

## Original Research Article

# Effect of hearing loss on P300 measures

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### ABSTRACT

**Background:** P300 is among the first auditory responses in a collection of event-related or endogenous evoked responses. Hearing loss has drastically reduced cognitive abilities in individual adults. P300 is used as an electrophysiological tool to assess cognitive functions. This study was framed to compare the effect of hearing loss in P300 amplitude and latencies in Indian population. As no such study was carried out in Indian population, this study will be helpful in evaluating the correlation between hearing loss and cognitive function.

**Methods:** We recruited a total of 60 participants out of which 30 were in group 1 having normal hearing and other 30 were included in group 2 having hearing loss. P300 was obtained using a Neurosoft instrument using tone burst stimuli. The acquisition of tonal stimuli was carried out in a sound-treated room.

**Results:** The t test value ( $t=4.75$ ,  $p<0.001$ ) for P300 amplitude indicates that the difference between the mean among normal hearing and hearing-impaired adult was statistically significant. But the  $p=0.68$  for P300 latency which indicates that the difference between the two groups is not statistically significant, which accepts hypothesis that There would not exist any relationship of P300 latency in normal hearing- and hearing-impaired adults. Pearson's correlation was found that hearing loss and amplitude of P300 has a strong negative correlation and latency of P300 has a poor positive correlation with hearing loss.

**Conclusions:** Hearing loss affects the P300 measures. Due to hearing loss cognitive decline occurs which results in reduced amplitude and prolonged latency in P300.

**Keyword:** P300, Hearing loss, Cognition and hearing loss, Event-related potentials, Sensorineural hearing loss

### INTRODUCTION

P300 is among the first auditory responses in a collection of event-related or endogenous evoked responses.<sup>1</sup> The P300 response is essentially a component within an extended ALR time frame that is under special stimulus conditions. The largest positive wave occurring at about 300 ms to 500 ms and whose amplitude of approximately 4-12  $\mu$ v was related to the probability of the stimulus.<sup>2</sup> The P300 is related to cognition and the use of knowledge about the environment. It may be bifocal, having "a" and "b" components. P300 is triggered by the hippocampus, where the short-term memory functions are stored, and is dependent on the internal thought process.<sup>3-6</sup> P300 has thus been found useful in the study

of memory, memory disorders, sequential information processing, and decision-making.<sup>7</sup> The anatomical and physiological changes or alterations in the auditory system due to the pathological condition or aging process leads to hearing loss. Therefore, hearing loss is the result of impaired physiological auditory system. Hearing loss and cognitive impairment are common problems and are associated with each other.<sup>8</sup> Hearing loss has drastically reduced cognitive function in individual adults.<sup>9</sup> P300 is used as an electrophysiological tool to assess cognitive functions.

Reis et al studied P300 in subjects with severe or profound sensorineural hearing loss. The P300 findings were statistically significantly correlated with the

duration of hearing loss ( $p < 0.0001$ ) and the degrees of hearing loss ( $p = 0.04$ ).<sup>10</sup> Noppamont et al conducted a study to compare the auditory P300 results of elderly patients with sensorineural hearing loss (SNHL) before and after hearing aid use. The findings show that just 21 subjects were able to capture P300 waveforms, which had a mean amplitude of 6.68 microvolts ( $\mu V$ ) and a mean latency of 374.48 milliseconds. The mean amplitude was 8.77  $\mu V$  and the mean P3 latency was 376.83 ms at two months after using hearing aids. Before and after using hearing aids, there was a statistically significant difference in the amplitude of P300 ( $p = 0.004$ ).<sup>11</sup>

As all the studies were conducted in foreign countries and with various parameters, this study was framed to compare the effect of hearing loss in P300 amplitude and latencies in Indian population. As no such study was carried out in the Indian population, this study will help evaluate the correlation between hearing loss and cognitive function.

### **Aim and objectives**

The study aimed to evaluate the effect of hearing loss in P300 measures. To obtain the result, the objective of the study was to perform P300 by using tone burst stimuli in normal hearing and hearing-impaired adults. After getting the responses the results were compared between groups.

## **METHODS**

### **Study design**

In this study, a simple survey design was employed to perform instrumental procedures and to observe its effects or responses. To support a hypothesis, the impacts of various independent factors on the dependent variables were compared. For this study, essentially a comparative experimental research approach was used. The study was carried out at the audiology department, AYJNISHD(D), Mumbai from January 2023 to November 2023.

### **Participants**

Recruited total of 60 participants out of which 30 were in group 1 having normal hearing and other 30 included in group 2 having hearing loss. Age range in group 1 was 18 to 40 years ( $M = 23.73$ ,  $SD = 1.90$ ). The mean age for group 2 was 28 years and  $SD = 6.40$ . In group 1 participants had a normal hearing threshold i.e.,  $PTA < 25$  dBHL in both the ear. In group 2 mean PTA in left ear is 36.19 ( $SD = 6.23$ ) and in right ear is 43.56 ( $SD = 12.89$ ).

### **Inclusion criteria**

#### **Group 1**

Individuals having normal hearing sensitivity were included in group 1. Participants must pass the ACE screening test.

#### **Group 2**

Individuals having sensorineural hearing loss at least in 1 ear included in group. They must pass ACE screening test. Normal cognitive abilities participants were added.

### **Exclusion criteria**

#### **Group 1 and 2**

Participants wearing amplification devices more than 2 month were excluded from this study. Individuals who have conductive/mixed hearing loss were excluded from this study. Participants who had other disorders, reading writing problems, any neurological problems, and left handedness participants were excluded from this study.

### **Materials**

#### **Addenbrooke's cognitive examination III**

Addenbrooke's cognitive examination III (ACE) is a screening test that usually takes 15-20 minutes to administer and is composed of tests of attention, memory, language, orientation, visual perceptual, and visuospatial skills. The participants who passed this test will be included in the study.

#### **P300**

**Test environment:** The acquisition for tonal stimuli was carried out in a quiet room.

**Subject preparation:** The subjects were seated comfortably. The electrode placement sites were cleaned using abrasive skin prepping gel i.e. Neuoprep solution. 10-20 conduction gel was used for optimizing electrode conductivity and electrodes were fixed to the site using microporous adhesive tape. The accepted electrode impedance was up to 5 kilo-ohms.

**Subject instruction:** You will hear a continuous beep-like sound and in between their sound you will hear infrequent high-frequency sound, have to pay attention to infrequent sound and press the button at same time.

**Presentation and task orientation:** The target stimuli (rare, abnormal, and uncommon stimuli) were delivered at 2 KHz at an intensity level of 30 dB SL. At 1 kHz and 30 dB SL, the baseline stimuli, or frequent stimuli, were provided. The oddball paradigm was used to offer uncommon stimuli at random. Rare stimuli were requested to be subjects' focus instead of baseline stimuli.

**Acquisition parameters:** Although single-channel recording was always used it is recommended to use dual-channel electrodes for better acquisition of results. In the normal individual, the maximum may occur from Cz to Pz. The nontarget (standard or frequent stimuli) and targets (rare stimuli) are averaged independently.

**Analysis time:** As the P300 peak may be obtained between 200 msec to 600 msec, the analysis time window was kept up to 700 msec.

**Electrode sites:** An electrode positioned at Fz, Cz, Pz, for the non-inverting electrode, and between C7 for the inverting electrode, can record the P300. The ground may be placed at Fpz. Linking of the inverted electrodes is usually done in P300 recording which leads to a "balanced reference"-so equal contribution from both ears and hence difference across scalp electrodes is attributed to hemispheric effect than the ear effect. A slight normal variation appears in the maximum amplitude of the P300 from individual to individual between Cz and Pz.

**Filter settings:** The typical low pass filter settings were on the order of 30 to 50 Hz, while the typical high pass filter settings were in the range of 0.01 to 0.25 Hz was used. Notch filter was turned off because important frequencies in the response will be removed.

**Averaging (No. of sweeps):** No. of stimulus presentations (repetitions or sweeps) must be adequate to produce SNR that permits detection of P300. Usually, no. of sweeps taken is 250/<500. No. of sweeps used was 400.

**Identification of latency and amplitude of P300:** Analysis of P300 waveform was done by the averaging process. A minimum of two tracings of both infrequent and frequent stimuli were recorded per patient for increased reliability. Tracings were then averaged. The wave with the highest positive peak after the N1-P2-N2 complex was selected. Latencies and amplitudes of the P300 response were marked on this curve. Latency measures were made at the centre of peak, whereas amplitude measures were made at the location of the largest slope in the peak. The latency reference values used were 225 to 265 ms while the amplitude reference values ranged between 5 to 20  $\mu$ v. Amplitude was marked from the N2-P3 waveform.

**Table 1: Parameters used in this study to obtain P300.**

| Parameters                         | Value                  |
|------------------------------------|------------------------|
| Stimulus type                      | Tone burst             |
| Analysis epoch                     | 250-700 ms             |
| Non-meaning full tone              | 30 dBSL                |
| Rare or meaningful tone            | 30 dBSL                |
| Filters: high pass cut off         | 50 Hz                  |
| Low pass cut off                   | 0.1 Hz                 |
| Frequency of meaning full tone     | 2000 Hz                |
| Frequency of non-meaning full tone | 1000 Hz                |
| Probability of target tone         | 20%                    |
| Transducer type                    | Insert earphone: Er-3A |
| Rate of stimuli                    | 1.1/Sec                |
| Polarity                           | Alternating            |
| Amplification                      | 75000                  |

## Procedure

The study was approved by the ethical committee of Maharashtra university of health science, Nashik. Written consent was obtained from each of the participants. A detailed case history was collected from each of the participants which included the history of hearing loss, causes of hearing loss, handedness, etc. Participants who were left-handed and history of conductive hearing loss were excluded from this study. After completing the case history otoscopic examination was carried out.

Pure tone audiometry (PTA) was carried out in Resonancer37a clinical audiometer for octave frequencies in a sound-treated two-room setup, with noise levels within permissible limits. (ANSI S3.1). Pure tone air conduction and bone conduction thresholds were determined for octave frequencies from 250 Hz to 8000 Hz by using a TDH-39 circumoral transducer and a B-71 bone vibrator respectively. Participants having a normal hearing threshold were included in group 1 and the hearing impaired were included in group 2. Immittance audiometry was conducted to rule out any middle ear pathology. After completing this P300 was obtained using a Neurosoft instrument according to above mentioned parameters. The acquisition of tonal stimuli was carried out in a sound-treated room. Participants were allowed to take a short break during the entire process. After collecting data all the data were analysed using SPSS-26 version software.

## RESULTS

In this normal hearing group total of 30 participants (12 female) having age range 19-40 years participated in this study. The mean PTA in the left ear was 9.16 (SD=3.12) and in the right ear was 9.27 (SD=3.87). The latency value of P300 varies from 258.00 msec to 424.20 msec. The mean latency was estimated as 333.70 msec. we found a standard deviation of 39.80 in latency. The range of amplitude varies from 2.20 to 7.90  $\mu$ v. The mean value stands at 5.43 and the standard deviation of 1.34.

In this hearing-impaired group total of 30 (13 females) participants having the age range of 18-40 participated in this study. The mean PTA in the left ear was 36.19 (SD=6.23) and in the right ear was 43.56 (SD=12.89). The latency value of P300 varies from 256.70 msec to 371.40 msec. The mean latency was estimated as 337.56 msec. we found a standard deviation of 31.47 in latency. The range of amplitude varies from 2.10 to 5.50  $\mu$ v. The mean value stands at 3.95 and the standard deviation of 1.02.

As all the data are normally distributed parametric test will be implemented to evaluate the significant difference between the two groups. To ascertain if the difference between the amplitude and latency of P300 in normal hearing and hearing-impaired adults is statistically significant independent sample t test was applied. The t

test value ( $t: 4.75, p < 0.001$ ) for P300 amplitude indicates that the difference between the mean among normal hearing and hearing-impaired adult was statistically significant, which rejects hypothesis i.e., there would not exist any relationship of P300 amplitude in normal hearing- and hearing-impaired adults. But the  $p=0.68$  for P300 latency which indicates that the difference between the two groups is not statistically significant, which accepts the hypothesis that there would not exist any

relationship of P300 latency in normal hearing- and hearing-impaired adults.

Pearson's correlation was conducted to estimate the correlation between hearing loss and P300 amplitude and latency. It was found that hearing loss and amplitude of P300 has a strong negative correlation ( $r=-0.916, p < 0.05$ ). latency of p300 has poor positive correlation with hearing loss ( $r=0.312, p > 0.05$ ).

**Table 2: Demographic details of participants.**

| Groups  | N  | Gender |        | Mean age (in years) | Standard deviation |
|---------|----|--------|--------|---------------------|--------------------|
|         |    | Male   | Female |                     |                    |
| Group 1 | 30 | 18     | 12     | 23.3                | 2.6                |
| Group 2 | 30 | 17     | 13     | 35.67               | 4.65               |

**Table 3: Descriptive statistics of normal hearing adult group.**

| Variables      | N  | Mean   | SD    | Skewness | Kurtosis |
|----------------|----|--------|-------|----------|----------|
| P300 amplitude | 30 | 5.43   | 1.34  | -0.60    | 0.27     |
| P300 latency   | 30 | 333.70 | 39.80 | 0.65     | 0.91     |

**Table 4: Descriptive statistics of hearing-impaired adult group.**

| Variables | N  | Mean   | SD    | Skewness | Kurtosis |
|-----------|----|--------|-------|----------|----------|
| Amplitude | 30 | 3.95   | 1.02  | -0.32    | -0.84    |
| Latency   | 30 | 337.56 | 31.47 | -1.46    | 0.91     |

**Table 5: Pearson's correlation coefficient test of hearing loss and P300.**

| Variables    | P300 amplitude | P300 latency |
|--------------|----------------|--------------|
| Hearing loss | $r=-0.961$     | $r=0.318$    |
|              | $p=0.000$      | $p=0.87$     |

**Table 6: Independent sample t test of P300 measures between normal hearing and hearing-impaired group.**

| Variables | T value | Df | Mean difference | P value |
|-----------|---------|----|-----------------|---------|
| Amplitude | 4.75    | 58 | 1.47            | 0.0001  |
| Latency   | -0.41   | 58 | -3.86           | 0.67    |

## DISCUSSION

The main aim of the test was to evaluate the effect of hearing loss on cognitive abilities by using P300 test. P300 was estimated in both normal hearing and hearing-impaired individuals. To determine whether there is any discernible difference between the P300 amplitude in healthy and hearing-impaired people, an independent sample t-test was applied. Between these groups, the study discovered a statistically significant difference. Adults with normal hearing have a higher amplitude than adults with hearing loss, which is consistent with Ana Cláudia Mirandola Barbosa Reis's (2015) earlier research.<sup>10</sup> In this investigation, there was no discernible difference between the groups' P300 latency estimates. This indicates that hearing loss has a significant effect on the amplitude of P300 but not on the latency of P300. As we know P300 measures are used to estimate the cognitive ability of individuals, and hearing loss has an

impact on cognitive decline. Numerous studies have demonstrated the impact of hearing loss on cognitive decline and the risk of dementia, particularly in older adults who also have hearing loss.<sup>12-15</sup> Additionally, this study showed that those with hearing loss had declining cognitive ability. The amplitude of P300 is the best indicator to evaluate cognitive abilities. In general, normal hearing adults have a higher amplitude ranging from 4  $\mu V$  to 12  $\mu V$ .<sup>16</sup> Due to auditory deprivation and loss of neural synchrony in the higher-order auditory system, the memory of hearing-impaired persons declines. Based on epidemiologic studies, there appears to be a link between dementia risk and hearing loss. This implies that focused interventions for hearing loss might be crucial in preventing dementia. Reis et al in his study found decreased amplitude and increased latency in profound sensorineural hearing loss individuals.<sup>10</sup> This study also reveals a similar result. Mongkalanantakul et al in his study found the P300 waveforms, with a mean



latency of 374.48 milliseconds and mean amplitude of 6.68 microvolts ( $\mu$ V) in hearing-impaired adults which was higher in comparison to our study.<sup>17</sup> That might be due to the use of speech stimuli and also the placement of electrodes.

A limited sample size was used to conduct the study. In group 2 the hearing loss of participants was restricted up to moderately severe SNHL. We used simple tone burst stimuli instead of speech stimuli which are the main limitations of the study.

## CONCLUSION

We can conclude from this study that hearing loss has drastically reduced the amplitude of P300 and increased the latency of P300. However, we did not find a statistically significant difference in terms of latency of P300 between normal hearing and hearing-impaired adults. This finding will be helpful while evaluating cognitive functions in persons with hearing impairment. From this study, we can conclude that P300 can be obtained in individuals with hearing impairment. This P300 can be used to evaluate the outcome results after rehabilitation.

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*Ethical approval: The study was approved by the Institutional Ethics Committee*

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