The Marginal Effects of Lyrics On Alpha Wave Activity, Blood Pressure, and Heart Rate

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May 8, 2015

auditory stimuli
cognitive load
alpha wave
blood pressure
heart rate
music
lyrics
EEG
ECG
performance

2891 word count

Abstract

We investigated the potential effect of music (lyrical and instrumental) on an individual's cognitive performance and physiological processes. The three measurements used in this analysis were heart rate, blood pressure, and alpha wave activity. It was hypothesized that when participants listened to instrumental music while completing a timed multiplication test, they would show decreased alpha wave activity (EEG), elevated heart rate (ECG), and increased blood pressure compared to completing the task in silence. Furthermore, it was expected that there would be a greater decrease in alpha brain wave activity and a greater increase in heart rate and blood pressure while listening to music with lyrics. It was also hypothesized that participants would answer fewer multiplication problems correctly while listening to instrumental music and even fewer problems correctly while listening to music with lyrics. On the whole, the lyrical component of music would exacerbate performance and further activate the sympathetic nervous system. No statistically significant differences of treatment on test performance, alpha wave activity, heart rate, or blood pressure emerged. However, instrumental music tended to elevate heart rates less dramatically than silence or music with lyrics. Ultimately, lyrical or instrumental music does not significantly affect a participant's performance, but because of the inherently stressful nature of timed tests, the physiological responses often include an increase in blood pressure and heart rate, and a decrease in alpha wave activity. Therefore, some students may prefer to incorporate auditory stimuli into their study environments to decrease the effects of stress and anxiety when engaged in complex cognitive processing.

Introduction

On average, undergraduates listen to music for 40% of their study sessions (Calderwood et al., 2014) and 46.4% of college students believe it helps them concentrate on the task at hand (Danhauer et al., 2009). Despite these preconceived notions, the effects of music listening on task performance remains to be elucidated. Does listening to lyrical music affect intellectual performance and physiological processes to a greater degree than instrumental music? As articulated in John Sweller's Cognitive Load Theory, high levels of cognition serve as a distraction and can reduce task performance (Sweller, 1988). A previous study shows that adding an auditory distraction increased the cognitive load—the amount of information being processed by the brain at one time (Jiang & Sengupta, 2011). Physiologically, an increase in cognitive load can relate to changes in brain wave activity, blood pressure, and heart rate (Lundqvist et al., 2011).

High cognitive load can decrease alpha wave activity, increase blood pressure, and increase heart rate. Alpha waves, which predominate during relaxation, decrease with high cognitive load (Lundqvist et al., 2011). High cognitive load also activates the sympathetic nervous system (Kawanaka et al., 2013). Neurons innervating muscles surrounding peripheral blood vessels are stimulated, which causes vasoconstriction and increases in blood pressure. Additionally, sympathetic neurons innervate the sinoatrial node, which controls heart contractions; therefore, heart rate also increases (Hart & Charkoudian, 2011). The more auditory information present in a stimulus, the greater the

corresponding increase in heart rate (Hart & Charkoudian, 2011). Therefore, we hypothesize that the greater cognitive load, the greater the decrease in alpha wave activity, increase in blood pressure, and increase in heart rate.

It was hypothesized that when participants listened to instrumental music while completing a timed multiplication test, they would show decreased alpha wave activity (EEG), elevated heart rate (ECG), and increased blood pressure compared to when they were not listening to music (Figure 1). Additionally, it was believed that when participants listened to instrumental music, they would answer fewer multiplication questions correctly in the given 60 seconds, indicating that they experienced a larger decrease in task performance, compared to when not listening to music. It was expected that there would be a greater decrease in alpha brain wave activity and task performance, and a greater increase in heart rate and blood pressure when participants listened to music with lyrics than when listening to instrumental music, due to the increasing amount of cognitive load associated with song lyrics.

Students in Physiology 435 served as participants for this experiment. Students were brought into a silent test room, where they were given 60 seconds to complete as many multiplication problems as they could, first while receiving no auditory distraction and then while listening lyrical or instrumental music. Finally, they completed a third test while listening to the same song but a lyrical or instrumental version, depending on which option the participant first had. These two distractions, lyrical or instrumental music, served as the independent variables. Data from each trial with music was compared to that student's negative control, their performance in silence. Background music during mental activity distracts from the task at hand while music with lyrics likely acted as a stronger distracter, thereby allowing us to test the dependent variables: effects of auditory distraction on performance (i.e. number of correct answers and total number of problems attempted), cognitive activity, heart rate, and blood pressure.

Methods and Materials

Twenty-five students, enrolled in Physiology 435 at the University of Wisconsin-Madison participated in this study. The group was made up of 13 females and 12 males, ages 20-25 years old, all with normal hearing capabilities. All of the participants were fluent in English, although one participant reported that English was not their first language. After obtaining their consent, participants were brought into a silent testing room where electrodes were attached to their bodies for electroencephalography (EEG) and electrocardiography (ECG) measurements, and the equipment was calibrated for each participant (Figure 2).

After participants were briefed on the experiment (Figure 3), initial blood pressure was recorded and baseline measurements for EEG and ECG were collected before the subject began the first multiplication test. The order of the multiplication tests (A, B, and C) was randomized. In addition, the lyrical or instrumental versions of the song played in Trials 2 and 3 was randomized. EEG and ECG data was collected for the duration of the experiment. The beginning and end of each test was marked in the data collection files.

The participant was then given 60 seconds to complete as many multiplication problems as possible, once prompted by the test proctor (Trial 1). After the blood pressure was taken at the end of the 60-second time period, the test proctor gave the subject a second test, face down, and began to play the lyrical or instrumental version of the song. After a 10-second waiting period, which was needed for baseline measurements of EEG and ECG, participants began the second multiplication test. They were given 60 seconds to complete as many questions as possible (Trial 2). Blood pressure was measured again before the third test was placed face down on the table. Then the lyrical or instrumental music began to play for 10 seconds before participants were instructed to complete as many questions as possible on the third multiplication test in 60 seconds (Trial 3). Blood pressure was again recorded after the test. Participants filled out a survey (Appendix 1) after their participation, inquiring about the participant's first language and their preferred study setting (in silence or with background music, lyrical or instrumental.)

To analyze blood pressure, mean arterial pressure (MAP) will be calculated. ANOVA tests will be conducted to determine the significance of auditory stimuli on number of questions attempted, number of questions correct, MAP, change in alpha wave activity, and change in heart rate.

Blood pressure readings were collected using the OMRON 10 series with blood pressure monitor (Model No. BP791IT) and a ComFit cuff. EEG and ECG data was collected on computer system Windows 7 using Biopac Student Lab System: BSL 4 software (MP36 hardware). EEG results were taken with the BIOPAC electro lead set (SS2L) while 3 BIOPAC Disposable Electrodes (EL503) were used for each participant (Figure 4). ECG results were also taken with the BIOPAC electro lead set (SS2L) while another 3 BIOPAC Disposable Electrodes (EL503) were used for each participant (Figure 5). BIOPAC Electrode Gel (GEL 1) was applied to each electrode before the proper placement; Purell Sanitizing Wipes were used to clean the gel off of the participant. A latex swim cap was worn by the participant to keep the electrodes in place for recording the EEG. An iPhone 5s stopwatch was used for timing each participant. The lyrical song was Taylor Swift's "Shake it Off", and in order to maintain the melody and beat, the instrumental song was "Shake it Off Instrumental". The songs were played from YouTube music videos at a constant volume level from an HP Envy 360 laptop, positioned in the same location during every test. Math multiplication tests were printed from math-drills.com (Appendix 2).

Results

Multiplication Test

When participants tested in silence (M=45.8), with instrumental music (M=49.5), and with lyrical music (M=48.8), they answered the same number of questions (p=0.58). Under all conditions, participants answered around 98.5% of the attempted questions correctly (p=0.88) (Figure 6). The version of the math test did not affect the number of questions answered (p=0.55) or the percentage of questions answered correctly (p=0.98).

Treatment order also did not affect the number of questions answered (p=0.12) or the percentage of questions answered correctly (p=0.96).

Blood Pressure

When testing in silence, 11 participants experienced a negative change in mean arterial blood pressure (MAP) (M=3.45), 2 participants experienced no change in MAP, and 12 participants experienced a positive change in MAP (M=4.56) (Figure 7). When directional changes in systolic and diastolic blood pressure were analyzed separately, no differences in systolic (p=0.47) or diastolic (p=0.57) change in pressure occurred between treatments.

When testing with instrumental music, 12 participants experienced a negative change in MAP (M=3.55), 2 participants experienced no change in MAP, and 11 participants experienced a positive change in MAP (M=3.64) (Figure 8).

When testing with instrumental music, 9 participants experienced a negative change in MAP (M=5.78) and 16 participants experienced a positive change in MAP (M=6.65) (Figure 9).

Alpha Wave Activity

When participants tested in silence, 12 experienced negative average changes in alpha wave activity (M=0.166) and 12 experienced positive average changes (M=0.146). When participants tested with instrumental music, 11 experienced negative changes in alpha wave activity (M=0.291) and 13 experienced positive changes (M=0.203). When participants tested with lyrical music, 13 experienced negative changes in alpha wave activity (M=0.217) and 11 experienced positive changes (M=0.119) (Figure 10). When directional changes in alpha wave activity were analyzed between treatments, no difference was found (p=0.84).

Heart Rate

When testing in silence (N=25), with instrumental music (N=21), and with lyrics (N=23), nearly all of the participants displayed an increased heart rate. An average increase of 16.5 beats per minute (BMP) was observed when testing in silence, an increase of 18.6 BMP was observed when testing with instrumental music, and an increase of 20.4 BMP was observed when testing with lyrical music (Figure 11). When all of the changes in BMP, regardless of direction, were analyzed, no difference in change of pulse was significant between treatments (p=0.57).

Discussion

In the study, participants were exposed to different auditory stimuli and the results were examined to see how they affected the participants' physiological responses. The results showed that the differences in alpha wave activity, blood pressure and heart rate between different testing conditions were not statistically significant.

Multiplication Test

The results showed that lyrical or instrumental music does not affect a participant's performance (Figure 6). Based on the averaged results, all groups attempted and correctly answered approximately the same amount of problems. Differences in each subject's mathematical background may have confounded our results. Subjects also varied in their preference for study environment. The post-experiment survey showed that while about one third of the participants prefer to study in complete silence, there was also a group that preferred background music, some lyrical and others, instrumental. Therefore, not all participants would have experienced the same physiological response under the different testing conditions based on their typical studying routines. Future studies could further elucidate this relationship. Additionally, differences in how the tests were administered between each subject, despite our attempt to standardize the protocol, may have had an impact on our results.

Blood Pressure

The results suggest that the presence or absence of music does not statistically affect blood pressure (Figures 7-9). It was hypothesized that tests taken with lyrics would increase blood pressure the most while tests taken in silence would increase blood pressure the least. This hypothesis was consistent with a study that compared the effects of silence and music on blood pressure, and found that the music indeed increased blood pressure above that of the blood pressure in silence (O'Riordan, 2012).

From the results, it was determined that there was no statistical significance and there were no observable trends in the data across all three testing conditions. While the tests taken with lyrics did affect the blood pressure the most, once again, the calculated effect was not statistically significant. This could be due to blood pressure being a slower process and having a slower rate of response. Future studies could be done to further explore why blood pressure was not affected in our study, contrary to the findings of other experiments. Perhaps if measured longer after test administration, blood pressure differences would emerge. Additionally, to allow for the blood pressure to normalize and to test between treatments, future studies should include a longer inter-test interval to remove the effects of the prior testing period.

There are other factors that could have affected blood pressure that could be taken into account. It is possible that some participants had consumed higher amounts of caffeine than other participants earlier in the day, affecting their blood pressure. Other participants may have also been taking medication or have preexisting health conditions, such as general or test anxiety, that could result in different physiological responses to different testing conditions. Thick sweaters or jackets worn by the participant that could not be removed to measure blood pressure may have also resulted in readings that were not completely accurate.

Alpha Wave Activity

The data showed that the differences in alpha wave activity between different testing conditions were not statistically significant (Figure 10). The lack of an observable trend was consistent with a study that compared the effects of classical instrumental music and lyrical rock music on alpha wave activity: neither type of music caused a statistically significant difference in activity (Bennet and Bennet, 2008). The study found that even with the presence of lyrics, the brain's temporal lobe interpreted the information as it would interpret a change of pace or tempo in the music, so the brain wave activity would not change significantly between lyrical and instrumental music. This finding would suggest, then, that in the experiment that was conducted for this paper, it would have been observed that alpha brain wave activity decreased between silence and the presence of music. This occurrence, however, was not observed to be statistically significant. A lack of difference could possibly be explained by the inability to achieve complete silence in the testing room. Although the participant was placed in a quiet testing room, auditory stimuli from neighboring rooms were audible during the testing period. The noise could have been a distraction to test takers, resulting in data that was similar to data from when the test was taken in the presence of music.

Heart Rate

The data suggest that the differences in heart rate between the baselines and each testing condition were not statistically significant. It was hypothesized that heart rate would increase more in the presence of music without lyrics (instrumental) compared to silence and the presence of lyrics would increase the heart rate even more than in the absence of lyrics. Despite the lack of statistical significance, the heart rate increased slightly when participants listened to music with lyrics, due to a greater cognitive load associated with lyrics (Figure 10). The results also show an observable trend not expected with the hypothesis; the data show that the treatment in silence increased the heart rate more than the treatment without lyrics (instrumental). These trends are consistent with a study that exposed students to a cognitive stressor task either in the presence of Pachelbel's Canon in D major (an example of instrumental music), or in silence. The study found that exposure to the music prevented a significant increase in the students' heart rate (Knight and Rickard, 2001). Moreover, this study supported the claim that music can inhibit anxiety. Therefore, the participants used for the experiment conducted for this paper could have experienced a more calming effect while listening to the instrumental music compared to silence, which was why their heart rates did not increase as much. Future studies using larger sample sizes could determine significance.

Another reason their heart rates increased more during the silent treatment compared to the instrumental treatment could be a result of participants being most nervous and/or anxious while taking their first timed multiplication test, which was always in silence due to the design of the study, because they didn't know what to expect right away.

In conclusion, this study suggests that taking a multiplication test in silence, while listening to lyrical music, or while listening to instrumental music marginally affects

performance, blood pressure, alpha wave activity, or heart rate. From the data collected, there was no statistical significance when analyzing the physiological responses within and between treatments. Future studies will continue to investigate the mechanisms behind interpreting background auditory information while studying.

Acknowledgements

The authors would like to thank Dr. Andrew Lokuta (Department of Neuroscience) for his guidance in our project, Kristin Byrne (statistic consultant) for her assistance in analyzing our data, Sonalee Barthakur (Department of Physiology) for reviewing our previous submissions, Paul Johnson, Sorabh Singhal, David Belair (Department of Physiology), Joseph Sepe (Department of Physiology), Caitlin Murphy (Department of Physiology) for their continued support throughout our project, and Physiology 435 students for their participation in our study.

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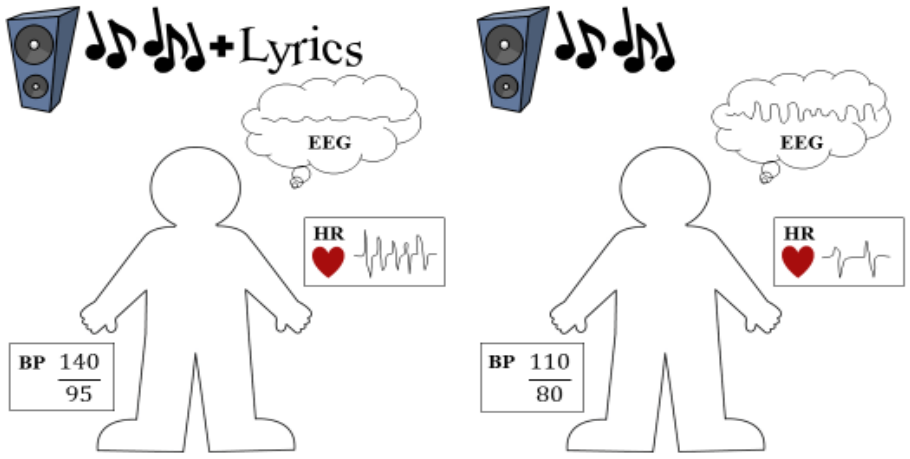
Figures and legends



http://medicalplanzone.com/; http://www.wpclipart.com/; http://imgkid.com/

Figure 1. Representation of hypothesis depicting a decrease in alpha wave activity (EEG), increase in heart rate (HR), and increase in blood pressure (BP) when participants exposed to lyrical music (left) compared to when exposed to music without lyrics (right).

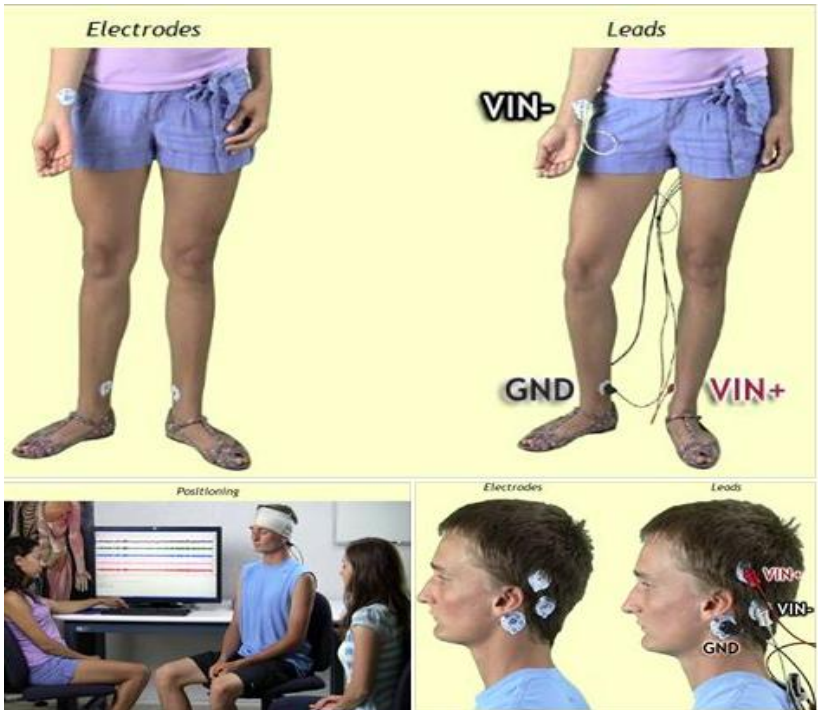


Figure 2. Placement of electrodes for ECG and EEG.

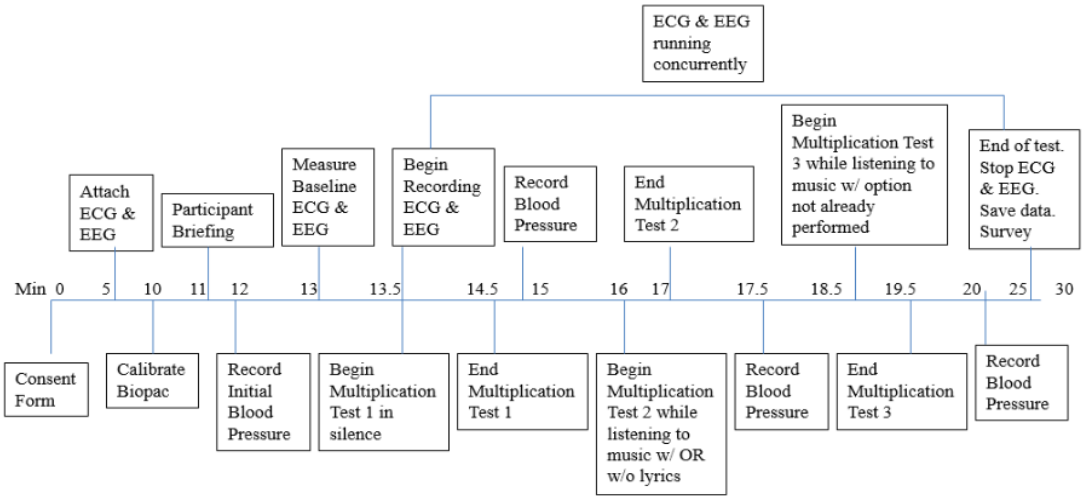


Figure 3. Timeline of events volunteers experienced.

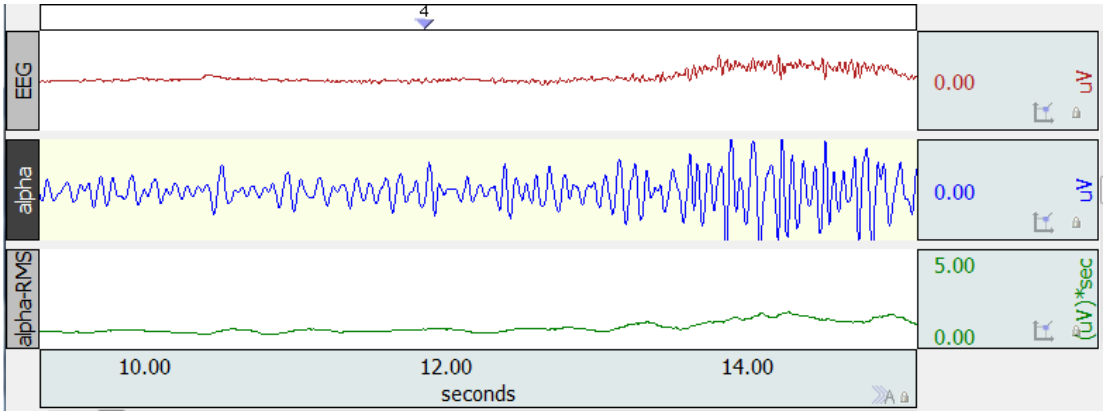


Figure 4. Screenshot of the BIOPAC program showing EEG and alpha wave activity. The x-axis is in seconds and the y-axis is in microvolts (uV) for both EEG and alpha wave activity. This shot is representative of a participant's baseline for Treatment 1 (prior to the ▲) and the beginning of the Treatment 1 (after the ▲). This shows how a typical participant's alpha wave activity changed while taking the timed multiplication test during Treatment 1.

Figure 5. Screenshot of the BIOPAC program showing ECG and Heart Rate. The x-axis is in seconds and the y-axis is in millivolts (mV) and beat per minute (BPM) for ECG and Heart Rate, respectively. This shot is representative of a participant's baseline for Treatment 1 (prior to the) and the beginning of the Treatment 1 (after the). This shows how a typical participant's heart rate changed while taking the timed multiplication test during Treatment 1.

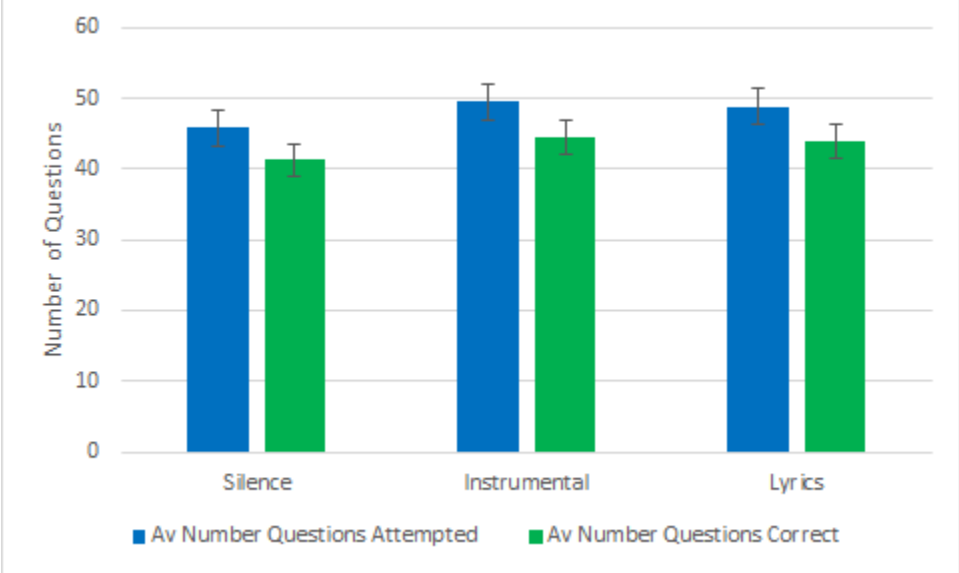


Figure 6. Average number of questions attempted and average number of questions answered correctly when participants tested in silence, with instrumental music, and with lyrical music (N=25). Bars represent +/- 1 SE.

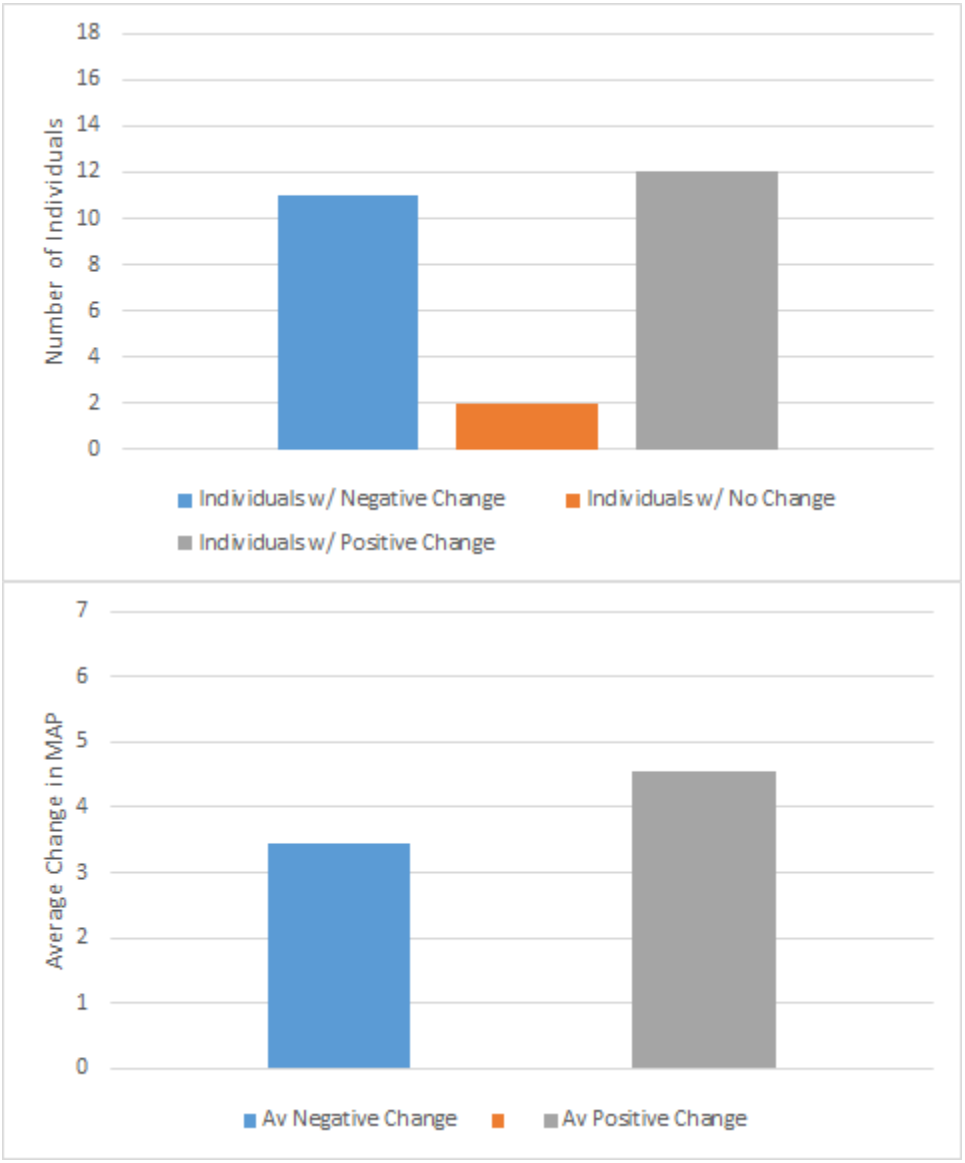


Figure 7. A) The number of participants who experienced negative, no, and positive changes in MAP when testing in silence (N=25). B) The average negative (N=11) and positive (N=12) changes among those experiencing them.

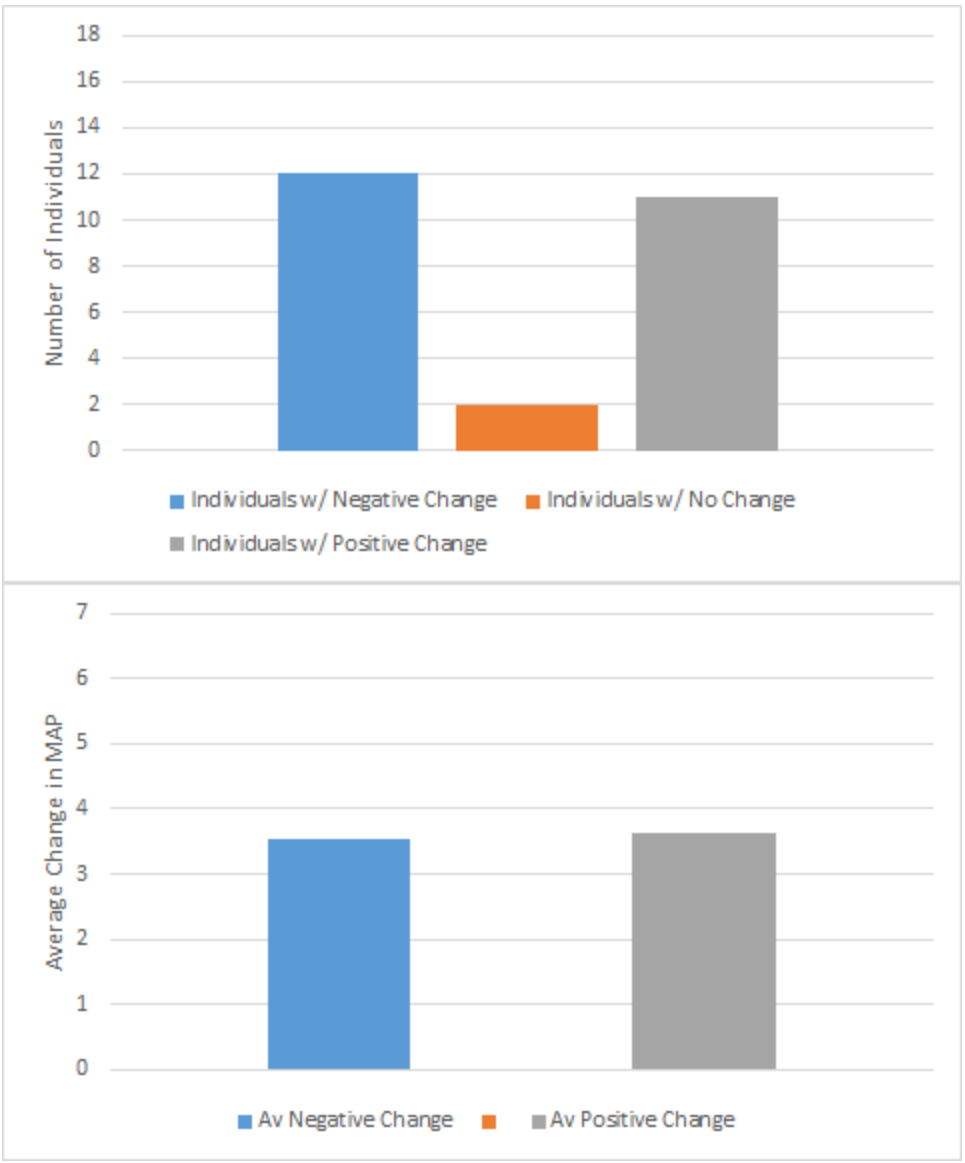


Figure 8. A) The number of participants who experienced negative, no, and positive changes in MAP when testing with instrumental music (N=25). B) The average negative (N=12) and positive (N=11) changes among those experiencing them.

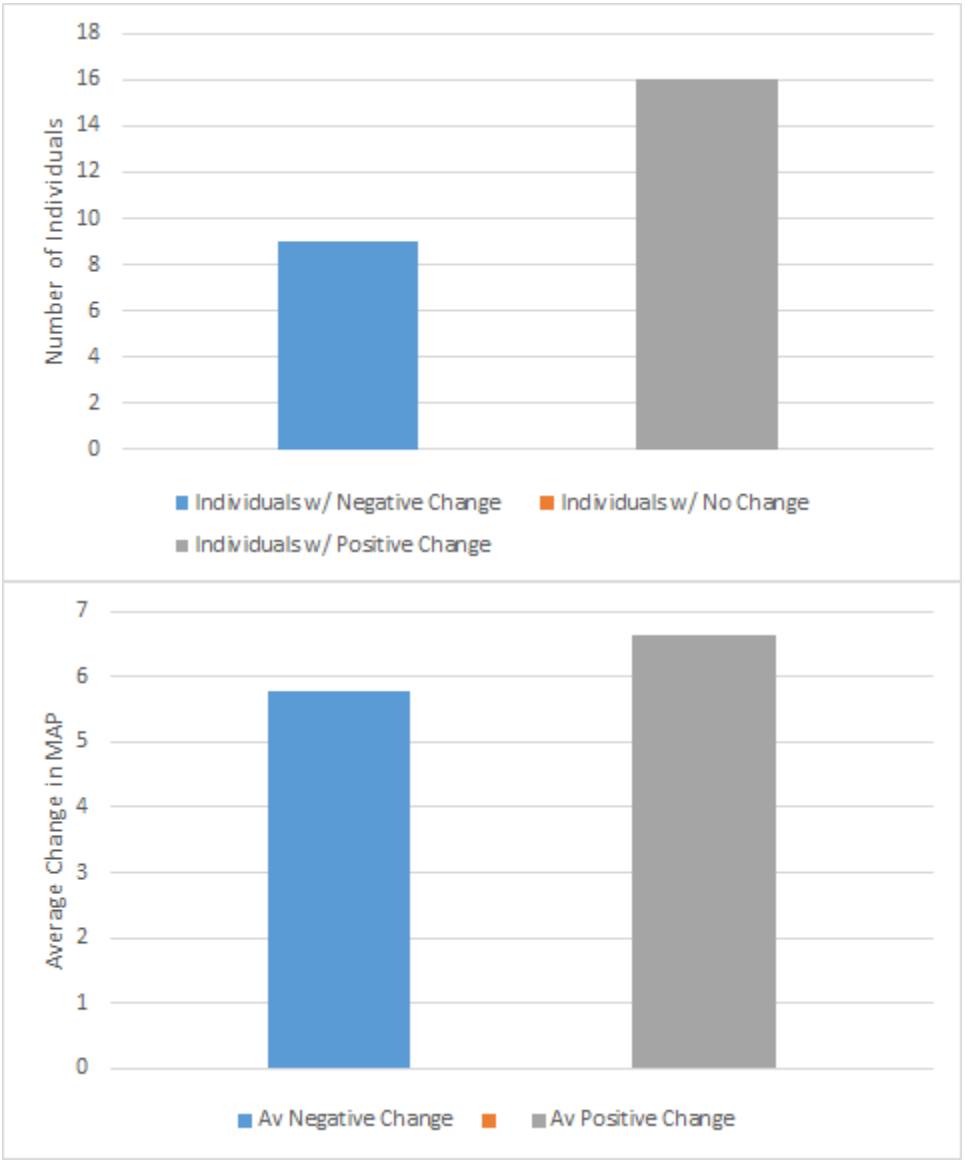


Figure 9. A) The number of participants who experienced negative, no, and positive changes in MAP when testing with lyrical music (N=25). B) The average negative (N=9) and positive (N=16) changes among those experiencing them.

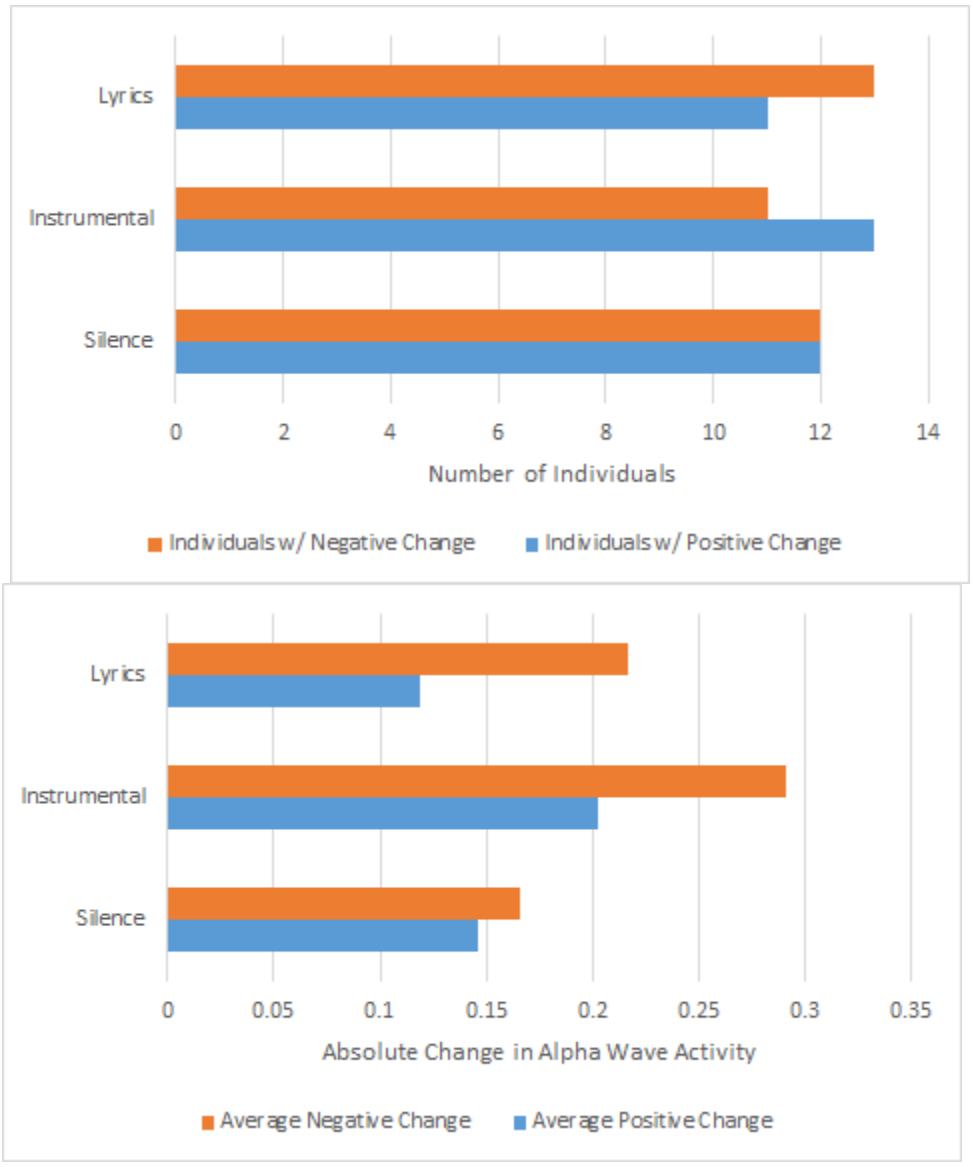


Figure 10. A) The number of individuals experiencing a change in alpha wave activity in each direction for the three treatments (N=24). B) Average change in alpha wave activity among those experiencing positive and negative changes for each treatment.

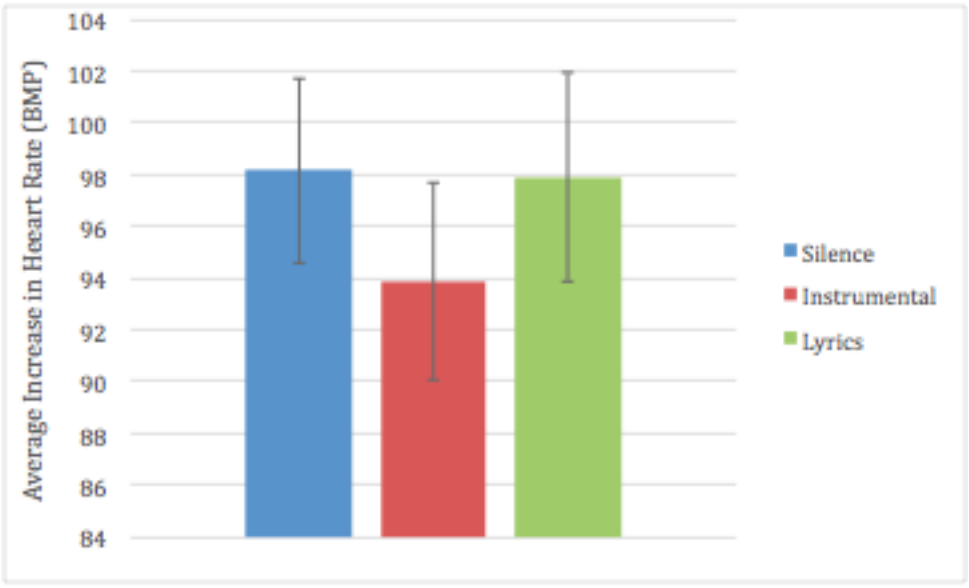


Figure 11. Average increases in heart rate when testing with different auditory stimuli. Bars represent +/- 1 SE.

Appendix 1

What is your first language?

In general, when you study, you prefer:

- € Complete silence
- € Background music without lyrics (classical, jazz, etc.)
- € Background music with lyrics
- € No preference
- € Other: _____

Thank you for participating in our study. We ask that for the integrity of our experiment and accurate data, you refrain from disclosing details of this experiment to other students. Thanks again!

Appendix 2

Multiplying With 1, 2, 3, 4, 5, 6, 7, 8, and 9 (A)
Note: The other factor has a range of 1 to 10.

6 x 3	8 x 7	2 x 7	6 x 9	8 x 7	2 x 1	1 x 3	1 x 3	4 x 3	9 x 5
5 x 5	7 x 4	2 x 1	5 x 5	2 x 3	5 x 8	6 x 3	3 x 4	1 x 8	1 x 4
8 x 7	8 x 1	8 x 3	1 x 9	5 x 2	3 x 6	1 x 6	6 x 4	2 x 7	8 x 4
10 x 2	4 x 5	5 x 8	1 x 2	6 x 9	9 x 9	3 x 4	1 x 1	8 x 4	7 x 9
9 x 6	8 x 1	9 x 9	8 x 9	4 x 5	1 x 7	2 x 1	8 x 7	8 x 6	8 x 7
8 x 9	9 x 8	8 x 4	7 x 4	4 x 9	10 x 9	9 x 9	2 x 7	8 x 9	10 x 9
7 x 1	10 x 8	7 x 4	2 x 1	2 x 3	9 x 9	1 x 4	3 x 2	4 x 8	7 x 3
8 x 8	6 x 4	3 x 3	9 x 3	2 x 7	6 x 3	8 x 9	7 x 9	2 x 5	7 x 7
7 x 8	5 x 8	7 x 5	5 x 2	9 x 8	9 x 6	8 x 4	4 x 3	2 x 6	1 x 6
6 x 4	3 x 6	6 x 2	9 x 5	8 x 7	8 x 8	1 x 4	1 x 7	4 x 8	7 x 2

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