

**Development of an ECG signal acquisition system and analysis
of effect of Odia music on the Autonomic Nervous System**

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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By

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Dated: May 10, 2015

CERTIFICATE

This is to certify that the thesis entitled “**Development of an ECG signal acquisition system and analysis of the effect of Odia music on the Autonomic Nervous System**”, submitted by **Mr. Utkarsh Srivastava** in partial fulfilment of the requirements for the degree of **Bachelor of Technology in Biomedical Engineering** embodies the bonafide work done by him in the final year of his B. Tech. degree under the supervision of the undersigned. The thesis or any part of it has not been submitted earlier to any other University/ Institute for the award of any degree or Diploma

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ABSTRACT

The current study delineates the effect of Odia music on the Autonomic Nervous System (ANS) of Odia volunteers. The analysis of the ECG signals using ANOVA showed the features obtained from the HRV domain were statistically insignificant. The results suggested that there is an increase in the parasympathetic activity when music is heard in the mother tongue. It is also expected that there might be a difference in the cardiac conduction pathway.

KEYWORDS:

ECG signal, music, Heart Rate Variability, Autonomic Nervous System, parasympathetic nervous system

Introduction

Studies by different specialists have demonstrated that the passionate/ inclination conditions of an individual may be modified by making to listen to music[1]. The music can likewise help in diminishing the tension of patients in the coronary consideration units. The adjustment in the perspective, as specified above, influences the working of the Autonomic Nervous System (ANS). ANS comprises of parasympathetic and thoughtful sensory system. The Parasympathetic sensory system builds the power of constriction of the hearts muscles because of the arrival of acetylcholine. This thus brings about the reduction in the heart rate. The Sympathetic sensory system, then again, discharges noradrenaline which brings about the increment in the rate of the heart muscle withdrawal. Subsequently, there is an increment in the heart rate. The ANS tries to keep up a parity amongst the thoughtful and parasympathetic framework (sympathovagal balance)[2]. A boost (either inward or outer) may build the parasympathetic or the thoughtful action relying on the way of the jolt. Accordingly, the ANS begins acting to convey both the exercises to an equalization. This outcomes in the variety of the cardiovascular movement. Consequently, the action of the ANS can be investigated by dissecting the ECG signals. The branch of study which permits to comprehend the ANS by examining the ECG signs is known as Heart Rate Variability (HRV).In this current study, we have tried to understand the effects of Odia song on the ANS activity of the volunteers.

LITERATURE SURVEY

Heart Physiology

1) *Heart Beat*

Heart beat is the quantity of heartbeats every unit of time – commonly communicated as beats per minute (bpm) – which can shift as the body's have to ingest oxygen and discharge carbon dioxide changes, for example, amid activity or slumber, The estimation of heart beat is utilized by restorative experts to aid in the determination and following of therapeutic conditions. It is additionally utilized by people, for example, athletes, who are occupied with checking their heart beat to increase greatest effectiveness from their training.

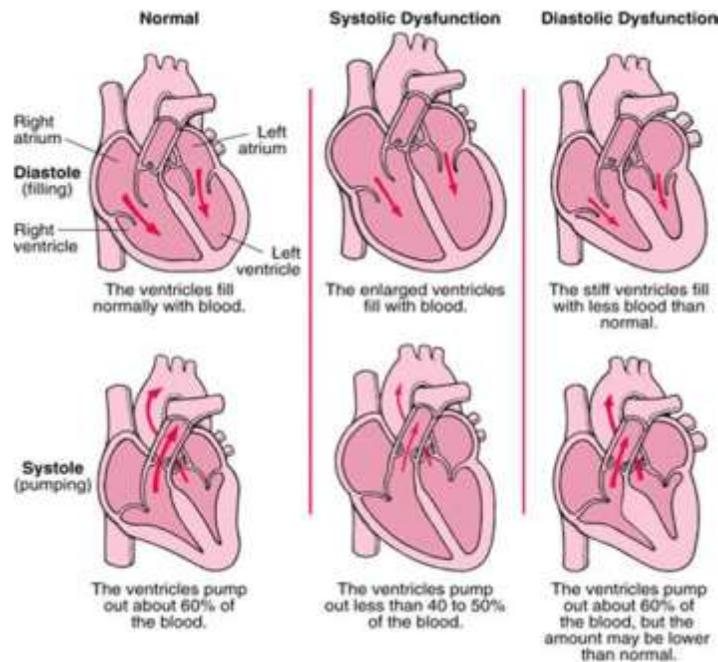


Fig-1 Pumping mechanism of Heart

2) *Basics of Heart Functions*

The heart is the organ in charge of pumping blood all through the body. It is situated amidst the thorax, marginally balance to left side and encompassed by the lungs. The heart is made out of four chambers; two atriums and two ventricles. The right chamber gets blood coming back to the heart from the entire body. That blood goes through the right ventricle and is pumped to the lungs where it is oxygenated and backtracks to the heart through the left

chamber, then the blood goes through the left ventricle and is pumped again to be conveyed to the whole body through the courses.

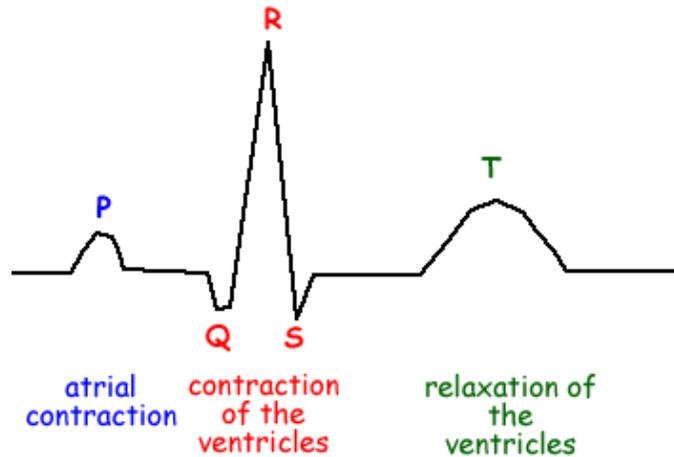


Fig-2 Different cardiac events in a PQRST complex

ECG Circuit Design

1. *Introduction-*

The initial phase of the ECG circuit incorporate instrumentation amplifier it is the most imperative part in the circuit is ought to give high pick up to intensify the weak ECG signal and be capable of resisting the noise (common mode signal) and other signal in electromagnetic spectrum.

2. *Noise-*

Noise from the environment will effortlessly overwhelm the minor pulse signal from the heart. The leads joining the electrode to the amplifier will act like a radio antenna which will incidentally get undesirable emanated signs. Such signals are for instance the 50Hz from electrical cables and emf's from fluorescent lights will include a small sinusoidal wave which is for the most part truly hard to filter away, however in our task we won't concern this sort of noise (50Hz) since our range of signal is from 0.5-5 Hz. Noise and impedance signals procured in this kind of framework are brought about by the electric establishment. The signals from the heart are too weak and it is important to increase the sign and diminish the common-mode voltage on the framework. Different perspectives that produce noise are muscle contractions, breathing, and electromagnetic discharges from electronic parts.

3. *Desired Amplification-*

A high pick up instrumentation amplifier with a large CMRR can be used to get the craved signal. A band pass filter will be actualized to evacuate the noise. An instrumentation amplifier is a kind of differential amplifier that has been furnished with input buffer amplifiers, which kill the requirement for input impedance coordinating and consequently make the amplifier especially suitable for utilization in estimation and test gear. Extra qualities incorporate low DC offset, low drift, low noise, high common-mode rejection ratio, and high input impedances. INA128p is utilized where incredible exactness and solidness of the circuit for both short and long duration are needed.

Instrumentation Amplifier (INA 128)

The signal acquisition is the first consideration when a HRV is actualized. However, the signal is too weak and contains a great deal of included noise. As we said over the signal separated from the heart has magnitude of roughly 0.5mV. Since, it is important to open up the signal and filter the noise, and afterward separate the QRS complex. An instrumentation amplifier is normally the first stage in an instrumentation framework. This is a result of the little voltages generally got from the tests need to be intensified significantly to the continuing stages.

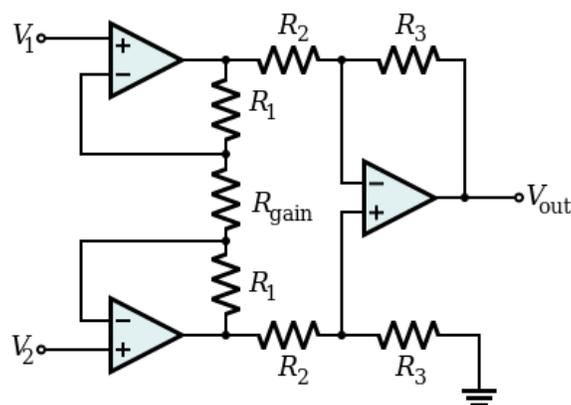


Fig-3 Circuit diagram of an Instrumentation Amplifier

This circuit is built using a buffer differential amplifier stage with three new resistors which are connected to the two buffer circuits together. Consider all resistors to be of equivalent worth with

the exception of R_g . The negative feedback of the upper-left operation amp causes the voltage at point 1 (top of R_g) to be equivalent to V_1 . Similarly, the voltage at point 2 (base of R_g) is held to a quality equivalent to V_2 . This creates a voltage drop crosswise over R_g equivalent to the voltage distinction in the middle of V_1 and V_2 . That voltage drop results in a current through R_g , and hence the feedback circles of the two information operational amplifiers draw no current, that same measure of current through R_g should get passing through the two "R" resistors which are above and below it.

Filtering stage-

The desired band width for ECG signal (0.5 Hz- 30 Hz) for typical heart human so we picked the bandwidth of the circuit close to this extent, now in the event that we pick the bandwidth (0.5-120Hz) notch filter is needed in configuration to expel 50 Hz noise from electrical cable lattice.

Heart Rate Variability

Heart Rate Variability (HRV) is considered a biological process which deals with the variations in the heart rate with respect to time intervals. It is estimated by calculating the fluctuations in heart beating intervals. Arbitrary and chaotic fluctuations in heart rate are an indication of good cardiac health. These variations narrow down with deterioration in physical condition of the individuals up to a point where adaptability to daily stresses is limited. Such conditions push the individuals into the danger of cardiac failure and can prove fatal. Lower Heart Rate Variability measurements indicate presence of disease of any other cardiac problem.

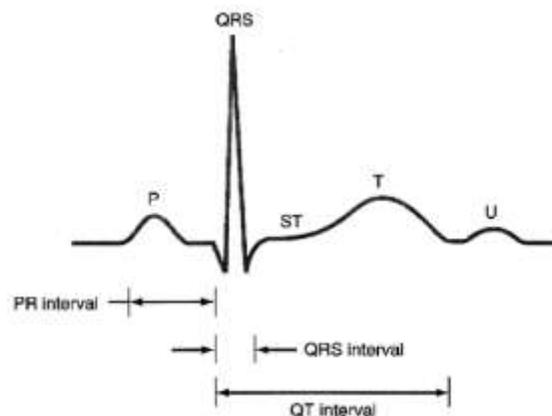


Fig-4 ECG Waveform

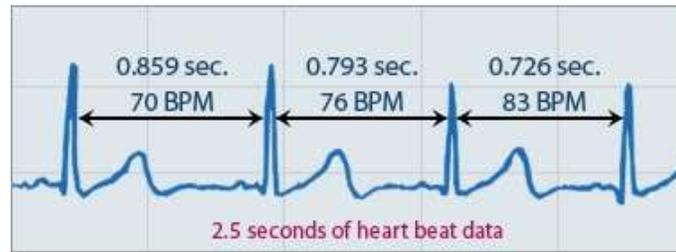


Fig-5 Heart Rate Variability is a measure of the changes in RR interval of the ECG signal

Relation between ANS and HRV

The nervous system can be classified into two parts on basis of their effect on human body, namely:

Somatic Nervous System (SoNS) - It is that part of the peripheral nervous system(PNS) that deals with the voluntary control of the skeletal muscle, in short it is responsible for different body movements.

Autonomic Nervous System (ANS) – It is that component of the PNS which deals with the working of internal organs and physiological processes. It works unconsciously and is responsible for several body functions such as digestion, heart rate, respiration rate, etc.

Many researchers have studied the effect of emotional changes on the working of Autonomic Nervous System (ANS) by studying the variations in Heart Rate Variability (HRV) which serves as the hypothesis for the current study. The ANS is further classified into Parasympathetic Nervous System and its complementary Sympathetic Nervous system. Parasympathetic innervations of the heart are interceded by the vagus nerve which causes an abatement in the SA node thereby diminishing the heart rate though incitement by the sympathetic fibers causes an increment in the heart rate. Accordingly the variability in the heart rate is because of the activity of balance and synergy between the two branches of the Autonomic system, which is fundamentally upheld through neural, mechanical, humoral and other physiological components. It keeps up

cardiovascular parameters in their most great ranges and grants suitable responses to change in outside or inside stimuli. This harmony between the impact of the sympathetic nervous system and the parasympathetic nervous systems is known as the sympathovagal balance and is accepted to be resounded in the beat-to-beat changes of the heart cycle. The heart rate is characterized by the corresponding of the RR interim with units of beats/min.

Interdependence of Cardiac Health and ANS

HRV is an estimation of the general condition of wellbeing of the heart. It is mainly effected by external stimuli that vary the heart rate. HRV is considered to be an indication of heart's ability to adapt to varying environmental and emotional situations quickly and adjusting to maintain the wellbeing of the individual. Many recent studies confirm the presence of a connection between different cardiac conditions like arrhythmias and estimation of HRV (increase in sympathetic activity or decrease in parasympathetic activity). Thus, HRV is a very dominant estimation of cardiac condition of an individual.

Many researchers have proved the fact that on providing stimuli that creates emotional anxiety or mental stress on the individual, the sympathetic activity increased, accompanied by a significant decrease in parasympathetic activity. Thus, bodily functions like heart rate, respiration rate, digestion, immune system associated with parasympathetic activity are affected. The increase in sympathetic activity is associated with the decrease in ventricular fibrillation threshold, resulting in an increased threat of fibrillation, on the other hand an increase in the parasympathetic activity safeguards the heart.

HRV Measurement

The physical value of the HF segment gave a record of vagal action and the size of the LF part gave a list of sympathetic activity with vagal modulation. The LF/HF proportion was utilized as a marker of moment sympathovagal balance.

The appropriation of the low frequency and high frequency power and in addition their central frequencies may not be settled but rather may change with changes in autonomic modulations of the heart. Estimations of Very Low Frequency, Low Frequency and High Frequency power segments is typically measured in outright estimations of power(ms^2), yet LF along with HF might likewise be measured in standardized units (n.u.), which speaks to the relative estimation of every power segment in part to the aggregate power barring the VLF parts.

The representation of Low Frequency and High Frequency in n.u. stresses the adjusted conduct of the two subsections of the ANS. The benefit of the n.u. units is that standardization has a tendency to minimize the impact on the estimations of Low Frequency and High Frequency segments of the variation in total power.

Significance of small period signal acquisition

In the event that systems in charge of heart period modulations of a certain frequency stay unaltered amid the entire time of recording, the comparing frequency parts of HRV may be utilized as a measure of these modulations. In the event that the modulations are not steady, translation of the outcomes of frequency examination is less well characterized.

Specifically, physiological components of heart period modulations in charge of LF and HF power parts can't be viewed as stationary amid the 24 hr period. In this manner, spectral examination performed in the whole 24 hr period and spectral results got from shorter fragments (e.g. 5 min) found the middle value of over the whole 24 hour period provides midpoints of the alterations inferable from Low Frequency and High Frequency segments. Such midpoints dark blur the data about autonomic modulation of RR interims accessible in shorter recordings.

Clinical applications of HRV

Reduction of HRV has been seen in numerous clinical situations, including autonomic neuropathy, heart transplantation, myocardial infarction (MI), congestive heart failure and other cardiac and noncardiac illnesses. Never the less, it is imperative to understand that clinical effect of HRV examination has been systematically perceived in just two clinical conditions:

- It can work as an indicator of chances of arrhythmic occurrence or sudden cardiovascular demise after intense MI.
- It is being used as a marker of developing diabetic neuropathy. Currently, its part in assessment and managing of heart failure has likewise been perceived.

Effect of music on HRV

Various studies have reported that listening to sleep inductive music (i.e. moderate beat, legato expressing, and insignificant element complexities) can prompt diminished heart rate, respiration rate and blood pressure. Significantly, these impacts are conflicting. Various randomized controlled trials have reported that music has anxiolytic and analgesic properties, and is connected with diminished heart rate, respiration rate and blood pressure in perioperative patients.

Many studies divulge the fact that on providing musical treatment, the parasympathetic activity increased accompanied with a decrease in sympathetic activity in old age patients with dementia. These discoveries propose that music treatment is helpful for allaying tension, improving comfort and encouraging relaxation. Music treatment can enhance state of mind states and diminish tension in patients in coronary care units, and have demonstrated that music treatment can help keep up cardiac autonomic balance after intense myocardial infarction. In healthy youths, soothing music can fundamentally decrease heart rate and heart rate variability, which are among the most broadly utilized pointers as a part of investigation of cardiac autonomic modulation.

Materials and Methods

Materials of the ECG circuit

Components used in the designing of circuit are as follows:

- INA128p (Texas Instruments)
- OP07 (Fairchild)
- Ni-MH 9V rechargeable batteries (UNIROS)
- Disposable pre-gelled electrodes (BPL)
- Data acquisition device (USB-4704) was procured from National Instruments, USA.

Designing of ECG amplifier

The design for the ECG amplifier was created using NI-Ultiboard software and NI- Multisim software. The design created in Multisim software is shown below in figure.

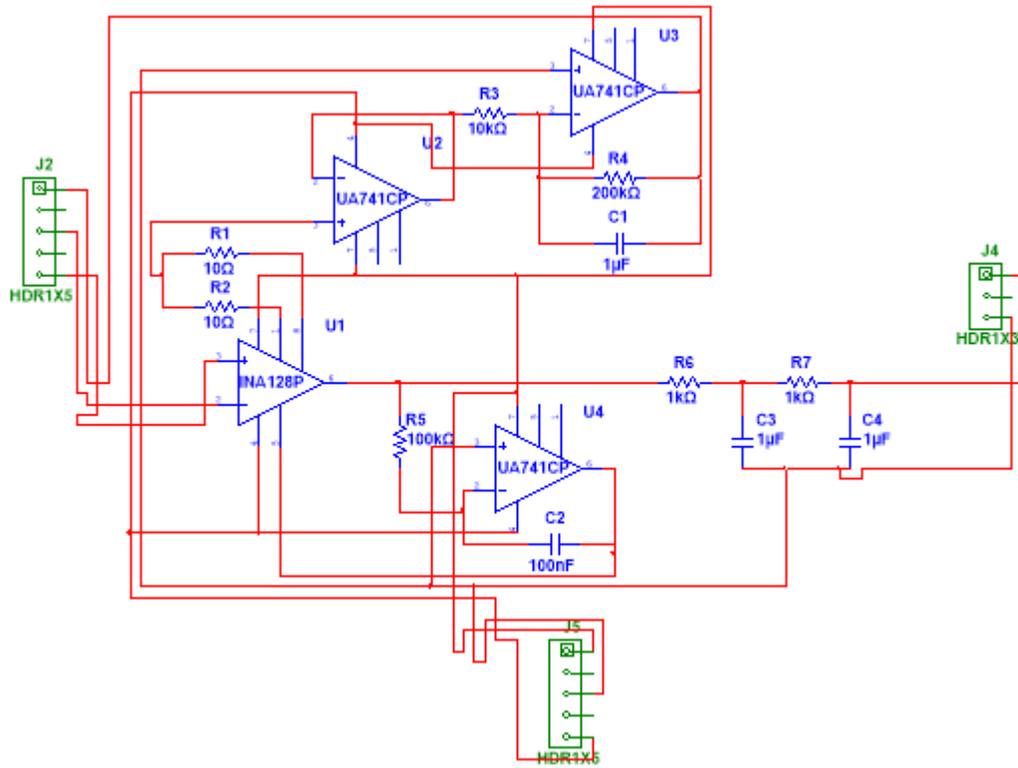


Fig-6 Circuit designed in NI Multisim



Fig-7 Acquisition Setup

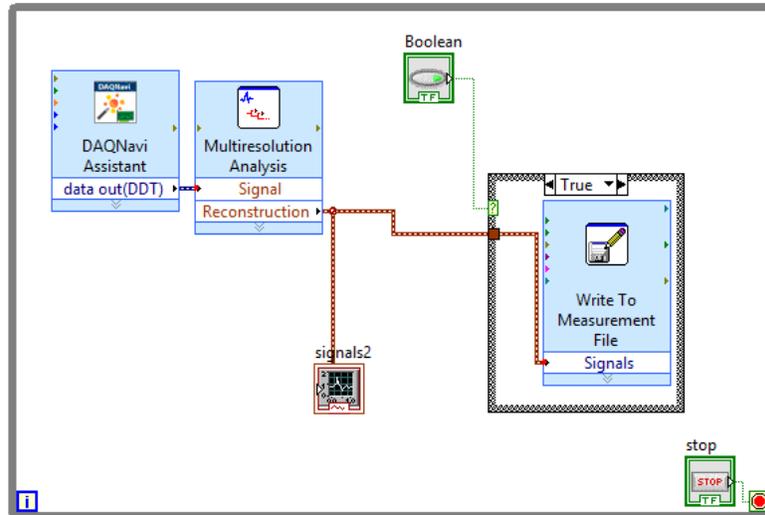


Fig-8 Block Diagram of the ECG acquiring program

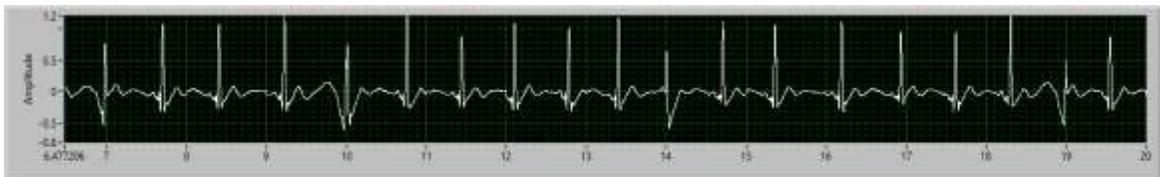


Fig-9 Signal acquired using above setup

Volunteers:

Fifteen male volunteers in the age group of 21.2 ± 2.24 were selected for the study. All the volunteers were Odia speaking. The selection was done such that chosen volunteers neither smoke cigarettes nor were engaged in any athletic/ swimming activities. This was done to ensure that the above-mentioned activities did not stimulate the autonomic nervous system. The ECG signal of the volunteers was acquired one week after mid-semester examination and at least two weeks before the end-semester examination so as to eliminate any anxiousness due to the examination. The volunteers were told verbally about the study in detail. If they agreed to involve in the study, they were asked to sign an ethical clearance consent form

Recording of the ECG signals

The volunteers were asked to sit on a wooden chair in a comfortable position. After they made themselves comfortable, the ECG signals were recorded using the in-house developed ECG signal acquisition system.

The volunteers were made to listen to Odia song and the ECG signals was recorded. The recording of the ECG signal was performed for 7 minutes.

Analysis of the ECG signal

5 minutes of the ECG signal was obtained from the ECG signal and was used for determining the HRV parameters[11]. The HRV parameters were calculated using Biomedical Workbench software (National Instruments, USA). The HRV parameters were observed. The important features were determined using linear (ANOVA) statistical methods.

Results and discussions

Development of ECG amplifier

The general bio-potential amplifier was made utilizing INA128p. INA128p is a low-power driven instrumentation amplifier with improved attributes (e.g. low counterbalance voltage, drift, and high common-mode rejection). The general enhancement of the amplifier was ~ 2500 . The filtering capacity of the amplifier was ~ 740 Hz. The data transmission of the amplifier was kept of high magnitude so that the transfer velocity of every last one of biosignals (ECG, EMG, and EOG) is suited. The band-confinement of the signals was obtained to utilizing a second-order low-pass filtering system. The 3D schematic diagram of the explained amplifier and the relating PCB planned has been indicated. The PCB was made utilizing carbon exchange copper etching method utilizing single-sided copper-cladded board[12].

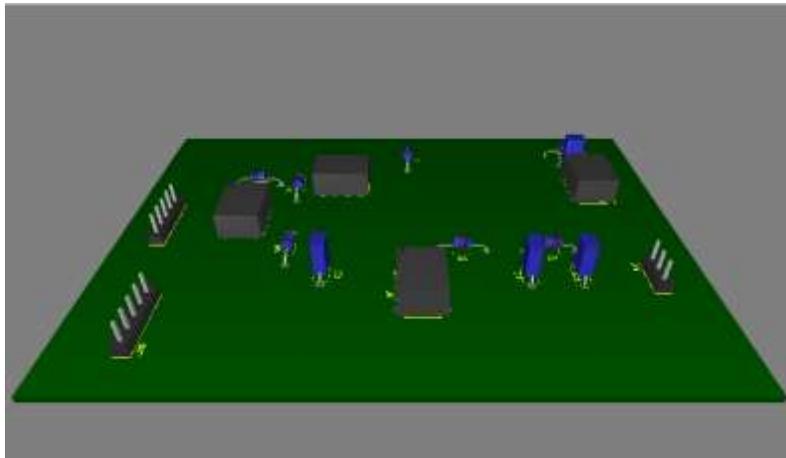


Fig-10 3D layout of the PCB developed in NI Multisim



Fig-11 Developed PCB on the copper cladded board

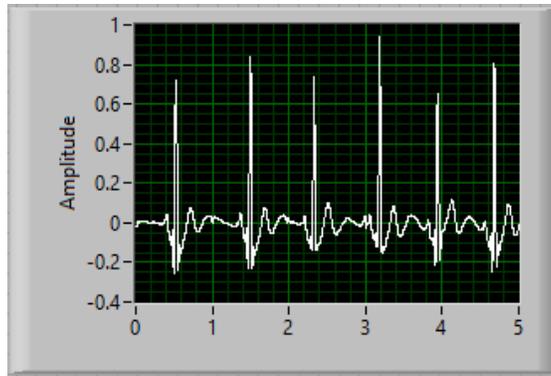


Fig-12 Signal Read using above setup

HRV Analysis

The results of the HRV analysis suggested that there was a decrement in the heart rate during post-stimulus condition. The differences in the heart rate were not significant. This suggested that there was an increment in the parasympathetic activity of the volunteers during the post-stimulus condition. Similar observations have also been made by many researchers. Like the heart rate, the differences of the remaining HRV features were also found to be statistically insignificant.

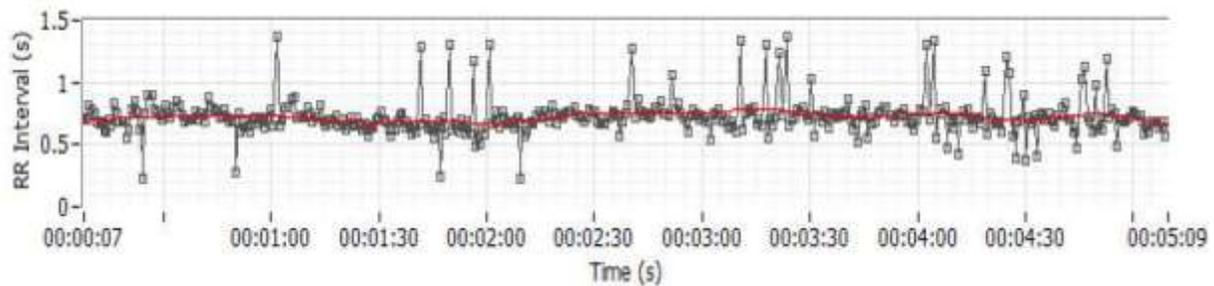


Fig-13 Waveform obtained in the HRV analysis.

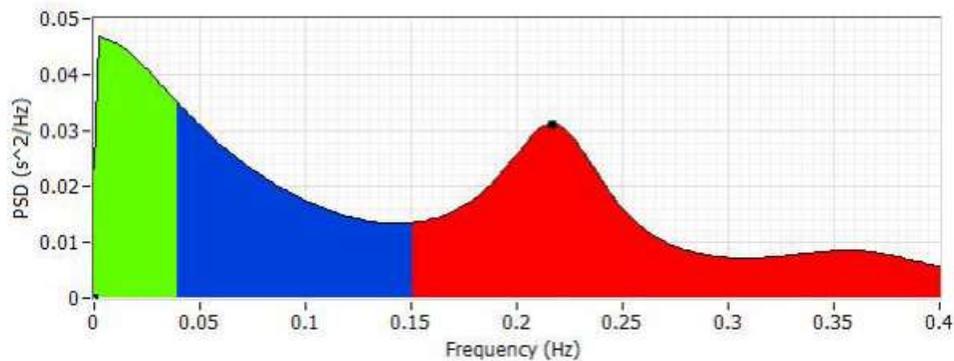


Fig-14 Curve of frequency vs. Power Standard Deviation in AR spectrum

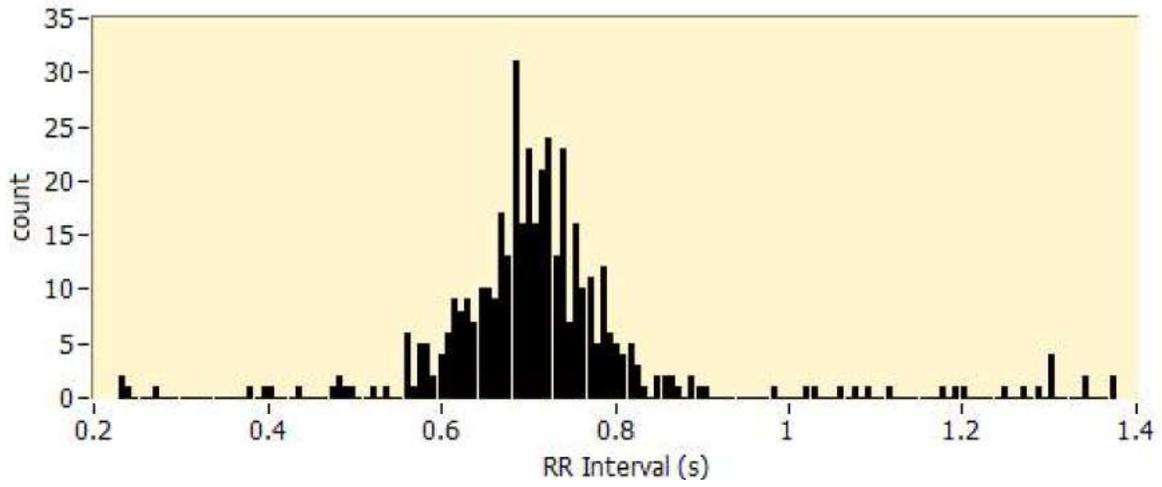


Fig-15 Histogram obtained from the HRV analysis

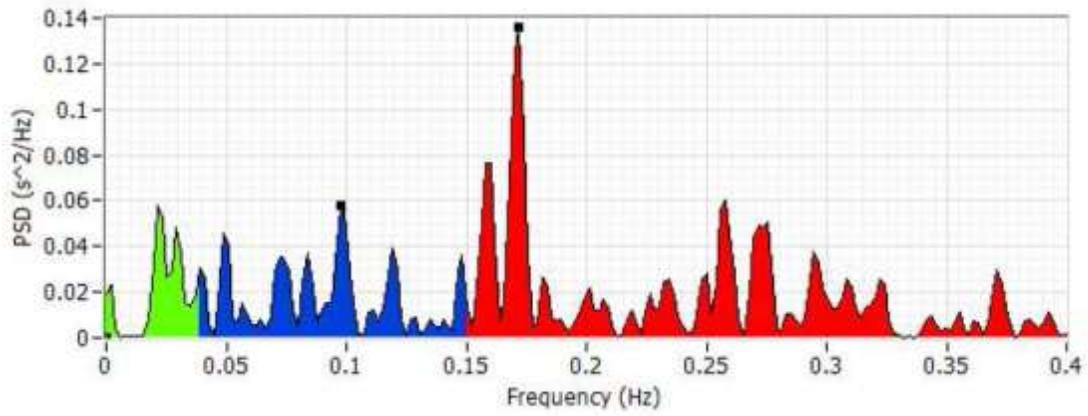


Fig-16 Curve of frequency vs. Power Standard Deviation

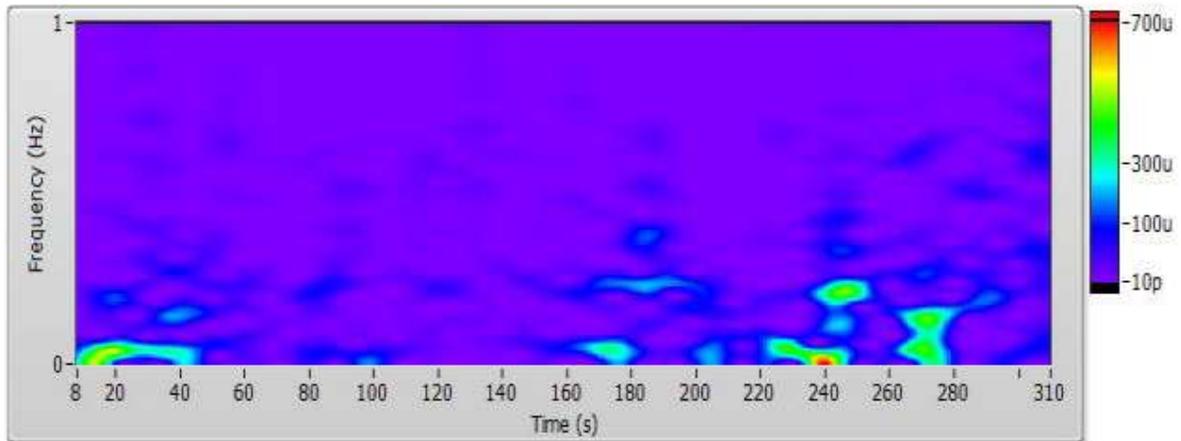


Fig-17 STFT Spectrogram

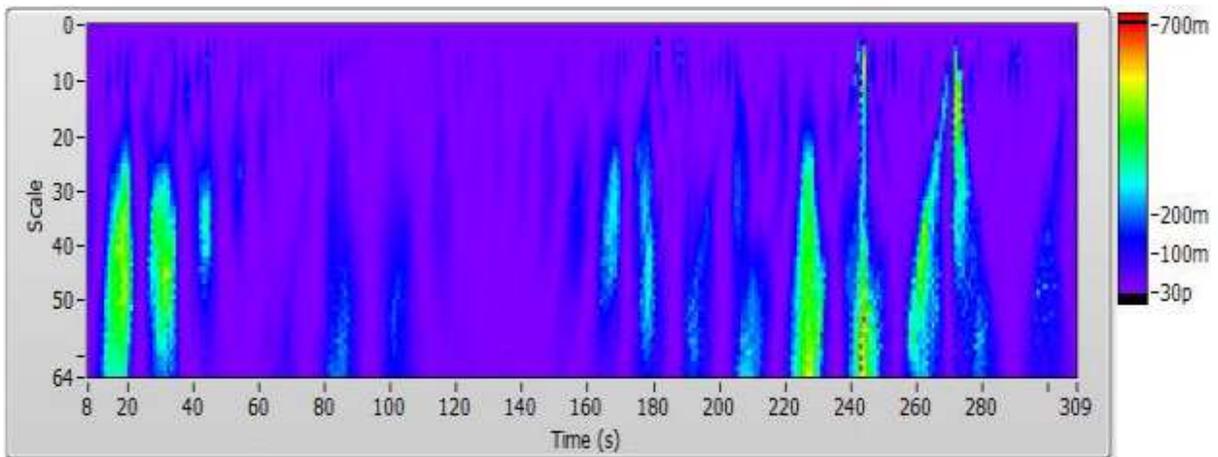


Fig-18 Gabor Spectrum

The HRV parameters were simultaneously analyzed using ANOVA method. This suggested that, the linear classifier Analysis of Variance (ANOVA) was not able to classify the signals

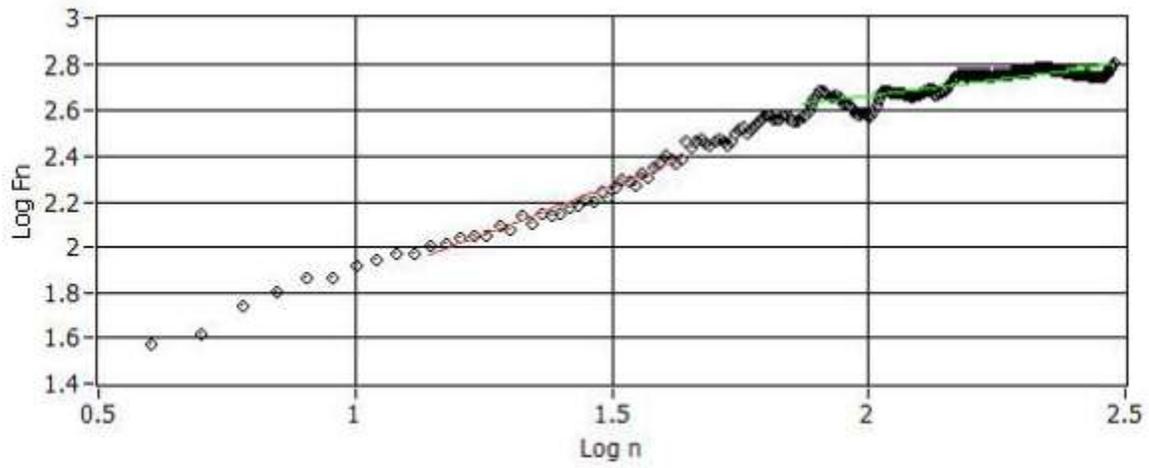


Fig-19 DFA Plot

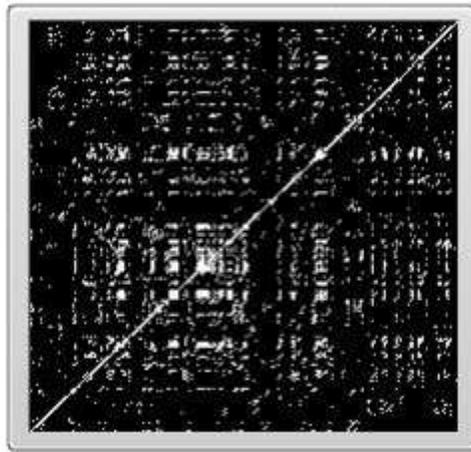


Fig-20 Recurrence Map

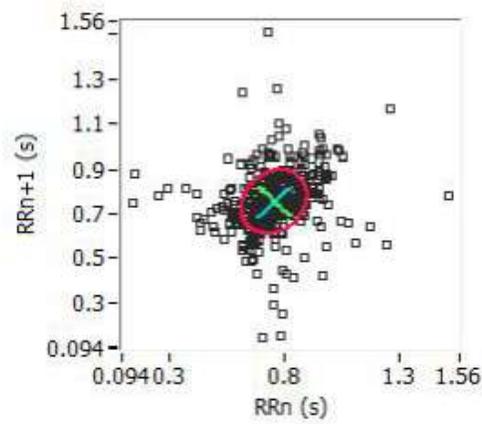


Fig-21 SD PLOT

Conclusion

The present study discusses the development of an ECG signal acquisition system and the effect of Odia music on the ANS of the Odia volunteers. The developed ECG signal acquisition system was tested for its functionality, successfully. Using the developed system, ECG signal of fifteen male Odia volunteers was acquired and the HRV analysis of the acquired ECG signal was done. It was observed that not even a single feature among the features which were obtained using HRV analysis, were able to predict the different conditions using Analysis of Variance (ANOVA) [18]. However, a decrease in the heart rate of the person was observed in post- stimulus condition. It explained that if a person is made to hear music in their mother tongue, there is a very small increment in the parasympathetic activity. This can be attributed by the fact that listening of the music in the mother tongue comforts the persons and help persons to relief anxiousness.

An in-depth analysis should be performed to have an idea about the precise changes in post stimulus condition. Extensive study of HRV features should be done to analyze the different effects of music in mother tongue. This may help to comfort persons suffering from cardiac issues and other anxiety related issues.

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APPENDIX



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EFFECT OF ODIYA&TAMILMUSIC ON THE PHYSIOLOGY OF HEART Volunteers History & Consent Form

NUMBER:

Date:

1. General Information

1. Name (Mr./Ms/Mrs.) _____
2. Date Of Birth _____ Age _____
3. Address _____

4. Contact No _____ E-Mail _____
5. Body Weight (kg) _____ Height (mt) _____ BMI (kg/m²) _____

2. Medical information

1. Medical History

- a) None _____
- b) Specify If Any _____

2. Surgical History

- a) None _____
- b) Specify If Any _____

3. Gynecological Problem

- a) None _____
- b) Specify If Any _____

4. Drug History

- a) None _____
- b) Specify If Any _____

5. Sleeping Disorder

- a) None _____
- b) Specify If Any _____

6. Appetite

- a) None _____
- b) Specify If Any _____

7. Diet Habit

- a) Vegetarian _____
- b) Non-Vegetarian _____
- c) Eggetarian _____



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3. Habitual information

Exercise

- a) Yes _____
- b) No _____
- c) If Yes, What Type _____
- d) Frequency And Activity
 - i) Regularly _____
 - ii) Weekly _____
 - iii) Rarely _____

Any other comments you may want to make: _____

Declaration:

I Mr. /Miss. _____ hereby declare that I have been verbally made aware about the details of the study and the risk involved in it. I give my consent to the below-mentioned researchers to acquire and analyze the ECG signal. I understand that the results obtained from the analysis of the ECG signals acquired will be used to compile a report which will lead to the B.Tech thesis dissertation of Mr Utkarsh Srivastava. I also give my consent to them to use the results for writing scientific manuscripts and dissemination to the scientific world either digitally or in print-form.

.....
Signature of the participant with date

Researchers involved in the study

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