Neuro-Cognitive Nonlinear Study for Categorization & Quantification of Effect of Colors & Ragas on Human Brain

Chandrima Roy[1]*, Souparno Roy[2], Kumardeb Banerjee[3], Dipak Ghosh[4]

[1]Assistant Professor, Electronics & Communication Engineering, Heritage Institute of Technology

[2]Sir C. V. Raman Centre for Physics & Music, Jadavpur University, Kolkata

[3]Professor, Department of Instrumentation and Electronics Engineering, Jadavpur University, Kolkata

[4]Professor Emeritus, Sir C. V. Raman Centre for Physics & Music, Jadavpur University, Kolkata

[1]chandrima.roy@heritageit.edu

Abstract

This work elaborates on a neuro-cognitive research on brain responses to various color stimuli. Red, Green, Blue: three primary colors utilizing the signals of electro-encephalograms and nonlinear multifractal approaches to establish the magnitude of complexity using a quantitative parameter. Color stimuli were imposed to subjects and the EEG readings from the corresponding lobes were taken note of and analyzed. Along with this, two ragas namely Chhayanat and Darbari, were used to study the effect on human brain using exactly the same methodology adopted in case of the colors. Along with this we also explored to correlate whether colors are also associated with Ragas of Indian Classical Music. The experiment reveals new data of extreme interest in color-raga-emotion scenario.

***Keywords**: Raga and Color, Nonlinear study, EEG, MFDFA*

1. INTRODUCTION

The association between the brain, emotion, color, and music has been desperately sought by researchers worldwide. Although the subject is still in its infancy, few literatures, described in the book, illustrate the kind of research that has been done so far with apparently different purposes but deep down in coherence, they all link to the extended spectrum of the subject. [1] Explored cerebral plasticity. Auditory-cognitive training strategies are either ineffective or unproven. Our inadequate understanding of how interventions improve cognitive and perceptual abilities and how various activities and experience positively modify brain systems underlies such abilities limits the benefits of such regimens. Music training improves auditory function biologically and long-term [2] researchers did a great job.

Researchers from all over the world have been trying hard to find out what links the human brain, emotions, colors, and music. Even though the subject is still young, the text mentions a few literatures that show the kinds of research that have been done so far. These researches have had different goals, but they all fit into the larger scope of the subject. In [1], an attempt was made to understand how big and wide brain plasticity is. Training programs that aim to help or improve auditory-cognitive skills have had mixed results or have yet to be fully validated. The limited benefits of these kinds of routines are mostly due to the fact that we don't know enough about how interventions improve cognitive and perceptual abilities in the most stable and long-lasting ways, and how the neural mechanisms that support these kinds of abilities can be positively changed by certain activities and experience. Recent studies show that learning to play music has strong, long-lasting biological benefits for hearing. The researchers in [2] have done a great job of testing how different emotional stimuli affect the two sides of the brain in the band range of gamma (30–90 Hz). The subjects were exposed to slides with content of different emotions. The frontal electrodes were used to record how the right and left sides of the brain responded when their emotions were stirred up, and the responses were compared. The wide spread of specific gamma band range activities could potentially indicate assemblies of cells with members in frontal, temporal and limbic neocortical structures that are spread out in different ways specific to the form of processing of

*Corresponding Author

emotion. [3] shows a multimodal data set for analyzing how people feel. The electro-encephalogram (EEG) and a number of other bodily indicators were documented from 32 individuals while they were exposed to 40 one-minute music video clips. The participants rated each video based on its level of valence, arousal, likeability, familiarity and dominance. A frontal facial video was also captured for 22 out of the 32 participants. Another thorough search in [4] shows that different versions of the MFDFA technique are used to look into different time series. It was inferred from the analysis that the singularity spectra obtained was extremely order sensitive with respect to the MFDFA detrending polynomial method. There is a clear link between the multifractal spectral width and the polynomial order of the one used to calculate it. Also, this relationship-type is dependent on the analyzed signal type. Such an analysis can tell us more about how the time series being studied are related to each other. In reference [5], the EEG was done on 10 people with a standard acoustic stimulus, a tanpura drone. Multifractal Detrended Fluctuation Analysis (MFDFA) was used on the extracted time series data of theta and alpha from the EEG time series to study how their complexity changed over time. It was found that the alpha and theta frequencies get more complicated in all of the frontal electrodes. This is clear from the fact that the width of the multifractal spectrum also grows. This study was done very recent and provides an interesting information about how the alpha and theta brain rhythms are activated by simple acoustic stimuli. This study is important in the sense of using the width of multifractal spectrum as a parameter to measure emotion and in the field of cognitive music therapy.

This paper is based on a neuro-cognitive study of how the brain reacts to different color stimuli. Red, Green, and Blue are the three primary colors. Using the signals from electroencephalograms and the multi-fractal method, you can measure the level of complexity with the help of quantitative parameters. We chose two subjects—one is a musician and the other is not—and gave them color stimuli. EEG signals from different lobes were recorded and analyzed using MFDFA. The significant observations were summed up and examined in the results and discussion section.
An attempt was made to see if colors and ragas make the same kind of emotional response. To do this, two ragas called Chhayanat and Darbari, which are usually associated with very different emotions, were used to study the effect on the human brain, using the same method as was used for the colors. The primary data is encouraging for validating our method. Both colors and music can be labeled by how they make you feel based on how much they change. Since we've taken EEG data from eight electrodes, we need to do a thorough analysis that includes multifractal cross-correlation with more data. But this approach and these data are new, and they can be seen as a step toward understanding a very complicated thing about how people understand emotions in the context of music and colors.

2. EXPERIMENTAL DETAILS

The work was divided initially in two interest regiments to correlate the relational interface between color and music stimuli. Three primary colors: Red, Blue and Green were exposed for a defined time period with an interval expose of grey color and their EEG was recorded during that time period. In the next half, music clips of Chhayanat and Darbari were played as audio stimuli to seven subjects (including the two, chosen for color test) with a defined protocol.

The color stimuli were three fundamental colors viz. red, Blue and Green. They were displayed for duration of 10 second to both the subjects with an interspacing of grey color of duration around 1 minute. The audio stimuli had seven counterparts. Initially the subject was exposed to no music phase for a defined interval. The next phase had a sound of drone from a tanpura which was noise free. The first music clip, Chhayanat, was played in the third segment. Fourth half was a sound of a drone again which was immediately followed by the other raga, Darbari, the raga of wide apart emotional arousal from Chhayanat. The sixth and seventh sessions were both no music parts of the predefined duration.

The collected EEG data was analysed with a tried-and-tested method by the name of MFDFA, with its establishment over chaos and fractals. Nature is essentially example of most of the complex phenomena, nonlinear in character - recent research has advocated the nonlinearity of manmade complex systems like music. EEG time series has been exhaustibly studied confirming the nonlinearity of brain functions. In view of above, we have opted the most vigorous approach proposed so far to analyse EEG time signal with music as well as color stimuli. The multifractal range reveals the digressions in the fractal configuration during time spans with significant and minor changes. Multifractals are inherently more intricate and depict time sequences characterized by exceedingly erratic dynamics, dotted with abrupt and strong surges of high-frequency variations [6]. The MFDFA methodology is in wide use across various sectors of work, from the stock market to disease prognosis in biomedical fields [7] [8].

3. RESULTS AND DISCUSSION

The EEG of the subjects in phase of color testing underwent certain analysis from which the MFDFA was performed to obtain the spectral widths and the plot of the complexities with reference to all eight chosen electrodes are as follows. The complexity for the musician as shown in the table and the following plots:

TABLE 1. THE MULTIFRACTAL SPECTRAL WIDTH FOR THE MUSICIAN FOR THREE PRIMARY COLORS IN ALL SELECTED ELECTRODES

Colors	P4	P3	O2	O1	F3	F4	F7	F8
Blue	-0.13402	0.245628	0.366371	0.404592	0.105536	0.168968	0.15388	0.165438
Green	-0.54546	-0.41928	-0.37856	-0.35794	-0.33949	-0.52549	-0.4619	-0.49935
Red	0.210326	-0.16914	0.043432	0.217274	0.054287	0.064133	-0.01061	0.007512

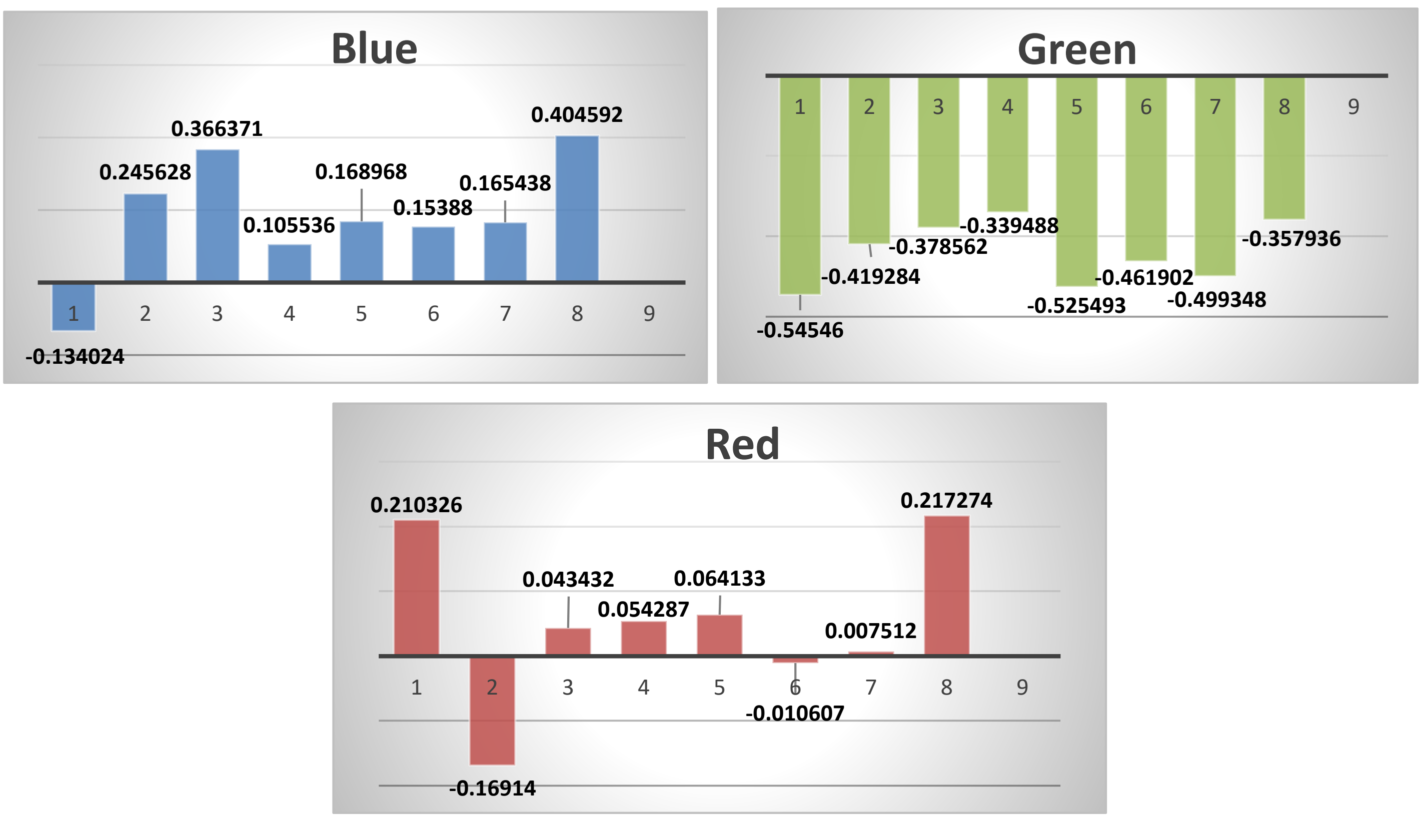

Figure 1. Variation of complexity for the musician in the selected electrodes (P4, P3, O2, O1, F3, F4, F7, F8) for the three primary colors

The same process was carried out to determine the complexity for the non-musician to obtain a comparable analysis of the results. The results are as follows:

Table 2. THE MULTIFRACTAL SPECTRAL WIDTH FOR THE NON-MUSICIAN FOR THREE PRIMARY COLORS IN ALL ELECTRODES.

Colors	P4	P3	O2	O1	F3	F4	F7	F8
Blue	-0.2889	-0.20126	-0.25267	-0.16572	-0.17568	-0.36631	-0.36615	-0.24935
Green	0.053849	-0.11921	-0.06182	0.15716	-0.10225	-0.10322	0.153174	-0.36035
Red	-0.25274	-0.31025	-0.14993	-0.05607	-0.15859	-0.01871	-0.15599	-0.20568

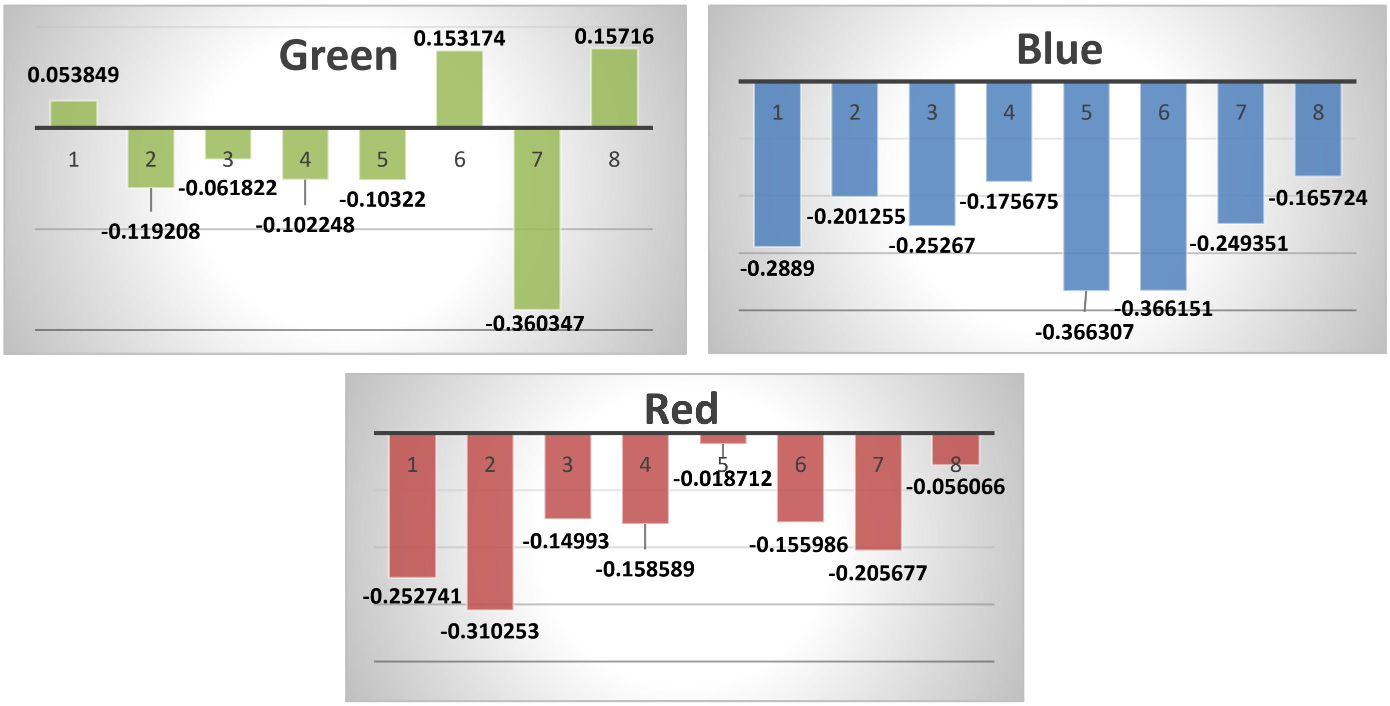

Figure 2. Variation of complexity for the non-musician in the selected electrodes (P4, P3, O2, O1,F3, F4, F7, F8)for the three primary colors

It was found that in case of the music practitioner, the degree of complexity in all the measured electrodes (O1, O2, P3, P4, F3, F4, F7, F8) is significantly low when he is exposed to GREEN color (HEX - #00FF00; R:0, G:255, B:0). In case of BLUE color (HEX - #0000FF; R: 0, G: 0, B: 255), only P4 electrode shows a little increase in complexity. For rest of the electrodes, the complexity is lower, though in a small amount. In P4, O2, O1, F3, F4, F8 electrodes, complexity increases in RED (HEX - #FF0000; R: 255, G: 0, B: 0) and decreases in P3 and F7 electrodes. Again, analysis of the non-musician subject shows a different trend. Here, the degree of complexity is significantly and consistently lower in all the electrodes in case of the blue color. Also exposed condition to Red color gives lower multi-fractal detrended fluctuation analysis values, whereas complexity is increased in P4, F7, O1 electrodes in cases of Green color and in the rest, it has lower and insignificant values.

In the experimental part for the music stimuli, the clips of Chhayanat and Darbari were played to seven different subjects preceded by a sound of drone in each case and process started and ended with no music session of predefined time frame. The nonlinear analysis using MFDFA was carried out on the emotional arousal in form of the EEG signal and the difference of the complexities with respect to the sound of the drone was calculated in each of the cases. The variations of the complexities in all selected electrodes for the seven subjects are shown below. The first table shows the difference in complexity in response to the clip of raga Chhayanat. And the next table depicts the same in reference to the clip of raga Darbari.

The averages of the spectral widths have been taken for each subject with regard to all the selected electrodes to infer further analysis in both the ragas and it is observed that both the ragas deliver positive as well as negative complexity values. The averages of the positive values as well as for the negative values are taken from the set of seven subjects. The results are as follows:

Table 3. DIFFERENCE OF COMPLEXITY IN SELECTED ELECTRODES FOR THE SUBJECTS IN RAGA CHHAYANAT

SUB	F3	F4	F7	F8	P3	P4	O1	O2
1	-0.11764	-0.19538	-0.02223	0.15545	0.040561	-0.01333	-0.08136	-0.0072
2	-0.11175	0.101016	-0.19497	-0.20265	0.058769	0.137888	-0.0483	0.099194
3	0.194118	0.034918	-0.0453	0.086613	0.236766	0.071304	0.036994	-0.09334
4	-0.00678	0.136008	-0.081	-0.18376	0.0066	0.441762	0.11616	-0.06371
5	-0.04007	0.115661	0.008872	0.041104	-0.09569	0.025076	-0.02448	0.186924
6	0.059554	0.052182	0.002922	-0.17516	-0.1578	0.002072	-0.04962	0.113642
7	-0.13292	0.037893	-0.05742	0.032044	-0.11842	-0.13719	-0.06003	-0.06761

Table 4. DIFFERENCE OF COMPLEXITY IN SELECTED ELECTRODES FOR THE SUBJECTS IN RAGA DARBARI

SUB	F3	F4	F7	F8	P3	P4	O1	O2
1	0.479994	-0.19221	-0.28564	0.081365	-0.01054	-0.09752	0.120307	0.013958
2	-0.16393	-0.00486	0.269524	-0.07948	-0.12779	-0.22387	-0.27031	-0.10561
3	0.01001	-0.19775	0.222891	-0.17127	0.070001	-0.05383	0.043424	0.133982
4	0.074835	-0.01327	0.046016	0.076165	-0.39446	-0.09155	-0.04842	-0.10371
5	0.008356	-0.20297	-0.19529	0.009554	-0.0091	-0.08467	-0.11218	-0.10117
6	-0.0328	0.107941	0.059712	0.219487	0.106503	-0.00941	0.282324	-0.11697
7	0.089985	0.139561	-0.23759	-0.22365	0.028115	-0.0126	0.287209	-0.01121

Table 5.

Choice of ragas	Positive average	Negative average
Chhayanat	0.046032	-0.03306
Darbari	0.026368	-0.07701

The beneath figures show the electrode wise variation of complexity in the seven subjects in case of raga Darbari and Chhayanat.

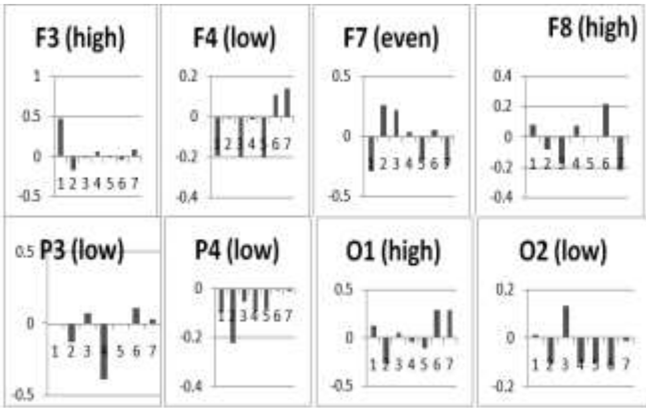

Figure 3. Electrode wise variation for Chhayanat

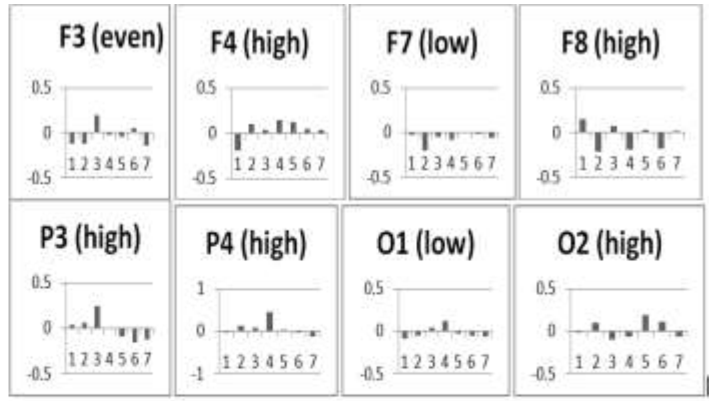

Figure 4. Electrode wise variation for Darbari

The average of the multifractal width of all the electrodes corresponding to the chosen three primary colors for both the subjects have been obtained and given in Table 5. The similar procedure was executed for achieving the same for the seven subjects of all electrodes with the audio stimuli of raga Chhayanat and Darbari and it yields to a set of averages incorporating both positive and negative values. Out of them, a mean was taken for the set of all positive values and the same for the negative values as well. These values are given in Table 6.

Table 6.

Subject	Red	Green	Blue
Musician	0.06953	-0.5879	-0.2460
Non musician	-0.2178	-0.0638	-0.3440

4. CONCLUSION

The table 1 and 2 show that the multifractal width of the two subjects in all selected electrodes for three primary colors. Table 3 and 4 depict the variation of complexity for the different ragas in the electrodes for the chosen subjects. It is highly interesting to observe that –the change of degree of complexity in different lobes is different for both color and music stimuli.

Finally, this experiment manifests that:

(1) Non-linear MFDFA technique applied to EEG signal can indeed quantify effects of color on human brain and of course the effect of music.

(2) The effect of color is more pronounced than that of music.

This pilot study can initiate similar studies with more specified color and music samples of different known emotions. The result of this experiment will find application in many important domains like music therapy and/or color therapy and of course in neuro-marketing, where exhaustive research is imminent. Further, this pilot study is useful to extract more info about the dynamics of cross-modal participation of the brain.

ACKNOWLEDGEMENT

We are sincerely thankful to Ranjan Sengupta for his kind cooperation and guidance during the execution period of this work.

REFERENCES

- Journal articles

[1] Moreno, S., & Bidelman, G. M. (2014). Examining neural plasticity and cognitive benefit through the unique lens of musical training. *Hearing research*,*308*, 84-97.

[2] Müller, Matthias M., et al. "Processing of affective pictures modulates right-hemispheric gamma band EEG activity." *Clinical Neurophysiology* 110.11 (1999): 1913-1920.

[3] Koelstra, Sander, et al. "Deap: A database for emotion analysis; using physiological signals." *Affective Computing, IEEE Transactions on* 3.1 (2012): 18-31.

[4] Oświęcimka, Paweł, et al. "Effect of detrending on multifractal characteristics."*arXiv preprint arXiv:1212.0354* (2012).

[5] Maity, Akash Kumar, et al. "Multifractal Detrended Fluctuation Analysis of alpha and theta EEG rhythms with musical stimuli." *Chaos, Solitons & Fractals*81 (2015): 52-67.

[6] Ihlen EAF. Introduction to Multifractal Detrended Fluctuation Analysis in Matlab. *Frontiers in Physiology*. 2012;3:141. doi:10.3389/fphys.2012.00141.

[7] Shang, P., Lu, Y., & Kamae, S. (2008). Detecting long-range correlations of traffic time series with multifractal detrended fluctuation analysis. *Chaos, Solitons & Fractals*, *36*(1), 82-90.

[8] Lan, Tong-Han, et al. "Detrended fluctuation analysis as a statistical method to study ion single channel signal." *Cell biology international* 32.2 (2008): 247-252.