Journal of
Biomusical Engineering
ISSN: 2090-2719

Sanyal et al., J Biomusic Eng 2016, 4:2
DOI: 10.4172/2090-2719.1000119

Review Article
OMICS International

Musical Improvisation and Brain Correlates: An EEG Based Neurocognitive Study Using Hindustani Music

Shankha Sanyal[1,2], Archi Banerjee[1,2]*, Shirsendu Mukherjee[1], Tarit Guhathakurata[1], Ranjan Sengupta[1] and Dipak Ghosh[1]

[1]Sir C.V. Raman Centre for Physics and Music, India
[2]Department of Physics Jadavpur University, Kolkata, India

Abstract

The concept of creativity and perception of a raga is revisited in this work from the brain electrical response of a professional Hindustani musician. EEG was done to record the response when a musician created the imagery of raga Jay Jayanti as well as when he listened to the same raga sung by him. We have quantified the correlation values obtained from different lobes of the brain during these two experimental conditions using a robust non-linear technique called multifractal detrended cross-correlation analysis (MFDXA). With this method, we have seen that both during imagination and perception the degree of cross-correlation is very high in the occipital lobe, purportedly due to the visualization of the raga by the musicians. In other electrodes also, inter/intra-lobe cross correlations have been found to be significantly during different conditions. With this study, we look forward to develop a paradigm with which we can quantify the definition of creativity. The results are discussed in detail.

Keywords: Imagining and listening raga; EEG; Frontal; Occipital and temporal lobe; MFDXA

Introduction

What happens inside the performer's brain when he is performing and composing a particular raga? Are there some specific regions in brain which are activated when an artist is creating or imaging a raga in his brain? Do the regions remain the same when the artist is listening to the same raga sung by him? These are the questions that perplexed neuroscientists for a long time. The endeavor to obtain insights to brain processes that take place during listening as well as composing music has been attempted several times by musicologists and psychologists. In this study we strive to answer this question by using latest state-of-the-art techniques to assess brain response. The effect of mentally composing a musical piece was studied in this work with the help of a Hindustani classical *raga*. The performers of Hindustani raga music insist that while performing or composing a musical piece, they have a visual imagery of that particular composition in their mind which helps them to improvise and reach to the audience better. We strive to quantitatively assess the proposition and several other unanswered questions in regard to musical imagination and perception by using latest state-of-the-art techniques to assess brain response.

Creative thinking has been one of the predominant issues of neuroscience that provided contradictory results in the past. Most of these works make use of coherence properties between the lobes using linear power spectral analysis in various frequency ranges to assess the amount of interdependence.

Coherence, a parameter obtained from spectral analysis of the EEG, is the normalized cross-spectrum of two signals and reflects the correlation between them with respect to frequency. Applied to EEG analysis, the value of coherence lies in its providing data on the relationships between the electric oscillations recorded from two locations on the skull [1]. Musical training can have strong effects on the structural and cognitive development of brain [2-6]. No previous study, to our knowledge has studied the non-linear aspects of EEG to study creative musical imagery on trained musicians with Hindustani raga music.

Musical improvisation by far the most challenging task that an artist has to undertake, requiring the real-time generation and production of novel melodic and rhythmic sequences in line with an ongoing musical performance. Thus, understanding musical improvisation is crucial to understand how in general creative processes are conducted in human being. A recent neuro-imaging study [7] reports increased surface area for subjects reporting high levels of musical creativity which suggests that domain-specific musical expertise, default-mode cognitive processing style, and intensity of emotional experience might all coordinate to motivate and facilitate the drive to create music. Earlier brain-imaging studies pointed the importance of Pre-Frontal cortex (PFC) in case of creative thinking [8,9]; while study on Jazz musicians [10] reveal that improvisation (compared to production of over-learned musical sequences) was consistently characterized by a dissociated pattern of activity in the prefrontal cortex: extensive deactivation of dorsolateral prefrontal and lateral orbital regions with focal activation of the medial prefrontal (frontal polar) cortex. In Western music, a number of neuro-imaging studies have been conducted on Jazz musicians and pianists [10-13]; where activity observed in the PFC included both deactivation of the DLPFC and lateral orbital (LOFC) regions and focal activation of the medial prefrontal cortex (MPFC). Also [10] reveals a state of free-flowing complex musical ideas that may result from the combination of internally generated self-expression (via the MPFC) and attenuation of activity in the DLPFC.

But, what about musical improvisation in Hindustani music (HM)? Till date, no study tries to harvest the immense potential that a Hindustani musician has to offer when it comes to the study of creativity in musical performances since there is no notation in HM system like western music and the musician is himself the composer. A musician

***Corresponding author:** Archi Banerjee, Sir C.V. Raman Centre for Physics and Music, Department of Physics, Jadavpur University, Kolkata, India, Tel: +919038569341; E-mail: archibanerjee7@gmail.com

Received October 25, 2016; **Accepted** November 22, 2016; **Published** December 05, 2016

Citation: Sanyal S, Banerjee A, Mukherjee S, Guhathakurata T, Sengupta R, et al. (2016) Musical Improvisation and Brain Correlates: An EEG Based Neurocognitive Study Using Hindustani Music. J Biomusic Eng 4: 119. doi:10.4172/2090-2719.1000119

while performing expresses the raga according to his mood. Thus there are differences from one rendition to another. Even if an artist sings or play same *Raga* and same *Bandish* twice then there is supposed to be some dissimilarity in between the two performances. These differences in the rendition of a raga several times on different days are generally called improvisation. Unlike symphony or a concerto, Raga is unpredictable; it is eternally blooming, blossoming out into new and vivid forms during each and every performance which is the essence of "improvisation" [14]. The performers of Hindustani raga music insist that while performing or composing a musical piece, they have a visual imagery of that particular composition in their mind which helps them to improvise and reach to the audience better. The literature regarding perception and imagination of a musical stimuli involving Hindustani raga music is quite scarce, though it is quite rich and diverse when it comes to the variety of emotions induced by it [15-18]. Simply put, a *raga* in Hindustani Classical music is a musical theme created by choosing a specific set of notes from within an octave. In the broadest sense, the word 'raga' refers to 'color', more specifically the emotion or mood produced by a particular sequence or combination of pitches [19]. Different sets of notes evoke different moods and inspire different feelings [20]. Issues of artistic creativity might involve too many variable parameters such as personality, inherent artistic ability, mood etc. and at the onset it may be difficult to tackle all these. But, with the onset of neurocognitive science we have robust neuro-imaging techniques with which we look forward to have an accurate insight of brain response while an artist is mentally creating as well as listening to a particular musical composition (raga in our case). The neuro-dynamical effect of mentally composing as well as listening to a 'raga' was studied in this work taking the help of an experienced performer of Hindustani music.

The Electroencephalography (EEG) is a neuro scientific tool to assess the brain electrical response in different regions of the brain. With the help of this tool we look forward to visualize the brain processes accompanying the composition and creativity of a particular raga in Hindustani music. The EEG signals generated from brain are essentially non-stationery and scale varying in nature. Different scaling exponents can be revealed for many interwoven fractal subsets of the time series. So, a multifractal analysis of the data would be more appropriate than a single scaling exponent as is obtained from detrended fluctuation analysis (DFA). A recent study by the authors shows multifractal scaling of EEG signals in response to a simple tanpura drone signal [21]. A method named detrended cross-correlation analysis (DXA) allows investigating the long-range cross-correlations between two nonstationary time series, which is a generalization of the DFA method. Here, we use a technique called multifractal detrended cross correlation analysis (MFDXA) [22,23], a generalization of the DXA method which can unveil the multifractal features of two cross-correlated signals and higher-dimensional multifractal measures. The two nonlinear signals from the two different groups of electrodes are analyzed with the help of MFDXA technique and the resultant cross correlation exponent gives the degree or the amount by which the two signals are correlated.

In this study, we took EEG data from an eminent Hindustani music performer having an experience of more than 20 years. The subject chose to think of the raga 'Jay Jayanti' in his mind, he recreated the imagery of the aalap of the raga in his mind for 2 min 30 seconds. Next, he was made to listen to the alaap of the same raga sung by him for another 2 min 30 seconds relaxation period. The EEG recording was continued during this entire period. We identified three different lobes of the brain namely frontal, temporal and occipital whose functions tally with our work. The frontal lobe is associated with reasoning, cognitive processing and expressive language, the temporal lobe is important for interpreting sounds and the language we hear while the occipital lobe is important for interpreting visual stimuli and information processing. The frontal lobe plays a key role in emotional processing and appraisal of musical stimuli [24-27]. So, we chose two pair of electrodes from each of these lobes (F3/F4 from frontal, T3/T4 from temporal O1/O2 from occipital) to study the brain electrical response of the listener. The total experimental period was divided into 5 parts namely "without stimuli", "imagining raga Jay Jayanti", "after imagination rest period", "with raga Jay Jayanti listening" and "after listening rest". We evaluated the cross correlation exponent for each of the possible combinations (i.e. 15 possible combinations) of 6 electrodes for the various experimental conditions. For uncorrelated data, the cross correlation coefficient, γ_x has a value 1 lower the value of γ_x, more correlated is the data [23,28]. Thus a negative value of γ_x signifies that the two signals originating from different lobes have very high degree of correlation between them. With the help of this technique, we intend to identify certain regions in the brain which are most correlated when an artist thinks of raga, while certain others which are most correlated when the artist listens to that particular raga. When a musician is listening and also thinking of a certain raga, the role of musical expectancy as well as the memory of the just listened phrases and the possible connection to this with immediately following expected musical events may be higher. This may lead to strong correlations in the specific lobes where the processing takes place. What we look forward to in this work is to conjure a general paradigm where the brain areas associated with musical creativity and perception can be conclusively identified.

Materials and Methods

Subjects summary

A male professional vocalist of Hindustani music (age ~35 years, average body weight ~60 kg) voluntarily participated in the study having experience of performing in stage for more than 30 years. The experiment was performed at the Sir C.V. Raman Centre for Physics and Music, Jadavpur University, Kolkata. It was conducted in the afternoon with a normal diet in a normally conditioned room sitting on a comfortable chair and performed as per the guidelines of the Institutional Ethics Committee Jadavpur University, Kolkata. The subject gave his written consent before participating in the study. This is a pilot study which mainly has its root grounded in the musical appreciation of an artist which again is very much influenced by the musical training of that particular artist. Thus, we chose to take EEG data of a single performer only as this study is very much subjective than generalized. As for statistical significance, we plan to take EEG data for different artists belonging to the same gharana of Hindustani music who have been trained similarly for a long time, where from we can generalize the data and reach a definite conclusion. This study is a pilot one in that direction.

Experimental details

The subject chose the raga *Jay Jayanti* for this particular study. Following the prescription of the performer, he was asked to bring a 3 min recording of his own recital of the same music sample (a 3 min *alaap* of *raga Jay Jayanti)*. The *alaap* portion of each raga was chosen as it gradually reveals the mood of the raga using all the notes used in that particular raga and allowed transitions between them with proper distribution over time. It reflects the temperament, creativity and uniqueness of musical training of a musician. Each of these sound signals was digitized at the sample rate of 44.1 KHZ, 16 bit resolution and in a mono channel. Both the signals were normalized to within 0dB and hence intensity or loudness and attack cue are not being considered. A sound system (Logitech R_Z-4 speakers) with high S/N ratio was used in the measurement room for giving music input to the subjects.

Experimental protocol

The subject was prepared with an EEG recording cap with 19 electrodes (Figure 1) (Ag/AgCl sintered ring electrodes) placed in the international 10/20 system. Impedances were checked below 5 kOhms. The EEG recording system (Recorders and Medicare Systems) was operated at 256 sample/s recording on customized software of RMS.

The data was band-pass-filtered between 0 and 50 Hz to remove DC drifts. Each subject was seated comfortably in a relaxed condition in a chair in a shielded measurement cabin. They were also asked to close their eyes. After initialization, a 20 min recording period was started, and the following protocol was followed:

1. 2 min 30 seconds "Before imagination"
2. 2 min 30 seconds "While imagination *raga Jay Jayanti*
3. 2 min 30 seconds "After imagination"
4. 5 min resting period
5. 2 min 30 seconds "Before Listening"
6. 2 min 30 seconds "With listening *raga Jay Jayanti*"
7. 2 min 30 seconds "After listening".

We divided each of the experimental conditions in three windows of 45 seconds each and calculated the cross-correlation coefficient for each window.

Method of Analysis

Multifractal detrended cross correlation analysis (MF-DXA)

We have performed a cross-correlation analysis of correlation between two non-linear signals originating from different lobes of the brain following the prescription of Zhou [7].

$$x_{avg} = 1/N \sum_{i=1}^{N} x(i) \text{ and } y_{avg} = 1/N \sum_{i=1}^{N} y(i) \quad (1)$$

Then we compute the profiles of the underlying data series x(i) and y(i) as

$$X(i) \equiv [\sum_{k=1}^{i} x(k) - x_{avg}] \text{ for } i = 1 \ldots N \quad (2)$$

$$Y(i) \equiv [\sum_{k=1}^{i} x(k) - x_{avg}] \text{ for } i = 1 \ldots N \quad (3)$$

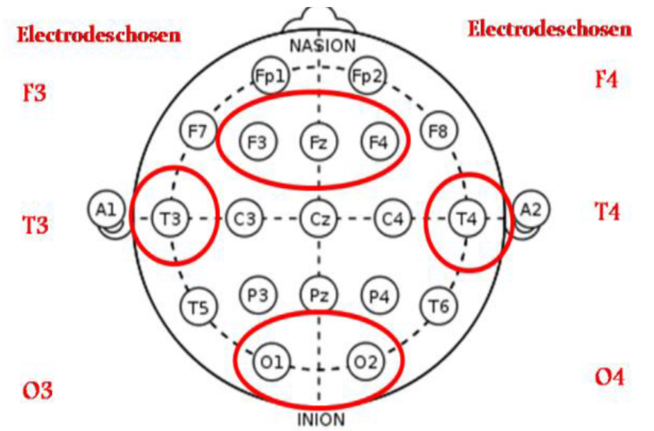


Figure 1: The lobes and electrodes chosen for our analysis.

The qth order detrended covariance Fq(s) is obtained after averaging over 2Ns bins.

$$F_q(s) = \{1/2N_s \sum_{v=1}^{2NS} [F(s,v)]^{q/2}\}^{1/q} \quad (4)$$

where q is an index which can take all possible values except zero because in that case the factor 1/q blows up. The procedure can be repeated by varying the value of s. Fq(s) increases with increase in value of s. If the series is long range power correlated, then Fq(s) will show power law behavior

$$F_q(s) \sim s^{\lambda(q)}.$$

Zhou found that for two time series constructed by binomial measure from p-model, there exists the following relationship [22]:

$$\lambda(q = 2) \approx [h_x(q = 2) + h_y(q = 2)]/2. \quad (5)$$

Podobnik and Stanley have studied this relation when q = 2 for monofractal autoregressive fractional moving average (ARFIMA) signals and EEG time series [28].

In case of two time series generated by using two uncoupled ARFIMA processes, each of both is autocorrelated, but there is no power-law cross correlation with a specific exponent [29]. According to auto-correlation function given by:

$$C(\tau) = \langle [x(i + \tau) - \langle x \rangle][x(i) - \langle x \rangle] \rangle \sim \tau^{-\gamma}. \quad (6)$$

The cross-correlation function can be written as

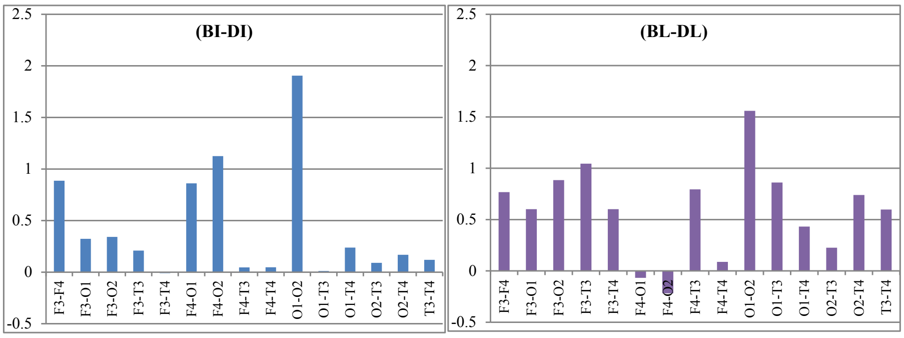
$$C_x(\tau) = \langle [x(i + \tau) - \langle x \rangle][y(i) - \langle y \rangle] \rangle \sim \tau^{-\gamma_x} \quad (7)$$

where γ and γ_x are the auto-correlation and cross-correlation exponents, respectively. Due to the non-stationarities and trends superimposed on the collected data direct calculation of these exponents are usually not recommended rather the reliable method to calculate auto-correlation exponent is the DFA method, namely $\gamma = 2 - 2h(q = 2)$ [29]. Recently, Podobnik et al., have demonstrated the relation between cross-correlation exponent, γ_x and scaling exponent $\lambda(q)$ derived from $\gamma_x = 2 - 2\lambda(q = 2)$ [28]. For uncorrelated data, γ_x has a value 1 and the lower the value of γ and γ_x more correlated is the data.

In other words, we want to have a quantitative estimate of how the different lobes of the brain are correlated when a performer is mentally creating the imagery as well as during the perception of the same raga. The cross correlation coefficient is an effective parameter with which we can assess the same and hence have a measure of creativity.

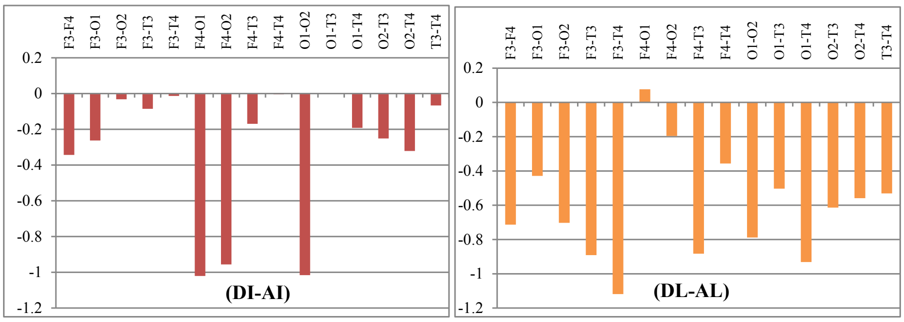
Results and Discussion

Figure 1 gives the positioning of electrodes according to the 10-20 International system and also marks the three lobes and six electrodes that were chosen for our analysis. The averaged cross correlation coefficient γ_x for q = 2 corresponding to the different experimental conditions are computed for different combination of electrodes. As already said, negative values of γ_x correspond to strong cross correlation between the two non-linear signals; we report the variation of cross-correlation coefficients in the different lobes while the performers "imagine" and "listen" to the raga *Jay Jayanti*. What we intend to study is how the degree of cross-correlation between different lobes of brain are affected when a performer is imagining or listening to the same raga, so we decided to report the amount of change in degree of cross-correlation in both the cases. The figures that follow (Figure 2) show a quantitative measure of how the cross-correlations between different lobes are affected while musical imagery and listening is constituted in a performer's brain. Figure 3 shows how the same combination of lobes behaves when there are no stimuli.



(a) (b)

Figure 2: Change in γ_x for different electrode combinations when Subject (a) imagines and (b) listens to raga.



(a) (b)

Figure 3: Change in γ_x for different electrode combinations after (a) imagination and (b) listening to raga.

A careful study of the figures shown above reveals the following interesting observations:

1. The frontal lobe has been considered to be important while it comes to higher level cognitive processing; we have seen that the cross correlation between the two frontal electrodes, F3 and F4 significantly increases in both the experimental conditions. The recreation of the imagery of a particular raga involves higher order cognitive processing in the performer's brain, hence the strong correlation between the two frontal electrodes become eminent.
2. The correlation between the temporal electrodes and other electrodes becomes sufficiently enhanced during the "listening" period of the raga as compared to the "imagination" period. As is seen from the figures, degree of cross correlation rises considerably for F3-T3, F3-T4, O1-T3 and O1-T4 for the "listening" period, while the enhancement is not so pronounced during the "imagination" period. This may be due to the simultaneous involvement of cognitive as well as auditory skills of the performer which is manifested in the enhancement of cross-correlation between the particular lobes.
3. The correlation between frontal and occipital lobes (F3-O1, F3-O2) has been found to significantly increase both during "imagination" and "listening" of the raga. The degree of cross correlation between F4-O2 and F4-O1 increased to a great extent during "imagination" part of the raga, but decreases during "listening" part. This result implies in the direction of simultaneous processing of cognitive and visual information in the performer's brain.
4. Another curious observation is the remarkable enhancement in the degree of cross correlation between the two occipital electrodes O1 and O2 for both the subjects. It has been found that the cross-correlation coefficient increases significantly both "during imagination" and "during listening" of the *raga*. More surprising is the fact that in some cases, the increase is quite considerable even in the "listening" part; though the subject was sitting with his eyes closed while the EEG experiment was performed. This result may have a far reaching conclusion, that even when an artist is listening to a raga performed by him, he is actually visualizing a picture of the raga in his mind, which eventually leads to higher degree of cross correlation manifested in the occipital lobe.

After the removal of stimulus, it is seen that the degree of cross-correlation decreases unanimously for all the electrodes to various extent; thus it can be said that music as a stimuli is able to enhance the correlation between different lobes of the brain to different extent, while the removal of the stimuli leads to decrease of cross correlation.

Conclusion

"If a person can't read or write, you don't assume that this person is incapable of it, just that he or she hasn't learned how to do it. The same is true of creativity. When people say they're not creative, it's often because they don't know what's involved or how creativity works in practice." wrote Sir Ken Robinson in his book THE ELEMENT. In this work, we have tried to visualize with the help of robust scientific methods, a general response of human brain while performing creative task.

The strong cross-correlation between the occipital electrodes both during imagination and perception of the musical piece indicates the creation of a visual imagery of that particular musical piece in the performer's brain. That the two occipital electrodes are strongly correlated during the listening part also is an important revelation of this study, and strengthens the claim of creation of visual imagery of a particular *raga* by the musicians. The strong cross-correlation between the frontal and fronto-temporal electrodes might be evidences of involvement of higher order cognitive thinking and auditory skills involved in the processing of musical stimuli. Interestingly, the cross-correlation between the electrodes decreases to a great extent after the removal of stimuli, pointing to enhancement of neural activity during creative imagery of a musical composition. Also, the combination of electrodes for which rise is significant, the fall after removal of stimuli is also significant, indicating that in the absence of any creative task diminishes the cross correlation between different lobes of the brain. Some of the features of this interdependence between inter as well intra lobes of brain during mentally creating as well as perceiving a musical composition, obtained from the degree of cross correlation are revealed for the first time from our new data. Thus, with this we have tried to obtain a quantitative definition of creativity, which till now was considered more of a philosophical term rather than a scientific one. The increase or decrease of the degree of cross-correlation between the different lobes of brain during a variety of cognitive tasks can now be related to creativity involved in each of the tasks. The obtained data thus, may be of immense importance when it comes to studying the neuro-cognitive basis of creativity and alertness to a certain cognitive function. An extension of this work is being carried out in our laboratory, where artistes of the same and different *gharanas* of Hindustani classical music are being taken and the neural responses corresponding to the musical creativity and improvisation are being studied to get a robust knowledge about the general paradigm of musical improvisation.

References

1. Petsche H, Richter P, Stein AV, Etlinger SC, Filz O (1993) EEG Coherence and Musical Thinking. Music Perception 11: 117-151.
2. Pinho AL, Manzano OD, Fransson P, Eriksson H, Ullén F (2014) Connecting to create: expertise in musical improvisation is associated with increased functional connectivity between premotor and prefrontal areas. J Neurosci 34: 6156-6163.
3. Bengtsson SL, Nagy Z, Skare S, Forsman L, Forssberg H, et al. (2005) Extensive piano practicing has regionally specific effects on white matter development. Nature neurosci 8: 1148-1150.
4. Hyde KL, Lerch J, Norton A, Forgeard M, Winner E, et al. (2009) Musical training shapes structural brain development. J Neurosci 29: 3019-3025.
5. Pantev, Christo, Sibylle C (2011) Herholz. Plasticity of the human auditory cortex related to musical training. Neurosci Biobehav Rev 35: 2140-2154.
6. Simonton DK (2000) Cognitive, personal, developmental, and social aspects. Am Psychol 55: 151-158.
7. Bashwiner DM, Wertz CJ, Flores RA, Jung RE (2016) Musical Creativity Revealed in Brain Structure: Interplay between Motor, Default Mode, and Limbic Networks. Sci Rep 6: 20482.
8. Jung RE, Mead BS, Flores C (2013) The structure of creative cognition in the human brain. Front Hum Neurosci **7**: 330.
9. Beaty RE, Benedek M, Wilkins RW, Jauk E, Fink A, et al. (2014) Creativity and the default network: A functional connectivity analysis of the creative brain at rest. Neuropsychologia 64: 92–98.
10. Limb CJ, Braun AR (2008) Neural substrates of spontaneous musical performance: An fMRI study of jazz improvisation. PLoS one 3: e1679.
11. Bengtsson SL, Csíkszentmiháyli M, Ullén F (2007) Cortical regions involved in the generation of musical structures during improvisation in pianists. J Cognitive Neurosci 19: 830-842.
12. Berkowitz AL, Ansari, D (2008) Generation of novel motor sequences: The neural correlates of musical improvisation. Neuro Image 41: 535-543.
13. Manzano D, Ullén F (2011) Goal-independent mechanisms for free response generation: Creative and pseudo-random share neural substrates. Neuro Image 59: 772-780.
14. Adrian M (2007) Improvisation as conversation: A cross cultural perspective.
15. Wieczorkowska A, Datta AK, Sengupta R, Dey N, Mukherjee B (2010) On search for emotion in Hindusthani vocal music.Advances in music information retrieval. Springer Berlin Heidelberg 6: 285-304.
16. Mathur A, Vijayakumar SH, Chakrabarti B, Singh NC (2015) Emotional responses to Hindustani raga music: The role of musical structure. Front Psychol.
17. Martinez JL (2001) Semiosis in Hindustani music. Motilal Banarsidass.
18. Banerjee A, Sanyal S, Patranabis A, Banerjee K, Guhathakurta T, et al. (2016) Study on Brain Dynamics by Non Linear Analysis of Music Induced EEG Signals. Physica A: Statistical Mechanics and its Applications 444: 110-120.
19. Ruckert, George, Widdess R (1998) The Garland Encyclopedia of World Music. Hindustani raga 5: 64-88.
20. Laura-Lee B, Thompson WF (1999) A cross-cultural investigation of the perception of emotion in music: Psychophysical and cultural cues. Music percept 17: 43-64.
21. Kumar A, Pratihar R, Mitra A, Dey S, Agrawal V, et al. (2015) Multifractal Detrended Fluctuation Analysis of alpha and theta EEG rhythms with musical stimuli. Chaos, Solitons, Fractals 81: 52-67.
22. Zhou WX (2008) Multifractal detrended cross-correlation analysis for two nonstationary signals. Phys Rev E 77: 066211.
23. Shankha S, Banerjee A, Guhathakurata T, Sengupta R, Ghosh D, et al. (2016) A study on Improvisation in a Musical performance using Multifractal Detrended Cross Correlation Analysis. Physica A: Statistical Mechanics and its Applications 462: 67-83.
24. Mellet E, Tzourio N, Crivello F, Joliot M, Denis M, et al. (1996) Functional anatomy of spatial mental imagery generated from verbal instructions. J Neurosci 16: 6504-6512.
25. Mellet E, Petit L, Mazoyer B, Denis M, Tzourio N (1998) Reopening the mental imagery debate: lessons from functional anatomy. Neuro Image 8: 129-139.
26. Stephen MK (1996) Image and brain: The resolution of the imagery debate. MIT press.
27. Mellet E, Tzourio N, Denis M, Mazoyer B (1995) A positron emission tomography study of visual and mental spatial exploration. J Cognitive Neurosci 7: 433-445.
28. Podobnik B, Stanley HE (2008) Detrended cross-correlation analysis: A new method for analyzing two nonstationary time series. Phys rev lett 100: 084102.
29. Movahed MS, Hermanis E (2008) Fractal analysis of river flow fluctuations. Physical A: Statistical Mechanics and its Applications 387: 915-932.

Citation: Sanyal S, Banerjee A, Mukherjee S, Guhathakurata T, Sengupta R, et al. (2016) Musical Improvisation and Brain Correlates: An EEG Based Neurocognitive Study Using Hindustani Music. J Biomusic Eng 4: 117. doi:10.4172/2090-2719.1000117