Review Article

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## 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 UDJD -D\ -D\DQWL DV ZHOO DV ZKHQ KH OLVWHQHG WR WKH VDPH UDJD VXQJ E\ KL 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

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while performing expresses the raga according to his mood. us there are di erences 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. ese di erences in the rendition of a raga several times on di erent 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]. e 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. e 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 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

e 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. e EEG recording system (Recorders and Medicare Systems) was operated at 256 sample/s recording on customized so ware of RMS.

e data was band-pass- ltered between 0 and 50 Hz to remove DC dri s. Each subject was seated comfortably in a relaxed condition in a chair in a shielded measurement cabin. ey were also asked to close their eyes. A er 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 "A er 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 "A er listening".

We divided each of the experimental conditions in three windows of 45 seconds each and calculated the cross-correlation coe cient 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 di erent lobes of the brain following the prescription of Zhou [7].

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

en we compute the pro les of the underlying data series x(i) and y(i) as

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

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

e qth order detrended covariance Fq(s) is obtained a er averaging over 2Ns bins.

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

where q is an index which can take all possible values except zero because in that case the factor 1/q blows up. e 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

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

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

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

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 speci c exponent [29]. According to auto-correlation function given by:

C ( ) = æ[x(i + ) æx ç][x(i) æx ç] ç ~ (6)

e cross-correlation function can be written as

$C_x$ ( ) = æ[x(i + ) æx ç][y(i) æy ç] ç ~ $_x$ (7)

where and $_x$ 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 = 2 - 2h (q = 2) [29]. Recently, Podobnik et al., have demonstrated the relation between cross-correlation exponent, $_x$ and scaling exponent (q) derived from $_x$ = 2 - 2 (q = 2) [28]. For uncorrelated data, $_x$ has a value 1 and the lower the value of and $_x$ more correlated is the data.

In other words, we want to have a quantitative estimate of how the di erent lobes of the brain are correlated when a performer is mentally creating the imagery as well as during the perception of the same raga

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. at 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. e 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 a er 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 signi cant, the fall a er removal of stimuli is also signi cant, indicating that in the absence of any creative task diminishes the cross correlation between di erent 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 rst time from our new data. us, with this we have tried to obtain a quantitative de nition of creativity, which till now was considered more of a philosophical term rather than a scienti c one. e increase or decrease of the degree of cross-correlation between the di erent lobes of brain during a variety of cognitive tasks can now be related to creativity involved in each of the tasks. e 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 di erent *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: