# Examining the Effects of Music with Words on Long Term Memory Encoding

Abby Wannow, Simran Kaur, Sean Peronto, Karan Singh

*The University of Wisconsin-Madison, Physiology Department*

Lab 302

Group 15

**Keywords:** Breathing Rate, Electrodermal Activity, Heart Rate, Long Term Memory, Lyric, Music, Stress

Word count: 4025

## Abstract

Many students listen to music while studying without knowing the effects that this could cause. The aim of this study was to investigate the effects of listening to music with words while studying on long term memory recall. It was hypothesized that listening to music with words while studying would reduce the number of words remembered on a long term memory recall test, as opposed to exposure to music without lyrics while studying. Fifty participants were included in the study and were randomly assigned to one of two treatment groups. One treatment group listened to music with words while attempting to memorize words and their definitions then after listened to music without words while memorizing different words and their definitions. The other treatment group was exposed in the opposite order. Physiological data was collected before the first treatment, during the first treatment, between the treatments, and during the second treatment. The physiological variables recorded were heart rate, galvanic skin response, and breathing rate. The data was analyzed by running a t-test comparing each treatment to their respective baseline. The t-test test comparing EDA values and respiratory values showed no significant difference between variables; however, heart rate did show statistically significant differences when listening to music without lyrics first. In addition, the data showed that overall participants were able to recall more definitions when listening to music without lyrics, though this was not statistically significant. More research needs to be done to get a clearer idea of how music affects cognition during studying.


## Introduction

Music is beneficial in many ways to a wide demographic consisting of newborn infants to older adults greater than 60 years of age. To young adults in particular, possible benefits of music include reduction of stress and anxiety levels, improved critical thinking and research skills and augmented memory (Dvorak & Hernandez, 2019). Listening to music while studying has become common practice among college and high school students as advancements in portable technology increase. Popular genres of music for this demographic include pop, hip hop and rap. Different genres are suggested to induce different responses in students while studying in terms of long term memory.

### *Tempo of music*

Studies show that the tempo of the music affects the memory of the listener while studying. The basis of this idea is that classical music promotes relaxation in an individual. In a relaxed state one's brain works more efficiently; therefore, memory is improved. According to a psychology experiment by the University of Tennessee, classical music which had 40 beats per minute showed greater performance for memory tasks. In comparison, rap music with 100 beat per minute was correlated with increased emotionality and reduced memory performances

(Bugter et al., 2012). In addition, it was found that hip hop and rap music, associated with fast tempos, cause negative influences on patients by increasing their blood pressure and heart rate (Trappe, 2010). This suggests that an increased tempo in music can hinder physiological and psychological processes which influence retention of memory.

*Presence of Lyrics*

Rap music induces arousal, while classical music induces relaxation (Bugter et al, 2012). The major difference between the two genres is the presence of lyrics. The idea of combining slow tempo music and learning has been explored for quite some time, but there remains a gap in studies concerning high tempo music and the presence of lyrics in music. Since college students more popularly listen to high tempo music, a perpetual question risen within our group was whether the presence of lyrics in high tempo music affect long term memory. We decided to study the effect of music with and without lyrics on long term memory on students attending the University of Wisconsin-Madison. Since the presence of lyrics can provide cause a distraction, our group inferred that fast tempo music with lyrics will have a greater decrease in long term memory in comparison to fast tempo music without lyrics.

*Alterations in memory related to Physiological stress*

When dealing with cognitive processes, it is thought that music can draw away from the to-be-remembered information, thus interfering with the encoding process (Ferreri, 2015). The basis of this principle is that the presence of music interferes with the synaptic pathways being used, thus, allowing the brain to become more disengaged and impede proper functioning. When distracted, the brain must work harder to concentrate, thus inducing a stress response within the body (Ferreri, 2015). When we are exposed to potential acute stressors, our brain initiates activation of the sympathetic nervous system and releases hormones called epinephrine and norepinephrine (Sapolsky, 2000). These two hormones work together to increase heart rate and respiration rate, dilate pupils, and decrease digestion (Sapolsky, 2000). One study done on rats, found that the hormones produced from acute stress primed the body for optimal alertness and cognitive function by proliferating stem cells into new nerve cells, allowing them to perform better on a memory test (Sanders, 2013). On the contrary, a study performed by Schwabe *et al.* showed participants that learned under stress had 30% less recall, independent of the learned material. Still other studies found that acute stress caused disintegration of dendrites which in turn limited synapses ability to collect and store memories (Irvine, 2008). Overall, the data are conflicting, proving more research on acute stress and its effect on memory needs to be done.

*Hypothesis*

In this study, we investigated how music with words effects heart rate, galvanic response, and breathing rate and whether these physiological changes correlated with long term

memory recall. We hypothesized that music with words will cause a brief stressful physiological response in participants, thus increasing the heart rate, breathing rate, and galvanic response. It was then expected that these physiological changes would hinder the encoding process and cause participants to have worse recall compared to control subjects listening to music without words. These physiological measurements were used for their connection to the sympathetic nervous system that is activated during times of stress. Recording heart rate, breathing rate, and galvanic response could lead to more information regarding the stressful effects of music with words on memory, which could be further used to help students study.

## Materials

Galvanic skin response, heart rate and respiratory rate were measured to determine the effects of listening to fast tempo (162 bpm) music with words on memory. Electrodermal activity/galvanic skin response was measured using an EDA Transducer two electrode system (Model: SS3LA; SN: 1602004165; Made by Biopac Systems, Inc. Goleta, CA) with isotonic gel (GEL101) to measure changes in sweat gland activity in microsiemens (μS). An electrocardiogram (Model: SS29L Lead II; SN: 10328; Made by Biopac Systems, Inc. Goleta, CA) was used to determine heart rate in beats per minute (bpm). Respiratory rate was measured in millivolts (mV) using a respiratory transducer (Model: SS5LB; SN:13116916). Data was recorded and analyzed using the Biopac Student Lab System (BSL 4 software, MP36). A Dell computer, computer 8, was used from the lab room in accordance with the Biopac System. This single computer was utilized to monitor all Biopac data from the EDA, ECG, and respiratory transducer. A Mac laptop was used with noise cancelling headphones (Bose QC 35) to play music for the participant. Equipment setup and data recording was directed by the Biopac Systems, Inc Student Laboratory Manual (Biopac Systems Inc. ISO 9001:2008). Six novel words were generated using a Fake Word Generator and definitions were created for these words. The music used was the song Her by BLOCK B with lyrics and the same song with no lyrics. The song's tempo was 162 bpm.

| **Word** | **Definition** |
|---|---|
| Sinpad | Used to clear your computer keyboard |
| Bronea | A cave behind a waterfall |
| Skivet | Tool used to chop wood |
| Naperone | Medicine for a stomach ache |
| Glowl | A vegetable from India |

| | |
|---|---|
| Novaly | To jump gracefully |

**Table 1.** Table of the words along with the definition that the participants were asked to memorize while listening to different treatments. Participants were asked to memorize three words and their definition at a time.

## Methods

*Introduction to study/ Consent*

Students enrolled in Physiology 435 at the University of Wisconsin-Madison were asked to read and sign a consent form before participating in the study. This form stated the potential risk of minor irritation, headache, and change in mood; length of the study, which was ten minutes; tasks participant had to perform; questions concerning hearing impairment; and confidentiality. Once the form was signed, participants were taken into a quiet room to begin the study. Each student participated in the study once to avoid repeated exposure to the words.

*Set up and Procedure*

The experiment was conducted in a quiet room to minimize distractions. Once the participants entered the study room, the two experimental leads explained the tasks and rules of the study and answered questions participants may have had. The participants were seated facing away from the computer and the lead experimenter so that their physiological readings were not altered by watching the monitor. The respiratory belt (SSLB) was snugly secured on the participants chest, directly below the armpits and slightly above the nipples. The lead was connected to Channel 1 of the Biopac Systems, Inc. on the computer. The ECG (SS29L) electrodes were placed on the participants inside right ankle, inside right wrist and inside left ankle. The white positive lead was connected to the right wrist, red negative lead to the left ankle and the black ground lead to the right ankle. The lead set for the ECG was connected to Channel 2 of the Biopac system. Finally, a drop of isotonic gel (GEL101) was placed on the participants right index and middle finger. Their fingers were then wrapped with the EDA transducers covering the gel. The wires were draped over the top of the index finger, and the EDA lead was connected to channel 3. A baseline recording was obtained for all participants during which time they were asked to relax in their seat and breathe normally. This was also used as the negative control. After the baseline data was collected, subjects were given headphones which played fast tempo music without words at 162 beats per minute. They were asked to memorize three words and their definitions for one minute. These words were five to six letters long, not real and were found on a word generator online. The definitions consisted of five to seven words. A 30 second break was given. The music changed to fast tempo at 162 beats per minute with words and they were given another set of three words and definitions to memorize for one minute. A counterbalanced technique, where one person listened to music with words first and the next person listened to music without words first, was used. This was

done to ensure that the order the treatments were given, didn't affect the behavior of the participants or elicit a false response. The data was collected and saved. The participants were called back exactly one week later and were given a recall test to examine how well they remembered the definition of the words under the different conditions. The participants were handed a sheet of paper and asked to recall and write the correct definitions corresponding to that word they were asked to memorize during the experimental trial. They were given five minutes for recall. Number of correct definition from each condition was noted for data analysis.

*Data Analysis*

After the experiment was complete, the data from the Biopac System was analyzed in regards to the EDA, ECG, and respiratory rate. These results were averaged and compared with the average baseline measurements of the total respective participants by finding each treatment's percent change from baseline. In addition, the number of correctly identified words was recorded and compared between both conditions. The statistical method of analysis used was an t-test which was completed on Microsoft Excel. The p-value was determined to be significant if it was less than 0.05.

*Positive Control*

Positive control tests were measured by the team of investigators to ensure functionality of Biopac equipment. The baseline measurements were taken for ECG to measure heart rate, EDA to measure galvanic skin response, and EEG to measure alertness under relaxed conditions. These values were analyzed through the Biopac system Inc. Memorization was indicated by number of words each participant remembered. Each investigator was asked his/her name, to count backwards by ten, and to count down from 30 with increments of increasing odd numbers. The average activity for EDA, ECG, and respiratory rate were 5.49 microsiemen, .025 mV, and .03 mV, respectively. The activity was compared to baseline measurements. Variable measurements were expected to increase after activity. This indicated that the system was functional.

*Negative Control*

The baseline measurements of each participants served as the negative control. These were collected while the participant was attached to all the equipment such as the respiratory belt (SSLB) and ECG (SS29L) electrodes. Measurements were collected in a relaxed state while breathing normally. The data was collected in millivolts and microsiemen on Biopac system. The results showed that the Biopac system and heart rate monitor were accurately measuring what was being tested in a rested state.


**Figure 1.** Experimental timeline for each participant. The chart describes when we administer each treatment and when rest periods are allotted. Overall, each participant spends about 15 minutes with us on two different days that are a week apart.

## Results

Physiological variables were recorded in four distinct stages which first included the baseline measurement, then the first part of recall test, a break where baseline was measured again, and the second part of the recall test. Deviation of the baseline was measured against respiratory rate, heart rate, and galvanic skin response. Once the measurements were complete, participants returned one week later to complete a six question recall quiz; the results were recorded and analyzed.

### Recall Test

Recall based examination was measured according to the number of correctly defined words in lyric and without lyric conditions. Figure 2 compares the number of words remembered while listening to music without lyrics versus the number remembered with lyrics. The average number of words recalled in music with lyric conditions was 0.97 words and the average number of words recalled in music without lyrics was 1.10 words. Overall, participants remembered more words from the music without lyrics treatment but it wasn't a big enough difference to be considered statistically significant.

### Galvanic Skin Response

Figures 7 and 8 compare the mean electrodermal activity while listening to music with lyrics and while listening to music without lyrics. These graphs report the average percent change of electrodermal activity between each treatment and baseline. Figure 7 compares the percent

change in electrodermal activity between participants who listened to music with lyrics first and music without lyrics second. Figure 7 shows that participants experienced an average -9.205 percent change from baseline when listening to music with lyrics. When listening to music without lyrics, participants experienced a +13.5 percent change. A t-test was performed comparing the two treatment's percent change from baseline and it was found to be insignificant, reporting a p-value of 0.144. Figure 8 compares the percent change in electrodermal activity between participants who listened to music without lyrics first and music with lyrics second. Figure 8 shows that when listening to music without lyrics, participants experienced a mean +5.83 percent change and when listening to music with lyrics, participants experienced a mean +10.97 percent change. A t-test analysis proved this difference of percent change to be insignificant (p=0.794). Overall, listening to music with lyrics proved to have no significant change on electrodermal activity, when compared to listening to music without lyrics.

Heart Rate

Figures 5 and 6 compare the difference in percent change for the average heart rate with the baseline listening to music with lyrics, and listening to music without lyrics in participants. Figure 5 compares the percent change in participants who listened to music with lyrics first and without lyrics second. The average percent change in heart rate for this figure is +4.71 from baseline when listening to music with lyrics first and +2.64 listening to music without lyrics first. To compare the two treatment's percent change from baseline, a t-test was performed and it was found to be insignificant with a p-value of 0.375. Figure 6 compares the percent change in participants who listened to music without lyrics first and with lyrics second. When listening to music without lyrics first a +7.53 percent change was demonstrated from the baseline while listening to music with lyrics second demonstrated a -1.08 percent change. A t-test analysis proved a significant change in heart rate (p-value= 0.0068). Overall listening to music without lyrics first and with lyrics second demonstrated a significant change in heart rate from the baseline.

Respiratory Rate

Figures 3 and 4 compare the mean respiratory rate percent change from baseline while listening to music with lyrics and listening to music without lyrics. Figure 3 compares the difference in average respiratory rate of participants who listened to music with lyrics first and music without lyrics second. Participants experienced an average of +32.28% change in their respiratory rate from baseline when listening to music with lyrics first, and an average of +15.98% change from baseline when listening to music without lyrics second. The t-test comparing the two treatment's percent change from baseline was found to be insignificant with a p-value of 0.09. Figure 4 compares the difference in average respiratory rate of participants who listened to music without lyrics first and with lyrics second. Participants had an average of a +33.01%

change in their respiratory rate from baseline when listening to music without lyrics first. When listening to music with lyrics second, participants had an average of a +14.19% change in their respiratory rate. A t-test found the difference in percent change to be insignificant with a p-value of 0.089. From this, listening to music with lyrics proved to have no significant change on respiratory rate when compared to listening to music without lyrics.

## Discussion

The purpose of this study was to investigate whether listening to music with words while studying correlates with long term memory recall of the studied material. It was hypothesized that listening to music with words while studying will cause a brief stressful physiological response which will in turn hinder the encoding process and worsen long-term memory recall, compared to music without words. Some aspects of our hypothesis was supported from our data.

A t-test was performed for each physiological measurement in order to confirm that listening to music with words induced an brief stressful physiological response that differed from the response created when listening to music without lyrics. The p-values of EDA, no matter the treatment order, both proved to be insignificant ($p=0.144$ and $p=0.794$). The p-values of respiratory rate, again independent of the treatment order, both were insignificant ($p=0.090$ and $p=0.089$). The p values of ECG depended on treatment order. When listening to music without lyrics first and with lyrics second, there was a significant difference in heart rate ($p=0.0068$). However, when listening to music with lyrics first an without lyrics second, there was no significant change in heart rate ($p=0.375$). Thus, it was found that there was statistical difference between a treatment for the ECG, but this was not evident with the EDA or the respiratory rate. Our group thinks this could be due to the short duration (3 minutes total) of the study. If our experiment was longer, the sympathetic branch of the the participants nervous system would be more greatly aroused which in turn would cause greater skin conductance and increased respiratory rate.

Although there was statistical significance between the treatment groups, it does not support our hypothesis that listening to music with words would induce a stressful response. Rather, the ECG and respiratory rate show more support for the opposite; that listening to music without lyrics induces a stressful response which would theoretically hinder the encoding process thus reduce long-term memory. The Yerkes Dodson Law could possibly explain these results in that that the presence of lyrics induced the optimal level of arousal to make the participants work more efficiently compared to fast tempo music alone. In contrast, the recall quiz demonstrated a greater positive correlation with music without lyrics and words recalled, though these results were not statistically significant. Furthermore, this data does not support the hypothesis that participants were able to recall more definitions in the “without lyrics” treatment group rather than the “with lyric” treatment group. In conclusion, the basis of this research was to investigate if the presence of lyrics within music has an impact on studying and

later recall. By looking at respiration and ECG, we saw the physiological impact of listening to fast tempo music without lyrics, rather than with lyrics, induced a physiological stress response though this was not proven to hinder the encoding process. Rather statistical results from the EDA and recall quiz were inconclusive in that they did not refute or show support for the hypothesis.

As a result of our conflicting data, it would be worthwhile to improve and replicate this study to evaluate whether a better experimental design would provide more promising results. A limitation of this study was a small sample size and a limited demographic. In order to make our findings more reliable, it would be beneficial to increase population size and include participants of varied backgrounds more representative of the student body at UW-Madison, as students solely enrolled in Physiology 435 do not constitute all races, ethnicities, ages, and majors of all students. Different demographics may experience the stress response differently, thus, having varied participants would be a better representation of the whole population.

Potential errors in the data can be attributed to several factors. For one, various distractors existed while participant data was collected which could have affected the participants responses. Throughout the study, students, TA's and professors openly walked in and out of rooms which had the potential to interrupt subject concentration or produce an additional stress response. Participants for the study were also collected through reciprocity and for the sake of their grade in the class; thus true effort to memorize/recall definitions and words is questionable. Furthermore different members of this team had to fulfill various roles which could provide inconsistent data. Although the equipment from the same company and model were used throughout the entirety of the experiment, it was not reliable as some respiratory belts failed to pick up data when needed.

Before taking the short examination, many participants exclaimed they would perform better if the test was matching instead of recall based. Thus, to further our studies, it would be interesting to explore memory and recognition and compare those results to the ones from the recall exam. This would allow us to determine whether stimuli such as music with and without lyrics affect recall based memory, or recognition based memory as well. Additionally, it would be helpful to give different participants different treatments all together rather than giving one participant both treatments. For instance, different subjects would be a control without stimuli, another would have music with lyrics, and another without lyrics. A different method of collecting data might yield more promising results.

In Physiology 435, the curriculum covers many topics including the autonomic nervous system. Sympathetic responses to psychological stress prepare the body for fight or flight. The general response to both physical and psychological stress is the activation of the sympathetic nervous system with downregulation of the parasympathetic nervous system. Sympathetic nerves accelerate heart rate and force of contraction through the release of epinephrine and norepinephrine. The sweat glands are regulated by sympathetic innervation which was one of the measurements in this experiment. By doing this experiment, we were able to see first-hand

some of the physiological responses to stress. By looking at the ECG, respiration, and EDA, we were able to get specific numbers of the human body and come up with conclusions based off those numbers. Though the study did not support our hypothesis, many modifications to the study may yield a more successful reproduction in the future. Music is already a major part of everyday life; expanding this study potentially may open new doors in research that could improve the way children, students, and adults listen to music.

**Acknowledgements**

We would like to thank Dr. Andrew Lokuta for the opportunity to perform this research experiment. We would also like to thank the teaching assistants, peer leader volunteers, and study participants for their time and help. Additionally, we would like to thank the University of Wisconsin- Madison for the facilities and equipment that made this experiment possible.

**References**

Bugter, et al. (2012) "The effect of music genre on a memory task," Modern Psychological Studies: Vol. 17 : No. 2 , Article 14. Available at: https://scholar.utc.edu/mps/vol17/iss2/14

Dvorak, et al. (2019), *Journal of Music Therapy*, Volume 56, Issue 1, Pages 30–60, https://doi.org/10.1093/jmt/thy020

Ferreri, et al.(2015) "The Influence of Music on Prefrontal Cortex during Episodic Encoding and Retrieval of Verbal Information." *Behavioural Neurology*. *National Center for Biotechnology Information*, www.ncbi.nlm.nih.gov/pmc/articles/PMC4609813/.

Sanders, Robert. (2015) "Researchers Find out Why Some Stress Is Good for You." *Berkeley News*.news.berkeley.edu/2013/04/16/researchers-find-out-why-some-stress-is-good-for you/.

Sapolsky, et al. (2000) "How Do Glucocorticoids Influence Stress Responses? Integrating Permissive, Suppressive, Stimulatory, and Preparative Actions ." *EndocrineReviews*,vol. 21, no. 1, pp. 55–89. *Oxford Academic*,academic.oup.com/edrv/article/21/1/55/2423840.

Schwabe, Lars. (2010) "Learning Under Stress Impairs Memory Formation ." *Neurobiology of Learning and Memory*, vol. 93, no. 2, pp. 183–188. *ScienceDirect* , doi.org/10.1016/j.nlm.2009.09.009.

Trappe, H. (2010). The effects of music on the cardiovascular system and cardiovascular health. Heart, 96(23), 1868-1871. doi:10.1136/hrt.2010.209858

University of California - Irvine. (2008, March 13) "Short-term Stress Can Affect Learning And Memory." ScienceDaily. ScienceDaily. www.sciencedaily.com/releases/2008/03/080311182434.htm.

**Figures and Legends**

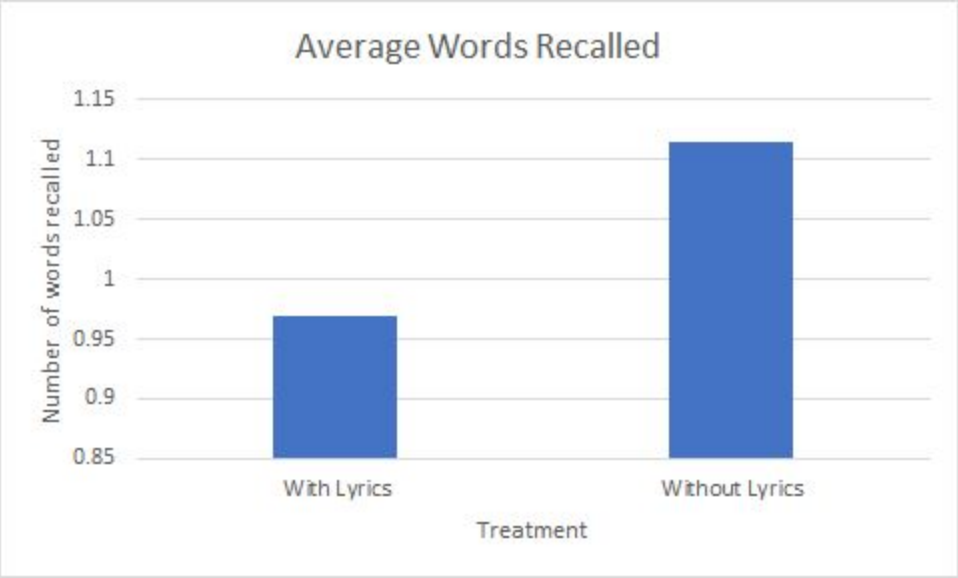


**Figure 2.** Average words recalled after listening to music with lyrics versus without lyrics. The average number of words recalled while listening to music with lyrics was 0.97 words, and the number recalled while listening to music without lyrics was 1.11 words.

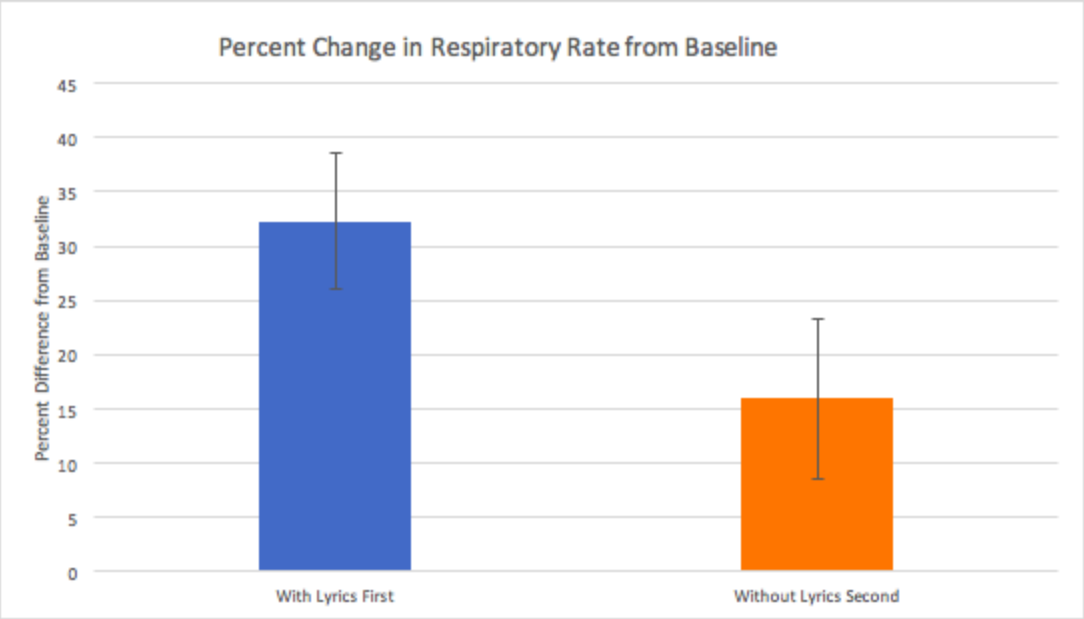


**Figure 3**. Average respiratory rate percent change from baseline of participants when listening to music with lyrics first verse when listening to music without lyrics second. This graph reports the percent change of average respiratory rate from baseline for both treatments. On the y-axis, 0 denotes the mean baseline measurement of respiratory.

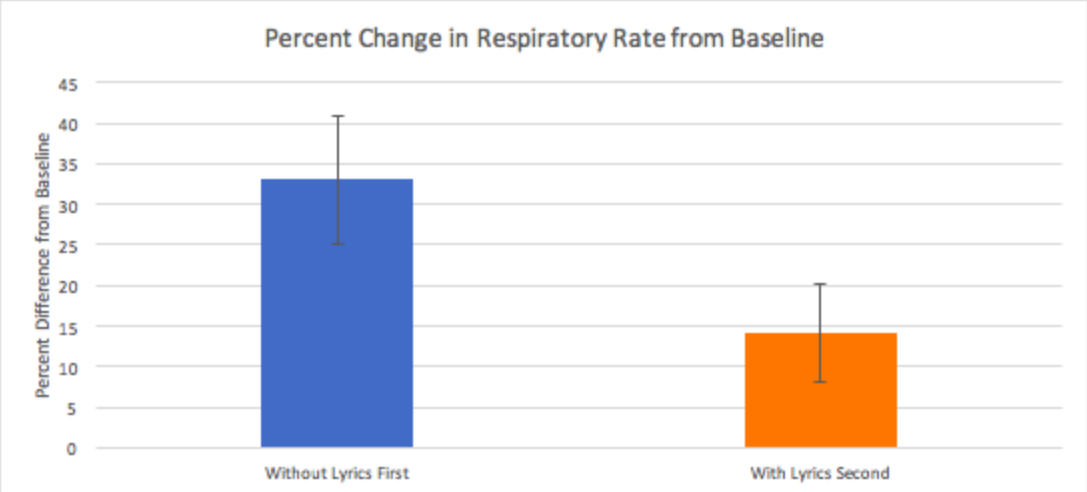


**Figure 4.** Average respiratory rate percent change from baseline of participants when listening to music without lyrics first verse when listening to music with lyrics second. On the y-axis, 0 denotes the mean baseline measurement of respiratory rate with anything above 0 showing an increased respiratory rate.

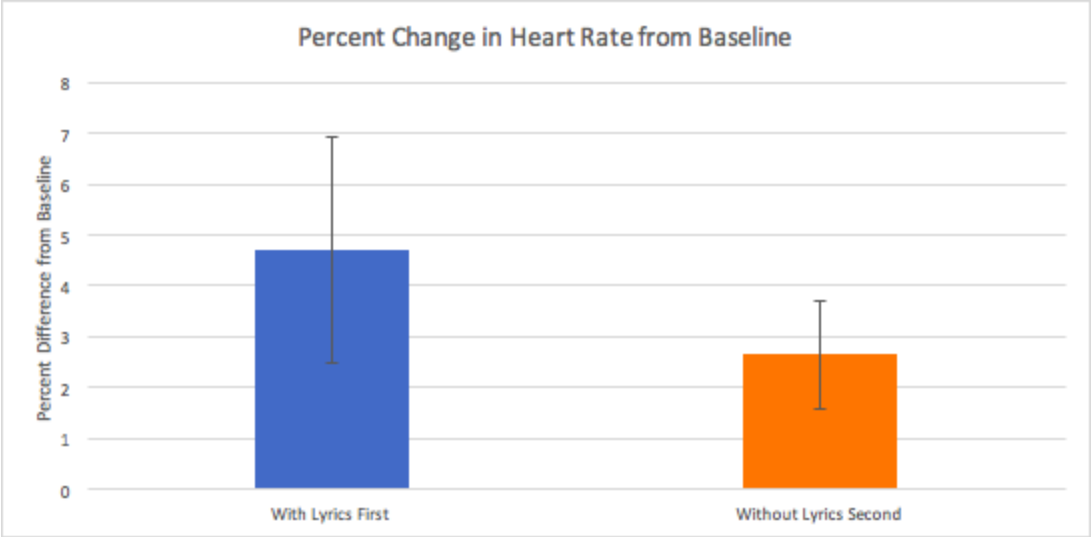


**Figure 5**. Average heart rate percent change from baseline of participants when listening to music with lyrics first verse when listening to music without lyrics second. This graph reports the percent change of average heart rate from baseline for both treatments. On the y-axis, 0 denotes the mean baseline measurement of respiratory.

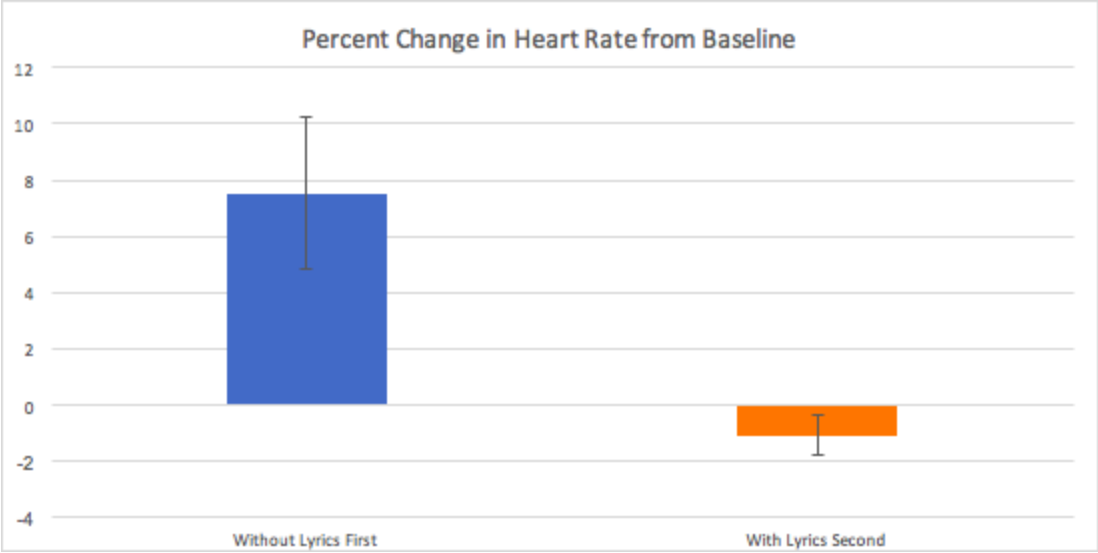


**Figure 6**. Average heart rate percent change from baseline of participants when listening to music without lyrics first verse when listening to music with lyrics second. This graph reports the percent change of average heart rate from baseline for both treatments. On the y-axis, 0 denotes the mean baseline measurement of respiratory.

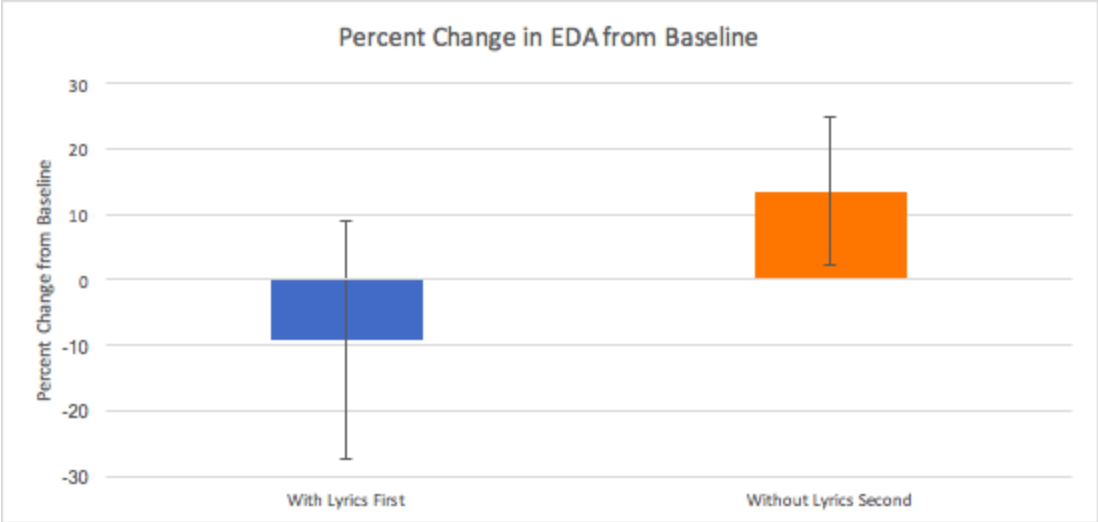


**Figure 7**. This figure compares the average electrodermal activity when listening to music with lyrics versus when listening to music without lyrics. These participants listened to music with lyrics first and music without lyrics second. This graph reports the percent change from baseline of average electrodermal activity for both treatments. On the y-axis, 0 denotes the baseline measurement of electrodermal activity with anything below 0 showing less electrodermal activity and anything above 0 showing more electrodermal activity.

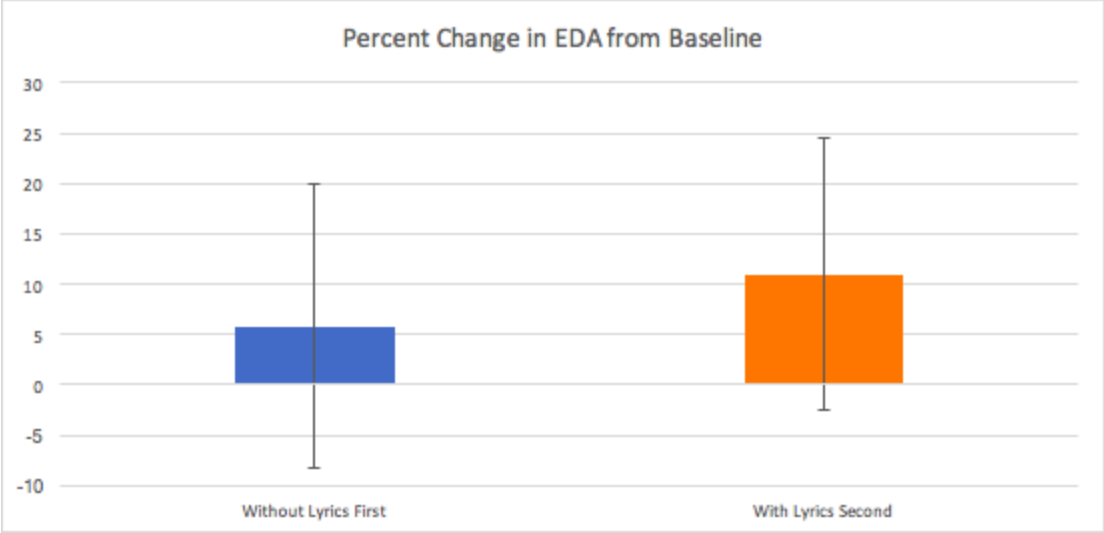


**Figure 8.** This figure compares the average electrodermal activity when listening to music with lyrics versus when listening to music without lyrics. These participants listened to music without lyrics first and music with lyrics second. This graph reports the percent change from baseline of average electrodermal activity for both treatments. On the y-axis, 0 denotes the baseline measurement of electrodermal activity with anything below 0 showing less electrodermal activity and anything above 0 showing more electrodermal activity.