



INDIAN KNOWLEDGE SYSTEMS DIVISION

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PROJECT COMPLETION REPORT

Important Points:

- i. The Project Completion Report (PCR) should cover the complete work done during the entire project.
- ii. Timely submission of report is essential to facilitate release of funds.
- iii. Report should be in the format given below.
- iv. Write “NIL” against items where there is nothing significant to report or if these items are not relevant.
- v. 78One soft copy in .pdf format of the report giving information on items listed in the format given below are required. There is no requirement to send a hardcopy.

PROJECT COMPLETION REPORT

PROJECT TITLE

**Impact of Indian Classical Raga on human cognitive function A
neuropsychological study using EEG.**

SUBMITTED BY

Prof. Laxmidhar Behera

(IIT Mandi)

01/01/25

FUNDED BY

**Indian Knowledge Systems Division of Ministry of Education,
Govt of India**

IKS Division File Reference No: AICTE/IKS/RFPI/2021-22/01

Project Duration: From...2ND APRIL 22 to...1ST APRIL 25.....

PROJECT COMPLETION REPORT

One soft copy of the Project Completion Report should be submitted on email. The Report should consist of Part A - Summary Report and Part B - Comprehensive Report. The report should be on the Standard Format provided.

1. Project Title: Impact of Indian Classical Raga on human cognitive function A neuropsychological study using EEG.

2. Duration of Project: From 2nd April 22__To 1st April 25.

3. Focus Area: Health, wellness, Indian Classical Music.

4. Principal Investigator

Name: Prof. Laxmidhar

Behera

Organisation/Institution:

IIT Mandi

5. Co-Principal

Investigators Name:

Prof. Braj Bhushan

Organisation/Institution:

IIT Kanpur

6. Collaborating Organisations

Organisation	Team Members	Activities/Tasks assigned
NA		

Part A - Summary Report

1. Project Objectives

Objective as per the approved Project:

- Music is linked to short-term enhancement of cognitive processing. We are looking into two important cognitive functions – intelligence and attention. However, due to the lack of clear and direct mechanisms demonstrating the cognitive effect of music on the brain, the end effect of music has been questioned in several studies. The present study would explore the neural mechanisms accountable for enhanced intelligence and attention on exposure to music specifically Indian classical music.
- Sad classical music is often heard when one is experiencing a sad situation. It offers as a means to express or vent one's feeling, to seek solace, to feel socially connected or as a mean to cope with the challenging situations. Sad music, although being sad, helps one to deal with one's sad circumstances. The neural mechanism responsible for this observed controversial effect will be studied. Our investigation would especially be focusing upon the emotional and memory areas of the brain.
- There is no systematic characterization of the individual brain state in relation to cognitive and emotion processing. Brain microstate analysis provides a unique way to characterize the brain in terms of its cognitive abilities like attention, mind wandering etc. This study performs Microstates characterization of the brain and explores the effect of listening to Indian Raga on the brain Microstates of the participants.

Fully Achieved/Partially Achieved (indicate shortfall) or Reason for Partial Achievement

- We have investigated the role of sad Indian classical music (Karuna Raga) in facilitating coping mechanism during sad experience/memory.
- Results show that recalling a sad experience (adverse situation), there is enhanced gamma wave activity, while listening to sad music leads to increased alpha brain activity.
- We proposed a three-channel framework involving the alpha brain wave underpinning coping mechanism.
- The research involving a sad Indian Raga and investigating its effect upon emotion regulation is 100 percent complete.
- Additionally, we extended our study on investigation of Indian music upon Intelligence and attention through microstate analysis.
- Earlier we have established how listening to Indian classical music (Raga Darbari) facilitates short term enhancement of cognitive function in particular Intelligence and attention through three neural mechanisms
- We have investigated the Microstate characterization of the Brain in response to listening to Indian Classical Music.
- The research involving Brain Characterization and investigating Raga effect upon attention and mind wandering microstate is 100 percent complete.
- Our findings illustrate that the microstate patterns in the brain during the exposure to happy and sad music exhibit unique and distinct characteristics. Notably, happy music listening is linked to heightened class D, suggesting increased attentiveness, whereas sad music listening is linked to elevated class C, signifying increased mind-wandering.

2. Deliverables

Deliverables as per the approved Project

- To provide a holistic model for how the brain processes and responds to music, considering both the stable as well as the dynamic changes that occur over time
- To identify the neural correlates of happy music listening in relation to brain cognitive processes. This involved analyzing Electroencephalogram (EEG) power and phase analysis of the brain and identifying any potential enhancements or alterations in EEG bio-markers associated with intelligence and attention upon happy music listening.
- To identify the neural correlates of the emotional circuitry in the brain when individuals listen to sad music, particularly in the context of challenging circumstances. This aspect aims to understand the brain's emotional processing during sad music listening and its potential implications for emotional regulation.
- To identify the alteration in the brain microstate of attention and mind wandering upon exposure to happy music. This involved studying the microstate linked to attention and mind wandering and how the dynamic properties of these microstates are influenced by the musical stimulus.
- To identify the alteration in the brain microstate of the emotion regulation when individuals listen to a sad music. This involves the understanding of how sad music influences the properties of microstate associated with the emotion regulation potentially leading to enhanced emotion and self regulation during adverse circumstances.

Fully/Partially/Not Achieved

All the mechanisms underlying the positive effect of listening to Happy and Sad music both Static and Dynamics have been identified. The study proposes comprehensive cognitive-emotion models that elucidate the effects of happy and sad music on cognitive and emotional processes, drawing upon insights from diverse neurophysiological measures.

3. Specific Benefits/Outcome

(Please give details)

- Patent, if any NA
- Product/Process developed/ technology transferred NA
- List of Publications arising from the Project
(Indicate Impact Factors of the Journals; attach Copies of the Papers)
- Gupta A, Bhushan B, Behera L (2023) Neural response to sad autobiographical recall and sad music listening post recall reveals distinct brain activation in alpha and gamma bands. PLoS ONE 18(1): e0279814. <https://doi.org/10.1371/journal.pone.0279814>
Impact Factor : 3.53 (Q1 Journal)

- Gupta, A., Bhushan, B., & Behera, L. (2018). Short-term enhancement of cognitive functions and music: A three-channel model. *Scientific reports*, 8(1), 1-12.
Impact Factor: 4.3 (Q1 Journal)

Gupta A, CK Srivastava, Bhushan B, Behera L (2025). A Comparative Study of EEG Microstate Dynamics during Happy and Sad Music Videos (Accepted in *Frontiers in Human Neuroscience*, section Brain Imaging and Stimulation) Impact Factor: 4.3 (Q1 Journal)
Impact Factor: 3.13 (Q2 Journal)

- Gupta A, CK Srivastava, Bhushan B, Behera L EEG Microstates dynamics of Happiness and Sadness during Music Listening (Communicated).
- Linkages developed: NA

4. Manpower trained

- No. of Students based on the project: 2
- No. of Master's Thesis/Reports based on the project: 2 PhD Thesis
- Position and Number of Other Technical Staff Trained: 1 Research Scientist

5. Methodology (Minimum 250 Words):

Sad Autobiographical recall and Sad Indian Raga:

Twenty right-handed participants with no musical training were enrolled from a technology institute. The participants were recruited through an electronic announcement. Their age ranged between 19–29 years (mean age = 22.14 years, SD = 3.68). Only male participants were considered in the study, as the brain networks used by males and females for processing music stimuli are shown to have differences. Any neurological or hearing disorders and usage of psychotic drugs in recent times were the exclusion criteria. Participants were also excluded if their response was yes to the following questions “During the past month, have you often been bothered by feeling down, depressed, or hopeless?” or “During the past month, have you often been bothered by little interest or pleasure in doing things?”.

The experimental sessions consisted of three conditions— (1) baseline resting-state condition for 9 min, (2) sad autobiographical recall condition for 9 min (participants recalled an event from their life that made them sad), and (3) sad music condition (passive hearing of a segment of the selected musical stimulus). All the participants were instructed to sit calmly with their gaze fixed on the cross printed centrally on a blank paper kept over the table during baseline and sad music listening conditions. The cross sheet was replaced with a writing pad upon the table during SAR. Participants were told to recall and write about a negative real-life event in which they experienced sadness like feelings of loss, loneliness, misunderstanding, heartbreak, betrayal, loss of a loved one, etc. Participants were encouraged to relive and report the event as vividly and detailed as possible in the writing pad. We used a g.HIamp bio-signal amplifier (Guger Technologies, OG, Graz, Austria) to capture the EEG from the participants. EEG was sampled at a frequency of 512 Hz with less than 5 Kohms impedance level at 32 scalp locations (as per the International 10–20 system). Source localization and analysis of 32 channel EEG data were conducted through eLoreta. Intracortical current source density (CSD) was calculated at 6239 voxels, sampled at 5 mm resolution. CSD was calculated as a linear weighted sum of potentials at the scalp through eLoreta software. Brain connectivity was computed by measuring lagged phase synchronization through eLoreta at the source level.

EEG Microstate Characterization of Indian Raga with respect to cognitive functions:

The primary data collection studies involved a total of forty participants recruited from a technology institute to participate in two separate experiments, with 20 participants in each. The mean age of the participants was 24.06 years (SD = 2.69) for the first experiment and 22.14 years (SD = 3.68) for the second. Participants were required to have no formal or informal music training and to be right-handed, with exclusion criteria including hearing disorders, neurological diseases, and recent psychoactive drug use.

To control for potential confounding variables, only male participants were included in both experiments. Previous studies confirmed that the Raga Darbari segment (duration: 9 minutes and 53 seconds) and the Mishra Raga Jogiya segment (duration: 8 minutes and 44 seconds) significantly induced feelings of happiness and sadness, respectively. Therefore, EEG data corresponding to these segments were selected for the first and second experiments.

The first experiment involved three distinct states: a baseline resting state (duration: 275 seconds), a period of attentive listening to happy music with eyes closed, and a post-music silence state (duration: 275 seconds).

The second experiment comprised four 9-minute conditions: a baseline resting state, a period of recalling a sad autobiographical event, listening to sad music, and a post-music silence condition.

Spatial k-means cluster analysis using the EEGLAB toolbox was conducted for each condition, utilizing maps based on the local maxima of the Global Field Power (GFP) to identify time points with the highest signal-to-noise ratio. The analysis did not consider map polarity. Microstate cluster analysis was performed on combined EEG data from all participants within each condition, resulting in four microstates (class A, class B, class C, and class D) determined by their largest spatial correlation and visual examination.

Subsequently, the identified maps for each condition were applied to each participant's EEG data, assigning each time frame to the template with the best spatial correlation match. This process generated participant-specific microstate sequences, which were used to calculate individual microstate parameters for each condition.

● Salient Research Achievements

- We have investigated the role of sad Indian classical music (Karuna Raga) in facilitating coping mechanism during sad experience/memory.
- Results show that recalling a sad experience (adverse situation), there is enhanced gamma wave activity, while listening to sad music leads to increased alpha brain activity.
- We proposed a three-channel framework involving the alpha brain wave underpinning coping mechanism.
- The research involving a sad Indian Raga and investigating its effect upon emotion regulation is 100 percent complete.
- Additionally, we extended our study on investigation of Indian music upon Intelligence and attention through microstate analysis.
- Earlier we have established how listening to Indian classical music (Raga Darbari) facilitates short term enhancement of cognitive function in particular Intelligence and attention through three neural mechanisms

The underlying neural mechanisms are: - (1) enhanced global efficiency of brain, (2) enhanced local neural efficiency at the prefrontal lobe, and (3) increased sustained attention

- We have investigated the Microstate characterization of the Brain in response to listening to Indian Classical Music.
 - The research involving Brain Characterization and investigating Raga effect upon attention and mind wandering microstate is 100 percent complete.
 - Our findings illustrate that the microstate patterns in the brain during the exposure to happy and sad music exhibit unique and distinct characteristics. Notably, happy music listening is linked to heightened class D, suggesting increased attentiveness, whereas sad music listening is linked to elevated class C, signifying increased mind-wandering.
- New Observations (minimum 200 words):
 - Results signify that music directly affects the cognitive system and leads to improved brain efficiency through well-defined mechanisms.
 - We performed Electroencephalography (EEG) source-level analysis for the brain during a sad autobiographical recall (SAR) and upon exposure to sad music. We specifically investigated the Cingulate cortex complex and Parahippocampus (PHC) regions, areas prominently involved in emotion and memory processing. Results show enhanced alpha band lag phase-synchronization in the brain during sad music listening, especially within and between the Posterior cingulate cortex (PCC) and (PHC) compared to SAR. This enhancement was lateralized for alpha1 and alpha2 bands in the left and right hemispheres, respectively. We also observed a significant increase in alpha2 brain current source density (CSD) during sad music listening compared to SAR and baseline resting state in the region of interest (ROI). Brain during SAR condition had enhanced right hemisphere lateralized functional connectivity and CSD in gamma band compared to sad music listening and baseline resting state. Our findings show that the brain during the SAR state had enhanced gamma-band activity, signifying increased content binding capacity. At the same time, the brain is associated with an enhanced alpha band activity while sad music listening, signifying increased content-specific information processing. Thus, the results suggest that the brain's neural correlates during sad music listening are distinct from the SAR state as well as the baseline resting state and facilitate enhanced content-specific information processing potentially through three-channel neural pathway.
 - In the initial experiment, examining the impact of happy music listening, we identified four microstates that accounted for variances (GEV) of 75.5, 77.4, and 74.43 during BL, MUS, and PMS conditions, respectively. In the subsequent experiment, focusing on the influence of sad music listening, we identified four microstates explaining variances (GEV) of 77.95, 77.77, and 76.98 during BL, MUS, and PMS conditions, respectively. The analysis of Global Explained Variance (GEV) and Global Field Potential (GFP) demonstrated that happy music led to an upregulation of class D microstate and a downregulation of class C microstate compared to the baseline resting state. Furthermore, listening to sad music was marked by an increased presence of class B, class C, and class D microstates. In contrast to the baseline state, sad music upregulated class C and class D microstates, as evidenced by GEV and GFP analysis. The assessment of GEV and coverage for the correlation between class C and class D microstates reveals a robust negative association during happy Indian Raga. This signifies that as attention increases, mind wandering decreases and vice versa. The analysis of GEV and coverage for the correlation between class C and class D microstates while listening to sad music shows a moderate negative correlation. It is crucial to note that this relationship explains only a small amount of variance in the data, as indicated by low R-squared values (0.3025 and 0.3249). This suggests the existence of other factors and parameters contributing to unexplained variance in the data. Future investigations should explore these additional elements for a more comprehensive understanding of mind wandering during sad music listening and its correlation with participants' attention.

- Innovations (Give bulleted list):

- We proposed a three-channel model explain the coping mechanism through sad Indian raga (Mishra Jogiya) during an adverse condition.
- (1) by enhancing the network connectivity in the emotion and memory processing regions (2) by enhancing local cortical integration of areas in emotion and memory processing regions, and (3) by enhancing sustained attention.
- Traditional, EEG analyses, such as power and phase connectivity, typically portray an apparent continuous activation of brain regions throughout the duration of music listening. Microstate analysis reveals that functional brain states, like enhanced attention, are not continuously present during music listening; instead, they manifest as brief episodes lasting tens of milliseconds.
- These microstates represent fundamental instantiations of human neurological tasks, and further analysis elucidates the duration, frequency, potential, and prominence of these microstates during music listening. Examining microstate properties offers a deeper, dynamic understanding of music's impact on the brain.
- We proposed a dynamic model explaining the enhanced cognitive and emotion processing mechanisms through Indian raga (Raga Darbari and Mishra Jogiya).
- The findings suggest that : (1) the heightened attention observed during happy music listening may be attributed to an increased class D and reduced class C microstates, and (2) the enhanced emotion regulation and self-regulatory goals during sad music listening may be related to an increase in class C along with class D microstates.
- Moreover, the mean duration of microstates was significantly longer irrespective of emotional valence and microstate class during music listening, indicating a larger average life span for the microstate.

6. Indication of scope for future work (Maximum 300 Words):

Future directions in this research involve several critical dimensions aimed at enriching our understanding of music-induced cognitive and emotional effects:

1. EEG Microstates and Brain Correlates: Exploring the direct relationship between specific EEG microstates (e.g., class C and D) and brain functional connectivity, power, or CSD activity could shed light on the neural basis of attention and mind-wandering.
2. Source Localization Analysis: Advanced source-level analysis could illuminate the neural origins of microstates under different conditions, distinguishing natural and music-induced mind-wandering processes.
3. Comparison with Relaxation Techniques: A comparative exploration of neural responses to music versus other relaxation methods could broaden insights into therapeutic effects.
4. Multimodal Approaches: Integrating EEG with tools like fMRI or MEG could provide a comprehensive view of neural dynamics associated with music listening.
5. Generalizability: Expanding studies to diverse populations across genders and musical genres would enhance result applicability. Longitudinal research could reveal lasting effects on cognitive functions.
6. Cultural and Individual Variations: Cross-cultural comparisons of musical influences and examinations of individual differences, such as personality traits and preferences, may inspire personalized interventions.
7. Clinical Applications: Utilizing music-induced neural changes for cognitive enhancement or emotion regulation among clinical groups (e.g., mood disorders, ADHD) holds promise.
8. Neurofeedback Techniques: Real-time EEG-based neurofeedback during music listening could

empower participants to modulate neural responses for self-regulation.

9. Music-Related Features: Detailed analysis of musical elements like tempo, rhythm, and melody would uncover their specific impacts on neural dynamics.
10. Developmental Perspectives: Investigating how music affects distinct age groups (children to elderly) may offer developmental insights.

Hypotheses

1. Extended exposure to happy music could enhance cognitive functions like attention and intelligence.
2. Structured sad music exposure might improve emotion regulation and coping in therapeutic contexts.

7. Procurement/Usage of Equipment:

Sr.	Name of Equipment	Make/ Model	Cost (Rs.)	Date of Purchase & Installation	Remarks regarding maintenance/ breakdown
	NA				

Part B – Comprehensive Report

(The Comprehensive Report should be precise in detail and self-contained)

1. Project Title Impact of Indian Classical Raga on human cognitive function A neuropsychological study using EEG.

2. Literature Review

- Identify gaps in knowledge that your project aims to address
- Explain how your research builds upon or contributes to existing knowledge

Music, a universal language, is woven into the fabric of every culture and continuously evolves in new directions. Its widespread presence across the world serves as compelling evidence of its profound importance for mankind. Traditionally, within Indian context music has also been utilized in therapeutic processes known as Raga Chikitsa¹. Its positive effects on neurological, physiological, and psycho- logical ailments have been observed². Indian ragas have shown the ability to activate the frontal cortex, an area responsible for cognitive processing, and these effects can persist even after the music has stopped³.

The broad impact of music has led to positive effects on cognitive, motor, emotional, and social functioning to both healthy individuals and those with aging or neurological conditions⁴. Cognitive functions such as attention and emotion regulation are essential processes for normal human functioning, and

¹ S. Sundar, "Traditional healing systems and modern music therapy in india," *Music Therapy Today*, vol. 8, no. 3, pp. 397–407, 2007.

² N. M. Desai, S. HS, D. M. Desai, K. Kunikullaya, and A. K. Sinha, "An overview of the indian system of raagas and their positive effects on health," *Journal of Drugs Addiction & Therapeutics*, vol. 2, no. 2, pp. 1–6, 2021.

³ D. Ghosh, R. Sengupta, S. Sanyal, A. Banerjee, D. Ghosh, R. Sengupta, S. Sanyal, and A. Banerjee, "Emotions from hindustani classical music: an eeg based study including neural hysteresis," *Musicality of human brain through fractal analytics*, pp. 49–72, 2018.

⁴ T. S`ark`am`o, "Cognitive, emotional, and neural benefits of musical leisure activities in aging and neurological rehabilitation: A critical review," *Annals of physical and rehabilitation medicine*, vol. 61, no. 6, pp. 414–418, 2018.

music has been used as a supplementary tool to enhance these functions^{5,6,7,8,9} but without much rationale. Pleasant music stimulates brain regions associated with memory, attention, cognition, and IQ¹⁰, moreover even brief exposure to it can enhance the spatiotemporal performance of individuals^{11,12}.

Likewise sad music can evoke a pleasurable experience characterized by a sense of solace¹³ and profound beauty¹⁴. This feeling is different from real life sadness^{15,16}. Sad music is frequently sought after by healthy adolescents and young adults as a means of seeking solace, consolation¹⁷, comfort, and

⁵ F. H. Rauscher, G. L. Shaw, and C. N. Ky, "Music and spatial task performance," *Nature*, vol. 365, no. 6447, pp. 611–611, 1993.

⁶ B. E. Rideout and C. M. Laubach, "Eeg correlates of enhanced spatial performance following exposure to music," *Perceptual and motor skills*, vol. 82, no. 2, pp. 427–432, 1996.

⁷ V. Putkinen, T. Makkonen, and T. Eerola, "Music-induced positive mood broadens the scope of auditory attention," *Social Cognitive and Affective Neuroscience*, vol. 12, no. 7, pp. 1159–1168, 2017.

⁸ A. Markovic, J. Kuřhnis, and L. J'ancke, "Task context influences brain activation during music listening," *Frontiers in human neuroscience*, vol. 11, p. 342, 2017.

⁹ L. J'ancke, J. Kuřhnis, L. Rogenmoser, and S. Elmer, "Time course of eeg oscillations during repeated listening of a well-known aria," *Frontiers in human neuroscience*, vol. 9, p. 401, 2015.

¹⁰ W. Verrusio, E. Ettorre, E. Vicenzini, N. Vanacore, M. Cacciafesta, and O. Mecarelli, "The mozart effect: a quantitative eeg study," *Consciousness and cognition*, vol. 35, pp. 150–155, 2015.

¹¹ F. H. Rauscher, G. L. Shaw, and K. N. Ky, "Listening to mozart enhances spatial- temporal reasoning: towards a neurophysiological basis," *Neuroscience letters*, vol. 185, no. 1, pp. 44–47, 1995.

¹² T. L. Wilson and T. L. Brown, "Reexamination of the effect of mozart's music on spatial-task performance," *The Journal of Psychology*, vol. 131, no. 4, pp. 365–370, 1997.

¹³ A. J. Van den Tol, J. Edwards, and N. A. Heflick, "Sad music as a means for acceptance-based coping," *Musicae Scientiae*, vol. 20, no. 1, pp. 68–83, 2016.

¹⁴ M. E. Sachs, A. Damasio, and A. Habibi, "The pleasures of sad music: a systematic review," *Frontiers in human neuroscience*, vol. 9, p. 404, 2015.

¹⁵ A. Gupta, B. Bhushan, and L. Behera, "Neural response to sad autobiographical recall and sad music listening post recall reveals distinct brain activation in alpha and gamma bands," *Plos one*, vol. 18, no. 1, p. e0279814, 2023.

¹⁶ L. Taruffi and S. Koelsch, "The paradox of music-evoked sadness: An online survey," *PLoS One*, vol. 9, no. 10, p. e110490, 2014.

¹⁷ T. F. Ter Bogt, A. Vieno, S. M. Doornwaard, M. Pastore, and R. J. Van den Eijnden, "'you're not alone': Music as

cope with their emotions. The positive effects of listening to sad music on managing difficult circumstances have been extensively studied and well documented^{18,19}.

Another important aspect in establishing a quantitative framework of mechanisms in music induced cognitive changes is the type of music that is used in the experimental study. Earlier studies used mostly Western music, especially Mozart, leaving scope to question whether other music forms from different cultural backgrounds would also show similar neural mechanisms. We used Indian as well as western music as the stimuli in the study.

In conclusion, music listening offers an array of benefits that encompass our mental, emotional, and physical well-being. From providing relief from stress and enhancing our mood to improving cognitive abilities and promoting emotion resilience, music has the power to transform our lives. The multifaceted benefits of music arise from its unique capacity to influence not only various musical domains but also non-music domains such as intelligence, attention, emotion, and the Default Mode Network (DMN)^{20,21}.

However, despite numerous benefits. Music research faces several challenges such as: -

- Music is not administered in a scientifically guided manner.
- Effects of listening to music have been reduced to artifacts of the aesthetic nature of the music or at best to mood and arousal features of music.
- The static and dynamic aspects of the neural and cognitive underpinnings of the brain during music listening are not well-established.
- Studying the impact of multifaceted musical stimuli on specific cognitive domains, such as intelligence and attention, demands meticulous analysis.

a source of consolation among adolescents and young adults,” *Psychology of Music*, vol. 45, no. 2, pp. 155–171, 2017.

¹⁸ A. J. Van den Tol and J. Edwards, “Exploring a rationale for choosing to listen to sad music when feeling sad,” *Psychology of music*, vol. 41, no. 4, pp. 440–465, 2013.

¹⁹ W. E. Hanser, T. F. ter Bogt, A. J. Van den Tol, R. E. Mark, and A. J. Vingerhoets, “Consolation through music: A survey study,” *Musicae Scientiae*, vol. 20, no. 1, pp. 122–137, 2016.

²⁰ R. W. Wilkins, D. A. Hodges, P. J. Laurienti, M. Steen, and J. H. Burdette, “Network science and the effects of music preference on functional brain connectivity: From beethoven to eminem,” *Scientific reports*, vol. 4, no. 1, pp. 1–8, 2014.

²¹ W. Trost, T. Ethofer, M. Zentner, and P. Vuilleumier, “Mapping aesthetic musical emotions in the brain,” *Cerebral cortex*, vol. 22, no. 12, pp. 2769–2783, 2012.

3. **Methodology adopted for Development of the Product/Process in the Research Project** *(State briefly in 800 words)*

Experiment 1

Participants

The study involved 20 male undergraduate students aged 21–29 (mean age = 24.06, SD = 2.69) from a technology institute. Inclusion criteria required right-handedness and no prior formal or informal music training. Participants with hearing disorders, neurological conditions, or recent psychoactive drug use were excluded. Male-only participation was due to sex differences in the neural biomarkers of intelligence. The study, approved by IIT Kanpur's Institutional Ethics Committee (IEC), followed ethical guidelines. Volunteers, recruited via advertisements, provided informed consent after receiving a detailed briefing.

Stimulus and Experimental Design

Raga Darbari, known for its potential therapeutic effects on diabetes, insomnia, and stress, served as the stimulus. The 9-minute, 53-second composition included a slow alaap (3:22) and a faster gat (6:31), capturing its distinct features. Participants underwent three experimental conditions: pre-music silence, music listening, and post-music silence (each 275 seconds), all conducted in a soundproof, dimly lit laboratory. Seated comfortably, participants listened to the raga through stereo speakers with eyes closed, minimizing distractions. Mood assessments were recorded pre- and post-session.

EEG Recording and Preprocessing

EEG signals were captured at 32 scalp positions using g.HIamp amplifiers (512 Hz sampling, 0.01–100 Hz bandpass filter) with the right earlobe as the reference. Electrodes near the eyes captured ocular artifacts, while data with motion-related disturbances were rejected. Artifact-prone channels were identified, with independent component analysis (ICA) and interpolation addressing residual issues. The experiment compared pre- and post-music conditions, focusing on alpha wave activity (8–13 Hz).

Phase and Power Analysis

Analyzing music's short-term effects, researchers examined alpha-band phase coherence, phase delay, and power across time periods (e.g., 25, 50 seconds) to identify peak alterations. Functional connectivity maps revealed reduced information flow post-music listening. Comparisons highlighted changes in alpha power in the prefrontal and occipital regions, providing insights into the neural effects of the raga.

Experiment 2

Participants and Stimulus Selection

This study featured 20 right-handed males aged 19–29 (mean age = 22.14, SD = 3.68), free from prior music training, neurological or hearing impairments, and significant psychological distress. Pre-screened using the Kessler Scale, participants with depressive tendencies were excluded. The IEC-approved protocol ensured ethical compliance. Judges rated compositions to select Mishra Jogiya Raag for its emotional potency, emphasizing sadness. The selected alap (8:44) conveyed sadness effectively.

Experimental Procedure

Participants engaged in three conditions: baseline rest (9 minutes), autobiographical sad recall (9 minutes), and passive sad music listening (9 minutes). Recall involved vividly describing personal sad experiences, facilitating authentic emotional states. EEG was recorded in a soundproof environment with controlled lighting and minimized participant movement. This design supported capturing dynamic brain responses to sadness-inducing tasks.

EEG Source Analysis

Electrophysiological data underwent intracortical current source density (CSD) computation using eLORETA. Focusing on cortical regions like the cingulate cortex (CC) and precuneus (PCC),

researchers analyzed frequency bands, including alpha and gamma, across 6239 voxels, enabling detailed functional mappings.

Experiment 3: Microstate Analysis

Microstates represent transient, stable patterns in EEG topography. This study categorized EEG microstates (class A, B, C, D) across three conditions (baseline, music, post-music silence) using spatial k-means clustering at high signal-to-noise peaks (Global Field Power maxima). Metrics like global explained variance (GEV), coverage, occurrence, and duration described each microstate. Transition probabilities quantified shifts between states.

EEG data segmentation supported temporal analyses of music's neural effects, correlating microstates with music-induced emotional and attentional changes. Metrics confirmed reduced neural complexity during music-induced states, enriching understanding of brain dynamics during structured auditory experiences.

This combined approach underscores the profound cognitive and emotional effects of Indian classical music.

4. Description of the any Product/Process developed during the project

NA

5. Outputs & Outcomes:

a. Technology Development*Technology developed at Lab scale/pilot scale/commercial scale:*

- Technology demonstration in field setup - Yes/No
- Technology Transfer to industry: If Yes (Name of the Industry)
- Buyers/End users of product:
- Affordability: The cost-estimate of the developed prototype

NA

b. Knowledge Creation

- Patent filings:
- Participation in conference/ training workshops attended:

Gupta A, Srivastava CK, Bhushan B, Behera L (2023). Do men and women process happy and sad music alike ? International Conference on Music Perception and Cognition and the 7th Conference of the Asia-Pacific Society for the Cognitive Sciences of Music (ICMPC17-APSCOM7), Tokyo, Japan, pp. 350-355.

Gupta A, Srivastava CK, Bhushan B, Behera L (2023). EEG microstate of Indian Raga. MIND, BRAIN, AND CONSCIOUSNESS Conference (MBCC 2023), IIT Mandi, India. (Accepted)

c. Knowledge Dissemination

- Describe the strategies used to disseminate the research findings and knowledge.
- Examples of dissemination methods:
 - i. Conference presentations
 - ii. Workshops and training sessions
 - iii. Online resources (websites, open access repositories)
 - iv. List of Courses developed
 - v. Social media/other media outreach

d . Publications

Type of Publications	Number of Publications	List of Publications	Authors & Co- Authors	Theme of the publication	References/links of the Publications (link not required for books)
Research Papers	3	1. Gupta A, Bhushan B, Behera L (2023) Neural response to sad autobiographical recall and sad music listening post recall reveals distinct brain activation in alpha and gamma bands. PLoS ONE 18(1): e0279814. https://doi.org/10.1371/journal.pone.0279814	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera	Indian Arts, Music, and Cognitive Functions	https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0279814
		2. Gupta, A., Bhushan, B., & Behera, L. (2018). Short-term enhancement of cognitive functions and music: A three-channel model. Scientific reports, 8(1), 1-12.	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera	Indian Arts, Music, and Cognitive Functions	https://www.nature.com/articles/s41598-018-33618-1
		3. Gupta A, CK Srivastava, Bhushan B, Behera L (2025). A Comparative Study of EEG Microstate Dynamics during Happy and Sad Music Videos (Accepted in Frontiers in Human Neuroscience)	Dr. Ashish Gupta, Chandan Kumar Srivasatava, Prof Braj Bhusahan, Prof Laxmidhar Behera	Indian Arts, Music, and Cognitive Functions	
		4. Gupta A, CK Srivastava, Bhushan B, Behera L EEG Microstates dynamics of Happiness and Sadness during Music Listening (Communicated).	Dr. Ashish Gupta, Chandan Kumar Srivasatava, Prof Braj Bhusahan, Prof Laxmidhar Behera	Indian Arts, Music, and Cognitive Functions	

Poster presentations		1. Best poster award at the National Youth Conference on Indian Knowledge System 2023, organized at IIT Roorkee in association with IKS division of MoE from August 25 to 27, 2023. Poster title: "Effect of Indian Raga on Cognitive Functions".	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera		
		2. Presented paper at the National Conference on Psychology, Science and Technology: IKS Application 2023, organized at NIT Kurukshetra. Title: "EEG Biomarker of Indian Classical Music".	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera		
		3. Presented Poster on "Decoding the Neurological response to listening a Sad Indian Raga", in Workshop on Indian Knowledge System and Mental Health (IKSMH), 2022 at IIT Mandi.	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera		
		4. Presented Poster on "A Neurophysiological Study on Listening to Indian Raga Darbari", in Next Level Innovation in Robotics and Autonomy workshop, 2019 at IIT Kanpur.	Dr. Ashish Gupta, Prof Braj Bhusahan, Prof Laxmidhar Behera		

e. Describe how the project How the project resulted in integration of IKS and Contemporary knowledge

The knowledge of the Indian music system is as old as Indian civilization and is one of the oldest music systems²². Traditionally the Indian classical has also been used in therapeutic processes known as Raga Chikitsa²³. It has been found to have positive effects in neurological, physiological and psychological ailments²⁴. Ragas balance Vaatha, Pittha and Kapha of the body³ and thereby has a curative effect. However, the benefits of Ragas are modulated by the time of day and seasons of the year³. Although benefits of Indian classical musical on enhancing cognitive functions like Intelligence, attention, emotion regulation and sleep are known, the underlying neural mechanisms in these effects are not well investigated. Thus, Indian classical musical (inspite of several benefits) is not administered in a scientifically guided term. Indeed, understanding how a single Raga would affect a number of brain processes simultaneously would also give a deeper insight into these brain functions; how and when they function efficiently and their interrelation with each other.

Primarily the current project facilitated:

- Scientific characterization of the Indian Raga in terms of its effect brain in alpha, Beta, Gamma, Delta bands.
- Scientific characterization of the Indian Raga in terms of its effect brain in different cognitive function.
- Static as well as dynamic impact of Indian Raga on the Human Brain.

f. Knowledge Repository

- Describe the structure and organization of the knowledge repository
- Explain how users/public can access and utilize the knowledge repository.

All the work which has been done is/will be published as research articles in standard Journals, accessible for users/public.

g. Capacity building

- Officers/faculty
- Temporary manpower recruited/trained

Trained 2 PHD students and one research scientist.

h. Results & Analysis with figures

- Present your findings in a clear and organized manner
- Include figures, Data analysis (Tables, Charts, Graphs), and Illustrations to support your findings.

Please refer the following paper for detailed Results.

Paper 1 [Gupta, A., Bhushan, B., Behera, L. \(2018\). Short-term enhancement of cognitive](#)

²². Hegde, S. (2017). Music therapy for mental disorder and mental health: the untapped potential of Indian classical music. *BJPsych international*, 14(2), 31-33.

²³. Sundar, S. (2007). Traditional healing systems and modern music therapy in India. *Music Therapy Today*, 8(3), 397-407.

²⁴. Desai, N. M., Sanjay, H. S., Desai, D. M., Kunikullaya, K., & Sinha, A. K. (2021). An Overview of the Indian System of Raagas and their Positive Effects on Health. *Journal of Drugs Addiction & Therapeutics. SRC/JDAT-112* Page, 3, 3-6.

functions and music: A three-channel model. Scientific reports, 8(1), 1-12.

Paper 2. *Gupta A, Bhushan B, Behera L (2023) Neural response to sad autobio- graphical recall and sad music listening post recall reveals distinct brain activation in alpha and gamma bands. PLoS ONE 18(1): e0279814.*

i. Achievements/ highlights of the project

To summarize, the impact of happy Raga is demonstrated through an elevation in cognitive function, specifically attention and intelligence. This effect is potentially achieved through the following distinct mechanisms:

By up-regulating brain area/microstate associated with attention and intelligence:

- (1) By enhancing local efficiency within the prefrontal region, as measured through enhanced EEG power, thereby resulting in elevated IQ.
- (2) By augmenting local efficiency within the occipital region, as measured through enhanced EEG power, thereby resulting in improved attention.
- (3) Through the amplification of class D microstates associated with heightened attention as measured through enhanced GEV.

By down-regulating the activity/microstate with unwanted brain activity:

- (4) By mitigating unnecessary connections (especially long distances), thereby enhancing global efficiency.
- (5) Through the suppression of class C microstates linked to wandering of the mind as measured through diminished GEV.

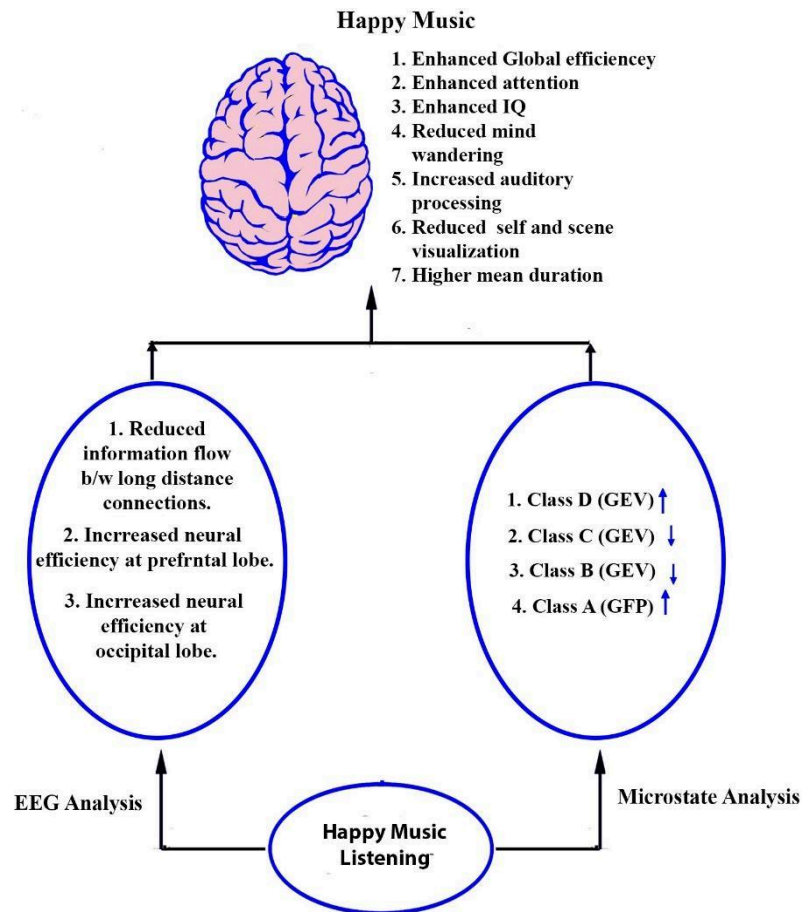


Figure: Schematic model for neural and cognitive underpinning happy Raga listening.

Moreover, the positive impact of sad Raga manifests in the enhancement of several self-regulatory goals, and this effect is potentially achieved through the following distinct mechanisms:

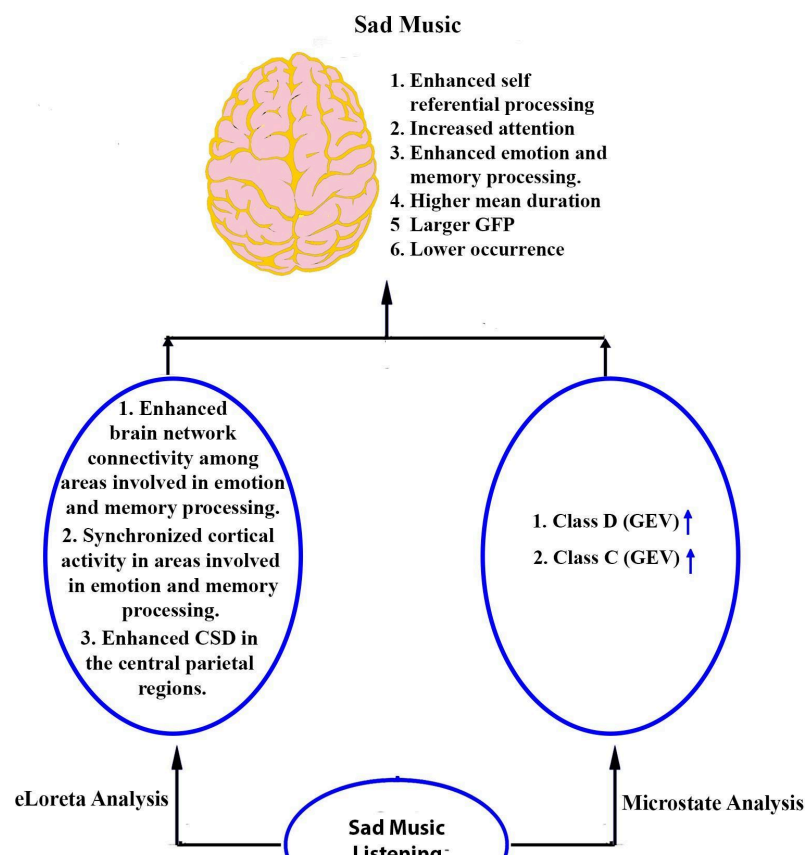


Figure: Schematic model for neural and cognitive underpinning sad Raga listening.

By up-regulating brain area/microstate associated with emotion and memory processing:

- (1) By augmenting brain activity in regions intricately tied to emotion and memory processing as measured through enhanced CSD, thereby enhancing these process.
- (2) By enhancing brain inter-connectivity in areas associated with emotion and memory processing as measured through enhanced lagged phase connectivity, thereby enhancing these process.
- (3) Through the augmentation of class C microstates linked to the visualization of scenes and self-referential thoughts and memories, as measured through GEV.
- (4) By boosting brain activity within regions linked to attention as measured through enhanced CSD, thereby enhancing the process.
- (5) Through the up-regulation of class D microstates associated with heightened attention as measured through GEV.

j. References

- List all references used in the report

Given Below.

k. Appendices

- Include any additional information that supports the research, may not fit within the main body of the report.

l. Project Outcomes Contribution to (Bullet points. No more than 250 words in each category)

Exploring Raga's Cognitive and Spiritual Impact Through Dr̥ṣṭi, Jñāna, and Laukika-Prayojana

Dr̥ṣṭi

- Deeper Truth: Indian classical music, rooted in Natya Sastra, enhances transcendental perception through Rasa (aesthetic emotion), helping perceive subtle aspects of consciousness.
- Ragas and Meditation: Meditative ragas like Raga Darbari invoke introspection and peace, encouraging alignment with Shanta Rasa and Karuna Rasa for deeper clarity.
- Experiential Transformation: The use of sound and melody in ragas creates a meditative state, broadening perception akin to mystical darshan (divine seeing).

Jñāna

- Metaphysical and Empirical Synthesis: Indian classical music integrates spiritual concepts of Bhava (emotion) and Dhvani (resonance) with modern brain EEG findings on cognition.
- Harmony in Consciousness: Music's ability to regulate brain waves, like enhancing alpha rhythms, reaffirms ancient wisdom on balancing body and mind for higher spiritual cognition.
- Path to Liberation: Aligning musical experience with Jñāna supports self-realization and Moksha by channeling higher states of awareness through sound vibrations.

Laukika-Prayojana

- Therapeutic Applications: Raga Chikitsa, an ancient therapeutic practice, helps balance emotions, such as using Mishra Jogiya to evoke Karuna Rasa and manage grief.
- Impact on Triguṇas: Specific ragas influence sattva, rajas, and tamas to stabilize mental states and promote resilience.

- Social Harmony: By addressing personal well-being through music, the practice aligns with the dharmic goal of promoting harmony in the collective societal fabric.

Conclusion

- Holistic Integration: Indian classical music integrates Dṛṣṭi, Jñāna, and Laukika-Prayojana, offering transcendence and worldly healing.
- Temporal and Eternal Force: Reflects the unity of cognition, emotion, and transcendence, reaffirming art as a sacred interplay of life’s practical and higher dimensions.
- Validation Through Modern Science: Modern EEG findings affirm traditional wisdom, cementing music as both a timeless cultural artifact and a forward-reaching spiritual tool.

Prof Laxmidhar Behera

Prof Braj Bhushan

Prof Laxmidhar Behera

Name of PI

Name of Co-PI

Head of the Institution



Signature of PI

Signature of Co-PI

Signature

References: