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Analysis of Heart Rate Variability during Meditative and Non-Meditative State using Analysis Of variance

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ABSTRACT

In this paper the main objective is to quantify and compare the instantaneous value of heart rate for normal breathing patterns during Meditation and Non Meditation conditions. This paper involves Analysis of Variance (ANOVA) technique for the analysis of the heart rate variability patterns during the meditative and non meditative states. The analysis is divided into three stages i.e. data acquisition, parameter estimation and comparison. The ECG signals are used as the input signals in given states. The features are then compared using ANOVA technique for HRV patterns. The HRV parameters were found to be better during meditation.

Key words: Heart Rate Variability (HRV), ECG , Meditation, ANOVA

INTRODUCTION

Meditation appeared more than five thousand years ago. Meditation is widely perceived as an effective method of reducing stress and enhancing wellbeing [1]. It was developed and practiced continuously. Up until now there are many types of meditation techniques that are available for practical uses for any people regardless of their religions [3]. Although there remains uncertainty about the difference and similarities between the effects of different form of meditation: mindfulness meditation and concentration meditation. Concentration meditation technique is used almost universally in religious and spiritual practices. The one who meditates focuses his or her attention on an internal or external object or idea for a long period of time. While minimizing distractions and bring the wondering mind back to attention on the chosen object. Psychological and chemical responses to meditation have all been observed and these provide useful division for discussion [2]. Meditation has been shown to have favourable effects on heart and blood vessel (cardiovascular function). One of the measures of heart health is HRV. HRV is defined in terms of how different the lengths of time between each heart beat are [4]. Relatively large number of research works has been carried out to study the potential benefits of meditation and non meditation technique. It is controlled by autonomic nervous system which also controls many other vital functions [1, 8]. The greater the difference in times between heart beats, the healthier is the heart thought to be. HRV

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signal derived from ECG signals are strongly related to the activity of autonomic nervous system. The HRV is an indication of the dynamic interaction and balance between the sympathetic and parasympathetic system. The sympathetic system is responsible for raising our heart rate, increasing blood pressure and dumping glucose into blood to fuel activity. In contrast, parasympathetic nervous system works in opposition-decrease of heart rate and storage of nutrients, effectively slowing everything back down. HRV analysis is mainly divided into time domain and frequency domain analysis measures. The RR interval variations presented during resting conditions represents a fine tuning of beat-to-beat control mechanisms. Because it helps to evaluate the equilibrium between the sympathetic and parasympathetic influences on heart rhythm, HRV signals analysis is very important and crucial for the study of the Autonomic Nervous System (ANS). The nervous system's sympathetic branch increases the heart rhythm resulting in shorter beat intervals whereas the parasympathetic branch decelerates the heart rhythm leading to longer beat intervals. Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups), in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. Doing multiple two-sample t-tests would result in an increased chance of committing a type I error. For this reason, ANOVAs are useful in comparing (testing) three, or more means (groups or variables) for statistical significance. In this paper, the heart rate variability signal using wavelet technique taken from subjects practising different forms of normal have been compared to find the underlying similarities among the and how they different from the yoga condition. The data have been obtained from the physionet side.

HEART RATE VARIABILITY, MEDITATION

Heart rate variability (HRV), the variation over time of the period between consecutive heartbeats, is predominantly dependent on the extrinsic regulation of the heart rate (HR). HRV is thought to reflect the heart's ability to adapt to changing circumstances by detecting and quickly responding to unpredictable stimuli. HRV analysis is the ability to assess overall cardiac health and the state of the autonomic nervous system (ANS) responsible for regulating cardiac activity. HRV is a useful signal for understanding the status of the ANS. HRV refers to the variations in the beat intervals or correspondingly in the instantaneous HR. The normal variability in HR is due to autonomic neural regulation of the heart and the circulatory system [9]. The balancing action of the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) branches of the ANS controls the HR. Increased SNS or diminished PNS activity results in cardio-acceleration. Conversely, a low SNS activity or a high PNS activity causes cardio-deceleration. The degree of variability in the HR provides information about the functioning of the nervous control on the HR and the heart's ability to respond. The best way of relaxation is meditation in which we energetically make the mind silent and control the flow of thoughts. The mind will be still during mediation which brings the clarity and inner peace. Kundalinis, a branch of Yoga provide the preliminary study on various types of meditation. Sahaja Yoga meditation gives the study on cooling of person's hand and relaxation during breathing who does meditation. A major drop in skin temperature by doing a Sahaja Yoga meditation is noted by the researchers. According to them, all other meditation increases the skin temperature except Sahaja Yoga meditation.

ANALYSIS OF VARIANCE

Analysis of variance is the statistical analysis tool for comparing more than two groups .it assigns sample variance to different subjects and decides whether the variation within or among different population

groups. This sample variance may be consider as the signal and the noise. The signal is seen as difference among group means. The noise is seen as variation within the groups, differences among group means can be compared. The main idea of ANOVA is summarize the variability among all the observation and partition it into separate sources. The summary is sum of squares total

$$SS_{total} = \sum X^2 - \frac{(\sum X)^2}{N}$$

Where, the summation is over all, N is the observation and X is the ground sample average.
This sum of squares total is partitioned into two separate, and additive, pieces. These are a sum of squares among, SS_{Among} and a sum of squares within, SS_{Within}. The SS_{Within} accumulates variability from within each group.

$$SS_{Within} = \sum (n_i - i) s_i^2$$

Where, s^2i is the sample variance of the i_{th} group and n_i is the number of observations in the i_{th} group.

The sum of squares among, SS_{Among} measures variability due to differences among the group means.

$$SS_{Among} = n_i \overline{(Yi} - \overline{\overline{Y)}}^2$$

Note that

$$SS_{Among} + SS_{Within} = SS_{Total}$$

Associated with each sum of squares is degree of freedom. In general, one starts With N degrees of freedom and loses one degree of freedom for every sample mean calculated. For the SS_{total}, there is one grand sample average; therefore there are N–1 degrees of freedom. There are n_i-1 degrees of freedom within each group. Therefore, there are $\sum(n_i–1)=N–k$ degrees of freedom for SS_{within} .that leaves k–1 degree of freedom for SS_{Among}.. A sum of squares divided by its associated degrees of freedom produces a mean square. The sum of squares, degrees of freedom, and mean squares are all summarized in an analysis of variance (ANOVA) table.

A. *Mean of square*

Mean squares are estimates of variance across groups. Mean squares are used in analysis of variance and are calculated as a sum of squares divided by its appropriate degrees of freedom. Let *N* equal the total number of samples in a survey, and *K* the number of groups, then the:

$$MS = \frac{SS_{total}}{N-1}$$

B. *Degree of freedom*

The number of independent ways by which a dynamical system can move without violating any constraint imposed on it, is called degree of freedom. In other words, the degree of freedom can be defined as the minimum number of independent coordinates which can specify the position of the system completely.

ANOVA performs a balanced two-way ANOVA for comparing the means of two or more columns and two or more rows of the observations in X.

ANOVA also displays a figure showing the standard ANOVA table, which divides the variability of the data in X into three or four parts depending on the value of reps:

- The variability due to the differences among the column means
- The variability due to the differences among the row means
- The variability due to the interaction between rows and columns (if reps is greater than its default value of one)
- The remaining variability not explained by any systematic source

C. *The ANOVA table has five columns:*

- The first shows the source of the variability.
- The second shows the Sum of Squares (SS) due to each source.
- The third shows the degrees of freedom (df) associated with each source.
- The fourth shows the Mean Squares (MS), which is the ratio SS/df.
- The fifth shows the *F* statistics, which is the ratio of the mean squares.
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METHODOLOGY

In this paper, our method consists of three major stages: data acquisition, parameter estimation and comparison. Details are elaborated below. In this paper, the method used is analysis of variance (ANOVA).

A. *Data acquisition*

During meditation practice, the subjects sat in a cross-legged position and kept their eyes closed as they were accustomed to doing during their meditation practices. Subjects were first instructed to sit quietly for 5 minutes. Pre-meditation measures were taken during this time. After that, they were instructed to perform meditation for at least 15 minutes. Yoga mediators, 2 women and 2 men (age range 20-52, mean 33 yrs), wore a Holter monitor for approximately one and half hours. 15 minutes of baseline quiet breathing were recorded before the 1 hour of meditation. The meditation protocol consisted of a sequence of breathing and chanting exercises, performed while seated in a cross-legged position. The beginning and ending of the various meditation sub-phases were delineated with event marks. In addition to comparing the pre-meditation and meditation states, we also doing comparisons non-meditating control groups from a database of retrospective electrocardiogram (ECG) signals: A spontaneously breathing group of 11 healthy subjects (8 women and 3 men; age range 20-35, mean 29) during sleeping hours [5]. In the case that the Samadhi state was achieved, the intervals during which each subject reported that he/she concentrated on meditation (other thoughts did not occur) were labelled as the segments of the Samadhi state.

B. *Parameter estimation*

The features which are obtained from analysis of variance (ANOVA) are as follows:

1. SS = Sum of Squares

2. DF = Degree of Freedom
3. MS = Mean of Squares
4. f= Frequency
5. Probability

C. *Comparative study*

The HRV signal for the meditation and non meditation condition are initially analysed by analysis of variance using this technique. The features which are described above are calculated. The comparison is also shown in the table [1, 2, 3, 4, 5] for meditation and non meditation condition.

N=Normal Subjects (Non meditation)
Y=Yoga Subjects (Meditation)

RESULTS AND DISCUSSIONS

The different features of the ANOVA technique for the Heart Rate Variability are shown in table. From the tables, it can be observed that the features for Meditation are better than the Non-meditation subject. From table 1(b) it can be seen that the value of various sources sum of squares are highly reduce as compared to the corresponding values for subject N1 shown in 1(a). The same pattern has been observed for subject 2, 3 & 4 in their normal and yoga state as shown in the table 2, 3 & 4. For instance the value of degree of freedom for subject 3 in normal state has been observed to be 17007 However, in meditation (yoga) state the value has been greatly reduced to 909 as shown in table 3(b). Similarly, the value of Mean of Square is going to reduced for subject 2 in normal and yoga state as shown in table 2(a) and 2 (b). This will happen for other cases also shown by table 1, 3 and 4. The value of frequency also reduced for each subject as shown by Table 1, 2, 3 and, 4.

TABLE: 1 (a) Subject N1

Source	SS	DF	MS	f	Prob>f
Column	$9.90*10^{13}$	1	$9.90*10^{13}$	-42211.9	1
Row	$8.39*10^{11}$	21321	$3.9*10^{7}$	-0.02	1
Inter.	$8.39*10^{11}$	21321	$3.9*10^{7}$	-0.02	1
Error	$-1.0*10^{13}$	42644	$-2.3*10^{7}$		
Total	$6.64*10^{11}$	42643			

TABLE: 1 (b) Subject Y1

Source	SS	DF	MS	f	Prob>f
Column	$2.34*10^{9}$	1	$2.34*10^{9}$	-1772.41	1
Row	$3.50*10^{7}$	1021	34255.4	-0.03	1
Inter.	$3.19*10^{7}$	1021	31218.9	-0.02	1
Error	$-2.70*10^{9}$	2044	$-1.32*10^{7}$		
Total	$-2.92*10^{8}$	2043			

TABLE: 2 (a) Subject N2

Source	SS	DF	MS	f	Prob>f
Column	$7.29*10^{13}$	1	$7.29*10^{13}$	-42693.6	1
Row	$8.36*10^{11}$	21636	$3.86*10^{7}$	-0.02	1
Inter.	$8.38*10^{11}$	21636	$3.87*10^{7}$	-0.02	1
Error	$-7.38*10^{13}$	43274	$-1.70*10^{9}$		
Total	$6.84*10^{11}$	43273			

TABLE: 2 (b) Subject Y2

Source	SS	DF	MS	f	Prob>f
Column	$3.58*10^{9}$	1	$3.58*10^{9}$	-1993.95	1
Row	$4.49*10^{7}$	1126	39867.8	-0.02	1
Inter.	$4.29*10^{7}$	1126	38068.8	-0.02	1
Error	$-4.05*10^{9}$	2254	$-1.79*10^{7}$		
Total	$-3.79*10^{8}$	2253			

TABLE: 3 (a) Subject N3

Source	SS	DF	MS	f	Prob>f
Column	$7.40*10^{13}$	1	$7.40*10^{13}$	-33772.5	1
Row	$3.94*10^{11}$	17007	$2.31*10^{7}$	-0.01	1
Inter.	$3.94*10^{11}$	17007	$2.32*10^{7}$	-0.01	1
Error	$-7.46*10^{13}$	34016	$-2.19*10^{9}$		
Total	$2.54*10^{11}$	34015			

TABLE: 3 (b) Subject Y3

Source	SS	DF	MS	f	Prob>f
Column	$5.42*10^{9}$	1	$5.42*10^{9}$	-1692.4	1
Row	$3.48*10^{7}$	909	38302.9	-0.011	1
Inter.	$3.57*10^{7}$	909	39283.3	-0.01	1
Error	$-5.83*10^{9}$	1820	$-3.20*10^{6}$		
Total	$-3.38*10^{8}$	1819			

TABLE: 4 (a) Subject N4

Source	SS	DF	MS	f	Prob>f
Column	$4.17*10^{9}$	1	$4.17*10^{9}$	-1715.99	1
Row	$3.27*10^{7}$	939	34863.5	-0.01	1
Inter.	$3.51*10^{7}$	939	37441.3	-0.02	1
Error	$-4.57*10^{9}$	1880	$-2.43*10^{7}$		
Total	$-3.31*10^{8}$	1879			

TABLE: 4 (b) Subject Y4

Source	SS	DF	MS	f	Prob>f
Column	$4.17*10^{9}$	1	$4.17*10^{9}$	-1715.99	1
Row	$3.27*10^{7}$	939	34863.5	-0.01	1
Inter.	$3.51*10^{7}$	939	37441.3	-0.02	1
Error	$-4.57*10^{9}$	1880	$-2.43*10^{7}$		
Total	$-3.31*10^{8}$	1879			

TABLE: 5 (a) Subject N5

Source	SS	DF	MS	f	Prob>f
Column	$6.40*10^{13}$	1	$6.40*10^{13}$	$-3.33*10^{6}$	1
Row	$6.58*10^{11}$	16858	$3.90*10^{7}$	-0.02	1
Inter.	$6.58*10^{9}$	16858	$3.90*10^{7}$	-0.02	1
Error	$-6.48*10^{13}$	33718	$-1.92*10^{9}$		
Total	$5.58*10^{11}$	33717			

TABLE: 5 (b) Subject N6

Source	SS	DF	MS	f	Prob>f
Column	$6.81*10^{13}$	1	$6.81*10^{13}$	$-4.50*10^{6}$	1
Row	$8.80*10^{11}$	22890	$3.85*10^{7}$	-0.03	1
Inter.	$8.81*10^{11}$	22890	$3.85*10^{7}$	-0.03	1
Error	$-6.92*10^{13}$	45782	$-1.51*10^{9}$		
Total	$7.21*10^{11}$	45781			

TABLE: 5 (c) Subject N7

Source	SS	DF	MS	f	Prob>f
Column	$6.25*10^{13}$	1	$6.25*10^{13}$	-39032.43	1
Row	$8.20*10^{11}$	19811	$4.14*10^{7}$	-0.03	1
Inter.	$8.22*10^{11}$	19811	$4.15*10^{7}$	-0.03	1
Error	$-6.34*10^{13}$	39624	$-1.60*10^{9}$		
Total	$6.95*10^{11}$	39623			

TABLE: 5 (d) Subject N8

Source	SS	DF	MS	f	Prob>f
Column	$1.02*10^{14}$	1	$1.02*10^{14}$	-50353.84	1
Row	$1.00*10^{12}$	25479	$3.92*10^{7}$	-0.02	1
Inter.	$1.00*10^{12}$	25479	$3.93*10^{7}$	-0.02	1
Error	$-1.03*10^{14}$	50960	$-2.03*10^{9}$		
Total	$7.70*10^{11}$	50959			

TABLE: 5 (e) Subject N9

Source	SS	DF	MS	f	Prob>f
Column	$8.32*10^{13}$	1	$8.32*10^{13}$	$-5.4*10^{6}$	1
Row	$1.11*10^{12}$	27373	$4.06*10^{7}$	-0.03	1
Inter.	$1.12*10^{12}$	27373	$4.08*10^{7}$	-0.03	1
Error	$-8.45*10^{13}$	54748	$-1.54*10^{9}$		
Total	$8.81*10^{11}$	54747			

TABLE: 5 (f) Subject N10

Source	SS	DF	MS	f	Prob>f
Column	$1.05*10^{14}$	1	$1.05*10^{14}$	$-5.3*10^{5}$	1
Row	$1.01*10^{12}$	26922	$3.76*10^{7}$	-0.02	1
Inter.	$1.01*10^{12}$	26922	$3.76*10^{7}$	-0.02	1
Error	$-1.06*10^{14}$	53846	$-1.98*10^{9}$		
Total	$7.58*10^{11}$	53845			

TABLE: 5 (g) Subject N11

Source	SS	DF	MS	f	Prob>f
Column	$7.37*10^{13}$	1	$7.37*10^{13}$	-42024.1	1
Row	$8.17*10^{11}$	21287	$3.84*10^{7}$	-0.02	1
Inter.	$8.16*10^{11}$	21287	$3.83*10^{7}$	-0.02	1
Error	$-7.47*10^{13}$	42576	$-1.75*10^{9}$		
Total	$6.66*10^{11}$	42575			

CONCLUSIONS

In ANOVA technique, the features should have lower values for better condition. The study shows that Results of heart rate variability during Meditation subject and Non Meditation subject was remarkably different. The following parameters: Sum of Square (SS), Degree of Freedom (DF), Mean of Square (MS), frequency (f) and probability were found to be remarkably low in case of meditation subject as compared to the one in the non meditative state.

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