Effect of Transcranial Direct Current Stimulation (Tdcs) On Auditory Evoked Potentials among Senior Citizens Aged 60-70 Years With Dementia

Yamini BK*[1],

Srividya A[2],

Palanimuthu Thangaraju Sivakumar[3]

ABSTRACT

Background: Auditory Event-related potentials (AEP's) provide insights into auditory perception, phoneme discrimination, language processing, and other cognitive processes. Bi-syllabic minimal pairs may be more challenging because they require processing and discrimination of more complex phonemic structures.

Aim: The aim of the study was to elicit and analyze the AEP's for bi-syllabic word stimuli in Kannada language among individuals with dementia, and to analyze the impact of Transcranial direct current stimulation (tDCS) on the AEP's.

Method: The prospective study was conducted on fifteen native kannada language speakers (5 male; 10 female) aged 60 -70 years diagnosed with Dementia. The naturally produced and recorded CVCV tokens (/ko:ti/-/ko:thi/; /a:me/-/a:ne/) in Kannada were used in auditory oddball paradigm to record the prominent peak for word (PPW) AEP's. The tDCS was administered for 10 sessions for each participant and the PPW were used to obtain the latency and amplitude, and pre and post tDCS were analyzed.

Results: Mean and SD values for the latency (msec) of the PPW and the amplitude (μV) of PPW were compared pre and post tDCS. The results indicated no statistically significant difference in both PPW latency and amplitude values, pre and post (p > 0.05). However, a change is observed in the values after the intervention for both stimuli.

Conclusion: Though the results of PPW are not conclusive of the effect of tDCS among patients with dementia, it was seen that the participants showed in a variability which can be explored with more participants, language backgrounds. The present findings are promising in the context of an intervention for subjects with impaired ability to process temporal acoustic features in the speech signal.

Keywords: Evoked potentials, Minimal pairs, tDCS, cognitive functions, auditory perception, Dementia, odd-ball paradigm.

[1]Post-Doctoral Fellow- ICSSR, Department of Speech Pathology and Audiology, NIMHANS, Bangalore
[2]Professor, Department of Speech Pathology and Audiology, NIMHANS, Bangalore
[3]Professor, Geriatric Psychiatric Unit, Dept. of Psychiatry, NIMHANS, Bangalore

*Send correspondence to
Yamini BKProfessor, Department of Speech Pathology and Audiology, NIMHANS, Bangalore, Tel: 99802 29280, Email:yaminihk@gmail.com

INTRODUCTION

Dementia is decline in cognitive abilities, such as memory, language, problem-solving, and judgment, that disrupt daily life. Individuals with Dementia can have difficulty understanding speech, especially in noisy settings or during group conversations, or recognizing familiar voices, follow conversations, or locating sound sources. Non-invasive Auditory Evoked Potentials (AEPs) can help assess auditory perception at different levels, including the auditory cortex. They do not require active participation of the testee, which can be an advantage for individuals with cognitive or physical limitations like in Dementia.

The P300 /P3wave is a long-latency Event-Related Potential (ERP) triggered by auditory or visual stimuli providing insights into auditory perception, phoneme discrimination, language processing, and other cognitive processes[1]. P300 is measured using the oddball paradigm, where rare target stimuli are mixed with frequent ones. Studies have looked into the ERP responses elicited by tonal stimuli, vowels or bi-syllables words indicating that longer stimulus durations result in increased latency and decreased amplitude[2-15].

Higher P300 latency in Alzheimer's Dementia(AD) patients than controls was reported also increased P300 latency and reduced amplitude among AD compared to healthy elderly and those with mild cognitive impairment[16-20]. Brain areas generating the P300 wave, such as the central-parietal cortex, frontal cortex, and hippocampus, are often affected in AD. Involvement of the cholinergic system in these regions further increases P300 latency in AD patients.

Hedges et al. (2016) revealed that P300 amplitude was smaller in AD subjects compared to healthy controls. This reduction in P300 amplitude was consistent across various brain regions, suggesting that it may serve as a biomarker for the early diagnosis of AD[21]. Srividya, et.al, (2024) reported PPW using bi-syllabic word stimuli in the Kannada language among individuals with dementia with the latency 545 ± 38 msec and the amplitude 2.5 ± 1.5 μV. They suggested that when lengthier speech stimulus duration was used, the latency value of auditory ERP was higher[15].

In individuals with dementia, the P300 wave is often found to be reduced in amplitude, delayed or even absent. This is thought to be related to the damage or dysfunction of specific brain regions, such as the temporal lobes, which are involved in attention and memory processes. Thus, P300 can be used as a biomarker of cognitive impairment related to dementia. However, this is still an active area of research, and more studies are needed to confirm the utility of P300 as a diagnostic tool for dementia.

Brain stimulation techniques are also used in patients with dementia. Non-invasive brain stimulation (NIBS) techniques use electromagnetic fields or electric currents to stimulate the brain without surgery. Transcranial

direct current stimulation (tDCS), one of the NIBS, uses electrodes to apply a constant, low-intensity electric current to the scalp, used for for enhancing cognitive and motor functions because of the low cost, portability, comfort, ease of use, and safety[22]. It is inexpensive and induces rare and mild side effects. It is not included in protocol for treatment of Dementia but some studies have suggested that tDCS may have the potential to improve cognitive function in individuals with dementia[23,24].

tDCS is used to modulate cortical excitability, producing either facilitatory or inhibitory effects on various behaviors. It involves applying a weak electrical current to the scalp through two electrodes. Anodal stimulation depolarizes neurons, increasing the likelihood of action potentials, and enhances excitability in the target cortical region whereas cathodal stimulation hyperpolarizes neurons, reducing the probability of action potentials and decreases excitability in the motor cortex[25-27].

The impact of tDCS on cortical auditory excitability and its corresponding influence on auditory processing, and in particular on hearing rehabilitation was reported[28]. tDCS applied over the dorsolateral prefrontal cortex (DLPFC) led to significant improvements in memory attention and executive function and working memory and attention in patients with AD[29-31]. Methodological heterogeneity across studies, including variations in stimulation parameters and outcome measures, participant characteristics complicates data interpretation and limits generalizability.

The effects of tDCS on reveal that tDCS does not broaden auditory frequency selectivity but instead degrad the ability to discriminate tones[32]. They recommend anodal tDCS when applied over the auditory cortex degrades frequency discrimination by affecting temporal, but not place coding mechanisms. Neurophysiological functions before and after tDCS, showed a reduction in latency of P300, proposing a faster cognitive process. An increase in P300 amplitude, suggesting a stronger neural response to cognitive stimuli. tDCS could be a treatment option for improving both neurophysiological and cognitive aspects in patients with vascular dementia[33].

Anodal tDCS showed statistical difference in post tDCS P300 potentials[34]. Repeated sessions of tDCS improved cognitive function or reduced the P300 latency in AD patients[31]. P300 amplitude also showed significantly increase following repetitive anodal TDCS[35]. Anodal frontal tDCS significantly increases amplitude of P300 recorded from parietal site but no effect was seen on latency[36]. Long term tDCS reduced the P300 latency, but had no effect on motor cortex excitability[37]. Anodal stimulation over the temporal cortex increased P50 amplitudes, while cathodal stimulation of temporo-parietal areas increased N1[38].

While studies revealed anodal tDCS caused an increasing effect, some recent studies showed no change or showed reduction in AEP[38-41]. The findings of studies involving the behavioural effects of tDCS on auditory temporal analysis are conflicting. Some studies reported that anodal tDCS

has a performance increasing effect in behavioral tasks that measure auditory temporal processing skills, while some studies reported a performance decreasing effect. Based on the these studies and conflicting results, there is limited understanding about the effects of tDCS on auditory temporal analysis[42-44]. The aim of the study was to analyse the effect of tDCS on auditory evoked potentials among senior citizens aged 60-70 years with Dementia.

METHODS

The prospective, observational study was conducted at the Department of Speech Pathology and Audiology, with both qualitative and quantitative comparison between groups. Convenient sampling was used. Based on the study done by Khedr, et.al,2014, the sample size was calculated using the GPower software and a two-tailed hypothesis design formula with superior design model testing for a duration of two years with a power of 80% at 5% level of significance and 1:1 allocation[31]. The minimum sample size was estimated to be around 13, for the group of dementia patients for the present study. The study design used was an observational study with within-group comparison.

Participants

Fifteen native Kannada language speakers (5 male ;10 female), aged 60 -70 years (Mean 64 ± 2) were recruited from the unit of Geriatrics clinic of the Hospital. The participants had no co-morbid conditions, were diagnosed with dementia by experienced geriatric Psychiatrists after comprehensive clinical assessment using clinical symptoms, according to the criteria established by the DSM V and Mini-Mental State Examination (MMSE) [45]. The severity of Dementia ranged from mild to severe, with Clinical Dementia Rating Scale rating ranging from 2-3. The participants were diagnosed as Frontotemporal dementia or Alzheimer's dementia based on the Brain Positron Emission Tomography Magnetic Resonance Imaging (PET-MRI) reports. Persons with the same dementia criteria but with any co-morbid conditions like cerebrovascular disease, or another ongoing neurological / psychiatric disease or a non-neurological medical condition, or with history of the use of medication with a substantial impact on cognition, or epilepsy were excluded (**Table 1**).

Addenbrooke's Cognitive Examination III in Kannada (ACE III-K), a brief cognitive screening tool, was administered on all the participants[46]. The ACE-III is a simple, brief, paper-and-pencil-based measure of global cognitive function, covers five cognitive domains with total score of 100 points. 18 points are for the attention and orientation domain, 26 for memory, 14 for verbal fluency, 26 for language, and 16 points for the visuospatial domain. A higher score is interpreted as better cognitive ability.

Table 1: Demography details of the patients.

Pt Id	Age	Gender	Radiological observation	Dementia type	ACE scores
1	61	F	Mild diffuse cerebral atrophy predominant in left temporoparietal region including left hippocampus, hypometabolism in left perisylvian area	Dementia in Alzheimer s disease with early onset	17
2	63	M	Bilateral cerebral atrophy	Mixed dementia with Pick's disease	17
3	65	F	Diffuse Cerebral atrophy	Dementia in Alzheimer s disease, unspecifed, Without additional symptoms	49
4	68	M	Hypometabolism in left temporal lobe	Frontotemporal Dementia (Language variant)	18
5	65	F	Ischemic changes seen bilaterally ,Vascular dementia	Dementia in Alzheimer s disease with late onset	15
6	66	F	Age related cerebral atrophy with old infarcts	Dementia in Alzheimer s disease	53
7	60	F	Atrophic changes in supra tentorial neuroparenchyma with predominant involvement of medial temporal and frontal regions microvascular ischemic changes	Dementia in Alzheimer s disease with early onset	15
8	64	M	Hypometabolism in anterior cingulate gyri, bilateral frontal lobes, hippocampi, medial temporal, anterior and lateral temporal regions	Frontotemporal Dementia (Language variant)	11
9	65	F	Bilateral cerebral atrophy	Dementia due to Alzheimer disease with early onset	33
10	69	F	Diffuse Cerebral atrophy	Dementia in Alzheimer s disease with late onset	41
11	69	F	Diffuse Cerebral atrophy with small ischemic changes	Dementia in Alzheimer s disease with early onset	89
12	64	M	not done	Dementia in Alzheimer s disease with early onset	11
13	67	M	Moderate Cortico-cerebellar atrophy with bilateral perfusion in fronto-occipital region	Alzheimer disease dementia	33
14	62	F	Diffuse Cerebral atrophy with small ischemic changes	Alzheimer disease dementia	6
15	69	F	Mild diffuse cerebral atrophy predominant in left temporoparietal region	Frontotemporal Dementia (Behavioural variant)	25

*F: Female, M: Male

Audiological profile of the participants

The pure tone auditory thresholds at 250 to 8KHz octave frequencies ranged from 40-60 dBHL, with air-bone gap (ABG) </=10 dBHL for all participants. The speech reception thresholds evaluated using Kannada spondee words correlated with the pure tone average, and they all had a speech discrimination scores within 75-95% for PB (Phonetically balance) Kannada word list. All the participants had mild to moderate sloping sensory neural hearing loss with correlating auditory brainstem responses. Represents the Pre- and Post-tDCS scores of PTA, SRT, SDS, Tympanogram and DPOAE in Right and Left Ears of Kannada-Speaking Patients (**Table 2**).

Procedure

The study was approved by the Institutional Ethics Committee of the Institute where the data was collected. Each participant and his/her legally accepted relative were informed in Kannada language about the need, expected duration, details of the procedure. The evaluation was done after the latter provided voluntary written consent (**Flow Chart 1**).

The tDCS procedure was conducted using standard equipment and strict safety protocols. Two conductive siliconized rubber electrodes housed in 0.9% saline-soaked sponge pockets (7x5 cm^2) were utilized, designated as the anode and cathode for stimulation delivery. According to the 10-20 international electrode placement system, the anode electrode was placed over the left DLPFC at the F3 position, while the cathode was positioned over the contralateral supraorbital ridge (Fp2). The F3 location was determined using F3 beam method software. To maintain electrode stability, non-conductive rubber straps were used to secure the electrodes around the participant's head. A constant current of 2 mA was administered for 30 minutes, incorporating ramp-up and ramp-down phases of 20 seconds at both the beginning and end of the session. Tolerance and skin sensations related to the tDCS procedure were assessed after each session using a structured questionnaire. Following a regimen of one daily tDCS session over a span of 10 days, assessments were repeated to evaluate any changes or effects resulting from the treatment. The tDCS was implemented using a program called WISER (Weak Intensity Stimulation for Enhancement and Re-integration), a neuromodulation device developed under the WISER Neuromodulation Program of NIMHANS (National Institute of Mental Health and Neuro Sciences), as part of the Instar (Individualized Schizophrenia Treatment and Reintegration) Clinics.

Auditory Event Related Potential Equipment and Procedure

A two-channel auditory evoked potential system, Intelligent Hearing Systems- Duet Smart EP version 3.54 was used to record latency and amplitude of the auditory evoked potentials.

The participants were seated in a comfortable, reclining chair within a sound-treated room and given instructions to focus on the stimuli. They were directed to remain attentive and avoid sleeping. Although no responses to the stimuli were required, staying alert was emphasized. Minimizing eye movements or blinks was encouraged to enhance the quality of the recorded results. After using the cleaning gel to clean each of the five electrode locations, conduction paste was used to place the gold-plated electrodes. Impedance between the electrodes was maintained at less than 5 KΩ and artefact rejection threshold of 250 microvolts was set. Electrode placement was done at Fz and Pz (recording sites), and on the forehead at Fpz (ground) according to the International 10-20 system[47]. To track eye movement, two more electrodes were positioned above and below the right eye to record an electrooculogram (EOG). The EEG was amplified and averaged using a filter bandpass of 1-30 Hz. Automatic artefact rejection facility was used. The details of the acquisition and stimulus parameters used to record Auditory evoked potential using minimal pair bi-syllabic stimuli in Kannada are represented (**Table 3&4**).
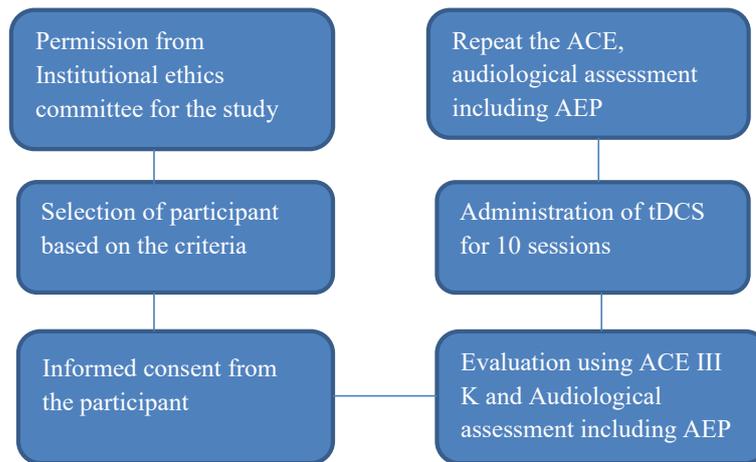
The naturally produced and recorded bi-syllabic words i.e. CVCV (Consonant vowel consonant vowel) tokens (/ko:ti/ (429 msec) and /ko:thi/ (421 msec); /a:me/ (326 msec). and /a:ne/ (359 msec)) were incorporated in an auditory oddball paradigm with a low-probability C1V1C2V2

Table 2: Pre and Post-tDCS Comparison of PTA, SRT, SDS, Tympanogram and DPAOE in Right and Left Ears.

Variables	Right ear Mean±SD		Left ear Mean±SD	
	Pre tDCS	Post tDCS	Pre tDCS	Post tDCS
PTA in dBHL	25.3 ± 12.7	24.8±11.2	29.2±14.7	27.9± 12.5
SRT in dB	31.3 ± 12.4	30.6 ±11.3	33.3 ± 14.8	32,6 ± 13.9
SDS in %	83.3 ± 18.7	84 ± 17.6	82 ± 20.4	82.6 ± 20.1
Tympanogram (n=15)	12 A type	12 A type	11 A type	11 A type
	2 B type	2 B type	3 B type	3 B type
	1 As type	1 As type	1 As type	1 As type
DPAOE (n=15)	6 present	6 present	6 present	6 present
	9 absent	9 absent	9 absent	9 absent

Legend of terms used in the Table 2: Pt.- Patient; PTA- pure tone average; dBHL- Decibel Hearing Level; SRT- speech reception threshold; dB SPL- Decibel Sound Pressure Level; SDS- Speech discrimination score; PB- Phonetically balanced; DPOAE- Distortion product otoacoustic emissions; tDCS – Transcranial direct current stimulation

Flow Chart of the Procedure of the Study

```
┌─────────────────────────┐      ┌─────────────────────────┐
│ Permission from         │      │ Repeat the ACE,         │
│ Institutional ethics    │      │ audiological assessment │
│ committee for the study │      │ including AEP           │
└─────────────────────────┘      └─────────────────────────┘
            │                                 │
┌─────────────────────────┐      ┌─────────────────────────┐
│ Selection of participant│      │ Administration of tDCS  │
│ based on the criteria   │      │ for 10 sessions         │
└─────────────────────────┘      └─────────────────────────┘
            │                                 │
┌─────────────────────────┐      ┌─────────────────────────┐
│ Informed consent from   │      │ Evaluation using ACE III│
│ the participant         │──────│ K and Audiological      │
│                         │      │ assessment including AEP│
└─────────────────────────┘      └─────────────────────────┘
```

Flow chart of the AEP procedure

```
┌─────────────────────────────────────────────────────────────────┐
│ Participants were seated in a comfortable, reclining chair        │
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Prepping the participant for AEP recording with electrode placement│
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Placement of insert earphones binaurally                          │
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Instrument setup for stimulus and recording paramteres as per the protocol│
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Instructions to the participant to be attentive and not asleep, with minimal movements│
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Stimulus presentation after the patient is stable, electrode impedance within limits│
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Recorded waveforms for both stimulus pairs, checking repeatability of the morphology│
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Repeated the recording and PPW peaks identified                   │
└─────────────────────────────────────────────────────────────────┘
                              ↓
┌─────────────────────────────────────────────────────────────────┐
│ Release of the participant from test environment                  │
└─────────────────────────────────────────────────────────────────┘
```
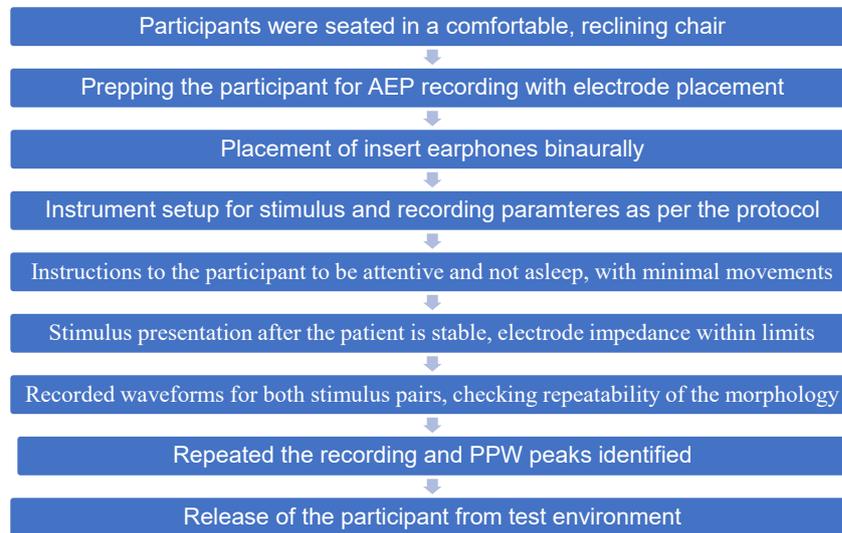
Table 3: Stimulus and recording parameters.

PPW Stimulus Parameters	/a:ne/ or /ko:thi/ - Frequent stimuli and /a:me/ or /ko:ti/. - Deviant stimuli
Intensity	70 dB SPL
Rate	0.9 / sec
Polarity	Alternating
Transducer	ER-3A insert ear phones
Presentation	binaural
% Presentations	80% Buffer 0 (frequent), 20% Buffer 1 (deviant) as in the HIS system

Table 4: PPW recording parameters.

Filter setting	1-30 Hz	
Analysis time	100 msec	
Artifact rejection	0-120 dB SPL	
Sweeps	100 sweeps	
Notch filter	Either Off or On if there is excessive electrical line noise present.	
Electrode montage	Channel 1: (midline)	Channel 2:
	Fpz (Ground)	Positive – above the orbit
	Pz (Positive)	Negative – below the orbit
	Nape of the neck behind the head (negative)	

token (/ko:ti/ or /a:me/) embedded in a stream of high probability C1V1C3V2 token (/ko:thi/ or /a:ne/). The target stimuli (20%) was low-probability C1V1C2V2 token (/ko:ti/ or /a:me/) and non-target (80%) high probability C1V1C3V2 token (/ko:thi/ or /a:ne/) and the order of occurrence was pseudo-random. The sequence was presented binaurally to each participant at a comfortable loudness level (intensity of 70 dB SPL at a rate of 0.9/ second.) using headset with IR -3A earphones connected to the computer with compatible AEP software. The rise time and fall time of the tones were 10ms while plateau time was 100ms.

Recordings containing eye blinks or movements, excessive muscle activity artefacts were either corrected with pauses while recording or rejected. If more than 15 of the 100 sweeps of a given recording were rejected for any reason, then the data in that condition for that subject was rejected. Thus, each waveform was based on a minimum of 75 sweeps. Once the presentation of the stimuli was completed, the morphology of the recorded waveform was carefully evaluated and marked for the positive peak for the word (PPW). This prominent peak for word (PPW) positive peak with clear morphology was used to obtain the latency and amplitude. The peak was found to be 100-150 msec later from the stimulus duration for the present study. This indicated the increase in duration of the time window for recording and analysis.

RESULTS & DISCUSSION

During tDCS low currents are delivered to the cerebral cortex resulting in a modulation of cortical excitability.[48] The current flows between an active and a reference electrode through the skull to the brain tissue, thereby inducing diminutions or enhancements of cortical excitability.25 The direction of the tDCS-induced effect depends on the current polarity. Anodal tDCS typically increases and cathodal tDCS decreases the cortical excitability in the region under the electrode. Electrical stimulation has an effect on cortical excitability and overall auditory abilities; the directionality of these effects is puzzling.[49] Anodal tDCS was used in the present study.

The participant's method of responding to the stimuli for eliciting PPW, was considered based on the clinical auditory event-related potential studies which employ auditory oddball task and support the hypothesis that individuals above 70 years of age are likely to have more neurodegeneration due to aging process. The cognitive tasks of auditory discrimination is too demanding to produce reliable results. Due to the high cognitive load at a rapid stimulus rate (0.9/sec), especially for those with dementia, the study recorded evoked potentials without needing participant responses. P300b tends to be more Centro-parietal, so electrodes were placed midline with a parietal Pz position. Hence passive participation and Pz electrode placement were considered to elicit PPW. In contrast to the lab-established norms, where tone stimuli lasting 100–150 msec triggered a P300 positive peak around 300 msec, the current bi-syllabic word stimuli,

lasting 330–420 msec, elicited a PPW around 600-msec. The latency of the PPW peak was measured from the time of onset of stimulus (in msec) to the appearance of the peak as displayed on the time window as mentioned in the guidelines given by Polich, 2007 for P300. For the amplitude, the negative peak-to-positive peak (like N2-P3), in μV was considered.

The mean and Standard Deviation (SD) values of latency and amplitude of PPW for both stimuli recorded at both conditions are as displayed in the (**Table 5**). For /ko:thi – ko:ti/ stimulus pair the mean and SD of latency of PPW was 616.9±36.1 in pre-tDCS and 623.3±51.1 in post tDCS condition. For the same stimulus pair, the mean and SD for amplitude of PPW was 2.034±1.6 for pre tDCS and 1.72±1.49 for post-tDCS condition. For /a:ne - a:me/ the mean and SD of latency of PPW was 620.6±39.7 in pre-tDCS condition and 615.2±34.1 for post tDCS condition. For the same stimulus pair, the mean and SD for amplitude of PPW was 1.67±1.4 for pre tDCS and 2.19±1.9 for post tDCS condition (**Table 5**).

It was seen that the mean latency value for PPW varied between the stimulus, the longer stimulus /Ko: thi- Ko:ti/ had longer PPW latency while the /a:ne- a: me/ had shorter PPW latency in both pre and post tDCS conditions. No specific trend in latency or amplitude values was seen across gender or age in these participants.

Shapiro Wilk test was conducted to assess the normality of the data, which revealed that PPW Latency /kothi:koti/ and /a:ne-a:me/ are normally distributed (p > 0.05), hence Paired t-test (parametric test) was administered to compare the latency values. While amplitude parameters failed to meet the assumptions of normality, hence, Wilcoxon signed rank test was administered to compare the amplitude values. Mean and SD is provided for parametric variables while median and interquartile range is provided for the non-parametric variables (**Table 6**). The results indicate that there is no statistically significant difference in the parameter scores between pre and post intervention periods (p > 0.05). However, a change is observed on individual basis in the values of the latency and amplitude after the intervention.

In the present study, the PPW values for latency are longer in pre-tDCS condition than typical P300 values obtained for other stimuli, and this is attributed to the longer stimuli duration. Tone and monosyllabic stimuli have been widely used in P300, providing insights into auditory perception, phoneme discrimination, language processing, and other cognitive processes. Studies have looked into the event related potential responses elicited by tonal stimuli, vowels, or bisyllables, indicating that longer stimulus durations result in increased latency[3-15].

Henkin, et al.(2002) elicited P300 using non-meaningful Consonant Vowel Consonant (CVC) stimuli which differ in their final position, the mean latency of P300 for these stimuli was longer (around 642.6 ms and 624.9 ms)[12]. When compared to non-speech stimuli, P300 latency

Table 5: Values of PPW for latency and amplitude for both stimuli for the participants.

| Patient Id | Positive peak for word stimuli (PPW) | | | | Positive peak for word stimuli (PPW) | | | |
| | PPW Latency in msec. kothi:koti | | PPW Amplitude in μV kothi:koti | | PPW Latency in msec. a:ne-a:me | | PPW Amplitude in μV a:ne-a:me | |
	Pre tDCS	Post tDCS	Pre tDCS	Post tDCS	Pre tDCS	Post tDCS	Pre tDCS	Post tDCS
1	595.5	610	6.34	1.82	589.5	585	0.97	0.5
2	645	658.5	1.74	1.01	573	561	2.2	0.79
3	580.5	613.5	0.16	0.09	631.5	670.5	1.21	0.59
4	573	585	1.61	2.8	652.5	624	2.17	1.07
5	682.5	562.5	4.5	4.96	621	612	1.35	3.61
6	582	588	2.12	0.21	672	645.5	0.41	0.36
7	642	720	1.84	3.51	672	651	0.47	1.71
8	621	613.5	2.07	0.88	627	618	0.64	1.54
9	678	720	2.92	4.28	622.5	583.5	0.61	1.91
10	606	604.5	0.31	1.42	627	628.5	1.37	1.35
11	646.5	649.5	1	0.63	561	550.5	1.19	2.63
12	579	565.5	2.61	0.54	670	612	2.03	2.83
13	583.5	600	1.02	1.5	640.5	618	2.05	1.97
14	631.5	580.5	0.36	0.9	606	657	2.23	4.29
15	607.5	679.5	1.91	1.38	544.5	612	6.2	7.74
Mean±SD	616.9±36.1	623.3±51.1	2.034±1.6	1.72±1.49	620.6±39.7	615.2±34.1	1.67±1.4	2.19±1.9

*PPW: Positive peak for word stimuli, tDCS: Transcranial direct current stimulation.

Table 6: Comparison of pre and post PPW Latency and Amplitude scores.

| | Mean ± SD / Median (IQR) | | Test statistic value | p-value |
	Pre	Post		
PPW Latency(/kothi:koti/)	616.90 ± 36.10	623.36 ± 51.15	-.527*	0.606
PPW Amplitude (/kothi:koti/)	1.84 (1.61)	1.38 (2.17)	-.369**	0.712
PPW Latency (/a:ne-a:me/)	620.66 ± 39.75	615.23 ± 34.17	.622*	0.544
PPW Amplitude (/a:ne-a:me/)	1.35 (1.53)	1.71 (2.04)	-1.477**	0.14

Legend for the table: *Paired t test, **Wilcoxon signed rank test.

reported in the Henkin, et al.(2002) study, is extremely prolonged in speech stimuli. The prolonged latency was attributed to less synchronous neural response with increase in task difficulty, longer duration of the stimuli, and the relative positioning of the acoustic cues in the linguistic stimuli (difference between standard and deviant stimuli was in the final position of the CVC stimuli).

The present study reveals that the PPW values of latency and amplitude vary pre and post anodal-tDCS conditions. Similar effect of tDCS on auditory evoked potentials are reported in literature. In general on AEPs, while some studies showed that anodal tDCS caused an increasing effect on auditory evoked potentials some recent studies showed no change or showed reduction in evoked responses[38-41]. The findings on behavioural electrophysiological effects of tDCS of Auditory Cortex (AC) on auditory temporal analysis are conflicting. Some studies reported that anodal tDCS has a performance increasing effect in behavioural tasks that measure auditory temporal processing skills, while some studies reported a performance decreasing effect[42-44]. Similarly, both improvement and disruption of performance were found with cathodal tDCS of auditory cortex[39,42].

Increase, decrease and no change in latency values of P300 pre and post tDCS have been reported in the literature. In the present study the mean values of the

PPW latency increased for /kothi-koti/ stimuli while it reduced for /a:ne-a:me/ stimuli. Decrease in latency values on P300 post tDCS was reported by Ramaraju, et.al (2014), Gangemi, et al., (2024), Voegtle, etal. (2022) and on P50-N1 latency by Zaele, et.al, (2011)[33-35,38]. They suggested that reduced latency values could indicate improved cognitive function post tDCS. These studies were however performed on healthy controls, while the present study was done on participants diagnosed with Dementia. Mendes, et.al (2022), with their systematic review study reported no tDCS effect was on P3 latency in general but also suggested long term effects may reduce the P300 latency[37].

In this study that the mean latency post tDCS increased for /ko:thi-ko:ti/ stimulus pair while it reduced for /a:ne-a:me/ stimulus pair. The mean amplitude values post tDCS decreased for /kothi-koti/ stimuli while it increased for /a:ne-a:me/ stimuli. This can be due to the innate differences between the two-stimulus pair in terms of linguistic complexity.

In terms of complexity, within the /ko:thi-ko:ti/ stimulus pair, the phonemes both /th/ and /t/ are unvoiced plosives, with place of articulation (/th/ is a alveolar plosive while /t/ is a retroflex plosive. In the /a:me-a:ne/ stimulus pair, both /m/ and /n/ are nasals continuants where /m/ is a bilabial while /n/ is an alveolar. The phonemes within the

stimulus pair differ only in one place of articulation, but between the stimulus pair, the phonemes differ in terms of manner of articulation, one being oral plosive and the other being nasal continuant. It is known from speech perception studies, that the nasal consonants are more likely to get assimilated with the neighbouring sound than the oral plosive. This makes the nasals more easier to perceive than the oral plosive. With the typical audiogram of geriatric population effecting the higher frequencies, and retaining low frequency cues, the low frequency nasal murmur is perceived making the nasal continuant stimulus pair (/a:me-a:ne/) less complex stimuli to perceive than the oral plosive stimulus pair (/ko:thi-Ko:ti/). The variation in the direction of latency and amplitude changes between both the stimuli could be thus due to the differences in the complexity levels of the stimulus pairs.

Importantly, it should be noted that the participants had mild to moderate degree of hearing loss and literature does report the hearing loss with aging plays a crucial role in cognition, speech perception. Auditory factors might be insufficient to explain individual differences in these situations because listeners with identical audiograms can have vastly different speech perception abilities[50-54].

The participants in the study are aged 60-70 years, with mild to moderate hearing loss. It is reported in literature that aging and hearing loss result in atrophy of cortical auditory regions and listening becomes effortful and cognitive load is constantly high, reducing the amount of available cognitive resources. The present findings are promising in the context of an intervention for subjects with impaired ability to process temporal acoustic features in the speech signal.

tDCS is known to have certain mild adverse effects like headache, tingling, numbness after the procedure that lasts for few hours. However during the present study it was seen that none of the participants had reported any of these.

The high variability within the sample, like duration of illness, degree of dementia, could have contributed to the results obtained. Only ACE-K scores were chosen for inclusion, the other aspects of cognition like visuo-spatial skills, language abilities, speech perception in noise, gap detection tests and other central auditory processing tests were not analysed in the present study.

LIMITATIONS

In the present study, the PPW peaks were elicited using the native language stimuli on individuals with different types of dementia, however the test can be administered on more participants with specific types and severities of dementia using their respective native languages. The sample size in this study is low which does not qualify for generalization of the application of PPW as an early indicator of speech discrimination issues. The PPW recording with active participation of the participants in stimuli identification could be compared with passive

participation. The wider sample, age rage and language stimuli can be considered in further studies to see the effect of tDCS in Dementia. The data can be studied based on the type of dementia in patients.

With respect to the electrode montage, the present study employed the conventionally used M1−contralateral superior frontal orbit arrangement, with an enlarged reference electrode (35 cm2) as suggested by Datta et al., 2009[55]. There are studies reporting slightly enhanced motor cortical excitability with multiple smaller electrodes in concentric ring arrangements[56,57]. This can be explored in further studies.

Ethical considerations and Consent for participate & publication

The study was approved by the Institutional Ethics Committee of the Institute, NIMHANS, Bangalore, where the data was collected. Each participant and his/her legally accepted relative were informed in Kannada language about the need, expected duration, details of the procedure. The evaluation was done after the latter provided voluntary written consent.

Declaration of Conflicting Interest

The authors declare that there are no conflicts of ineterest

Data Availability

"Subject to appropriate ethical and legal considerations, authors are encouraged to:

- Share your research data in a relevant public data repository

- Include a data availability statement linking to your data. If it is not possible to share your data, use the statement to confirm why it cannot be shared.

- Cite this data in your research"

REFERENCES

1. Sutton S, Braren M, Zubin J, John ER. Evoked-potential correlates of stimulus uncertainty. Sci. 1965;150(3700):1187-8.

2. Shukla R, Trivedi JK, Singh R, Singh Y, Chakravorty P. P300 event related potential in normal healthy controls of different age groups. Indian J Psychiatry. 2000;42(4):397-401.

3. Cass M, Polich J. P300 from a single-stimulus paradigm: auditory intensity and tone frequency effects. Biol Psychol. 1997;46(1):51-65.

4. Katayama JI, Polich J. P300, probability, and the three-tone paradigm. Electroencephalogr Clin Neurophysiol. 1996;100(6):555-62.

5. Massa CG, Rabelo CM, Matas CG, Schochat E, Samelli AG. P300 with verbal and nonverbal stimuli in normal hearing adults. Braz J Otorhinolaryngol. 2011;77:686-90.

6. Kalaiah MK, Shastri U. Cortical auditory event related potentials (P300) for frequency changing dynamic tones. J Audiol Otol. 2016;20(1):22.

7. Perez AP, Ziliotto K, Pereira LD. Test-retest of long latency auditory evoked potentials (P300) with pure tone and speech stimuli. Int J Otolaryngol. 2017;21(02):134-9..

8. Ramteke BB, Meshram SN. Latency and amplitude of P300 using speech and non-speech stimuli-a normative study. Int J Otorhinolaryngol Head Neck Surg. 2020;6(10):1867.

9. Tiitinen H, Sivonen P, Alku P, Virtanen J, Näätänen R. Electromagnetic recordings reveal latency differences in speech and tone processing in humans. Cogn Brain Res. 1999;8(3):355-63.

10. Beynon AJ, Snik AF, Stegeman DF, Van den Broek P. Discrimination of speech sound contrasts determined with behavioral tests and event-related potentials in cochlear implant recipients. J Am Acad Audiol. 2005;16(1):42-53.

11. Kayser J, Bruder GE, Tenke CE, Stuart BK, Amador XF, Gorman JM. Event-related brain potentials (ERPs) in schizophrenia for tonal and phonetic oddball tasks. Biol Psychiatry. 2001;49(10):832-47.

12. Henkin Y, Kishon-Rabin L, Gadoth N, Pratt H. Auditory event-related potentials during phonetic and semantic processing in children. Audiol Neurotol. 2002;7(4):228-39.

13. Lovrich D, Novick B, Vaughan Jr HG. Topographic analysis of auditory event-related potentials associated with acoustic and semantic processing. Electroencephalogr Clin Neurophysiol. 1988;71(1):40-54.

14. Weber-Fox C, Leonard LB, Wray AH, Tomblin JB. Electrophysiological correlates of rapid auditory and linguistic processing in adolescents with specific language impairment. Brain Lang. 2010;115(3):162-81.

15. Srividya A, Yamini BK, Sivakumar PT. Auditory Event-related Potentials for Word Stimuli in Kannada Language Among Native Kannada Speakers with Dementia. Indian J Psychol Med. 2025;47(2):133-41.

16. Caravaglios G, Costanzo E, Palermo F, Muscoso EG. Decreased amplitude of auditory event-related delta responses in Alzheimer's disease. Int J Psychophysiol. 2008;70(1):23-32.

17. Polich J, Ladish C, Burns T. Normal variation of P300 in children: age, memory span, and head size. Int J Psychophysiol. 1990;9(3):237-48.

18. Ball SS, Marsh JT, Schubarth G, Brown WS, Strandburg R. Longitudinal P300 latency changes in Alzheimer's disease. J Gerontol. 1989;44(6):M195-200.

19. Golob EJ, Starr A. Effects of stimulus sequence on event-related potentials and reaction time during target detection in Alzheimer's disease. Clin Neurophysiol. 2000;111(8):1438-49.

20. Patterson JV, Michalewski HJ, Starr A. Latency variability of the components of auditory event-related potentials to infrequent stimuli in aging, Alzheimer-type dementia, and depression. Electroencephalogr Clin Neurophysiol. 1988;71(6):450-60.

21. Hedges D, Janis R, Mickelson S, Keith C, Bennett D, Brown BL. P300 amplitude in Alzheimer's disease: a meta-analysis and meta-regression. Clin EEG Neurosci. 2016;47(1):48-55.

22. Summers JJ, Kang N, Cauraugh JH. Does transcranial direct current stimulation enhance cognitive and motor functions in the ageing brain? A systematic review and meta-analysis. Ageing research reviews. 2016;25:42-54.

23. Benussi A, Dell'Era V, Cosseddu M, Cantoni V, Cotelli MS, Cotelli M, et al. Transcranial stimulation in frontotemporal dementia: a randomized, double‑blind, sham‑controlled trial. Alzheimers Dement TRCI. 2020;6(1):e12033.

24. Cammisuli DM, Cignoni F, Ceravolo R, Bonuccelli U, Castelnuovo G. Transcranial direct current stimulation (tDCS) as a useful rehabilitation strategy to improve cognition in patients with Alzheimer's disease and Parkinson's disease: an updated systematic review of randomized controlled trials. Front Neurol. 2022;12:798191.

25. Nitsche MA, Cohen LG, Wassermann EM, Priori A, Lang N, Antal A, et al. Transcranial direct current stimulation: state of the art 2008. Brain Stimul. 2008;1(3):206-23.

26. Nitsche MA, Paulus W. Excitability changes induced in the human motor cortex by weak transcranial direct current stimulation. J Physiol. 2000;527(Pt 3):633.

27. Lawrence BJ, Gasson N, Johnson AR, Booth L, Loftus AM. Cognitive training and transcranial direct current stimulation for mild cognitive impairment in Parkinson's disease: a randomized controlled trial. J Parkinsons Dis. 2018;2018(1):4318475.

28. Nooristani M, Augereau T, Moïn-Darbari K, Bacon BA, Champoux F. Using transcranial electrical stimulation in audiological practice: the gaps to be filled. Front Hum Neurosci. 2021;15:735561.

29. Cruz Gonzalez P, Fong KN, Chung RC, Ting KH, Law LL, Brown T. Can transcranial direct-current stimulation alone or combined with cognitive training be used as a clinical intervention to improve cognitive functioning in persons with mild cognitive impairment and dementia? A systematic review and meta-analysis. Front Hum Neurosci. 2018;12:416.

30. Bennabi D, Pedron S, Haffen E, Monnin J, Peterschmitt Y, Van Waes V. Transcranial direct current stimulation for memory enhancement: from clinical research to animal models. Front Syst Neurosci. 2014;8:159.

31. Grammer G, Green V, Amin R, Alampay M. The Role of rTMS in the Treatment of Psychiatric Disorders Other than Major Depression. Psychiatr Ann. 2014;44(6):293-8.

32. Tang MF, Hammond GR. Anodal transcranial direct current stimulation over auditory cortex degrades frequency discrimination by affecting temporal, but not place, coding. Eur J Neurosci. 2013;38(5):2802-11.

33. Gangemi A, Fabio RA, Suriano R, De Luca R, Marra A, Tomo M, et al. Does Transcranial Direct Current Stimulation Affect Potential P300-Related Events in Vascular Dementia? Considerations from a Pilot Study. Biomedicines.2024;12(6), 1290.

34. Ramaraju S, Izzidien A, Roula MA, McCarthy P. Effect of tDCS application on P300 potentials: a randomized, double blind placebo controlled study. IEEE CCMB. 2014; 111-114.

35. Voegtle A, Reichert C, Hinrichs H, Sweeney-Reed CM. Repetitive anodal TDCS to the frontal cortex increases the P300 during working memory processing. Brain Sci. 2022;12(11):1545.

36. Mendes AJ, Pacheco-Barrios K, Lema A, Gonçalves ÓF, Fregni F, Leite J, et al. Modulation of the cognitive event-related potential P3 by transcranial direct current stimulation: Systematic review and meta-analysis. Neurosci Biobehav Rev. 2022;132:894-907.

37. Khedr EM, Salama RH, Abdel Hameed M, Abo Elfetoh N, Seif P. Therapeutic role of transcranial direct current stimulation in Alzheimer disease patients: double-blind, placebo-controlled clinical trial. Neurorehabil Neural Repair. 2019;33(5):384-94.

38. Zaehle T, Sandmann P, Thorne JD, Jäncke L, Herrmann CS. Transcranial direct current stimulation of the prefrontal cortex modulates working memory performance: combined behavioural and electrophysiological evidence. BMC Neurosci. 2011;12(1):2.

39. Heimrath K, Fiene M, Rufener KS, Zaehle T. Modulating human auditory processing by transcranial electrical stimulation. Front Cell Neurosci. 2016 Mar 7;10:53.

40. Kunzelmann K, Meier L, Grieder M, Morishima Y, Dierks T. No effect of transcranial direct current stimulation of the auditory cortex on auditory-evoked potentials. Front Neurosci. 2018;12:880.

41. Matsushita R, Puschmann S, Baillet S, Zatorre RJ. Inhibitory effect of tDCS on auditory evoked response: simultaneous MEG-tDCS reveals causal role of right auditory cortex in pitch learning. Neuro Image. 2021;233:117915.

42. Ladeira A, Fregni F, Campanhã C, Valasek CA, De Ridder D, Brunoni AR, et al. Polarity-dependent transcranial direct current stimulation effects on central auditory processing. PLoS One. 2011;6(9):e25399.

43. Rahimi V, Mohamadkhani G, Alaghband-Rad J, Kermani FR, Nikfarjad H, Marofizade S. Modulation of temporal resolution and speech long-latency auditory-evoked potentials by transcranial direct current stimulation in children and adolescents with dyslexia. Exp Brain Res. 2019;237(3):873-82.

44. Heimrath K, Kuehne M, Heinze HJ, Zaehle T. Transcranial direct current stimulation (tDCS) traces the predominance of the left auditory cortex for processing of rapidly changing acoustic information. Neurosci J. 2014;261:68-73.

45. Sterr A, Elbert T, Berthold I, Kölbel S, Rockstroh B, Taub E. Longer versus shorter daily constraint-induced movement therapy of chronic hemiparesis: an exploratory study. Arch Phys Med Rehabil. 2002;83(10):1374-7.

46. Mekala S, Paplikar A, Mioshi E, Kaul S, Divyaraj G, Coughlan G, et al. Dementia diagnosis in seven languages: the Addenbrooke's Cognitive Examination-III in India. Arch Clin Neuropsychol. 2020;35(5):528-38.

47. Klem GH. The ten-twenty electrode system of the international federation. The international federation of clinical neurophysiology. Electroencephalogr Clin Neurophysiol Suppl. 1999;52:3-6.

48. Bindman LJ, Lippold OC, Redfearn JW. Long-lasting changes in the level of the electrical activity of the cerebral cortex produced by polarizing currents. Nat. 1962;196(4854):584-5.

49. Nooristani M, Augereau T, Moïn-Darbari K, Bacon BA, Champoux F. Using transcranial electrical stimulation in audiological practice: the gaps to be filled. Front Hum Neurosci. 2021;15:735561.

50. Wasano K, Nakagawa T, Kaga K, Ogawa K. The effect of aging and asymmetrical hearing on speech discrimination. Commun Med. 2024;4(1):166.

51. Luterman DM, Welsh OL, Melrose J. Responses of aged males to time-altered speech stimuli. J Speech Lang Hear Res. 1966;9(2):226-30.

52. Phillips SL, Gordon-Salant S, Fitzgibbons PJ, Yeni-Komshian G. Frequency and temporal resolution in elderly listeners with good and poor word recognition. J Speech Lang Hear Res. 2000;43(1):217-28.

53. Pichora-Fuller MK, Singh G. Effects of age on auditory and cognitive processing: implications for hearing aid fitting and audiologic rehabilitation. Trends Amplif. 2006;10(1):29-59.

54. Pichora-Fuller MK, Souza PE. Effects of aging on auditory processing of speech. Int J Audiol. 2003;42.

55. Datta A, Bansal V, Diaz J, Patel J, Reato D, Bikson M. Gyri-precise head model of transcranial direct current stimulation: improved spatial focality using a ring electrode versus conventional rectangular pad. Brain Stimul. 2009;2(4):201-7.

56. Zimerman M, Heise KF, Hoppe J, Cohen LG, Gerloff C, Hummel FC. Modulation of training by single-session transcranial direct current stimulation to the intact motor cortex enhances motor skill acquisition of the paretic hand. Stroke. 2012;43(8):2185-91.

57. Kuo HI, Bikson M, Datta A, Minhas P, Paulus W, Kuo MF, et al. Comparing cortical plasticity induced by conventional and high-definition 4× 1 ring tDCS: a neurophysiological study. Brain Stimul. 2013;6(4):644-8.