The Implications of Musical Stimuli on Human Physiological Value

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Abstract
The main purpose of this research was to study the effects of musical stimuli on physiological outcomes including heart rate, blood pressure, and reaction time. A sample population of 50 students from the University of Wisconsin-Madison were included in our research. This study used non-probability sampling to select participants from the Physiology 435 class as the sample frame. The experiment consisted of two measuring techniques: Omron Digital Automatic Blood Pressure Monitor and a ComFit Cuff, and an Online Reaction Time Test generated at the University of Washington. Participants engaged in both techniques in a set experimentation timeline to measure physiological outcomes while the musical stimuli was applied. We hypothesized classical music could cause a decrease in heart rate, blood pressure, and maintain reaction time, while death metal music would increase heart rate, blood pressure, and decrease reaction time. The significant findings in this experiment were reaction time got faster for death metal music (p-value=0.0006) and classical music (p-value=0.0143). Significant change in systolic pressure for both stimuli when compared to the initial baseline data was also observed (death metal p-value=0.0349, classical p-value=0.0463), but no statistically significant evidence was acquired to reject the null hypothesis. The implications of musical stimuli on physiological outcomes is further discussed.
Introduction

In the 21st century, humans are increasingly surrounding themselves with music. In the car, in the elevator, walking down the street, one is almost certain to hear music throughout their day. Experiments into how musical stimuli affects the human body have been a point of study for hundreds of years (Menon & Levitin, 2005). Listening to music has more impacts on your brain than just the auditory system; regions of your brain that control emotion, attention, cognitive function memory, and reaction are also influenced by the melody (Harvard, 2018 and Kalinowska et. al, 2013). A study by Deutsches Aerzteblatt Online found that listening to classical music, particularly Mozart and Strauss, results in lower blood pressure and heart rate (Trappe & Voit, 2016). Investigating the full physiological effects that music has on the body and reaction time can potentially be applied to real life scenarios where music is prevalent such as driving a car, or studying. Reaction time is the time interval between the arrival of a stimulus at a receptor inside the body and the external response of the body to the stimulus (Halpern, 1986).

As music is played aloud, sound waves enter through the outer ear and vibrate the eardrum and the bones of the middle ear (malleus, incus, and stapes), then transfer the sound vibrations into the cochlea of the inner ear. The hair cells in the cochlea bend back and forth to generate afferent nerve impulses through the auditory nerve to the central nervous system (CNS) (Hudspeth, 1989). The CNS, via neurotransmitter, can affect the parasympathetic or sympathetic division of the autonomic nervous system. For example, it can increase or decrease metrics such as blood pressure and/or heart rate. Similarly, there is a complex neural pathway when measuring reaction time in response to an auditory stimuli. Although it is measured entirely outside of the
body, reaction time depends upon this neural pathway. Once the CNS obtains the incoming auditory stimulus, in the process previously described, the efferent motor neurons of the somatic nervous system send the stimulus to the skeletal muscle of the effector tissue (Widmaier, Raff, & Strang, 2019).

Further action was taken to investigate how musical stimuli affects the reaction time, heart rate, and blood pressure. Reaction time can be crucial when performing various activities such as operating machinery or driving a vehicle. If a distraction, such as an auditory stimuli, is delaying reaction time, then this may negatively impact the performance of the task at hand. By assessing if there is a change in reaction time upon two different musical stimuli, it will be evinced whether or not listening to different genres of music may alter a person’s ability to react in a slower or faster amount of time, much like listening to the radio while driving a car. Measuring changes in heart rate and blood pressure can illustrate the changes that the autonomic nervous system is experiencing due to musical stimuli.

We hypothesized that intense death metal music would increase heart rate and blood pressure, but slow down reaction time in comparison to the baseline measurements. Death metal music has an intense upbeat tempo that may stimulate excitatory signals in the body leading to higher values of heart rate and blood pressure. Furthermore, the aggressive rhythm of the song may distract the participants’ attention from the task at hand; these constant distractions can lead to a delay in reaction time. In contrast, we hypothesized the less aggressive, classical music would decrease heart rate and blood pressure relative to the baseline measurements, and maintain reaction time at a value comparable to the baseline measurement. Studies show that listening to classical music has a tendency to lower blood pressure and decrease epinephrine concentrations in the blood, demonstrating the opposite effect on the sympathetic nervous system (Trappe,
2016). Additionally, the relaxing melody may help participants focus on the task, thus maintaining reaction time at a measurement more comparable to the baseline reaction time. We hypothesize the intensity of musical stimuli will have an indirect correlation with change in reaction time, and a direct correlation with change in sympathetic nervous system activity.

**Materials**

While participants were listening to different genres of music, two different measuring techniques were used to record heart rate (HR), blood pressure (BP), and reaction time. Blood pressure (mmHg) and heart rate (BPM) were measured using an Omron Digital Automatic Blood Pressure Monitor and a ComFit Cuff (Model: BP791IT, Omron Healthcare, INC. Lake Forest, IL 60045). The last variable, reaction time, was measured in seconds using the *Online Reaction Time Test* created at the University of Washington. The program was run on a MacBook Pro laptop where the data was organized using a Microsoft Excel spreadsheet. The stopwatch function was used on an IPhone X to keep track of time intervals. Participants listened to music throughout the experiment through a pair of Sony AE headphones while the music was streamed through YouTube. The songs used in this study were “Widowmaker” by The Black Dahlia Murder and “Claire de Lune” by Nina Postolovskaya.

**Methods**

Fifty students ages 20-28 from the University of Wisconsin -Madison 435 Physiology class were used to test what effects various music genres (death metal vs. classical) had on blood pressure, heart rate, and reaction time. Each of these students had to sign a consent form to participate in the study, then took a preliminary survey asking if they regularly listen to classical
or death metal music, if they have any hearing impairments, or if they are colorblind. Participants who did listen to either of these genres regularly, had hearing impairments, or were colorblind were not used in the study.

A private room was utilized to eliminate distractions and to give the participants plenty of space. Upon entering, participants sat for one minute without any equipment on to allow their vitals to reach their resting rates. Blood pressure (BP), heart rate (HR), and reaction time data were then taken without any stimulus as a baseline. In order to record and collect proper blood pressure data, the following steps were taken in preparing the equipment. An Omron automatic blood pressure monitor unit was obtained to read the blood pressure and heart rate of the subject. After the subject was seated and relaxed with their legs uncrossed and on the floor for one minute, as previously stated, the blood pressure cuff was then placed approximately 5 cm above the antecubital fossa and positioned over the brachial artery on the subject’s nondominant arm, while the subject was in a seated position with his/her arm resting at heart level on a wooden table. After the start button was pressed, the cuff was inflated and released, the BP was recorded in mm/Hg and heart rate was recorded in beats per minute. Reaction time was then recorded in seconds using the Online Reaction Time Test while each subject was in a seated position facing a screen with the red, yellow, and green stoplight on the screen (Allen, 2002). The subject was prompted to click every time the light turned green for a total of five times, and the program averaged their reaction time in seconds. Sony headphones were connected to a Apple Macbook laptop and the headphones were given to the participant to place over their ears. The Macbook laptop was set to 8 squares of volume which was an average volume of 64.1 decibels throughout the two songs used. After the participant had been allowed to listen to each musical stimuli for 30 seconds, BP, HR, and reaction time data were taken for that particular music. A one minute
break was given in between the transition of each musical stimuli where BP and HR were taken again to measure the baseline in between songs. The order of the musical stimuli and the order of the tests was alternated for each participant in order to eliminate any BP, HR, or reaction time correlation that may be associated with the order of the tests. Data was recorded and analyzed on Microsoft excel.

**Preliminary Survey**

**PRELIMINARY SURVEY (Please Circle Options or Fill as needed)**

Do you regularly listen to classical music?
YES       NO
If so, how frequently?

Do you regularly listen to death metal music?
YES       NO
If so, how frequently?

What is your age?
(FILL) ______

What is your sex?
MALE     FEMALE     OTHER     PREFER NOT TO SAY

Do you have any hearing impairments?
Yes    No

Are you color blind?
Yes    No
Data Analysis

Statistical t-tests, averages, standard deviation, and percent change were calculated on Microsoft Excel. The HR, BP, and reaction time data was divided into three different musical categories: baseline (no music), death metal, and classical. Once the data was divided into these 3 different categories, the average, standard deviation, and percent change was calculated. A paired two-tailed t-test assuming unequal variances was used to obtain a p-value comparing baseline to classical, baseline to death metal, and the first baseline to the second baseline. An Unpaired two-tailed t-test assuming unequal variances was used to compare classical one to classical two, death metal one to death metal two, and death metal to classical for each of the physiological data values (HR, BP, and reaction time). If the calculated p-value was less than 0.05, then the data was determined to be statistically significant. Box and whisker plots and box
plots were used to visually demonstrate the statistical difference in measurements of BP, HR, and reaction time when exposed to two different audio stimuli.

Positive Controls

The HR, BP, and reaction time were assessed with a stimulus such as running up and down a staircase, legs crossed, and watching tv, respectively. The Omron automatic pressure cuff was used to assess blood pressure and heart rate, and reaction time was tested using the Online Reaction time Test (Allen, 2002). Experimenters participated in the positive control tests in order to confirm functionality of equipment and tests. Baseline measurements for all tests were acquired before positive control tests for HR, BP, and reaction time were taken one time for each person, these baseline average measurements were 77 +/- 23.82 bpm, 109.6 +/- 10.52 mmHg (systolic), and 0.215 +/- 0.037s, respectively. Average measurements for positive control tests were acquired for HR, BP, and reaction time after baseline measurements. To increase heart rate the experimenter had to run up the stairs and then take HR (Figure and Table 1). Blood pressure was altered by having the experimenter cross their legs which increased blood pressure (Figure and Table 2). Lastly, to change reaction time the experimenter had to watch a TV show and still click every time the light turned green (Figure and Table 3). Average measurements were 112 +/- 8.17 bpm, 123.4 +/- 20.65 mmHg (systolic), and 0.2958 +/- 0.0514 s respectively. All measurements were expected to increase in the period of time tested. These variables indicate proper functionality of equipment and desired variable outcomes.
**Figure 1:** Positive control on Heart Rate.
Change in heart rate was detected by the Omron Automatic Blood Pressure and Heart Rate Machine after the experimenter (n=1) had to run up and down the stairs. The overall percent change was 59.4% (n=5).

<table>
<thead>
<tr>
<th></th>
<th>Trial before Physical Exercise</th>
<th>Trial after Physical Exercise</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Heart Rate (BPM)</td>
<td>77.4</td>
<td>123.4</td>
<td>59.4</td>
</tr>
<tr>
<td>Standard Deviation (BPM)</td>
<td>23.8</td>
<td>20.64</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1:** Summary data for the positive control on heart rate. The table above shows heart rate did increase for all experimenters (n=5) as expected when they ran up and down stairs which induced a percent change of 59.4%.

**Figure 2:** Positive control on blood pressure. After the experimenter was asked to cross her legs (n=1), it was evident that blood pressure did increase with an overall percent change of 2.5% (n=5).
<table>
<thead>
<tr>
<th></th>
<th>Trial Before Crossing Legs</th>
<th>Trial after Crossing Legs</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Systolic Blood Pressure (mmHg)</td>
<td>109.6</td>
<td>112.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Standard Deviation (mmHg)</td>
<td>10.526</td>
<td>8.172</td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Summary table on blood pressure. The table shows before and after the experimenters had to cross their legs (n=5). The blood pressure increased as expected for all experimenters with a percent change of 2.5%.

![Change in Reaction Time When an External Distraction is Present](chart.png)

**Figure 3: Positive control for reaction time.**
When an external distraction of a TV show was added the reaction time decreased as expected for this experimenter (n=1). The overall percent change for reaction time is 37.6% (n=5).

<table>
<thead>
<tr>
<th></th>
<th>Reaction Time without External Stimulus of Television</th>
<th>Reaction Time with External Stimulus of Television</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Reaction Time (seconds)</td>
<td>0.215</td>
<td>0.2958</td>
<td>37.6</td>
</tr>
<tr>
<td>Standard Deviation (seconds)</td>
<td>0.037</td>
<td>0.0515</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Summary of positive control results for reaction time. The table shows data for experimenters (n=5) and reaction time. Reaction time increased as expected in the presence of an external distraction with a percent change of 37.6%.
**Negative Controls**

To evaluate the negative control, the five experimenters were used as subjects (n=5). The heart rate, blood pressure, and reaction times were assessed without inducing any stimulus in order to get the resting values. These values were measured once and then measured again 10 minutes after in order to demonstrate the lack of change in resting value, these values can be seen summarized and visually graphed in tables and figures 4-6. The Omron automatic pressure cuff was used to assess resting blood pressure and heart rate and the *Online Reaction Time Test* used to assess baseline reaction time. The average reaction time for the first trial was 0.298 +/- 0.035 seconds, average HR was 78 +/- 31.6 BPM, and average systolic BP was 106 +/- 9.74 mmHg. These values were measured without any stimulus and exhibited no physiological change. After 10 minutes, we tested the baseline values for each experimenter again (n=5) to make sure it was an accurate negative control, the values were as follows; average reaction time 0.2938 +/- 0.030 seconds, average systolic HR was 80 +/- 26.7 BPM, and average BP was 105 mmHg +/- 10.15 mmHg. These negative control values provided sufficient evidence that the physiological values did not change over time.

<table>
<thead>
<tr>
<th></th>
<th>Trial at time 0 min</th>
<th>Trial at time 10 min</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Systolic Blood Pressure</strong></td>
<td>106 mmHg</td>
<td>105 mmHg</td>
<td>-1.19%</td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>9.74</td>
<td>10.15</td>
<td></td>
</tr>
</tbody>
</table>

*Table 4: Summary table of negative control on blood pressure.* Summary of negative control results for experimenters (n=5) and systolic blood pressure. Blood pressure minimally changed over a 10 minute time period without stimulus applied, as expected.
Figure 4- The above figure provides visual evidence for the change in blood pressure of a single experimenter (n=1). Overall, the percentage change for all experimenters (n=5) was 1.19%.

<table>
<thead>
<tr>
<th></th>
<th>Trial at time 0 min</th>
<th>Trial at time 10 min</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Heart Rate</strong></td>
<td>78 bpm</td>
<td>80 bpm</td>
<td><strong>2.56%</strong></td>
</tr>
<tr>
<td><strong>Standard Deviation</strong></td>
<td>31.6</td>
<td>26.7</td>
<td></td>
</tr>
</tbody>
</table>

Table 5: Summary table of negative control on heart rate. Summary of negative control results for experimenters (n=5) and heart rate. Heart rate minimally changed over a 10 minute time period without stimulus applied, as expected.

Figure 5- The above figure shows the change in heart rate for a single experimenter. The HR for this experimenter did not change in the 10 minute time frame given (n=1). Overall, the percentage change for all experimenters (n=5) was 2.56%.
Table 6: Summary table of negative control on Reaction Time. Summary of negative control results for experimenters (n=5) and reaction time. Reaction time minimally changed over a 10 minute time period without stimulus applied, as expected.

<table>
<thead>
<tr>
<th></th>
<th>Trial at time 0 min</th>
<th>Trial at time 10 min</th>
<th>Average % Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Reaction Time</td>
<td>0.2985</td>
<td>0.2938</td>
<td>1.60%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.035</td>
<td>0.030</td>
<td></td>
</tr>
</tbody>
</table>

Figure 6 - The above figure represents the change in reaction time for an experimenter after trials 1 and 2 (n=1). Overall, the average percentage change for all experimenters (n=5) was 1.60%.

Results

A total of 51 participants underwent testing, but one was excluded for color blindness.

Any participant that regularly listened to either classical or death metal music (more than 3 times a week), was asked not to complete the experiment and was excluded from the study. 20 males and 30 females participated in the study. The participants aged from 20-28 years old and were all involved in Physiology 435 at The University of Wisconsin-Madison.

A two tailed paired t-test assuming unequal variances was run between the two baseline values and the p-value was 0.00102 for MAP, 0.00005 for systolic pressure, 0.0535 for diastolic pressure, and 0.7333 for HR (Table 7). The p-value for BP was statistically significant, so when calculating the percent change and p-value for the BP in response to musical stimuli we compared each music to their corresponding baseline (baseline one or two). For example, if
someone listened to classical music first, then we calculated percent change and a p-value with
the first baseline. Then, when the person listened to death metal music, we calculated the
percent change and p-value using the second baseline data that was taken. The p-values for HR
between the two baselines were statistically insignificant and we only took one reaction time
baseline so the first baseline measurements for HR and reaction time were used to compare to the
rest of the data.

Two-tailed unpaired t-tests were used to test if the order of musical stimuli presented
resulted in physiological values that were statistically significant. There were no statistical
differences that resulted if classical music was presented first or second, with a systolic BP p-
value of 0.7615, diastolic BP p-value of 0.8558, MAP p-value of 0.9666, a HR p-value of 0.60,
and a reaction time p-value of 0.749 (Table 7). This was the same case for when death metal was
played first or second with a systolic BP p-value of 0.2954, diastolic BP p-value of 0.1268, MAP
p-value of 0.2954, HR p-value of 0.126, and a reaction time p-value of 0.9195 (Table 7). The
order of the music did not affect the physiological outcome which allowed for all the data to be
combined and not separated based on musical order.

Blood pressure proved to be technical due to three different calculations that were made.
Average systolic, diastolic, and mean arterial pressure (MAP) were calculated for BP to test if
any of these physiological values in the presence of musical stimuli had any statistical
significance when compared to their baseline values (baseline one or two depending on which
music was first). None of these BP values had any significant change in the presence of classical
or death metal music (Table 7), except for systolic BP for classical and death metal when
compared to the first baseline value, which had p-values of 0.0463 and 0.0349 respectively (table
7). The percent change between the first systolic BP and the first music played (classical or
death metal) was used to present this data in a visual format due to the significance of change (-3.8% and -3.25% respectively) (Table 8, Figure 8).

Once all the data was organized into baseline vs. classical vs. death metal, the averages, standard deviations, and percent changes were calculated (Table 8), statistical paired two-tailed t-tests were used to determine if musical sound altered any of the three physiological tests (HR, BP, and reaction time) significantly. Significant findings apart from the blood pressure as mentioned above was also found between the reaction times for death metal and classical music with p-values of 0.0006 and 0.0143 respectively (Table 7, Figure 7), and percent changes of 6.1% for death metal and 4.3% for classical (Table 8, Figure 8).

**Discussion**

The purpose of this study was to assess the physiological changes of the human body while listening to various musical stimuli. Physiological changes were measured in the form of blood pressure (BP), heart rate (HR), and reaction time. Measurements of these metrics were taken at the beginning of the study and at various points throughout the study with each stimuli applied separately.

We were not able to statistically accept our hypothesis that intense death metal music would increase HR and BP, but slow down reaction time in comparison to the baseline measurements. Likewise, we were not able to accept our hypothesis that classical music would decrease HR and BP relative to the baseline measurements, and maintain reaction time at a comparable value. We did not find significant data that was able to accept our hypothesis, therefore, we are failing to reject the null hypothesis.
Although our initial hypothesis wasn’t supported, we found statistical significance between the effects of death metal music and classical music with reaction time. The p-value obtained from paired t-tests provided evidence that while listening to either song, the participants’ reaction time was observed to speed up, rather than slow down as predicted. A study conducted in 1999 found participants’ performance was enhanced by high-intensity/loud music in activities that require increased attention, such as reaction times. This is due to the participants being less likely to activate their parasympathetic system and therefore, less likely to enter into a relaxed state (Beh et al., 1999). Similarly, a study conducted in 2012 had students perform a reaction time test while listening to classical music; the group of students listening to classical music performed the reaction time test faster and with less errors than the control group that performed the test without music (Chraif, Burtaverde, & Angela, 2013). Additionally, prior research found that while listening to music other regions of the brain are activated, such as the cerebellum and motor cortex, which may enhance performance of precise movements that are needed for reaction time tests (Weinberger, 2004). Based on these results, it is suggested that listening to music should be encouraged while performing tasks that require concentration. It is possible music may help improve the focus of people in their daily activities, such as driving a car. More studies will be required to test this hypothesis with different ways to measure reaction time.

Despite the results aligning with previous research, it is probable the participants became familiar with the stimulus they were responding to after taking the reaction time test three times, which could have led to the increase in their reaction time for both the death metal and classical songs. In future experimentation, there should be a different reaction time test offered for each of the three assessments, in order to mitigate this familiarity issue. We suggest new reaction time
test programs that offer three different tests but measures data similarly, to ensure the reaction times are still precise and eliminate discrepancies when using different programs.

The results suggest the overall trend was an insignificant decrease in heart rate and a significant decrease in systolic blood pressure after the musical stimulus were applied. Another study was conducted to evaluate the effect of music on cardiovascular function; the study found that both fast and slow tempo music produce cardiovascular changes. It was concluded that fast tempo music prompted an arousal effect and showed an increased HR and BP. On the contrary, slow tempo music induced a relaxed effect and a decrease in HR and BP (Bernardi, Porta, & Sleight, 2006). Upon comparison, our results with the results found by Bernardi et al., the physiological effect that music has on HR and BP do not match, because both musical stimuli decreased HR and BP; it is possible the insignificant decrease in HR values is due to error in methodology, and not the musical stimuli itself.

Regardless of the order that each musical stimuli was applied, the first measurement showed a significant decrease in systolic blood pressure when compared to its baseline, while the second measurement showed an insignificant decrease in systolic blood pressure compared to its baseline. Additionally, there was a significant decrease in BP between the first baseline and the second baseline. Due to the overall BP decline in these two results, it is feasible the one minute rest period before baseline measurements were taken was not adequate for each participant to return to their resting vital signs. In future studies, this can be tested by giving more time to rest at the beginning of the study, such as three minutes rather than one minute. If there is consistent decrease in BP and HR, then it is more likely that the decrease is due to musical stimuli and not error. Furthermore, research on why we observed a significant decrease in systolic BP after music stimuli was applied is suggested.
A factor not controlled for within this experimentation is the music preferences of the participants. In the preliminary survey, participants were asked whether or not they listened to classical or death metal music, and if so how frequently. We were not able to control whether or not participants liked the song after hearing it for the first time, upon listening to it during the study. There were numerous participants that made comments while listening to the music indicating they enjoyed the song being played. Research has shown that hypothalamic activity increases while listening to music someone enjoys. The hypothalamus is responsible for controlling physiological responses such as heart rate, respirations, and blood pressure (Menon & Levitin, 2005). It is possible the physiological measurements could have been affected differently based on the participants’ like or dislike for the song being played.

**Conclusion**

According to our research, there was no significant data to reject the null-hypothesis. One significant finding in our study was that reaction time improved when listening to death metal music (p-value = 0.0006) and while listening to classical music (p-value=0.0143). Based on our results, the relationship between auditory input and physiological outcomes will need to be further investigated to better understand the effect they have on one another. Further investigations are encouraged to advance support on the correlation between music and reaction time, which could potentially be useful in concentration-based tasks.

This research is relevant to the University of Wisconsin-Madison physiology 435 class because it utilizes concepts covered in the course material (HR, BP) to apply in a real life situation. As a research group we were able to measure HR and BP and use this as an indication if music played a major role in altering physiological homeostatic state. This allowed us to
observe how the body can detect an auditory stimulus and transduce a signal to the brain through afferent neurons. As action potentials reach the brain, the signal is integrated and efferent neurons from the CNS release acetylcholine to stimulate nicotinic receptors on postganglionic cells. Once stimulated, they will release norepinephrine to stimulate beta-one adrenergic receptors on all cell types in the heart to cause a response in the circulatory system, which will increase HR and BP through altered cardiac output. Our data, which showed a significant change in reaction time when participants listened to death metal music, can potentially be related to the increased stimulus to the CNS which may result in more attentiveness due to the frequency of action potentials (Widmaier et al., 2019). This research further developed our understanding of human physiology by analyzing different physiological values and investigating scientific explanations as to why a change was produced.
References


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We would like to thank Dr. Andrew Lokuta, Dr. Beth Altschafl, Ashley Mulchrone, and everyone in the UW-Madison Department of Physiology who supported and guided us throughout the semester with our project. We are also thankful for the facilities and equipment supplied throughout our project by the UW-Madison Department of Physiology. Lastly, we would like to thank all of the Physiology 435 students and our team of researchers who participated in our study.
Figure 7: Percent Change for Blood Pressure, Heart Rate, and Reaction Time in the Presence of Musical Stimuli. The above figure shows the percent change for systolic blood pressure, heart rate, and reaction time between classical and baseline and death metal music and baseline (n=50). The biggest percent change was between the death metal reaction time and the baseline with a 6.1% faster reaction time. This was deemed statistically significant by a paired two-tailed t-test with a p-value of 0.0006, which is less than 0.05. Classical music also decreased by a significant amount (p-value= .0143, with a 4.3% decrease). Systolic blood pressure was also significant between the first baseline and the first musical stimuli (classical p-value= 0.0463, 3.8% and death metal p-value= 0.0349, 3.25% decrease).
**Figure 8: Reaction Time Differences between No Music, Death Metal, and Classical Music.** The above box and whisker plot visually represents the difference between baseline reaction time, death metal reaction time, and classical reaction time (n=50). Death metal and classical music was statistically different than the baseline with a p-value of less than 0.05. When death metal reaction time was compared to classical this yielded a p-value of 0.4920 which is greater than 0.05 so there was no statistical difference between death metal and classical music when compared to each other.

<table>
<thead>
<tr>
<th></th>
<th>Mean Arterial Pressure (mmHg)</th>
<th>Diastolic BP (mmHg)</th>
<th>Systolic BP (mmHg)</th>
<th>Heart Rate (Beats/min)</th>
<th>Reaction Time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline First</td>
<td>0.00102</td>
<td>0.0535</td>
<td>0.00005</td>
<td>0.733</td>
<td>N/A</td>
</tr>
</tbody>
</table>
**Table 7: Summary table of p-values between Musical Stimuli and Baseline values.** The above table summarizes the p-values for different two-tailed t-tests that were run on the data (n=50). Any p-value that was greater than 0.05 was deemed statistically insignificant. The reaction times between the baseline and death metal and baseline and classical music were statistically significant (p-value= 0.0006, and .0143 respectively). These value suggested that reaction time did get faster by a significant amount when participants were under the stimulus of death metal or classical music. There was also a significant decrease in systolic BP for classical and death metal music when compared to the primary baseline (p-value= 0.0463, 0.0349 respectively). The two baseline blood pressure values were also statistically significant with p-values of 0.00202 for MAP, 0.0535 for diastolic, and 0.00005 for systolic BP.

<table>
<thead>
<tr>
<th>vs Baseline</th>
<th>First p-value</th>
<th>Second p-value</th>
<th>First p-value</th>
<th>Second p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical First vs. Classical Second p-value</td>
<td>0.9666</td>
<td>0.8558</td>
<td>0.7615</td>
<td>0.5898</td>
</tr>
<tr>
<td>Death Metal First vs. Death Metal Second p-value</td>
<td>0.2954</td>
<td>0.1268</td>
<td>0.9195</td>
<td>0.7292</td>
</tr>
<tr>
<td>Classical vs. Baseline p-value</td>
<td>Baseline 1: 0.0777 Baseline 2: 0.2509</td>
<td>Baseline 1: 0.4984 Baseline 2: 0.1788</td>
<td>Baseline 1: <strong>0.0463</strong> Baseline 2: 0.8142</td>
<td>0.0600</td>
</tr>
<tr>
<td>Death Metal vs. Baseline p-value</td>
<td>Baseline 1: 0.1043 Baseline 2: 0.9185</td>
<td>Baseline 1: 0.4381 Baseline 2: 0.9120</td>
<td>Baseline 1: <strong>0.0349</strong> Baseline 2: 0.6418</td>
<td>0.1669</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>vs Baseline</th>
<th>Mean Arterial Pressure (mmHg)</th>
<th>Diastolic (mmHg)</th>
<th>Systolic (mmHg)</th>
<th>Heart Rate (Beats/min)</th>
<th>Reaction Time (Seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline First</td>
<td>Mean: 87.84 SD: 10.45</td>
<td>Mean: 75.04 SD: 9.822</td>
<td>Mean: 113.43 SD: 15.87</td>
<td>Mean: 74.27 SD: 13.83</td>
<td>Mean: 0.3519 SD: 0.0761</td>
</tr>
<tr>
<td>Baseline Second</td>
<td>Mean: 85.13 SD: 8.211</td>
<td>Mean: 73.12 SD: 7.83</td>
<td>Mean: 109.15</td>
<td>Mean: 73.09 SD: 12.835</td>
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</tr>
<tr>
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<td>Mean: 85.36</td>
<td>SD: 13.49</td>
<td>Mean: 83.67</td>
<td>SD: 8.49</td>
<td>Mean: 73.0</td>
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<td>----------------</td>
<td>----------------------</td>
</tr>
<tr>
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<td>First</td>
<td></td>
<td>% Change: -2.04</td>
<td></td>
<td>% Change: -3.27</td>
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<tr>
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<td>Second</td>
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<td>% Change: -1.66</td>
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<td>% Change: -0.76</td>
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<tr>
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<td></td>
<td>% Change: -2.08</td>
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<td>% Change: -1.21</td>
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<tr>
<td>Death Metal</td>
<td>Second</td>
<td></td>
<td>% Change: 0.15</td>
<td></td>
<td>% Change: -0.26</td>
</tr>
</tbody>
</table>

**Table 8: Summary table of Average Physiological values between Musical Stimuli and Baseline values.** The above table summarizes the average physiological values, their standard deviations (SD), and percent change when compared to the baseline values (n=50). Percent change for the first musical stimuli was calculated when comparing to the first baseline and percent change for the second musical stimuli was calculated comparing to the second baseline values for blood pressure values only.