

The Swedish hearing in noise test for children, HINT-C

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ARTICLE INFO

Keywords:

Hearing in noise
HINT
Children
Speech audiometry
Speech recognition

ABSTRACT

Objective: The aim of this study was to develop and evaluate a Swedish version of the Hearing In Noise Test for Children (HINT-C).

Design: In the first part, the Swedish HINT lists for adults was evaluated by children at three signal to noise ratios (SNRs), -4, -1 and +2 dB. Lists including sentences not reaching 50% recognition at +2 dB SNR were excluded and the rest constituted the HINT-C. In the second part, HINT-C was evaluated in children and adults using an adaptive procedure to determine the SNR for 50% correctly repeated sentences.

Study Sample In the first part, 112 children aged 6–11 years participated while another 28 children and 9 adults participated in the second part.

Results: Eight out of 24 tested adult HINT lists did not reach the inclusion criteria. The remaining 16 lists formed the Swedish HINT-C which was evaluated in children 6–11 years old. A regression analysis showed that the predicted SNR threshold (dB) was $0.495 - 0.365 \times \text{age (years + months/12)}$ and the children reached the mean adult score at an age of 10.5 years.

Conclusions: A Swedish version of HINT-C was developed and evaluated in children six years and older.

1. Introduction

Audiometric tests based on speech signals are useful in the clinic for diagnosing a hearing impairment, assessing hearing aid fittings, and evaluating the benefit of other assistive listening technology [1,2]. During the development of such test, there are several aspects to consider, such as the target signal, type of maskers, and listening environments. All of these aspects influence the performance on the test, especially for listeners with hearing loss.

Children's learning environments, where they spend much of their time, are often noisy and thus challenging hearing speech [2–4]. Therefore, it is important during a hearing aid fitting, which is most often based on pure tone audiometry, to assess the speech recognition in noise with the hearing aids. Tests of speech in noise provide a good prediction of a child's functional hearing ability [2–4]. Even so, the number of studies using sentences in noise to assess children's ability to hear in noisy environments are limited.

The British Bamford-Kowal-Bench lists (BKB lists) developed in 1979 [6] are the origin of the American English Hearing In Noise Test (HINT) lists. In this HINT version, British English idioms were removed, the

sentence length was adjusted to better fit the American speakers and 250 sentences were divided into 25 phonemically balanced and matched lists [7]. The sentences are used in an adaptive procedure for determining the threshold where 50% of the sentences are correctly repeated. After a correctly repeated sentence allowing minor variations in articles and verb tenses, the noise level is increased by 2 dB, and reduced again by 2 dB if the answer is wrong [7]. The children's version of the American English HINT (HINT-C) was developed based on the HINT for adults [8].

In the American HINT-C, the child repeats short sentences which are presented either with or without noise, which requires both language skills and concentration. The American HINT-C is based on 130 sentences that are divided into 13 phonemically balanced lists adaptively adjusted to produce a speech recognition threshold. The American HINT-C was evaluated in children divided into four age groups (6–8, 9–11, 12–14 and 15–18 years), and it was found that HINT could be used from 13 years of age [8]. A French-Canadian, a Norwegian, a Brazilian and a Danish version of the HINT have also been developed for testing speech recognition in children (6–13 years) in a similar way [2,9–11]. They all showed that the speech recognition thresholds (SRTs) improved with age up to the age of 10 years after which the SRTs corresponded to the result of adults. This is consistent with the available literature on age

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<https://doi.org/10.1016/j.ijporl.2020.110509>

Received 20 September 2020; Received in revised form 14 November 2020; Accepted 14 November 2020

Available online 19 November 2020

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Abbreviations

HINT	Hearing In Noise Test
HINT-C	Hearing In Noise Test - Children
TEOAE	Transient Evoked Oto Acoustic Emissions
SNR	Signal-to-Noise Ratio
SRT	Speech Reception Threshold
SPL	Sound Pressure Level
HL	Hearing Level

effects in speech audiometry indicating stable performance starting at ages ranging from 9 to 12 years [2,5,8–11].

The Swedish HINT consists of everyday sentences that are grouped into 25 phonemically balanced lists of 10 sentences each [12]. Currently, the Swedish HINT has not been evaluated for testing children.

The primary aim of this study was to develop and validate the Swedish HINT to be suitable for testing in children with normal hearing, a Swedish HINT-C. A secondary aim was to investigate age related changes in speech recognition in noise using the Swedish HINT-C in children with normal hearing aged six to eleven years.

2. Materials and METHODS

The study is divided into three parts where the first part is a pilot study investigating result on the Swedish HINT in children, the second part is the development of a Swedish HINT-C, and the third part is an evaluation of the Swedish HINT-C children and adults.

2.1. Ethics

The study was approved by the Regional Ethical Review Board for Medical and Health Research. Dnr:2013/456-31.

2.2. Part 1: The pilot study

To find suitable SNRs for testing the children, a pilot study comprising 42 children aged six to eleven years (mean age 8.6 years, SD 1.65) with normal hearing and Swedish as first language was conducted using the Swedish HINT. They were tested according to the adaptive algorithm to achieve 50% correctly repeated sentences. The results showed lower (better) SNR with age, larger variability in the younger compared to the older children, but no significant gender or learning effect. The SNRs ranged between -4.48 dB and 4.00 dB (mean -0.94 dB). Based on the results, three SNRs were chosen for the main study, 2 dB where most children could correctly repeat the sentences, -1 dB which was close the mean result, and -4 dB at which only a few of the children could correctly repeat the sentences. The most difficult level chosen, a SNR of -4 dB, is close to the average SNR on the Swedish HINT for adults, that was reported to be -3 dB [12].

2.3. Part 2: Development of Swedish HINT for children

2.3.1. Participants

For this part, children aged six to eleven years were invited to the study by contacting local elementary schools. To be included in the study the child had to have Swedish as his or her native language and have normal hearing. In total, 112 children (60 boys, 52 girls) accepted participation and met the inclusion criteria. The children were grouped according to their age: Group 1 ($n = 38$) six and seven-year-olds (mean age 6.3 years, SD 0.47), group 2 ($n = 42$) eight and nine-year-olds (mean age 8.5 years, SD 0.50), and group 3 ($n = 32$) ten and eleven-year-olds (mean age 10.7 years, SD 0.47). In addition, a group of 10 adults aged between 23 and 40 years (mean age 33.3) that met the inclusion criteria

from the Audiological clinic at Linköping University Hospital, were tested in the same way as the children.

2.3.2. Test equipment

A portable audiometer GSI 66 (Grason-Stadler) and TDH-39P earphones were used to screen the children for pure-tone hearing. The integrity of the outer hair cells was tested with TEOAE using a portable PC with software Otodynamics LTD ILO OAE Auditory Screener, Model ILO288-USB Interface. The HINT was tested using a portable PC with an external sound card (M-Audio Transit) and TDH-39P earphones placed inside Audiocups Amplivox noise protectors to reduce the impact of environmental sounds. The HINT was computer-based with software developed in Matlab (Mathworks Inc.) that presented the sentences at a level of 65 dB SPL and noise at three SNRs: -4 , -1 and 2 dB in random order. The outputs of the earphones were calibrated on a Brüel & Kjær artificial ear type 4153.

2.3.3. Hearing tests

Screening with TEOAE and pure tone hearing were conducted after the ears were examined with an otoscope, and when normal hearing (passed our screening criteria at 10 dB HL at 250–8000 Hz and normal TEOAE) had been verified the participant was tested with the HINT. The total test time per child was approximately 30 min.

Twenty-four lists with 10 3-6-word sentences in each list, and one additional practice-list, from the Swedish HINT recorded with a female voice were used and monaurally presented to the right ear. Only exact repetition was accepted as correct. Each list and SNR were tested on 8–10 children and one adult.

First, training list 1 was used where the child listened to and repeated two sentences without noise and then two sentences at 2 dB SNR. The training list was used to ensure that the children understood the instructions, which were to listen to each sentence and repeat aloud what they heard. The children were encouraged to guess if they were uncertain. After the training stage, the children were tested with 60 randomly chosen HINT sentences at the three SNRs, 20 sentences at each SNR. A short break was taken after 35–40 sentences. The adult group was tested in the clinic but in exactly same way. The criterion for a list to be included in the HINT-C was that all sentences in that list were correctly repeated by at least 50% of the children at 2 dB SNR.

2.4. Part 3: Evaluation of Swedish HINT-C

2.4.1. Participants

For the evaluation, twenty-eight children aged six to eleven years were recruited at the Audiological clinic at Linköping University Hospital among the staff's children and siblings of hearing-impaired children that visited the clinic. The inclusion criteria were the same as in the previous testing, normal hearing and Swedish as the child's native language. The results were analyzed in the entire group of children and also when the children were grouped according to age with group 1 ($n = 8$) comprising six to seven-year-olds (mean age 6.5 years SD 0.53), group 2 ($n = 11$) comprising eight to nine-year-olds (mean age 8.3, years SD 0.44), and group 3 ($n = 9$) comprising ten to eleven-year-olds (mean age 10.5 years, SD 0.50). An additional group (group 4, $n = 9$) of adults aged between 23 and 38 years (mean 28.6 years), was recruited from the Audiological clinic at Linköping University Hospital. These adults had not been part of the previous testing and all met the inclusion criteria.

2.4.2. Test equipment and procedures

The audiometer Madsen Aurical Plus Program version 2.41 and, TDH-39P earphones were used to screen the children for pure-tone hearing. The integrity of the outer hair cells was tested with TEOAE using a portable PC with software Otodynamics LTD ILO OAE Auditory Screener, Model ILO288-USB Interface. The HINT-C was tested using a portable PC with an external sound card (M-Audio Transit) and Rotel RMB-1066 power amplifiers and speaker Fostex SP8 in an anechoic test

room.

2.4.3. Hearing tests

Pure tone screening audiometry and TEOAE testing for verifying the inclusion criteria were conducted in the same way as described in 2.3.3. To evaluate the eight Swedish HINT-C lists with twenty 3-6-word sentences devised in the previous part the participant was placed in an anechoic test room. The Swedish HINT-C lists were presented in a sound field from a loudspeaker approximately 1 m in-front of the participant. First, the participant was familiarized with the test situation by repeating two sentences without noise and then two sentences at 2 dB SNR. After the training the participant was tested with one list of 20 sentences, and after a short break another list of 20 sentences. The speech and noise were co-located in front and the speech was presented at a level of 65 dB SPL. An adaptive up-down procedure determined the presentation levels; the first sentence in each list was presented at 0 dB SNR and the SNR decreased by 2 dB when repeated correctly or increased by 2 dB when repeated incorrectly. Scoring was based on correctly reported whole sentences allowing minor variations in articles and verb tenses. The SNR-threshold for a list was computed as the mean SNRs of the fifth to the twenty-first trials, where the SNR of the twenty-first sentence was predicted from the response of the twentieth sentence.

The procedure is similar to others who developed HINT-C in different languages with the difference that here the speech level was fixed at 65 dB SPL and the noise level adapted during the evaluation.

2.5. Statistics

The results were analyzed using the software package IBM SPSS Statistic version 19. Results between groups were analyzed by analysis of variance (ANOVA) while linear regression was used to predict SNR threshold on HINT-C based on age. A p level < 0.05 was considered as significant.

3. Results

3.1. Development of HINT-C

Fig. 1 shows the result from the HINT sentence testing at -4 , -1 , 2 dB SNRs as the mean ± 1 SD speech recognition score in percent for the three groups of children and one adult group. According to Fig. 1, the speech recognition increases with better SNR for all groups. Also, there is a clear trend of better speech recognition as a function of age where the speech recognition improves with age for all three SNRs. When the results were analyzed with a repeated measures ANOVA, the Mauchly's test of sphericity was significant for the SNR [$\chi^2(2) = 10.501$, $p = 0.005$] and the degrees of freedom was adjusted according to Greenhouse-Geisser. The analysis showed a main effect of age-group [$F(3,116) = 3930.90$, $p < 0.001$, $\eta^2 = 0.97$] and SNRs [$F(1.86,213.38) = 1127.86$, $p < 0.001$, $\eta^2 = 0.91$] and the interaction between the age-group and the SNR was significant [$F(5.52,213.38) = 7.03$, $p < 0.001$, $\eta^2 = 0.15$]. Pairwise comparisons showed that all groups differed significantly at the $p < 0.001$ level, except group 2 and 3 which differed with $p = 0.009$. Pairwise comparisons of the SNR showed significant differences between all three SNRs ($p < 0.001$). Post hoc analysis (Sidak) based on the 95% confidence intervals showed significant differences between the three SNRs in each group, except for the adult group where the result at the two easiest SNRs did not differ significantly. When the post hoc analysis was done between the groups at the same SNR, there were no significant differences between group 1 and 2 at -4 dB SNR, between group 2 and 3 at -1 dB SNR, and between group 2 and 3 and between group 3 and 4 at 2 dB SNR. All other differences were significant.

To devise HINT-C, all lists that included sentences with speech recognition score of less than 50% at a SNR of 2 dB were excluded. Thirteen of 240 sentences had a speech recognition score below 50% and the 9 lists containing these 13 sentences were removed. The rationale for removing the entire list and not only the sentence that was too difficult

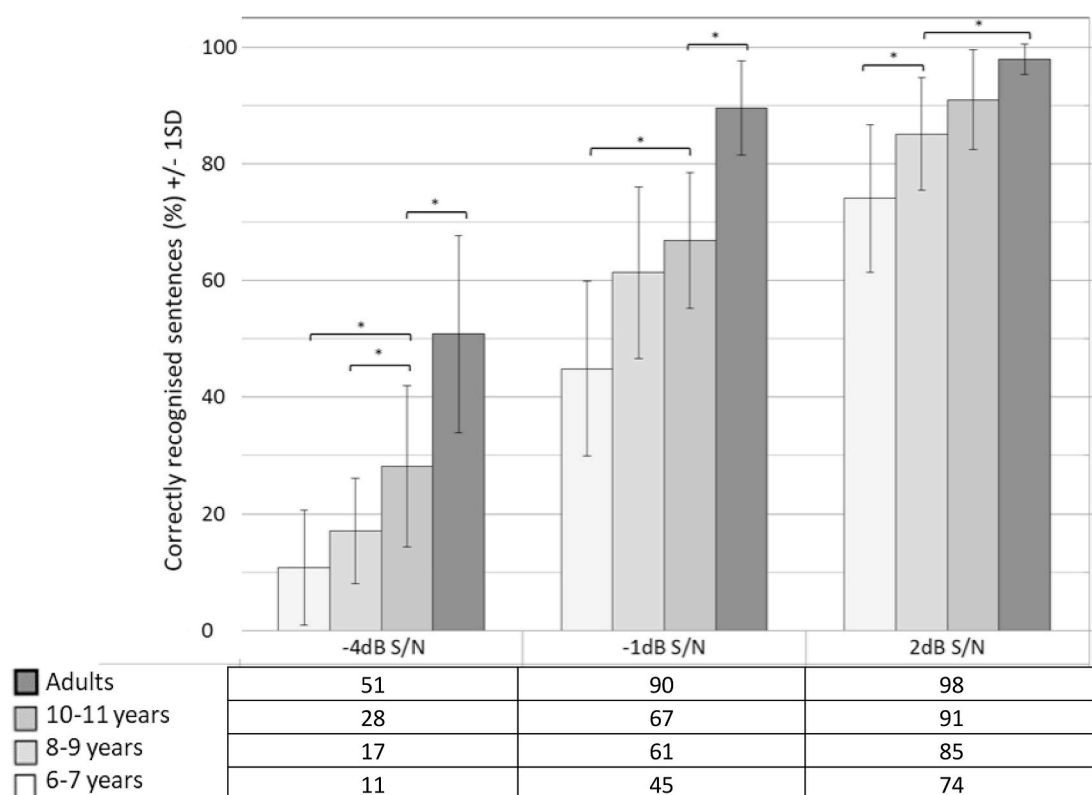


Fig. 1. The average results plus standard deviation of speech recognition scores in percent for the three age-groups of children and one adult group at the three SNRs tested.

according to our criteria was to maintain the phonemic balance of the material. After removing 9 lists, 16 lists from the original HINT with 10 sentences in each remained. The remaining lists were combined so that a list among the eight lists with the lowest speech recognition scores were combined with a list among the eight lists with the highest speech recognition scores. This resulted in 8 lists comprising 20 sentences constituting the Swedish HINT-C. Fig. 2 displays the speech recognition scores in percent for each list and group as well as an average score for all lists and groups in the three SNRs tested.

3.2. Evaluation of HINT-C

Twenty-eight children aged six-to eleven years were tested with the Swedish HINT-C and a linear regression was computed to investigate the relation between the SNR threshold and age. A significant regression equation was found ($F(1,26) = 25.775$, $p < 0.001$), with an R^2 of 0.498. According to the regression equation, a participant's predicted SNR threshold in dB based on age was $0.495 - 0.365 \cdot \text{age}$, where the age is given as years + months/12.

Fig. 3 shows the individual SNR thresholds as well as the results of the regression analysis for the entire children group tested on the HINT-C with an adaptive procedure. For the whole children group, the HINT-C mean SNR threshold is -2.6 dB. The adult result on the HINT-C is shown in a boxplot on the right-hand side of Fig. 3 indicating a mean SNR of -3.6 dB (SD 0.76). According to the regression equation based on the children's HINT-C scores, the mean adult score is achieved at an age of 10 and a half years.

3.3. Learning effect

The children were tested with one list of 20 sentences and after a short break another list of 20 sentences. The average SNR-thresholds at the first and the second test lists are presented in Fig. 4 for all four groups, and the difference between these two can be interpreted as a learning effect of the test. For all groups, the average SNR thresholds improved (became more negative) for the second test list compared to the first test list. When the HINT-C scores for the first and second test list were analyzed with a repeated measures ANOVA, a significant effect of groups was seen, [$F(2,25) = 19.32$, $p < 0.001$, $\eta^2 = 0.35$] as well as a significant learning effect [$F(1,25) = 13.48$, $p = .001$, $\eta^2 = 0.10$]. However, the interaction between learning effect and groups was not significant [$F(2,25) = 1.49$, $p = .24$] indicating that the learning effect was not significantly different between the different age groups.

4. Discussion

In this study, the Swedish HINT was investigated for its usability in children at ages of 6 years and up to 11 years. Similar to other studies creating HINT-C, some of the sentences were too difficult for the children and the lists containing these sentences were removed [8–10]. After removal of the lists containing the difficult sentences, a Swedish HINT-C was created with 8 lists each comprising 20 sentences.

Based on the original HINT development [7] the standard procedure to compute the HINT SNR score is to average the SNRs from sentence 5 and onwards. This means that for a 10 sentence list the score is the average of the SNRs from sentence 5 to sentence 11, where the 11th sentence SNR is based on the result of the 10th sentence, and for a 20 sentence list the score is the average of the SNRs from sentence 5 to sentence 21, where the 21st sentence SNR is based on the 20th sentence [2,8–11]. For the Swedish HINT-C we chose the procedure described above where the HINT score is based on a 20-sentence list also used in Danish and Brazilian-Portuguese HINT-C [2,11]. This was based on the results from the pre-study where we saw stable results in the later part of the testing and it is also the same as in the ordinary Swedish HINT facilitating easier comparison between them, even if the Swedish HINT-C shows slightly better SNRs than the original Swedish HINT in the adult population.

Another procedure is based on the HINT scores from three 10-sentence lists where the final HINT-C score is computed as the average of the two best scores out of the three lists. This procedure is reported for HINT-C in American-English and Canadian French [8,9]. A third procedure is similar to the secondly described procedure but uses only two 10-sentence lists and compute the average of those two if they are within 2 dB, otherwise a third 10-sentence list is obtained and the HINT score is computed as the average of the two closest SNRs. This procedure is used for HINT-C in Norwegian [10]. Consequently, the use of different scoring algorithms in different languages makes comparison between languages difficult, both in the absolute scores, but also the difference between scores, for example before and after a hearing aid fitting.

The adaptive protocol described in this study differs from other HINT languages, where the noise is fixed, and the level of the speech is adapted. The main reason to keep the speech level fixed is to ensure audibility of the speech signal during the testing. This is mostly an issue in subjects with hearing impairment as altering the speech level may cause the speech to become inaudible and the test result is then a speech level threshold rather than a speech in noise threshold.

In the current study, the average Swedish HINT-C SNR threshold for the adults was -3.6 dB with a standard deviation of 0.76 dB. Hällgren [12] reported an average SNR threshold of -3.0 dB with a standard deviation of 1.1 dB for the HINT in adults with normal hearing. In the Swedish HINT-C, a few of the most difficult sentences for the children were removed, and it is plausible that these sentences were the most difficult for adults as well. It is therefore not unexpected that the adults' average result on the HINT-C is slightly better than the average result on the original HINT.

The result on the HINT-C was expected to be worse in children than in adults [2,8,9,13,20], i.e. they were expected to need a stronger speech signal in relation to the noise in order to understand the sentences. The results in Fig. 3 corroborate this hypothesis and the statistical analysis indicates that the differences between the first and the second test lists were significant (Fig. 4). According to the literature, most children achieve adult-like performance in the age range of 9–12 years for speech in stationary speech-shaped noise [5,14,15]. Here, the regression analysis of the current results in Fig. 3 indicates adult-like performance on

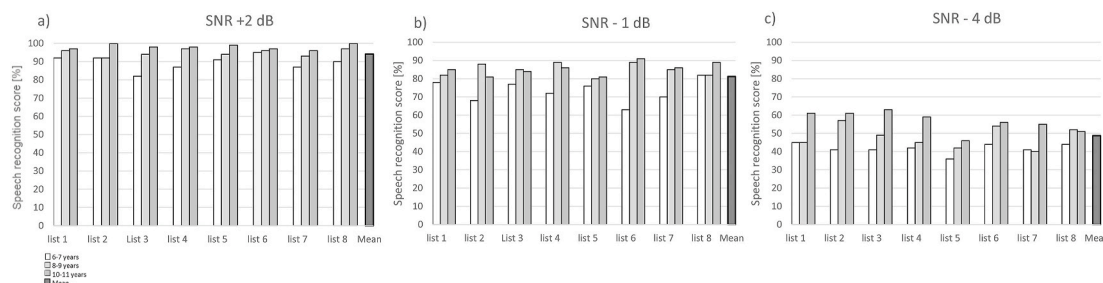


Fig. 2. The speech recognition scores for each list in the HINT-C for the three children age groups with and SNR of a) +2 dB, b) -1 dB, and c) -4 dB. In addition, the overall mean presented in % for all lists and age-groups are presented for each SNR.

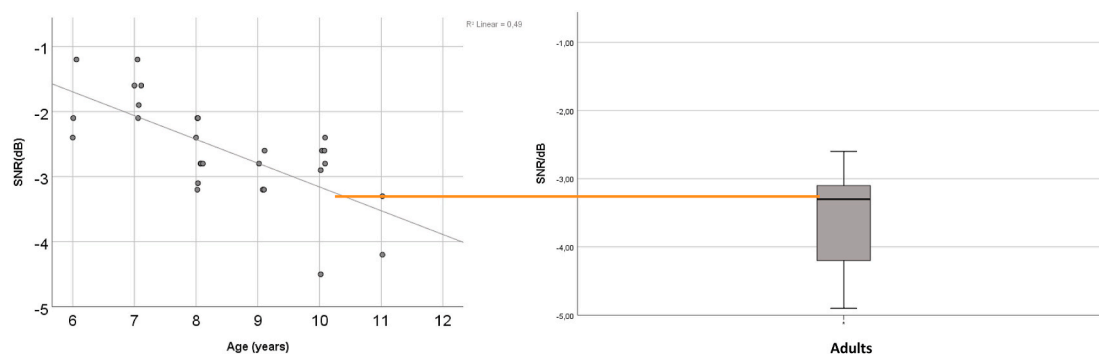


Fig. 3. The individual SNR threshold in relation to the age of the child is presented as a black dot. A regression line indicates an improvement in SNR threshold of 0.36 dB per year. The right-hand panel shows the adult SNR thresholds where the red line is the mean -3.6 (SD 0.73). As the box-plot indicating that the children reach adult behavior at approximately 10 and a half years old. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

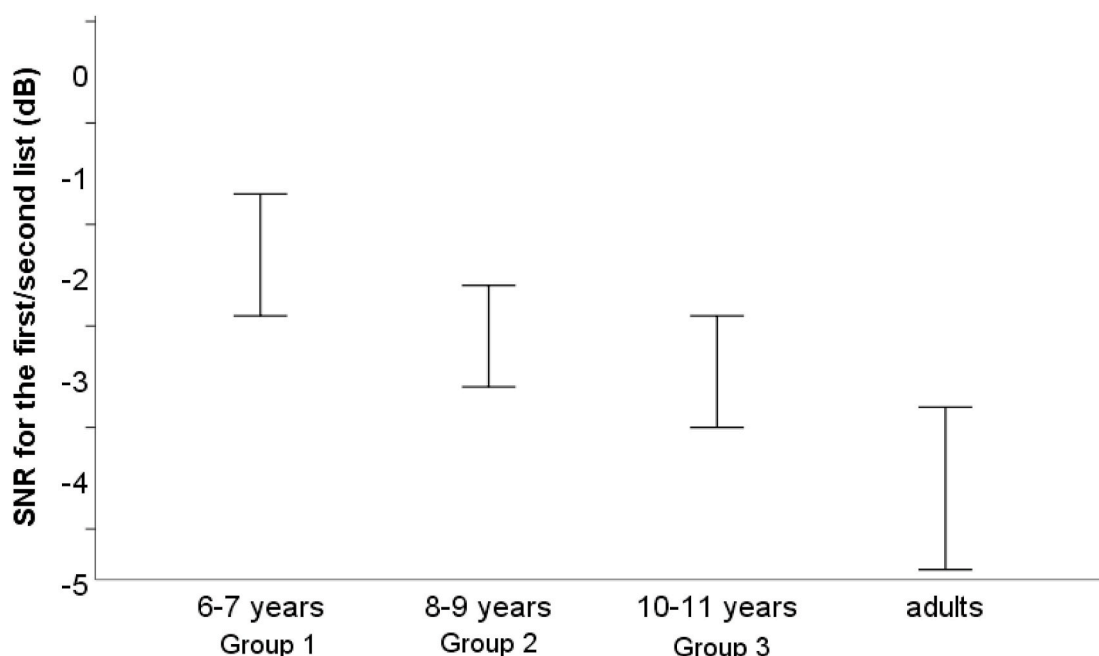


Fig. 4. The SNR-thresholds at the first and the second test. The upper part of the bar shows the result for the first test-list and the lower part of the bar shows the result for the second test-list.

the HINT-C for children aged 10.5 years. Previous studies have shown that children's test performance on speech-in-noise tests improves with age and that children's speech recognition abilities depend on their ability to separate speech from noise [14]. The ability to separate speech from noise seems not to fully develop until the age of 10–12 years [10, 17]. This was also found in the current study where the younger children performed worse than the older children (Fig. 3). Thus, the speech recognition abilities of children with normal hearing may not mature until the mid-to-late teens in listening condition involving reverberation plus noise [14,17,18].

The difference in speech-in-noise performance between children and adults indicates a need for a Swedish HINT-C. The present study showed that children with normal hearing as young as 6 years can be tested with HINT-C. The children had no problem performing the task, but they required better SNRs than adults did. The study showed similar results as previous studies of HINT-C in other languages including that of Koiek et al. and Vaillancourt et al. [2,9] where a better performance (worse SNR threshold) with increasing age was found. In Vaillancourt's material, the children reached adult performance at the age of 12 years [9] while in the present study, the regression analysis indicates adult-like

results at the age of 10.5 years. Buss et al. [16] studied the effects of noise on the speech recognition abilities of children, and found that the performance improved with age, and that children under the age of 14 years needed a more favorable SNR to perform as well as adults. Blandy and Lutman [4] showed, using BKB sentences, that even if the children have pure tone audiometric thresholds better than or equal to young adults, 7-year-olds generally have worse results on speech recognition in noise compared to younger adults, and the children's results get adult-like from the age of 10 years.

Only children with Swedish as their first language were included and their parents were requested to complete a health declaration for the child. Although children with specific language problems, concentration difficulties etc. were excluded, it should be emphasized that children at 6–11 years of age is a heterogeneous population. One explanation for the poorer performance of the youngest children (6 and 7 years old) can be their limited linguistic knowledge. Another suggestion is that young children have poorer frequency resolution than adults which makes detection of the speech signal more difficult in noise than in quiet [19]. They may, have differences in working memory capacity which plays an important role for children's abilities to acquire knowledge and new

skills [19]. Children also have different ability to sit still, to be concentrated and/or motivated, which could explain some of the variation in our results, especially in the youngest group.

5. Conclusions

The Swedish HINT-C was shown to be an appropriate speech audiometric test in noise for children above 6 years of age. The similarity in learning effect among the age-groups suggest that the test is fast enough even for the youngest participants to maintain the attention throughout the test. The predicted SNR threshold versus age can be used as age-corrected normative results on the Swedish HINT-C with normal hearing function. However, future work of the speech-in-noise perception in children with hearing loss is required.

Funding

Hörsselforskningsfonden (Hearing Foundation), County council of Östergötland and Stiftelsen Tysta Skolan, Stockholm.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

- [1] K. Neumann, N. Baumeister, U. Baumann, U. Sick, H.A. Euler, T. Weißgerber, Speech audiometry in quiet with the oldenburg sentence test for children, *Int. J. Audiol.* 51 (2012) 157–163, <https://doi.org/10.3109/14992027.2011.633935>.
- [2] S. Koiek, J.B. Nielsen, L. Kjaerbæk, M. Baltzer Gormsen, T. Neher, A Danish sentence corpus for assessing speech recognition in noise in school-age children, *Trends in Hearing* 24 (2020) 1–8, <https://journals.sagepub.com/doi/full/10.1177/2331216520942392>.
- [3] P. Nelson, K. Kohnert, S. Sabur, D. Shaw, Classroom noise and children learning through a second language: double jeopardy? *Lang. Speech Hear. Serv. Sch.* 36 (2005) 219–229, [https://doi.org/10.1044/0161-1461\(2005\)022](https://doi.org/10.1044/0161-1461(2005)022).
- [4] S. Blandy, M. Lutman, Hearing threshold levels and speech recognition in noise in 7-year-olds, *Int. J. Audiol.* 44 (2005) 435–443, <https://doi.org/10.1080/14992020500189203>.
- [5] R.H. Wilson, N.M. Farmer, A. Gandhi, E. Shelburne, J. Weaver, Normative data for the words-in-noise test for 6- to 12-year-old children, *J. Speech Hear. Res.* 53 (2010) 1111–1121, [https://doi.org/10.1044/1092-4388\(2010\)09-0270](https://doi.org/10.1044/1092-4388(2010)09-0270).
- [6] J. Bench, A. Kowal, J. Bamford, The BKB (Bamford-Kowal-Bench) sentence list for partially-hearing children, *Br. J. Audiol.* 13 (1979) 108–112, <https://doi.org/10.3109/03005367909078884>.
- [7] M. Nilsson, S.D. Soli, J.A. Sullivan, Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise, *J. Acoust. Soc. Am.* 95 (1994) 1085–1099, <https://doi.org/10.1121/1.408469>.
- [8] M.J. Nilsson, S.D. Soli, J. Gelnett, Development of the Hearing in Noise Test for Children (HINT-C), House Ear Institute, 1996, <https://doi.org/10.1121/1.408469>.
- [9] V. Vaillancourt, C. Laroche, C. Giguère, S.D. Soli, Establishment of age-specific normative data for the Canadian French version of the hearing in noise test for children, *Ear Hear.* 29 (2008) 453–466, <https://doi.org/10.1097/01.aud.0000310792.55221.0c>.
- [10] M. Myhrum, O.E. Tvete, M.G. Heldahl, I. Moen, S.D. Soli, The Norwegian hearing in noise test for children, *Ear Hear.* 37 (2016) 80–92, <https://doi.org/10.1097/aud.0000000000000224>.
- [11] C.V.L. Novelli, N.G. de Carvalho, M.F. Colella Santos, Hearing in noise test, HINT-Brazil, in normal-hearing children, *Int. J. Pediatr. Otorhinolaryngol.* 17 (2017) 66–72, <https://doi.org/10.1016/j.ijporl.2017.05.019>.
- [12] M. Hällgren, B. Larsby, S. Arlinger, A Swedish version of the Hearing in Noise Test (HINT) for measurement of speech recognition, *Int. J. Audiol.* 45 (2006) 227–237, <https://doi.org/10.1080/14992020500429583>.
- [13] S. Nitttrouer, A. Tarr, E. Caldwell-Tarr, J.H. Lowenstein, C. Rice, A.C. Moberly, Improving speech-in-noise recognition for children with hearing loss: Potential effects of language abilities, binaural summation, and head shadow, *Int. J. Audiol.* 52 (2013) 513–525, <https://doi.org/10.3109/14992027.2013.792957>.
- [14] N.E. Corbin, A.Y. Bonino, E. Buss, L.J. Leibold, Development of open-set word recognition in children: Speech-shaped noise and two-talker speech maskers, *Ear Hear.* 37 (2016) 55–63, <https://doi.org/10.1097/AUD.0000000000000201>.
- [15] A.C. Neuman, M. Wroblewski, J. Hajicek, A. Rubinstein, Combined effects of noise and reverberation on speech recognition performance of normal-hearing children and adults, *Ear Hear.* 31 (2010) 336–344, <https://doi.org/10.1097/AUD.0b013e3181d3d514>.
- [16] E. Buss, L.J. Leibold, J.W. Hall, Effect of response context and masker type on word recognition in school-age children and adults, *J. Acoust. Soc. Am.* 140 (2016) 968–977, <https://doi.org/10.1121/1.4960587>.
- [17] C.E. Johnson, Children's phoneme identification in reverberation and noise, *J. Speech Hear. Res.* 43 (2000) 144–157, <https://doi.org/10.1044/jslhr.4301.144>.
- [18] L.S. Eisenberg, K.C. Johnson, A.S. Martinez, Clinical Assessment of Speech Perception for Infants and Toddlers, *Audiology Online*, 2005, <https://doi.org/10.3851/IMP2701.Changes>.
- [19] A. Stuart, Development of auditory temporal resolution in school-age children revealed by word recognition, *Ear Hear.* 26 (2005) 78–88, <https://doi.org/10.1097/00003446-200502000-00007>.
- [20] B. Larsby, M. Hällgren, L. Nilsson, A. Mc Allister, The influence of female versus male speakers' voice on speech recognition thresholds in noise: effects of low- and high-frequency hearing impairment, *Speech Hear. Res.* 18 (2015) 83–90, <https://doi.org/10.1179/2050572814Y.00000000053>.