The Physiological Response to Music Tempo: The Investigation of the "Pump-Up" Song

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Abstract:

Music as a therapeutic tool has well been documented and studied; however, concrete data examining the direct, rapid response of the body to music is controversial. Focusing on these parasympathetic and sympathetic responses, the common idea of fast-paced music as a "pump-up" tactic used before sports events to energize the players and the crowd was investigated. More specifically, a correlation between tempo and biorhythm, accompanied by maximal muscle contraction (MMC) and reaction time, was studied. Six females and seven males between the ages of 18-25 from the University of Wisconsin-Madison participated in the study. For each participant, four physiological markers (blood pressure, pulse, MMC, and reaction time) were measured in response to three different music tempos. The three distinct music samples were 60 beats per minute (bpm), 120 bpm and 200 bpm. For each participant a baseline, relaxation control, and excitation control were taken for all four physiological markers. Following these measurements, each participant listened to the three music samples in random order while the same sequence of physiological markers was measured. A statistical analysis was performed using a T-test: Paired Two Sample for Means. For pulse, MMC, and reaction time baseline and trial value differences were statistically insignificant. Blood pressure analysis showed statistically significant changes. Furthermore, trends in MMC and reaction time were noted. The results of the study do not support the proposed hypothesis involving song tempo and physiological responses.

Introduction:

The use of music as a temporary anti-anxiety is well known, including its ability to uplift the spirit and provide a diversion from mental concerns (Scheck and Berger, 2006). Additionally, it is acknowledged that music is most relaxing at 60bpm (Holm and Fitzmaurice, 2008). Given that the autonomic nervous system (ANS) is both associated with the maintenance of physiological homeostasis and the response to stimuli, the ANS may serve as one path by which music exerts its effects on the body. Simply stated, the autonomic nervous system is divided into two divisions; sympathetic (SNS), which is involved in excitatory responses, and parasympathetic (PNS), which promotes relaxation. In this manner, the ANS regulates a majority of the body's physiological systems. For example, chronotropic control of the heart, the timing of the heart beat, is achieved through the interaction of the sympathetic and parasympathetic division of the nervous system (Ellis, 2009), with the parasympathetic division mainly regulating resting function (Levy, 1971; Porges, 1992). During sensory stimulation, such as music exposure, the PNS and SNS generate responses to the presented stimuli. While it has been shown that relaxing and music creates a parasympathetic response, it is supposed that fast tempo music will cause similar responses to that of an environmental stressor, causing a sympathetic response.

Currently, concrete data examining the direct, rapid response of the body to music is lacking and contradictory. Data from Cockertown et.al (1997) shows no difference in heart rate due to music exposure during cognitive testing. Similarly, in the experiment by Yamamoto et. al (2003) on pre-exercise listening and exercise performance, no significant changes in heart rate were observed from no-music to music trials. Contrarily, Edworthy and Waring (2006) showed that fast, loud music correlated with faster heart rate in their experiment examining the effects of music on treadmill exercise. In regards to another physiological marker, Cassidy and MacDonald (2010) showed increased response speed with exposure to fast tempo music. Schneck and Berger (2006) demonstrated that exposure to slow tempo music calms a person, and consequently increases concentration.

Furthermore, music exposure elicits both emotional and physiological responses, and it is difficult to separate the two. The previous experiments by Cassidy and MacDonald (2010) as well as Witvliet and Vrana (2007) show the importance of music likeness in the physiological response. Specifically, Witvliet and Vrana demonstrated that heart rate increased when participants listened to music they liked. While information regarding the mechanistic cause for a response to music is lacking, previous studies show a synchronization of heart rate and neuronal firing with music rhythm. "The first element of music an organism instinctively detects and entrains through neural mechanisms is tempo (Schneck and Berger, 2006)."

It is this correlation between tempo and biorhythms that was further investigated. Culturally, fast tempo music is used before sports events to energize athletes and the crowd. It is assumed that playing music has advantages because of its ability to energize or "pump-up" the players in preparation for the competition. The experiment conducted is novel as it investigated the physiological response to the "pump-up" song by measuring the changes in several physiological markers in response to differing music tempos, varying from slow to fast. The combination of several tempos of music with four different biomarkers will allow us to create a more concrete answer in the response of the body to music. We hypothesize that each tempo of music elicits physiological responses with different efficacies and expect a fast tempo song to cause an increase in blood pressure, pulse, and maximal muscle tension and a decrease in reaction time.

Materials:

Electromyogram
Dynamometer
BIOPAC Program
Electronic sphygmomanometer
Pulse Oximeter
"The Online Reaction Time Test"

Methods:

Participants

Fourteen University of Wisconsin-Madison students, six females and seven males, between 18 and 25 years of age participated in the study. All were deemed healthy and physically capable of completing the required tasks. Healthy was defined as lacking symptoms of illness and physically capable defined as possessing the ability to complete ten jumping jacks and maximally exert grip strength at regular intervals. A consent form was obtained from each participant prior to participation (Appendix).

Music

Music samples were chosen at three distinct tempos: *Largo* by Handel (60bpm), *Y* by MBLAQ (120bpm) and *Analirritatio* by Barbaque (200bpm). Instrumental, unique samples were chosen to control for the influences of lyrics and listener familiarity. All songs were played for four minutes through headphones with the iTunes program at a predetermined, consistent volume. The order of songs was chosen at random using the "shuffle" function of iTunes.

Measurements

In order to assess physiological changes in response to the three different music tempos, the maximal muscle contraction (MMC), blood pressure, pulse and reaction time were measured. MMC was measured via an electromyogram (EMG) and dynamometer. The maximal force was observed and recorded using the BIOPAC 3.0.4 program in accordance with the manufacturer's protocol (Pflanzer, Uyehara, and McMullen, 1998). Blood pressure and pulse were taken using a digital sphygmomanometer. In order to assure accurate readings, pulse was also measured using a pulse oximeter, which was placed on the middle or second finger of the participant and recorded simultaneously with the values from the sphygmomanometer. Reaction time was recorded using an online reaction time test found at http://getyourwebsitehere.com/jswb/rttest01.html, which measured an average reaction time from five trials (Allen, 2002).

Procedure

Upon participant arrival and after two to five minutes of rest, blood pressure, pulse, MMC and reaction time were recorded to establish their respective baseline readings. This was then followed by, first, a relaxation control of ten deep breaths and then an excitation control of ten jumping jacks. Blood pressure, pulse, MMC and reaction time were recorded for each control. After the controls, each participant listened to the three different music samples. After three minutes of listening, blood pressure, pulse, and MMC were recorded as the subject continued listening to the music. At the conclusion of each music sample, reaction time was recorded. The order of measurements was maintained throughout all trials and for all participants. A rest period of three minutes was included between each music sample. After each rest period, participant blood pressure and pulse baseline readings were remeasured.

Statistical Analysis

A statistical analysis was performed using a T-test: Paired Two Sample for Means, and p-values of less than 0.05 were considered statistically significant. All data was normalized to the subjects' baseline and presented as a mean (± SD). Graphs comparing trials to baseline values were also constructed.

Results:

Pulse data analysis involved comparing each trial to an average baseline measurement, composed of a primary baseline and two reestablished baselines between trials. Exposure to all three tempos demonstrated an increase in pulse rate. At 60bpm, the pulse was 1.0078 (± 0.0718) times higher than the baseline. With increased tempos of 120bpm and 200bpm, the respective pulse increases were 0.9939 (± 0.0755) and 1.0168 (± 0.0548) (Figure 1). The baseline recording was compared to 60bpm (t=2.18, DF=12, p=0.7021), 120 bpm (t=2.18, DF=12, p=0.7758) and 200 bpm (t=2.18, DF=12, p=0.2904). This data was found to be statistically insignificant. Pulse measurements were made using both a sphygmomanometer and pulse oximeter to confirm the precision of the measurements. There was no statistical difference between the values.

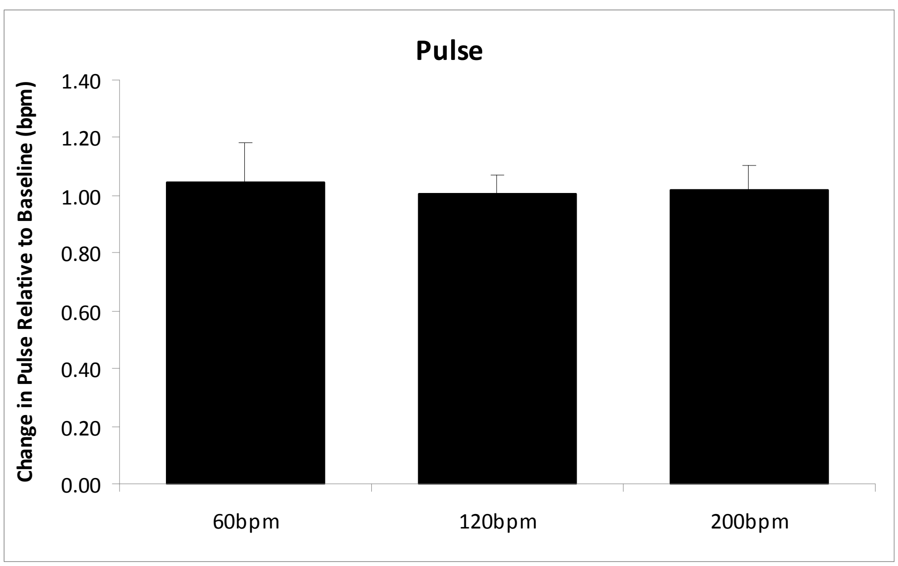

Figure 1: The effects of three different music tempos on subjects' mean pulse rate. All pulse rates were normalized to the subjects' respective averaged baseline recordings. Values represent mean ± SD (n=12).

For blood pressure data, the music tempos elicited systolic and diastolic values below those of the average baselines in all tests, except for 120 bpm diastolic, which increased slightly above the average baseline. A ratio was generated of (trial data)/(average baseline data) and was used in statistical analysis. A tempo of 60 bpm induced systolic and diastolic values 0.9682 (± 0.0556) and 0.9631 (± 0.0465) times the average baseline. The 120 bpm tempo had systolic and diastolic values 0.9561 (± 0.0608) and 1.0060 (± 0.0659) times the average baseline. At a tempo of 200 bpm, the systolic value was 0.9676 (± 0.0445) times the baseline, and the diastolic value was 0.9993 (± 0.0583) times the average baseline. When observing systolic values for the three music tempos, the highest value was achieved with 60 bpm, followed by 200 bpm, then 120 bpm. For diastolic values, the reverse order was observed (Figure 2). Systolic values were statistically different from the baseline for 120 bpm (t=2.18, DF=12, p=0.0232) and 200 bpm (t=2.18, DF=12, p=0.0222). The diastolic value for 60 bpm (t=2.18, DF=12, p=0.0143) was statistically significant as well. However, the systolic values for 60 bpm (t=2.18, DF=12, p=0.0619), the diastolic for 120 bpm (t=2.18, DF=12, p=0.7484) and the diastolic for 200 bpm (t=2.18, DF=12, p=0.9636) were not statistically significant.

Due to variability in blood pressure data for a given subject, mean arterial blood pressures were calculated (diastolic + 1/3(pulse pressure)) for all observations and also used in analysis (Figure 2). Paired t-tests for means now demonstrated only the fast control and 60 bpm trials to have statistically significant data; t=1.78, DF=12, p=.0317 and t=1.78, DF=12, p=.0105 respectively. The values for the slow control (t=1.78, DF=12, p=.4407), 120 bpm trials (t=1.78, DF=12, p=.2275), and 200 bpm trials (t=1.78, DF=12, p=.05224) gave statistically insignificant results.

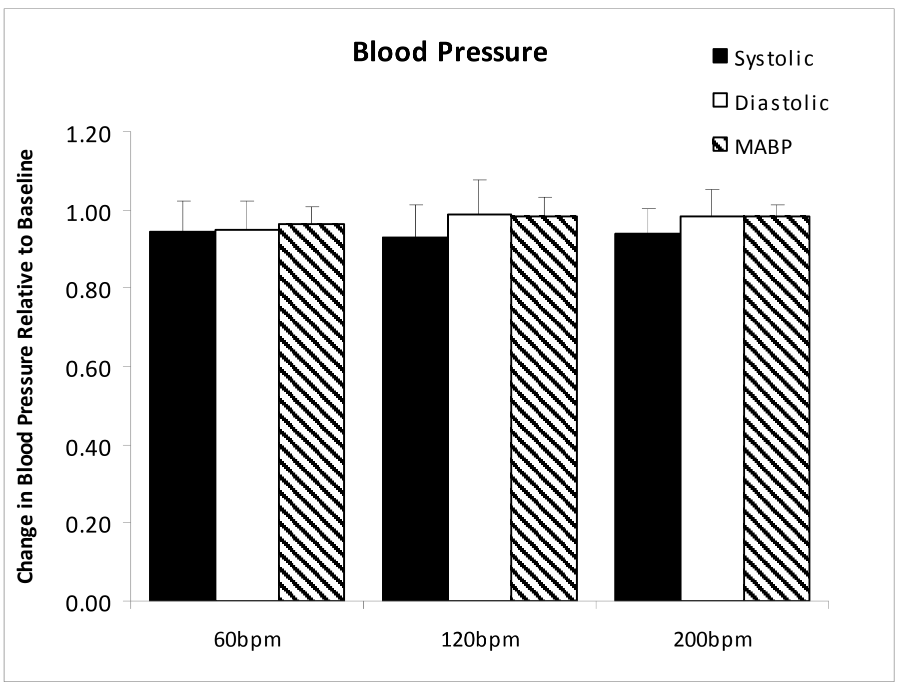

Figure 2: Comparison of systolic blood pressure, diastolic blood pressure and mean arterial blood pressure at the three different music tempos. All subjects were normalized to their respective mean baselines. Values represent mean ± SD (n=12).

Music tempos of 60bpm and 200bpm gave rise to increased MMC as compared to the baseline reading. Subjects exhibited a MMC of 1.0608 (± 0.4096) times higher than the baseline in response to the 60bpm tempo, with tempos of 120 bpm and 200 bpm eliciting MMCs of 0.9660 (± 0.5400) and 1.0244 (± 0.3185), respectively (Figure 3). The difference between the baseline and the 60 bpm (t=2.18, DF=12, p=0.6021), 120 bpm (t=2.18, DF=12, p=0.8241) and 200 bpm trials (t=2.18, DF=12, p=0.7872) were not statistically significant.

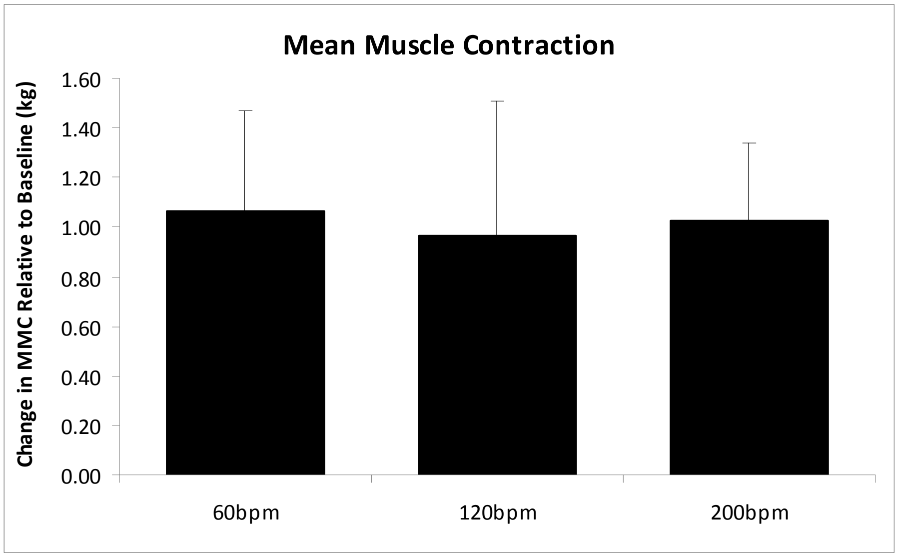

Figure 3: Mean muscle contraction averages in response to the three different music tempos. All subjects were normalized to their respective baselines. Values represent mean ± SD (n=13).

In response to increasing music tempos, subject reaction times demonstrated a downward trend. With tempos of 60bpm (1.1114 (± 0.3059)) and 120bpm (1.0171 (± 0.1154)), reaction times are increased compared to the baseline. At 200bpm (0.9675 (± 0.1457)), reaction time is slightly decreased, in comparison to the baseline (Figure 4). In comparison to the baseline, 60bpm (t=2.18, DF=12, p=0.2460), 120bpm (t=2.18, DF=12, p=0.6769) and 200bpm (t=2.18, DF=12, p=0.3398) tempos did not exhibit statistical significance. Reaction time data was also compared between 60 bpm and 200 bpm in order to examine differences between the two most opposing trials. This data was not significant (t=2.18, DF=12, p=0.3398).

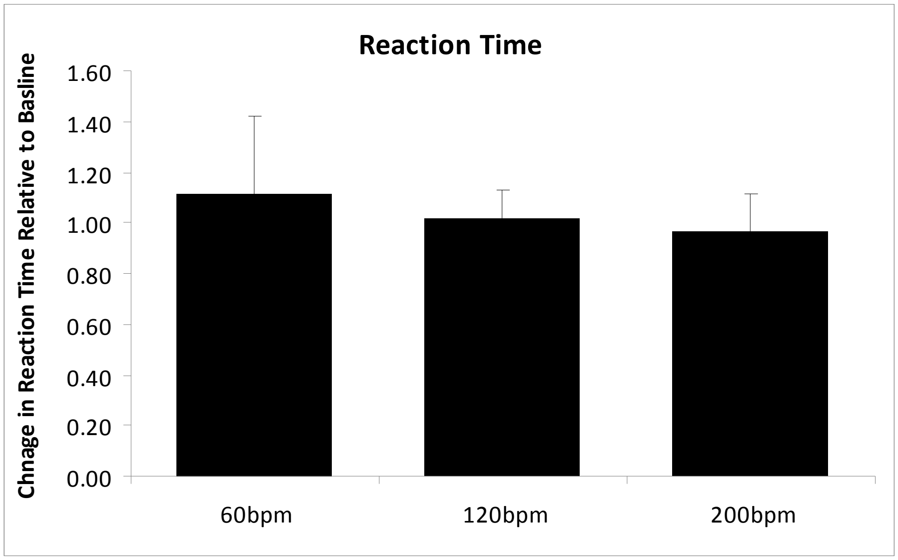

Figure 4: Comparison of mean reaction times after listening to each of the three different music tempos. All subjects were normalized to their respective baselines. Values represent mean ± SD (n=13).

A comparison between male and female reaction times for each trial was also performed. For males, the reaction time was increased over the baseline by 1.0882 (± 0.4362) times at 60 bpm. For both 120 bpm and 200 bpm, reaction time was decreased by 0.9238 (± 0.2410) and 0.9516 (± 0.2643), respectively (Figure 5). The data was not statistically significant at 60 bpm (t=2.36, DF=7, p=0.5851), 120 bpm (t=2.36, DF=7, p=0.4007) or 200 bpm (t=2.36, DF=7, p=0.6210). For females, at 60 bpm the reaction time was increased 1.0242 (±0.2016) times and to 1.0392 (±0.0980) at 120 bpm. It was decreased 0.8953 (±0.0871) times at 200 bpm. The 60 bpm (t=2.57, DF=5, p=0.7991) and 120 bpm (t=2.57, DF=5, p=0.4127) were not statistically significant. At 200 bpm (t=2.57, DF=5, p=0.0434), the data is significant.

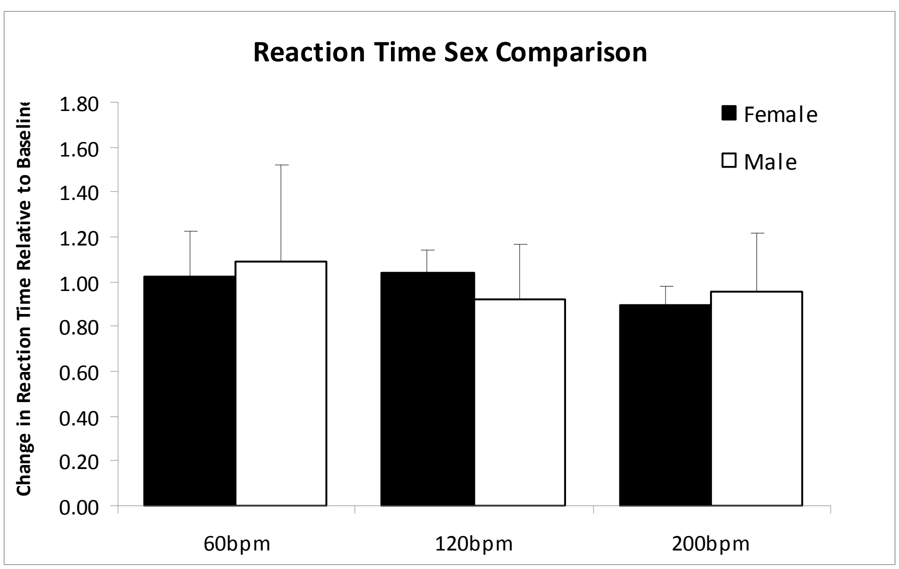

Figure 5: Comparison between changes in reaction time relative to baseline in males and females (n=7, n=6).

Discussion:

The results suggest that music tempo does not have a statistically significant effect on pulse, MMC, or reaction time. However, the blood pressure results demonstrate statistically significant differences between trial and baseline data, possibly indicating a considerable physiological response. Overall, the hypothesis is not supported by these results. These findings do not support the common idea that a “pump-up” song will improve an athlete’s performance through direct physiological changes.

Significant differences from baseline in music-exposure trials were only noted in blood pressure measurements. As seen in the 60 bpm trials, the diastolic values were statistically different from the average baseline values and were less than the comparative baseline. Interestingly, while systolic blood pressure measurements in the 120 bpm and 200 bpm trials were statistically different from the average baseline, the average blood pressure while listening to music was less than that of the baseline; thus opposing the proposed hypothesis. One may speculate that music, no matter the tempo, will decrease the blood pressure of the listener. From previous research, one can assume the subjective nature of the music experience is an important factor in a person’s physiological response to music; suggesting music likeness and familiarity are supposed to contribute to a response. Accordingly, Schneck and Berger state that when people are exposed to an unfamiliar song they prefer music with higher tempos (2006). The above hypothesis that music at various tempos will elicit a similar physiological response is also supported by the lack of statistical difference between the blood pressures of the subjects when exposed to the 60 bpm or 200 bpm songs. Further research and experimentation is needed to elaborate and support this hypothesis.

Overall, a mechanistic explanation for these findings is lacking. While the parasympathetic nervous system can affect the heart directly, no notable changes in pulse were detected and therefore action via the heart is unlikely. We speculate the effects may be due to vasodilatation of the systemic arterioles. It should be noted that the majority of changes were seen in the systolic blood pressure. However, in analysis of the 60 bpm trial compared to the average baseline, only the diastolic pressure showed statistical significance, but these differences may actually be due to individual variation. Correspondingly, the differences in the systolic pressure may also be due to variations in preload volume between different ventricle contractions. Furthermore, although some data presented statistically significant results, one may question the physiological significance of the findings. While some subjects’ trial readings differ from their average baseline by 15-20 mmHg, the majority of subjects only show differences of 5-10 mmHg. Additionally, it is difficult to discern the actual effects of music on the blood pressure due to confounding variables including hydration, caffeine, and other extraneous variables.

Further analysis using mean arterial blood pressure (MABP), which may be more indicative of actual cardiac output, demonstrates that only the 60 bpm trial produced statistically significant values. In concordance with Schneck and Berger, our experiment shows that slow music tempo is able to elicit a calming, parasympathetic response (2006).

MMC values were statistically insignificant but did produce a trend when comparing fast tempo and baseline measurements. MMC for subjects exposed to music at 200 bpm was larger than their baseline MMC in 62% of participants (Figure 2). For the 60 bpm and 120 bpm trials, no trends are evident. With a larger sample size, it may be possible to discern a significant trend in the 200 bpm trial. There are also two distinct outliers in the MMC data. Participants seven and nine both produced music trial MMC values much greater than their baseline. This inconsistency could possibly be due to unfamiliarity with the equipment when performing their baseline test. Another confounding factor is the occurrence of fatigue in later trials, which may have lead to discrepancy within the data. Nevertheless, before conducting MMC trials on participants, it was shown that muscle fatigue should not be a factor. A female and male were tested for muscle fatigue by collecting MMC data over a period of time equivalent to the length of the actual experiment, with equivalent rest time. Neither subject showed muscle fatigue upon completing the simulated trials, indicating that fatigue should not affect the overall data of the experiment (Figure 6). In the experiment, the tempo trials were randomized so that each subject had a different order of music exposure, and therefore we can only speculate the effects of muscle fatigue.

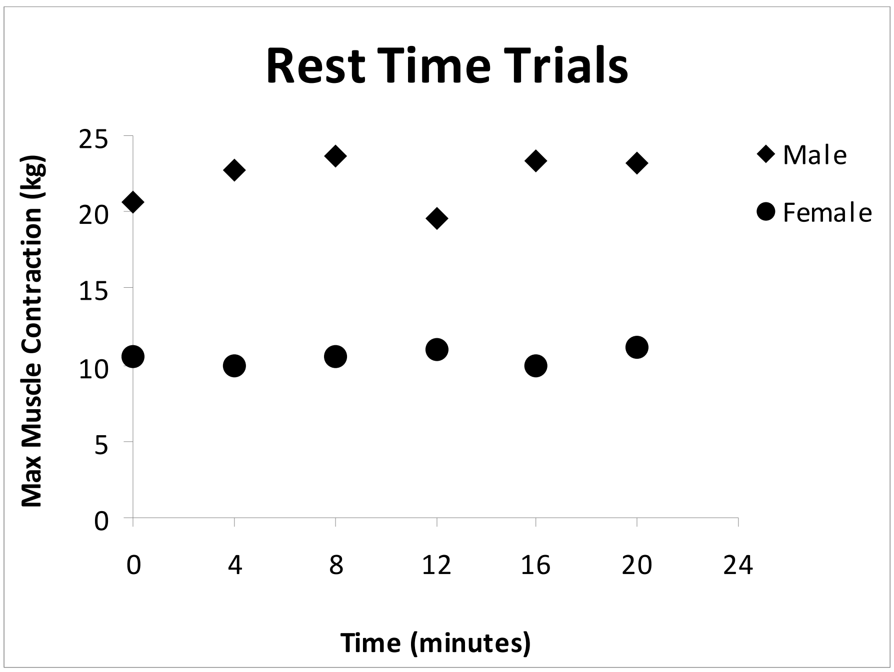

Figure 6: The effects of mean muscle contraction were examined prior to the start of the study for both males and females. Mean muscle contraction was recorded every 4 minutes for 20 minutes to depict the actual study (n=1, n=1).

Reaction time was not statistically significant but did produce a noticeable trend. Decreased mean reaction time was noted after listening to a 200bpm tempo song. Tempos of 120bpm and 60bpm exhibited increased mean reaction times, with 60bpm exhibiting the greatest increase in response time from the baseline. This indicates that slow and medium tempo music slows one's response time, while a fast tempo song leads to a faster response. This trend further supports previous research. In a study by Cassidy and MacDonald, increasing the tempo of experimenter-selected music resulted in faster performance (2011). The data also produced similar trends between males and females. Both genders followed analogous changes in reaction time for each trial. In both males and females, the 60 bpm trial elicited the slowest reaction time while 200 bpm elicited the fastest reaction times when compared to baseline values. It was also noted that males have larger error margins than females (Figure 5).

In measurements throughout the experiment, both controls elicited similar responses to the assumed physiological response, indicating both were well designed controls. The fast control gave statistically significant values when compared to the baselines; however, the slow control elicited statistically insignificant responses when compared to the baseline. An important factor in the slow control, and all trial results, was the surrounding environment. Due to constraints in available testing times, subjects participated in the study during various days and times. Some trials were conducted during time periods in which there were various distractions including noise, movement, and other experimenters, all of which can affect the participants' attention. Contrarily, other participants were tested in a quiet atmosphere. Therefore, the surrounding environment presented uncontrollable variables that consequently could have influenced the data. Another uncontrollable factor in the experiment was the long testing period. Each individual experiment lasted approximately 30 minutes, allowing the participant to become familiarized to the study and possibly bored. The prolonged test time also included long periods of sitting, possibly affecting blood pressure and pulse data. An important limiting factor of the study is the small sample size. With less than 10 participants from each gender, it is difficult to see any grand trends or statistical significance. A larger sample size could allow the MMC and reaction time trends to be further explored.

In conclusion, the results of the experiment do not support the hypothesis that fast-tempo music will elicit a direct sympathetic response. The weak trends in MMC and reaction time are not sufficient to support our hypothesis and also illustrate the importance of large sample sizes and further investigation. However, the collected blood pressure data supports the already established idea that slow-tempo music can elicit a parasympathetic response, which is in concordance with results obtained by Schneck and Berger (2006). The reaction time data also supports that fast-tempo music elicits faster responses when compared to slow-tempo music (Cassidy and MacDonald, 2011). Overall, the data is divisive. Reaction time data and the MMC trend demonstrate fast-tempo music improves performance by decreasing reaction time and increasing muscle contraction, while the pulse data shows no specific trend and blood pressure values show a decrease in comparison to the average baseline. Therefore, further investigation is needed to examine these inconsistencies.

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Appendix:

Figure A: Consent Form

I ______________________________ agree to be involved in the Physiology 435 research study involving music perception. I understand that my reaction time, maximum muscle contraction force (EMG) and blood pressure will be recorded. If at any time I feel uncomfortable or do not want to continue participating, I am able to leave the experiment, and my data will not be used. I understand I will be performing simple aerobic activities. I allow my information and results to be used and published, yet my name or any identifiers will not be published or associated with my data.

Signature: _______________________________

Date: _____________________