Estimates of interaural attenuation in children and the implications for masking in clinical audiometry

J Young & A Milchard
The Department of Audiology & Hearing Therapy, University Hospitals Southampton (UHS) Trust
Email: Jacqueline.young@uhs.nhs.uk

NHS
University Hospital Southampton
NHS Foundation Trust

Introduction

- What is the smallest difference in hearing threshold levels between the left and right ears that requires masking in children?
- With asymmetrical hearing loss, there is a risk that sound presented to the test ear could cross the head and be detected by the (better) non-test ear. When this cross hearing happens, masking noise can be applied to the non-test ear to allow the true hearing threshold level (HTL) of the test ear to be established (BSA, 2018).
- The risk of cross hearing is determined by Interaural attenuation (IA), defined as the drop in intensity of the acoustic signal from the test ear transducer to the non-test cochlea [1]. IA is highly variable between individuals, and it can be influenced by transducer type, transducer-ear coupling, test frequency, and the ear canal size and condition [1].
- Values of IA measured in adult participants (e.g. [2], [3]) can be used to infer the minimum asymmetry at which masking should be recommended in clinical audiometry. For air-conduction stimuli, this minimum asymmetry is currently ≥ 40 dB for supra-aural earphones or ≥ 55 dB for insert earphones [4].
- We wanted to understand if estimates of IA in children, under clinical test conditions, are different from those seen in the adult studies under controlled research conditions, and what implications this may have for the application of masking in clinic.

Methods

With HRA approval, we reviewed our clinical database of audiograms for children (aged 8 months to 16 years) showing ear-specific results obtained using the relevant age-appropriate behavioural clinical procedures. They were measured during standard clinical care using a mix of Otometrics Aurical, Kamplex KC35, and Grason Stadler GSI 67 audiometers with either supra-aural Telephonics TDH-39P headphones or E-A-RTONE 3A insert earphones with foam tips.

Audiograms were selected for analysis if all of the following criteria were satisfied at that frequency:

I. Values of better ear air conduction hearing threshold level (HTL), poorer ear not-masked air conduction HTL, poorer ear masked air conduction HTL were all documented at single clinic visit
II. Any air-bone gaps recorded were ≤ 15 dB
III. The transducer type was clearly indicated
IV. There was evidence of cross hearing, operationally defined as a deterioration of more than 15 dB in the HTL of the poorer ear when comparing the masked and not-masked conditions.

Estimated IA was calculated for each subject for each stimulus frequency at which cross hearing had been identified, using the difference between the not-masked air-conduction HTL of the poorer and better ears.

Results & Discussion

Results

Table 1 shows estimated IA values for a range of stimulus frequencies for each transducer. The number of subjects per condition varies from 2 to 21 as data was not available for every stimulus frequency for every child. Any repeated measures from the same subject on different clinic dates are excluded from table 1, instead only the smallest IA value is retained for each subject. Based on 10 participants who had a retest, the difference in estimated IA values was less than 5 dB for 75% of the estimates and less than 10 dB for 88% of the estimates.

Table 2 shows values of estimated IA grouped into age ranges (0-3 years, 4-7 years, 8-12 years, and 13-16 years) for each transducer type. These data are not separated into different stimulus frequencies, as there was no statistically significant effect of frequency on estimated IA.

Shaded cells in table 1 & 2 indicate where the values of estimated IA fall below 40 dB for supra-aural headphones or 55 dB for inserts.

Transducer	Supra-aural headphones								Insert earphones with foam tips							
Stimulus Frequency	250	500	1000	2000	3000	4000	6000	8000	250	500	1000	2000	3000	4000	6000	8000
Number of subjects (n)	8*	17	19	18	3*	19	7*	10	2*	11	16	21	4*	16	2*	5*
Mean IA (μ), dB	53.8	58.2	60.0	63.1	71.7	60.3	67.9	59.1	67.5	70.9	68.4	67.6	61.3	70.6	72.5	71.0
Median IA, dB	50.0	55.0	60.0	65.0	75.0	55.0	75.0	65.0	67.5	75.0	67.5	65.0	65.0	75.0	72.5	70.0
Variance	241	65	106	83	33	165	149	184	1513	274	175	100	240	160	13	30
Minimum IA, dB	40	50	40	45	65	35	45	30	40	40	40	40	40	40	70	65
Maximum IA, dB	90	75	75	80	75	80	80	70	95	95	90	80	75	85	75	80
5th percentile, dB		50	45	45		35		30		40	40	42		42		

Table 1 *Estimated interaural attenuation (IA) for different stimulus frequencies and transducers. Values of IA which fall below 40 dB (for supra-aural headphones) or 55 dB for inserts are highlighted. Conditions with fewer than 10 subjects are marked with *, and were excluded statistical analysis. Blank cells indicate absent data, due to low subject numbers for the corresponding test condition.*

Table 2*. Estimated interaural attenuation (IA) for different age groups. The highlighting and * are used in the same way as table 1.*

Transducer	Supra-aural headphones				Insert earphones			
Age group (years)	0-3	4-7	8-12	13-16	0-3	4-7	8-12	13-16
No. of data points	4*	31	58	34	9*	32	30	20
Mean (dB)	62.5	60.0	64.0	57.7	60.0	69.8	66.5	78.3
Median (dB)	60	60	65	55	65	72.5	70	77.5
Variance	175	82	116	140	113	91	195	109
Minimum (dB)	50	40	35	30	40	50	40	60
Maximum (dB)	80	75	90	85	70	85	85	95
5th percentile (dB)	50	46	45	38	40	53	40	60

Discussion: Variations with Age or stimulus frequency

Test frequency: For all children (aged 8 months -16 years) collectively there was no significant effect of stimulus frequency on the mean estimated IA, for either type of transducer.

Age: For insert earphones, there were significant differences in the mean estimated IA between the oldest age group and the younger ones. Given this age effect is most prominent for insert earphones, we surmise that shallow foam tip insertion depth of foam tips may be responsible. In contrast, for supra-aural headphones, there is no significant difference in the mean estimated IA between any of the age categories. In fact, all the values of mean IA are within ± 5 dB of 60 dB for each of the age groups.

Discussion: Study limitations

IA measures published for adults subjects are based on small subject numbers (between 6 and 30 [5, 6]). Our study extends that data to include IA estimates in children aged 8 months to 16 years, with some caveats associated with the retrospective use of our clinical data:
① Low subject numbers as shown in tables 1 and 2 ② Not-masked bone conduction values were not typically available, which could lead to under-estimates of IA but reflects the compromised data available to paediatric audiologists when attempting to make decisions about the need for masking in clinics ③ The transducers in this study are still widely used but newer models are available that may differ in their IA properties ④ The fit of the transducers was not monitored and so, for insert earphones, the selected tip size and insertion depth is not known and there is no record of factors that may have limited optimal insertion in individual cases.

Despite these caveats, the mean and median IA values for the oldest age group in our study (13-16 years), shown in table 2, are within ±10 dB of published frequency-averaged IA mean [7] and median [3] values for adults.

Discussion: Implications for masking

In our clinic, audiologists are encouraged to apply masking in cases where they suspected cross hearing, even if the asymmetry would not have been sufficient to require masking based purely on BSA guidelines [4]. This means masking was sometimes applied for asymmetries less than 40 dB for supra-aural headphones and 55 dB for inserts. Looking at audiograms showing evidence of cross hearing, how many would have contained one or more inaccurate thresholds had the audiologist not applied this extra masking?

For s**upra-aural headphones,** only 2 out of 38 audiograms (5%) would have contained inaccurate thresholds. But with **inserts**, 5 out of 30 audiograms (17%) would have contained at least one inaccurate threshold. Figure 1 shows two example audiograms exhibiting low IA with insert earphones.

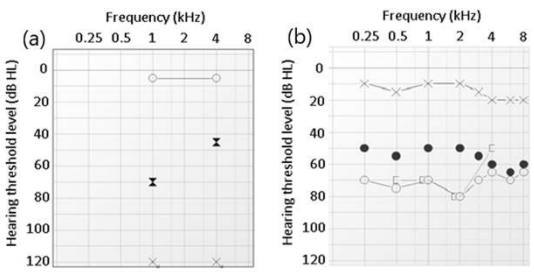

Figure 1*. Audiograms obtained with inserts for children with low interaural attention (IA) aged (a) 2 years and (b) 10 years. Audiogram symbols are consistent with BSA (2018). Tympanometry was within normal limits bilaterally in both cases.*

Conclusions

Under clinical conditions, cross hearing in children should be considered when the difference between the better ear and poorer ear not-masked air conduction thresholds is ≥ 40 dB for inserts with foam tips in children under 13 years. Cross hearing can also occur for interaural differences as small as 30 dB with supra-aural headphones in some individuals. For insert earphones we speculate that the deep and snug fitting of foam tips which could be achieved with adult subjects under laboratory conditions was not replicated by audiologists in this paediatric clinical setting, resulting in the lower values of estimated IA for inserts for children in this study compared to published adult data. Further work is needed to confirm these findings in a larger cohort of children and to monitor any impact of foam tip positioning in clinical practice. Measures of bone conduction for the better ear could also be informative.

References

[1] Goldstein & Newman, 1994. [2] Martin & Blosser, 1970. [3] Munro & Agnew, 1999. [4] BSA PTA recommended procedure, 2018. [5] Martin and Blosser, 1970, [6] Gumus et. al., 2016, [7] Killion et. al., 1985.

Acknowledgements

Thank you to all the Audiology staff at the Royal South Hants Hospital, Southampton, UK for supporting this study and providing valuable comments on the presentation of results.