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CHANGE OF CORTICAL AUDITORY EVOKED POTENTIALS ON DIFFERENT HEARING AID GAIN- PRELIMINARY STUDY

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ABSTRACT

The study aimed on investigating the efficacy of optimal hearing aid gain using subjective and objective methods. The results showed subjective method has significant differences at three different gains of the hearing aids and there were significant high negative correlation observed between speech identification scores (SIS) and gain of the hearing aids in these individuals. There were differences in mean latency and amplitude of P1, N1 and P2 at different speech stimuli. However, when compared with gains of the hearing aid, results show no significant differences across different speech stimuli (/m/, /t/, & /g/) as well as at different gain of hearing aids. To conclude these finding reflects increase in gain of hearing aids solely not accountable for changes observed using CAEP but it is prominently observed in subjective measures in these individual too.

Key words: *CAEP, SIS, Optimal Gain, Prescribed Gain*

Introduction

There is growing interest in cortical auditory evoked potentials (CAEPs) as a measure of cortical function in hearing aid users. Aided CAEP, or evoked potentials recorded from individuals while wearing their hearing aids, may be of use to evaluate hearing aid fittings as well as experience-related plasticity associated with amplification. Aided CAEPs are not new, in fact reports of recording CAEPs from aided individuals date back to 1967 (Rapin&Graziani, 1967), and the idea has been revisited many times since (Billings et al., 2007; Gatehouse & Robinson, 1996; Golding et al., 2007; Gravel et al., 1989; Korczak et al., 2005; Kraus & McGee, 1994; Kurtzberg, 1989; Marynewich, 2010; Purdy et al., 2005; Rapin andGraziani, 1967; Sharma et al., 2004; Stapells&Kurtzberg, 1991; Tremblay, Billings, 2006; Tremblay, Kalstein e, 2006).

However, more than 40 years later, the utility of aided evoked potentials has yet to be established. One reason for this is conflicting evidence showing that CAEPs are affected by amplification in some individuals/studies but not others. Given these conflicting results, it is important to consider how the hearing aid signal processing alters the acoustic content of the stimulus and, in turn, affects the evoked responses. Hearing aid signal processing causes many acoustic modifications to a stimulus (e.g., rise-fall time, signal level, etc) that are likely to affect CAEPs; however, it remains unclear if and how these acoustic modifications affect the aided CAEP. Before aided CAEPs are to be of use clinically, it must be determined what hearing aid factors contribute to the aided evoked potential.

There is enormous growth in cortical auditory evoked potential (CAEP) which has been highly used by the clinicians for validating the hearing devices, hearing aids provide a fundamental solution to the deficits associated with hearing loss (Dillon, 2001) by amplifying sound to make it audible to the listener. Restoring audibility is undoubtedly the clinician's most important goal in

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providing rehabilitation to individuals with hearing impairment (Ching, 2001). Appropriate amplification is particularly crucial for infants with hearing impairment, as adequate reception of the speech signal is needed for the development of speech and language (Stelmachowicz, 2000). When the hearing impairment detected at very young age, generally the hearing thresholds are estimated using the auditory brainstem response which helps to fit the hearing aid appropriately. However, there can be an error happens eventually with the inconsistent fitment of the hearing aid gain or optimized hearing aid gain.

CAEP recorded from the vertex (relative to one of the mastoids) at a rate of about one a second generally consists of a positive peak ranging from about 250 ms (at birth) to 100 ms (in childhood), followed by a low-amplitude negative deflection ranging from 450-600 ms (at birth) to 200 ms (in childhood). The latency decrease is explained by the development of the auditory system over time (Sharma, Dorman, & Spahr, 2002) and is also dependent on the duration a person has been subjected to sound, the so called time-in-sound (Ponton, Don, Eggermont, Waring, Kwong, & Masuda, 1996). The appearance of an extra negative deflection N1 separates the positive deflection into peaks P1 and P2 after the age of eight years. This transformation continues until adulthood, where the CAEP has a distinct P1-N1-P2-N2 pattern.

CAEPs seem well suited to hearing aid fitting evaluation for several reasons. First, it is possible to use speech sounds, which are the sounds whose audibility we are most interested in knowing, rather than the brief tones or clicks that are needed for ABRs, or the modulated continuous sounds used for auditory steady state responses (ASSRs). While it is possible to estimate the audibility of speech sounds from knowledge of hearing aid gain plus pure tone behavioural thresholds, or tone-burst electrophysiological thresholds, many assumptions about auditory filter widths, detection efficiency, and temporal integration must be made. Second, the longer duration of speech sounds allows the hearing aid more time to react to the presented sound, so that the hearing aid is more likely to be in a state similar to a real-life speech signal. Third, CAEPs represent the detection of sound at, or near the end of, the auditory pathway, so they are affected by all parts of the auditory system as well as by the hearing aid gain-frequency response.

The main reason of implementing the CAEP in hearing aid fitting evaluation is that variability across the population clearly, successful aural habilitation critically depends on providing audibility of the complete range of speech sounds. As a known criterion the prescriptive formulas are used to determine the effectiveness of the hearing aid benefit, and it is a known fact that it is based up on the individual hearing threshold (Dillon, 2001). The relationship between the gain and the hearing loss are based on certain assumptions, the more weightage is majorly due to the prescriptive formulas. Even when reliable thresholds can be obtained and hearing aids can be vary precisely fitted to match prescriptive targets, there is still a need to evaluate the success of the hearing aid fitting (Dillon, 2001).

In this experiment, the study aimed to evaluate the efficacy of optimal hearing aid gain using subjective (Speech identification scores) and objective (aided CAEPs) methods. The study focussed on evaluating three objectives: i) To obtain the speech identification score using three respective gain of the hearing aid such as optimal hearing aid gain, +10 dB and -10 dB from the optimal hearing aid gain. ii) To obtain the aided CAEPs using optimal hearing aid gain, +10 dB and -10 dB of the optimal hearing aid gain and iii) To obtain the relationship between the subjective and objective outcomes of the hearing aid at three different conditions.

Method

There were 15 participants in the age range of 40-60 years (mean age 52.8 years) having moderately severe sensorineural hearing loss, i.e., pure tone average (PTA) ranging from 55 to 70 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 were followed in the present study as per the institute ethical committee recommendations and the written/oral consent were obtained from all the participants.

Equipment & tools

A calibrated sound field audiometer (GSI-61) was used with the loudspeaker was positioned at 0^0 azimuth and at a distance of one meter to establish the speech identification scores in quiet in aided condition. A calibrated immittance meter (GSI tympstar version 2) was used obtain tympanometry and acoustic reflexes which enables to assess middle ear function. HEARLab evoked system was used to record the aided CAEP with the calibrated loudspeaker at 0^0 azimuth. All the audiological tests were conducted in an air conditioned sound treated room with noise level within permissible limits.

Procedure

The preliminary procedure was initiated with a detailed case history and basic audiological evaluation. The audiometric testing was done using a calibrated double channel diagnostic audiometer. The pure tone audiometric thresholds were obtained using modified Hughson-Westlake procedure across octave frequencies from 250 Hz to 8000 Hz for air-conduction and 250 Hz to 4000 Hz for bone-conduction. Tympanometry showed ‘A’ type tympanogram and absent reflexes for 500 to 4000 Hz. Speech audiometry was done to obtain the speech recognition threshold (SRT), speech identification scores (SIS) and uncomfortable level (UCL) for speech. There was good agreement between SRT and PTA for all the participants. The present study conducted in three phases. Phase I included the programming and optimization of the digital behind the ear (BTE) hearing aid for each participant, phase II included the subjective measures (SIS) using hearing aids and phase III included the objective measure (aided CAEPs) using hearing aids.

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Phase I: Hearing aid programming and optimization

The participants were involved for optimization of their hearing aids performed for audibility of Ling's six sounds. After optimization of the hearing aid, aided thresholds were established for all the participants, from 250 Hz to 4000 Hz. Each participant was made to sit at 0 degree azimuth and one meter away from the loudspeaker of the audiometer. The aided thresholds for all the participants were within speech spectrum up to 4 kHz.

Phase II: subjective measures

Speech identification score in quiet (SIS) were obtained for all the participants in three aided conditions (Optimal gain, +10 dB from the Optimal gain and -10 dB from the Optimal gain). The participants were presented with the PB-word list which consisted of sets 25 words. The words were presented at 40 dBHL for all the participants. The participants were instructed to repeat the words heard. Each correctly identified word was given a score of '1'and the wrong response was given as '0'. The maximum score was 25 as the number of words in each list was 25.

Phase III: Objective measures

Aided cortical auditory evoked potentials (CAEPs) were recorded from each participant at three aided conditions (optimal gain, +10 dB from the optimal gain and -10 dB from the optimal gain). 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 eye blink was monitored / controlled by playing a muted movie through a battery operated laptop computer, while recording the CAEP. The protocol used for measuring aided CAEP is given in the Table 1

Table 1: The Protocol Used for Recording Aided CAEPs

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

Results and Discussion

Statistical analysis was performed using Statistical Package for Social Science (SPSS-17). Descriptive statistics was done to find out mean and standard deviation for both subjective and objective measures. The normality test was performed using Shiparo-Wilk test, which show non-normal distribution of the data. Non-parametric test like Kruskal-Wallis test was done to compare between the

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different hearing aid gain with the subjective and objective measures. Finally, Pearson correlation analysis was done to evaluate the relationship between subjective and objective measures with the different hearing aid gains.

Aided subjective measure

The data of the subjective measure i.e. the speech identification score in quiet was measured for three different gains such as optimal gain, +10 dB and -10 dB of the optimal hearing aid gain. Table 2 provides the mean, SD and range values of the subjective measures.

Table 2 Mean, SD and range SIS in quiet for three different hearing aid gains

Gain	**Aided subjective measure (SIS in quiet)**		
	Mean*	**SD**	**Range**
Optimal gain (OG)	23.00	1.0	21-23
+10 dB of the (OG)	23.00	1.0	22-23
-10 dB of the (OG).	15.9	2.9	9-15

Maximum possible score=25

The findings depicts that the mean of the optimal gain and the +10dB of the optimal hearing aid gain is having the same mean and SD in compassion to -10 dB of the optimum gain mean, which probably signifying the higher consistency of the data. Even though the gain is increased from the optimal gain there could not be any difference noticed but the decrease in the optimal gain had a reduction in the mean scores in hearing aid users.

The above findings also partially supported by Deepika and Manjula (2014), where they also observed better scores at optimum gain in experienced hearing aid users. In the current study the possible reason could be that since participants had lesser degree i.e. moderately severe sensorineural hearing loss which in turn would have showed the higher mean scores for the speech identification abilities. Optimal gain and did not show any difference at +10 dB of the optimal gain. The above finding indirectly infer that just by increasing the gain of hearing aid may not immediately represented at cortical level while recording aided CAEPs. Individuals needs to be exposed to external environment at that particular gain to be reflected in cortical potential so called plasticity which occurred due to stimulus.

The automatic analysis of the presence of cortical response can be visualized. It is possible to observe the increasing presence of response when the hearing aid is being used. In all of the presentations of speech sounds /m/, /g/, and /t/, in the condition of wearing a hearing-aid device, the individual reported sound perception. Therefore, there was agreement between the perception and the automatic detection, according to the proportion of automatic detection at the presence of response, 91% for /g/ and /t/ speech sounds, and ranging from 73 to 86% for the /m/ sound as reported by Durante, Wieselberg, Carvalho, Gudayo, and Almeida in 2014.

The CAEP has enormous application in the clinical findings, The acoustic characteristics of complex sounds can be reflected in the form and latency of these potentials; therefore, they can be used to determine the integrity of the neural codification of these characteristics, thus contributing with the determination of speech perception. Recent studies suggest that consonants and vowels have different representations in the central auditory system, both in laboratory animals reported by Perez, Engineer Carraway , Perry , Kilgard in 2013and Kuuluvainen , Nevalainen , Sorokin , Mittag , Partanen , Putkinen 2014.

In this study, results with the use of speech sounds suggest that CAEPs can be used as an objective tool to assess the characteristics of amplification and the validation of hearing-aid fittings, thus enabling the measurement of audibility of speech sound amplification among individuals who cannot collaborate, which is also stated by Golding, Dillon, Seymour, and Carter in 2009. However the findings from the present study depicts the minimal hearing aid gain or the hearing aid properties requires to elicit the CAEP but the better or poorer speech perception cannot be always concluded, the mentioned studies are in partial support with the present findings.

Effect of gain on CAEP

In the literature there are effects of intensities are been studied as the stimulus intensity increases, the CAEP components become shorter that is the neural conduction time required and the better amplitude indicating the strength of the system. Adler, Adler in 1989.The reduced latency of components P1, N1 and P2, with the use of hearing-aid devices, is also expected. Such an effect occurs independently if sound is presented in the free field, with or without hearing-aid devices. However the effect of sound amplification could not be very well established such facts could be justified that such a fact could be justified because sound amplification does not have the same effect as the real increase in sound intensity.

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The hearing-aid device changes the characteristics of the stimulus, as well as the relationship signal/noise, which may affect the capture of AEP. These findings reinforce the importance of controlling the characteristics of the hearing-aid device and the levels of intensity of the stimulus when the individual is assessed wearing a hearing-aid device. By testing the same person in different evaluation sessions, or even by comparing the response of individuals, it is important to mention different gain adjustments of the hearing device.

Therefore, in this present study confirms of that CAEP can be used to verify the hearing aid and it is one of the objective tool for providing the validation for the amplification however ever the CAEP can comment on the minimal gain of the hearing aid requires to elicit the cortical response and the gain required elicit the better speech perception can be exhibited through behavioural outcomes and as it is evaluated with the different hearing aid gain hence the changes in the hearing aid gain could not be very well established though the CAEP outcomes has been reported by Purdy, Katsch, Dillon, Storey, Sharma in 2005.

Although the original issue of amplification seeming to have no effect on cortical responses need not further be considered based on these findings, discussion in the literature over the appropriateness of using cortical potentials to assess hearing aid fittings has raised several other issues that might affect the validity of assessing hearing aid fittings using cortical response measurement. Hearing aids typically employ non-linear processing, which certainly can change the acoustics of speech, either by design or as a by-product of their intended effect. This is not inherently a problem. If the purpose of performing cortical response measurement is to determine if speech is audible when the hearing aid is being worn in real life, then it is desirable that the hearing aid also affects the acoustics of the speech signal during the cortical response measurement.

Conclusion

This study aimed on investigating the hearing aid gain on CEAP amplitude and latency of the participants with hearing loss. It also investigated the relationship between the cortical responses and speech identification, the results were found that CAEP amplitude did not show much difference across the gain this significantly revealed probably due degree of hearing loss and duration of the hearing aid usage, hence this was preliminary study this can implemented in larger sample and also with different hearing loss and duration of the hearing aid usage.

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