Enhancement of task performance aided by music

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Our study demonstrates the enhancement of task performance aided by music. Task performance and associated physiological changes were studied in participants who listened to music (Indian classical instrument or Indo jazz). Their mood and their perceived emotions were evaluated using positive and negative affect schedule and self assessment manikin scales, and their pulse rate was measured. Visual Go and No-go trials were given as task stimuli and task performance was measured. Changes in the mean pulse rate were significantly low ($P < 0.05$) during Indo jazz. We conclude that Indian classical instrument and Indo jazz induced positive effects and enhanced task performance.

Keywords: Music, pulse rate, reaction time, task performance.

LISTENING to music is habitual for many people while doing a variety of tasks. Listening to the right type of music can enhance task performance. Music can improve reading skills and mathematical abilities, thereby facilitating learning[1]. There is a significant relation between certain types of music and learning[2]. Classical music or instrumental tracks can improve cognitive performance[3] and listening to classical music improves learning compared to other types of music[4]. Listening to music is an inexpensive way to improve cognitive abilities in the elderly[5] affecting their arousal and mood. Listener's enjoyment has a major influence on cognitive performance[6].

Music can improve the moods of listeners. Selecting the right type of music based on one's preference will yield a better task performance. Mozart's music enhances visuospatial abilities[2,7]. Music evokes a pleasant mood and increases the arousal level[8] which results in an increase in creative problem-solving and task performance. Listener's music perception is also reflected in their mood. Music can induce and sustain a positive effect (mood) state while performing a task[9]. Listening to music can modify one's mood[10] influencing their cognitive performance and creativity[11–14]. Isen[15] demonstrated a positive effect (mood) while listening to music, which enhanced decision-making and problem-solving capabilities[16]. Conversely, Knight and Rickard[17] selected sedative music for participants preparing for an oral presentation. Their study concluded that blood pressure and heart rate were reduced significantly when preparing with sedative music as compared to participants who prepared without music (in silence).

Most earlier work was oriented to the study of task performance of the western population, who are naturally inclined to Western music. However, this may not hold for Indian population owing to differences in music cultures. Indian music with which we are familiar may induce better stimuli as music has a potential to change moods. Further, Indian music has been studied for therapeutic application[18,19]. Our study focuses on two Indian ragas played on different types of musical instruments – Indian classical instrument and Indo jazz – and their effects were studied with regard to pulse rate and task performance enhancement. Go and No-go trials of quick reaction response to task setting were also adopted. Based on previous findings we hypothesize that listener's perception also plays an important factor in inducing changes in physiological variable (pulse rate) and task performance, in addition to the type of instruments played. Our study is somewhat unique as earlier studies focused on using Indian music for therapy, while we used self-assessment manikin (SAM)[20] scale to measure valence and arousal. Positive and negative affect schedule (PANAS)[21,22] is used to measure the participant's mood associated with selected music listening.

Methods and materials

Twenty participants (12 males and 8 females) were selected for this study. They had an interest in listening to Indian music while studying but did not have any formal training in music. Their average age was 20 years (SD = 0.4 years) and average body weight was 68 kg (SD = 5.5 kg). All participants were right-handed with no auditory impairment. A mini mental test (MMT)[23] was conducted on them before starting the experimental protocol to check whether they were competent for the test. Participants who scored above 24 out of 30 in MMT were

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selected for recording. The entire experiment was conducted in the morning in a soundproof room, where participants sat on comfortable chairs. The study was carried out in accordance with the Institutional Ethics Committee for Human Volunteer Research and all volunteers had given concurrence to participate.

Musical stimuli selection

The participants were asked to choose their musical stimuli based on their liking. They were presented with four sets of Indian musical stimuli (Indian classical instrument (Malahari), Indo jazz (Kapi), Nat Bhairav and Dharmavathi). Ten out of 20 participants preferred Malahari and others preferred Kapi. Hence, only these two ragas were considered for analysis. In order to assess their mood before and after listening to the music, the participants were asked to rate the current mood using PANAS[21,22]. To measure the valence and arousal of the chosen music, SAM[20] scale was used after listening to the music (Appendix A).

Task stimuli

The task stimuli, visual Go and No-go trials, were selected using Psytask from Mistar Ltd. The task consisted of small coloured squares appearing either at the top or bottom edge and it was presented for a duration of 100 ms with 1000 ms inter-stimulus interval in a pair. The stimuli was presented in pairs corresponding to the trials. Two different pairs of stimuli, top-top pair ('Go trial') and Top-Bottom pair ('No-go trial') were offered. The participants had to press the right arrow key on the computer keyboard as soon as the task stimuli were presented. Trials were presented in random order with 50% probability. The interval between trials was 1500 ms, the parameters of the performance were calculated for Go and No-go conditions[24]. The task performance was measured by finding the error of commission for visual Go and No-go trials (failure to withhold the response), error of omission (failure to respond to Go trials), and reaction times for various experimental conditions being recorded to build the database for evaluating the participants' task performance. The task was performed with selected music (jazz and Indian classical instrumental) and in silence (without music).

Experimental protocol

The participants were instructed to remain relaxed during the entire protocol (Table 1). The pulse rate was recorded for three consecutive time intervals for each task and rest conditions, and the average values of these consecutive time intervals were considered for analysis. The pulse was constantly measured using a multi-parameter monitor (Star Plus L&T Ltd make was used).

Music stimuli

The Indian classical instrument and jazz were recorded and played as only the digital audio has the sampling rate of 44,100 Hz per second and the sampling resolution of 16 bit. The dBFS (decibels relative to full scale) measured decibel amplitude levels in the music that was being played. Zero dBFS represented the highest possible value and the lowest possible value for 16 bit ADC was –96 dBFS. The power spectra for the music played were plotted using Hanning window with the window size of 1024 using NI LabVIEW 14 software tool (Figures 1 and 2).

Statistical analysis

The data extracted (pulse rate, omission error for Go trials, commission error for No-go trials and reaction time for Go trials) were not normally distributed. Listening to Indian classical instrument, jazz music and without music was considered independent variables. The pulse rate, omission error for Go trials, commission error for No-go trials, reaction time for Go trials, decibel level, PANAS and SAM scores of the played music were all considered as dependent variables. The groups (Indian classical Instrument, jazz music and without music) were compared using Kruskal-Wallis *H* test, a non-parametric substitute for one-way ANOVA. Mann-Whitney U Post Hoc test was also performed to find out the statistically significant difference between two specific groups. The significant difference within the group for Indian classical instrument and jazz was measured using Friedman test, which is a non-parametric alternative to the one-way ANOVA with repeated measures and Wilcoxon signed-rank Post Hoc test was performed, to find out the statistically significant difference between two related groups. The alpha value was set at 0.05; asymmetric signed (two-tailed) values were noted. Analyses were conducted using IBM SPSS statistics for Windows (version 20.0, Armonk, NY: IBM Corporation).

Table 1. The experimental protocol of our study

Condition	Duration (min)
Baseline	2
Listening to the chosen music (Task 1)	3
Rest 1 (silence)	2
Task with listening to chosen music (Task 2)	3
Rest 2 (silence)	2
Task with no music (Task 3)	3
Rest 3 (silence)	2

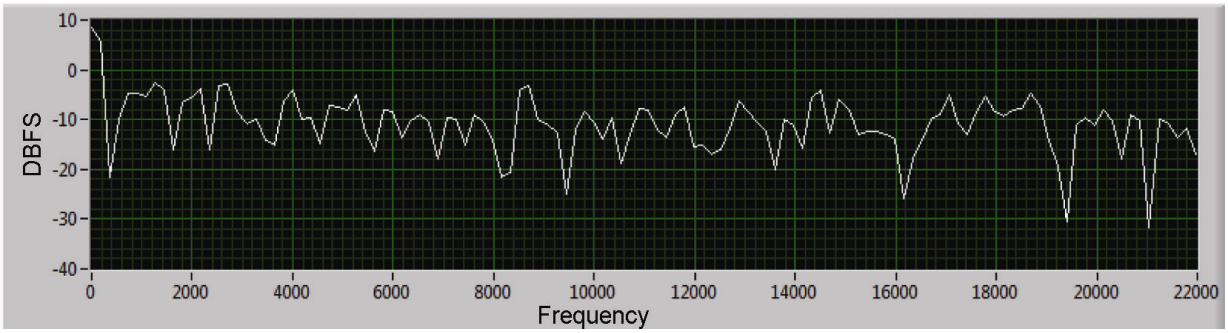

Figure 1. Power spectrum of the played Indian classical instrument. The highest average root mean square level was –8.38 dBFS/maximum peak levels at 0 dBFS.

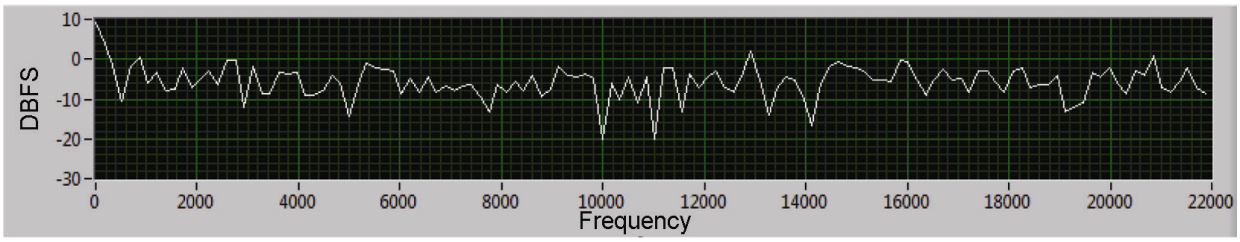

Figure 2. Power spectrum of the played jazz music. The highest average root mean square level was –19.84 dBFS/maximum peak level at 0 dBFS.

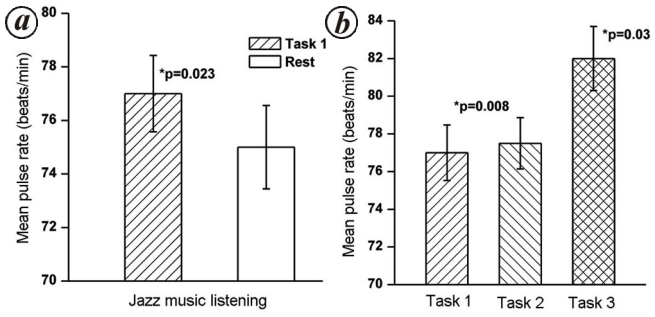

Figure 3. Mean ± standard error values of the measured pulse rate while listening to jazz music: ***a***, During Task 1 and Rest conditions. ***b***, During Tasks 1, 2 and 3 conditions.

Results

The participants listened to their choice of Indian classical instrument or Indo jazz music. Task 1 represented listening to music, Task 2 to listening to selected music and performing visual Go and No-go trials (task stimuli) and Task 3 represented performing the task in silence. The physiological response to the music played was estimated by measuring the pulse rate. Task performances were obtained by calculating the omission error and reaction time for Go trials, and commission error for No-go trials. The pulse rate was compared between all tasks and rest conditions (silence). The task performances measured were compared between Tasks 2 and 3. The rating of participants before and after listening to selected music was compared for the current mood (PANAS). The subjective scoring for SAM scale (valence/arousal) was compared between subjects who listened to Indian classical instrument and jazz.

Jazz music

The pulse rate was significantly different ($P < 0.05$) and low while listening to jazz (Task 1) compared to Rest 1 condition (silence) (Figure 3). This change was noted only while listening to music stimuli. The pulse rate was same for the baseline (before the beginning of the experiment) and the remaining rest periods (Rest 1, Rest 2 and Rest 3).

Figure 4 shows the variation in pulse rate for various tasks. The pulse rates were similar while listening to jazz music alone (Task 1) and while performing task with jazz music (Task 2). The pulse rates were significantly different ($P < 0.05$) and low while listening to jazz music and performing the task (Task 2) compared to the performing the task in silence (Task 3).

The pulse rate was significantly high ($P < 0.05$) while performing the task in silence compared to Rest 3 state (Figure 4).

Indian classical instrument

While listening to Indian classical instrument, the pulse rate was the same compared to Rest 1 (no music). Moreover, the pulse rate was similar for the baseline (before

the beginning of the experiment) and the remaining rest period (Rest 1, 2 and 3).

Figure 5 shows that the mean pulse rate was significantly low ($P < 0.05$) while performing the task with Indian music when compared to performing in silence. The mean pulse rate was significantly high ($P < 0.05$) when performing in silence compared to Rest 3 state.

The mean pulse rate was low ($P < 0.05$) and significantly different while listening to music alone compared to performing in silence. The mean pulse was significantly low ($P < 0.05$) while performing with Indian classical instrument compared to performing in silence (Figure 6).

Mean pulse rate between Indian classical instrument and jazz

The pulse rates of the participants who listened to selected music alone (Task 1) were similar for Indian classical instrument and jazz ($P = 0.891$). The changes in pulse rate were noticed when the participants performed the task in silence (Task 3) compared to participants who listened to selected music along with task (Task 2).

Task performance

Omission error for Go trials: The omission error was calculated for visual Go trials. The participants had to respond to the correct answer while listening to Indian classical instrument/jazz music and in silence (no music).

The omission error for Go trials was significantly high ($P < 0.05$) while performing the task in silence compared to while listening to jazz music and Indian classical instrument during the task performance (Table 2). The same visual Go trials were performed in all conditions. We found that participants who missed the target were more, for completing the task in silence compared to those who listened to both forms of music.

Commission error (No-go trials): The participants had to withhold the response for the No-go stimuli. The commission error for their response for No-go stimuli while listening to jazz music and performing the task was 0.66% and it was 3.56% when performing in silence. Moreover, the commission error for No-go trials while listening to Indian classical instrument and performing the task was 0.44% and it was 2.3% when performing in silence. This indicates that while performing in silence, the participant responded more to the No-go trials (Figure 7).

This specifies that the failure to withhold the response to the incorrect answer was more while performing in silence compared to performing the task while listening to jazz music and Indian classical instrument. The task performance degraded while performing the task in silence compared to while listening to music as shown in Figure 7.

Reaction time (for Go trials): The reaction time was calculated as soon as the participants pressed the key (button) when the visual Go trials (task stimuli) were presented to them. It indicates how fast the participants pressed the correct key.

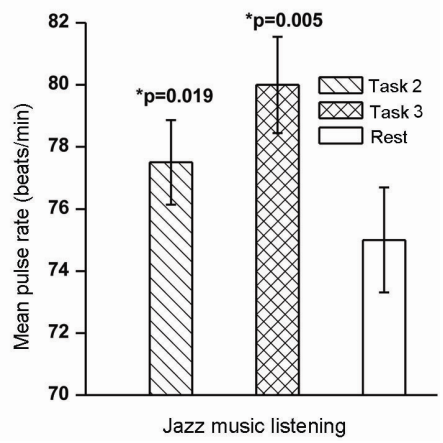

Figure 4. Mean ± standard error values of the measured pulse rate while listening to jazz music during Tasks 2 and 3 and Rest conditions.

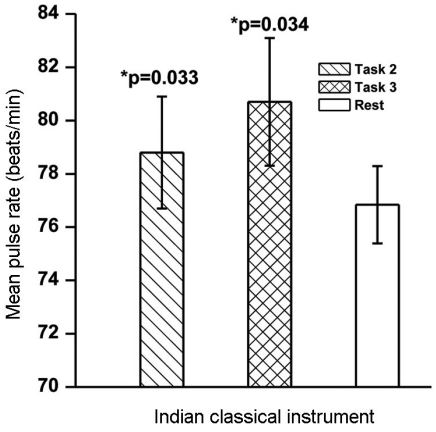

Figure 5. Mean ± standard error values of the measured pulse rate while listening to Indian classical instrument during Tasks 2 and 3 and Rest conditions.

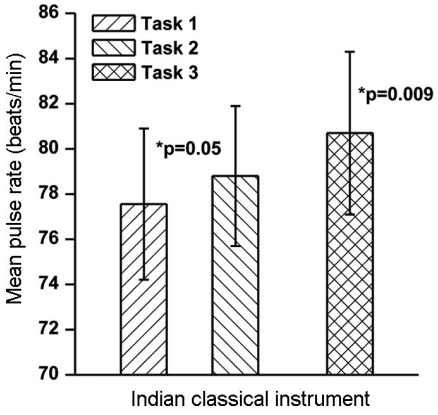

Figure 6. Mean ± standard error values of the measured pulse rate while listening to Indian classical instrument during Tasks 1, 2 and 3 conditions.

Table 2. Omission error for Go trials for Task 2 (task performance with listening to chosen music) and Task 3 (task performance with no music)

	Omission error for Go trials	
Statistical test	Task 2 (Jazz) – Task 3	Task 2 (Indian classical) – Task 3
Wilcoxon signed rank	$Z = -2.191$, $P = 0.028$	$Z = -2.293$, $P = 0.022$

Table 3. Reaction time for Go trials for Task 2 (task performance with listening to chosen music) and Task 3 (task performance with no music)

	Reaction time for Go trials	
Statistical test	Task 2 (Jazz) – Task 3	Task 2 (Indian classical) – Task 3
Wilcoxon signed Rank	$Z = -2.701$, $P = 0.007$	$Z = -2.552$, $P = 0.011$

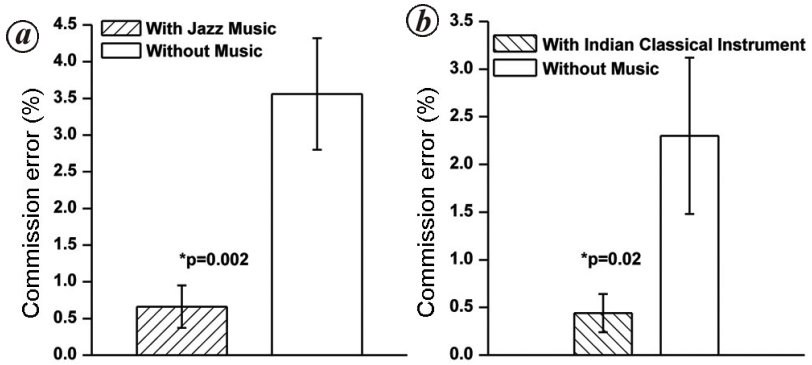

Figure 7. Percentage of commission error for visual No go trials: ***a***, With jazz music and without music. ***b***, With Indian classical instrument and without music (bars represents the standard error values).

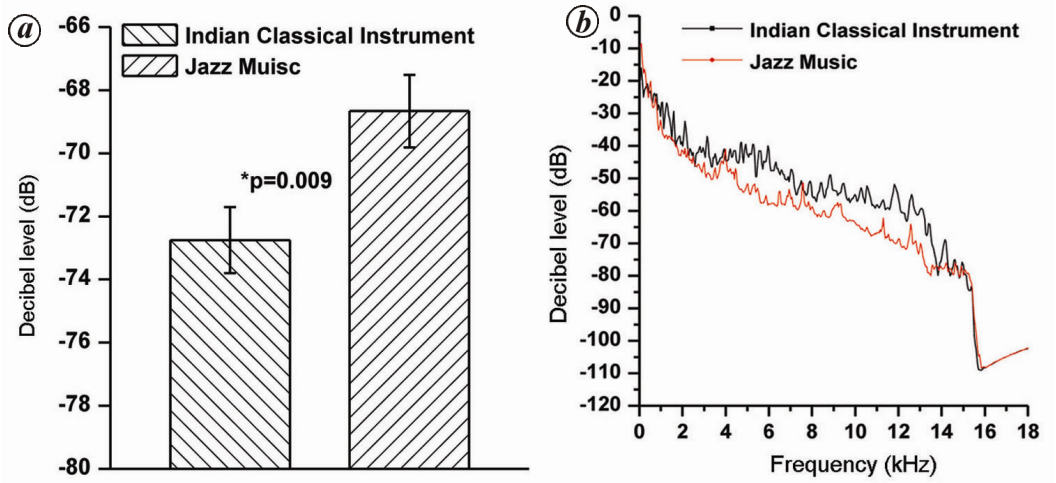

Figure 8. ***a***, Decibel level (dB) between Indian classical instrument and jazz music. ***b***, Decibel levels (dB) of the played music plotted against frequency.

The reaction time was significantly low ($P < 0.05$) for participants who were listening to jazz music and the Indian classical instrument compared to those performing the task in silence (Table 3). The jazz music and Indian Classical instrument played did not impose any distractions and in fact improved the task performances when compared to their performance in silence.

While listening to jazz and Indian classical instrument during task performance, the omission error for Go trials was the same ($\chi^2(2) = 2.908$, $P = 0.088$) and the percentage

of commission error for No-go trials was the same ($\chi^2(2) = 0.023$, $P = 0.880$). The reaction time was similar for both forms of music ($\chi^2(2) = 0.116$, $P = 0.733$). The task performances were the same for both.

The sound level (decibels) at different frequencies of dissimilar musical instrument used in Indian classical instrument and jazz was compared using independent samples *t*-test. The sound levels of the Indian classical instrument and jazz music were significantly different (t (1020) = –2.626, $P = 0.009$) (Figure 8) which indicate the sound levels (dB) of the music played at different frequency bands.

Assessing mood using PANAS

In our study, the positive affect scores before and after listening to Indian classical instrument were significantly different ($P < 0.05$) (Figure 9 *a*). The mean positive affect score was high after listening to Indian classical instrument. Further, the positive affect scores before and after listening to jazz music was significantly different ($P < 0.05$) (Figure 9 *b*). The mean positive affect score was high after listening to jazz music. However, there is no change in the mean negative affect scores before and after listening to the selected music.

Valence and arousal for the selected stimulus (SAM scale)

The valence and arousal levels were measured using SAM scale. The valence ratings for those who listened to music were on the scale of 1 to 5 where 1, 2, 3, 4 and 5 stand for unpleasant, unsatisfied, neutral, pleased and pleasant respectively. The arousal ratings for those who listened to music were on the scale of 1 to 5 where 1, 2, 3, 4 and 5 stand for calm, dull, neutral, wide awake and excited respectively.

The participants were asked to rate their choice of selected music using SAM scale for valence and arousal to measure the perceived emotion. These ratings were used to assess the pleasantness and unpleasantness (valence) resulting from played music and the low to high arousal. Indian classical instrument and jazz music resulted in a pleasant or excited condition (Figure 10).

Discussion

We recruited two independent set of participants without formal training in music. However, they used to listen to Indian music while learning. In order to assess the mood prior to experiment and after listening to the selected form of music, the participants were asked to rate the current mood using PANAS. The effect of each raga in Carnatic music as explored in the human mind, played in specific periods of the day on a particular scale. Based on this fact, we focused on two ragas – Malahari and Kapi. The Malahari is known as the morning raga, whereas Kapi raga can be played at any time[25]. SAM scale was used to measure the pleasure and arousal levels associated with listening to selected music. The participants' evaluation based on SAM scale and PANAS scoring for the Indian classical instrument and Indo jazz were appraised as pleasant/excited and induced a positive effect (mood). Independently selected music was able to induce and sustain positive mood states in listeners during driving as well[9,26]. The subjective scoring indicates that the positive effect (mood) was retained before and after listening to selected music when performing a task.

Pleasurable experience of listening to music causes changes in autonomic responses[27]. These changes were evident in our current study and were reflected in the pulse rate. Based on the results of a SAM questionnaire, the scoring for pleasantness was high for both forms of musical stimuli. The changes in pulse rate were significantly low only during Indo jazz compared to silence. It was observed that the pulse rate continued to be the same

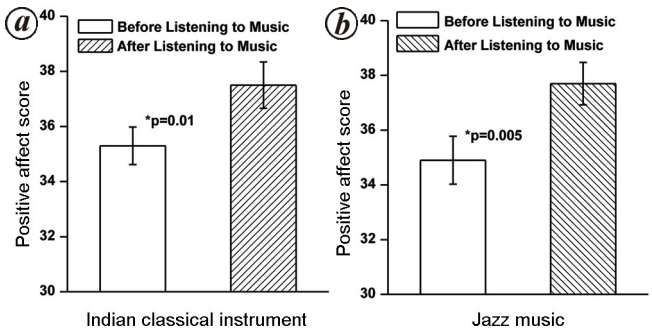

Figure 9. Positive affect score obtained before and after listening to (***a***) Indian classical instrument and (***b***) jazz music.

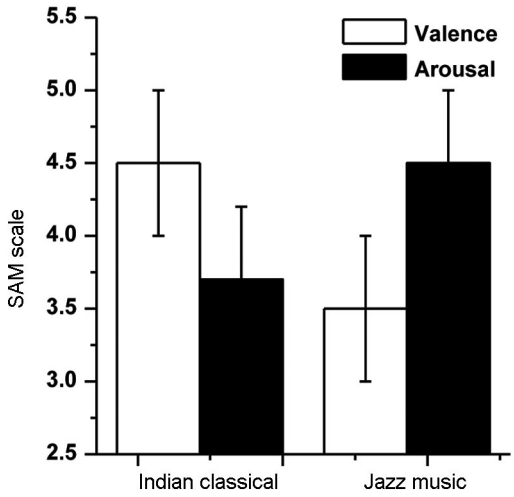

Figure 10. Mean ± standard error values of the SAM scale for valence and arousal of the played Indian classical instrument and jazz music.

Appendix A[31]

1. Indian Classical Instrument played by Arun Mohan (violin, sitar, tabla)
2. Indo Jazz played by Joe Harriott-John Mayer (saxophone, violin, trumpet, flute, piano, sitar, tambura, bass, drums, tabla)
3. Raga Nat Bhairav 1 played by Sultan Khan (sarangi) and Ustad Zakir Hussein (tabla)
4. Raga Dharmavathi played by Ganesh and kumaresh bros (violin)

Music stimuli – scale

Music played	Scale of played raga	Pitch	Instruments used in the played music	Fast beat or slow beat	Impact
Indian Classical Instrument	Malahari (Carnatic raga) This ragam is an asymmetric scale. Five notes in the ascending scale and six notes in the descending scale. Arohana: S R1 M1 P D1 S Avarohana: S D1 P M1 G3 R1 S	High	Violin, Sitar, Tabla	Slow	This raga is known to be a morning raga which brings out a sense of calmness and improves concentration.
Indo Jazz	Kapi (Carnatic music). The equivalent raaga in Hindustani is Pilu. Kapi is with an ascending pentatonic scale and a descending scale with seven notes, but not in a descending order. Arohana: S R2 M1 P N3 S Avarohana: S N2 D2 N2 P M1 G2 R2 S	Low	Saxophone, Violin, Trumpet, Flute, Piano, Sitar, Tambura, Bass, Drums, Tabla	Slow and medium speeds	Capable of inducing moods of commitment and reduces absent mindedness in the listeners.

while listening to Indian classical instrument and during silence. This clearly indicates that the style, pitch and the different instruments used to play the Indo jazz played a major role in reducing pulse rate, than subjective perception.

Our study supports the findings that listening to music is an inexpensive way to improve the cognitive abilities in elderly adults[5] and background music tend to improve the cognitive performance when compared to no music and white noise. When music evokes a pleasant mood and there is an increase in the arousal level, there is an increase in creative problem-solving and task performance[8]. The Indo jazz raga played was Kapi which is capable of inducing moods of commitment and improves attention of the listener[28]. The played Indian classical instrument raga was Malahari which brings out a sense of calmness and improves concentration[28]. Both Kapi and Malahari ragas enhance task performance. The omission error for Go trials and commission error for No-go trials and the reaction time were significantly less while listening to Kapi and Malahari during task performance compared to task performance in silence. The missed targets and the failure to withhold the response to the incorrect answer were more while performing in silence compared to task performance aided by music.

Moreover, the reaction time was significantly low for jazz music and the Indian classical instrument, when compared to task performance in silence. The participants responded to the Go trials very quickly compared to their response in silent condition. This clearly indicates that jazz music and Indian classical instrument played no distractions and in fact enhanced task performance.

To support this further, we conducted a parallel study to explore the brain activation of selected ragas on attention processing areas. The task performance is mostly associated with tedium and negative moods[29], and listening to preferential music[30] would prevent boredom without compromising task performance as an external commotion. The current research finding provides corroborative evidence to the observations in existing literature[29,30]; the participants perceived both the selected forms of music as pleasant, induced excitement and produced positive mood, in turn these were reflected in the enhanced task performance.

This study was conducted in the morning and the same protocol can be followed in extending the study to different periods of the day or night. In such cases, the impact of music on the human mind may be interesting and the reflection in the task performance can be analysed.

Conclusion

Based on the participants' perception, our study concludes that, their chosen Indian classical instrument and Indo jazz music induce a positive affect pleasure/ excitement. Both forms of music played brought calmness to listeners and this was reflected in the reduction of the pulse rate, when compared to silence. The Indian classical instrument played was Malahari raga that improved concentration whereas Indo jazz played was Kapi raga which improved attention; as revealed in the enhanced task performance. Therefore, this study supports the hypothesis that listener's perception in addition to

different types of instruments played influences the physiological variable (pulse rate) and contributes to enhancement of task performance.

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