaking children, the predicted values would be 2.1 dB ($4.22 - 0.22 \times 9.5$) for dQ, 1.3 dB for dNF ($3.18 - 0.2 \times 9.5$), and 2.4 dB ($6.04 - 0.38 \times 9.5$) for dNS in children aged 9.5 years.

Discussion

The current study aimed at developing a children's version of the CHINT and establishing correction factors to account for age effects in the measurement of SRTs. To achieve these aims, sentences in the adult versions of the CHINT that were appropriate for assessing speech understanding in children were identified. This procedure also ensured that performance was not affected by factors such as cognition, attention, or linguistic knowledge (Fallon et al., 2000; Hnath-Chisolm et al., 1998). The SRTs were obtained in children aged 6 to 17 years in four test conditions. Age-specific correction factors were established. Results for test-retest and interlist reliability and within-list variability showed that the CHINT-C exhibited sound psychometric properties to reveal potentially small differences across age groups. Further, the current results are consistent with previous findings on the effect of maturation on speech understanding and provide support for the use of age-specific norms to assess speech understanding ability in children (Vaillancourt et al., 2008).

The present study also revealed that the twelve 10-sentence lists were equivalent in difficulty and that the SRTs obtained from children aged 6 to 17 years using any of the lists should be within 1 dB of the true SRTs in all test conditions. Within-list variability was mostly within 2.5 dB, which is small for an adaptive procedure that employs a 2-dB step size. This finding compares favorably with previous reports of the adult version of the CHINT (Wong & Soli, 2005; Wong, Soli, Liu, Han, & Huang, 2007b) and the HINT (Nilsson et al., 1994). Overall, the results indicate that the CHINT-C for children is a reliable measure of speech understanding in Cantonese-speaking children.

Age Effects on Speech Understanding

Results from the different age groups also suggested that speech understanding ability in the noise front (NF) condition improves from age 6 to approximately age 10 or 11, at which time the performance approximates that of adults. In other words, children are better able to take advantage of spatial separation of speech and noise (the two NS conditions) as they become older. In the present study, a DA of about 5.5 dB was noted at age 6 and gradually increased to about 6.5 dB at approximately age 13, where DA mimics that of adults. This is in line with previous research, as a similar amount of DA has been reported using the children's version of the HINT in Canadian French (e.g., Vaillancourt et al., 2008). The present age-specific correction values were very similar to those obtained with the English and Canadian French ($\pm$1 dB) versions of the HINT in all values except for the dQ values (Nilsson et al., 1996; Vaillancourt et al., 2008). Although dQ values typically reduce as children become older, English and Canadian-speaking children exhibited a much wider range of dQ values compared with Cantonese-speaking children. These predicted values can be used as correction factors to account for age effects in the measurement of SRTs using the CHINT-C.

These findings support previous studies, which have suggested that sentence perception does not reach adult level until after 12 to 13 years of age. For instance, using the Canadian French version of the HINT for children, Vaillancourt et al. (2008) demonstrated that children aged 12 years perform at a level similar to that of adults. Similarly English- and Norwegian-speaking children approached adult performance at age 13 when they were evaluated using the English HINT (Nilsson et al., 1996) and Norwegian HINT (Myhrum et al., 2016), respectively. Although the present study was not designed to document maturation in speech perception, that the CHINT-C shows improvement in SRT is consistent with the previous literature suggests that the test is a valid measure of speech perception in young children and the impact of maturation on sentence understanding is universal across languages, as would be expected.

As mentioned earlier, other than those for the quiet condition, correction factors for noise conditions were within 1 dB of those for the the English and Canadian French versions. Therefore, very similar correction factors can be applied to these speakers. This has important implications when considering the HINT in other languages. If a set of universal correction factors could be used across languages, then correction factors would not have to be developed for individual language versions. Further research is needed to verify this. In addition, the correction factors progress with age, and while this effect is statistically significant, the differences are actually quite small. In other words, the correction factor for a 6-year-old was approximately 2 dB greater than that necessary for a 12-year-old in the quiet, NF, and NS conditions. Finally, correction factors for the CHINT can be added to normative data collected from a sample of adults to derive age-specific norms for a particular sound field, as suggested earlier in the Introduction section.

It is worth noting that a statistically different level of performance was not observed between 6-and 7-year-olds and 13 year-olds or adults; however, 6-and 7-year-olds did appear to perform significantly in quiet better than did the 8-, 10-, and 11-year-olds in quiet. Conversely, 8-year-olds and the other younger age groups underperformed in relation to the older age groups in the same condition, as would be expected. Despite careful examination of the data and recalculation, a satisfactory explanation for the anomalous findings for 6- and 7-year-olds could not be determined. No individual outliers (>2SD) in the younger or older groups were identified, nor did the particular selection or removal of any data occur. We suspected that this could be attributed to the fact that 6- and 7-year-olds may have better pure-tone average compared to their older peers. Better pure-tone average is significantly associated with SRTs in quiet but not necessarily in noise among children with otitis media with effusion (Cai, McPherson, Li, & Yang, 2018). This may also hold true for children with normal hearing. Unfortunately, only an audiometry screening was performed in the present study, and therefore, it is not possible to confirm this speculation. Future studies are needed to examine whether the effects of hearing thresholds override maturation effects on the intelligibility of speech in quiet. Before the reasons are determined, caution should be taken while applying the norms and correction factors for the youngest groups (6- and 7-year-olds). The results for the youngest groups (i.e., 6- and 7-year-olds) were omitted from the correction factors listed in online Appendix 2. These age-specific correction values were similar to those obtained with the English and Canadian French ($\pm$1.1 dB) HINT for all values (Nilsson et al., 1996; Vaillancourt et al., 2008).

Implications of the Findings

The correction factors established for listening in noise in the present study can be added to adult norms obtained in various sound fields, to obtain age-specific norms for the evaluation of children. The findings in this study also suggest that maturation effects should be considered when evaluating changes in speech understanding in noise in longitudinal studies or in clinics. For example, the auditory progress of children, such as those with cochlear implants, can be monitored over time. Unless the improvements exceed the changes associated with maturation, researchers/clinicians cannot conclude that the changes are due to implant experience. Thus, applying correction factors can help to delineate the effects of maturation from improvement due to device use.

Conclusions

The CHINT-C was developed for assessing speech understanding among school-age Cantonese-speaking children in both quiet and noise, with noise originating from the front, right, and left azimuths. It exhibits good test–retest and interlist reliability, as well as within-subject variability. Young children are less able to extract speech cues in noise, but this process continues to improve until 10 to 13 years of age, when performance, particularly in noise, plateaus at adult levels. In addition, correction factors were determined in the present study to derive age-specific norms for the evaluation of speech intelligibility in children in various sound fields, which can be used as a benchmark for future research within the field.

Acknowledgments

The authors wish to thank the children and all the schools that participated in this study. Without them, the study could not have been completed. In addition, the authors appreciate the help of Joyce Au and Iris Ng for the data collection and analyses, and Fiona Yip for editing the article.

Author Note

This study was a research project for the Master of Science in Audiology degree at the University of Hong Kong. The dissertation can be retrieved from http://dx.doi.org/10.5353/th_b2915211.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was funded by RGC Competitive Earmarked Research Grant Award number HKU 7689/05, Hong Kong and the Research Support Scheme 2017/2018 (SEC/RSS2017-18-007) of the Department of Special Education and Counselling at the Education University of Hong Kong.

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