Original Research Paper

Volume - 15 | Issue - 08 | August - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Neuroscience

THE NEUROPHYSIOLOGICAL CORRELATES OF RELIGIOUS CHANTS COMPARED TO NON-RELIGIOUS CHANTS: AN EEG STUDY

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ABSTRACT *Chanting is a rhythmic vocalization found across cultures, but its neurophysiological effects based on the nature of chanted words remain unclear. This study examines whether religious and non-religious chants elicit distinct brain activity patterns. Participants who believed in the sacredness of religious chants (OM, Ra-dha-sva-aa-mi [RS]) but were not regular practitioners engaged in sessions involving both religious and non-religious chants (Table, Vande Mataram [VM]). EEG recordings were taken before and after a minute of internal chanting. Results showed a significant increase in alpha power following religious chanting across all brain regions, particularly in the occipital lobe, suggesting relaxation. Additionally, RS exhibited decreased gamma amplitude and increased alpha power compared to non-religious chants, indicating a state of transcendental bliss. These findings highlight the potential calming effects of religious chanting and encourage further research on the broader impact of different chants on brain activity.*

KEYWORDS : *Chanting stimuli, Electroencephalography (EEG), Neurophysiology, spectral analysis.*

INTRODUCTION

Chanting, an age-old practice rooted in diverse cultural and spiritual traditions, involves the rhythmic repetition of specific words or phrases to foster focus and inner calm (Lutz et al., 2008; Oman et al., 2022; Perry et al., 2021). It is frequently employed as a tool for spiritual communication and general well-being by practitioners (Hansen, 2008; Newberg et al., n.d.). Beyond its ritualistic significance, chanting influences cognitive processes and emotional regulation (Zhang et al., 2022). Despite these recognized benefits, its underlying neural mechanisms remain a topic of ongoing research (Gao et al., 2019a).

In the pursuit of advancing our scientific comprehension of chanting and its effects on brain rhythms, numerous studies have strived to unveil a multitude of neurophysiological correlates associated with various chanting practices (Das et al., 2022a; Perry et al., 2021, 2022). Research on OM chanting, for instance, has shown an increase in post-theta power (Rajput et al., 2023a). Furthermore, the repetition of the OM mantra has been suggested to possess therapeutic potential, aiding in the management of depression and stress (Harne & Hiwale, 2018). Similarly, EEG and fMRI has shown that the Gayatri Mantra affects the temporal and parietal regions of the brain (Susan Thomas & Shobini L. Rao, 2016). These studies provide insights into the neuro-dynamics of different chanting practices primarily through the analysis of frequency power. Therefore, it can be inferred that by examining changes in frequency power patterns, researchers can better understand the neurophysiological correlates of chanting. While source localizations are sometimes explored but the primary focus remains on investigating how chanting influences brain activity in terms of frequency power dynamics.

Comparative studies have begun to explore chanting in varied contexts, such as Quranic recitations versus hard music (Taha Alshaikhli et al., 2014). However, the specific influence of the linguistic or spiritual nature of chanted words on brain activity remains less explored. While religious chants like OM and Ra-dha-sva-aa-mi (RS) are believed to have distinct effects, non-religious phrases encountered in daily life—such as multiplication tables (Table) or national songs like Vande Mataram (VM) of India—have received comparatively little attention. This study aims to bridge this gap by examining whether chanting religious and non-religious words elicits distinct neurophysiological responses, thereby contributing to a deeper understanding of how different linguistic and spiritual elements influence brain activity.

II. Method

A. Participants

Our subject pool consists of twelve subjects, with a mean age of 31 y, SD 5.41, 8 F. The participants were Indians who occasionally engage in chanting during special occasions such as festivals, based on their beliefs, but they are not regular practitioners. All participants have signed informed consent before participating in the experiment. They were right-handed without any background of neurological disorders. Two subjects' data was excluded as their raw files have got corrupted.

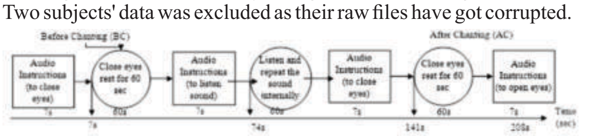


Figure 1. Chanting Experiment Design Timeline.

Experimental timeline illustrating the sequence followed by each participant. The experiment began with a random mobile game to ensure attentiveness, followed by a one-minute rest period (before chanting). An auditory cue then signalled the start of a one-minute internal chanting phase (during chanting), followed by another one-minute rest period (after chanting). Audio instructions guided participants through these phases. This sequence was repeated for four different chanting conditions: OM, Radha Svā ā mi (RS), multiplication table recitation (2×1=2), and the national anthem Vande Mataram (VM).

B. Study Design

During the experiment, participants engaged in chanting sessions involving both religious chants such as OM & RS as well as non-religious chants like Table recitation & national song VM. Each chanting session consisted of a minute of internal chanting. Subsequently, EEG recordings were taken using a *gel-based 64-channel ACTi Champ EEG system* before and after the chanting sessions, with participants resting with closed eyes for one minute each time. The EEG recordings included markers indicating the beginning of the rest period for both the before and after chanting stimuli, as well as a marker at the onset of same stimuli. These markers were placed via *E-prime 3.0* experimental design setup through *chronos*. To mitigate potential interference between different chanting blocks, a mobile game was played for approximately one minute before the commencement of each chanting block (refer to Figure 1).

C. Analysis

We utilized Brainstorm, a popular open-source software, to perform data analysis (Tadel et al., 2011). Initially, we applied *average reference*; a method that involves subtracting the average signal from all electrodes from each individual electrode signal to remove artifacts that are common across multiple channels, such as pulse artifacts (Tsuchimoto et al., 2021). We then check for bad channels or bad segments (if any), and we exclude them for future analysis. For this study, the artifact-corrected EEG data is band-pass filtered between

0.5-45 Hz to remove slow drifts and ignore high frequency noise. We add markers at 5[th] second of the beginning of before and after chanting rest conditions for each chanting block, assuming that transitioning into rest takes that time (Cahn & Polich, 2006). For example, for *table recitation*, there are two rest conditions: one before internal chanting and the other after internal chanting, so we add two markers named Table_B and Table_A after 5 seconds of the start of the rest within each condition. We then import the selected markers with a baseline of 100ms to 55 seconds, as the rest lasts for 60 seconds. The same procedure is repeated for all chanting blocks of each subject (refer to Supplementary material).

D. Power Spectral Analysis

In this study, we computed Power Spectral Density (PSD) using the Welch Function within Brainstorm (Tadel et al., 2011). PSD analysis allows for the examination of the distribution of power across different frequencies in a signal, helping to compare changes in frequency content and overcome the 1/f nature of EEG data (Buzsáki, 2006). The Welch method was employed for computing PSD due to its reliability and widespread use, offering a balance between frequency resolution and variance while remaining robust for non-stationarity signals (Same et al., 2021). The grouped frequencies include delta/δ (0.5-4 Hz), theta/θ (5-8 Hz), alpha/α (9-13 Hz), beta1/β_1 (14-20 Hz), beta2/β_2 (21-30 Hz), gamma1/γ1 (31-38 Hz) and gamma2/γ2(39-45 Hz). The computed PSD plots data are exported as "*Before/After_Chantingblock_S#*", where *Before/After* denotes the condition (before & after chanting), *chanting block* refers to any one of the four chanting types, *S* denotes the subject, and # represents the unique subject identifier. These files serve as valuable resources for subsequent analysis and interpretation of the data.

We developed a MATLAB script to analyse the exported PSD plot values, which performs several key functions: (i) computation of average power across all the channels/electrodes, as well as separately for frontal, temporal, parietal, and occipital lobes. The frontal lobe channels include: 'Fz', 'F3', 'F7', 'FC5', 'FC1', 'FC6', 'FC2', 'F4', 'F8', 'Fp2', 'AF7', 'AF3', 'F1', 'F5', 'FC3', 'FC4', 'F6', 'AF8', 'AF4', 'F2'. The temporal lobe channels include: 'T7', 'TP9', 'TP10', 'T8', 'FT7', 'TP7', 'TP8', 'FT8'. The parietal lobe channels include: 'C3', 'CP5', 'CP1', 'Pz', 'P3', 'P7', 'P4', 'P8', 'CP6', 'CP2', 'Cz', 'C4', 'C1', 'C5', 'CP3', 'P1', 'P5', 'P6', 'P2', 'C6', 'C2'. The occipital lobe channels include: 'O1', 'Oz', 'O2', 'PO7', 'PO3', 'POz', 'PO4', 'PO8'. (ii) Computation of the normalized percentage changes between after and before conditions for all the chanting blocks. This computation is conducted using the following formula:

$$\frac{A-B}{A+B} \times 100$$

where *A* represents the *after chanting condition* and *B* represents the *before chanting condition*. (iii) Comparison of religious and non-religious chanting blocks, specifically between Table vs. OM, Table vs. RS, OM vs. VM, and VM vs. RS (refer to Figure 2). This comparison was conducted using the normalized percentage change in frequency power computed in the previous step, followed by statistical analysis. (iv) Application of the Wilcoxon rank-sum test (non-parametric t-test) and calculation of effect size using Rank-Biserial Correlation (RBC) method, quantifies the strength of differences between groups in non-parametric tests (refer to table 1 & 2) (Kerby, 2014; Mann & statistics, n.d.). (v) Creation of comparative bar plots between religious and non-religious chanting conditions (refer to figure 2 & 3).

RESULTS

A. Neurophysiological Correlates of different Chanting Stimuli

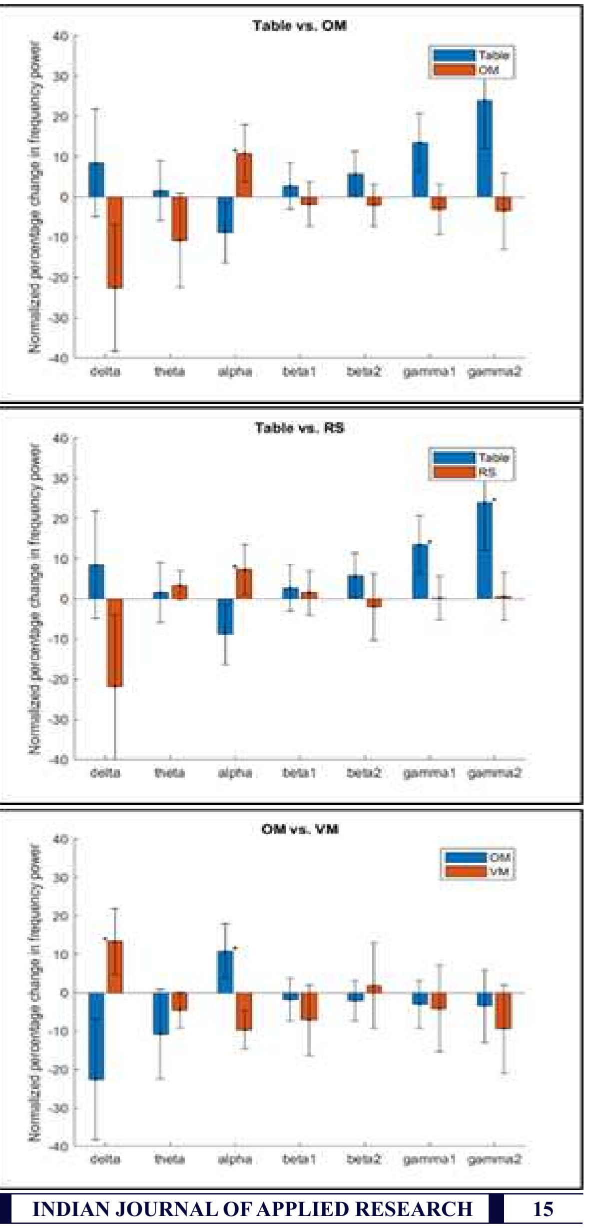
The primary objective of the study was to investigate the neurophysiological correlates elicited by various chanting stimuli. In pursuit of this goal, spectral analysis was conducted to examine changes in frequency power before and after exposure to chanting sessions, as detailed in Section II.

Figure 3 compares non-religious and religious chanting blocks: (i) Table vs. OM, (ii) Table vs. RS, (iii) OM vs. VM, and (iv) VM vs. RS. It shows the averaged normalized percentage change in frequency power across all channels for each chanting stimulus. A significant increase in alpha power was observed following religious word chanting, setting it apart from non-religious chanting. Notably, there was a decrease in gamma amplitude during the chanting of the religious word RS compared to the non-religious word Table.

Table 1. Exact P-values And Effect Sizes Of Normalized Power Changes Among All EEG Channels Comparing Different Chanting Condition.

Frequency Bands	Table vs. OM		Table vs. RS		OM Vs. VM		VM vs. RS	
	p-value	effect size	p-value	effect size	p-value	effect size	p-value	effect size
delta	0.07211	0.57142857	0.19959	0.38888889	0.0401	0.642857	0.05923	0.555556
theta	0.33566	0.32142857	1	0	0.6126	0.178571	0.23587	0.361111
alpha	0.0289	0.67857143	0.0274	0.63888889	0.0401	0.642857	0.0274	0.638889
beta1	0.4634	0.25	1	0	0.5358	0.214286	0.37038	0.277778
beta2	0.18928	0.42857143	0.13879	0.44444444	0.5358	0.214286	0.54142	0.194444
gamma1	0.07211	0.57142857	0.0464	0.58333333	0.8665	0.071429	0.96257	0.027778
gamma2	0.07211	0.57142857	0.03595	0.61111111	0.5358	0.214286	0.32127	0.305556

Statistical comparisons were conducted between chanting conditions: (I) Table vs. OM, (II) Table vs. RS, (III) OM vs. VM, and (IV) VM vs. RS, analyzing the power changes after and before chanting across all EEG channels. Wilcoxon rank-sum tests were used to assess significance, with effect sizes reported using rank-biserial correlation (RBC). Significant differences were observed in the α, γ1 and γ2 frequency band.



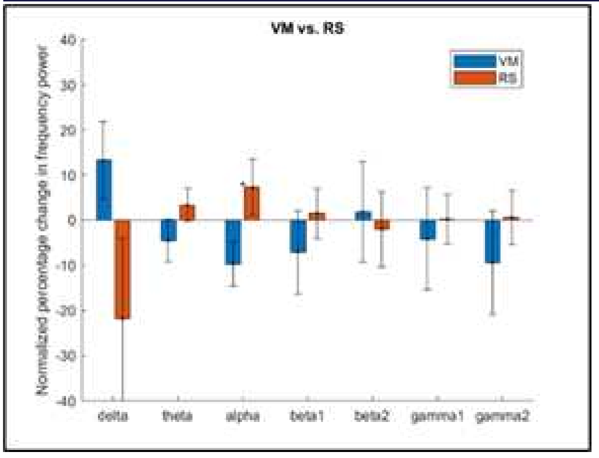


Figure 2. Normalized percentage change in frequency power after and before chanting, compared between religious and non-religious chants, averaged across all EEG channels.

The percentage change in power was computed for each chanting condition by analyzing the difference between after and before chanting power levels. This change was then compared across conditions: (I) Table vs. OM, (II) Table vs. RS, (III) OM vs. VM, and (IV) VM vs. RS for all frequency bands averaged across all channels. Wilcoxon rank-sum tests were used to assess significance, with $p \leq 0.05$ indicated by ''. Results highlight a significant increase in α power for religious chants across all brain regions, distinguishing them from non-religious chants. Additionally, the religious chant "Radha Svā ā mi" exhibited reduced γ1 and γ2 amplitudes compared to Table recitation.*

Figure 4 focuses on the same comparisons (i) Table Vs OM, (ii) Table Vs RS, (iii) OM Vs VM, and (iv) VM Vs RS, but averaged normalized percentage change in frequency power across the channels of occipital lobe. Again, a significant increase in alpha power was observed following religious chanting, further differentiating it from non-religious chanting.

In the absence of recorded subjective experiences, we referred to existing literature to interpret changes in frequency band powers. The increase in alpha power during religious chanting may be associated with states of relaxation and calmness, suggesting the potential of religious chants to induce inner peace and tranquility (Lee et al., 2018). Additionally, the observed decrease or lack of change in gamma power during chanting may be linked with existing literature where they associate this with physiological change such as transcendental bliss and reduced self-focused cognition (Gao et al., 2019b).

Table 2. Exact P-values And Effect Sizes Of Normalized Power Changes Across Occipital Channels Comparing Different Chanting Condition.

Frequency Bands	Table vs. OM		Table vs. RS		OM Vs. VM		VM vs. RS	
	p-value	effect size	p-value	effect size	p-value	effect size	p-value	effect size
delta	0.396892	0.285714	0.199589	0.388889	0.072106	0.571429	0.01522	0.694444
theta	0.955089	0.035714	0.321267	0.305556	0.955089	0.035714	0.321267	0.305556
alpha	0.020513	0.714286	0.046401	0.583333	0.020513	0.714286	0.02065	0.666667
beta1	0.612587	0.178571	0.814809	0.083333	0.694328	0.142857	0.605841	0.166667
beta2	0.866511	0.071429	0.199589	0.388889	0.778866	0.107143	0.113945	0.472222
gamma1	0.694328	0.142857	0.480708	0.222222	0.955089	0.035714	0.962567	0.027778
gamma2	0.53582	0.214286	0.480708	0.222222	0.955089	0.035714	0.742986	0.111111

Statistical comparisons were conducted between chanting conditions: (I) Table vs. OM, (II) Table vs. RS, (III) OM vs. VM, and (IV) VM vs. RS, analyzing the power changes before and after chanting across occipital lobe channels. Wilcoxon rank-sum tests were used to assess significance, with effect sizes reported using rank-biserial correlation (RBC). Significant differences were observed in the α frequency band.

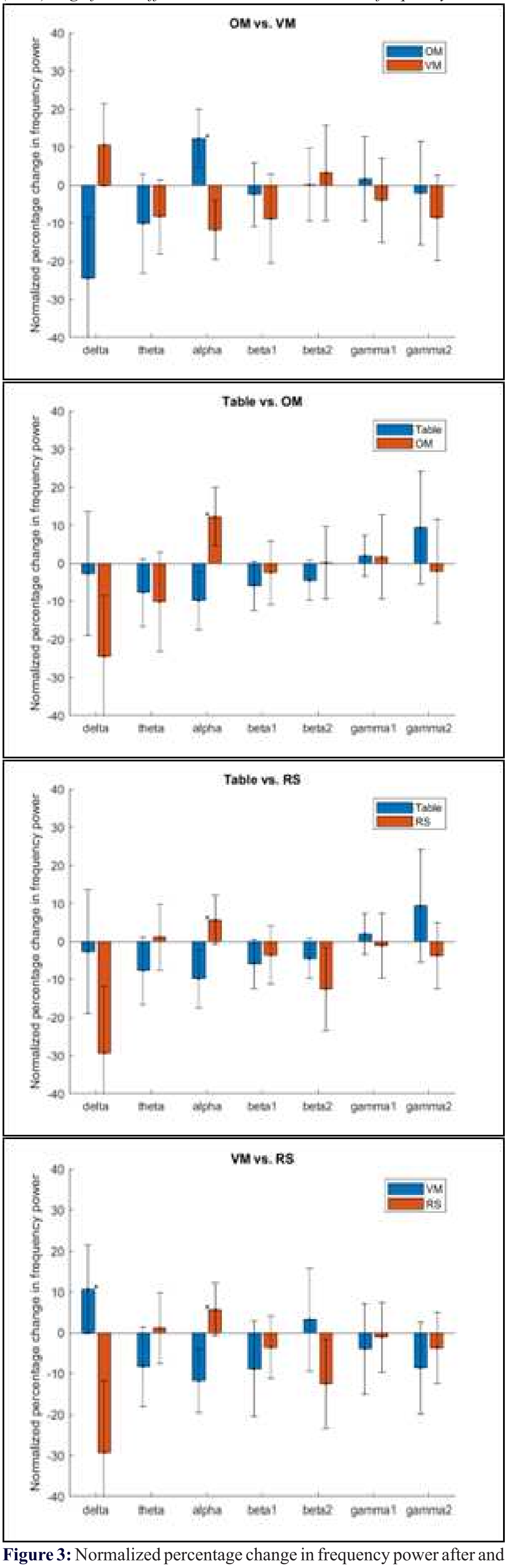


Figure 3: Normalized percentage change in frequency power after and

before chanting, compared between religious and non-religious chants, averaged across occipital channels.

The percentage change in power was computed for each chanting condition by analyzing the difference between after and before chanting power levels. This change was then compared across conditions: (I) Table vs. OM, (II) Table vs. RS, (III) OM vs. VM, and (IV) VM vs. RS, for all frequency bands averaged over occipital lobe channels. Statistical significance was assessed using Wilcoxon rank-sum tests, with $p \leq 0.05$ indicated by ''. Results indicate a significant increase in α power in the occipital region during religious chanting in contrast to non-religious chanting.*

Several important inferences can be drawn based on the results: (i) Religious words elicit a notable increase in alpha power, indicating distinct neurophysiological correlates compared to non-religious stimuli. (ii) The increase in alpha power and the decrease or lack of change in gamma power during religious chanting may contribute to relaxation and a state of transcendental bliss.

DISCUSSION & CONCLUSION

In this study, we employed EEG to investigate the neurophysiological effects of chanting, analyzing normalized changes in frequency power to compare responses during religious and non-religious chanting. Our findings contribute to the growing body of research on how chanting influences brain activity, particularly in terms of frequency band power modulation.

Previous research has consistently shown that chanting induces relaxation and stress reduction, often reflected in increased alpha and theta power. For instance, EEG studies on 'Hare Krishna Mantra (HKM)' chanting reported heightened alpha power, particularly in central brain regions (C3 and C4), which has been associated with relaxation (Das et al., 2022a). Similarly, 'OM' chanting has been linked to increased theta and alpha power across prefrontal, parietal, and occipital regions (Rajput et al., 2023a). Additionally, research on 'Vedic' chanting has shown similar effects in subcortical regions, further supporting its stress-reducing properties (Deolindo et al., 2020).

While these studies primarily focused on individual chanting practices, our study takes a comparative approach, distinguishing between religious and non-religious chants. Non-religious stimuli include Table recitation, are neutral and repetitive and 'Vande Mataram (VM)' carries patriotic significance, potentially eliciting distinct emotional response. By comparing (i) Table vs. OM, (ii) Table vs. RS, (iii) OM vs. VM, and (iv) VM vs. RS, we aimed to isolate the specific neurophysiological effects of religious content in chanting. Our results revealed a notable increase in alpha power for religious chants compared to non-religious ones, reinforcing previous findings on relaxation (Das et al., 2022b; Deolindo et al., 2020; Rajput et al., 2023b). Additionally, the RS vs. Table comparison showed a significant decrease in gamma power, aligning with studies that associate reduced gamma activity with meditative and contemplative states (Gao et al., 2019b, 2020; Perry et al., 2022).

Beyond corroborating prior research, our study offers key advancements. Unlike most studies that analyze pre-post changes within a single chanting condition, we adopted a comparative framework to directly assess differences between religious and non-religious chants. Moreover, by normalizing frequency power changes, we minimized inter-individual variability, ensuring a more robust comparison.

Despite these contributions, our study has certain limitations. The sample size, although modest, aligns with similar neurophysiological studies reporting significant findings (Hotho et al., 2022). Additionally, the absence of psychological assessments limits our ability to directly attribute neural changes to subjective experiences. Future research integrating psychological measures with EEG data could provide deeper insights into the cognitive and emotional mechanisms underlying chanting-induced brain activity.

In conclusion, our study highlights the distinct neurophysiological effects of religious and non-religious chanting, reinforcing prior evidence while introducing a novel comparative approach. These findings pave the way for further exploration into how chanting modulates brain function across different cultural and emotional contexts.

Data Accessibility

Data is available upon request because of IRB (Institutional Review Board) restrictions on human data. Readers are welcome to send their requests to authors at their respective email IDs. Codes are provided within supplementary material.

Acknowledgements:

We extend our deepest gratitude to Prof. P.S. Satsangi, Emeritus Chairman, Advisory Committee on Education, Dayalbagh Educational Institute (D.E.I.), for his visionary talks and pioneering experimentation, which have inspired this research. We sincerely thank all the participants who volunteered for this study. We are also indebted to Prof. C. M. Markan for providing access to the EEG facility at D.E.I. Additionally, we acknowledge the valuable contributions of Abhishek Gupta, Madhavi (undergraduate students), Dr. Sheena Sharma, and Goutam Kumar in data collection. Damisetti Geeta Prem Chandoo gratefully acknowledges the support of Rajya Anand Sansthan (RAS) for providing a Doctoral Fellowship (RAS/2/ADF/I/11/2022). This research is funded by seed money for research projects of D.E.I.

Conflict Of Interest: Authors declare that they have no conflict of interest.

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