*Full-length article*

# Event-related potential changes on listening to specific modes of Indian music in healthy young individuals - *a randomized controlled trial*

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**Abstract**

Music is known to have a positive impact on mood and cognition. Music listening involves cognitive processing, and it is not clear how different musical features engage this process in the listeners and help disengage from distracting stimuli. To address this, we examined event-related potentials (ERPs) to study attention to a 3-stimulus active oddball task before, during, and after listening to a 10-minute Indian music clip intervention of 3 different *Ragas* or Modes, in 3 separate groups. Intermittent 'nature sounds' were used as a control intervention in a separate group. If a particular music was improving general attention to the surroundings (a dominant argument), the ERP components (N1 & P3) would show increased amplitude and reduced/increased latency, during or after intervention. Whereas, if a particular piece of music is engaging and helps disconnect oneself from distracting stimuli, the ERP components (N1 & P3) would show decreased amplitude and minimal latency change. Our results show the latter case. Group A (*Raga Miyan ki Todi*) showed the effect on P3 amplitude during and after music, and Group B (*Raga Malkauns*) showed the effect only after music. Group B (*Raga Malkauns*) showed a consistent effect on N1 latency during music and Group C (*Raga Puriya*) after music. Therefore, cognitive engagement by music depends on its musical composition and could influence the cognitive processing of other stimuli even after the music-listening period. This understanding would help design appropriate music therapy for cognitive training.

**Keywords**: event-related brain potentials; N100; P300; music-based interventions; musical components; indian classical music; classical music; musical modes.

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## Introduction

Cognition is a combination of mental processes in the brain that includes the ability to learn, memorize, and make judgments. The global prevalence of cognitive impairment as per a recent systematic review report ranges between 19.7% (95% CI: 18.3–21.1), with prevalence in Asia being 19.8% (18.0-21.5) [1]. Preventive measures to avoid cognitive decline range from lifestyle measures to pharmacological treatments. Lifestyle measures include engagement in physical and mental activity, quitting smoking, and alcohol, weight control, eating a balanced diet, rich in fruits, and vegetables, and maintaining homeostasis (blood pressure, cholesterol, and blood sugar). The literature review suggests that the best hope against the onset of cognitive decline or dementia is the implementation of preventive measures in cognitively healthy individuals [2]. Research on the influence of music listening on different psychological functions has substantially increased in the past two decades. Music has versatile effects, including the regulation of mood and emotions [see [3-6] for reviews]. Music is shown to have the potential to enhance a variety of cognitive functions, such as attention, learning, language, and memory [7]. Music is made up of many features, including pitch, dynamics, contrast, tones, tempo, and rh ythm. Previous works have concentrated on the cognitive

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COI statement: The authors declared that no financial support was given for the writing of this article. The authors have no conflict of interest to declare.

effects of listening to Western music, or music of short durations (music clippings of 30 seconds to a minute) and have analyzed scores after task performance with music intervention [8,9]. Under natural conditions, music lasts for longer durations. Research on the effect of listening to specific tones of music under natural conditions or the complete duration of the musical composition on cognition in healthy young individuals is significantly lacking. Since music is known to be a cognitively enriching stimulus, it will be important to understand the different features of music and build evidence for the use of music for cognitive remediation.

A Digital music study conducted in 2022 examined music consumption across people aged 16–64 years, in different geographical locations in India and concluded that Indians listen predominantly to local music, spend approximately 25.7 hours per week (~3.5 hours a day), and 75% of this activity is while relaxing at home [10]. It is important to note that mere time spent listening to any music need not imply a positive influence on cognition. The type of music one listens to and the features of that music could play an important part. The central theme of variation in music lies in the tones or the frequencies of the notes that are present within it. In Western music, the systematic combination of tones is called musical scales or modes, and in Indian music, they are called *ragas*. *Ragas* are broadly described as musical compositions capable of inducing specific moods or emotions [11], based on the combination of the tones within it, as per music literature. This has also been investigated and confirmed in several scientific studies [12-14]. Since it is widely accepted that positive mood, emotions, or affect can improve cognitive functions and modulate performances on visual and auditory attention tasks [15-17], a study analyzing the cognitive effects of listening to different musical scales or raga of music will add to this literature. This will also serve as an alternate mode of preventive intervention in cognitive disorders while advancing the cognitive modalities of healthy individuals in a positive direction.

Research groups have studied the brain processes evoked by musical excerpts using different neurophysiological approaches, such as electroencephalography (EEG) and neuroimaging [18-22]. In our previous study, we observed unique raga-specific changes in EEG during and after listening to Indian music ragas [23]. It will be interesting to understand the effects of listening to different modes of Indian music on cognitive engagement using Event-related potentials (ERPs). Various sensory, cognitive, and motor events elicit ERPs, which can be used as an objective index to quantify cognitive engagement toward such events. ERPs in humans can be divided into 2 categories, the early 'sensory' or 'exogenous' waves, which peak within 100 milliseconds after the stimulus, depending on the physical parameters of the stimulus, and the later 'cognitive' or 'endogenous' ERPs reflect how the subject evaluates the stimulus or processes the information. The different positive and negative deflections recorded are named by their latency or order of appearance (P1, P2, P3, N1, N2, and so on) [24-26]. The P3 or P300 latency reflects the speed of information processing while the amplitude is associated with the number of resources allocated for this processing. Shorter P300 latencies and larger amplitudes usually indicate better information processing [25,27]. Studies have explored the cognitive aspects of music listening and training using ERPs. Musically trained individuals were shown to have lower latency periods and higher amplitudes in an auditory paradigm of P300 [28], similar to that seen in a recent study among participants trained in Indian classical music [29]. Instrumental music increases auditory attention through the modulation of the mood [15]. Pleasant music led to a higher average amplitude of P3 in the Fz region [30]. After listening to Baroque music, the P3 amplitude increased during the performance N-Back test [31]. Music facilitated sustained attention by altering P300 amplitude [32]. Turkish participants had a larger P300 amplitude on listening to a familiar ney or flute instrument than the less familiar, violin or cello [33], similar to another study among Chinese participants listening to 'guqin', a culturally familiar instrument, that elicited a higher P300 amplitude in the frontal region than piano [34]. The above-mentioned studies provide evidence that prior listening to music can have a positive effect on memory and attentional resources for subsequent cognitive efforts. At the same time, P300 amplitude is known to reduce during music listening, especially when the music is more engaging or relaxing [35]. This is attributed to the fact that music listening per se recruits cognitive processes for engagement, whereby external distracting sensory events would be allocated fewer resources.

To the best of our knowledge, no study has examined the effect of listening to different modes/ragas of Indian music on ERPs in young healthy individuals, to trace the differences in attention and other cognitive resource use with the raga heard. The current exploratory study aimed to investigate this aspect using three different ragas in Indian music. Each raga is made up of specific combinations of tones (frequencies). The current study hypothesizes that listening to a particular raga will result in distinct levels of cognitive engagement, recorded as an effect on ERP (amplitude/latency variation) to attention-catching non-musical stimuli, which in turn is characteristic of the tones in that raga. The findings from this study can be used as preliminary evidence to help choose musical modes/ragas with cognitive engagement appropriate to target cognitive deficits in patients with disorders such as schizophrenia, and dementia using music-based cognitive remediation. It can also extend our knowledge about neural underpinnings and neural mechanisms underlying music and attention.

## Materials and Methods

### Study design

This was a randomized control triple-blinded trial with 140 participants, 4 groups, and 35 participants in each group. Each group received one of the acoustic interventions, Group A received *raga Miyan ki Todi,* Group B *raga Malkauns*, and Group C received *raga Puriya*, with Group D as a control group received natural sounds. ERPs were recorded during three conditions: silence (before intervention), music/control stimulus (during intervention), and silence (after intervention), each lasting 10 minutes. The data presented here were taken from a larger experiment (full trial protocol Clinical trials.gov.in - NCT03790462).

### Sample Size Calculation

The sample size was calculated as part of the larger study where heart rate variability was one of the physiological measures collected from the participants. Thus the sample size was calculated based on a study conducted by Okada *et al* [36] where the RMSSD (root mean square standard deviation of NN intervals on ECG), a parasympathetic index increased from 17.4±7.2 ms to 24.1±15.5 ms after music therapy. With an effect size of 0.59, power of 90%, and confidence interval of 95%, the minimum sample size required was thus estimated to be 32.

### Ethical Approvals

The study protocol was approved by the institutional Scientific Committee on Human Research and Ethical Review Board (Reference: MSRMC/EC/2017, dated: 25 July 2017). The study period ranged from 2019 to 2021 (June 2019 - first recruitment and February 2021 - last). The research was conducted following the Declaration of Helsinki guidelines [37].

### The recruitment

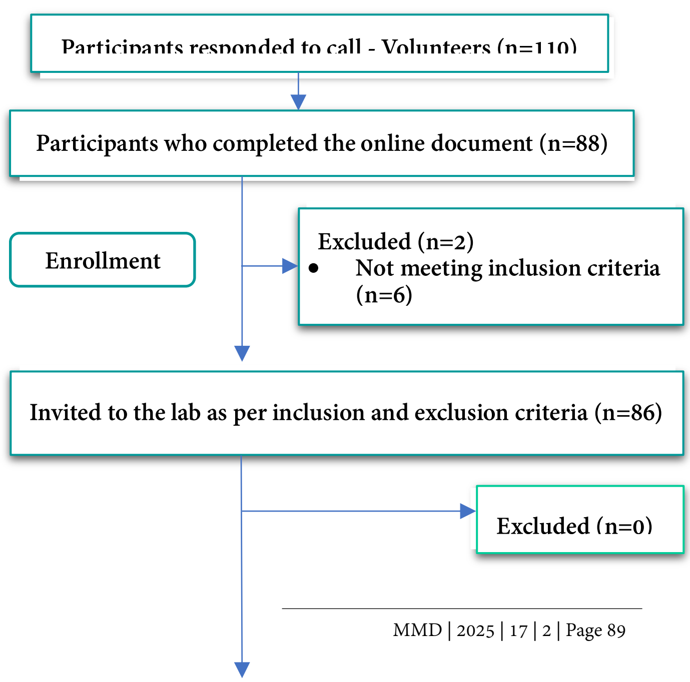
Participants were recruited from educational institutions in Karnataka, India. Healthy Indians aged 18–30, of either gender, were invited to participate through social media announcements. Participants responding to the call received an online questionnaire via Google Forms. Participants with any past or current medical or surgical disorders, hearing impairment, and self-reported BMI of over 30 $kg/m^2$ were excluded from the study (Fig 1). The participants who fulfilled the inclusion and exclusion criteria were invited to the lab for further recordings.

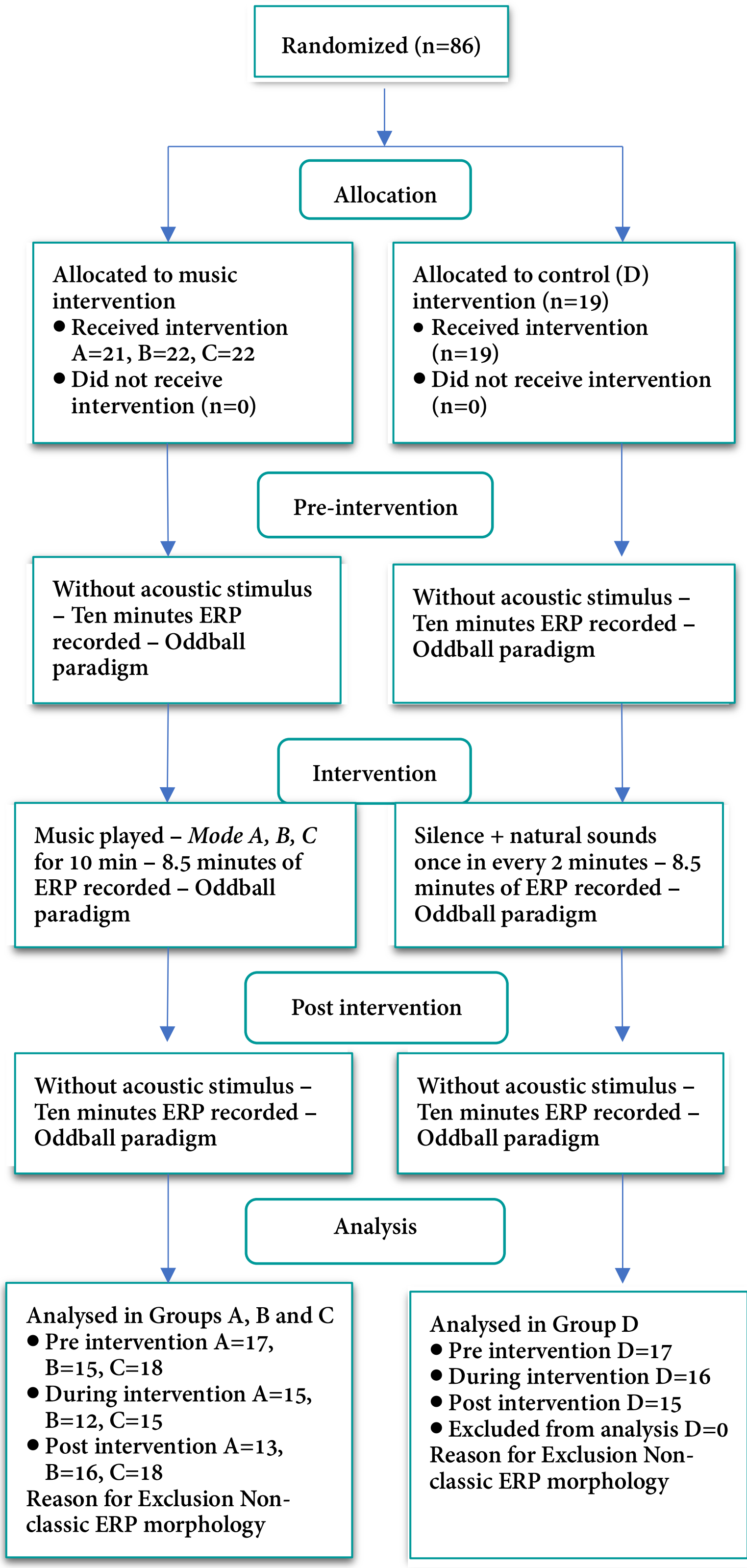
### Randomization

A simple randomization technique was used to randomize participants into four groups. Random numbers were generated using MS Excel (4 sets of 34 each) and were sealed in an opaque envelope. The serial number of the participants was written on the top of the envelope. The envelope was opened after the baseline assessment of each participant and then they were assigned to their respective arms. All the investigators who did the outcome assessments were blinded to the interventions.

Due to Covid 2020 peaking in the middle of the study, the study was done in two phases. In the first phase, anxiety, electrocardiogram (ECG), blood pressure, salivary markers, and EEG, were recorded as explained in [38]. The total recording time lasted more than two hours per participant. In the second phase, ERPs were recorded. The reason for conducting the study in two phases was a) Covid, b) the long duration of recording, and c) the fact that recording of ERPs during simultaneous music intervention meant that the music had to be repeated in the same participant, resulting in unintended familiarity effects. Thus, the participants were invited again to the lab with a gap of more than 2 to 3 months between the two recording phases, thus reducing the memory effects of the musical clip due to the random chance of a participant being assigned to the same group as before. The randomization technique was followed for both phases with a separate set of random numbers. In the second phase, we thus had 84 participants in total.

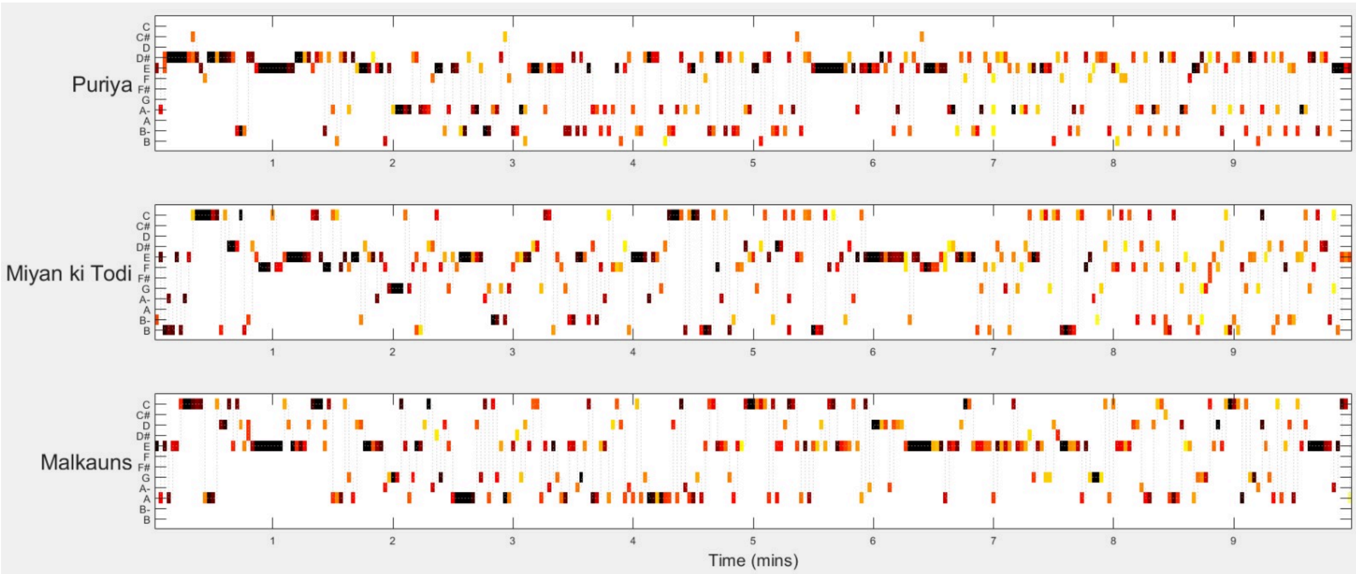
**Figure 1:** *Consort diagram of participant recruitment, distribution, and follow-up Intervention; Note: All values are in actual number (N=number of subjects); *After removing data not showing classical ERP morphology, we had the following number of participants in each group, from which the final analysis was done.*






The acoustic intervention was coded as A (*Miyan ki Todi)*, B (*Malkauns)*, C(*Puriya)* & D (Control group auditory stimulus, see further) by a person uninvolved in the project. We instructed the participants to listen to this with eyes closed, and minds relaxed, for the duration it was played (it always started from the beginning of the piece up to 10 minutes). Indian classical melodic scales/modes (*ragas) Malkauns* (C, E♭, F, A♭, B♭), *Puriya* (C, D♭, E, F#, A, B) *&* *Miyan ki Todi* (C, D♭, E♭, F#, G, A♭, B) were chosen based on our previous work [38]. The pitch class note densities or frequency of occurrence of each note in specific ragas are shown in Figure 2.

**Fig 2.** *Note distribution in each pitch class in the three music interventions shown in the chromagram*

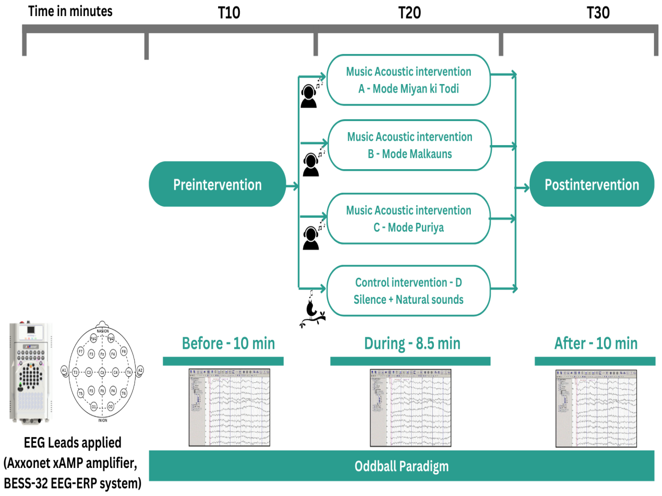



A detailed description of each scale is in the supplementary file (Supplementary file (Text S1; Figures S1 – S7). The music used for this study was 10-minute-long instrumental (Flute/*Bansuri*) music recorded by an eminent musician (exclusively for the present study), playing the improvisation method named *alaap* [38,39] in the respective scales. We chose the flute as the instrument to play the melodic scales, as it will contain only musical components such as pitch, intensity, rhythm, and timbre with the lyrical and percussion components avoided [40-47]. All participants listened to the music through headphones [previous studies using headphones, have considered this ideal [48]], connected to a laptop, at uniform volume (50%). The subjects in group D (control group) did not have any intervention except a few natural sounds that were played at the same volume levels once every 2 minutes, for 10 seconds. This was done in the mid 10 minutes of the protocol, to avoid sleep in the participants and to aid in better matching of intervention (with an acoustic stimulus) than no intervention at all.

**ERP recording and analysis**

EEG data was collected using the BESS-32 EEG-ERP system (Axxonet, Bengaluru) with a 500Hz sampling rate and 0.01-250Hz bandwidth, throughout the intervention period. Following the 10-20 system of electrode placement, Ag-AgCl disc electrodes were placed on the scalp with conductive paste at the frontal, central, parietal, and temporal (Fz, Cz, Pz, F7, F8, T5, T6 - Figure 3) sites, with reference at bilateral mastoid. The impedance at the sites was maintained below 5 K Ohms. The BESS system's paradigm presentation module was used to create a P300 protocol (three-stimulus auditory oddball paradigm) and present time-locked markers during the EEG acquisition. The paradigm was of 8.5 min duration and presented three times: pre-, during, and post-intervention. The paradigm consisted of 1000 Hz Frequent tones (70%) interspersed with 2000 Hz Target tones (15%) and 500 Hz Distractor tones (15%), with an interstimulus delay of 1200ms. In the oddball paradigm, a subject identifies a non-frequent target tone by providing a button response as quickly as possible. Participants were asked to remain awake with closed eyes in a silent room and to attend to all target stimuli. Both the music as well as the paradigm's auditory tones were presented through the same headphones, and care was taken to avoid disturbing the state of the participants while switching on/off the music. After the recording, the participants were comfortably unplugged from the EEG-ERP system, electrodes removed, head washed, and relieved from the lab.

**Fig 3.** *Flow chart describing the process of recording*




All ERP analyses were done using the ERP modules of BESS software (version: 6.9.1; Axxonet, Bengaluru, India). The data were visually inspected to detect and mark bad channels and gross bad segments. The bad channels were interpolated (spline interpolation) and data were re-referenced to the average of mastoids. The data was then epoched around stimulus markers into 1s segments (100 ms pre-stimulus baseline and 900 ms post-stimulus data), and grouped into bins (Frequent, Rare, and Distractor). Each segment/epoch was visually inspected to reject those with gross artefacts (like muscle activity, electrode popouts, movements, etc.). The cleaned epochs were averaged according to the bins, into ERP waveforms. A grand average of all subjects was done to manually determine the most likely latency of the ERP peaks and the optimal electrode site (used only for later plotting of the waveforms), unbiased by group information (all groups averaged together to prevent 'cherry-picking' the time window based on observable group differences). Based on the thus determined latency parameter with some allowance on either side, the automated peak detection algorithm of BESS software was run to detect the peaks for N1 and P3 components (N1 search window = 90-200ms; P3 search window = 250-500ms; both based on Cz electrode).

The ERP peak amplitudes and latencies (N1 and P3) extracted from all seven electrodes (that represent scalp maps of ERP parameters) were taken into MATLAB software for statistical comparison. Using the functions of the LIMO toolbox, we did Yuen's trimmed mean test (20% trimming) for the During versus Before and After versus Before comparisons for each electrode within each group ('mass univariate tests'), and the p-values were adjusted using threshold-free cluster enhancement (tfce) approach exploiting the 'spatial neighborhoodness' across the scalp.

## Results

Based on sociodemographic data the groups were comparable, with no significant differences concerning age, age group and gender distribution, education, and BMI (Table 1). Music listening patterns and preferences are detailed in the Supplementary file (Text S2).

**Table 1.** *Distribution of subjects based on Socio-Demographic characteristics*

| Variables | Group A | Group B | Group C | Group D | P - Value |
|---|---|---|---|---|---|
| **Sample** | N=21 (%) | N=22 (%) | N=24 (%) | N=19 (%) | |
| **Age (Years)** | | | | | |
| <=18 | 3 (24.3) | 0 | 0 | 2(10.5) | 0.472 |
| 19-21 | 6 (28.6) | 9 (40.9) | 11 (45.8) | 9 (47.4) | |
| 22-24 | 8 (38.1) | 10(45.5) | 8 (33.3) | 5 (26.3) | |
| >=25 | 4 (19.0) | 3 (13.6) | 5 (20.8) | 3 (15.8) | |
| **Age (years) Mean;SD** | 22.10; 3.16 | 22.45; 2.84 | 22.46; 3.17 | 21.53; 3.48 | 0.759 |
| **Gender** | | | | | |
| Female | 10 (47.6) | 15 (68.2) | 11 (45.8) | 8 (42.1) | 0.314 |
| Male | 11 (52.4) | 7 (31.8) | 13 (54.2) | 11 (57.9) | |
| **Education** | | | | | |
| High school / Intermediate | 6 (28.6) | 7 (31.8) | 6 (25.0) | 3 (15.8) | 0.680 |
| Graduate/ Post graduate | 15(71.4) | 15 (68.2) | 18 (75.0) | 16 (84.2) | |
| **Marital status** | | | | | |
| Married | 1 (4.8) | 1 (4.5) | 2(8.3) | 2(10.5) | 0.850 |
| Single | 20(95.2) | 21 (95.5) | 22(91.7) | 17(89.5) | |
| **Diet** | | | | | |
| Vegetarian | 8 (38.1) | 3(13.6) | 9(37.5) | 9(47.4) | 0.117 |
| Non-vegetarian | 13 (61.9) | 19(86.4) | 15(62.5) | 10(52.6) | |
| **BMI ($kg/m^2$) Mean; SD** | 23.67; 5.20 | 23.40; 3.00 | 22.37; 4.27 | 22.93; 4.57 | 0.762 |

**Note:**

a) N is the number of subjects in each group.
b) All the values of the two groups are in absolute values and in parenthesis are in percentages.
c) P Value of < 0.05 is considered significant.
d) P calculated using the Chi-square test / Fisher exact test.
e) Mean age and BMI comparison was done using ANOVA

**Results of ERP analysis**

The ERP waveforms showed clear N1 and P3 components. The N1 was most prominent at FZ and CZ sites, whereas the P3 was most prominent at CZ and PZ sites (Fig 4,5).

**Fig 4.** *Grand average ERP waveforms for each condition and group at all seven electrode sites.*

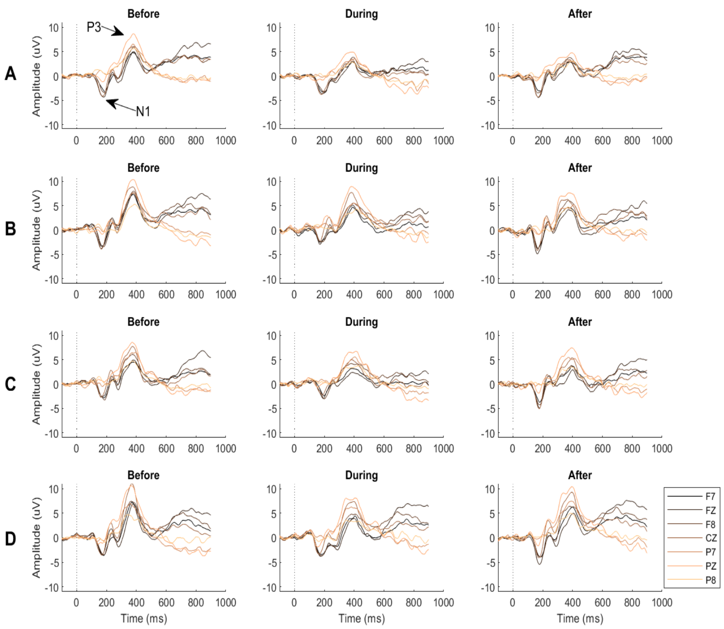
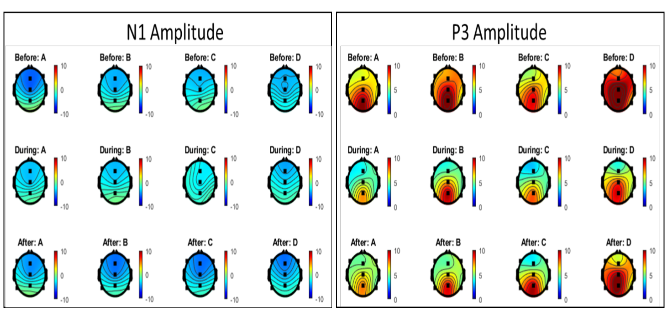



**Fig 5.** *Scalp distribution of the Grand averages in the search windows of N1 and P3 for each condition and group.*




In terms of amplitude change relative to before intervention condition, the N1 ERP component in the FZ site showed a significantly more negative value only in the control group (group D) after the intervention, whereas the music groups (groups A, B & C) only showed a trend change (Fig 6). P3 ERP amplitude showed a decrease after intervention in group A (PZ site) and group B (CZ site), whereas no significant changes were seen in the other two groups (groups C & D) (Fig 7).

**Fig 6.** *Boxplots showing condition differences in N1 ERP amplitude for each group at significant electrode sites.*

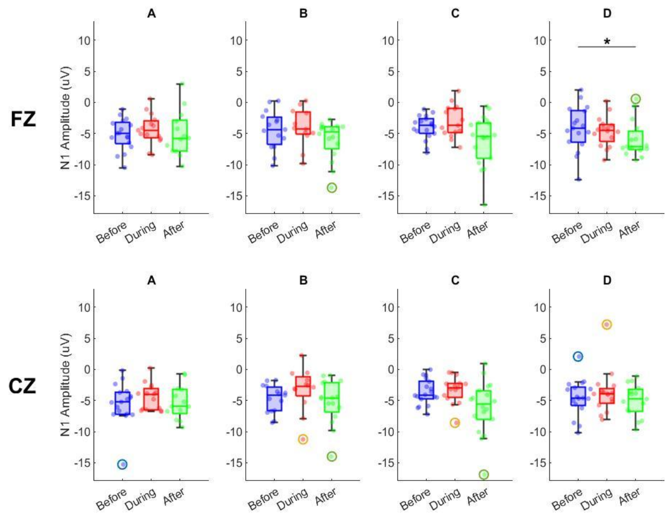
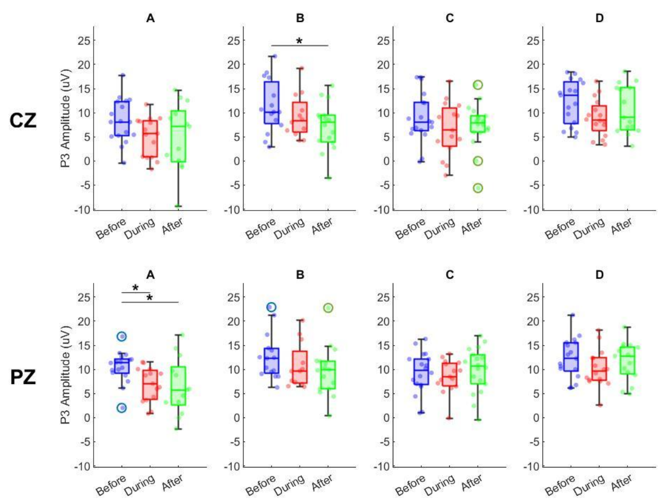



**Fig 7.** *Boxplots showing condition differences in P3 ERP amplitude for each group at significant electrode sites.*




In terms of latency change relative to the before condition, the N1 ERP component showed a significant delay for group B (FZ & CZ sites) and group C (CZ site) during the intervention, whereas the other groups (groups A & D) showed no significant change. P3 ERP component latency showed significant delay after intervention in group C (FZ site) and group D (PZ site), and no change in the other two music groups (groups A & B) (Fig 8, 9).

**Fig 8.** *Boxplots showing condition differences in N1 ERP latency for each group at significant electrode sites.*

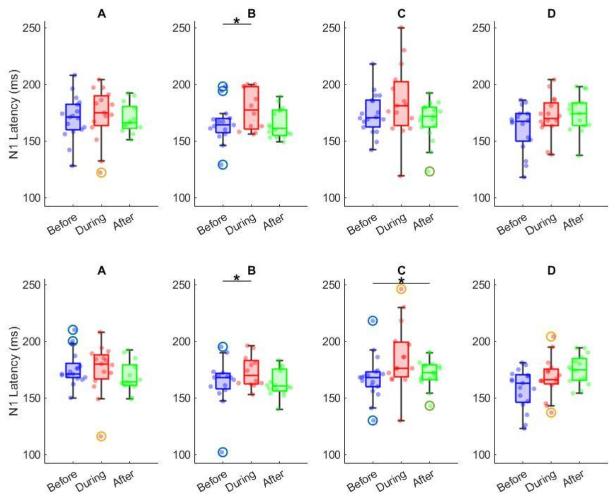
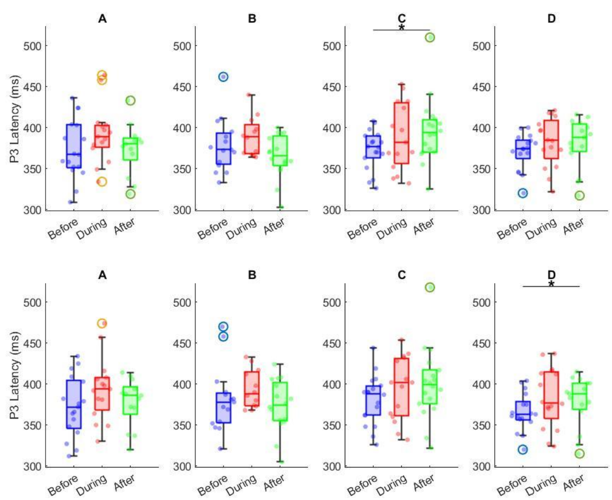



**Fig 9.** *Boxplots showing condition differences in P3 ERP latency for each group at significant electrode sites.*




Taken together, the N1 response (high amplitude and low latency) during/after intervention (relative to before intervention) was greatest for group D, then A, then C, and least for B. The P3 response was also greatest for group D, then C, then B, and least for A. In other words, N1 and P3 responses to oddball tones were least affected by intervention in the control group (D), whereas the music groups (A, B, and C) showed either a decrease in amplitude or an increase in latency (Table 2). Please note that there was no significant interaction effect seen between the groups and conditions (see Supplementary Tables S3-S6).

**Table 2.** *Summary of ERP components finding for each group, combining inference from during and after intervention relative to before intervention.*

| | | A | B | C | D |
|---|---|---|---|---|---|
| **N1** | Amplitude | - | - | - | ↑ (t=2.80; p=0.023) After |
| | Latency | - | ↑↑ (t=3.49; p=0.010) During | ↑ (t=2.28; p=0.044) After | - |
| **P3** | Amplitude | ↓ (t=2.47; p=0.039) During & After | ↓↓ (t=3.03; p=0.016) After | - | - |
| | Latency | - | - | ↑ (t=2.77; p=0.018) After | ↑ (t=2.74; p=0.025) After |

## Discussion

The current exploratory study aimed to investigate whether music listening can modulate the amplitude and latency of ERPs reflecting attention and cognitive engagements in young healthy individuals listening to Indian classical music and no study hitherto has been carried out in this subset of the population using three different modes (*Hindustani ragas*) in Indian music, to date. This randomized trial was conducted on 4 sociodemographically comparable groups each of which was made to listen to one acoustic intervention which was allotted to their group on a random basis. The acoustic intervention included listening to one of the three different *ragas* of Indian classical music (*Miyan ki Todi = Group A, Malkauns = Group B, and Puriya = Group C*), chosen based on Indian music ancient literature texts called *Sama Veda* and *Raga Chikitsa* that specified health benefits of different scales or predominant silence (group D) as intervention. The duration of these auditory interventions was 10 minutes. We assessed the change in ERP response to odd-ball auditory tones (N1 & P3 components), before, during, and after the acoustic intervention (listening to music versus control audio clip). We found that listening to different Indian music *ragas* is associated with smaller or delayed N1 and P3 ERP components during/after listening (relative to before intervention), suggesting a lowered cognitive engagement to odd-ball stimulus. Specifically, the groups listening to *Malkauns* or *Puriya* showed longer N1 latency, *Miyan ki Todi* and *Malkauns* showed smaller P3 amplitude, and *Puriya* showed longer P3 latency. This could be due to the effect of music persisting beyond the listening period, possibly due to a short-term change in attentional orientation towards bodily and less towards external stimuli. Whereas, the control group showed an increase in N1 amplitude with only a delay in P3 latency, with time. Overall, the findings suggest that the brain activity response to attention-catching external stimuli is lowered during or immediately after music listening, in terms of reduction in early perceptual response (lower N1 amplitude or delayed N1 latency[49]) or later attention allocation (lower P3 amplitude or delayed P3 latency [50]). This pattern is best seen for the *Malkauns* group and lowest for the Control group.

In the present study, we observed a significant reduction in P3 amplitude in groups listening to *raga Miyan ki Todi* and *raga Malkauns* and a reduction in P3 latency in listening to *raga Puriya*, after intervention relative to before intervention. A reduction in P3 amplitude would suggest a reduced attention allocation to the task [51], and possibly more towards the oddball stimuli. P3 amplitude reflects stimulus information and thus greater attention produces larger P3 waves [52]. The latency indicates the speed of stimulus classification resulting from the discrimination of one event from another. Shorter latencies are seen with superior mental performance relative to longer latencies [53]. In the present study, a trend towards a decrease in peak amplitude or increase in peak latency of P3 was observed during music intervention but continued even after the music stopped (statistically significant). Therefore with music intervention, subjects allocated less attentional resources to odd-ball stimuli and more to music / internal attention (which is the plausible reason behind the continuation in the rise of P3 latency even after the intervention was stopped). Moreover, this influence on attention was highest for *Miyan ki Todi* (Group A) and least for *Puriya* (Group C).

Though no significant changes were seen with N1 amplitude in music listening groups, in the present study, N1 latency was delayed in groups listening to *raga Malkauns* and *raga Puriya*. It is important to note that N1 is a marker of the preattentive perceptual process and its amplitude is strongly dependent upon the low-level stimulus features like rise time of the onset of a sound, loudness, interstimulus interval with other sounds, and the frequency of the sound [54]. This indicated that subjects listening to the music showed less perceptual response to odd-ball stimulus, to allow perceptual continuity of musical and associated experience (even after the music stopped). This effect was highest for *Malkauns* (Group B) and least for *Miyan ki Todi* (Group A).

Recently, music has been used as a tool to modulate P3 in normal subjects since it regulates arousal and emotions. To appraise the effect of music exposure on P3 wave measurements, a study used the oddball paradigm similar to the current study where the participants had to mentally count the number of target stimuli and P3 was recorded thrice- without music, with slow music, and with fast music. The results indicated that slow music favors attention and memory processing thus enhancing cognitive potential [55]. In another study, researchers recorded ERP while listening to a Tango Nuevo piece, a deep techno track, and an acoustic lullaby. Music features related to timbre, harmony, and dynamics were computationally extracted. The ERP responses (N1 and P2) to peak changes in the acoustic features were distinguishable and were the largest for Tango Nuevo [56]. Participant-preferred background music during task performance was not shown to alter their efficacy [57].

Literature suggests greater attention and neuroplasticity, hence superior auditory evoked potential in musicians compared to non-musicians [58]. 'The Mozart effect' refers to a phenomenon of enhanced spatiotemporal abilities and task performance for about 15 minutes after listening to Mozart's Piano Sonata [59].

To the best of our knowledge, this is the first time that 3 different Indian classical *ragas* have been scientifically studied, among healthy individuals, with simultaneous recording of evoked potentials. The strengths of the study are that music intervention did result in altered attentional responses and this varied with the raga the participants listened to. The musical clip had only a single instrument against the background of a drone instrument, and was full-length, resulting in physiological effects recorded under more naturalistic settings. Percussion instruments, beats, and lyrical components were avoided. However, the specific features of music to which these ERP responses may be attributed are difficult to comment upon without a detailed further feature extraction and correlation analysis of the musical stimulus used in the current study. It is still not very clear if ERP effects are due to the specific scale or the *thaat* from which it arises [39]. The choice of music, which was experimenter selected, is also a confounding factor to be considered in future studies [60-62]. Indian music is known to have ragas to be heard and performed only during certain times of the day. Thus timing of the recording is to be well thought of in the future to analyze the specific attentional differences seen with ragas meant to be used during different times of the day. Nevertheless, our study indicates the calming effect of listening to Indian music which may be associated with reducing external attention and possibly increasing internal attention, which needs to be further confirmed through correlational analysis of the musical features characteristic of each raga.

### Data Availability Statement

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to ethical reasons.

### Acknowledgments

The authors acknowledge funding agencies, and the exclusive recording shared by Vidhwan Pandit Pravin Godhkhindi, an eminent flutist, for this study. We thank Dr. Suresh Kirthi K for his assistance in using the software to extract detailed note information from each of the ragas employed. We like to thank all the volunteers who participated in the study.

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## Supplementary text S1: Music intervention – Melodic scales in detail

Indian classical melodic scales/modes (ragas) Malkauns (C, E♭, F, A♭, B♭), Puriya (C, D♭, E, F#, A, B) & Miyan ki Todi (C, D♭, E♭, F#, G, A♭, B) were chosen based on our previous work and based on the criteria of having beneficial cardiovascular effects as per ancient music literature (1–3). *Also, see the supplementary Excel file with note densities after splitting 10 mins audio into 30000 units of 2 s each.*

***Miyan ki Todi*, the *raga* A of this study,** is a Hindustani classical raga that gave its name to the *Todi thaat*, one of the ten modes of Hindustani classical music, also known as *Darbari Todi*, and sometimes Shuddha Todi, is amongst the more popular morning ragas of Hindustani music. The scale of *Miyan ki Todi* is *Arohana:* S r g m d N S' or 'd 'N S r g m d N S' or S r g m d P, m d N S' or S r g m P, m d N S' and *Avarohana:* S' N d P m g r S or S' N d P m d m g r g r S. *Vadi* and *Samavadi* are *Komal Dha* and *Komal Ga*. *Re, ga,* and *dha* are intoned slightly low, and *tivra ma* is very sharp. Bhatkhande pronounces *Komal Dha* as *Vadi* (primarily dominant), but some musicians accord this status to *Komal Ga*. According to him, *Komal Ga and Komal Re*, are candidates for the status of *samvadi* (secondary dominant). *Todi* is a *Raga* of the late morning. The prescribed time for the raga is the first three-hour slot after sunrise.

The equivalent *raga* in Carnatic music is *Shubhapantuvarali. Miyan ki Todi* predominantly is mostly pervaded by a pensive, mournful mood which is then relieved in the *drut* (faster tempo) part, by a festive piece, possibly to alleviate the heavy pathos in the earlier stages of rendering, though not always. The composition is such as to afford an artist of high caliber to mold it in either the inherent pensive mood or to entirely present a festive mood. Despite this, the raga has attained a decent presence in the classicist as well as romanticist genres of Hindustani music. The common phrases used in this scale are: N. N. S r g / r g r / r g M^ P or r g M^ g P/ g M^ d P / M^ g M^ d / N d P / d d N S' [or] M^ d N S'/ N S' r' g' r'/ d N S' r' g' / r' g' r' S'/ N r' N d P / M^ P d M^ g [or] N d M^ g / r g r S (4). Popular songs based on this *raga* are: *Bhini bhini bhor (Asha Bhosle's Album Dil Padosi Hai), aeri mai to prem diwani mera dard na jane koi (A meerabai bhajan from the movie – Meera), Watan pe jo fida hoga (movie – Phool bane angaare)*(5), *oora serabahude neenu (title track of T N Seetharam Kannada serial 'magalu jaanaki').*

**Fig S1.** *Note densities in Raga Miyan ki Todi represented as a chromagram with pitch class information*

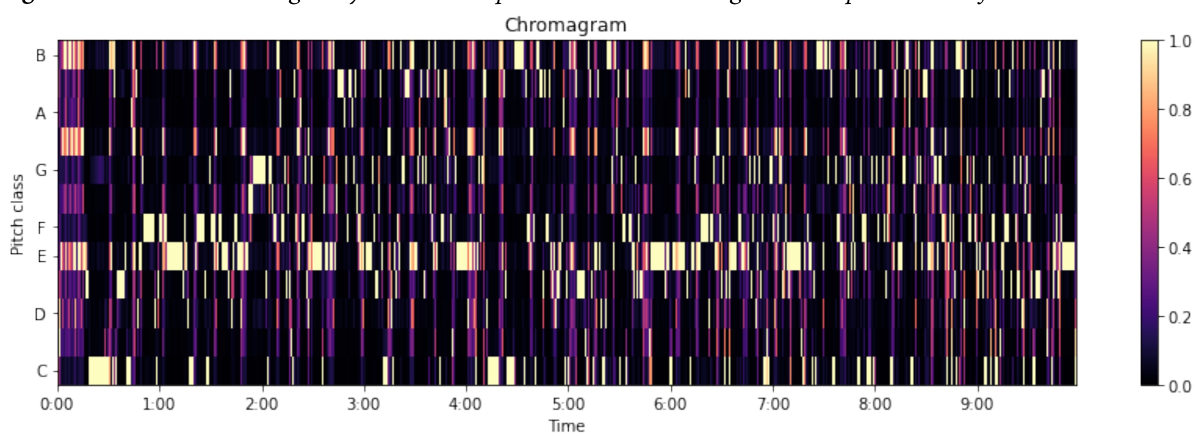
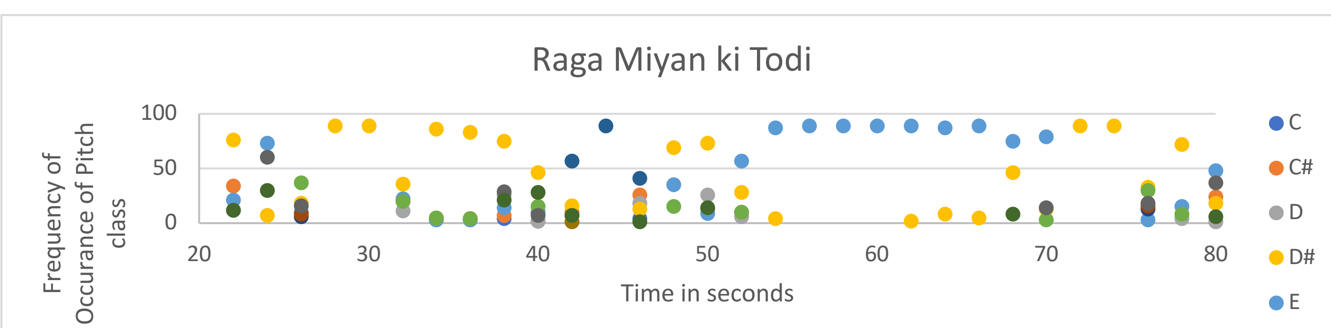



**Fig S2.** *An example of Note distribution in Raga Miyan ki Todi between 20 to 80 seconds of the musical clip.*



***Raga Malkauns*** belongs to *Kalyan thaat*, and is a majestic and somewhat introverted pentatonic raga. Ma is the pivotal tone of this *raga* and the tone in which the first string of the *tanpura* is usually tuned. *Ga, Dha,* and *Ni* may slightly oscillate. *Malkauns* should be performed in a slow and dignified manner, and to bring out its ethos the notes should be linked by glides, in particular N / D, D / M, and M / G (6). Time: Late night, 12 - 3. *Aarohan* (ascending scale): S G M D N M D S*; *Avaraohan* (descending scale): S* N D M G M G S, D S; * indicates a higher (third) octave. The *Rishabh* and the *pancham* are skipped in the scale. It is an *audhav - audhav* (5 notes in ascent and descent of the scale) *vakra (nishad* is rarely employed in *avaroh)*. The *vaadi samavaadi swaras* for this raga are d and g. The *vishranti sthaan* for this scale are G; D; S'; - D; G;. Example of *sanchar* (move/ phrases / flow) through this *raga*, S; G M D G M G ; M G ; G S ; ,D ,D S ; ,N ,M ,D S ; S G M D ; G M G ; M D S' ; N M D ; G M M G ; S ; ,D ,D S;. It is this preponderance of the *tivra madhyam,* thus intense training is required to perform this raga. Time for best effects is between (12 night - 3 am): 3rd *prahar* of the night (*Ragas* are divided into *prahaars* whereby each *raga* has a specific period of the day when it is performed). The popular Hindi film songs based on *raga Malkauns* include *Aaye Sur Ke Panchhi Aaye (Movie - Sur Sangam), Adha Hai Chandrama Raat Adhi and Tu Chhupi Hai Kahan (Navrang), Man Tarapat Hari Darshan Ko (Baiju Bawra)* (6). **Malkauns was the *Raga* B in this study.**

**Fig S3.** *Note densities in Raga Malkauns represented as a chromagram with pitch class information.*

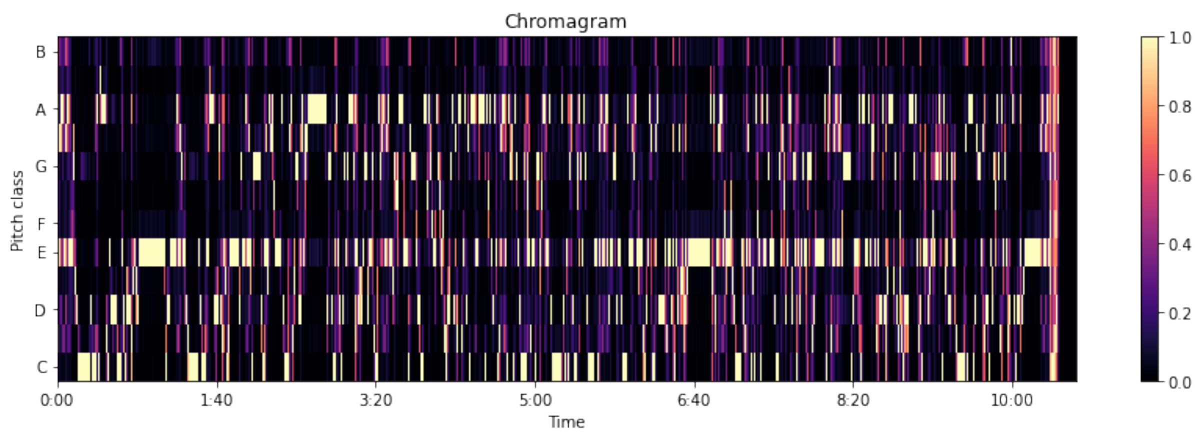
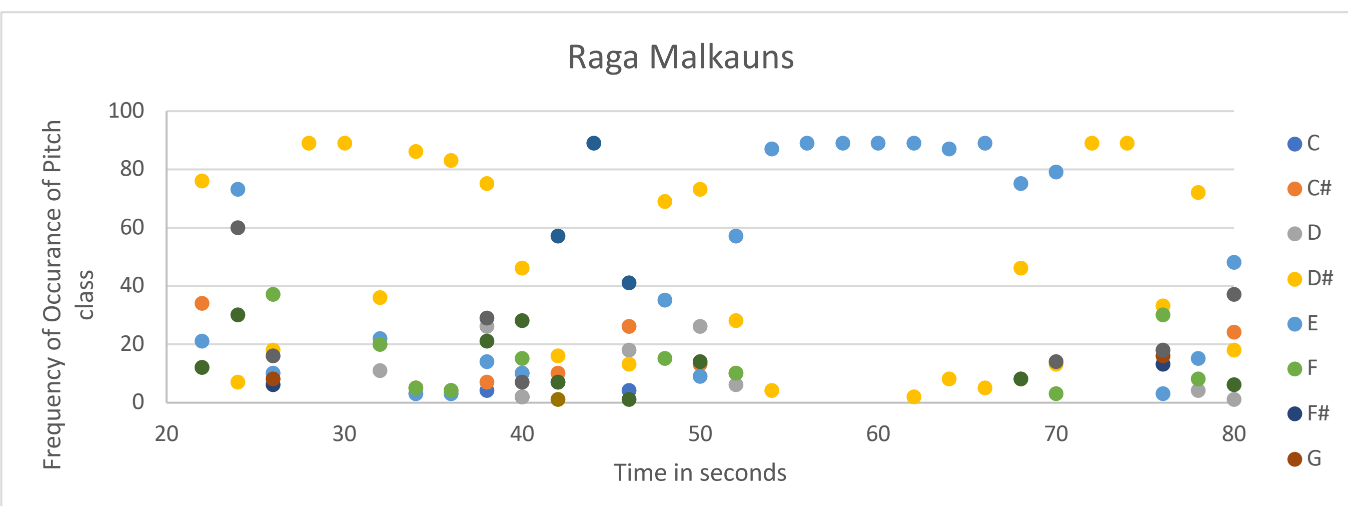



**Fig S4.** An example of Note distribution in Raga Malkauns between 20 to 80 seconds of the musical clip.



***Raga Puriya*** is a major hexatonic raga (*Shadhav – Shadhav*) of Hindustani classical music, belonging to the *marwa thaat*. Best performed just after sunset ($2^{nd}$ prahar of the night). What is common among all types of *Puriya raag* are *komal* (flat) *Re*, *shuddha* (natural) *Ga*, *tivra* (sharp) *Ma*, and *shuddha* (natural) *Ni*. Aarohan: N r G M D N r S and avarohan: S N D M G r S N or r N D M Gg, M G r S. *Pancham Varjya. Rishabh Komal, Madhyam Teevra*. Rest all *Shuddha Swaras*. Mandra Saptak Nishad is the Nyas swar in Puriya. Illustrative combinations are: N r G ; G r ,N ,D ,N; ,N ,M ,D S; G M D N; N M G; G M D G M G; r S; G M D N D S'; N r' N M G ; G M D G M G r S (7). In this *raga*, N-M and D-G *sangati* is observed. Nishad is often skipped in Aaroh like G M D N D S'.  *Raag Puriya* is often referred to as king of night *ragas*. The rasa / emotions related to this raga are *Shanti* (equanimity/peace) and *Gambhir* (seriousness) (8). ***Puriya* was the *Raga* C in this study.** Pure *Puriya* has not been very commonly used for film music.

Time

**Fig S3.** *Note densities in Raga Puriya represented as a chromagram with pitch class information*

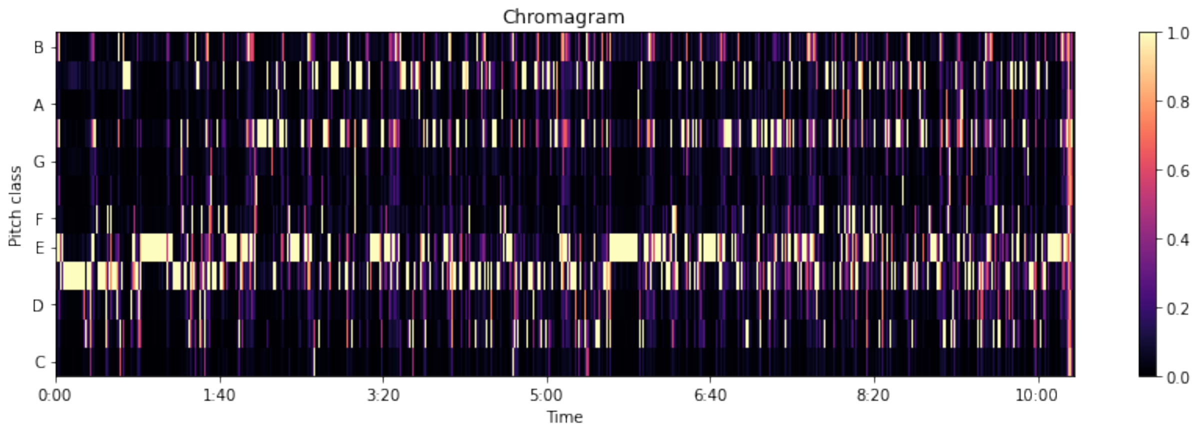



**Fig S6.** *An example of Note distribution in Raga Puriya between 20 to 80 seconds of the musical clip*

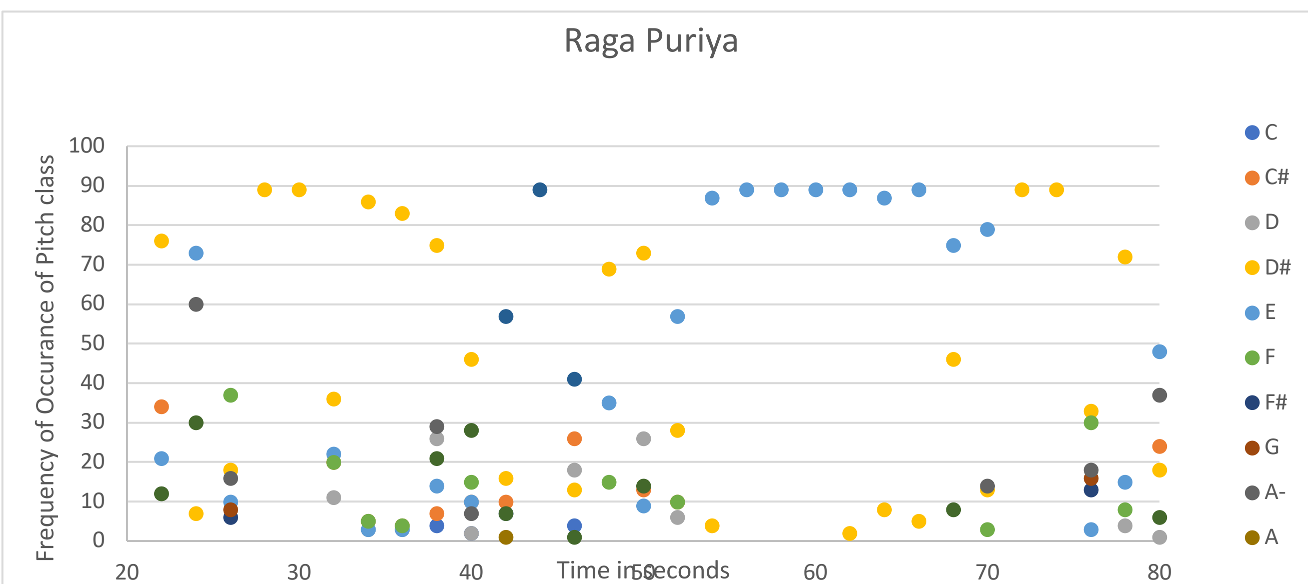
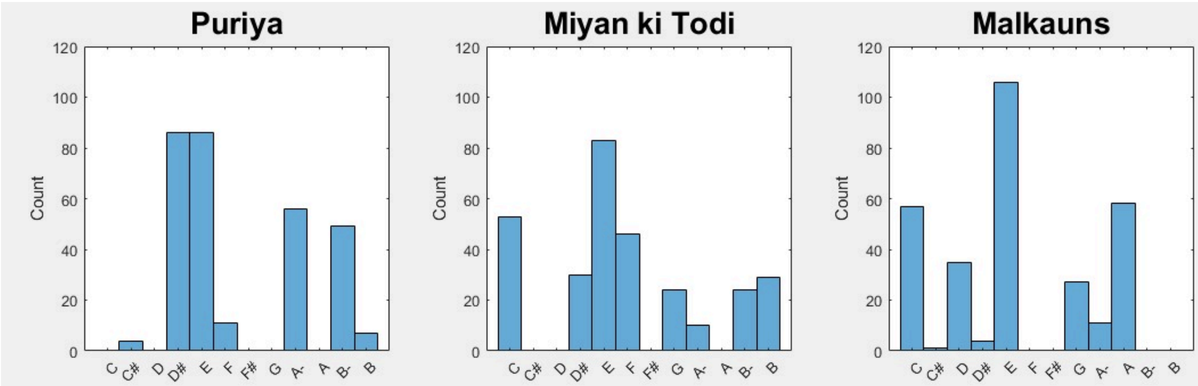


**Fig S7.** *Overall density distribution or Frequency of occurrence of notes in each specific raga*




**Note:** ***All Chromagrams were made using the Librosa program.***

**Supplementary text S2:** *Music preference and listening patterns:*
All participants responded to their music preferences through an online Google Form where the participants indicated listening to different genres and the ragas that they were familiar with. The most preferred type of genre among the subjects was Hindi movie songs [see Table 5]. When asked to name a few ragas that the subjects were familiar with they named *ragas* such as *Ananda bhairavi, Bhairavi, Bhimpalasi, Brindavani sarang, Bhupali, Classical Hamsadhwani, Kal bhairava, Kalyani, Shankarabharanam, Kharaharapriya Kadanakuthuhala, Kamavardhini, Kamboji, Mohana, Lalat, Madhyamavathi, Dhenuka, Malkauns, Yaman, Shreeraagam, Sindhu Bhairavi, Revathi, Darbari kanada, Bhimpalasi, Shuddh Kalyan, Reethigowla, Miyan ki malhar*. Only about 27 individuals of the whole group could name the *ragas*.

**Table S1.** *The choices of genre liked by the participants*

| | |
|---|---|
| Q1 | Indian Classical - Carnatic |
| Q2 | Indian Classical - Hindustani |
| Q3 | Western Classical |
| Q4 | Western Rock/Jazz |
| Q5 | Hindi Movie Songs - old/new |
| Q6 | Indian Folk songs |
| Q7 | Instrumental |
| Q8 | Others |

**Table S2.** *Descriptive statistics data of sets of preferred genres liked by subjects - Questions as per Table shown above*

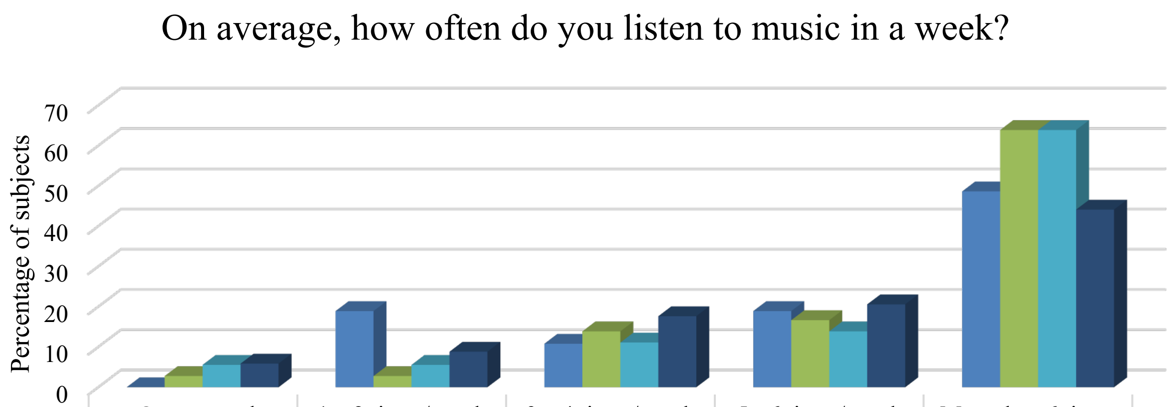
| A | | | B | | | C | | | D | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Qn | N | % | Qn | N | % | Qn | N | % | Qn | N | % |
| 1 | 2 | 5.4 | 1 | 2 | 5.6 | 1 | 4 | 11 | 1 | 1 | 2.9 |
| 1, 2, 3 | 2 | 5.4 | 1, 2 | 1 | 2.8 | 1, 2 | 1 | 2.8 | 1, 2, 3 | 1 | 2.9 |
| 1, 2, 7 | 1 | 2.7 | 1, 2, 3 | 1 | 2.8 | 1, 2, 3 | 3 | 8.3 | 1, 2, 4 | 1 | 2.9 |
| 1, 3, 4 | 2 | 5.4 | 1, 2, 5 | 2 | 5.6 | 1, 2, 5 | 1 | 2.8 | 1, 2, 5 | 1 | 2.9 |
| 1, 4 | 1 | 2.7 | 1, 4, 5 | 1 | 2.8 | 1, 6 | 1 | 2.8 | 1, 3, 5 | 1 | 2.9 |
| 1, 4, 7 | 1 | 2.7 | 1, 5 | 1 | 2.8 | 1, 7, 8 | 1 | 2.8 | 1, 5, 7 | 1 | 2.9 |
| 1, 5, 7 | 2 | 5.4 | 1, 5, 6 | 1 | 2.8 | 2, 3, 4 | 1 | 2.8 | 1, 7 | 2 | 5.9 |
| 2 | 3 | 8.1 | 1, 5, 7 | 1 | 2.8 | 2, 4, 5 | 1 | 2.8 | 2 | 1 | 2.9 |
| 2, 3, 5 | 1 | 2.7 | 2 | 1 | 2.8 | 3 | 1 | 2.8 | 2, 3, 4 | 1 | 2.9 |
| 2, 4, 5 | 1 | 2.7 | 2, 4, 7 | 1 | 2.8 | 3, 4, 5 | 4 | 11 | 2, 5 | 1 | 2.9 |
| 3 | 1 | 2.7 | 3, 4, 5 | 2 | 5.6 | 4, 5 | 2 | 5.6 | 2, 6, 7 | 1 | 2.9 |
| 3, 4, 5 | 1 | 2.7 | 3, 4, 7 | 1 | 2.8 | 4, 5, 6 | 2 | 5.6 | 3, 4, 7 | 1 | 2.9 |
| 4 | 2 | 5.4 | 3, 5, 7 | 1 | 2.8 | 4, 5, 7 | 2 | 5.6 | 3, 5, 6 | 1 | 2.9 |
| 4, 5, 6 | 1 | 2.7 | 4 | 3 | 8.3 | 4, 6, 7 | 1 | 2.8 | 3,4,5,7 | 1 | 2.9 |
| 4, 5, 7 | 2 | 5.4 | 4, 5 | 3 | 8.3 | 4, 7 | 2 | 5.6 | 4 | 1 | 2.9 |
| 4, 5, 8 | 1 | 2.7 | 4, 5, 7 | 2 | 5.6 | 5 | 5 | 14 | 5 | 9 | 27 |
| 5 | 3 | 8.1 | 4, 7 | 1 | 2.8 | 5, 7 | 1 | 2.8 | 5, 7 | 4 | 12 |
| 5, 7 | 1 | 2.7 | 5 | 5 | 14 | 7 | 1 | 2.8 | 6 | 3 | 8.8 |
| 6 | 1 | 2.7 | 5, 6, 7 | 1 | 2.8 | 8 | 2 | 5.6 | 7, 8 | 1 | 2.9 |
| 7 | 5 | 14 | 6 | 2 | 5.6 | Total | 36 | 100 | 8 | 1 | 2.9 |
| 8 | 3 | 8.1 | 7 | 2 | 5.6 | | | | Total | 34 | 100 |
| Total | 37 | 100 | 8 | 1 | 2.8 | | | | | | |
| | | | Total | 36 | 100 | | | | | | |

Note:

a) N is the number of subjects in each group.

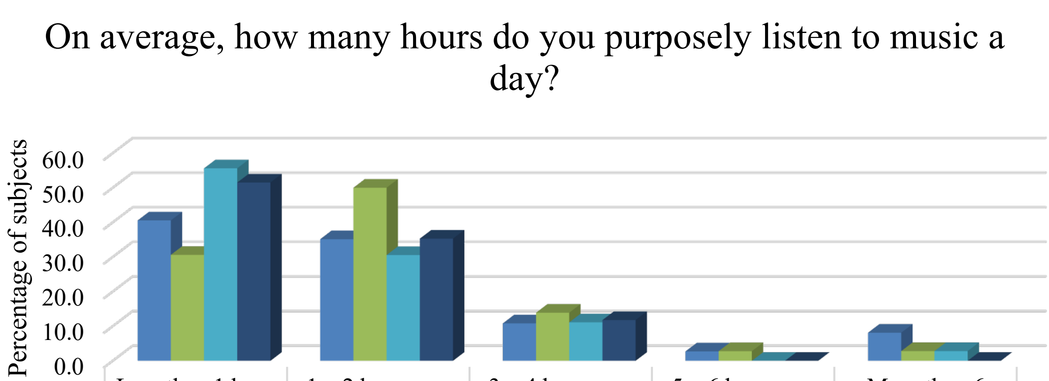
b) All the values are in absolute values and percentages.

**Fig S8.** *Music Listening pattern among participants in a week. Note: Values in the table below the graphs are in percentages.*




| | <Once a week | 1 – 2 times/ week | 3 – 4 times/ week | 5 - 6 times/ week | More than 6 times a week |
|---|---|---|---|---|---|
| A | 0 | 18.9 | 10.8 | 18.9 | 48.6 |
| B | 2.8 | 2.8 | 13.9 | 16.7 | 63.9 |
| C | 5.6 | 5.6 | 11.1 | 13.9 | 63.9 |
| D | 5.9 | 8.8 | 17.6 | 20.6 | 44.1 |

**Fig S9.** *Music Listening pattern among participants in a day. Note: Values in the table below the graphs are in percentages.*




| | Less than 1 hour per day | 1 – 2 hours per day | 3 – 4 hours per day | 5 – 6 hours per day | More than 6 hours per day |
|---|---|---|---|---|---|
| A | 40.5 | 35.1 | 10.8 | 2.7 | 8.1 |
| B | 30.6 | 50.0 | 13.9 | 2.8 | 2.8 |
| C | 55.6 | 30.6 | 11.1 | 0.0 | 2.8 |
| D | 51.5 | 35.3 | 11.8 | 0.0 | 0.0 |

Further the listening patterns were noted, where no significant differences were observed between the groups concerning the number of days per week they listened to music or the number of hours per day spent listening to music.

**Supplementary Table S3.** *Two-way ANOVA for N1 Amplitude*

| A | B | C | D | - |
|---|---|---|---|---|
| -3.06 ± 1.56 | -3.04 ± 1.47 | -2.69 ± 1.57 | -3.57 ± 2.08 | |
| -2.94 ± 1.39 | -2.22 ± 2.10 | -2.29 ± 1.56 | -2.95 ± 2.03 | |
| -3.17 ± 2.12 | -3.51 ± 2.22 | -4.06 ± 2.53 | -3.55 ± 1.48 | F=4.994 (p=0.008) |
| | | | F=0.551 (p=0.648) | F=0.840 (p=0.541) |

**Supplementary Table S4.** *Two-way ANOVA for N1 Latency*

| A | B | C | D | - |
|---|---|---|---|---|
| 172.59 ± 16.95 | 169.17 ± 15.18 | 170.48 ± 15.26 | 162.23 ± 17.80 | |
| 169.51 ± 20.96 | 176.49 ± 18.16 | 182.60 ± 29.94 | 166.46 ± 13.47 | |
| 168.35 ± 12.87 | 169.02 ± 10.60 | 164.27 ± 14.82 | 171.68 ± 16.28 | F=2.303 (p=0.103) |
| | | | F=1.143 (p=0.333) | F=1.948 (p=0.075) |

**Supplementary Table S5.** *Two-way ANOVA for P3 Amplitude*

| A | B | C | D | - |
|---|---|---|---|---|
| 7.60 ± 2.65 | 9.11 ± 4.23 | 7.25 ± 3.63 | 9.10 ± 3.00 | |
| 4.74 ± 2.70 | 7.07 ± 2.99 | 5.86 ± 3.92 | 7.03 ± 2.48 | |
| 4.73 ± 4.61 | 6.46 ± 3.89 | 6.28 ± 3.38 | 8.47 ± 2.85 | F=8.185 (p=0.000) |
| | | | F=6.010 (p=0.001) | F=0.647 (p=0.692) |

**Supplementary Table S6.** *Two-way ANOVA for P3 Latency*

| A | B | C | D | - |
|---|---|---|---|---|
| 377.01 ± 29.26 | 383.60 ± 30.42 | 379.51 ± 25.24 | 372.62 ± 19.01 | |
| 395.48 ± 37.79 | 395.21 ± 22.78 | 394.97 ± 35.89 | 382.46 ± 28.88 | |
| 376.27 ± 26.95 | 372.91 ± 24.48 | 398.01 ± 36.65 | 385.77 ± 28.31 | F=4.236 (p=0.016) |
| | | | F=1.309 (p=0.273) | F=1.379 (p=0.225) |

**Supplementary file References**

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