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Effects of Raga Kirwani on EEG Microstates: An Inquiry of Brain Network Dynamics

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Abstract

The raga system of Indian classical music has long been associated with emotional and cognitive regulations, but its effect on large-scale brain networks is still not adequately explored. This study sought to examine the impact of Raga Kirwani on resting-state brain dynamics using EEG microstate analysis. A within-subject approach was utilized with 10 healthy adult volunteers (*M* = 20.5 years, *SD* = 3.32). EEG data were acquired prior to and after a 5-min listening session of Raga Kirwani. Microstate characteristics, such as mean duration, occurrence, coverage, global explained variance (GEV), and transition probabilities, were obtained using the MICROSTATE toolbox in EEGLAB. Results indicated a decline in coverage of microstate B, reduced transition from C to B, and increased transition from C to D—a reduction in visual-spatial processing and an increase in executive activities. Although early, these findings offer basic evidence that Indian classical music may in fact function as a culturally ingrained instrument of mental alignment and control. Subsequent research with larger sample size and control is needed to expand upon these findings.

Keywords: Raga Kirwani; EEG; microstates; resting-state; Indian classical music; cognitive flexibility; DMN; music neuroscience

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Introduction

Music is one of the most ancient and universal forms of human experience and expression that is capable of putting profound effects on cognition, emotion, and physiological processes. In the last few decades, with the advent of recent technologies, cognitive neuroscience has gradually focused understanding on how our brain reacts to music and its influence on mood (Blood & Zatore, 2001; Koelsch, 2010; Zentner et al., 2008), memory (Särkämö et al., 2008), attention (Meltzer et al., 2015; Treder et al., 2015; Xiao et al., 2024), and functional connectivity within and even across large-scale brain networks (Koelsch, 2014; Salimpoor et al., 2011). Despite the global variety of musical traditions and dispositions, the majority of them focused on western tonal systems, often neglecting the rich diversity of other global musical traditions (Cross, 2012; McDermott & Hauser, 2005).

Indian classical music is characterized by its deep and ancient intellectual foundations, intricate melody, and sophisticated and nonnatural rhythm. It has been historically linked to certain emotional, mental, and physiological conditions (Ubrangala et al., 2022). The central foundation to this system is the concept of raga, functioning as a melodic framework, that integrates sounds and melodies while also evoking certain moods and mental states, referred to as *rasa* (Clayton, 2000; Jairazbhoy, 1995). These ragas have shown unique cognitive and emotional impact and have been utilized with meditative practices and music therapy. Despite the increasing empirical focus on both the psychological and the physiological impact of ragas—especially concerning relaxation of anxiety, heart rate regulations, and improvement in attention—a substantial gap still persists in our comprehension of their neurodynamic influence, particularly regarding intrinsic brain states during rest.

Raga Kirwani can be distinguished by its unique structure, forming a symmetric 7-note scale in both its ascent (arohana) and descent (avarohana). Specifically, with its notes being S–R–g–M–P–d–N–S′ (where *g* and *d* are lowered), it is very similar to the harmonic minor scale and has been conventionally linked to a self-reflective calm state. Although anecdotal and therapeutic applications of Kirwani have been recorded in traditional practices (Sharma et al., 2017; Ubrangala et al., 2022), its impact on the brain's intrinsic activity, particularly on the resting-state dynamics, has yet to be investigated.

Electroencephalography (EEG) microstate analysis provides an effective approach for investigating rapid dynamics of the resting-state activity of the brain. Microstates are transient, quasistable configurations of scalp potential topographies that endure for around 80–120 ms and have been believed to represent distinct global functional states of the brain (Michel & Koenig, 2018) and have also been referred to as the “the atom of thought” (Lehmann et al., 1998). A consensus has developed on four canonical microstates, designated A, B, C, and D (Koenig et al., 1999; Lehmann et al., 2005; Strik et al., 1997; Strelets et al., 2003; Kikuchi et al., 2011; Kindler et al., 2011), although studies have found other template maps to be useful too (Britz et al., 2010). These microstates are thought to be correlated with certain global functional networks:

- **Microstate A** – Auditory processing
- **Microstate B** – Visuo-spatial attention
- **Microstate C** – Default mode network (DMN)
- **Microstate D** – Executive control and salience network (Britz et al., 2010; Seitzman et al., 2017)

Alterations in the microstate parameters—specifically mean duration, occurrence frequency, coverage, and transition probabilities—have been associated with diverse mental states including alertness, meditation, mind wandering, and psychiatric disorders, such as schizophrenia and depression (Khanna et al., 2015; Michel & Koenig, 2018; Milz et al., 2016). Moreover, music has been demonstrated to influence EEG microstates. Previous research indicates that listening to emotionally charged or organized music can alter microstate characteristics in both skilled musicians and nonmusicians, suggesting that music may affect the brain’s plastic organization even during rest (Hill et al., 2017).

Despite all the advancements, the influence of Indian classical music—particularly Indian ragas—on EEG microstate dynamics has yet to be investigated. To our knowledge, this study is the first investigation into the impact of Raga Kirwani on EEG microstates in healthy persons. We recorded the resting-state EEG before and after a passive listening session with Raga Kirwani using a within-subject, pre–post methodology. We obtained the four canonical microstates and assessed the alterations in their temporal characteristics (length, occurrence and coverage), global explained variance (GEV), topographic consistency, and transition probabilities.

It was hypothesized that listening to Raga Kirwani would impact the dynamics of specific microstates, possibly indicating changes in attention, self-referential processing, and cognitive control. Considering Kirwani is conventional to meditative tranquility and introspective awareness, we expected a decrease in visuospatial and default mode activities (microstates B and C) and increase in auditory and salient network activity (microstates A and D).

This pilot study seeks to offer initial insights into how culturally rooted musical genres like the ragas may influence inherent brain processes and generate hypotheses for future studies in this niche area.

Methodology

Participants

Ten healthy adult participants (Mean age = 20.5 years, *SD* = 3.32) took part in the study. All of the participants were right-handed, with hearing sensitivity within normal limits, and did not report any diagnosed psychological or neurological disorder. None of them had received formal music training or had any knowledge regarding raga grammars. Informed consent was obtained from all individuals prior to participation.

Procedure

The study followed a within-subject pre–post design. Participants were seated in a sound attenuated lab and were instructed to keep their eyes closed and relax, and to inform the experimenter if they felt drowsy or might fall asleep. Three minutes of resting-state EEG were obtained, after which a 5-min instrumental excerpt of Raga Kirwani was played through a stereo sound system at a comfortable volume. Finally, another 3 min of eyes-closed resting EEG data were recorded.

EEG Recording

EEG data was recorded using a medical grade 24-channel EEG system, with electrodes placed following the international 10–20 system. Signals were sampled at 256 Hz with impedance kept below 10 kΩ. The ground electrode was placed at the cheek and the reference electrode was attached to the left mastoid. Electro-oculographic (EOG) activity was recorded from additional electrodes placed above and below the eyes to monitor eye blink.

EEG Preprocessing

Data preprocessing was done using EEGLAB (Delorme & Makeig, 2004) in MATLAB following standard preprocessing protocol. Continuous resting-state EEG data were passed through 1 Hz highpass and 40 Hz lowpass filter and rereferenced to the average. Noisy data segments were first manually scanned and removed, and also cleaned utilizing artifact subspace reconstruction (ASR; Mullen et al., 2015; specifically, artifact-laden intervals were removed employing a burst criteria of 20 as advised by Chang et al., 2020). Bad channels were removed and interpolated if they (a) were flat for over 5 s, (b) exhibited more than three standard deviations of line noise compared to all other channels, or (c) correlated at less than 0.80 with adjacent channels. Independent component analysis (ICA) decomposition was done subsequently, and any remaining artifacts other than brain (e.g., muscle, eyes, heart, and signal noise) were removed. After careful consideration, 20 s of EEG data from each participant was finalized to be used for microstate analysis.

In EEG, or as in other signal processing methods, “garbage in = garbage out” is a phrase that researchers always adhere to. Thus, EEG data quality was of utmost importance to us and was rigorously screened and assessed; complete data from 5 out of an initial pool of 15 participants had to be removed for not passing the quality standard, resulting in the final pool of 10 participants.

Microstate Analysis

Microstate analysis was conducted using the MICROSTATE TOOLBOX (Poulsen et al., 2018) in EEGLAB. The data was segmented using the peaks from the Global Field Power (GFP), and the maps were clustered using a modified k-means clustering (Pascual-Marqui et al., 1995). A four-class solution (A–D) was selected to align with existing research. The last phase of microstate analysis, known as backfitting, was conducted on the preprocessed, spatially filtered data of each participant, yielding rich and comprehensive temporal information, individually for every participant. The mean maps and temporal plots of both the conditions were extracted for interpretation. The following microstate parameters were extracted:

1. Mean duration (ms): the average length of each microstate occurrence
2. Occurrence (Hz): the frequency of each microstate’s appearance per second
3. Coverage (% in time): the proportion of total time allocated to each of the microstate
4. Global explained variance (GEV): the amount of variance explained by each microstate class.
5. Transition probabilities: the probability of moving from one microstate to another

Statistical Analysis

All statistical analyses were performed using JAMOVI. Paired-comparison Wilcoxon Rank Test with rank biserial effect size was used to compare each microstate parameter between Rest 1 and Rest 2 conditions, controlling for FDR (Benjamini & Hochberg, 1995).

Ethical Declaration

This study was carried out in accordance with the ethical standard approved by the declaration of Helsinki. Ethical approval was obtained from the Internal Quality Assurance Cell (IQAC) of Sarojini Naidu College for Women and follows all ethical rules and guidelines to protect the identity of study participants. Individuals who took part were told they would be part of a study about Indian classical music, and they were also explained how the EEG would be administered in general. The people who took part in the experiment were also made very clear that they could leave right away if they felt any physical or mental pain. Before taking part, all volunteers were given a consent form where they gave written consent and were remunerated for their time.

Results

Microstate Temporal Parameters

Prior to the paired test, the descriptive statistics (Mean, *SD*, Skewness, Kurtosis, Shapiro-Wilk Test of Normality) were calculated which have been included below in Table 1.

Table 1
Descriptive Statistics

			Skewness		Kurtosis		Shapiro-Wilk	
	Mean	*SD*	Skewness	*SE*	Kurtosis	*SE*	*W*	*p*
TotalExpVar_Post	0.6793	0.06446	0.79629	0.717	0.9472	1.4	0.914	.346
TotalExpVar_Pre	0.6989	0.07612	0.08526	0.717	−1.4132	1.4	0.937	.554
TotalTime_Post	18.2608	0.36947	−0.20824	0.717	−1.9574	1.4	0.868	.118
TotalTime_Pre	18.4310	0.30929	−0.77132	0.717	0.3188	1.4	0.959	.790
Coverage_A_Post	30.2184	9.80493	−0.51444	0.717	−0.9390	1.4	0.920	.394
Coverage_A_Pre	27.3256	8.76498	0.29018	0.717	−1.2392	1.4	0.941	.596
Coverage_B_Post	19.3421	6.80554	−0.73612	0.717	0.6384	1.4	0.959	.790
Coverage_B_Pre	25.8501	8.37976	0.57846	0.717	−1.2817	1.4	0.897	.233
Coverage_C_Post	24.0232	8.30042	0.61245	0.717	−1.4110	1.4	0.862	.101
Coverage_C_Pre	26.4322	8.28414	0.52180	0.717	−0.2165	1.4	0.877	.145
Coverage_D_Post	27.3993	6.59225	1.94646	0.717	4.8014	1.4	0.749	.005
Coverage_D_Pre	19.7940	6.07969	0.41735	0.717	−0.5623	1.4	0.951	.700
DeltaTM_A→B_Post	−2.3450	18.89756	0.8209	0.717	0.8051	1.4	0.934	.523
DeltaTM_A→B_Pre	−2.1624	12.10113	−0.1919	0.717	−1.0712	1.4	0.942	.602
DeltaTM_A→C_Post	−4.5318	12.38031	0.6262	0.717	−0.7763	1.4	0.934	.517
DeltaTM_A→C_Pre	−8.2072	17.00817	−0.5791	0.717	−1.3977	1.4	0.890	.202
DeltaTM_A→D_Post	3.3214	12.71463	−1.7261	0.717	3.6362	1.4	0.831	.046
DeltaTM_A→D_Pre	8.7572	11.49947	0.5113	0.717	−1.4374	1.4	0.892	.207
DeltaTM_B→A_Post	1.2178	15.49359	−0.7045	0.717	−0.3319	1.4	0.933	.506
DeltaTM_B→A_Pre	−6.4780	13.53143	0.8708	0.717	−0.3678	1.4	0.899	.249
DeltaTM_B→C_Post	4.3856	19.82063	1.3737	0.717	1.0897	1.4	0.836	.052
DeltaTM_B→C_Pre	5.6810	9.61665	−0.8742	0.717	1.0531	1.4	0.951	.703
DeltaTM_B->D_Post	−8.6830	21.47835	−0.0313	0.717	−0.6383	1.4	0.977	.948
DeltaTM_B→D_Pre	−3.5866	20.43776	−0.8405	0.717	−0.6098	1.4	0.872	.130
DeltaTM_C→A_Post	9.6983	16.78708	−0.0122	0.717	1.5703	1.4	0.932	.504
DeltaTM_C→A_Pre	9.7430	12.46186	−0.0512	0.717	−0.3811	1.4	0.995	1.000
DeltaTM_C→B_Post	−14.9008	9.83953	0.5115	0.717	−1.8576	1.4	0.832	.047
DeltaTM_C→B_Pre	3.4866	18.38546	−0.1193	0.717	−1.0343	1.4	0.920	.394
DeltaTM_C→D_Post	2.4484	20.56274	−0.3426	0.717	0.4803	1.4	0.976	.941
DeltaTM_C→D_Pre	−20.0101	15.76679	−0.7811	0.717	0.8825	1.4	0.956	.758
DeltaTM_D→A_Post	−6.0860	15.31460	−0.8122	0.717	−0.3831	1.4	0.894	.220
DeltaTM_D→A_Pre	0.6416	20.94175	0.9077	0.717	1.3911	1.4	0.940	.580
DeltaTM_D→B_Post	2.2111	20.69236	−1.9507	0.717	4.6590	1.4	0.805	.023
DeltaTM_D→B_Pre	−8.4979	16.06718	−0.8021	0.717	−0.2705	1.4	0.921	.399
DeltaTM_D→C_Post	−4.1166	7.73106	−0.8466	0.717	0.8793	1.4	0.922	.408
DeltaTM_D→C_Pre	1.6457	19.28997	0.0874	0.717	−1.1650	1.4	0.963	.833

Table 2

Paired-Comparison Wilcoxon Rank Test With Rank Biserial Effect Size

		Wilcoxon (W)	*p*	Effect Size
TotalExpVar_Pre	TotalExpVar_Post	29	.496	0.2889
TotalExpVarPre_Pre	TotalExpVarPost_Pre	27	.652	0.2000
TotalTime_Pre	TotalTime_Post	29.5	.441	0.3111
TotalTime_Pre_Pre	TotalTime_Post_Pre	26	.721	0.1556
Coverage_A_Pre	Coverage_A_Post	15	.426	−0.3333
Coverage_A_Pre	Coverage_A_Post	25	.820	0.1111
Coverage_B_Pre	Coverage_B_Post	41	.027	0.8222
Coverage_B_Pre	Coverage_B_Post	31	.359	0.3778
Coverage_C_Pre	Coverage_C_Post	31	.359	0.3778
Coverage_C_Pre	Coverage_C_Post	27	.652	0.2000
Coverage_D_Pre	Coverage_D_Post	6	.055	−0.7333
Coverage_D_Pre	Coverage_D_Post	13	.301	−0.4222
DeltaTM_A→B_Pre	DeltaTM_A→B_Post	23	1.000	0.0222
DeltaTM_A→C_Pre	DeltaTM_A→C_Post	20	.820	−0.1111
DeltaTM_A→D_Pre	DeltaTM_A→D_Post	28	.570	0.2444
DeltaTM_B→A_Pre	DeltaTM_B→A_Post	15	.426	−0.3333
DeltaTM_B→C_Pre	DeltaTM_B→C_Post	28	.570	0.2444
DeltaTM_B→D_Pre	DeltaTM_B→D_Post	26	.734	0.1556
DeltaTM_C→A_Pre	DeltaTM_C→A_Post	22	1.000	−0.0222
DeltaTM_C→B_Pre	DeltaTM_C→B_Post	42	.020	0.8667
DeltaTM_C→D_Pre	DeltaTM_C→D_Post	5	.039	−0.7778
DeltaTM_D→A_Pre	DeltaTM_D→A_Post	26	.734	0.1556
DeltaTM_D→B_Pre	DeltaTM_D→B_Post	7	.074	−0.6889
DeltaTM_D→C_Pre	DeltaTM_D→C_Post	30	.426	0.3333

Note. The *p*-values reported are FDR-adjusted (Benjamini–Hochberg).

The coverage of microstate B showed a significant reduction after listening to Raga Kirwani (*W* = 41, *p* = .027, *r* = 0.82). No significant change was observed in the coverage of microstates A, C, and D. While delta transition from microstate C to B was reduced in Rest 2 condition compared to Rest 1 (*W* = 42, *p* = .020, *r* = 0.87), delta transition from C to D increased (*W* = 5, *p* = .039, *r* = 0.78).

Global Explained Variance (GEV)

Analysis of GEV showed no significant difference across the microstates between Rest 1 and Rest 2 conditions suggesting that the overall stability and explanatory power of the microstate maps remained relatively stable between both the conditions.

Figure 1. *4-class Topography Maps of Rest 1 Condition (Percentage Representing Global Explained Variance of each Microstate).*

Figure 2. *4-class Topography Maps of Rest 2 Condition (Percentage Representing Global Explained Variance of each Microstate).*

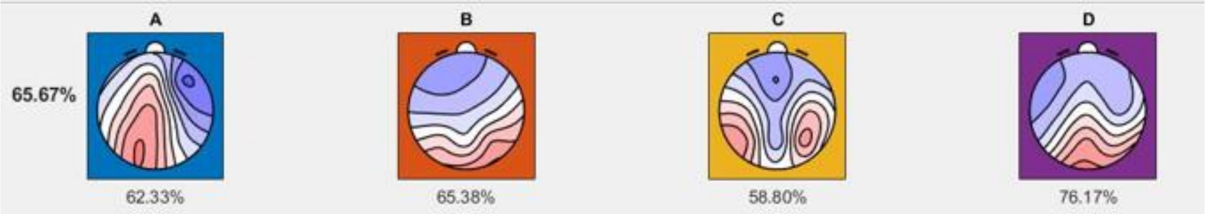


Figure 3. *Transition Matrix of Rest 1.*

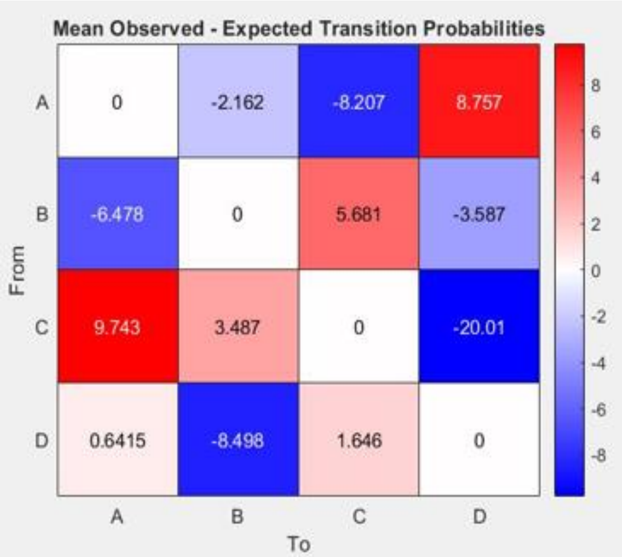
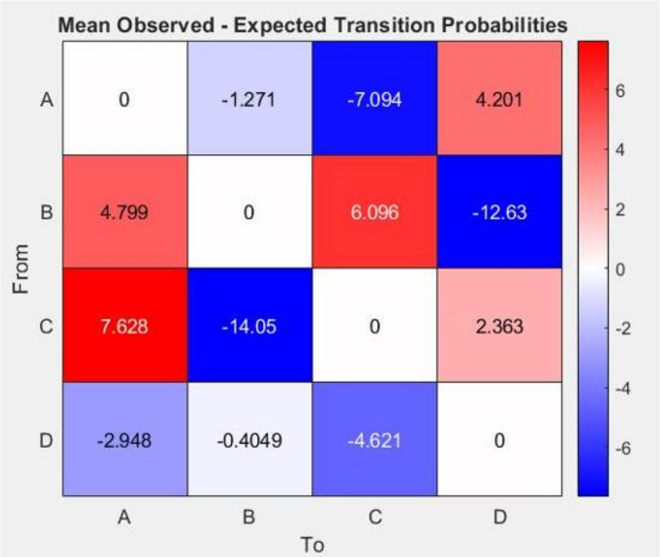


Figure 4. *Transition Matrix of Rest 2.*



Discussion

This study aimed to examine the effects of passive listening to Raga Kirwani, a traditional Carnatic raga, on resting-state brain dynamics by EEG Microstate Analysis. As far as we are aware, this is the first study that investigates the impact of this raga on microstate dynamics. The finding indicates three notable effects: (a) reduction in coverage of microstate B, (b) reduction in transition from microstate C to B, and (c) increased transition from microstate C to D.

Reduced Coverage and Return to Microstate B: Reduction in Visual-Spatial Processing

Microstate B has been generally associated with visual-spatial attention—activation in the parietal and occipital networks (Britz et al., 2010; Michel & Koenig, 2018). The observed reduction of its coverage following an exposure to Raga Kirwani indicates a transition from externally oriented visual processing. This corresponds to the subjective attributes of Kirwani, often described as meditative, introspective and emotionally soothing. This decrease in the visual microstate may correlate to diminished extrinsic awareness thereby promoting a more inward directedness of mental energy. This finding is in line with research indicating a similar reduced microstate B activity, in response to mindfulness meditation and other introspective techniques (Milz et al., 2016; Zanesco et al., 2021). Reduced return to microstate B from C further compliments the above finding, suggesting that following Kirwani's auditory input, the brain would be less inclined to revert back to visual sensory processing after self-reflection.

Increased Transition From C to D: Flexible Executive Switching

The increased transition from microstate C to D is especially noteworthy due to the fact that microstate C is often connected to the default mode network (DMN) and the self-referential processing, whereas microstate D indicates activation of the dorsal attention and salience network, associated with cognitive regulation and attentional reorientation (Michel & Koenig, 2018; Seitzman et al., 2017). This rise in C to D transition may signify improved flexibility and dynamic switching between the introspective (DMN) and executive control networks (Hao et al., 2025). Consequently, listening to Raga Kirwani may improve the adaptive connection between self-focused and goal-directed states, perhaps aiding control of emotions or cognitive rebalancing.

Cultural and Theoretical Implication

Raga Kirwani, traditionally linked to introspection, self-reflection, and emotional depth seems to influence both sensory and control-related neural states, even with just a 3-min passive listening session, indicating that Indian classical music may serve as a cognitive tool for mental alignment. This study adds to a growing body of work bridging Indian music with cognitive neuroscience, emphasizing the impact of culturally rooted, freely, and universally available music on brain activity.

Conclusion

Listening to Raga Kirwani produced significant and quantifiable alterations in EEG microstate activity during rest. There was a decline in visual-attentional microstate coverage, a reduction in transitions to visual states, and an improvement in the shift towards executive control modes. These findings indicate a transition from externally influenced processing to a more balanced and reflective brain condition, providing first evidence for the application of Indian classical music as a means of mental and emotional control.

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Authors' Declarations

The authors declare no conflict of interest related to this research. No funding was received for this study. All content of this manuscript is original and was developed by the authors. No generative AI tools were used to write the scientific content, analyses, or interpretations. AI-assisted tools (Research Rabbit and Perplexity) were used to support the literature search and review process only. Grammarly and QuillBot were used for language refinement and alignment with academic writing standards. The authors remain fully responsible for the accuracy, integrity, originality, and ethical compliance of the manuscript. The EEG data used in the study will be available from the corresponding author upon reasonable request, in accordance with ethical guidelines.

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