CORRELATION BETWEEN REAL EAR INSERTION GAIN AND GAIN OBTAINED THROUGH ASSR

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Master's Dissertation as a part of fulfillment of Final Year M.Sc (Audiology), Submitted to the University of Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MYSORE – 570006

May, 2005

CERTIFICATE

This is to certify that this master's dissertation entitled **"Correlation between real ear insertion gain and gain obtained through ASSR"** is the bonafide work done in part fulfillment of the degree of Master of Science (Audiology) of the student with register number: A0390016.

Prof. M. Jayaram

Director

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May, 2005

CERTIFICATE

This is to certify that this master's dissertation entitled **"Correlation between real ear insertion gain and gain obtained through ASSR"** has been prepared under my supervision and guidance. It also certified that this has not been submitted in any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this Master's Dissertation entitled "Correlation between real ear insertion gain and gain obtained through ASSR" is the result of my own study under the guidance of Mrs. Manjula.P, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

Mysore

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Acknowledgement

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Millllllllllli, chechi, ashley,,, thanks a lot……….

For you.......

Amma, Nanna & Anna

With love....

CHAPTER 1

INTRODUCTION

Hearing aid fitting follows three main steps: assessing hearing loss, prescribing an aid to compensate for this hearing loss and verifying that this aid provides adequate benefit (Scollie & Seewald, 2001). Each step provides its own data. "Hearing assessment" evaluates the hearing thresholds, maximum comfort levels and loudness discomfort levels at different frequencies. "Prescription" sets the gain and other parameters of a selected aid, so that the average spectrum of speech sounds is amplified with in the range of the unaided thresholds and the loudness discomfort levels (Byrne & Dillon, 1986). The data at this step concern the real ear insertion gain or the hearing aid at the different frequencies, a measurement that combines the amplifier gain functions with the resonance characteristics of the individual external ear. "Verification" provides some measurement of how well sounds are heard when the aid is used at its prescribed settings (Stelmachowicz, Kopun, Mace, Lewis & Nittrouer, 1996).

The measurements required during the hearing aid fitting procedure are either objective or subjective. Insertion gain and its related measurements, obtained using electro acoustic procedures are objective, in the sense that they do not require any active response from the subject. However, the infant must agree not to move or cry during the measurement procedure. Average normative values from other infants can also be used, but these do not consider individual variability. Conventional audiometric measurements of threshold, loudness discomfort and speech perception are all subjective measurements, and are not possible in young infants.

One of the objective techniques used is ABR. Auditory brainstem responses can measure frequency-specific thresholds using two main approaches (Stapells, Picton & Durieux-Smith, 1994). The first presents a click and isolates responses from different regions of cochlea using high-pass masking (Ponton, Eggermont, Couplandand & Winkelaar, 1992). The second and more widely used approach presents brief tones with or without masking noise in order to limit the spectral splatter caused by the brevity of the stimulus. Stapells (2000a, 2000b) has reviewed the use of tone-evoked brainstem responses to assess hearing thresholds in infants and young children. Estimating the audiogram using the tone evoked ABR has limitations. First, recognizing the response is not always an easy task. Second, the threshold is not precisely estimated and third the procedure takes a long time.

Auditory steady state response is an evoked potential that can measure frequency specific auditory sensitivity. The auditory steady state responses (ASSR) offer several advantages over transient evoked potentials like ABR. First, the response is easy to recognize, since the statistical techniques that distinguish the response from the background noise in which it is recorded (Dobie & Wilson, 1993, 1996; John & Picton, 2000) need not vary with the latency or morphology of the response. Second, thresholds can be estimated with about the same accuracy and the same frequency-specificity (Herdman, Picton & Stapells in review) as when using tone-evoked auditory brainstem responses. Third, multiple responses can be recorded at the same time (Lins, Picton & Boucher, 1996). Fourth, the presentation level can be until 120 dBHL with a frequency range from 250 Hz to 8 kHz. A steady state response is evoked by regularly modulating the stimuli. After the initial few modulations of stimuli, the response stabilizes and there after contains constituent frequency components that remain constant in amplitude and phase over time (Regan, 1989). In the auditory system, these responses can be evoked by amplitude and frequency modulated tones, which are frequency specific. They are unlikely to be distorted when presented through a sound field speaker for assessing hearing aid benefit.

Need for the study:

As mentioned earlier insertion gain measurement is an objective technique for hearing aid selection. However, accurate individual real ear acoustic measurements are not always possible for infants and young children as it requires modest co-operation from the subject. Infants can not provide reliable behavioral responses to either aided or unaided sounds. Fitting young infants with hearing aids is therefore much more uncertain than in older children or adults. Electrophysiological tests like ASSR can assist in hearing aid prescription since they can measure frequency specific auditory thresholds. Therefore, effectiveness of using ASSR for hearing aid selection needs to be investigated, so that ASSR can be used for fitting hearing aid even in difficult-to-test population such as infants and young children

Aim:

The study aimed at investigating the relationship between the gain obtained through ASSR (i.e., difference between aided and unaided ASSR threshold) and the real ear insertion gain.

CHAPTER 2

REVIEW OF LITERATURE

Auditory steady state evoked responses (ASSR) evoked by modulated tones have been extensively evaluated as an objective means to estimate behavioral pure tone thresholds. ASSR might estimate the audiogram more efficiently than tone-ABRs, although there are relatively less normative and clinical data available for these responses.

Vanaja and Manjula (2004) studied ASSR as an objective method for hearing aid fitting by comparing aided ASSR responses with functional gain. There was a positive correlation between functional gain and aided ASSR suggesting that ASSR could be used for fitting hearing aid.

Zenker, Delgado and Barajas (2001) investigated the relationship between amplitude and intensity of the ASSR in a group of adults with normal hearing and varying degrees of sensorineural loss. They examined this relationship assuming that growth of loudness is related to the amplitude growth of the ASSR. Particularly, they propose a method to derive information of hearing aid characteristics from the amplitude-intensity function of the steady-state responses. This procedure enables determination of some basic properties of hearing aids, such as average gain, type of compression, compression factor and onset level.

One of the recent investigations suggest that ASSR can be used for assessing the cochlear implant candidacy. Swanepoel and Hugo (2004) studied the estimations of auditory sensitivity for young cochlear implant candidates using the ASSR. Preliminary results indicate that absent ABR and behavioral thresholds do not preclude the possibility of residual hearing, making the ASSR a primary source of information regarding profound levels of hearing loss, as ASSR can be measured even for 120 dBHL signal.

Auditory evoked potentials have been used in the past to assess hearing aids. Most reports considered using the clicked-evoked ABR to assess how well a hearing aid is working (Kileny, 1982; Hecox. 1983; Mahoney, 1985). The general aim was to adjust the hearing aid until the latency of the ABR wave V decreased to within normal range. These procedures were limited since the click ABR is mainly related to high frequency gain and since the correlation between wave V latency and loudness is low, particularly when there is a sloping hearing loss (Serpanos, 1997). Many technical problems have been reported in the use of ABR for the evaluation of amplification. Since the click is very brief, it can be significantly distorted in the sound field speaker and in the hearing aid. The resultant stimulus artifacts can obscure the interpretation of the response (Kileny, 1982; Mahoney, 1985). Other investigators have used the amplitude-intensity function of the unaided click evoked ABR to predict the optimal gain for a hearing aid (Keissling, 1982; Davidson, Wall & Goodman, 1990). However this approach is problematic since the amplitude of the ABR is loosely correlated with loudness. In general, hearing aids handle rapidly changing acoustic stimuli (such as those used to evoke ABR) differently from more continuous stimuli such as speech, and it is difficult to predict the steady state characteristics of hearing aids from onset responses (Gorga, Beauchaine & Reiland, 1987).

Several studies stated that auditory steady state responses could be used to estimate the frequency specific auditory sensitivity as accurate as other electrophysiological tests like ABR. These studies reported that there was a good correlation between behavioral thresholds and estimated ASSR thresholds.

Dimitrijevic, John and Van Roon (2002) estimated the audiogram using multiple auditory steady state responses. The modulation frequencies varied from 80 to 95 Hz and the carrier frequencies were 500, 1000, 2000 and 4000 Hz. For air conduction, the difference between the physiologic thresholds and behavioural thresholds for sensorineural hearing impairment and normal hearing were 14±11, 5± 9, 5± 9 and 9±10 dB for the 500, 1000, 2000 and 4000 Hz carrier frequencies respectively. Similar results were obtained in simulated conductive hearing losses. For bone conducted stimuli presented through forehead showed the physiologic-behavioral threshold differences of 22 ± 8, 14 ± 5, 5 ± 8, and 5 ± 8 for carrier frequencies 500, 1000, 2000, and 4000 Hz respectively. These results were comparable to other studies done by Lins, Picton and Boucher, 1996; Picton, Giguère, Beauregard, Durieux-Smith, Champagne, Whittingham and Moran, 1998; Herdman and Stapells, 2001; Perez-Abalo, Savio and Torres, 2001.

Stueve and Rourke (2003) compared thresholds from 76 children using ABR, ASSR and behavioural test methods. He stated that the correlations were strong between these measures and supported the inclusion of ASSR in the standard paediatric test battery. There was a strong and positive correlation for ASSR and behavioral thresholds depending on the frequency range from 500 to 4000 Hz. ASSR testing provides audiometric information that is essential in the management of children with severe-to-profound hearing loss. ASSR is also beneficial in patients who are especially difficult-to-test for a variety of reasons. Patients with developmental delays, language disabilities, neurological delays, multiple genetic anomalies that are non-syndromic, oral disorders, motor disorders, feeding disorders, or blindness are good candidates for ASSR because testing is efficient, accurate and effective.

Roberson, O'Rourke and Stidham (2003) evaluated auditory steady-state responses (ASSR) for determining frequency-specific hearing impairment and compared this technology with conventional auditory brainstem responses (ABR). The study was a prospective clinical trial. Twenty-eight paediatric patients ranging in age from 7 to 61 months who were undergoing sedated ABR testing for evaluation of hearing impairment were also evaluated using ASSR. Estimated audiograms of the ASSR were compared with the ABR results. In 20 ears in which an ABR tracing was absent at the maximum level of 90 dB, 13 ears had measurable ASSR thresholds with an average threshold of 98.9 dB at 250 to 8000 Hz. They stated that ASSR showed sensitivity equal to that of ABR for individuals with hearing levels (HL) from 0 to 90 dB HL. In patients with hearing impairment greater than 90 dBnHL, ASSR showed distinct advantage over ABR testing in that recordings were reliably produced up to 127 dB nHL

Cone-Wesson, Dowell, Tomlin, Rance and Ming (2002) reported the findings of their study in which the threshold estimates from auditory steady-state response (ASSR) tests are compared to those of click- or toneburst-evoked auditory brainstem responses (ABRs). The first, a retrospective review of 51 cases, demonstrated that both the click-evoked ABR and the ASSR threshold estimates in infants and children could be used to predict the pure-tone threshold. The second, a prospective study of normal-hearing adults, provided evidence that the toneburst-evoked ABR and the modulated tone-evoked ASSR thresholds were similar when both were detected with an automatic detection algorithm and that threshold estimates varied with frequency, stimulus rate, and detection method. The study illustrates that ASSRs can be used to estimate pure-tone threshold in infants and children at risk for hearing loss and also in normal-hearing adults.

Recently, auditory steady-state responses (ASSRs) have been proposed as an alternative to the auditory brainstem response (ABR) for threshold estimation (Vander, Brown, Gienapp & Schmidt, 2002). They investigated the degree to which ASSR thresholds correlate with ABR thresholds for a group of sedated children with a range of hearing losses. They studied thirty-two children ranging in age from 2 months to 3 years and presenting with a range of ABR thresholds. Strong correlations were found between the 2000-Hz ASSR thresholds and click ABR thresholds (r =0.96), the average of the 2000- and 4000-Hz ASSR thresholds and click ABR thresholds (r =0.97), and the 500-Hz ASSR and 500-Hz toneburst ABR thresholds (r =0.86). Additionally, it was possible to measure ASSR thresholds for several children with hearing loss that was great enough to result in no ABR at the limits of the equipment. The results of this study indicate that the ASSR may provide a reasonable alternative to the ABR for estimating audiometric thresholds in very young children.

John, Brown, Muir and Picton (2004) examined the auditory steady-state responses evoked by amplitude-modulated (AM), mixed-modulated (MM), exponentially modulated (AM2), and frequency-modulated (FM) tones in 50 newborn infants (within 3 days of birth) and in 20 older infants (within 3-15 weeks of birth). Their hypothesis was that MM and AM2 tonal stimuli would evoke larger responses than either the AM or FM tones, and that this increased size would make the responses more readily detectable. Multiple auditory steady-state responses were recorded to four tonal stimuli presented simultaneously to each ear at 50 dB SPL. The carrier frequencies of the stimuli were 500, 1000, 2000, and 4000 Hz and the modulation rates were between 78 and 95 Hz. The responses to MM and AM2 tones were larger than those evoked by AM tones. Using these stimuli will increase the reliability and efficiency of evoked potential audiometry in infancy. Responses at 50 dB SPL are more easily detected at 3 to15 weeks of age than in the first few days after birth. Comprehensive frequency-specific testing of hearing using steady-state responses will likely be more accurate if postponed until after the immediate neonatal period.

Gorga, Neely, Hoover, Dierking, Beauchaine and Manning (2004) determined the maximum stimulus levels at which a measured auditory steady-state response (ASSR) can be assumed to be a reliable measure of auditory thresholds. On an average, the ASSR thresholds were observed at 100 dB HL (SD = 5 dB). Because these responses were at least 18 to 22 dB below the limits of the equipment where all subjects had no behavioral responses, it is reasonable to conclude that the ASSRs were not generated by the auditory system, an artifact or distortion may be present in the recording of ASSRs at high levels. These data bring into question the view that there is a wider dynamic range for ASSR measurements compared with auditory brain stem response measurements, at least with current implementation.

Small and Stapells (2004) investigated, in hearing-impaired participants who could not hear the stimuli, the possibility of artifactual auditory steady-state responses (ASSRs) when stimuli are presented at high intensities. They stated that, high-intensity air- or bone-conduction stimuli can produce spurious ASSRs, especially for 500 and 1000 Hz carrier frequencies. High-amplitude stimulus artifact can result in energy that is aliased to exactly the modulation frequency. Choice of signal conditioning electroencephalogram, filter slope and low-pass cutoff) and processing (A/D rate) can avoid spurious responses due to aliasing. However, artifactual responses due to other causes may still occur for bone-conduction stimuli 50 dB HL and higher (and possibly for high-level air conduction). Because the phases of these spurious responses do not invert with inversion of stimulus, the possibility of non-auditory physiologic responses cannot be ruled out. The clinical implications of these results are that artifactual responses may occur for any patient for bone-conduction stimuli at levels greater than 40 dB HL and for high intensity air-conduction stimuli used to assess patients with profound hearing loss.

The auditory steady state responses can be recorded using free field stimuli presented to subjects using hearing aids (Picton, et al., 1998). This study showed that the aided thresholds could be reasonably well estimated from the thresholds for steady state responses in a group of children using aids. One obvious difficulty with using aided thresholds to assess how well a hearing aid is working is that the assessment is occurring at levels that are not relevant to the perception of amplified speech. One does not fit a hearing aid to allow the patient to listen to faint sounds. Furthermore, given the non-linear amplification functions of modern hearing aids, it is difficult to extrapolate from threshold levels to the levels at which normal speech occur. Aided thresholds are not uninformative, if the aided thresholds are below the intensities at which speech normally occurs, the aid can not improve speech perception. Nevertheless some measurement of supra-threshold discrimination would be more helpful in terms of adjusting a hearing aid or monitoring its performance.

According to Picton, Van Roon and John (2002) the auditory steady responses to amplitude modulated tones with modulation frequencies between 80 and 105 Hz can be recorded when multiple stimuli presented simultaneously through a sound field speaker and amplified using a hearing aid. The aided thresholds for the auditory steady state responses were on average between 13 and 17 dB higher than the behavioral thresholds. The physiologic-behavioral difference is less than that found in normal subjects. The effect was probably related to recruitment. In the hearing impaired, the response reaches a level where it is recognizable at intensity closer to threshold than in normal subjects.

CHAPTER 3

METHOD

Subjects

Twenty subjects with mild to moderately-severe sensorineural hearing loss participated in the study. The age range was 15-50 years, with a mean age of 32 years.

Instrumentation

- Calibrated sound field audiometer and Immittance meter to select the subjects for the study.
- GSI Audera to record ASSR.
- Calibrated FP 40 D (Software version 3.50) hearing aid test system to measure REIG.
- Digital hearing aids of BTE model, with appropriate sized eartip.

Environment

All the test procedures were conducted in a sound treated environment with ambient noise levels within permissible limits (ANSI 1991, cited in Wilber, 1994)

Procedure

Two digital BTE hearing aids were pre-selected based on the degree of the hearing loss. These hearing aids were programmed with NOAH (3.0) and hearing aid appropriate software.

The measurement was carried out in two steps.

Step 1: - Hearing aid selection based on real ear insertion gain measurement

Step 2: - Measurement of unaided and aided auditory steady state responses (ASSR).

Step 1: -Hearing aid selection based on real ear insertion gain measurements

1. The subject was seated in front of the loud speaker of the FP 40D equipment. The speaker was located on the speaker stand as for real ear measurement. The loud speaker was placed at 45º azimuth and one-foot distance from the subject's test ear.
2. The instrument was leveled by placing the probe and reference microphones near the test ear.
3. Target gain curve was obtained by feeding the hearing thresholds of the subject's test ear and selecting NAL-2 fitting formula.
4. Later, the real ear unaided response was measured. This was done by routing the stimulus (ANSI digi speech at 60 dBSPL) through loudspeaker and measuring the SPL in the ear canal of the test ear by means of the pre-measured length, 25-30 mm past-tragal notch, of probe tube microphone inserted in the test ear.
5. Real ear aided response (REAR) was measured for the same stimulus with the same length of the probe tube inserted in the ear canal with a hearing aid in the test ear in 'on' setting in the test ear. Caution was taken not to disturb the length of the probe tube being inserted.
6. After the measurement of REUR and REAR, the instrument computed the insertion gain (REAR- REUR) curve. The real ear insertion gain curve (REIG) was obtained for the two pre-selected digital BTE hearing aids. The hearing aid that best matched the target curve was the one selected for further evaluation with ASSR.

Test protocol for REIG measurement using Fonix FP 40 D:

- The transducers were calibrated
- Sound field was equalized.
- Probe tube was placed in ear canal 25 – 30 mm past the tragal notch
- Stimulus type: Digi speech signal (ANSI)
- Stimulus intensity: 60 dB SPL.
- A target curve was generated based on subject’s hearing thresholds and NAL-2 fitting formula.
- Measurement of REUR and REAR.
- REIR was typically automatically computed by subtracting the REUR from REAR.
- Measurement of REIR was repeated with another pre-selected hearing aid until the best match to the target curve was obtained.

The insertion gain at different frequencies for the selected hearing aid, for each subject was tabulated.

Step 2: -Measurement of unaided and aided ASSR

The subject was seated on the chair, instructed to relax, close the eyes and sleep if possible, while recording ASSR. The site of electrode placement was prepared with skin preparing gel. Disc type silver coated electrodes were placed with conducting gel. The non-inverting electrode (Fz) was placed on fore head, inverting electrodes (M1 & M2) on the test ear and the non-test ear and common was placed of (FPz). It was ensured that the inter-electrode impedance was less than 5 k Ohms.

Test protocol for ASSR measurement using GSI Audera:

- Type of stimuli: AM / FM tones
- Amplitude modulation 100 % and Frequency modulation 10 %.
- Transducer: loudspeaker at a distance of one foot and 45 º A from the test ear
- Test frequency: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz
- Carrier frequency: 78 Hz for 500Hz; 81 Hz for 1000 Hz ; 88 Hz for 2000 Hz; 95 Hz for 4000 Hz.
- No. of samples: Maximum of 64

The hearing aid that best matched with the target curve during insertion gain measurement was used for ASSR measurements. ASSR thresholds for each of the above frequencies were obtained with and without the hearing aid in sound field stimulus presentation condition. The gain (difference between unaided and aided ASSR thresholds) was calculated at each test frequency, for each subject.

Insertion gain and ASSR derived functional gain at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz for each subject were tabulated for statistical analysis.

Statistical analysis

Statistical evaluations were carried out using SPSS for windows (Version 10.0). Initial calculations assessed the mean and standard deviations of the two different measures i.e., real ear insertion gain (REIG) and gain obtained through auditory steady state responses (ASSR) and the differences between them. Comparisons among the different conditions were assessed. The relations between the two measures were evaluated using Pearson's product moment correlations.

CHAPTER 4

RESULTS

The data obtained from the real ear insertion gain (REIG) and auditory steady state responses (ASSR) measurements were analyzed for the correlation.

Table 4.1 shows the mean and standard deviation of the gain obtained through ASSR at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. It is evident from the Table 4.1 that, the mean and standard deviation were less for 500 Hz and 4000 Hz when compared to other test frequencies i.e., 1000 Hz and 2000 Hz. The same can be observed for the gain obtained through real ear insertion gain (Table 4.2). It is also evident from the table that, the range is more for ASSR at 500 Hz and it is less at 2000 Hz and 4000Hz when compared to insertion gain. It is similar for both the gains at 1000 Hz

Table 4.1: Mean, standard deviation and range of hearing aid gain (dB) obtained through ASSR at different test frequencies.

Frequency	ASSR Gain (dB)			
	Mean	Standard deviation	Range	
			Minimum	Maximum
500 Hz	20.75	2.93	15.00	30.00
1000 Hz	30.25	4.12	20.00	40.00
2000 Hz	26.50	4.00	20.00	30.00
4000 Hz	22.25	3.43	20.00	30.00

Table 4.2: Mean, standard deviation and range of hearing aid gain (dB) obtained through REIG at different test frequencies.

Frequency	REIG (dB)			
	Mean	Standard deviation	Range	
			Minimum	Maximum
500 Hz	19.47	2.60	15.10	25.00
1 kHz	29.94	4.61	21.10	38.90
2 kHz	27.81	3.72	19.40	35.20
4 kHz	22.82	4.39	13.00	30.10

There was a significant correlation between the gains obtained through real ear insertion gain (REIG) and gain measured through auditory steady state responses (ASSR). Table 4.3 shows the Pearson's product moment correlation (r-value) and significance values of gain obtained through ASSR and REIG. It can be observed from the table that the correlation is high at 1000 Hz when compared to other frequencies. Other test frequencies had similar correlation values. The correlation is significant at 0.01 levels at all the test frequencies.

Table 4.3: The correlation (r-value) and significance values between REIG and gain obtained through ASSR at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz Frequency.

Frequency	Pearson's Correlation	Significance
ASSR & IG 500 Hz	0.631	0.003**
ASSR & IG 1000Hz	0.672	0.001**
ASSR & IG 2000Hz	0.621	0.003**
ASSR & IG 4000Hz	0.629	0.003**

**. Correlation is significant at the 0.01 level (2-tailed)

Figure 4.1 shows the mean values of gain measured through ASSR and REIG. Among the different test frequencies the mean difference is very less at 1000 Hz and 4000 Hz when compared to other frequencies.

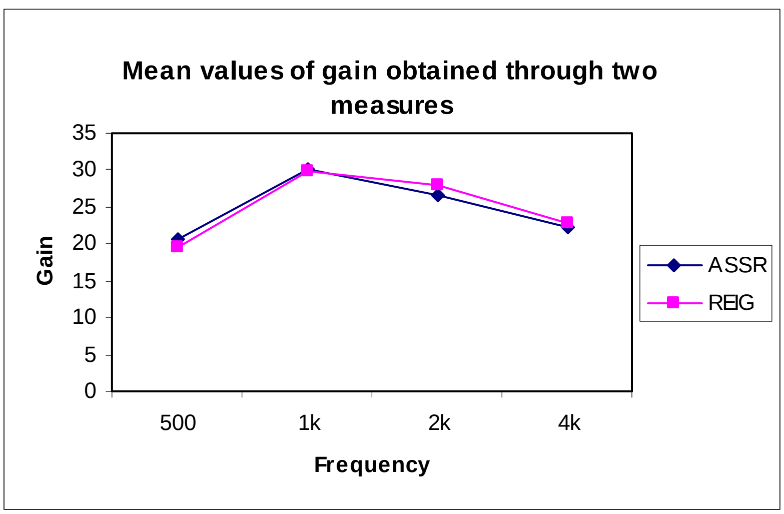


Figure 4.1: Mean values of gain obtained through REIG and gain obtained through ASSR

The gain measured from ASSR and REIG measurements for one of the subjects are shown in the figures 4.2 and 4.3 respectively. In figure 4.2 the arrow marks show the threshold estimated. The blue colored arrows are unaided responses and the red arrows are aided responses. Gain was calculated by taking the difference between them at each frequency. In Figure 4.3, the REIG values at different frequencies are depicted. It can be observed that the obtained gain was similar for both the measurements. Figure 4.4 shows the REIG curve.

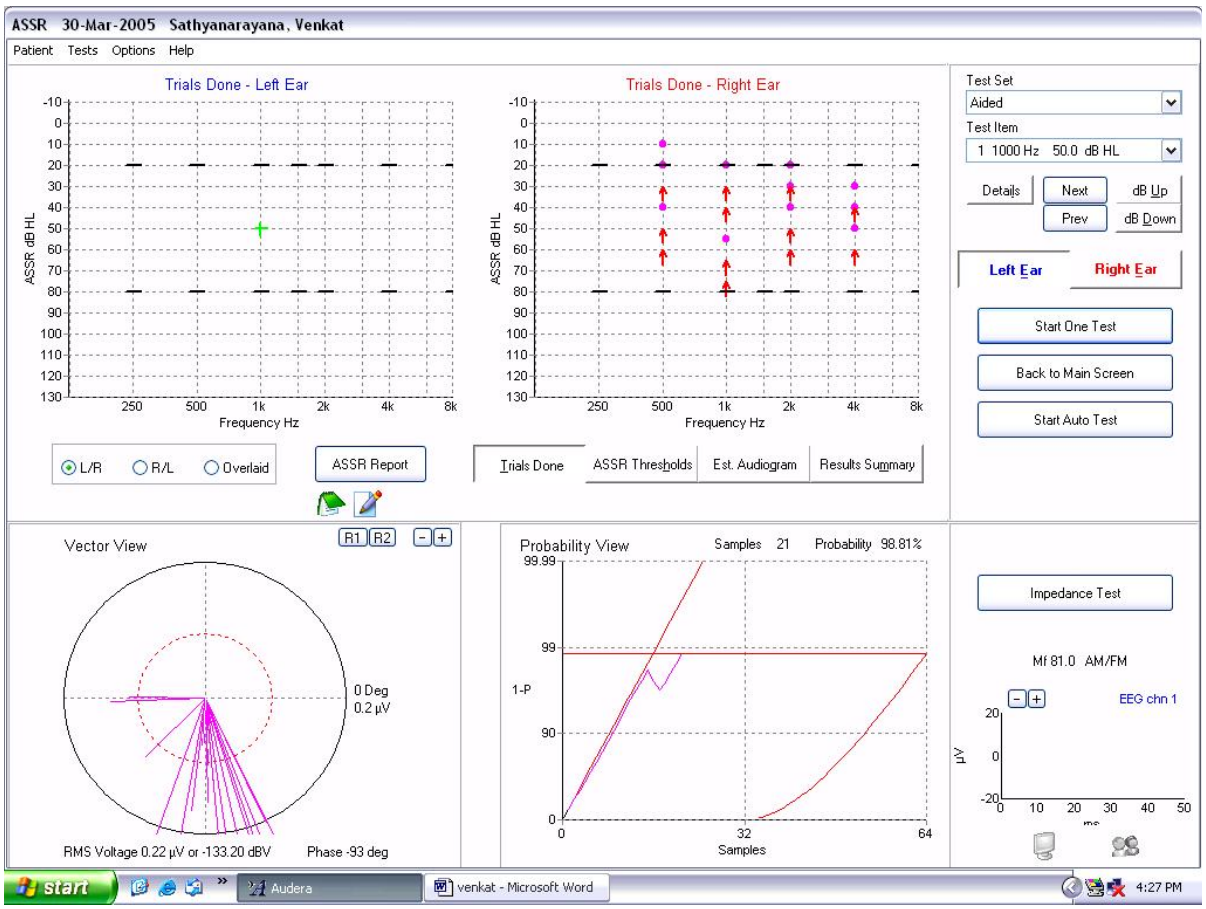
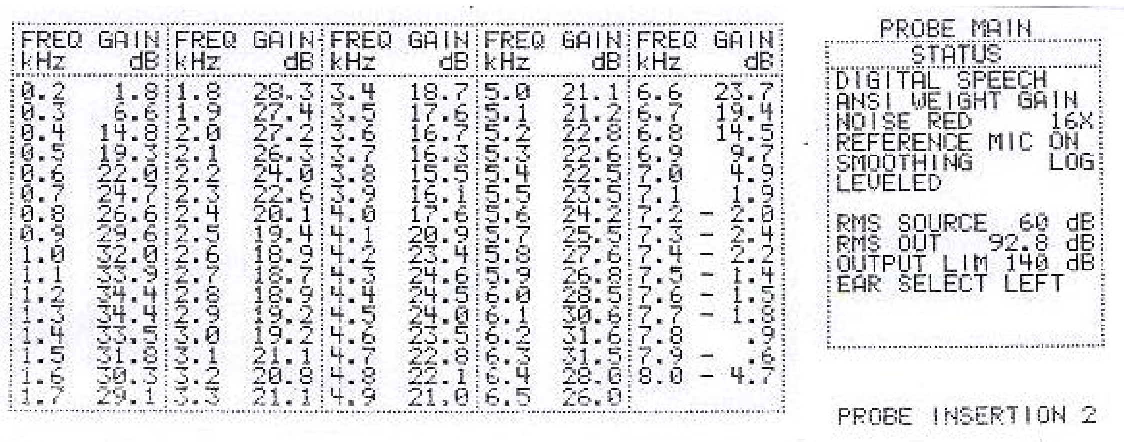


Figure 4.2: Shows the report of measurement of hearing aid gain through ASSR.



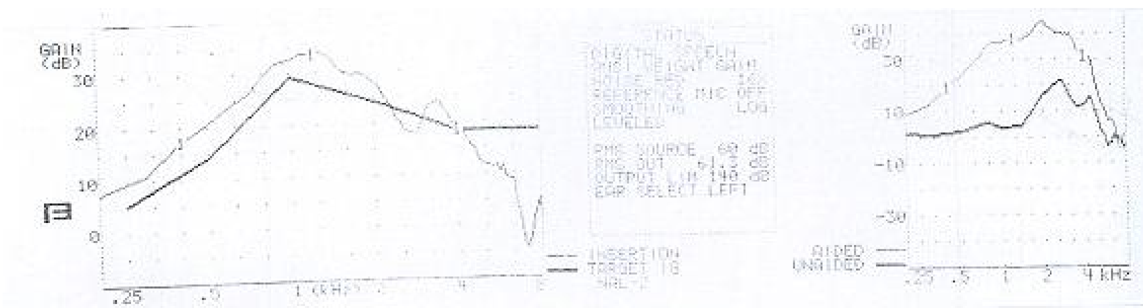
FREQ kHz	GAIN dB	FREQ kHz	GAIN dB	FREQ kHz	GAIN dB	FREQ kHz	GAIN dB	FREQ kHz	GAIN dB
0.2	1.8	1.8	28.3	3.4	18.7	5.0	21.1	6.6	23.7
0.3	6.6	1.9	27.4	3.5	17.6	5.1	21.2	6.7	19.4
0.4	14.8	2.0	27.2	3.6	16.7	5.2	22.8	6.8	14.5
0.5	19.3	2.1	26.3	3.7	16.3	5.3	22.6	6.9	9.7
0.6	22.0	2.2	24.0	3.8	15.5	5.4	22.5	7.0	4.9
0.7	24.7	2.3	22.6	3.9	16.1	5.5	23.5	7.1	1.9
0.8	26.6	2.4	20.1	4.0	17.6	5.6	24.2	7.2	- 2.0
0.9	29.6	2.5	19.4	4.1	20.9	5.7	25.5	7.3	- 2.4
1.0	32.0	2.6	18.9	4.2	23.4	5.8	27.6	7.4	- 2.2
1.1	33.9	2.7	18.7	4.3	24.6	5.9	26.8	7.5	- 1.4
1.2	34.4	2.8	18.9	4.4	24.5	6.0	28.5	7.6	- 1.5
1.3	34.4	2.9	19.2	4.5	24.0	6.1	30.6	7.7	- 1.8
1.4	33.5	3.0	19.2	4.6	23.5	6.2	31.6	7.8	.9
1.5	31.8	3.1	21.1	4.7	22.8	6.3	31.5	7.9	- .6
1.6	30.3	3.2	20.8	4.8	22.1	6.4	28.0	8.0	- 4.7
1.7	29.1	3.3	21.1	4.9	21.0	6.5	26.0		

PROBE MAIN
STATUS
DIGITAL SPEECH
ANSI WEIGHT GAIN
NOISE RED 16X
REFERENCE MIC ON
SMOOTHING LOG
LEVELED

RMS SOURCE 60 dB
RMS OUT 92.8 dB
OUTPUT LIM 140 dB
EAR SELECT LEFT

PROBE INSERTION 2

Figure 4.3: Shows the REIG values at different frequencies.



4.4a 4.4b

Figure 4.4: Shows the REIG graph. In 4.4a, solid curve represents the estimated target and dotted line represents the IG curve (REAR-REUR). In 4.4b, solid curve is the REUR and the dotted curve (with 1 mark) is the REAR

CHAPTER 5

DISCUSSION

The present study was aimed at evaluating relationship between the rear ear insertion gain and functional gain obtained through ASSR. The results suggested that there was a significant correlation between the gains obtained through these two different procedures at all the test frequencies i.e., 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz. The study done by Vanaja and Manjula (2004), suggested that there was a positive correlation between the functional gain obtained through ASSR and behavioral method. The correlation was more for 500 Hz and 2000 Hz and moderate at 1000 Hz. Insertion gain measurements have many advantages over behavioral functional gain measurements. It is more accurate, can be measured at less time and not affected by the problem of masked aided thresholds. It can be measured at range of input levels, this is not a problem for linear hearing aids but for the non-linear hearing aids the gain varies with input levels, hence more advantageous. The main disadvantage is that these measurements are not accurately performed in infants and difficult-to-test population as it requires modest co-operation from the subject.

Hearing aid selection is mainly based on the frequency-gain characteristics of the aid for a particular hearing loss. ASSR can be used to assess the frequency-gain of a hearing aid as there was a good correlation (0.631 at 500 Hz, 0.672 at 1000 Hz, 0.621 at 2000 Hz and 0.629 at 4000 Hz) between the insertion gain and functional gain obtained through ASSR and the correlation is significant at 0.01 levels. From the results of the study it is inferred that, ASSR is useful in hearing aid selection.

It was observed that, as the input intensity level was increased during aided ASSR measurements, the number of samples to obtain phase locked response was lesser and at some point it reached saturation. And also the amplitude of the response did not vary as the input level increased.

It is possible that the amplitude of the steady state responses might correlate in some way with the loudness of the sounds. We might therefore be able to use the amplitude of the response to construct the input-output function for the hearing aids. This could provide an objective assessment of such hearing aid measurements as comfort levels, and might be a more efficient approach to fitting hearing aids than determining aided thresholds. As well as assessing the effect of the hearing aid, aided thresholds might also be helpful in demonstrating hearing that cannot be recognized using other objective techniques.

Certain precautions are necessary while recording ASSR. It should be ensured that the distance between the loud speaker and the ear should be kept constant. The environmental noise should be low and also the subject should not move as it reduces the probability of response.

Auditory evoked potentials have been used in the past to assess hearing aids. These procedures were limited since the click ABR is mainly related to high frequency gain and since the correlation between wave V latency and loudness is low. Many technical problems have been reported in the use of ABR for the evaluation of amplification. Since the click is very brief, it can be significantly distorted in the sound field speaker and in the hearing aid. The resultant stimulus artifacts can obscure the interpretation of the response (Kileny, 1982; Mahoney, 1985). Other investigators have used the amplitude-intensity function of the unaided click evoked ABR to predict the optimal gain for a hearing aid (Keissling, 1982; Davidson, Wall & Goodman, 1990). However, this approach is problematic since the amplitude of the ABR is loosely correlated with loudness. In general, hearing aids handle rapidly changing acoustic stimuli (such as those used to evoke ABR) differently from more continuous stimuli such as speech, and it is difficult to predict the steady state characteristics of hearing aids from onset responses (Gorga, Beauchaine & Reiland, 1987). Middle and long latency evoked potentials can be used to evaluate hearing aid performance, as it uses longer duration stimuli such as speech, but are affected by sleep. So these tests are not good for infants and young children.

Auditory steady state responses (ASSR) overcome some of the limitations of auditory brainstem responses. The stimuli used are more frequency specific as it uses modulation tones (AM/FM). These stimuli are not affected or distorted when presented through a sound field speaker or amplified using a hearing aid (Picton, et al, 1998). ASSR is also used to derive information of hearing aid characteristics from the amplitude-intensity function of the steady-state responses (Zenker, Delgado & Barajas, 2001). This procedure enables determination of some basic properties of hearing aids, such as average gain, type of compression, compression factor and onset level. ASSR is not affected by sleep (Cohen, Rickrds & Clark, 1991) so it can be effectively used to evaluate hearing aid benefit in sleeping infants.

The stimuli used for both the measurements i.e., digi speech for REIG and modulation tones (AM/FM) for ASSR, considers the speech spectrum and fine modulations as it occurs in normal speech. It would be better if we use independent amplitude and frequency modulated (IAFM) stimuli for ASSR measurement as IAFM responses are significantly correlated with word recognition scores (Dimitrijevic, John, and Van Roon, 2004). Thus, it provides an objective tool for examining the auditory system's ability to process the auditory information needed to perceive speech in normal as well as in hearing impaired population.

Predicting aided thresholds of infants would help in deriving the benefit from the amplification. The Joint Committee on Infant Hearing (1994) recommended that all hearing impaired infants be identified and treatment initiated by the age of six months. Meeting this goal requires methods to evaluate aided performance in the treated infants. So, keeping in mind the limitations of other objective techniques, ASSR would be useful in selecting hearing aid for infants and young children who can not provide reliable behavioral thresholds. ASSR can also be used for selecting candidacy for cochlear implant (Swanepoel & Hugo, 2004), by assessing the aided thresholds.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Hearing aid fitting follows three main steps: assessing hearing loss, prescribing an aid to compensate for this hearing loss and verifying that this aid provides adequate benefit. The measurements required during the hearing aid fitting procedure are either objective or subjective. Insertion gain and its related measurements, obtained using electro acoustic procedures are objective, in the sense that they do not require any active response from the subject.

One of the objective techniques used is ABR. Many technical problems have been reported in the use of ABR for the evaluation of amplification. These procedures were limited since the click ABR is mainly related to high frequency gain and it can be significantly distorted in the sound field speaker and in the hearing aid. In general, hearing aids handle rapidly changing acoustic stimuli (such as those used to evoke ABR) differently from more continuous stimuli such as speech, and it is difficult to predict the steady state characteristics of hearing aids from onset responses.

Several studies stated that auditory steady state responses could be used to estimate the frequency specific auditory sensitivity. The auditory steady state responses (ASSR) offer several advantages over transient evoked potentials like ABR. These studies reported that there was a good correlation between behavioral thresholds and estimated ASSR thresholds.

Accurate individual real ear acoustic measurements are not always possible for infants and young children as it requires modest co-operation from the subject. Infants can not provide reliable behavioral responses to either aided or unaided sounds. Fitting young infants with hearing aids is therefore much more uncertain than in older children or adults. Electrophysiological tests like ASSR can assist in hearing aid prescription since they can measure frequency specific auditory thresholds. Thus, the present study aimed at investigating the relationship between the functional gain obtained through ASSR (i.e., difference between aided and unaided ASSR threshold) and the real ear insertion gain.

Twenty adult subjects with mild to moderately-severe sensorineural hearing loss were taken for the study. Based on the degree and configuration of the hearing loss two digital behind-the-ear hearing aids were pre-selected. These hearing aids were programmed with NOAH (3.0) and hearing aid appropriate software. The measurement with hearing aid was carried out in two steps. First, real ear insertion gain was measured with two pre-selected hearing aids. Second, ASSR was recorded with the selected hearing aid. The hearing aid that best matched with the target curve during insertion gain measurement was used for ASSR measurements. ASSR thresholds for the frequencies 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz were obtained with and without the hearing aid in sound field stimulus presentation. The gain (difference between unaided and aided ASSR thresholds) was calculated at each test frequency (i.e., 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz) for each subject

The results suggested that there was a significant correlation (0.631 at 500 Hz, 0.672 at 1000 Hz, 0.621 at 2000 Hz and 0.629 at 4000 Hz) between the gains obtained through these two different procedures. The correlation is significant at 0.01 levels.

ASSR can be used to assess the frequency-gain characteristics of a hearing aid as there was a good correlation between the insertion gain and functional gain obtained through ASSR. From the results of the study it is inferred that, ASSR is a useful tool in hearing aid selection.

It is possible that the amplitude of the steady state responses might correlate in some way with the loudness of the sounds. We might therefore be able to use the amplitude of the response to construct the input-output function for the hearing aids. This could provide an objective assessment of such hearing aid measurements as comfort levels, and might be a more efficient approach to fitting hearing aids than determining aided thresholds.

Thus, ASSR serves as an objective tool in hearing aid selection process for difficult-to-test population such as infants, young children in whom reliable behavioral responses can not be obtained.

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