The effects of genre of music on physiological stress response after moderate exercise

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Abstract

The advent of portable music devices and growing popularity of music-guided exercise classes have ushered in an era in which music and exercise increasingly intersect. Previous research suggest that music can produce positive, soothing effects during exercise; however, no research group has previously investigated how music affects the physiological recovery rate of the body after physical activity. Determining the significance of music's effects on the complex psychobiological stress response resulting from exercise provides information vital to 1) determining whether different styles of music elicit predictable style-dependent effects on autonomic physiological measures of stress, 2) establishing whether one's perceived exertion differs depending on music style, and 3) guiding music selections of individuals undergoing cardiovascular exercise to most effectively expedite recovery. With our results, individuals can determine if music can elicit a robust calming effect in scenarios of moderate physiological stress. Eighteen healthy normal volunteers, between the ages of 20-23, performed three brief trials of moderate physical exercise while being exposed to three different auditory stimuli: white noise, classical music, and heavy metal music. Heart rate, respiratory rate, and perceived exertion were measured post-exercise to determine to rate at which each participant returned to their pre-measured baseline levels. The results of this study support no significant difference (p-value= 0.2015) in recovery rate between trial exposures to classical music versus heavy metal music. While the findings of this study indicate that the physiologic stress response appears impervious to music style, further research is necessary to delineate the relationship between music and exercise physiology.

Introduction

While prior research has investigated the effects of music given exposure to a cognitive stressor, our study represents the first of its kind in coupling music to physiological stressors such as moderate exercise. Exercise and music independently produce predictable, highly personal psychobiological sensations that exist on a spectrum from blissful catharsis to agonizing misery; however, the manner and degree to which music affects the physiological processes underlying the human stress response resulting from exercise remains unclear. Previous research on the effect of music on physiological stress and self-reported anxiety exhibit inconsistent individual physiological responses to music compared to significant reductions in self-reported anxiety after exposure to music (Knight et al. 2001). Further research on the effect of exposure to a stressor followed by listening to self-select or classic music shows reductions in physiological arousal and self-reported negative emotional states compared to heavy metal music or silence (Labbé, 2007). While prior studies have employed cognitive stressor tasks to investigate the effects of different genres of music on the human stress response, few studies have explored how different genres of music affect the physiological stress response resulting from moderate physical exertion (Thoma et al. 2013; Labbé, 2007). Existing findings by Thoma et al. provide evidence that listening to self-selected music provides relief from stress, independent of exercise as well as during intense cardiovascular exercise. We hypothesize that the rate at which individuals recover from the physiological stress response resulting from cardiovascular exercise will differ depending on the nature of auditory stimuli to which individuals are exposed. Furthermore, we predict that different auditory stimuli will affect the perceived self-exertion of individuals performing moderate cardiovascular exercise depending on the music preference of the individual.

In popular group exercise activities such Zumba, CrossFit, and spinning classes, instructors strategically select music to motivate participants to modulate their physical activity as the music changes throughout the class. Judicious use of high energy, fast tempo music motivates participants to increase exertion during the beginning and middle of class. Conversely, less intense, slower tempo music in the last stage of the class contains purportedly promotes physiological relaxation. Thus, this commonplace example suggests that perception of different auditory stimuli differentially affect the physiological stress state of the perceiver. The findings of this study will help guide individuals performing moderate cardiovascular activity to choose music genres that most effectively will return the human physiological systems responsible for stress to baseline measurements.

Methods

Participants were recruited from the Physiology 435 class at the University of Wisconsin-Madison to participate in this study. Each participant filled out a consent form. Researchers explained the procedure and answered any questions or concerns the participant had. The BSL Respiratory Effort Xdcr SS5LB was attached to the Biopac Systems MP36 and then was then attached to the participant around the chest, under the armpits and above the nipple line. The respiratory monitor was left on for the duration of the procedure. The participant then sat on a Gold's Gym 390R Cycle Trainer stationary bike. The Nonin Pulse Oximeter was attached to left index finger. The pulse oximeter stayed on for the duration of the procedure. The participant held his or her left hand on the upper bike handle for the duration of the procedure.

Basal respiratory rate was measured for a minute using the respiratory monitor. Respiratory rate was continuously measured for the full duration of the experiment. After 30 seconds of measuring the respiratory rate, experimenters began measuring the basal heart rate using the pulse oximeter for another 30 seconds. During this 30 second interval, an experimenter recorded a minimum and maximum heart rate value to establish a resting heart rate range. White noise was used as the control for this experiment instead of silence to emulate a neutral auditory stimulus. Complete silence was not feasible due to varying levels of background noise in the testing space.The participant listened to "Original White Noise" by White! Noise using Sony MDR7506 Dynamic Stereo Headphones. An experimenter presented a sign that reads "Start Pedaling" to notify the participant to begin pedaling. The participant was instructed at the start of the procedure to pedal at a constant rate between 8-10 mph, intermittently monitored by experimenters to ensure the subject remained pedaling within the desired speed range.

Experimenters adjusted the resistance within the range of 8-11 on the stationary bike while the participant maintained a constant pedaling rate to ensure the participant's heart rate fell in the desired target heart rate range. Participants achieved the target heart rate range of between 55-65% of the participant's age-predicted maximum heart rate. According to Centers of Disease Control and Prevention, 50-70% of an individual's age-predicted maximum heart rate is considered moderate-intensity physical activity (2011). Once in the range, the participant remained pedaling within the desired heart rate range for two minutes to ensure the participant's heart rate stayed within the desired range. The resistance was adjusted to keep the participant's heart rate within the range. After two minutes, the subject was shown a "Stop Pedaling" sign, at which point the exercise stopped. The heart rate was measured at this point. The participant remained seated and did not move or speak until a researcher signaled that the trial was complete, as explained before the start of the procedure. The heart rate was measured every 30 seconds until it reached basal heart rate. The respiratory rate was measured every minute until it reached basal respiratory rate. The breaths per minute were determined by counting the number of peaks (inhales) in a 60 second interval as shown in Figure 3. Once the subject reached basal heart rate and respiratory rate, the headphones were removed. The time each participant took to reach the resting heart rate range and respiratory rate did vary between individuals. Participant rated his or her perceived exertion using the Borg Rating of Perceived Exertion Scale. This scale is numbered from 6 to 20, 6 representing no exertion and 20 maximal exertion. Moderate exertion is be considered a rating of 12-14 on this scale. The participant received a one minute break, but remained seated on the stationary bike, in order to ensure the participant was within his or her previously determined resting heart rate range and respiratory rate.

The procedure was then repeated using the auditory stimulus to which the subject had been randomly assigned to receive first; the participant was subjected to either "Hammer Smashed Face" by Cannibal Corpse, or "Prelude to the Afternoon of a Fawn" by Claude Debussy. Following another one minute break, the procedure was repeated again using the auditory stimulus to which the subject had not been exposed. Figure 1 shows the condensed version of the procedure along a timeline. Once the experiment was completed, the participant was asked to complete a short questionnaire consisting of their average weekly exercise and their opinion towards classical and heavy metal music (1=dislike, 2=neutral, 3=like).

Results

Heart Rate

Figure 4 shows the time taken for each participant to reach resting heart rate for the three stimuli. For trials exposed to the white noise stimulus, the mean time it took for participants to reach resting heart rate was 275 seconds with a standard deviation of 134.66 seconds. When the participants listened to white noise the average time it took for the individuals to reach resting heart rate was 253.33 seconds with a standard deviation of 143.77 seconds.The average time taken for individuals listening to heavy metal to reach resting heart rate was 296.67 seconds with a standard deviation of 145.84 seconds. Figure 5 graphically depicts these average values. To compare the mean we conducted a Welch Two Sample T-test comparing white noise and classical music, white noise and heavy metal music, and classical music and heavy metal music; none of the data was found to be statistically significant. When comparing the time for white noise and classical music, the p-value was 0.6437, degrees of freedom were 33.855 and the 95% confidence interval was -72.7047, 116.03809. Analyzing white noise and heavy metal resulted in a p-value of 0.6463, degrees of freedom of 33.786 and a 95% confidence interval of -116.77214, 73.43881. Comparing classical and heavy metal music resulted in a p-value of 0.3757, degrees of freedom were 33.993 and the 95% confidence interval was -141.4320, 54.76537.

Respiratory Rate

Figure 6 shows the results of the time it took to for each participant to reach resting respiratory rate for each of the three stimuli. The mean time it took for participants to reach resting respiratory rate while listening to white noise was 246.67 with a standard deviation of 94.06. For trials exposed to classical music the mean time to reach baseline was 236.67 with a standard deviation of 78.29. While listening to heavy metal music the mean time it took participants to reach resting heart rate was 296.67 with a standard deviation of 132.53. Figure 7 shows the average values for each of the stimuli for respiratory rate. To determine if there was a significant change between the time it took to return to baseline respiratory rate we performed a Welch two sample t-test and found that there was not a statistically significant change between stimuli. Between white noise and classical music the p-value was 0.731, degrees of freedom were 32.916 and the 95% confidence interval was -48.691, 68.691. The p-value for a difference between white noise and heavy metal music was 0.2015, the degrees of freedom were 30.66 and the 95% confidence interval was -128.15997, 28.15997. The t-test between classical music and heavy metal music resulted in a p-value of 0.1095, degrees of freedom of 27.577 and a 95% confidence interval of -134.3705, 14.3705. This showed there was not a statistically significant difference in the time it took for participants to reach respiratory baseline between the three stimuli.

Perceived Exertion

Figure 8 shows the perceived exertion of the three stimuli for each participant. The mean for perceived exertion of biking while listening to white noise was 11.56 with a standard deviation of 2.09. For perceived exertion while listening to classical music the mean was 11.28 with a standard deviation of 2.24. Listening to heavy metal resulted in a mean perceived exertion of 11.5 with a standard deviation of 1.79. Figure 9 shows a box and whisker plot of the average values for the three stimuli of perceived exertion. We performed a Welch Two Sample T-test to determine if there was a statistical significance between the perceived exertion of the different stimuli. The t-test for comparing white noise and classical resulted in a p-value of -.7033, degrees of freedom of 33.835 and a 95% confidence interval of 11.55556, 11.27778. When comparing white noise and heavy metal music the t-test resulted in a p-value of 0.9323, degrees of freedom of 33.206 and a confidence interval of -1.264826, 1.375937. The t-test for the difference in perceived exertion of heavy metal and classical resulted in a p-value of 0.7447, degrees of freedom of 32.402 and a 95% confidence interval of -1.599879, 1.155434. The t-test shows that there was not a statistically significant change between the perceived exertion of biking between white noise and classical music, white noise and heavy metal music, and heavy metal music and classical music.

Discussion

Statistical and Graphical Analysis

The results do not support the hypothesis that the rate of recovery from the physiological stress response resulting from cardiovascular exercise differs depending on the nature of auditory stimuli. Moreover, significant differences in the relaxation rates while listening to a favored, more pleasant genre of music compared to an unfavored genre were expected. Our expectations were based on previous studies in which different music tempos caused significant differences in the recovery rate after submaximal physical exertion (Savitha et al. 2010). However, our results show no significant effect of music on physiological measures, regardless of style and/or subject preference. Several confounding factors within the design and execution of the study provide potential explanation for the reported findings.

Methodological Error

Intrinsically unreliable pieces of equipment may have given inaccurate results in certain circumstances. The inconsistency of the pulse oximeter due to sweat from the participant's fingers created doubt in the accuracy of the data retrieved. Anatomical differences between male and female participants made it difficult to place the respiratory band correctly in every trial. The band had to be adjusted several times before and during the experiment to ensure the most correct reading. The stationary bike allowed for a stable form of exercise to allow for the ease of recording heart rate and to accurately monitor and modify resistance. Few participants experienced the bike shifting and changing the range between the seat and pedals, making it difficult to continue exercising.

The use of the BORG perceived exertion scale as a subjective measure had disadvantages. Even with the randomized order of each trial, the perceived exertion of the participants may have been influenced by one or both of the following naturally occurring physiologic phenomena: 1) muscles warming up as the individual executed the trial and 2) consequent gradual muscle fatigue onset. Despite brief rest intervals, the natural course of muscle fatigue onset as exercise continues may have surmounted the impact of the auditory stimuli on the physiological stress response. Another source of error involves the truthfulness of the participant response when polled on perceived exertion. The subject may not have responded truthfully in order to give the impression of being more fit than they physically are or had been under the assumption that they should perceive different exertions under each auditory stimulus. As well, participants may have ranked their perceived exertion based on numbers close to the median for the sake of simplifying their decision. The candid manner in which questions were asked required participants to verbally respond to questions about exercise habits and music preferences may have led to erroneous answers. Individuals hoping to appear more or less attuned to fitness or opinionated about music preferences may have been swayed to answer dishonestly. As well, the wording of the questions and possible answers may have made it difficult to make unbiased responses.

Timing of the experiment affected the results in several directions. All three trials were run in succession to each other, separated by a subject-determined rest time. This variability may have prevented a full return to baseline. Therefore baseline physiologic measures for the second and third trials were subjective, since they were only measured prior to the first trial. As the trials proceeded, the participants' muscles were progressively warming up, and consequently became more fatigued. Given the sequential nature of trials, one cannot expect that any given individual started every trial at the same state of muscle fatigue. It is impossible to retroactively evaluate the degree and significance of discrete changes in muscle state as individuals completed sequential trials. Thus, we are unable to assess the impact of muscle state changes across sequential trials. This confounding variable may threaten the validity of intertrial comparisons of physiologic stress measurements.

Experimenter Error

Due to the duration of the experiment, lapses of attention while recording heart rate may have resulted in misrepresented data. Respiratory rate measurements were subjective to the researcher. As mentioned in the methods section, measurements consisted of the number of inhales per minute, represented by the peaks in waveform data (Figure 3). Interpersonal variation in the interpretation of the peaks could also result in misrepresented data. The protocol of the experiment included the participant rating their perceived exertion after each of the three trials. However, on occasion, the order in which the perceived exertion scale was presented to the participant was not followed (the participant was asked for their perceived exertion for the first trial after the second trial).

Experimental Conditions

Due to the duration of the experiment, it was not feasible to recruit more participants in the time allotted to run the experiment. This time limitation allowed for a smaller data pool than desired. Furthermore, the time required to collect data for each participant, approximately 30 minutes, proved problematic for two reasons. Not only did the long duration of data collection for each participant temporally limit the possible number of participants given finite laboratory space available, but also the long duration for data collection deterred potential subjects from volunteering. Variability in the temperature of the facility used and time of day the experiment was conducted may have led to different levels of relaxation for each participant. Muscle fatigue and perceived exertion may have varied at different times of the day for each participant, depending on individual daily routines.

Future Directions

Follow up research on this topic will produce more fruitful results through a series of changes to the study design and execution. First, increasing the population of the study without changing the selection process would produce more representative data. One can expect that as the population size increases, the data will more faithfully represent the impact of music on physiological stress response. Secondly, more accurate physiological stress measurements will result from increasing the time for each trial and degree of cardiovascular stress output. As well, conducting trials on separate days will control for subtle changes in muscle state following sequential trials. Lastly, allowing individuals to choose the music to which they are exposed in addition to preselected exposures will provide insight into the effect of music preference on both psychological and physiological components of the stress response.

Our study represents the first of its kind in coupling music exposure to physiological stressors such as moderate exercise. The preliminary findings of this study serve as a foundation for future investigation into the psychobiological interactions between exercise and music genre.

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Figures

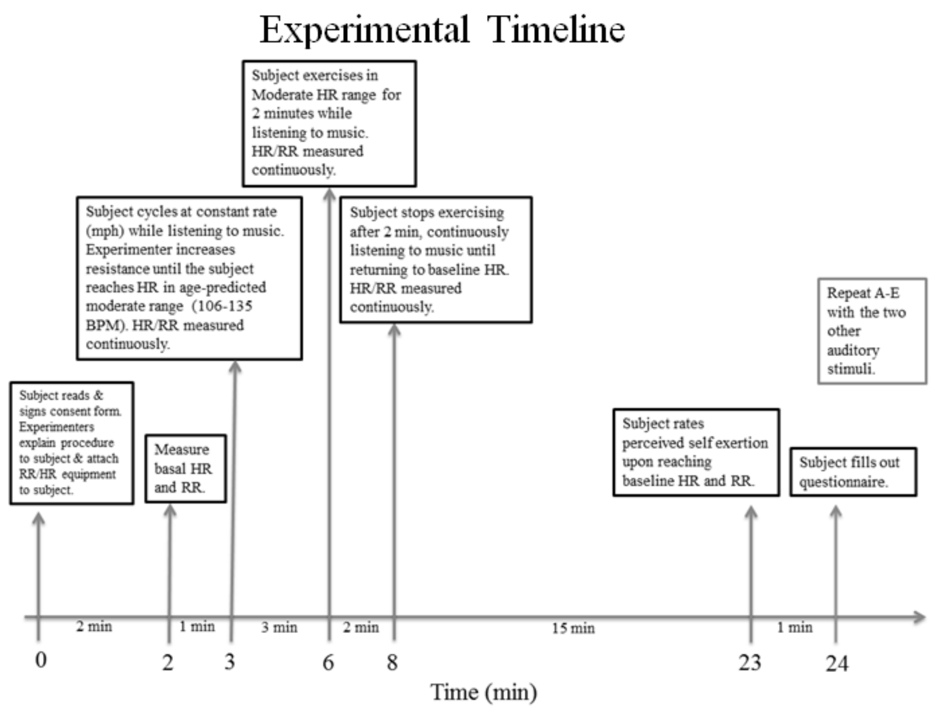
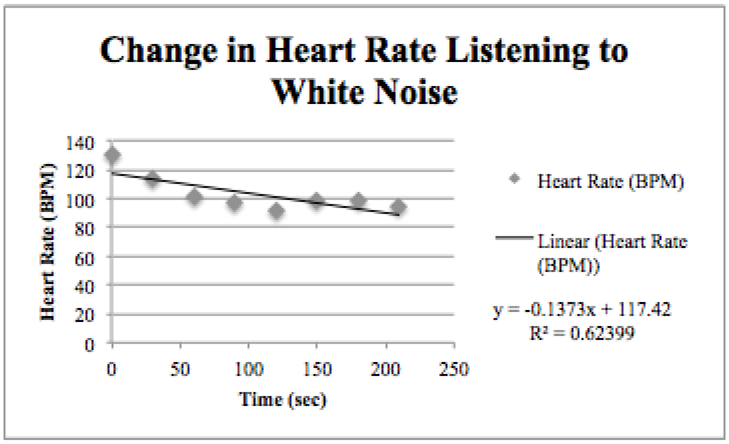
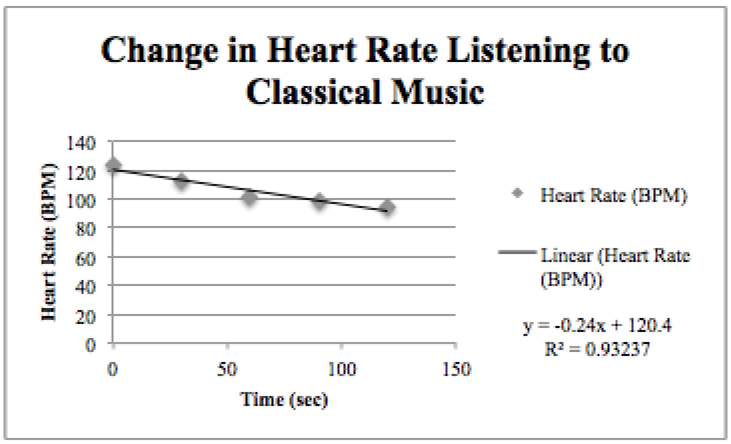


Figure 1. Timeline of procedure described above.



A.



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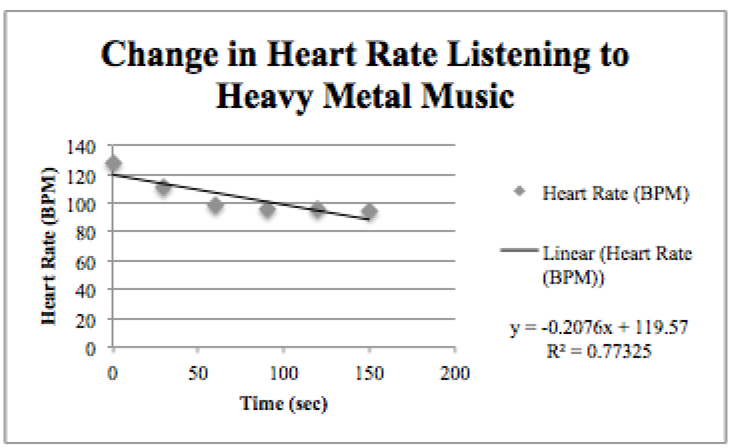

C.

Figure 2. A) Changes in heart rate while listening to white noise. B) Changes in heart rate while listening to classical music. C) Changes in heart rate while listening to heavy metal music.

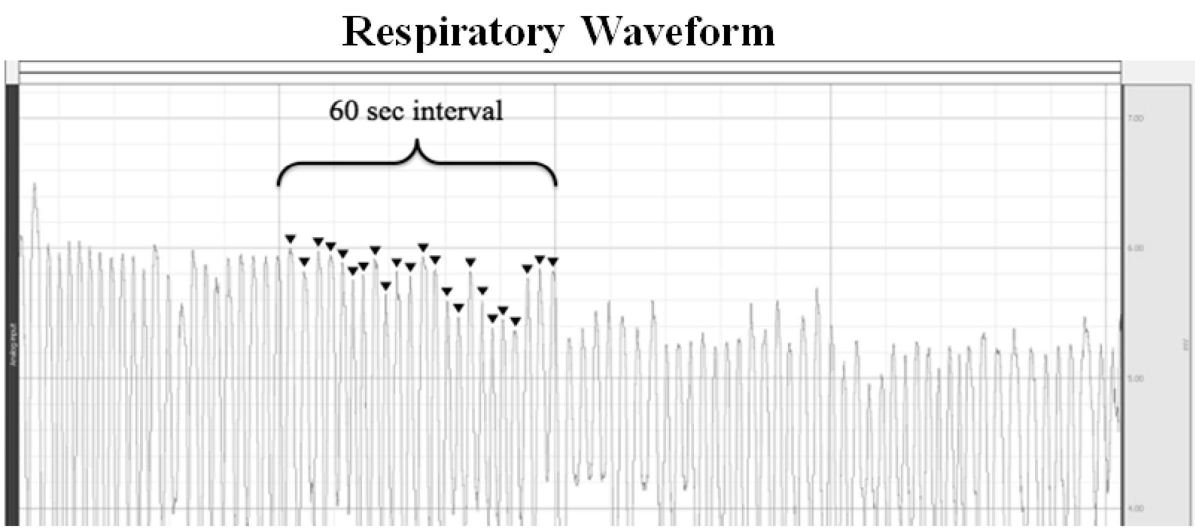

Figure 3. An example of the waveform produced from BioPac. It shows the respiratory rate of participant #17 while listening to white noise. The arrows above the each peak in the 60 second interval depict a point at which a breath was counted (in this example 23 breaths/minute).

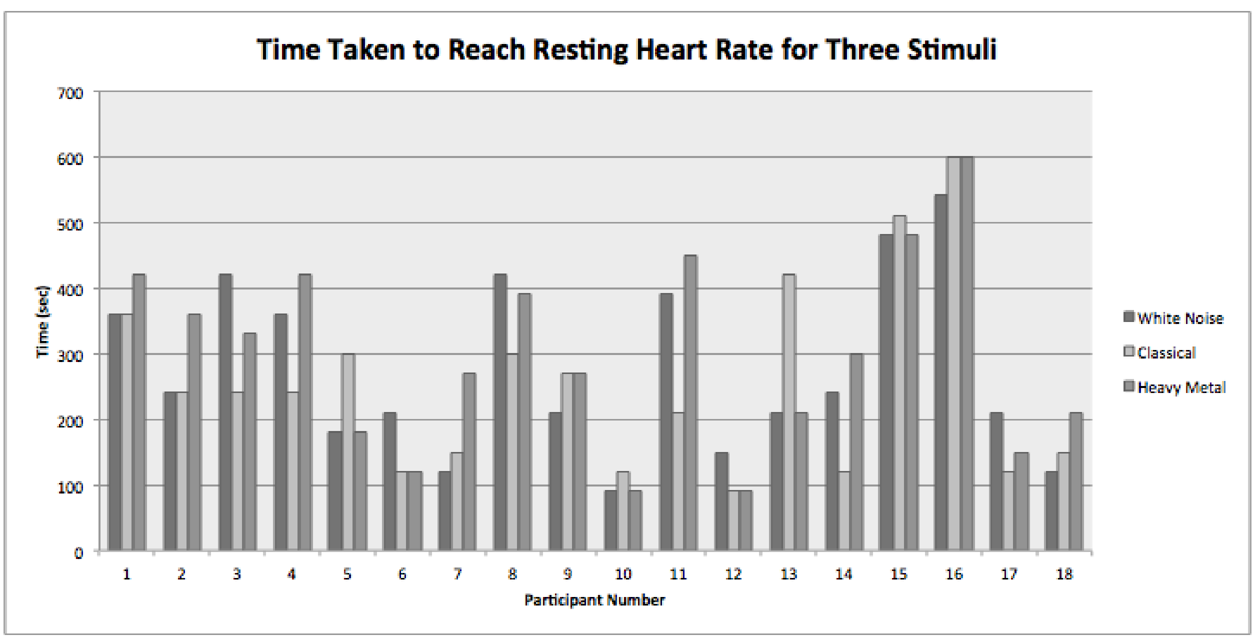

Figure 4. Time taken by each participant to reach resting heart rate for all three stimuli.

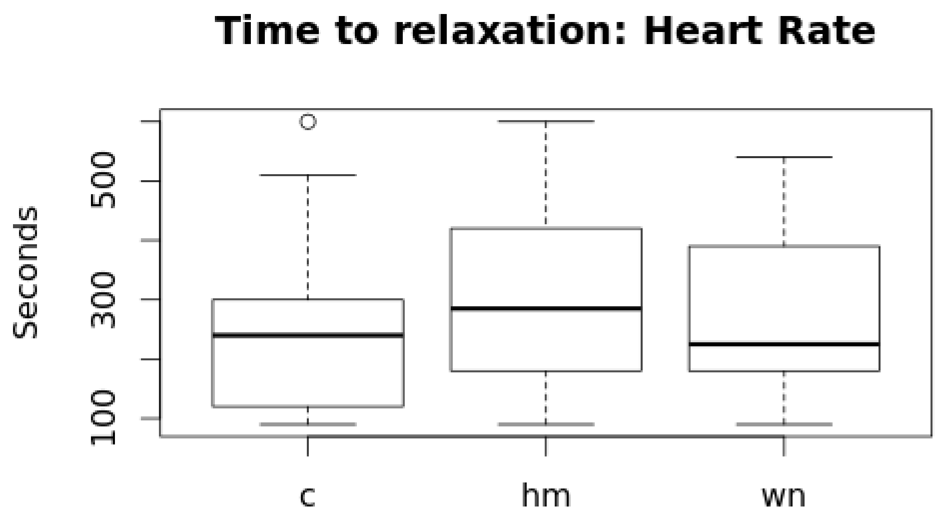

Figure 5. Average relaxation time for heart rate for classical music (c), heavy metal music (hm), and white noise (wn). This figure depicts a box and whisker plot that was generated using the R software. The dark line represents the median heart rate for each stimuli and the box reflects the interquartile range. To find the interquartile range, the median divides the data into two halves. Two new medians are then determined for each of the halves separating the data into quarters. In between these two medians is the interquartile range shown as the height of the box. The lines above and below the box show the range of the data. The dot above or below the lines depicts an outlier. Statistical difference of the median (dark line) between each stimuli suggest a change in the time it took to reach baseline.

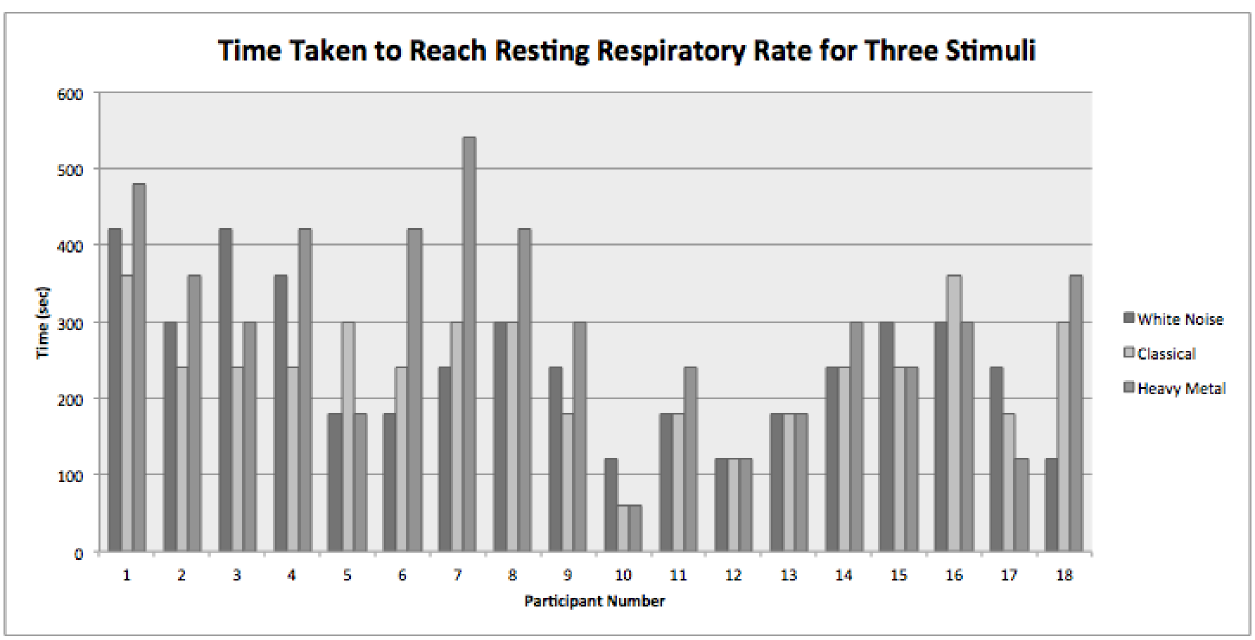

Figure 6. Time taken by each participant to reach resting respiratory rate for all three stimuli.

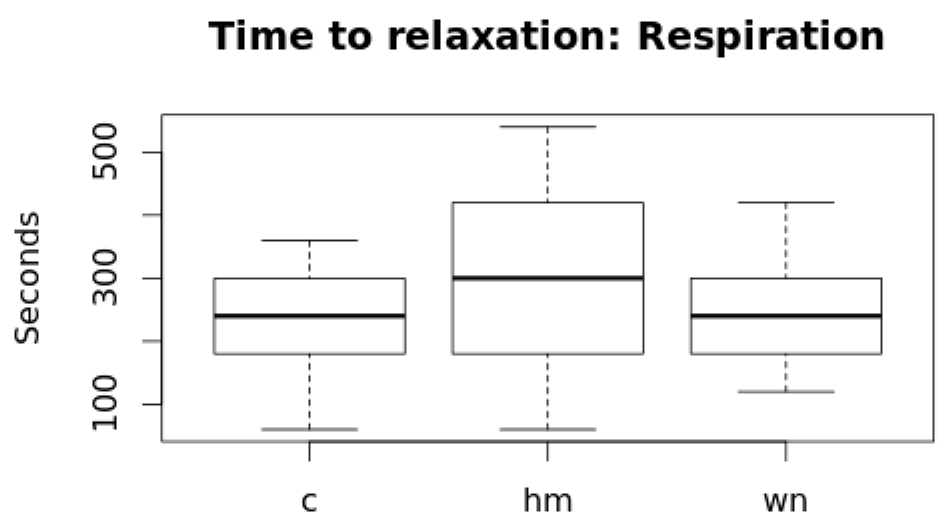

Figure 7. Average relaxation time for respiratory rate for classical music (c), heavy metal music (hm), and white noise (wn). See Figure 5 for the explanation of the generation of this plot.

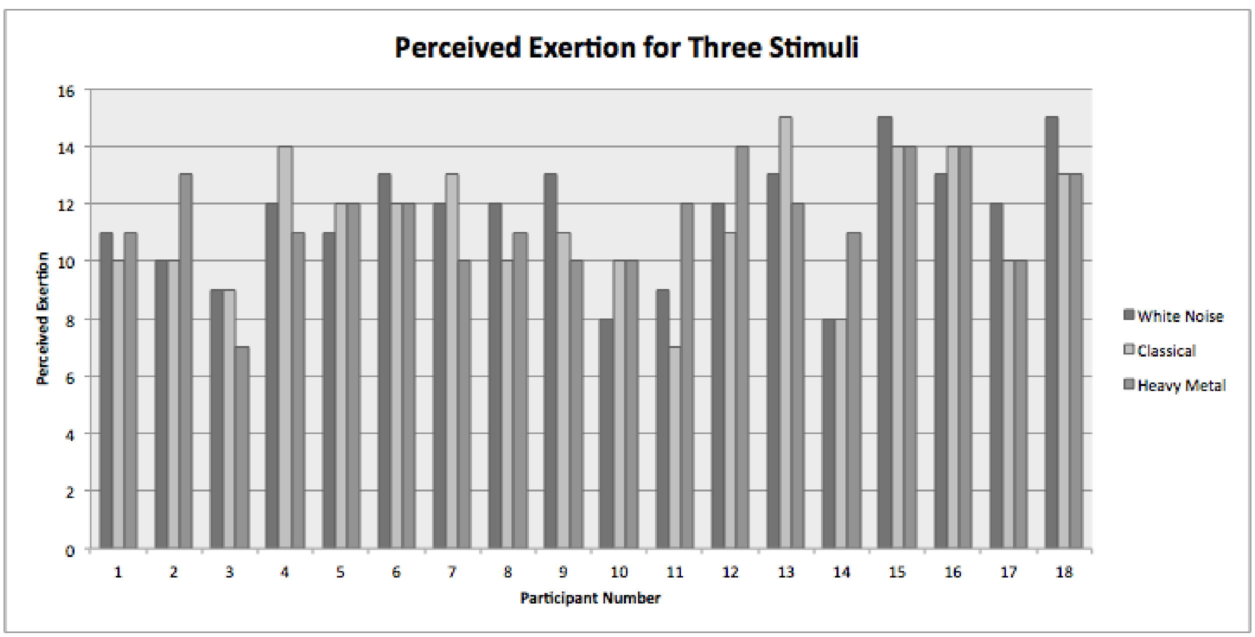

Figure 8. Perceived exertion for all three stimuli for each participant.

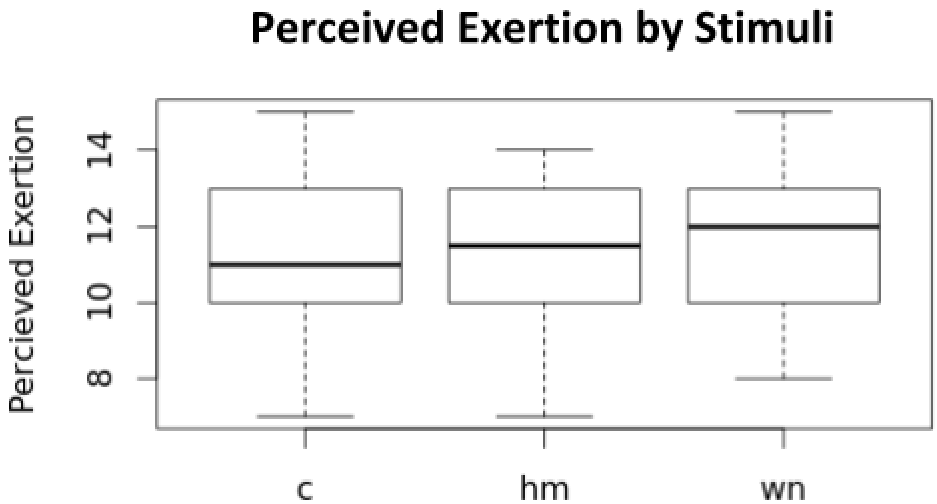

Figure 9. Average perceived exertion for classical music (c), heavy metal music (hm), and white noise (wn). See Figure 5 for the explanation of the generation of this plot.