<u>The Effects of Music on Short-Term Memory and Physiological Arousal</u>

Anne Gustavson
Kevin Hanneken
Anna Moldysz
Brad Simon

Physiology 435
Lab 602
Group 7

Abstract

In order to determine whether studying with music impacts the maintenance of written information in short-term memory, we evaluated the performance of 20 individuals during a word memorization and recall task under three separate environmental conditions. Individuals memorized words in silence, during an instrumental version of a popular hip-hop song, and during the lyrical version of the same song. We measured skin conductance, heart rate, and respiratory rate during all trials to monitor the physiological state of individuals during test administration. Analysis of variance (ANOVA) showed no significant difference in short-term memory scores among the three testing conditions ($p>.6$). There was also no significant difference in physiological arousal among the three testing conditions with regard to skin conductance, heart rate, or respiratory rate. However, all three auditory conditions showed significant increased arousal when compared to baseline physiological measurements acquired before the testing ($p<.001$ for heart rate; $p<.01$ for skin conductance; $p<.01$ for respiratory rate). These results suggest that the efficacy of short-term memory in a verbal task is not affected by music or lyrics, and that the physiological arousal was caused by the memory task itself, not the nature of the auditory environment. This study contributes to the growing literature about music's effect on physiological arousal and its indirect effects on learning.

Introduction

On a physiological level, memory is considered a function of neural cells' ability to consolidate information and make connections between neurons. According to a current popular model, memory consists of three processes: echoic memory, short-term memory (STM), and long-term memory (LTM). Short-term memory is also referred to as working memory (WM) and is composed of both processing and storage components. The most prevalent model of STM is divided into two independent subsystems: the "phonological loop" and the "visuospatial sketchpad" (Baddeley, 1981). Information held in STM is easily lost if not rehearsed and is subject to disruption. More specifically, it has been suggested that the presence of an auditory distracter interferes with the "phonological loop" portion of Baddeley's model (Cocchini et al., 2001; Salamé and Baddeley, 1982). When memorizing verbal information, the phonological loop is employed in maintaining and rehearsing the information. Auditory distraction, however, also requires use of the phonological loop, so the two processes essentially compete for neural space and interfere with each other, resulting in impaired short-term memory.

It has been shown that unattended speech (speech that is not relatable to the task at hand) as well as vocal music impairs STM (Salamé, 1982, 1989). However, both of these experiments were explained purely on a cognitive level, disregarding physiological responses. It was later found that if the level of musical complexity becomes too high, a person may become over-aroused, including increased heart and respiratory rate, resulting in distraction and thus causing observational and memory test scores to fall (Furnham, 1999). Additionally, it has been found that vocal music is significantly more detrimental to STM as compared to instrumental music (Alley and Greene, 2008).

The inclusion of various physiological measures may provide insight into the degree and cause of STM disruption. For example, individuals who perform poorly on a memory test may display unique physiological features, indicating that the stress response system moderates STM in some way. The three physiological responses that were measured during a memory recall test included heart rate, respiratory rate, and galvanic skin response. Heart rate was expected to rise during mental stress, and we expected the degree of mental stress to be inversely correlated with memory formation. Respiratory rate has also been shown to increase during periods of mental anxiety, which may be evident during the memorization and retrieval phases of the task (Masaoka & Homma, 1997). Finally, the galvanic skin response, a measure of sweat gland secretion, was also chosen to measure physiological arousal, which was expected to rise during stressful episodes. These three measures can indicate the level of effort, stress, and concentration the person applies to a memorization task with or without the distraction of lyrics and music.

This study in particular focuses on hip-hop, a lyric-intensive genre of music that is popular amongst college students. Through both physiological and memory tests, we attempted to answer the following question: is there a difference in short-term memory performance between those who listen to vocal hip-hop music, instrumental hip-hop music, or no music at all during the memorization process? Additionally, we searched for a correlation between memory performance and the three aforementioned physiological responses. Based on previous studies, our prediction was that the participants' level of arousal would increase (increased heart rate, GSR, and respiratory rate) with each successive addition of complexity to the music (i.e. lyrics), and in turn their short-term memory performance would suffer.

Materials and Methods

Participants

Our participants were volunteers between the ages of 19 to 25 who were enrolled in Physiology 435 at the University of Wisconsin-Madison. All participants signed a consent form prior to participation in the study. They were tested during just one session, lasting about ten minutes, and were not asked to return for any follow up sessions.

Memory Task

Participants had thirty seconds to memorize a list of twenty words. A fifteen second silent latent period followed, ensued by a maximum of one minute to write down as many words as they could remember (subjects could stop before sixty seconds if they felt they were not able to remember any more words). This procedure was completed a total of three times: once in silence, once while listening to an instrumental hip-hop song, and once while listening to the same hip-hop song with the vocals included. A different list of twenty words was used for each section. The order of the three testing conditions was randomized, and participants had a two-minute break between each trial (Fig. 1). To score the memory test, each word correctly recalled counted as one point for a maximum of twenty points. Words recalled from prior lists were not counted towards their score. Experiments complied with the policies and regulations of this University.

Music

The hip-hop song the participants listened to during the experiment was *Go-Go-Gadget Flow*, by Lupe Fiasco. Both the lyrical and instrumental versions were accessed through *YouTube*. Participants listened to the first verse of the song (0:38 seconds through 1:08) using *AKG K-44* stereo headphones. The volume through the headphones remained consistent between each participant because we kept the level at 75% of the maximum. This song was chosen due to its dense word content, fast tempo, and popularity among college students.

Measurements

The participants' respiratory rate and galvanic skin response were recorded continuously using *Biopac Student Lab System BSL 4* software. They were seated in a chair without armrests and fitted with a Respiratory Transducer, according to the *Biopac* instructions. Electrodermal Activity transducers were attached to the index and middle fingers of the hand that was not used for writing. Heart rate was measured using a *Nonin Model 9843* pulse oximeter attached to the ring finger of the same hand. This was manually recorded every fifteen seconds, beginning at the start of the memory task through the end of the experiment. Baseline measurements of these three physiological tests were taken over a period of thirty seconds before the memorization task to be used as a control.

Analysis

The data from the memory and physiological tests were used to compute a four-way ANOVA test using *Microsoft Excel*. The four categories included were baseline measurements, the silent trial, the instrumental trial, and the vocal trial. The means and standard errors were compared between trials. If significance was found in the ANOVA, paired t-tests were performed between each testing condition.

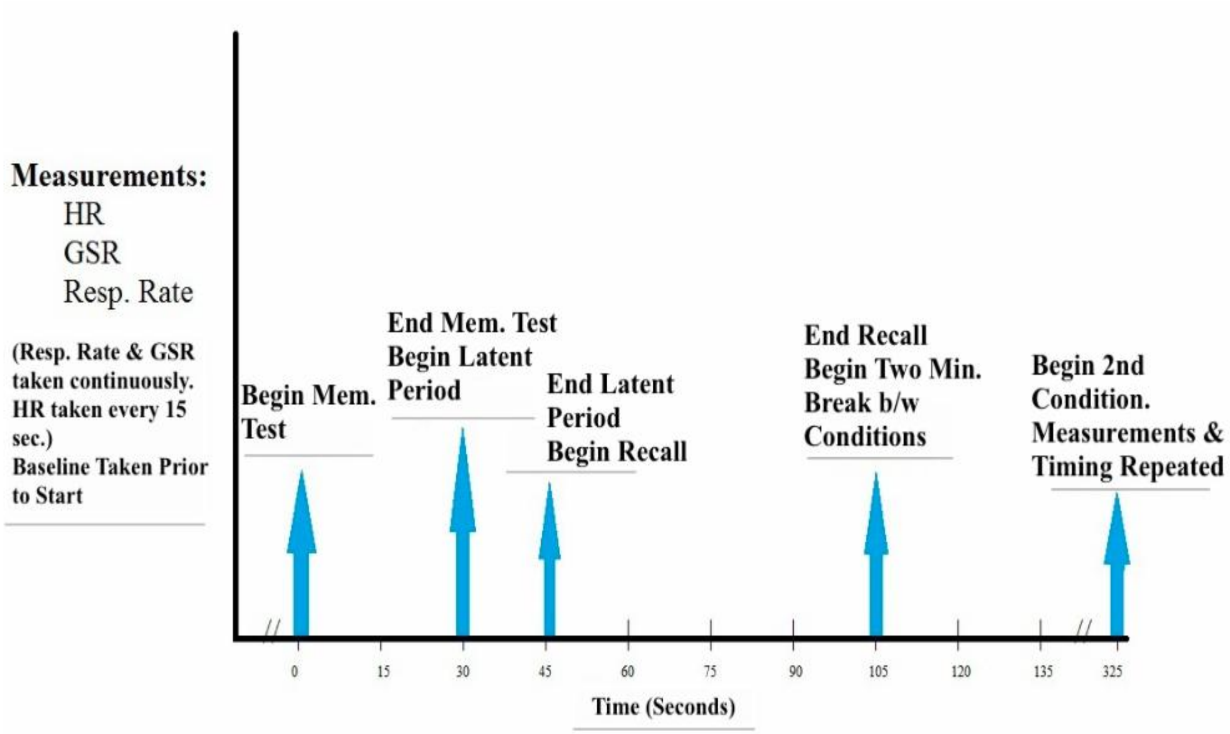

Figure 1: Experimental Design.

Participants had thirty seconds to memorize a list of twenty words. A fifteen second silent latent period followed, ensued by a maximum of one minute to write down as many words as they could remember. This procedure was completed three times for the three test conditions: silent, instrumental, and vocal. Participants had a two-minute break between each trial. The respiratory rate and galvanic skin response were measured and recorded continuously, while heart rate was manually recorded every fifteen seconds. Baseline measurements of these three physiological tests were taken before the memorization task to be used as a control.

Results

In n=20 participants, heart rate, respiration rate, and galvanic skin response were tested. Significance was determined using a single-factor, within-subjects ANOVA. Results with a p-value less than .05 were considered significant. Findings are as follows.

To measure short-term memory retention, we scored the number of words correctly recalled after the subjects were given 30 seconds to study a list of words either in complete silence, while instrumental music was playing, or when music with vocals was playing. The mean of words recalled during the silent condition was 6.9±0.5. The mean of words recalled during the instrumental music was 6.45±0.4, while the mean of words recalled during the music with words was 6.4±0.6 (Fig. 2). Analysis of this data reveals that there is no statistical significance among these different conditions ($p>0.6$).

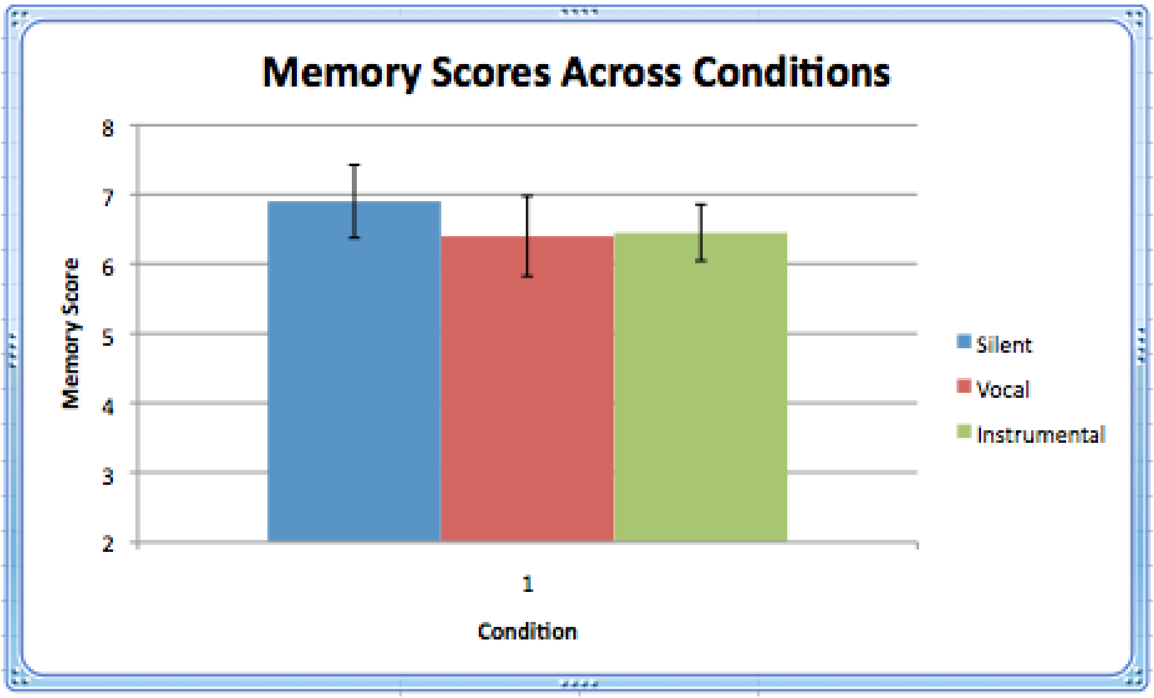

Figure 2: Memory Scores

No significant difference between testing conditions on STM using ANOVA ($F(1,19)=1.5$, $p>0.6$). Silent (M=6.9, SE=0.5), Instrumental (M=6.5, SE=0.4), Vocal (M=6.4, SE=0.6).

We measured heart rate during the silent, instrumental, and vocal conditions. The mean of the baseline measurements was 70.6±2.6 beats per minute. The mean of heart rate during the silent condition was 78.7±2.4, the mean during the instrumental music was 77.8±2.9, and the mean during the vocal music was 77.3±2.3 (Fig. 3). Analysis of this data reveals that the testing condition did result in a significant increase in heart rate ($p<.001$). However, a paired t-test revealed no significant differences between the three test conditions themselves ($p>0.05$).

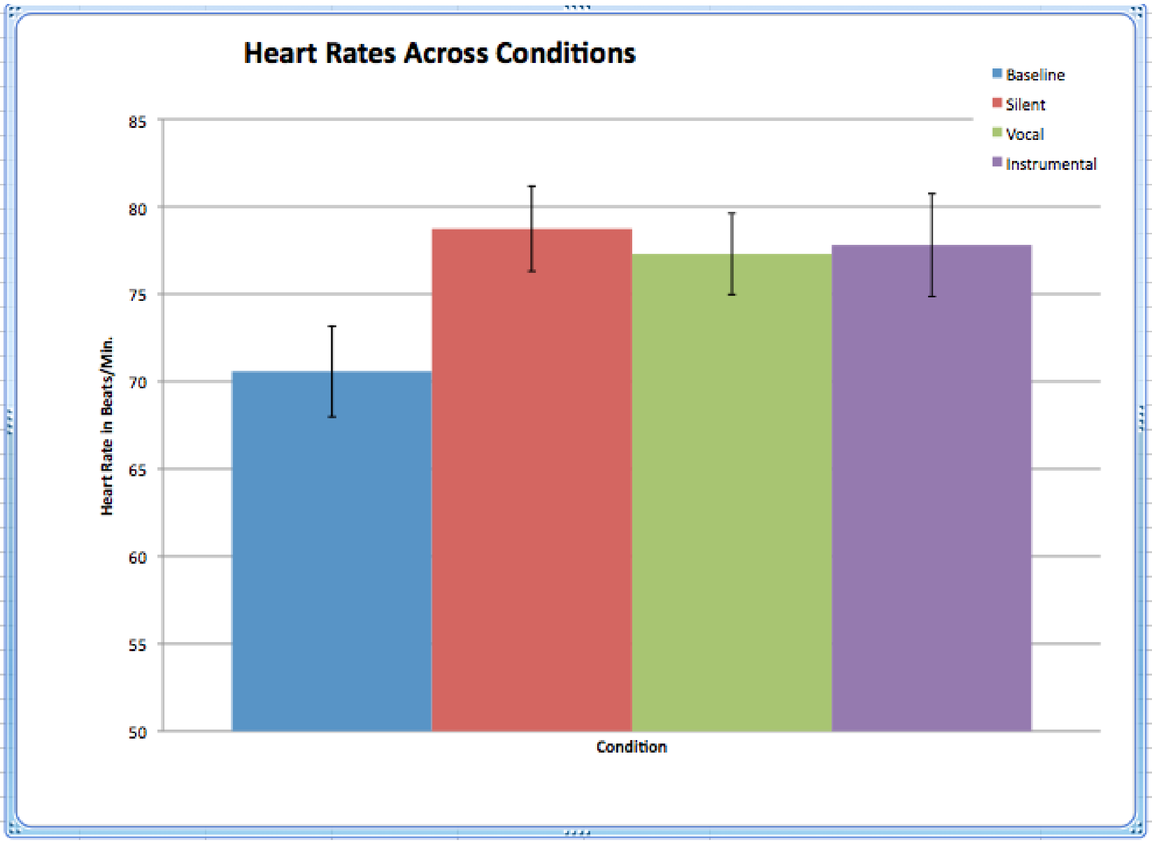

Figure 3: Heart Rate

Compared to baseline (M=70.6 beats per minute [BPM], SE=2.6), all three test conditions displayed a significant increase in heart rate using ANOVA ($F(1,19)=11.0$, $p<0.001$). Silent: $t(19)=5.0$, $p<0.001$, (M=78.7, SE=2.4), Instrumental: $t(19)=4.2$, $p<0.001$, (M=77.8, SE=2.9), Vocal: $t(19)=5.3$, $p<0.001$, (M=77.3, SE=2.3). No significant differences occurred between the three test conditions themselves ($p>0.05$ for all t-tests).

Respiration rate was measured during the three test conditions, as well. The mean of the baseline measurements was 15.4±1.0 breaths per minute. The mean of respiration rate during the silent condition was 18.0±0.9. The mean during the instrumental music was 19.1±1.0, while the mean during the vocal music was 19.1±1.1 (Fig. 4). Analysis of this data reveals a significant increase in respiration rate during testing conditions when compared to the baseline ($p<0.001$). A paired t-test revealed no significant differences between the three test conditions themselves ($p>0.05$), which was similar to the results of heart rate.

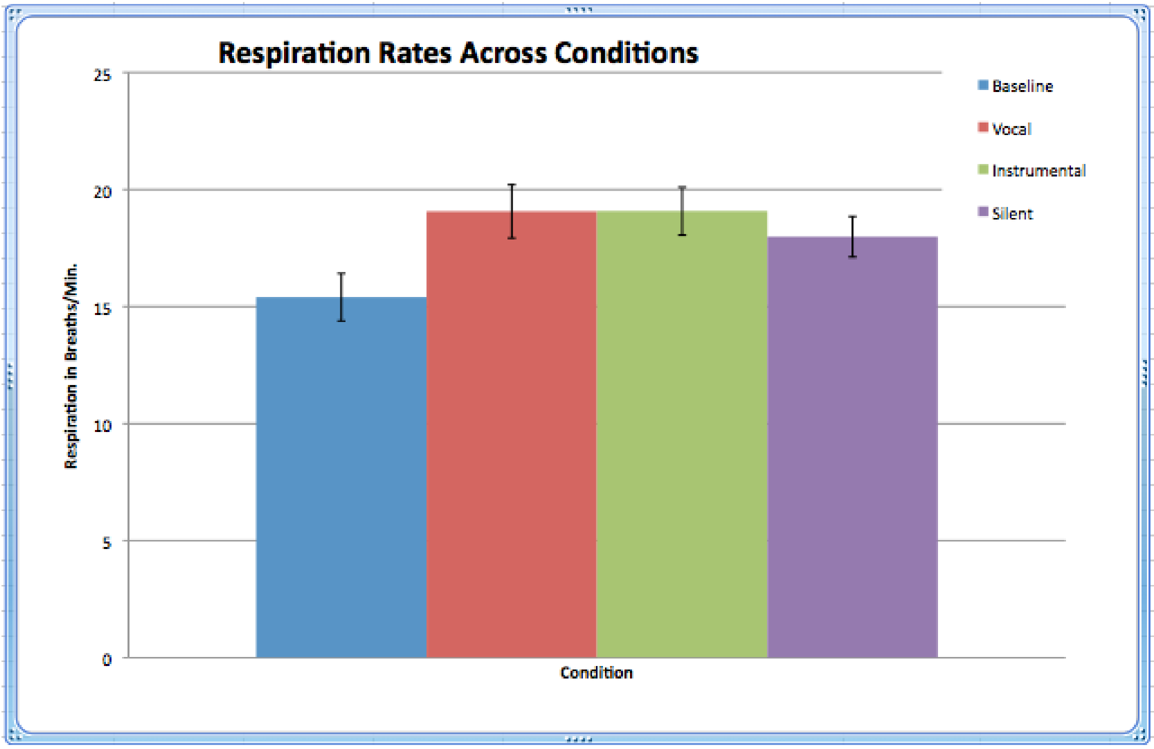

Figure 4: Respiration Rate

Respiration rate significantly increased from baseline (M=15.4 breaths per minute, SE=1.1) according to ANOVA ($F(1,19)=7.0$, $p<0.001$) as compared to all three testing conditions. Silent: $t(19)= 2.9$, $p=0.004$ (M=18.0, SE=0.9). Instrumental $t(19)=3.5$, $p=.001$ (M=19.1, SE=1.0). Vocal: $t(19)= 3.0$, $p=0.003$ (M=19.1, SE=1.1). No significant differences were found between the three test conditions themselves ($p>0.05$ for all t-tests).

Galvanic Skin Response was also measured during all three memory tests. The mean of skin conductance during the baseline measurements was -1.4±0.6 delta microsiemens-seconds. The mean during the silent memory task was 0.83±0.7, the mean during the instrumental music was 2.68±1.2, and the mean during the vocal music was 1.17±0.4 (Fig. 5). Analysis revealed a significant increase of GSR during testing conditions when compared to baseline measurements ($p<0.01$). A paired t-test revealed no significant differences between the three test conditions themselves ($p>0.05$).

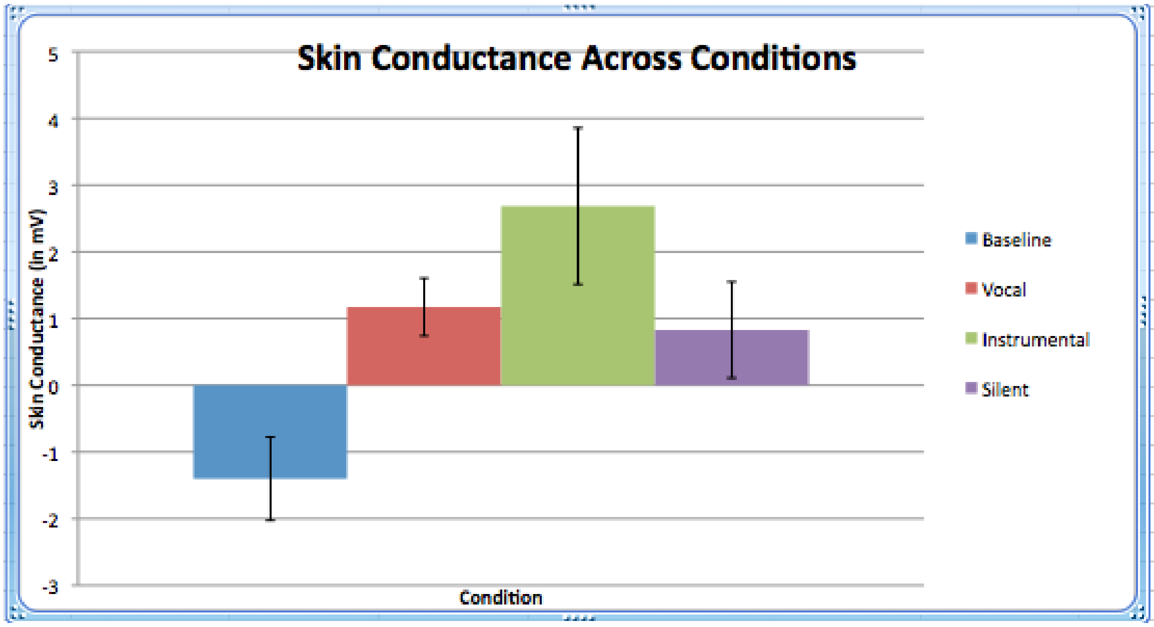

Figure 5: Galvanic Skin Response

Compared to baseline (M= -1.4 delta microsiemens-seconds, SE=0.6), all three test conditions showed significant increases in GSR using an ANOVA ($F(1,19)=4.1$, $p<.01$). Silent: $t(19)= 2.7$, $p<.008$, (M=0.8, SE=0.7).
Instrumental: $t(19)=3.0$, $p<.003$, (M=2.7, SE=1.2). Vocal: $t(19)=3.9$, $p<.001$, (M=1.2, SE=0.4). Using a paired t-test, no significant differences were found between the three test conditions themselves ($p>.05$ for all t-tests).

Discussion

The sympathetic nervous system responds to increased levels of epinephrine and norepinephrine during times of stress. By having subjects listen to music during a memory test, we hypothesized that GSR, heart rate, and respiratory rate would all increase during the memory task as an indicator of this heightened arousal. We also postulated that memory scores would decrease as rates of arousal increased with added complexity of the music. Despite a significant increase in sympathetic activity during testing as compared to baseline, subjects did not significantly vary in memory scores between the three testing conditions or in level of arousal from condition to condition.

The fact that the levels of arousal between the various conditions (silent, instrumental and vocal) were not significantly different from one another, but were significantly different from baseline levels, indicates that it was the participation in the memory test itself that increased arousal, which explains why memory performance was not changed between auditory conditions.

Sensitivity may have been an issue during the tests, especially with the GSR. When testing GSR on preliminary participants, we startled them with a loud, unexpected noise in hopes of inducing a stress response. In doing this, there was little significant change in the amplitude of the recording. Therefore in our actual experiment, when the stimulus was even less startling, the change in GSR was most likely quite minute. An alternative possibility is that the program may be running perfectly well, but GSR may simply not be the best indicator of physiological arousal.

One other problem with GSR was a matter with limited analysis capability in *Biopac.* It would have been ideal to be able to measure the absolute value of the integral of the GSR values because the graph oscillated above and below zero. Instead, we were forced to choose the next best option, which was simply the overall integral, but this most likely off-set some of our results, and also explains why some of the GSR values are negative numbers. Future studies should use software that allows researchers to complete this analysis properly.

One other issue that must be considered is the sample of participants that was used in this experiment. Unfortunately participants were required to be enrolled in our Physiology 435 class, so this experiment was made up of a Convenience Sample, rather than a Simple Random Sample, which is most preferred. Some biases may have arisen due to the restriction on ages, demographics, and education, however we hope that by randomizing the order of the tests and blinding the participants, this bias was kept to a minimum.

Future studies should employ a more organized approach to sampling and exert a significant effort in adjusting the sensitivity of the measuring equipment to ensure similar magnitudes of effects across subjects. A larger number of participants would be beneficial as well in order to decrease the possibility of chance affecting results. In addition to these technical remedies, future studies should attempt to further extrapolate on the comparisons that approached, but did not reach, significance. For example, heart rate data revealed that there was a slight, but noticeable difference in heart rate for those in the silent condition (M=78.7) compared to those in the vocal condition (M=77.3), ($t=1.2$, $p=0.1$). This result, though statistically non-significant, is still noteworthy in that it contradicts the hypothesis that complex music would cause greater physiological stimulation than silence. One other confound that should be controlled for in future experiments is whether the participants were familiar with the song that was playing during the memory test. It is possible that people who knew the song well could have been more distracted during the test than those to which the song was novel.

In conclusion, our results indicate that performing a short-term memory test increases one's level of physiological arousal, as indicated by heart rate, respiratory rate, and GSR, but the auditory conditions in which the memory test was taken has no effect on either memory performance or level of arousal.

References

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Research Consent Form

You are being asked to take part in a research study. Research studies include only people who choose to take part. This document is called an informed consent form. Please read this information carefully and take your time making your decision. Ask the researchers to discuss this consent form with you if you have any questions. No immediate risks are anticipated in association with this study.
We are asking you to take part in a research study called: *The Effects of Music on Short-Term Memory and Physiological Arousal*
Principle Investigators: Anne Gustavson, Kevin Hanneken, Anna Moldysz, and Brad Simon

The research will be conducted at The University of Wisconsin-Madison, Medical Sciences Center, in the Physiology 435 Laboratory.

Purpose of the study

The purpose of this study is to determine the affects of music on physiological arousal and short-term memory. You have been asked to participate because you are enrolled in Physiology 435.

Study Procedures

If you take part in this study, you will be asked to:

- Memorize and recall 3 separate lists of 20 words while listening to hip-hop music, instrumental hip-hop music, and no music at all.
- Allow us to measure your heart rate, respiratory rate, and galvanic skin response.
- Spend about ten minutes for this one and only session.

Benefits

You will most likely not receive any benefits by taking part in this research study.

Risks

There are no immediate risks anticipated in participating in this study.

Compensation

You will receive no payment or other compensation for taking part in this study. However your participation is greatly appreciated and will further benefit the enhancement of science.

Cost

There will be no additional costs to you as a result of being in this study.

Your Rights:

You can refuse to sign this form. If you do not sign this form you will not be able to take part in this research study. Your grade will not affected if you decide to withdraw or participate in this study.

How Do I Withdraw Permission to Use My Information?

You can revoke this form at any time by clearly stating that you wish to withdraw your authorization. If you revoke your permission:

- You will no longer be a participant in this research study;
- We will not use the information collected about you during the study

Privacy and Confidentiality

We will keep your study records private and confidential. The only people who will be allowed to see these records are the four experimenters. We may publish what we learn from this study, but no names of the participants will be included. If you are not satisfied with the response of the research team, you should contact Dr. Andrew Lokuta, 608-263-7488 or ajlokuta@wisc.edu

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Statement of Participant

It is up to you to decide whether you want to take part in this study. If you want to take part, please sign the form, if the following statements are true.

I freely give my consent to take part in this study. I understand that by signing this form I am agreeing to take part in research. I have received a copy of this form to take with me.

____ ____________

Signature of Person Taking Part in Study Date

____

Printed Name of Person Taking Part in Study

Word Lists

LIST 1
lid
ship
coil
foam
bus
peach
bike
pipe
cello
shoe
key
body
music
clock
plane
heat
check
yellow
grape
fan

LIST 2
mat
ring
table
sway
rose
worm
butter
arm
corner
letter
ticket
stone
apple
book
stick
moon
queen
rope
nun
towel

LIST 3
nine
plugs
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space
desk
fish
stand
phone
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orange
file
lamp
case
sun
swap
chair
grass
bank
horse
cell