The Effect of Music on Concentration, Heart Rate, Blood Pressure and Respiratory Rate

Eric Bobel, Prateek Chhetri, Amy Pedersen, Brittany Seidl, Tzu-Wei Tsao

University of Wisconsin-Madison
Physiology 435 Lab 601-14
Medical Sciences Center
1330 University Ave.
Madison, WI 53706

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ABSTRACT

This study aims to investigate how music affects one's concentration, heart rate, blood pressure and respiratory rate. Twenty-four participants were randomly assigned to one of three groups. Group one was our control group and did not listen to any music. Group two listened to classical music and group three was given a choice between eight different lyrical songs from four different genres. Participants took a Stroop test, a test measuring capacity to direct attention, while listening to the selected music, or lack thereof when placed in the control group. Heart rate, blood pressure and respiration rate were measured before and after the Stroop test. There were no significant p-values for the change in heart rate, blood pressure, or Stroop test score. However, the change in respiratory rate ratio (measured in breaths per second) between classical and lyrical music groups was significantly different ($p=0.007$). Our hypothesis that people listening to no music would do better on a Stoop test measuring concentration than people listening to music was not supported. Our hypothesis that the blood pressure, heart rate, and respiratory rate would be highest for people listening to lyrical music, lowest for people listening to classical music and somewhere in the middle for the non-musical group was not supported based on the physiological findings of this study.

INTRODUCTION

College students are told that they should not listen to music while studying. But when walking around campus, one can always find one student, if not more, who is studying with their earphones. Are these students' grades being negatively affected by their habit of listening to music while studying? Or are they actually able to learn more effectively with their music playing? It has been shown in previous studies that listening to music leads to lower performance levels of short-term memory (Anderson and Fuller, 2010). In a study by Anderson and Fuller, junior high students were given a reading comprehension test with or without music. About 75% of participants in the group that were listening to lyrical background music performed poorly with a mean reading comprehension score of 26.49 than the group without the music with a mean reading comprehension score of 30.56.

The negative effect of background music on short-term memory was shown in a memory study relating to music's effect on memory (Salamé and Baddeley, 1989). In the study, each test subject was exposed to lyrical music, instrumental music and silence in three separate trials. Participants were then asked to memorize a line of nine numbers and to replicate the line a short time later. Participants in the silent control situation had an overall higher level of performance than those in either of the groups with music. Another study looked at college age students who liked to listen to rock and roll and had them take reading comprehension tests (Daoussis and McKelvie, 1986). They found that the students performed worse on the reading comprehension test when listening to the rock and roll music ($M=8.08$) than without listening to music at all ($M=8.40$).

Numerous studies have been conducted that showed a decrease in heart rate while listening to music. According to another study, slow paced music decreases your heart rate,

blood pressure, and respiratory rate whereas fast-paced music has the opposite effect (Hyde and Scalapino, 1918). A fourth study looked at how blood pressure would respond after completing a stressful task (Chafin et. al, 2004). They observed a significant effect of music condition on recovery, showing a significant difference between the classical and control, ($p<0.3$), classical returning systolic blood pressure closer to baseline (M ¼ 2:1 mmHg) than the control condition (M ¼ 10:8 mmHg). Although these studies show a correlation between music and physiological factors, we would like to assess the effect of music chosen by the participants on their concentration. This is more directly applicable in analyzing common study strategies of students.

Does listening to music affect your ability to concentrate and by extension, your test scores? Clearly more research is needed in this field. To further examine this, we chose the Stroop test in order to measure the selective attention, cognitive flexibility, and processing speed of the participants (Howieson et al., 2004; Spreen et al., 2006). Concentration is an important factor in the mental processes of attention, learning, memory and problem solving. We hypothesize that people who take a Stroop test, measuring concentration, while listening to music would have lower test scores than those taking the test without listening to music, and people who listen to lyrical music will have even lower scores than the group who listens to classical music. Based on the previous research mentioned, we also hypothesize that the blood pressure, heart rate, and respiratory rate (measured in breaths per second) will be highest for people listening to lyrical music and lowest for people listening to classical music, and the no music group in the middle.

MATERIAL AND METHODS

Ethical Approval

This experiment involved consenting human volunteers. Specifically, written consent was obtained from every volunteer before proceeding with the experimental protocol. The experiment was conformed to the guidelines set down by the Physiology 435 lab instructors and pre-approved before any experimentation began.

General Procedure Overview

The materials used in this study include a blood pressure cuff and a stethoscope to measure blood pressure, a pulse oximeter provided by the BIOPAC Systems, Inc. to measure heart rate, Biopac Student Lab software and a respiratory belt to measure respiratory rate, and an online Stroop test (http://www.onlinestrooptest.com/). A Stroop test evaluates the brain's ability to distinguish the interference of reaction time and correction between words and colors; it examines the effect of interfering word stimuli upon naming its colors serially (Stroop, 1935). A word of a color will appear in either the color of the word or a different color from the word, for example, the word "blue" printed in green. There will be five sets of congruent tests, in which the color of the word matches the meaning of the word, and fifteen sets of incongruent tests, the color of word doesn't match the meaning of the word. The two types of questions will be randomly distributed throughout the Stroop test. The test subject will be required to choose the

correct answer as fast as they can at the bottom of the screen corresponding to the color of the word (in this case "green") rather than the color that the word says (in this case "blue") For our study, concentration was defined based on the speed and accuracy when taking a Stroop test. A participant who took the test quickly and accurately was interpreted as having optimum concentration while a participant who took longer or did not answer all the questions correctly was understood to have compromised concentration.

In this study, twenty-four students from a Physiology 435 lab of the University of Wisconsin - Madison volunteered to participate. The average age of the participants was twenty-one and the study group included eleven women and thirteen men. Participants were randomly assigned to three different groups (eight people each): no music, classical music, and lyrical music. The test without music was our control. The classical song used was *Eine Kleine Nachtmusik* by *Mozart*. If participants were selected for the lyrical music group, they were allowed to choose from eight different song choices. These song choices spanned four different genres (pop, rock, rap, and country) and included one male and female artist for each genre. The possible song options were *Thrift Shop* by Macklemore, *Bad Romance* by Lady Gaga, *Not Afraid* by Eminem, *Sweet Child of Mine* by Guns n' Roses, *Dirt Road Anthem* by Jason Aldean, *Tim McGraw* by Taylor Swift, *Super Bass* by Nicki Minaj, and *Raise Your Glass* by Pink. Allowing participants to choose their song from a diverse list allowed control for different preferences of music and better simulate what they might listen to while studying. The participant was able to choose what volume to listen to the music at in order to help provide a comfortable environment. The music in the experimental setup was played through headphones rather than a larger speaker, therefore participants were asked to wear headphones regardless of whether or not they were listening to music. This was to control for any effect that the headphones or their cord may have caused. In all of the experiments Apple brand headphones were used.

The heart rate and blood pressure of each participant were measured at the beginning of the test in order to get a baseline measurement. For control data, the participants' heart rate and blood pressure were taken without the influence of music. After the baseline heart rate and blood pressure were taken, the respiratory belt was wrapped around the participant's chest and a calibration of their breathing was taken before actual recording began. The respiration belt was used to track the changes in respiration before, during, and after the Stroop test, as instructed by the Biopac Student Manual (Pfanzer, et al. 2008). After calibration of the respiration belt, data collection began and allowed for ten seconds to pass before the start of the online Stroop test. At the time the participant finished the Stroop test, an additional ten seconds of respiratory data was collected. Heart rate and blood pressure were also recorded right after completing of the Stroop test (Fig. 1). The time it took for the participant to finish the Stroop test was recorded along with the number of correct answers. After the data was collected, it was analyzed using Microsoft Excel, OriginPro and the Biopac Student Lab system.

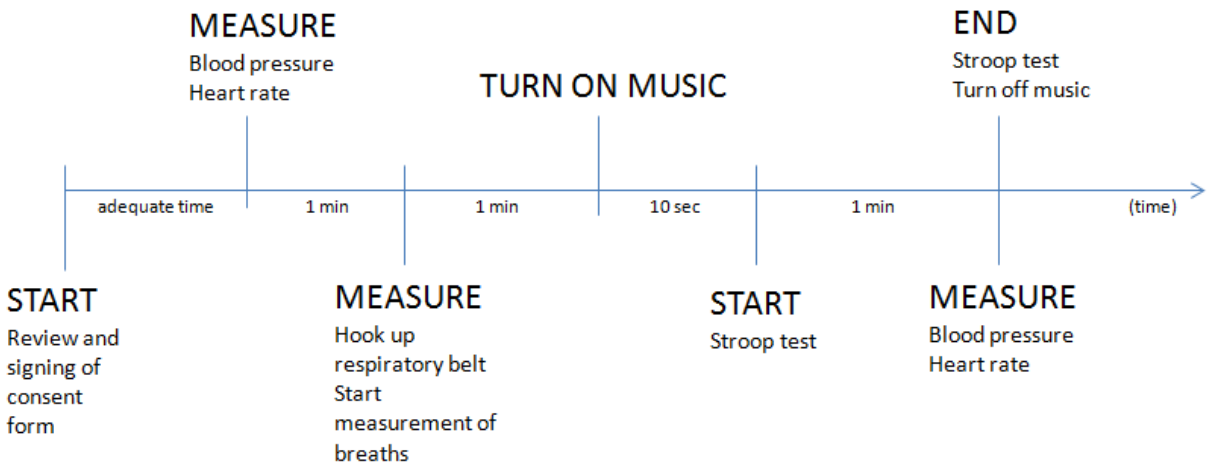

Figure 1. Timeline of the experimental procedure. Eight participants listened to no music, eight to classical music, and eight to lyrical music of their choice.

RESULTS

There were no significant p-values for the change in heart rate, blood pressure, or Stroop test score. There was also no change in respiratory rate when comparing the lyrical music group to the group with no music. There was, however, a significant p-value when comparing the breathing rate of participants listening to classical music while taking the Stroop test to those listening to lyrical music of their choice.

Effect of music on the time to complete the Stroop Test

A

quiet	classical	lyrics
22	26.5	28
38	31	27
30	32	33
33	28	33
26	30	35
29	34	33.5
24.5	36	36
35	32.5	42.5
29.7±1.9	31.3±1.3	33.5±1.7

(sec)

B

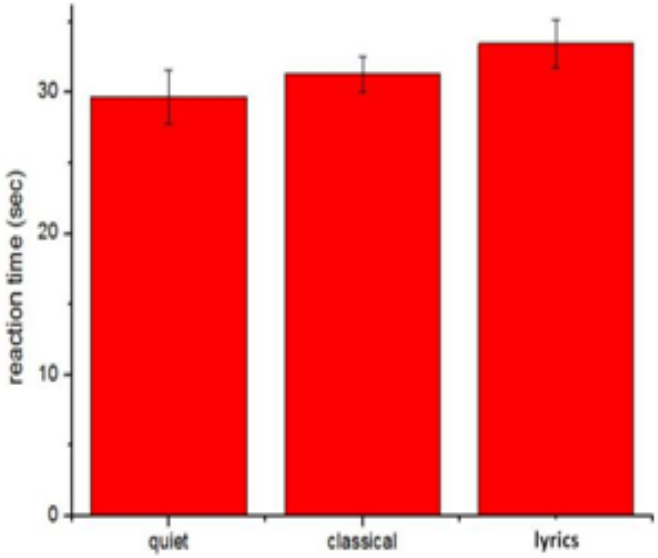

Figure 2. Completion time of the Stroop test between music groups. (**A)** Raw data of the completion time (sec) during the Stroop test for each participant in different groups. (**B)** No significance was observed among the completion time of the three groups.

The completion time measured in the Stroop test was used to examine the participant's level of concentration during the test. The average time it took for the participants to complete the Stroop test were 29.7±1.9, 31.3±1.3, 33.5±1.7 seconds for the groups of no music, classical music, and lyrical music group, respectively (Fig. 2A). There were no significant difference ($p>0.05$) between these groups for the time spent on the Stroop test (Fig. 2B).

Number correct of congruent and incongruent questions in Stroop test

A

congruent			incongruent		
no music	classical	pop	no music	classical	pop
5	5	5	15	15	15
5	5	5	14	15	15
5	5	5	15	15	15
5	5	5	15	15	14
5	5	5	15	15	14
5	5	5	13	14	14
5	5	5	15	15	15
5	5	5	15	15	13
5	5	5	14.6±0.3	14.9±0.1	14.4±0.1

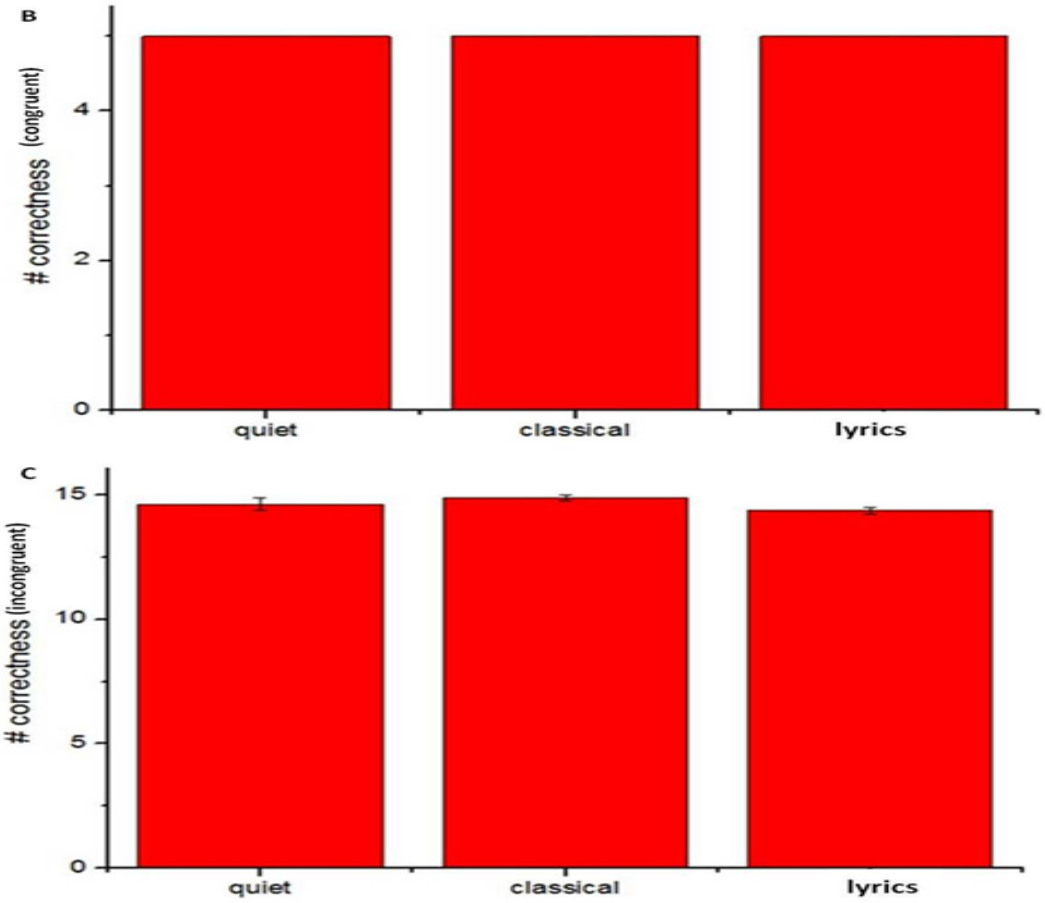

Figure 3. Number of correct answers to congruent, color of the word and the word refer to the same color, and incongruent, color of the word and the word refer to different color, Stroop test questions. **(A)** Raw data for the numbers of correctness accomplished during each Stroop test per group. **(B)** Graph showing number of correctness of the congruent tests for each group. Congruent is defined as the color of the word being the same as the word itself. Incongruent is defined as the color and meaning of the word being different.

All the groups scored 5 out of 5 on the Stroop test for congruent words, while the average incongruent score out of 15 were: 14.6±0.3 for quiet, 14.9±0.1 for the classical group, and 14.4±0.1 for the lyrical music group (Fig. 3A). The difference in the number correct for either congruent or incongruent questions in the Stroop test showed no significant difference between groups (Fig. 3B).

Effect of music on respiratory rate

A

quiet	classical	lyrics
1.50	1.78	1.17
1.05	1.34	1.03
1.03	2.00	1.25
0.90	1.07	0.94
0.86	1.03	0.64
0.85	0.71	0.60
1.11	0.97	0.72
1.45	1.05	0.76
1.10±0.09	1.24±0.15	0.89±0.09

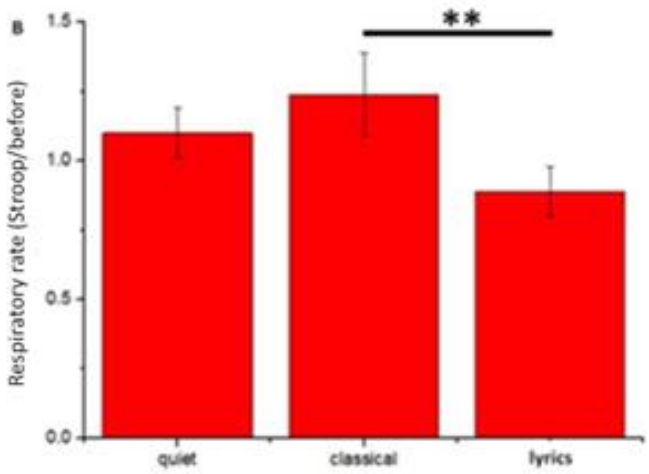

Figure 4. The ratio of respiratory rate (RR) in breaths per second during the Stroop test to RR before the Stroop test. **(A)** Raw data of the ratio of RR for each group. **(B)** A significant difference (**p<0.01) was found between the classical music group and the lyrical music group.

By using the Biopac Student Lab System, it was easy to measure a participant's respiratory rate (RR). With the respiratory belt, the participant's breathing pattern was easily monitored both before and during the Stroop test. A subsequent analysis of calculating the RR in breaths per second was used as an index to examine any change in a participant's respiratory rate.

The ratio of RR during the Stroop test to RR before the test was 1.10±0.09, 1.24±0.15, and 0.89±0.09 for the groups with no music, classical music, and lyrical music, respectively (Fig. 4A). The change in RR ratio between classical and lyrical music groups was significantly different (p=0.007) while the other comparisons between either no music and classical music or no music and lyrical music of their choice were not found to be significantly different. There was however a trend indicating that RR was highest when listening to classical music and lowest when listening to lyrical music of choice.

Effect of music on blood pressure and heart rate

The blood pressure and heart rate results showed no significant difference before or immediately after the Stroop test regardless of the type of music. The change in heart rate and blood pressure were not hypothesized to be large, so the measurement was needed to be taken immediately after in order to detect any changes from the resting measurements taken before the start of the Stroop test.

A

DIASTOLIC								
quiet			classical			lyrics		
before	after	after/before	before	after	after/before	before	after	after/before
80	84	1.05	90	90	1.00	80	90	1.13
75	80	1.07	90	100	1.11	80	70	0.88
70	76	1.09	80	89	1.11	78	70	0.90
83	80	0.96	80	85	1.06	90	80	0.89
75	85	1.13	70	78	1.11	76	80	1.05
80	76	0.95	75	80	1.07	72	80	1.11
80	78	0.98	90	85	0.94	80	80	1.00
75	78	1.04	75	80	1.07	90	95	1.06
		1.03±0.02			1.06±0.02			1.00±0.04

B

SYSTOLIC								
quiet			classical			lyrics		
before	after	after/before	before	after	after/before	before	after	after/before
118	118	1.00	130	135	1.04	124	130	1.05
121	120	0.99	135	140	1.04	117	122	1.04
124	124	1.00	115	120	1.04	118	122	1.03
115	113	0.98	130	140	1.08	135	125	0.93
120	120	1.00	134	134	1.00	126	126	1.00
120	112	0.93	115	115	1.00	110	124	1.13
120	120	1.00	128	128	1.00	126	130	1.03
120	120	1.00	127	120	0.94	138	138	1.00
		0.99±0.01			1.02±0.01			1.03±0.02

(mmHg)

C

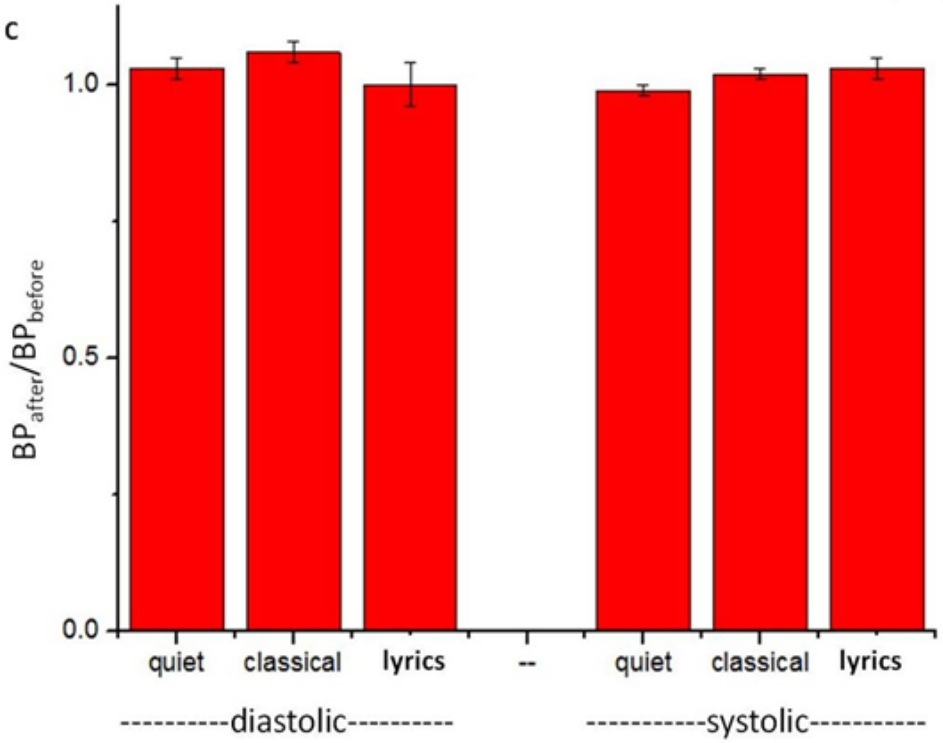

Figure 5. Ratio of blood pressure (BP) after Stroop test to BP before Stroop test for both diastolic and systolic BP. **(A)** Raw data of diastolic BP for each group. **(B)** Raw data of systolic BP for each group. **(C)** Bar graphs of the BP ratio of after-Stroop-test to before-Stroop-test. No significance were shown among the groups.

The ratio of the blood pressure after the Stroop test to blood pressure before the test tends to be slightly higher, except the systolic blood pressure of the quiet group. The ratios for the diastolic blood pressure after the Stroop test over before are 1.03±0.02, 1.06±0.02, and 1.00±0.04,

respectively for the groups of no music, classical and lyrical music of their choice (Fig. 5A), and 0.99±0.01, 1.02±0.01, 1.03±0.02 for the systolic blood pressure (Fig. 5B). None of the groups had a significant difference between them (Fig. 5C).

A

quiet			classical			lyrics		
before	after	after/before	before	after	after/before	before	after	after/before
54	63	1.17	88	82	0.93	82	95	1.16
67	67	1	65	71	1.09	95	80	0.84
53	54	1.02	80	77	0.96	85	83	0.98
102	99	0.97	102	90	0.88	60	55	0.92
95	90	0.95	75	55	0.73	73	76	1.04
84	95	1.13	80	70	0.88	90	80	0.89
73	70	0.96	70	77	1.1	65	60	0.92
80	70	0.88	73	72	0.99	90	77	0.86
		1.01±0.03			0.95±0.04			0.95±0.04
								(beats/min)

B

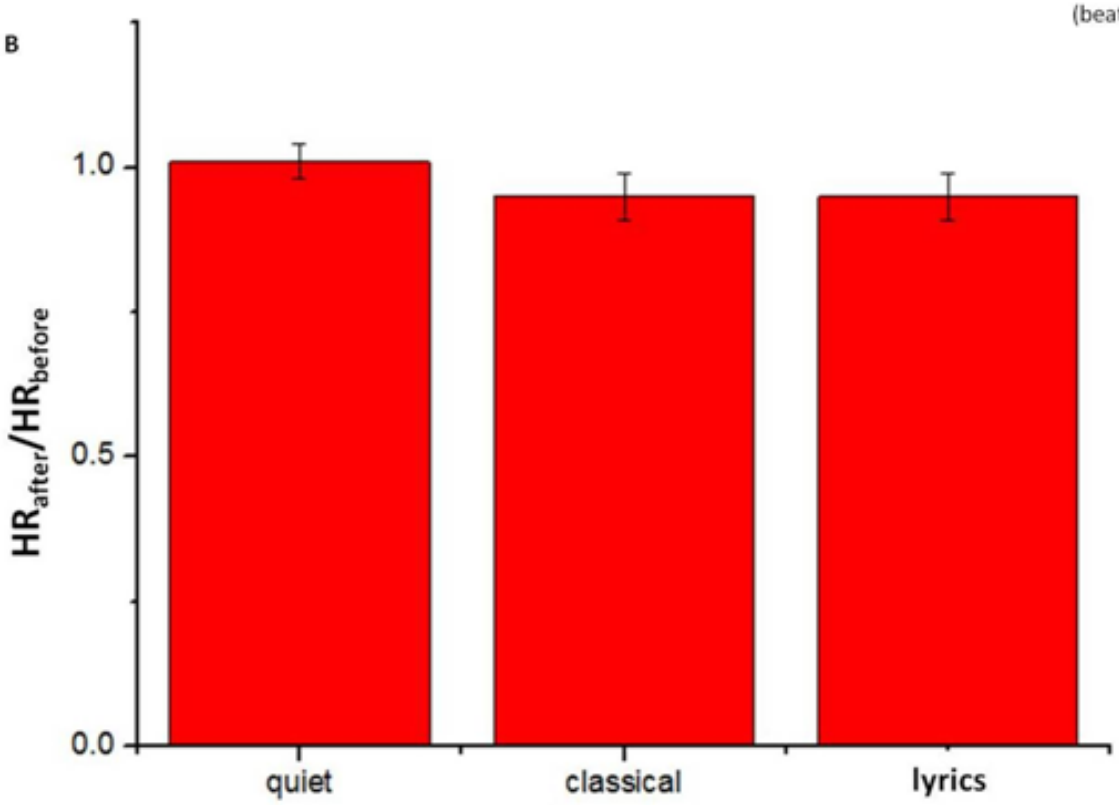

Figure 6. Ratio of heart rate after Stroop test over heart rate before Stroop test for groups. HR, heart rate. **(A)** Raw data of HR before and after the Stroop test and the ratios of after to before. **(B)** Bar graph of the ratio of HR for each group. No significance were shown within the groups.

On average, there was no change in heart rate before and after taking the Stroop test. Without music, variation was equally distributed between positive and negative change, a change was hardly discovered. Overall, participants' heart rates decreased after listening to music, either classical or lyrical, while taking the Stroop test (Fig. 6A, 6B). In the classical music group, participants' heart rates decreased by 4.88±3.23 beats per minute, and with the lyrical music of

their choice, the observed heart rate decreased by 4.25±3.22 beats per minute (figure not shown). Through this we can observe a downward trend in heart rate with the quiet control group having the overall highest heart rate.

DISCUSSION

Several factors contribute to the outcome of the completion time and number of correct responses in the Stroop test in terms of the working memory and cognitive development (Demetriou and Efklides, 1993; Demetriou, 2002). The reaction time needed to accomplish the Stroop test decreases as a child grows up to an adult. As a person ages, cognitive functions develop more and people are thus able to finish a task faster. In our experiment, the participants were chosen within a specific age range of early adulthood, between 19 through 23, in order to reduce the variation in cognitive development due to age.

All participants performed well in the congruent cases of the Stroop test. This exemplifies that while concentration may vary in different musical settings, all participants were able to focus enough to read the word when it was written in the same color and choose the right answer even while under the pressure of a testing situation. This served as an unexpected baseline to which we can compare incongruent scores. Most participants also performed well in the incongruent cases of the Stroop test, but not as well as the congruent cases.

The hypothesis concerning blood pressure, heart rate, and respiratory rate stated these would be highest in lyrical music group compared to classical and control was not supported based on the physiological findings of this study. There were no significant results showing that heart rate, blood pressure, or RR was lower in the classical music group than in non-music and lyrical music groups.

The only significant difference observed in the physiological values measured was in the respiratory rate ($p=0.007$), and this was observed between the classical music group and the lyrical music group. This is interesting because it was also the only consciously regulated physiological value recorded. While the result was significant, it did not support our hypothesis.

There was no significant change in heart rate between the different groups. Heart rate measurements yielded a similar result. The quiet control group had no overall average change in heart rate during the experiment. Both musical groups experienced a decrease in heart rate, with the classical group's participants experiencing a slightly greater decrease in heart rate than the lyrical group's participants. One possible factor relating to this might be the effects of other groups' experiments. In the case of this experiment, the focus was on small changes in heart rate that would be due to the stress of the Stroop test or the change in setting when music was playing. The test subjects were however, also involved in other groups' experiments relating to heart rate, including exercise related activities including running up and down the stairs. These would have had a larger effect on heart rate than this experiment. Some participants were undoubtedly still recovering from an increased heart rate as a result of other experiments while participating in this one. The result is a large range in heart rates between participants and by extension, an increased standard deviation. On average no change in heart rate was observed in the quiet group and a

decrease in heart rate was observed in both groups which listened to music. This change however, was not significant due to the large variation in heart rates among participants and a small sample size. In the future, this experiment could be repeated in an environment which controls for outside factors that might impact heart rate.

While few measurements resulted in significance, this could be due to a small sample size resulting in an increased standard deviation. Because of this, trends are worth mentioning in the analysis. Overall, completion time increased for all participants listening to classical music, and increased more for those listening to lyrical music. While all participants identified all congruent colors correctly, there was some variation in correctness in the event of incongruent questions. The group listening to classical music scored slightly better overall on incongruent Stroop test questions, followed closely by the quiet control group and then the lyrical music group. The quiet group finished the Stroop test the fastest but had more errors in the incongruent answers while the classical group had the less errors but took slightly longer to complete the test. Thus, further experiments are required to control for the variables to get an accurate effect of music on concentration and we can't infer support of our hypothesis relating to concentration.

Another important factor contributing to the results received is the duration of the experiment itself. This study of music affecting concentration is based on a Stroop test that is less than a minute long. A longer time period of listening to music are suggested in future work. The conducted experiment does not reflect the actual environment or duration of a typical student studying. We chose to use a short time interval (6 minutes) with the Stroop test in order to reduce habituation effects to the test, which does not reflect the actual studying time for students. Also, a shorter experiment duration time was chosen in hopes of increasing participation. The length of the experiment as well as the refractory period are important factors to note in future studies. Another error in the experimental process may be found in the fact that the test was administered in a moderately noisy room. It was impractical to move to a quiet library for the experiment. Also, different measurement equipment was used each time to for blood pressure and heart rate; this could contribute small errors due to variation in equipment. The blood pressure was taken manually instead of using a machine and different people took this measurement for different participants, so human error could be introduced. Error could also be introduced due to a small sample size of participants. In addition to our small sample size, some of our participants participated in other physiological tests that required raising their basal rates through strenuous activities. Lastly, there was trouble with the pulse oximeter measuring the heart rate, as there were instances of the equipment taking above normal times to register the heart rate.

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AUTHOR CONTRIBUTIONS

All authors were involved in the design and execution of the experimental project. Tasks were divided as follows: Pedersen was responsible for taking the before and after blood pressure, Chhetri was responsible for putting all of the data into a Microsoft Excel document, Tsao was responsible for running the respiratory belt data collection on the computer and analyzing the data, Seidl was responsible for taking the before and after heart rate as well as obtaining the consent form, and Bobel was responsible for explaining and starting the Stroop test. All authors participated in the data analysis and revisions of the final research paper.

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APPENDIX

	Music Choices:	# Of Times Selected:
Classical:	*Eine Kleine Nachtmusik* by *Mozart*	8
Lyrical:	*Thrift Shop* by Macklemore	3
	Bad Romance by Lady Gaga	2
	Not Afraid by Eminem	1
	Sweet Child of Mine by Guns n' Roses	0
	Dirt Road Anthem by Jason Aldean	1
	Tim McGraw by Taylor Swift	0
	Super Bass by Nicki Minaj	0
	Raise Your Glass by Pink.	1

PILOT STUDY

To further enrich our data, we conducted a pilot study by controlling for factors by increasing the duration of music and ensuring that no participants were exposed to strenuous physical activity prior to participating in the study. The experimental design was similar to our initial experiment but the duration that participants were exposed to music or no music was increased to 45 seconds instead of having the participants listening to it only while they were taking the Stroop test.

RESULTS

Similar to our results, music, either classical or lyrical, made the participants more relaxed by slowing down their heart rate, but only little change between the heart rate before and after. The blood pressure and correctness of congruent and incongruent Stroop tests are also similar.

The results of the respiratory rate is slightly different than the previous results. In both classical and lyrical music group we observed decreased respiratory rate during the Stroop test, especially in the lyrical group. As for the reaction time of the Stroop test, the trend is different from the previous results. We observed classical having the longest completion time with lyrical having the fastest, while in our initial study lyrical had the slowest completion time and no music had the fastest (Table 1).

	Quiet	**Classical**	**Lyrical**
HR (after/before)	1.06	0.95	1.02
Diastolic BP (before/after)	1.02	0.98	1.00
Systolic BP (before/after)	0.99	0.98	1.03
RR (before/after)	1.41	1.28	0.97
# correctness of congruent	5	5	5
# correctness of incongruent	15	12.7	15

Completion time of Stroop test	27.8	30.7	24.0

Table 1. Averages of the various physiological measure taken before and after the Stroop test. The factors measured were heart rate, systolic and diastolic pressure, respiratory rate, the correctness of congruent and incongruent Stroop tests, and the time taken to complete the Stroop test.

DISCUSSIONS

Despite changing the experimental design to control for factors in the pilot study, we were unable to observe any significant changes from our pilot study except the completion time of the Stroop test. The change in the completion time we observed in comparison to our initial study was due to an outlier in the classical group that affected our data. However, removing the outlier still showed the same general trend. This anomaly could be a random error as our sample size was smaller than the initial study. Due to time constrictions, we couldn't recruit more participants to gain a larger sample size. Although we controlled for most of the errors from our initial study, future studies with larger sample size need to be conducted to validate the effects of music on concentration, heart rate, blood pressure and respiratory rate.