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CORTICAL AUDITORY EVOKED RESPONSES AND BEHAVIOURAL OUTCOMES IN HEARING AID USERS

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ABSTRACT

The behavioural outcome measure and cortical potentials can be used for evaluating the benefits from hearing aids. These can provide reliable information, especially in the children. Therefore, the present study aimed at investigating the relationship between behavioural outcome with hearing aid and the aided Late Latency Response. The data were collected from two groups of participants, children and adults. The subjective questionnaire, SIS in quiet and Articulation Index were the behavioural measures used. The objective measures included P1 and N1 latencies, P1-N1 amplitude and P1-N1 slope of aided LLR. The results revealed that there was a significant moderate negative correlation between articulation index (AI) and latency of P1 for /g/ stimulus. Further, there was a significant correlation between speech identification score (SIS) and latency of N1 for /t/ stimulus. There was no correlation for other parameters studied.

Keywords: SIS, Articulation Index, outcome questionnaire, aided LLR.

Introduction

There is much interest in the measurement and quantification of hearing aid outcome (Humes, Halling, & Coughlin, 1996; Mueller, 1997). According to Weinstein (1997), 'outcome' refers to the measurable effect, either real or perceived, of the hearing aid on the hearing disability or hearing handicap of the user. The outcome can be either positive or negative. That is, the use of a hearing aid can either decrease or increase the problems faced due to hearing loss. The subjective outcome measured using questionnaires and interviews are available to document the opinions and attitudes of the client or parent. The subjective measures of performance, on the other hand, rely entirely on the judgement or opinion of the user and have no external reference for evaluation. Examples of subjective performance measures include loudness judgments as accomplished by scaling, category rating, or matching, quality judgments (clarity, harshness, spaciousness, etc.), and perceived disability or handicap measured by questionnaire.

A common approach to verifying the hearing aid fitting in young population is to use information gained from behavioural measures, the outcome of which is highly dependent on the state of infant (Hodgson, 1994). Ewing (1944) pioneered this form of assessment and used a wide variety of noise makers such as bells, rattles, and rustling paper to elicit a response. The technique involves the presentation of noise makers in the sound field at known levels and then observation of the response of the infant to these sounds.

The electrophysiological measure is useful for verifying the fit of a hearing aid in infants and toddlers, especially those with multiple disabilities. The recording of auditory brainstem response (ABR) thresholds to brief-tone stimuli provides valuable diagnostic information and threshold estimates for hearing aid prescription (Dillon, 2001).

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The cortical auditory evoked potentials (CAEPs), which have generators at a higher level in the auditory pathway than ABRs, are more indicative of whether neural signals are reaching the auditory cortex and thus should be more closely related to the perception of sound. Consequently, they are said to be more appropriate for objective assessment of speech and language development as reported by Stapells (2009). This has been shown to be related to speech perception scores and functional measures of hearing ability (Golding, Pearce, Seymour, Cooper, & Ching, 2007; Kurtzberg, 1989). In the current study, it is intended to study the relationship between behavioural measure and CAEPs in children and adults using hearing aids.

Need for the study

There are many behavioural measures which are used for evaluation of the hearing aids, but the effectiveness of all the tests is not similar. The behavioural tests used for evaluating the performance of the hearing aids are similar to those used for evaluating the hearing. They include measures such as aided thresholds, speech identification scores, and subjective questionnaires. Golding, Pearce, Seymour, Cooper, and Ching (2007) have reported on the relationship between obligatory CAEPs and functional measure in young infants. They opined that a significant relationship exists between LLR and functional outcomes for infants who were aided. This relationship was not seen when ABR or electrocochleargraph (ECochG) results were similarly compared with functional performance. This information is likely to complement existing test batteries and assessment tools in the verification of hearing aid fittings, especially in young children.

Assessment of aided speech skills could be a difficult task in young children and infants. Accordingly, there is a need for objective tests such as the aided evoked potentials to effectively establish the efficacy of the hearing aids. This objective evaluation gives the information regarding the performance of the hearing aids. There are many objective tests currently available, but having their own merits and demerits as they may or may not give the information on speech perception or recognition skills.

Though studies have used behavioural measures and cortical auditory evoked potentials, more evidence is required to generalize the findings. There is a dearth in literature on the relationship between the behavioural measures, subjective outcomes and the LLR Hence, the present study intends to use different behavioural tests / measures and their relationship with LLR.

Aim and objectives of the study

The aim of the present study was to evaluate the efficacy of the hearing aids using the behavioural measures and objective measures in hearing aid users. The specific objectives included exploring the behavioural measures i.e., AI, SIS, SNR-50, subjective questionnaires, for evaluating the outcome of hearing aid, in adults and children. Further, to investigate the objective measure i.e., aided LLR, for examining the outcome of hearing aid, in adults and children. In addition, the objective was also to compare the behavioural and objective outcomes of the hearing aids, in adults and children.

Method

Participants

Two groups of participants were included in the study. Group I included 15 ears of ten children having severe sensorineural hearing loss, i.e., pure tone average (PTA) ranging from 70 to 90 dB HL in the test ear. Group II comprised of 10 ears of seven adults having a severe sensorineural hearing loss, i.e., PTA ranging from 70 to 90 dB HL in the test ear. All the participants had Kannada, a south Indian language, as their mother tongue. The Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects Committee guidelines were followed in the present study.

Inclusion criteria

The participants in this study were diagnosed to have severe hearing loss on pure tone audiometry, with 'A' type tympanogram in the test ear in Group I Their age ranged from 4 to 12 years. Their aided closed-set speech identification scores (SIS) was not less than 60%. Written informed consent was obtained from the participants or parents of the participants prior to data collection. All the children had congenital hearing impairment. All of them used the hearing aid for at least a period of one year. Group II comprised of participants with age ranging from of 20 to 50 years. They had post-lingually acquired hearing impairment, with adequate speech and language. The aided thresholds of the test ear were within speech spectrum, and the aided open set SIS was not less than 60%.

Exclusion criteria

Individuals having middle ear infections, neurological disorders and cognitive deficit were excluded from the study.

Procedure

For the purpose of evaluating the objectives, the data collection process was done in three phases. Phase I included the programming and optimization of the digital BTE hearing aid of the participant. In this phase, all the participants underwent optimization of hearing aid for audibility of Ling's six sounds. Phase II comprised of administration of Parent's Evaluation for Aural oral performance of Children (P.E.A.C.H) questionnaire (Ching & Hill, 2005) for Group I and Self-Assessment of Hearing Handicap (SAHH) questionnaire (Vanaja, 2000) for Group II. This phase also involved establishment of articulation index (AI), speech identification scores (SIS) in quiet for both the groups; and signal to noise ratio for 50% speech recognition (SNR-50) for Group II alone. Phase III involved objective assessment by recording the aided LLR.

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Phase I: Hearing aid programming and optimization.

In this phase, the participants from both Group I and Group II were involved. Optimization of their hearing aids was performed for audibility of Ling's six sounds. After optimization of the hearing aid, aided thresholds were established for both the groups, from 250 Hz to 6000 Hz. Each participant was made to sit at 0 degree Azimuth and one meter away from the loudspeaker of the audiometer, in an air-conditioned two-room sound treated room. The aided thresholds were within speech spectrum. This phase was proceeded by Phase II of the study.

Phase II: Behavioural measures.

Phase II involved administration of questionnaire on parents for evaluation of aural oral performance of children with the hearing aid (PEACH) or self-assessment of hearing handicap scale (SAHH) to measure the hearing aid benefit for adults. This phase also involved computation of articulation index (AI) and establishment of SIS in quiet. This was done for both children and adults. The SNR-50 was established only on adults.

Parent's evaluation for aural oral performance of children (PEACH).
The participants from Group I were administered the P.E.A.C.H. questionnaire. The participants and the parent/caretaker were made to sit comfortably. The questionnaire was administered in Kannada language, in the form of interview. This was administered in order to know the performance of the child with the hearing aid. The questions were asked to evaluate the performance in quiet and in noise. This quantified the performance of the child in everyday life situations and this gives the outcome on efficacy of the hearing aid.

The scoring for PEACH was done on a five-point rating scale (0-4 points) i.e., 0 (0% of the time) to mean 'never', 1 (1-25% of the time) for 'seldom', 2 (26-50% of the time) for 'sometimes', 3 (51 -75% of the time) for 'often', 4 (75% -100% of the time) for 'always'. The scoring was done for quiet, noise and overall sections. The five-point rating scores were summed up and it was taken as the raw score, this was also converted into the percentage.

Self-assessment of hearing handicap (SAHH)
The participants from Group II were made to sit comfortably and they were interviewed, in Kannada language, to obtain information regarding the performance with hearing aids. This was done based on the SAHH questionnaire. The scoring for SAHH was done on a five- point rating scale (0-4 points) i.e., 0 (0% of the time) to mean 'never', 1 (1-25% of the time) for 'seldom', 2 (26-50% of the time) for 'sometimes', 3 (51 -75% of the time) for 'often', 4 (75% -100% of the time) for 'always'. The five-point rating scores were summed up and it was taken as the raw score; this was also converted into the percentage.

Articulation Index (AI)
The AI was computed by feeding the aided thresholds at 250 Hz, 500 Hz, 750 Hz, 1000 Hz, 1500 Hz, 2000 Hz, 3000 Hz, 4000 Hz and 6000 Hz in the excel based software program (Manjula, 2008). The AI values were calculated automatically as the aided threshold data were entered into the excel program sheet. This was done for each test ear.

Speech identification score in quiet (SIS)

The aided speech identification score in quiet was obtained for each test ear of participants from Group I and Group II. The participant was seated in the calibrated position one meter away from the loudspeaker of the audiometer, at 0^0 Azimuth. The participants from Group I were presented with the PB-word list which consisted of 25 words (Vandana, 1998). The words were presented through monitored live voice mode and the presentation level was 45 dB HL. The VU meter monitoring was done to ensure that it did not exceed the average deflection.

The SIS for Group I was obtained through closed-set task of picture identification. The picture book consisted of four pictures in a page. The child was instructed to point to the target picture. The participants were instructed to point to the picture when they heard the test word, and given practice items prior to the actual testing. The scoring of the test words was done by counting the number of words identified correctly. Each correct identification of words was given a score of '1'. The maximum score was 25, as there were 25 words in the PB word list.

For each participant in Group II, the aided SIS in quiet was obtained through recorded mode of presentation. The laptop with the CD having the recorded PB wordlists (2 nos.) in Kannada for adults (Manjula, et al., 2013) was connected to the auxiliary input of the audiometer. A calibration tone of 1 kHz was used to ensure the desired intensity. The stimulus was presented at an intensity of 45 dBHL. The participants were instructed to repeat the words heard. Each correctly identified word was given a score of '1'. The maximum score was 25 as the number of words in the list was 25.

Signal to Noise Ratio-50 (SNR-50)
The SNR-50 was measured only for participants from Group II. The signal to noise ratio (SNR) required for 50% performance is termed SNR-50. The participant was made to sit comfortably on a chair, in the calibrated position, in the sound treated room. The recorded PB word lists were presented, from the CD loaded in the laptop computer, to the loud speaker, through the auxiliary input of the audiometer. The speech was presented at 45 dB HL, through the loudspeaker which was kept in front of the participant at 0^0Azimuth and one meter distance. The level of speech stimuli was kept constant at 45 dB HL. Later, speech noise was introduced through the same loud speaker, the initial level of which was set at 30 dB HL. The level of noise was increased, in

5-dB steps, till the participant repeated two out of four words correctly, i.e., 50% of the words being presented at a particular level of speech noise. From this level, the noise was varied in 2-dB steps in order to obtain a more precise level of speech noise at which 50% of the words were correctly repeated. At this point, the difference in the intensity of speech and the intensity of speech noise, in dB, was noted as the SNR-50.

Phase III Objective measure

Aided cortical auditory evoked potentials (CAEPs), i.e., LLR was recorded from each participant from both the groups. The participants were made to sit comfortably in the air-conditioned sound treated room. The electrode placement sites were cleaned with the cleaning gel. The disposable electrodes were placed on the test sites. The vertical montage that included the upper forehead, lower forehead and mastoid of the non-test ear was used. It was ensured that the impedance was within 5 kOhms. The ongoing EEG activity was monitored to prevent the contamination of the response or high rejection. For Group I, the eye blink was monitored/controlled by playing a muted movie or cartoon through a battery operated laptop computer, while recording the LLR. The aided LLR recording was repeated to check for replicability. The protocol for measuring aided LLR is given in the Table 1.

Table 1:**The Protocol Used for Recording Aided LLR**

Parameters	***Settings***
Test type	Cortical Auditory Evoked Potentials – LLR
Aided/unaided	Aided
Transducer	Loudspeaker
Position of the Loudspeaker	1 metre distance with the Azimuth of 90^0 (side of the hearing aid worn).
Electrode sites	Active – vertex upper forehead(Cz) Reference – non-test ear mastoid Ground – forehead
No. of epoch	200
Intensity level	65 dB SPL
Stimulus used	Three recorded speech sounds: - in low frequency /m/ (30 ms) - in mid frequency /g/ (20 ms) - in high frequency /t/ (30 ms)
Filter settings	0.16-30 Hz
Polarity	Alternating
Recording of LLR	Aided, recorded twice

Analysis of latency and amplitude of aided LLR

The latency and the amplitude of the aided LLR wave form were visually inspected by extracting the latency and the amplitude information by three audiologists. They were instructed to mark the presence of peaks and to rate the presence of peaks on a 5-point rating scale. This was created using the code in the MATLAB program. After complete evaluation, the latency and amplitude of aided LLR for each test ear were tabulated and subjected for statistical analysis**.**

Results and discussion

The data included the behavioural and objective measures, i.e., questionnaire, AI, SIS, SNR-50 (only for Group II), and latency and amplitude of aided LLR. These data were tabulated and analyzed. In children, except for SNR-50, data on the other measures were subjected to statistical analyses. Descriptive statistics was used to compare the mean, standard deviation and range for all the behavioural measures, in children and adults.

Aided Behavioural Measures

The mean, standard deviation (SD) and range of these data are provided in Table 2. It can be inferred from Table 2 that the two groups are slightly different in terms of the mean values of behavioural measures of the adult and children groups. The mean values of AI, SIS, and questionnaire with the hearing aid are higher in the adult group compared to that of children group.

The performance of adult group in noise, i.e., SNR-50, revealed that they require speech to be at a higher level compared to noise. This present finding supports that of Lee and Humes (1993), where in individuals having severe impairment required higher SNR than those with normal hearing. This is because the degree of hearing loss and presence of noise which will further reduce the audibility. Thus, there is a requirement of higher SNR in the individuals having severe hearing loss. In addition, it was noted that there was a low SD in both the adult and children groups suggesting that the groups were homogenous.

Aided Electrophysiological measures

The data in terms of latency and amplitude of aided LLR, in children and adults, were tabulated for analyses and comparison. Tables 3 and 4 depicted the mean, SD and range for the latency, amplitude and slope of aided LLR peaks, for the three different stimulus, i.e., /m/, /g/ and /t/. The findings in the present study show that the mean value of the latencies was prolonged in children compared to that of adults. This finding is in support with the study done on the maturation of CAEP in infants and children reported by Wunderlich et al. (2006). Also this finding supports the study on vowel evoked CAEP in the children, which found a large positive P1 around the latency 130 ms and the two negative peaks at around 250 ms and 450 ms (Ceponiene et al., 2003).

Table 2
Mean SD and range of aided AI, SIS, and questionnaire response in children and adults; of aided SNR-50 in adults only.

Behavioural measures	*Children*		*Adults*	
	Mean (SD)	*Range*	*Mean (SD)*	*Range*
AI (Range=0-1)	0.68 (0.05)	0-0.18	0.740 (0.09)	0-0.29
SIS (Range=0-25)	17.80 (1.66)	16-21	18.60 (1.35)	15-22
SNR-50	-	-	8.00 (2.06)	5
Questionnaire Quiet (Range= 0-100%)	76.27% (6.66)	70-85	79.30% (5.44)	65-88
Noise (Range= 0-100%)	63.67% (10.93)	60-75	65.70% (4.69)	35-75
Overall (Q+N) (Range= 0-100%)	70.00% (8.20)	65-80	73.10% (4.77)	50-81

The finding of the present study also supports that reported by Cunningham, Nicol, Zecker, and Kraus (2000). In their study, it was observed that there was generation of the positive and negative peaks initially soon after the hearing aid was fitted. Once the auditory system is stimulated and with the maturation, there is a reduction in the amplitude of P1 and reduction in latency of P1 which signifies maturation. The children group showed a higher mean amplitude for the P1-N1 for the stimulus /g/. This pattern is similar to that obtained for /m/. The prominent presence of N1 peak reported was less and this signifies the developmental changes. As the age increases, the N1 peak latency decreases or prominence of the peaks increases by the changes in the amplitude component.
There may be a possibility that the N1 peak can be absent or even if it is present, the prolongation of latency will take place over 100 ms to 150 ms as reported by Cunningham, Nicol, Zecker, and Kraus. (2000) .In the current study too, the presence of prominent N1 peak with prolongation of latency probably reflects the maturation, for all the three stimuli used in the study.

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Table 3

Mean SD and Range of Latency, Amplitude and slope of aided LLR in Children

Aided LLR	*Latency(ms)* *P1*	*Amplitude in (µV)* *N1*	*P1-N1*	*Slope of P1-N1*
		Stimulus /m/		
Mean	115.80	203.46	6.01	-0.61
(SD)	(12.83)	(31.49)	(2.87)	(0.028)
Range	92-132	142-272	3.17-13.9	-0.12 - -0.03
		Stimulus /g/		
Mean	117.06	192.26	5.67	-0.87
(SD)	(19.69)	(31.26)	(2.29)	(0.05)
Range	94-158	151-268	2.38-9.05	-0.2 - -0.2
		Stimulus /t/		
Mean	116.66	202.13	5.52	-0.71
(SD)	(16.28)	(20.81)	(2.09)	(0.03)
Range	94-148	157-244	2.89-9.43	-0.16 - -0.03

Table 4

Mean SD and Range of Latency, Amplitude and Slope of LLR components in Adult Group

Aided LLR	*P1*	*Latency in (ms)* *N1*	*P2*	*N2*	*P1-N1*	*Amplitude in (µV)* *N1-P2*	*P2-N2*	*Slope P1-N1*
				Stimulus /m/				
Mean	64.50	127.40	226.60	374.33	5.209	6.091	8.348	-0.191
(SD)	(14.28)	(19.25)	(8.93)	(10.96)	(1.98)	(4.73)	(0.26)	(0.39)
Range	44-94	112-172	217-214	368-387	2.74-9.48	1.52-13.1	8.19-8.64	-0.18- -0.03
				Stimulus /g/				
Mean	57.70	121.60	199.20	364.00	3.413	3.533	5.915	-0.075
(SD	(20.46)	(39.76)	(12.29)	(15.52)	(1.36)	(2.08)	(0.45)	(0.05)
Range	39-101	66-167	186-212	349-380	1.65-5.44	0.08-6.68	5.67-6.43	-0.22 –0.02
				Stimulus /t/				
Mean	56.50	111.20	231.40	349.33	3.285	4.210	7.220	0.016
(SD)	(20.59)	(34.74)	(21.76)	(24.82)	(1.12)	(2.134)	(0.70)	(0.015)
Range	39-100	66-167	212-265	335-378	2.03-5.18	1.17-7.11	6.46-7.85	-0.16- -0.02

The Table 4 depicts the descriptive statistics in terms of the mean, SD and range of latency, amplitude and slope of the components of aided LLR in adults. This finding in adults supports that reported by Wunderlich et al. (2006). In their study, it was reported that as the age increases, there is a reduction in the latency of the P1 and N1. In the present study too, the mean of the P1 and N1 peaks showed a reduction in latencies for the adult group compared to that in the children group.

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In the present study, it is clearly observed that the mean amplitude of the P1-N1 of adults is lesser when compared to the mean amplitude of N1-P2 complex, as depicted in the Table 4. This is in consensus with the findings reported by Sharma et al. (2002). The peaks P2 and N2 were prominently observed in the adult group, and were not present in the children group.

The data collected on behavioural and electrophysiologic measures were subjected correlational test.
In order to evaluate the third objective of the study to compare the behavioural and objective outcome of the hearing aids in adults and children, the results will be discussed separately for correlation.

Relationship between behavioural and objective outcomes in children and adult
The Pearson's correlation was used to evaluate the relationship between the behavioural measures and the aided LLR.

The correlation between aided LLR with AI, SIS, questionnaire - in quiet, noise and overall conditions was carried out for children.

The correlation between aided LLR with AI, SIS, SNR-50, and questionnaire - quiet, noise, overall conditions was carried out for adults.

Relationship between behavioural and objective outcomes in children
The Tables 5 A and 5B depict the correlation of the behavioural measures and electrophysiological measures. There is no significant correlation for most of the parameters Table 5A). There was no significant correlation between the questionnaire measure and the LLR measures in the current study. However, the results revealed that there was a significant moderate negative correlation between articulation index (AI) and latency of P1 for /g/ stimulus. Further, there was a significant correlation between speech identification score (SIS) and latency of N1 for /t/ stimulus. Further, there was no correlation between the amplitude and slope of LLR with the behavioural measures Table 5B).

Table 5(A)

Correlation between behavioural measures and latency of P1 and N1 of LLR in children

	Aided LLR components : Latency (ms)					
	P1			N1		
Behavioural measures	/m/	/g/	/t/	/m/	/g/	/t/
AI	0.220	-0.531**	0.220	0.098	0.156	0.089
SIS	0.133	0.028	0.140	0.153	0.131	-0.543**
Questionnaire in quiet	0.146	0.166	0.140	-0.068	-0.082	-0.068
Questionnaire in noise	0.119	0.249	-0.119	0.141	0.237	0.142
Questionnaire overall	0.032	-0.033	0.014	0.035	0.101	0.136

Note:**correlation is significant at the 0.01

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Table 5(B)

Correlation between behavioural measures and P1-N1 amplitude and P1-N1 slope of LLR in children

Behavioural measures	Aided LLR components					
	P1-N1 Amplitude (μV)			P1-N1slope		
	/m/	/g/	/t/	/m/	/g/	/t/
AI	-0.74	0.317	0.236	0.135	-0.138	-2.870
SIS	-2.74	-0.430	0.100	0.135	-0.80	-0.106
Questionnaire in quiet	0.044	-0.082	0.044	0.128	-0.58	-0.195
Questionnaire in noise	-0.068	-0.129	-0.068	0.499	0.255	0.152
Questionnaire overall	0.013	-0.062	0.013	0.289	0.149	-0.0254

There was no significant correlation between P1-N1 amplitude and slope with the behavioural measures. The finding from the present study is contradicting that reported by Golding et al. (2007). They reported a significant relationship between the aided LLR and functional outcome measures (i.e., PEACH), and they opined that the presence of LLR can predict the auditory performance in the real-life situation.

Relationship between behavioural and objective outcomes in adults

The Tables 6A and 6B depict the correlation of the behavioural measures and electrophysiological measures in adults. There is no significant correlation for all the parameters (Table 6A). There was no significant correlation between the questionnaire measure and the LLR measures in the current study. Further, there was no correlation between the amplitude and slope of LLR with the behavioural measures Table 6B).

Table 6 A
Correlation between behavioural measures and latency of P1 and N1 of LLR in adults

Behavioural measures	Aided LLR components : Latency (ms)					
	P1			N1		
	/m/	/g/	/t/	/m/	/g/	/t/
AI	0.426	0.221	0.426	0.485	0.415	0.485
SIS	-0.045	-0.052	-0.045	-0.394	0.026	-0.394
Questionnaire in quiet	0.212	0.442	0.212	0.094	0.405	0.094
Questionnaire in noise	-0.167	-0.020	-0.167	0.451	-0.211	-0.451
Questionnaire overall	0.050	0.278	0.050	0.007	0.193	0.007
SNR-50	0.512	0.413	0.091	0.416	0.019	0.197

Table 6(B)

Correlation between behavioural measures and P1-N1 amplitude and P1-N1 slope of LLR in adults

	Aided LLR components					
Behavioural measures	P1-N1 Amplitude (µV)			P1-N1slope		
	/m/	/g/	/t/	/m/	/g/	/t/
AI	-0.096	-0.031	-0.096	0.067	0.298	0.298
SIS	-0.462	0.319	-0.462	0.233	0.277	0.691
Questionnaire in quiet	*-0.195*	*0.574*	*-0.195*	-0.015	0.011	-0.004
Questionnaire in noise	-0.258	0.191	-0.258	0.094	-0.035	0.115
Questionnaire overall	-0.200	0.328	-0.200	-0.267	-0.038	-0.004
SNR-50	0.098	-0.407	-0.028	-0.051	0.076	0.012

There was no significant correlation between P1-N1 amplitude and slope with the behavioural measures. In order to validate the hearing aid, Hassan (2011) reported that the aided LLR can be used as a valuable tool for assessing the hearing aid benefit. Long duration of hearing aid use can have a direct effect on the hearing aid benefit, and the speech perception ability. In his study, behavioural measures such as aided thresholds, speech recognition in quiet and noise were used and it was found that there was no correlation between the speech recognition in quiet and aided LLR. There was a significant positive correlation between the speech recognition abilities in noise and aided LLR. His report is partly in support with the current finding as there was no significant correlation between the SIS in quiet, noise and the aided LLRs in adults. Possibly, severe hearing loss and the duration of the hearing aid use could be factors influencing the finding.
The Wong et al. (2008) reported that there is a correlation between the behavioural findings such as aided thresholds, speech thresholds measured using Cantonese hearing in noise test in adults, in different conditions i.e., quiet, noise from front and left. They concluded that the speech scores and LLR are highly correlated with the behavioural audiometric thresholds. However, in the present study, there was no correlation with the different behavioural tests such as AI, SIS, questionnaire and SNR-50 with the aided LLRs in adults.

The present study revealed that there was a significant negative moderate correlation between articulation index (AI) and latency of P1 for /g/ stimulus in children. Further, there was a significant correlation between speech identification score (SIS) and latency of N1 for /t/ stimulus. There was no correlation for other parameters studied.

It is reported that the substantial use of hearing aids in the individuals can improve the detectabilty of the LLR. The possible explanation of the presence or absence of LLR findings could reflect the accurate information based on the behavioural speech measures in experienced hearing aid users and the degree of hearing loss (Korezak et al., 2005). In the present study, the participants had a minimum of one year of experience with the use of hearing aid and had severe degree of hearing loss.

Summary and Conclusions

The aim of the present study was to evaluate the efficacy of the hearing aids using the behavioural measures and objective measures in hearing aid users. The specific objectives of the study were -

i. To study the behavioural measures such as AI, SIS, SNR-50, subjective questionnaires, for evaluating the outcome of hearing aid, in adults and children.
ii. To study the aided LLR for evaluating the outcome of hearing aid, in adults and children.
iii. To compare the behavioural and objective measures of the hearing aids, in adults and children.

The data for the present study were collected from 15 ears of 10 children; and 10 ears of 7 adults. The criteria for inclusion were that the aided thresholds were within speech spectrum; SIS was not less than 60%; and the participants having a PTA of greater than 70 dB HL. All the participants had at least one year experience with the hearing aid usage.
The data collection process was done in three phases. Phase I included the programming and optimization of the participant's own digital BTE hearing aid. In this phase, all the participants underwent optimization of hearing aid using the Ling's six sounds. Phase II comprised of administration of P.E.A.C.H questionnaire for Group I and SAHH questionnaire for Group II. It also involved establishment of SIS in quiet for both the groups; and SNR-50 for Group II. Phase III involved objective assessment by recording aided LLR for /m/, /g/ and /t/ stimuli. The aided LLR was recorded for participants from both the groups. Thus, the data on the behavioural measures and electrophysiological measures were collected, tabulated and analysed.

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The data collected were subjected to statistical analyses using Statistical Package for Social Sciences (Version 17.0). The descriptive statistics was used to obtain the mean, SD and range of the behavioural and objective parameters collected. To investigate the correlation between behavioural measures and electrophysiological measures, Pearson's correlation was used.

The results revealed that there was a significant moderate negative correlation between articulation index (AI) and latency of P1 for /g/ stimulus in children. Further, there was a significant correlation between speech identification score (SIS) and latency of N1 for /t/ stimulus. There was no correlation for other parameters studied.

Future directions for research

The study was done only on the individuals having greater than or equal to severe hearing loss. There is a need for the study to be done with the different degrees of hearing loss (mild, moderate, moderately severe hearing loss), and in individuals who are experienced and naive hearing aid users.

This study could be done on individuals with different configuration of audiogram. The aided LLR is one of the tests for the detection, possibly the higher potentials like P300 and MMN can be used to evaluate the relationship between the behavioural measures and CAEP. Further it would be interesting to evaluate the relationship between behavioural and electrophysiological measures in experienced and naive hearing aid users and individuals using cochlear implants.

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