

Development of the Hearing In Noise Test for Children (HINT-C)

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INTRODUCTION

The ability to understand speech is considered a critical hearing ability in adults. Speech understanding is similarly important for children, but because of the lack of efficient and reliable speech materials for testing children, testing has emphasized other hearing abilities. A version of the Hearing In Noise Test (HINT, Nilsson et al., 1994) has been developed for assessment of binaural speech understanding in children with sufficient linguistic ability to be tested with speech materials. The test requires the child is to repeat aloud short sentences that are presented in quiet or noise, and requires linguistic as well as attentional abilities. The children's version of the HINT, which has been named the HINT-C, is formed from a subset of the adult sentences that are repeatable by 5- and 6-year old children in optimal listening conditions (i.e., "live voice" or via tape recordings presented in quiet). The sentences are sorted to form phonemically balanced lists for use in adaptive threshold measurements in the soundfield.

The purpose of the current study was to measure performance for various age groups in the soundfield to develop norms that allow comparison of a child's performance to that of age matched, normal-hearing children. Children ranging in age from 6 years to 18 years were tested in the norming study.

Because of the difficulty of maintaining the attention of the youngest children, especially in quiet, a visual cueing system was installed and used with approximately half of the youngest listeners. This system consisted of a light placed above the loudspeaker that came on 200 milliseconds before the sentence was played. This light cued the child to listen for the sentence. Attentional difficulties when testing in noise were not as much of a concern because the onset of the noise was shortly before the sentence began, and thus it served to cue the following sentence.

METHOD

Development of Sentence Materials

The 250 sentences that make up the adult version of the HINT were read aloud to 5- and 6-year old children to verify the ability of the children to remember and repeat the sentences under ideal presentation conditions. Any sentence that was not repeated correctly 100% of the time was dropped from the set. The method of presentation was then changed to tape recordings and the remaining sentences were presented again. Any sentence that was not repeated correctly was dropped from the set. A total of 130 sentences were selected for the HINT-C in this fashion. These sentences were sorted into lists of 10 with approximately equal phonemic content.

Subjects

A total of 93 normal-hearing, native-English speaking subjects were tested, including 9 subjects above the age of 25. Normal hearing was defined as pure-tone thresholds of 25 dB HL or less from 250 to 6000 Hz, bilaterally. Table 1 summarizes number and ages of each group tested. Adult subjects were included for several reasons. Previous norming work made it clear that performance was significantly affected by the soundfield in which testing occurred. Because previous norms with adults were gathered in a different soundfield than where the children were tested, the measurement of adult performance in this soundfield was necessary in order to link the child and adult norms.

Not all subjects were tested in all three noise conditions because of attentional or time constraints; some were tested in only the 0° and 90° noise or the 0° and 270° noise. As can be seen, equal numbers of subjects were not found for all cells of the analysis. Also, because the cueing light was added part-way through the testing, equivalent numbers for the testing with and without the lights were not possible.

TABLE 1: Number of subjects tested in each age group with and without alerting light.

Age	With Cueing Lights		Without Cueing Lights		Total
	Males	Females	Males	Females	
6	0	3	6	3	12
7	6	2	2	0	10
8	3	0	5	2	10
9	3	0	3	1	7
10	3	5	4	1	13
11	5	2	1	2	10
12	2	4	2	3	11
13	2	0	1	0	3
14	2	1	0	0	3
15	2	1	1	0	4
18	1	0	0	0	1
25+	0	0	1	8	9

Apparatus

Testing was performed in a 6' by 6' single-walled soundroom. Portions of the walls were covered with 4" SONEX acoustic foam. Because the soundroom was not exclusively used for HINT-C testing, a low table, several small chairs, and two wall mounted speakers were in the room during testing in addition to the speakers and chair used for the HINT-C testing. Signals were generated in a custom designed computer sound board. The board not only generated the signals, but also controlled relative signal levels. Signals were routed through a Grason-Stadler GSI16 audiometer which provided amplification and routing control.

Design and Procedure

The protocol was designed to assess gender effects, age effects, effects of the alerting lights, and to compare the performance of each age group to the performance of adults. Testing involved the measurement of Reception Thresholds for Sentences (RTS), in contrast to a traditional clinical Speech Reception Threshold (SRT). The adaptive technique used for an RTS and an SRT is similar, but the RTS uses sentences while the SRT uses monosyllabic words. The listener's task is to listen to the sentence, presented in quiet or in noise, and

repeat aloud what was heard. Correct repetition of the entire sentence causes the presentation level of the following sentence to be decreased by 2 dB. Incorrect repetition of a sentence causes the presentation level of the following sentence to be increased by 2 dB. The average presentation levels of the fifth to the eleventh sentence are used to estimate the presentation level where the sentences can be repeated correctly 50% of the time. There was no eleventh sentence, but its presentation level, had there been one, is known from the response to the tenth sentence.

Because of the difficulty maintaining attentional focus, especially with the youngest children tested, a cueing light was installed and used during the last half of the testing. The cueing light preceded the sentence onset, to draw the child's attention to the speaker at the beginning of the sentence. The cueing light was most effective for the quiet conditions, since the noise onset in the noise conditions cued the beginning of the sentence.

Originally four, and finally three RTS measurements were made in each of the presentation conditions, with the best two out of three scores averaged to produce the child's overall score. In the majority of cases, the best two scores were from the last two sentence lists. The order of conditions was counterbalanced between subjects, as was the list order. The order of the sentences within the lists was randomized by the computer.

RESULTS

In an attempt to deal with the empty cells in the data tables, the main effects of gender, age, and cueing lights were analyzed to allow the combining of cells where possible. Interactions must not be eliminated when combining cells. A cursory analysis of the quiet data makes it clear that an interaction between age and cueing lights could be present, and therefore the data with and without lights cannot be combined. But the age groups (which vary greatly in the number of scores in each cell) can be combined in groups corresponding to every three years (6-8, 9-11, 12-14, 15-18). These combinations eliminate empty cells and do not interfere with the ability to detect any age, gender, or cueing light effects.

TABLE 2: Mean scores in the quiet condition (dB SPL) for each group

Age	With Cueing Lights		Without Cueing Lights		Mean
	Males	Females	Males	Females	
6		15.18	22.64	21.60	20.51
7	18.11	18.02	21.63		20.07
8	17.38		20.30	23.18	20.58
9	12.47		16.77	17.57	15.04
10	14.10	14.23	16.40	13.86	14.94
11	14.42	15.39	14.95	19.24	16.03
12	14.21	13.90	17.26	13.50	14.46
13	10.88		14.66		12.14
14	12.73	15.17			13.54
15	12.71	12.16	10.15		
18	16.32				16.32
adult			20.21	16.41	16.83

TABLE 3: Mean scores in the 0° noise condition (dB S/N ratio)for each group

Age	With Cueing Lights		Without Cueing Lights		Mean
	Males	Females	Males	Females	
6		0.18	0.04	0.06	0.08
7	-0.41	-1	-1.54		-0.68
8	-0.84		-1.75	-1.68	-1.37
9	-0.98		-0.92	-1.83	-1.08
10	-1.64	-1.00	-1.78	-1.89	-1.42
11	-2.21	-2.26	-1.32	-3.72	-2.43
12	-1.23	-1.53	-2.32	-2.40	-1.86
13	-0.68		-2.2		-1.19
14	-2.44	-2.37			-2.41
15	-1.06	-1.66	-2.29		
18	-2.26				-2.26
adult			-3.22	-2.56	-2.63

Preliminary analyses were run and no effect (or interaction) of gender was found for any of the test conditions (quiet, 0° noise, 90° noise, or 270° noise). This implies that any age effects are not maturational, but experiential. It is not the maturation of the system (which would occur faster in females), but the experience with the signals of

interest (which will occur at the same rate for males and females).

The analysis was then run with presence/absence of the light and age (in three year ranges) as grouping variables. Because none of the adults were tested with the cueing light, only the three youngest age groups were included in the analysis (6-8, 9-11,

TABLE 4: Mean scores in the 90° noise condition (dB S/N ratio) for each group

Age	With Cueing Lights		Without Cueing Lights		Mean
	Males	Females	Males	Females	
6		-6.64	-5.59	-4.43	-5.56
7	-6.39	-6.46	-8.14		-6.94
8	-6.26		-6.90	-8.38	-6.91
9	-6.59		-10.2	-8.4	-8.10
10	-9.33	-7.87	-9.74	-8.06	-8.64
11	-9.24	-7.40	-9.77	-10.06	-9.09
12	-7.88	-8.14	-11.26	-10.61	-9.14
13	-8.06		-11.03		-9.05
14	-8.58	-8.94			-8.70
15	-6.78	-8.92			
18	-7.6				-7.6
adult			-10.92	-9.68	-9.82

TABLE 5: Mean scores in the 270° noise condition (dB S/N ratio) for each group

Age	With Cueing Lights		Without Cueing Lights		Mean
	Males	Females	Males	Females	
6		-7.57	-5.55	-6.87	-6.67
7	-7.06	-8.46	-8.75		-7.47
8	-10.08		-9.60	-7.66	-9.38
9	-10.58		-9.32	-10.86	-10.08
10	-10.93	-10.16	-10.62	-8.52	-10.06
11	-10.84	-10.16	-10.35	-9.94	-10.53
12	-9.23	-10.78	-11.66	-10.69	-10.53
13	-9.79		-13.26		-10.95
14	-10.34	-11.80			-10.83
15	-10.52	-10.17	-13.32		
18	-10.34				-10.34
adult			-11.49	-11.30	-11.32

12-14). A consistent main effect of age was found in all conditions, with improved thresholds in older subjects. A main effect of the cueing light was found in quiet, with an overall improvement of 3.2 dB when the cueing light was present. No significant interactions were seen.

FIGURE 1: RTS in the quiet condition as a function of age and presence/absence of warning lights.

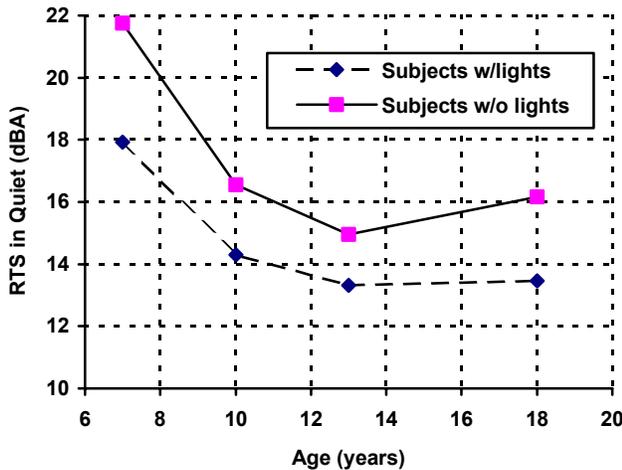
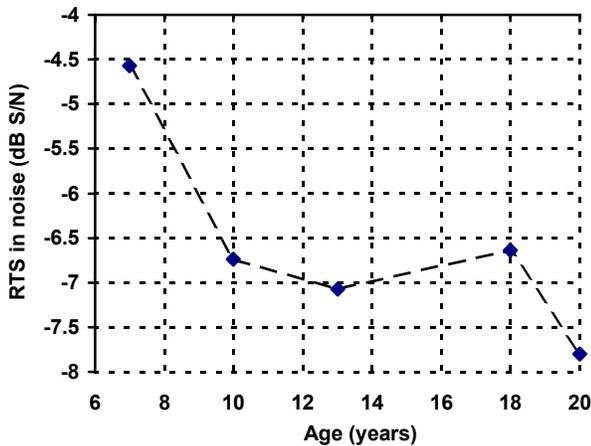


FIGURE 2: RTS averaged across noise conditions as a function of age. The 20 year old group corresponds to adults.



The light was not expected to have an effect in noise, which can be best seen when combining the scores from all three noise conditions. Analysis in noise averaged across noise conditions found no main effect of the cueing light ($F(1,243)=.90$, $p>.05$), and no significant interactions ($F(4,243)=.22$, $p>.05$). The main effect of age was

significant ($F(4,243)=4.84$, $p<.01$), with the highest thresholds seen with the youngest age group.

The main effect of the cueing light and the lack of an interaction with age raises the question of whether adults show a cueing effect when tested with a cueing light. To answer this question, five adults were tested in quiet both with and without the cueing light. These were some of the same adults that were tested during the norming study. No significant effect of the cueing light was found ($F(1,6)=.21$, $p>.05$), but overall performance was improved when compared with their norming results. This result may be due to the noise floor of the test system. The noise floor is dependent upon the dial setting of the audiometer. The second testing session with the adults was performed only in quiet with the system calibrated with less gain, and therefore a lower noise floor. The quiet thresholds of normal-hearing individuals are low enough that any elevation of the noise floor of the test system can shift performance in quiet. This observation underscores the importance of reducing the audiometer gain when testing normals in quiet to lower the noise floor and allow a more accurate measure of absolute sensitivity.

One of the goals of the current work is to provide percentile distributions of performance as a function of age for normal hearing children. The current sample did not measure performance in a sufficiently large sample to estimate the distribution of the normal hearing population for each age group. Instead, the performance of the various age groups relative to adult performance was measured. Previous measures with the adult version of the HINT (Nilsson et al., in press) have established the population distributions and reliability measures. From these adult data, percentiles and ranges can be calculated and applied to the children's data, with the assumption that the distribution of children's scores is similar to that of the adults, except that the mean of the threshold distribution is higher. By applying these assumptions, corrections can be applied to the adult distributions to estimate the distributions for each of the children's age groups. The mean thresholds from each age group in each condition were used to compute regression equations predicting mean RTS score for each age. Because of the lack of significant effects of gender

and cueing light in the noise conditions, means across these variables were calculated. The children's means asymptotically approach the performance of adults, so linear regression is not appropriate. Instead, second order polynomial regression was used to analyze the data. Table 6 shows the equations, as well as the squared multiple correlation coefficient (R^2) for each equation. The equations for the two noise at the side conditions (noise right and noise left) have very similar coefficients, with the main difference occurring in the intercept. This implies that any room effects that cause differences in performance between the noise right and noise left conditions are consistent across ages, making a single side correction feasible.

TABLE 6: Regression equations and correlation coefficients for prediction of age matched HINT scores.

Condition	Regression equation	R^2
Quiet, no lights	$y=0.48x^2 - 7.73x + 55.58$	0.9994
Quiet, lights	$y=0.32x^2 - 5.08x + 39.36$	0.9943
Noise front	$y=0.006x^2 - 0.32x + 1.22$	0.9664
Noise right	$y=0.02x^2 - 0.92x - 1.39$	0.9454
Noise left	$y=0.03x^2 - 0.99x - 2.49$	0.9474
Noise side	$y=0.03x^2 - 0.97x - 1.84$	0.9483

Table 7 shows the predicted mean RTS for each condition for each age group between 6 and 13. Differences between these mean scores and predicted performance for adults are shown in Table 8. As can be seen, the differences are less than 1 dB in all conditions once age exceeds 12 years, making

the performance measured with normal-hearing 13 year olds and older not significantly different from the performance of normal-hearing adults. Performance measured in quiet with a cueing light found significant differences only with children less than 8 years of age.

DISCUSSION

A sample of normal-hearing children has been tested to calculate the relationship between age, gender, and the presence/absence of a cueing light on HINT performance using the HINT-C developed for children. The results show that no effect of gender was found. The lower limit of ages tested show the largest age effects in quiet, which indicates that attentional factors affect thresholds in quiet. This interpretation is supported by the effect of the cueing light, which only produced significant differences in quiet.

The data were gathered by administering three lists of 10 sentences, calculating a threshold for each 10 sentence list, and averaging only the two best scores. Many clinical settings will not have the time necessary for this procedure, and therefore the average of two 10-sentence thresholds is recommended. The correction factors should still be accurate since the same method was used with all ages, including adults. The effect of such a change will be an elevation in performance for all ages. As with the adult version, a small group of normal-hearing subjects should be run to calibrate the norms for the particular soundfield being used. The adults norms (Nilsson et al., in press) can then be adjusted

TABLE 7: Mean predicted HINT RTS (dB S/N ratio) for each age group and condition.

Condition	Age							
	6	7	8	9	10	11	12	13
Quiet, Lights	19.00	17.27	15.92	14.90	14.18	13.72	13.49	13.44
Quiet, no lights	24.45	21.74	19.57	17.89	16.64	15.75	15.17	14.84
Front	-.52	-.77	-1.01	-1.23	-1.45	-1.65	-1.84	-2.02
Right	-6.05	-6.65	-7.21	-7.73	-8.19	-8.61	-8.98	-9.30
Left	-7.49	-8.14	-8.74	-9.28	-9.77	-10.21	-10.59	-10.92
Side	-6.73	-7.37	-7.96	-8.49	-8.98	-9.41	-7.80	-10.13

TABLE 8: Correction factor by age for HINT RTS (dB S/N ratio). The correction factor is based upon the children's score minus the adult's score.

Condition	Age							
	6	7	8	9	10	11	12	13
Quiet, Lights	3.90	2.17	0.82	-.20	-.92	-1.38	-1.61	-1.66
Quiet, no lights	10.09	7.38	5.21	3.53	2.28	1.39	0.81	0.47
Front	2.43	2.18	1.94	1.72	1.50	1.30	1.11	0.93
Right	4.15	3.54	2.98	2.47	2.00	1.59	1.22	0.90
Left	4.24	3.59	2.99	2.45	1.96	1.53	1.14	0.81
Side	4.31	3.67	3.08	2.55	2.06	1.63	1.24	0.91

for the soundfield of interest, and the age corrections used when children are tested. The norms are useful because percentiles and cut-points for normal performance are defined, and large numbers of normal hearing subjects are not needed when correcting for each soundfield.

The correction factors listed show corrections for a 1 year increment in age up to the age of 13. Corrections can be calculated for ages beyond this point, but the correction factors become less than 1dB. The regression equations listed in Table 6 can be used if additional correction factors are required, but the error associated with repeated measures is about 1 dB, making corrections smaller than 1 dB unnecessary. It should therefore be possible to use the HINT (versus the HINT-C) with anyone 13 years of age or older, since performance should not be significantly different from adults.

REFERENCES

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