The Effect of Music-Induced Psychological Stress on Heart Rate Variability

Kabir K. Sharan *Student*, Tarek Issa *Student*, Brayden Vasudev *Student*, Joshua T. Hayles *Student*, Adam Rocco *Student*

***Abstract*— Multiple studies have shown that heart rate variability (HRV) decreases in response to psychological stress. In order to further define this relationship, participants (N=18) were exposed to both calming and stressful music, while HRV data was obtained by electrocardiography. Overall the participants showed a decrease in HRV when listening to the stressful music (0.002495 s) when compared to the calming music (0.003047 s). In order to determine statistical significance a t-test was performed, the critical value (1.6918) was larger than the test value (0.033), therefore these results were not statistically significant. These results may be due to errors in methodology, specifically an insufficient stress state induced in the participants.**

Keywords: Heart rate variability, electrocardiogram, stress, music

I. INTRODUCTION

Electrocardiograms (ECG's) are recordings of biological signals which provide a physical representation of the various activities that occur during a heart beat. The portion of the ECG wave that is of relevance is the QRS complex. The QRS complex corresponds to the depolarization of the right and left ventricles of the heart [1]. This portion of the wave allows for the calculation of various parameters such as heart rate (HR) and heart rate variability (HRV). For the purpose of this study the parameter of HRV is of interest. HRV is calculated by finding the RR interval in the time domain of corresponding QRS complexes [2]. The complexes are shown in Figure 1.

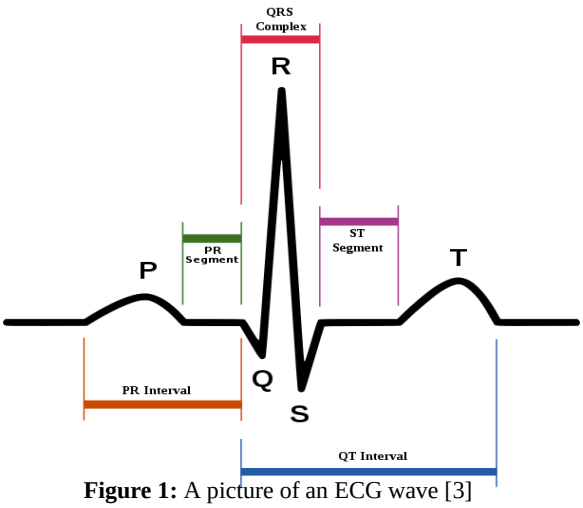

Figure 1: A picture of an ECG wave [3]

A varying heart rate is an indication of a healthy cardiovascular and autonomic nervous systems (ANS). The ANS is responsible for regulating functions of involuntary body processes, maintaining homeostasis, and controlling the stress response system [4]. HRV is the measure of time between each heartbeat and is used as a way of measuring the response of the ANS. The result is that any changes to the body will be elicit a change in ANS function [5]. A low HRV is accompanied by the body's fight-or-flight response. This response is an indication of stress induced on the body as the heart provides blood to the body rather than controlling the time between heart beats. [6] A high HRV is associated with a relaxed body response. The larger HRV is related to the ANS response for controlled breathing and relaxation after accumulation of stress [6]. Therefore, a relaxed body response or high HRV is favorable.

A study performed at the Sri Venkateshwara Medical College Hospital in India [7] utilized the frequency domain parameters of HRV to determine the underlying stress levels of participants. The results indicated that participants that were in the music group had much higher HRV than those who were in the control group. Individuals that possess a greater HRV are deemed to have a greater tolerance to stress and be healthier overall compared to individuals with lower HRV.

Another study done in Brazil tested the acute effects of different styles of music on HRV. [8] The study examined the HRV of women that were placed into two groups; group one listened to both types of music while group two listened to both types accompanied with white noise auditory stimulation. [8] The musical styles were classical and heavy rock. The results indicated that both types of music slightly decrease global HRV due to the sound level being similar in both cases. [8] This indicates there should not be a large difference in HRV between the two types of music. It can also be assumed that the results would not be different if men were the participants instead of women.

The objective of this study is to identify the relation between HRV and psychological stress. This will be achieved by exposing participants to two different genres of music. Both calming and stressful genres will be played, to induce states of low and high stress. The calming genre will be classical music and the stressful genre will be rock music. In the short term, this study aims to define a correlation between HRV and stress. The long-term goal is to expand this correlation and standardized testing conditions in order to develop a clinical measure of stress.

Based on previous HRV studies, it is predicted the HRV of participants when exposed to calming music will be higher than when exposed to stressful music. To test this hypothesis, the null hypothesis will be that the mean HRV for calm testing is equal to the mean HRV for stress testing. The alternate hypothesis will be that the mean HRV for calm testing is greater than the mean HRV for stress testing. Another goal for this study is to reject the null hypothesis and prove the alternate hypothesis.

This paper will cover the steps used to carry out the experiment in the METHODS section. This section will also cover the techniques for obtaining HRV and a description of the tested participants. The next section, RESULTS, presents the data and analytics for the HRV of all the participants. In the DISCUSSION section, the data and main results are explained and compared to other studies. The CONCLUSION section summarizes the results obtained in this study. The last sections are the APPENDIX, ACKNOWLEDGEMENT, and REFERENCES which outline any extra data, acknowledges support, and presents the used references, respectively.

II. METHODS

A. Psychological Stress Factors

Stress is a necessary part of the body's response to a perception of danger. [9] This response triggers a cascade of hormones that travel through the entire body and cause physiological changes to occur, such as increased heart rate.[9] These changes help the body prepare the muscles and any necessary organs (such as the brain, heart, and lungs) for quick action. The problem with stress is that it is meant for short-term response and not for prolonged responses. These types of responses can come from psychological factors such as repeated traffic, anxiety, depression, and other mental conditions. Prolonged and repeated exposure to stressors can cause physical and psychological damage in the form of disease.

In this work, psychological stress was induced in participants using music. Two different songs with different music intensities were used to evaluate how heart HRV can be affected by different stress levels affecting the mind.

The change in music intensity should give the mind a feeling of an external pressure. This would provide anxiety causing the body to use its stress response changing how much blood the heart would pump. The first song that was used was Erik Satie's Gymnopédie No. 1. [10] This song consists of a gentle melodic beat that was used to view how the heart would react in a relaxed state. The second song that was used was Denzel Curry's cover of Bulls on Parade by Rage Against the Machine. [11] This song provided a heavier intensity to cause a higher stress which allows for the analysis of the heart in a higher stress state. Participants participanted to this experiment were all above the age of 18. The number of participants was 18, the sex demographic amongst participants was 9 males and 9 females. It is expected that there will be no difference in HRV between male and female participants. under this pretext the samples will be lumped together. A within-participant test will be carried out with all the levels (music genre tests) being performed on each participant. The participants were excluded from this study if they exhibited cold/flu symptoms, had any known heart conditions or any hearing problems.

B. *Data Collection*

Data was collected using a BioRadio manufactured by Great Lakes Neurotechnology. It is a bluetooth equipped ECG and EMG monitoring device that will only be used in the context of ECG data collection. Three Ag/AgCl electrodes were placed on participants, one placed on the knuckle to act as a ground and the others being placed on the inside of each wrist. The BioRadio was configured to have a sampling frequency of 250 Hz. The data collected by the BioRadio was sent to a computer containing the BioCapture software which displayed the ECG.

Participants were required to listen to a mix for a total of 2 minutes, one minute of the gentler song at the beginning and then one minute of the intense song at the end. The mix changed songs halfway through without any warning. This was done to induce psychological stress quickly allowing for change in HRV to be observed in real time. Participants sat at a desk and were asked to keep their hands still to prevent the capture of inaccurate ECG data. They were given headphones that were disinfected before use. A test sound was played to ensure the volume would be at a comfortable level. Once the volume was set, the 2-minute mix was played.

C. *Analysis techniques*

The data collected from the BioRadio was input into the Pan-Tompkins function from MATLAB which allowed for the extraction of participant HRV. The Pan-Tompkins algorithm generated the magnitude

of every R-R interval between each heartbeat and its corresponding index number. The time element was found by dividing the data point index number by 250 which is the sampling rate. HRV is the R-R variation over time which is calculated by finding the variance of the calm and stress R-R intervals for each participant. The equation for variance is as follows:

$$s^2 = \frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1} \quad (1)$$

A two-sample t-test was used to test the null hypothesis. The two samples that were compared were the HRV means of Calm and Stress portions of the ECG Signal. The type of t-test that was performed was a one tail t-test as it is only necessary to test if the mean of Calm HRV is higher than that of the Stress HRV. It was predicted that the low induced stress (calm) HRV would be higher than the high induced stress HRV which is why it was only necessary to test one tail of the distribution. To carry out the test, the means and standard deviations of Calm HRV and Stress HRV samples were determined using the following equations:

$$\mu = \frac{\sum_{i=1}^{n} x_i}{n} \quad (2)$$

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \mu)^2}{n-1}} \quad (3)$$

The point rejection t-test method was used, and it requires the critical t-value and the test t-value. To find the critical t-value, the degree of freedom of the data was determined using the sample populations of Calm and Stress HRV as follows:

$$DoF = n_1 + n_2 - 2 \quad (4)$$

The significance level chosen for this study was 0.05 as it is a standard level commonly used. This low significance level indicates that the probability of rejecting the null hypothesis when it is true is low. Using the significance level and the degrees of freedom, the critical t-value (represented as t) was found in the t - distribution table [12]. The test t-value was determined according to the null and alternate hypothesis shown below with Calm HRV mean and stress HRV mean as mu1 and mu2, respectively.

null hypothesis - Ho: $\mu_1 - \mu_2 = 0$

alternate hypothesis - Ha: $\mu_1 - \mu_2 > 0$

The test t- value formula is as follows:

$$T_o = \frac{\mu_1 - \mu_2}{\sqrt{Sp^2\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}} \quad (6)$$

Using the point rejection test, if the test t-value is larger than the critical t-value (To>t), the null hypothesis is rejected, and the alternate hypothesis can be accepted. Otherwise (To<t), the null hypothesis is not rejected, and no conclusions can be drawn from the test.

III. RESULTS

The HRV results for all the participants are shown in figure 2 below. The bar graph shows the HRV of participants during music testing displayed in a randomized order. Classical music was used to calm the participant and the corresponding HRV data is represented as Calm HRV (in blue). Rock music was used to induce psychological stress on the participant and the corresponding HRV is the Stress HRV data (in red).

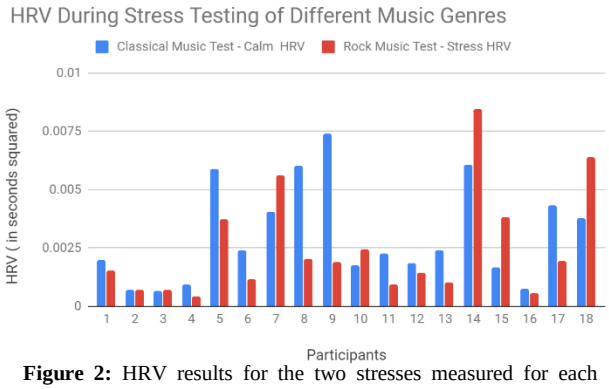

Figure 2: HRV results for the two stresses measured for each participant.

The results show that 11/18 participants have a higher HRV when tested with classical music than when tested under stress using rock music. Most of the participants have higher HRV when calm than when stressed which agrees with the literature review and predictions stated earlier.

To test the hypothesis, a one-sided, two-sample t-test was used to compare the means for Calm HRV and Stress HRV. The relevant data for the t-test is summarized in Table 1 below.

Table 1: Summarized results from the hypothesis testing using a t-test

Mean of Calm HRV	0.003047 s
Standard deviation of Clam HRV	0.002125 s
Mean of Stress HRV	0.002495 s
Standard Deviation of Stress HRV	0.002262 s
Degrees of Freedom	34
Significance level	0.05
Critical t-value (t)	1.6918
Test t-value (To)	0.033

As expected, the mean of the Calm HRV is larger than the mean of the Stress HRV. Meanwhile the standard deviation of Calm HRV is lower than the standard deviation of Stress HRV. The point rejection method was used to test the hypothesis. In order to identify if there was a difference between the mean of

low induced stress HRV and high induced stress HRV, the null hypothesis assumes the means are equal. The resulting critical t-value (1.6918) was larger than the test t-value (0.033). From the t value, the null hypothesis can be rejected or not rejected.

IV. DISCUSSION

It was hypothesized the HRV in a state of low stress will be greater than the HRV in a state of high stress. Figure 2 shows the HRV for both types of stress for each participant and in most participants, the low stress HRV is higher. This agrees with the results of previous studies. [6] However, we can also say with 95% confidence that there is no statistical difference between the low and high stress HRV. Previous literature determined that there should be a significant difference when the body is at rest compared to a state of high stress but when solely induced by music, the different genres did not have much effects. [8] This is confirmed by the results found in this experiment. The volume was similar for both genres of music which made the auditory effect of music similar thereby only having the tempo and excitability of the music be the stressor.

The main anomaly found was in participants whose high stress HRV was greater than their low stress HRV. This is mainly caused by the methodology that was used. To have the body experience a sudden onset of stress, there was no break between music genres. The music switched from the slow to the fast-paced music instantly. During the switch, those participants who present the anomaly in the data, especially participants 7, 14, 15, and 18, produced a large movement for 1-2 beats due to the sudden change. The electrodes placed on the wrists of the participants were extremely sensitive to movement so the sudden move would cause the reading to be slightly inaccurate. Also, the body may have required a longer period of exposure to the music to respond to the stimulus and reach the desired state of stress. Auditory stimuli usually combine with visual stimuli to cause the body's fight-or-flight response to kick in. [5] Due to the stimulus being strictly auditory, a longer exposure time may yield different results.

V. CONCLUSION

Heart rate variability has a big effect on a person's health. By using an electrocardiogram, it was possible to view how the heart rate variability was affected by an induced stressor, music. It was hypothesized that low induced stress HRV will be greater than high induced stress HRV. After completing the experiment, we can say that although there was a slight difference in HRV, we can also say with 95% confidence that there was no statistical difference between the low and high stress HRV. The only effect the music had on participants HRV was during the transition of low stress to high stress, the participant's ECG wave displayed a change. This was most likely due to the sudden change in music intensities.

REFERENCES

[1] "Waves and Intervals on the ECG", *Medicine-on-line.com*, 2019. [Online]. Available: http://www.medicine-on-line.com/html/ecg/e0001en_files/05.htm.

[2] P. Bryn Farnsworth, "Heart Rate Variability - How to Analyze ECG Data", *iMotions*, 2019. [Online]. Available: https://imotions.com/blog/heart-rate-variability/.

[3] "How To Read An EKG (electrocardiograph)", *Today I Found Out*, 2011. [Online]. Available: http://www.todayifoundout.com/index.php/2011/10/how-to-read-an-ekg-electrocardiograph/.

[4] J. Furness, "Autonomic nervous system - an overview | ScienceDirect Topics", Sciencedirect.com, 2009. [Online]. Available: https://www.sciencedirect.com/topics/neuroscience/autonomic-nervous-system.

[5] M. Campos, "Heart rate variability: A new way to track well-being - Harvard Health Blog", Harvard Health Blog, 2017. [Online]. Available: https://www.health.harvard.edu/blog/heart-rate-variability-new-way-track-well-2017112212789.

[6] J. Moore, "Heart Rate Variability vs. Heart Rate", Heart Rate Variability Educational Courses, 2016. [Online]. Available: https://hrvcourse.com/heart-rate-variability-vs-heart-rate/.

[7] R. Latha, H. Sairaman, S. Srikanth and N. Edmand Dity, "Effect of music on heart rate variability and stress in medical students", International Journal of Clinical and Experimental Physiology, vol. 1, no. 2, p. 131, 2014. Available: 10.4103/2348-8093.137409.

[8] A. Roque et al., "The effects of auditory stimulation with music on heart rate variability in healthy women", *Clinics*, vol. 68, no. 7, pp. 960-967, 2013. Available: 10.6061/clinics/2013(07)12.

[9] "Stress | Psychology Today", *Psychology Today*. [Online]. Available: https://www.psychologytoday.com/us/basics/stress.

[10] DistantMirrors, "Erik Satie - Gymnopédie No.1," *YouTube*, 07-May-2012. [Online]. Available: https://www.youtube.com/watch?v=S-Xm7s9eGxU&fbclid=IwAR3kJKv75JGmexm2EO_1fWCnhjM5v_Q-FBwcBygiQMyYdVAj5t0iNQFErEA.

[11] triple j, "Denzel Curry covers Rage Against The Machine 'Bulls On Parade' for Like A Version," *YouTube*, 14-Feb-2019. [Online]. Available: https://www.youtube.com/watch?v=ZY4ywyFXdik&fbclid=IwAR1rBhd-hrCFyrrBmsHEysWZG50KTcwvdFhdDgJ8SvxQ8yLcedE7qjKMxI0.

[12] J. Devore, Probability and statistics for engineering and the sciences, 8th ed. San Luis: Brooks/Cole, Cengage Learning, 2012, p. 718.