

Music & Physical Performance:
*The effects of different music genres
on physical performance
as measured by the
heart rate, electrodermal arousal,
and maximum grip strength*

Physiology 435
Lab 602
Group #5

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Abstract :

The effect of music on physical performance is thought to increase physical strength with different tempos and fluctuating rhythms as opposed to no music being present. By using three types of music, an ambient instrumental, white noise with equal frequencies for baseline, and a rock instrumental that is upbeat, there was an aim to find a correlation with maximum grip strength, heart rate and electrodermal arousal. Through this experiment, these three factors' levels were being tested with the goal that the rock music would allow the highest activity in the physiological elements. After data collection, the results indicated no significance in relation to music with maximum grip strength. Averages of the participants' data did not prove to be lower in numbers for the three factors when listening to ambient music containing slow pace. The averages also did not support the hypothetical statement of the three physiological factors' levels being higher when there was exposure to fast paced rock music. Hence, there is no correlation between the three different types of music chosen and heart rate, electrodermal arousal and maximum grip strength.

Introduction:

Previous research studies have consistently concluded that the synchronization of music with physical tasks is associated with enhanced performance or increased work output (Anshel & Marisi, 1978; Michel & Wanner, 1973; Uppal & Datta, 1990). Research has also found that certain metabolic increases are associated with listening to music (Ellis & Brighthouse, 1952). Research suggests songs with faster tempos and strong rhythms are expected to activate the sympathetic nervous system and enhance performance. In contrast, songs with slower tempos and weaker rhythms are more likely to activate the parasympathetic nervous system and induce relaxation. The effect of background (non-synchronized) music on physical performance remains unclear. Some studies have shown background music increases physical performance in karate and treadmill running, while other studies have found that there were no physiological differences during dart throwing or sit-ups (Copeland & Franks, 1991; Dorney, Gon, & Lee, 1992; Ferguson et al., 1994). Previous studies also suggest that increases in physical performance are greatest when listening to music during the activity versus performing the activity after the music has stopped (Anshel & Marisi, 1978). While these previous studies have found enhanced

performance to be associated with music in general, the specific effects of different genres of music are less understood. Music has been shown to have a greater effect on performance than white noise alone, which leads to the question of how songs of varying tempos and rhythms affect performance (Anshel & Marisi, 1978).

Various physiological measurements can be taken to determine whether an individual's sympathetic nervous system has been activated and their physical performance has increased. One such measurement is electrodermal arousal (EDA), which is associated with the skin's electrical response to sweat secretion. The electrical response occurs in body fluids that contain electrolytes because a voltage gradient is often formed (Lagopoulos, 2007). Sweat glands are a common place for electrodes to measure EDA levels. Sweat glands are stimulated by the release of acetylcholine during sympathetic activation (Lagopoulos, 2007). In past studies EDA levels are highest during high activity of the sympathetic branch of the autonomic nervous system (Benedek & Kaernbach, 2010). Research also suggests that unexpected changes in music leads to a peak in EDA (Chapados & Levitin, 2008).

Heart rate is another physiological measurement indicative of overall physical performance. Because it is directly impacted by sympathetic nervous system activation, heart rate seemed an obvious inclusion for a study on the physiological effects of music. A study conducted at Oxford's John Radcliffe Hospital tested which aspects of music could produce changes in cardiovascular and respiratory variables. Subjects listened to 6 short tracks of music chosen for factors such as rhythm, syncopation, and speed while the researchers monitored their blood pressure, heart rate, breathing rate, cerebral artery flow velocity, and baroreflex. Unlike earlier studies, this study found no effect of musical style or preference on any cardiovascular parameters. It showed that only 1 factor mediated the physiological effect of listening to music: tempo. Fast music, whether classical or techno, caused increases in blood pressure, heart rate, and breathing rate, and reduced baroreflex sensitivity. Slow music, on the other hand, whether classical music or reggae-style sitar music, caused a significant fall in heart rate and breathing frequency compared with the baseline (Bernardi, Porta, & Sleight, 2006).

The final and perhaps most direct method of measuring physical performance changes in response to music is grip strength. It is a common conception that listening to certain types of music can activate feed-forward mechanisms, leading to increases in physical performance. To determine whether this belief holds true, a study at the University of Kansas measured subjects' initial grip strength and then their grip strength while listening to stimulative music, sedative music, and silence. The results indicated that listening to sedative music decreased grip strength relative to silence, while listening to stimulative music had no effect on strength relative to silence (Pearce, 1981).

This study aims to determine whether significant physiological changes of heart rate, electrodermal activity, and grip strength are dependent on the genre of music used in the experiment. It is expected that rock music, with its strong rhythms and fast tempos, will increase these physiological measurements. Conversely, listening to ambient music with little or no rhythm and slow tempos is expected to decrease physical performance as measured by heart rate, electrodermal activity, and grip strength.

Methods:

The subjects in this study were Physiology 435 students ages ranging from 20 to 24 years old. Of the 13 students participating, 8 were male and 5 were female. At the beginning of each trial, the subject was instructed to sit in a chair in a relaxed position (see Figure 7). A pulse

oximeter sensor was then placed on their dominant hand and two EDA sensors were placed on their nondominant hand. While listening to each audio clip, electrodermal activity (microsiemens) and heart rate (bpm) were recorded. A BIOPAC hand dynamometer was placed on the table in front of the subject. After putting on a pair of noise-cancelling headphones, four minutes of an audio clip were played. During this time, the subject relaxed and focused on listening to the music. At the end of the four minute period, the pulse oximeter was removed from the dominant hand and the hand dynamometer was picked up for the maximum grip strength trial (see Figure 8).

The audio clips were selected based on genre, rhythm, and tempo characteristics. One song from the rock genre and one from the ambient genre were selected. These songs were further analyzed to ensure they contain the appropriate rhythm and tempo characteristics for their respective genres. The rock song contained strong rhythms and a fast tempo while the ambient song contained weaker rhythms and a slow tempo. Furthermore, only instrumental clips were chosen to eliminate any bias due to lyrics. Each subject listened to three different audio clips. The first was from the song “Weightless” by Marconi Union. This song represents the ambient genre due to its virtually nonexistent rhythm and steady tempo of 60 beats per minute. Next, a white noise audio clip was played at the same volume as the other two songs. This provided baseline measurements for auditory stimulation alone with which to compare the rhythm and tempo of the songs. Finally, the subject listened to an instrumental version of “Battery” by Metallica. This song is characteristic of the rock genre because it contains heavily rhythmic guitar riffs and a fast-paced tempo of 120 beats per minute. As a control, the audio clips were instrumental-only so that rhythm and tempo could be more directly compared. Each audio clip was also played at the same volume level. The order of audio clips from sedative to stimulative was chosen to prevent the skewing of data by the fast-paced song.

During the four minutes of the audio file playing, heart rate was recorded using a pulse oximeter. A pulse oximeter determines functional oxygen saturation of hemoglobin by measuring absorption of red and infrared light through the tissue. Every 15 seconds, the instantaneous heart rate in beats per minute was recorded. All data points were then averaged upon conclusion of the trial. Heart rate data will provide evidence for the hypothesis in that a higher heart rate is expected during the audio with stronger rhythms and faster tempos as opposed to the lower heart rate during the audio with weaker rhythms and slower tempos.

Electrodermal activity (EDA) was also recorded during the four minutes of listening to the audio clip. EDA is a method of measuring skin conductance. These measurements vary because of differing moisture levels of the skin due to sweat gland activity. Since sweat glands are exclusively controlled by the sympathetic nervous, EDA can effectively measure arousal level. Galvanic Skin response was considered the predecessor to EDA although these techniques measure analogous readings. For example, changes in peripheral autonomic tone may alter sweating and blood flow. The EDA measures the increase in water and electrolytes as an increase in conductivity; therefore, an increase in arousal. Both heart rate and electrodermal activity are correlated to the level of sympathetic nervous system activity in response to the auditory stimulus.

After listening to each four minute audio clip, the subject picked up the hand dynamometer in preparation for the maximum grip strength test. Holding the dynamometer just below the white tape and their arm flexed at a right angle, the subject clenched their hand three times. The BIOPAC system recorded the force of each of these clenches in kilograms. The three

maximum clench forces were then averaged for consistency among trials. In between listening to each audio clip, a 30 second rest period was included to avoid influence from the previous clip.

The controls in this study were chosen to keep constant all variables in the trial except for the rhythm and tempo of each audio clip. All the clips were instrumental only and were played at the same volume level. Furthermore, the audio clips were played in order from sedative to stimulative in order to avoid lingering sympathetic effects. A 30 second rest period was also given in between each clip so the subject's measurements could equilibrate. Finally, each of the 3 measurements (heart rate, electrodermal activity, and grip strength) were calculated as averages from many data points. This eliminated outliers and gave a more accurate representation of their physiology throughout the course of the trial.

Results:

The arousal of the subject was collected continuously by the BIOPAC system during each of the three listening periods for the different music types. This data set was averaged as microsiemens per second and was graphed in Figure 1 for each of the 13 subjects that participated as labeled A-M. The maximum grip strength of the subject was collected during each of the three listening periods for the different music types as graphed in Figure 2. The heart rate in beats per minute was taken every 30 seconds during the three listening periods for the different music types and then was averaged. This data is shown in Figure 3.

T tests were performed for each of the three physiological tests: arousal, grip strength, and heart rate. The data for these three *t* tests is presented in Figures 4-6 respectively. The arousal data procured a 0.32 p-value, grip strength a 0.9556 p-value, and heart rate a 0.35 p-value.

Therefore the difference between the baseline and ambient music shows no statistical significance when compared to the difference of rock and the baseline for any of the three physiological tests performed.

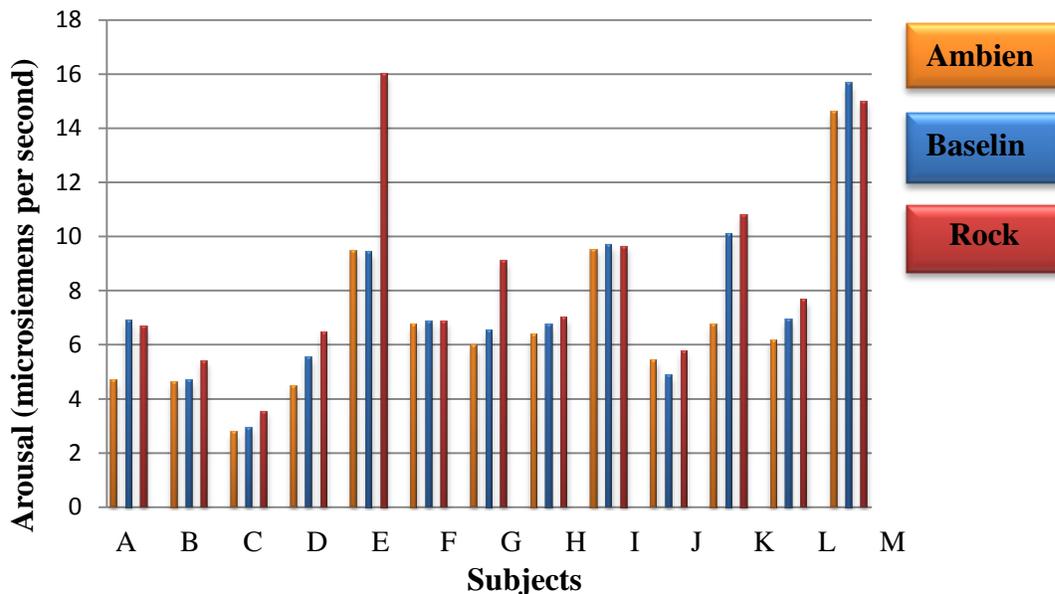


Figure 1. Average arousal for each of the 13 subjects (labeled A-M) was recorded three times during the listening period for each of the three music genres: ambient, baseline, and rock.

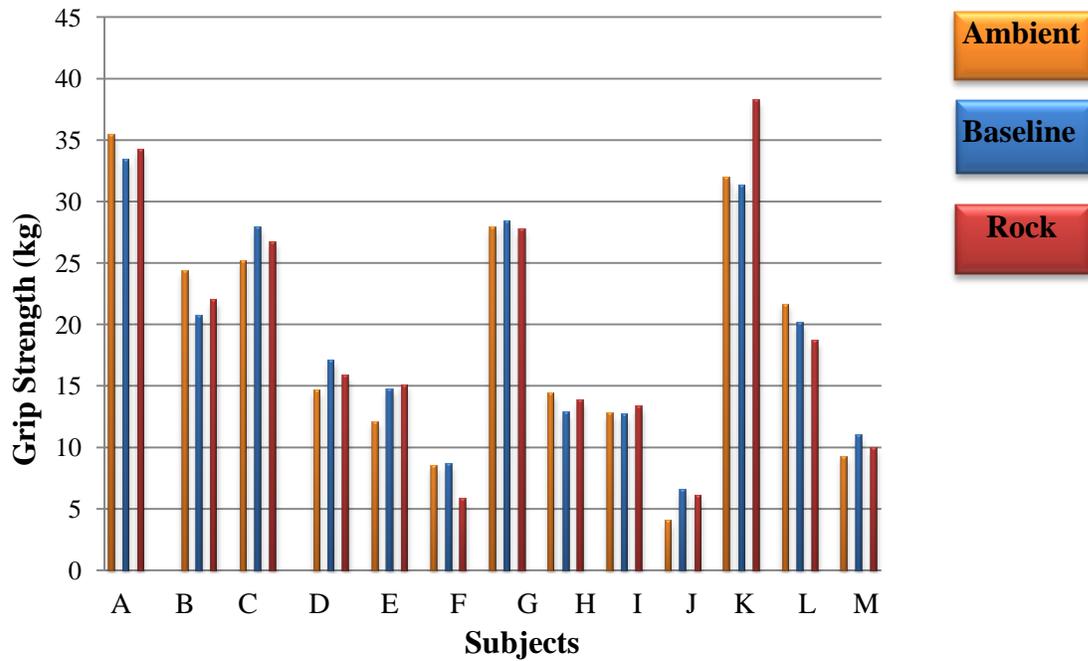


Figure 2. Maximum grip strength for each of the 13 subjects (labeled A-M) was recorded three times during the listening period for each of the three music genres: ambient, baseline, and rock.

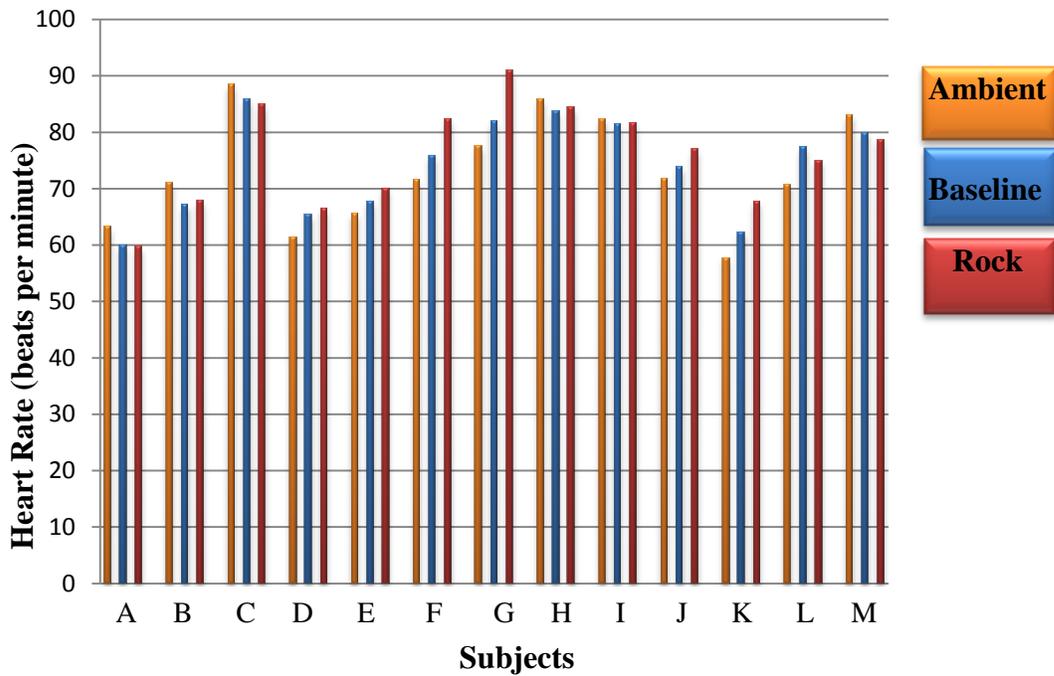


Figure 3. Average heart rate for each of the 13 subjects (labeled A-M) was recorded three times during the listening period for each of the three music genres: ambient, baseline, and rock.

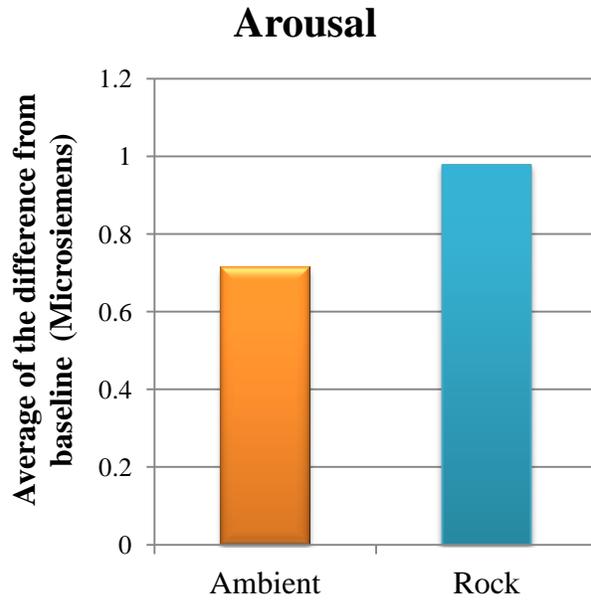


Figure 4. The arousal while listening to the ambient music was subtracted from the arousal while listening to baseline for each individual and then averaged (left). The arousal while listening to baseline was subtracted from the arousal while listening to rock music for each individual and then averaged (right).

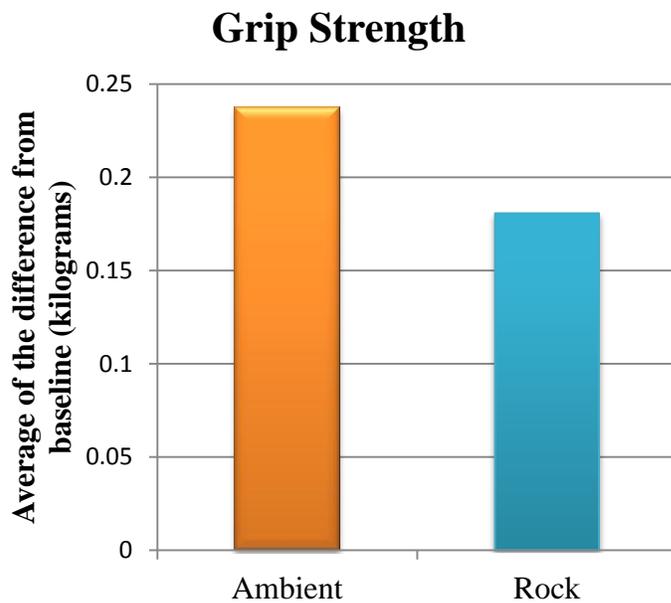


Figure 5. The grip strength while listening to the ambient music was subtracted from the grip strength while listening to baseline for each individual and then averaged (left). The grip strength while listening to baseline was subtracted from the grip strength while listening to rock music for each individual and then averaged (right).

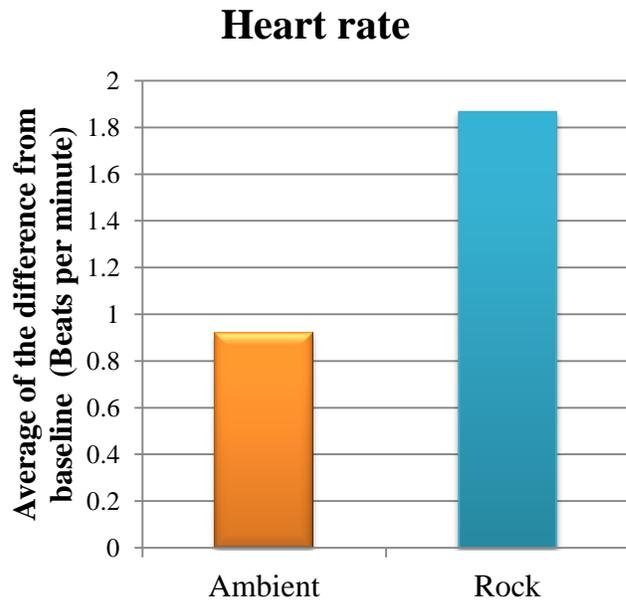


Figure 6. The heart rate while listening to the ambient music was subtracted from the heart rate while listening to baseline for each individual and then averaged (left). The heart rate while listening to baseline was subtracted from the heart rate while listening to rock music for each individual and then averaged (right).



Figure 7. The subject is about to pick up the hand dynamometer after listening to four minutes of the ambient audio clip. The subject will clench the device three times with her dominant (left) hand while her electrodermal activity is measured on her opposite hand.



Figure 8. The subject is currently holding the hand dynamometer after listening to the rock audio clip. The BIOPAC system on the far computer is measuring the force of each of these clenches. The BIOPAC system on the near computer is measuring electrodermal activity which is attached to her index and middle fingers.

Discussion:

The data was analyzed so that each individual's measurements were first compared to their own measurements. Then the averages were compared which standardized the data for comparisons between participants. The difference between the ambient music trial vs. baseline trial was taken to measure the effect of ambient music, and the difference in rock vs. baseline trial measured the effect of fast paced music based on the three measured variables - heart rate, arousal, and grip strength. The reason these differences were taken was because the change in a person's physiology is only relevant when compared to that same individual's analogous physiological reading. For example, one person's average heart rate and average arousal level are comparable because the individual is the same, so the change in these variables can indicate an effect of music on the individual.

The experimental results indicated that there is no significant evidence for a change of grip strength for both ambient music and rock. This indicated that participants fell within an average range regardless of the music type they were hearing. Also, a t-test of the differences of ambient vs. baseline and baseline vs. rock, found that for arousal, heart rate, and grip strength the p-value was very large. This means that the data is very probable that there is no difference

between which music is being listened to and a physiological change of these variables due to the music. Therefore, lacking a significant relationship in any of the variables, further analysis of the data ended because a hypothesis of a correlation between variables would be meaningless. For instance, a correlation of arousal levels based on music type versus grip strength based on music type would be useful, but we found no such relationship since there was no variation due to music. Based on these results, background music has no effect on physical grip strength, arousal, and heart rate.

Many studies differed in both types of physiological readings as well as relative experimental apparatus and also experimental procedures. Numerous studies focused on endurance tasks which aided in the synchronic nature of the music while our focus was on non-synchronized music to determine an underlying cause of music's effectiveness on physical performance. (Anshel & Marisi, 1978; Michel & Wanner, 1973; Uppal & Datta, 1990). One particular experiment by Anshel and Marisi included the lyrics to the music which likely added to the synchronization of music and physical activity. Our experiment attempted to analyze the effects of non-synchronized music on physical strength. A criticism of this study would be that the subjects were allowed to pick which music they preferred from a selection. This leaves underlying psychological effects to be undermined since music is known to cause changes in physiology without physical performance (Bernardi P, Porta C, Sleight P). Only one study conducted by Pearce had a similar apparatus relative to ours by examining grip strength, arousal level, and three basic levels of music, sedative, stimulative, and silence. This particular study found no significant change in grip strength between the stimulative trial and the silence trial. There was a relative change in grip strength for the sedative vs. silence trial with $p = 0.07$ which is marginally significant while we found a very low level of significance. The control for this experiment was silence versus the white noise we used as a baseline in our experiment which is weaker because it is possible that simply hearing a stimulus provokes some amount of arousal. Additionally, the tempo of the songs was not mentioned; just the name of the specific song as well as if it was classified as sedative or stimulative.

One of the problems we encountered is if the participant is given too much information about the experiment, the participant could anticipate their own physiological responses due to their own expectation. For example, many participants had tremors in arousal level after doing the grip strength test until roughly 30 seconds into the next song yet normalized afterward. A solution to this problem would be to censor how much information we disclose and only provide essential information regarding the experiment. Another problem was the lack of controlling external stimuli of the participant. The individual could often hear tiny pieces of conversations suggesting that our apparatus was not adequate enough to completely remove the influence of external stimuli. For instance, the pulse oximeter was in view of the participant meaning they could read their own heart rate and unknowingly influence their arousal and heart rate. A simple blind experiment which ensures that the volunteer does not alter their responses based on outside influences would be sufficient to fix this problem. Erroneous and misleading data was removed prior to statistical analysis. The statistical sampling of the experiment was based on convenience and time constraints. Due to the fact that each individual took at least 15 minutes per trial, the amount of time to get a larger sample wasn't pragmatic. Our sample size was restricted to individuals we could subject to testing, most being in the class for convenience, and is only representative of a narrow age range.

The finding that there was no statistically significant change in terms of any of the three variables to background music goes against conventional wisdom. The belief that subliminal

auditory stimuli are influencing our behavior would appear misleading based on this research. Further experimental controls and specificity in terms of investigating a direct relationship between music and its effects on physiology could be implemented to obtain more significant results. Preliminarily, the outcome shows that there is still a discrepancy between whether music does affect physical performance and to what extent. The possibility remains that any significant effect on overall physical performance is perhaps minimal or simply non-existent.

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Pilot Study

A pilot study was conducted in order to prevent flaws, bias, and misinterpretation of the larger scale study for different music genres affecting three physiological factors. This was performed to check the reliability and validity of the results with consistent protocols such as establishing controls, avoiding any distraction of sounds, keeping language the same when providing instructions and containing unbiased participants. The music choices chosen were white noise for the baseline, ambient and rock music in order to see any affects on heart rate, arousal rate and grip strength.

The study was done in a small, soundproof room with five researchers and three females as the sample size. Simple instructions were given prior to collecting data and limited information was provided about the details of the experiment. Ambient music was exposed first and all physiological factors were measured. Secondly, white noise, the baseline, was introduced including the same instructions. Thirdly, rock music was played with the same physiological factors being measured. The results of the pilot study showed no significant differences in the strength's measurements correlated with different type of music genres. Minimal differences in data were retrieved in terms of arousal rate and heart rate factors. It can be concluded from the pilot study that there is limited to no effect of music in terms of grip strength, which is supported in the larger scale experiment.