Effects of Audiovisual Stimulation on Working Memory Recall

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Lab 603 Group #1

2,383 words

Key words: Electrodermal activity (EDA), heart rate, memory recall, stress, respiratory rate, working memory

Abstract

High levels of stress have been shown to negatively impact working memory recall. For many students these levels produced by academic demands could actually hurt test performance (Kuhlmann et al., 2005). To decrease test anxiety many students distract themselves via television or social media. We hypothesized that the physiological response induced by a startling video will negatively affect memory recall in a way that mimics a direct stressor, thus fewer words will be recalled during the experimental condition. Physiological activity was measured in subjects both before a startling video as well as after during memory recall by measuring electrodermal activity, respiration rate and pulse. Subjects were asked to memorize and then orally recall words. Experimental results were not significant ($p < 0.05$) and failed to reject the null hypothesis that there would not be correlation between the physiological response induced and memory recall performance. Students showed similar physiological responses between the control and experimental testing and also had similar recall performance.

Introduction

Stress can be defined as a physical, mental, or emotional factor that causes bodily or mental tension, and is often correlated with a negative impact on memory and cognition. A typical physical response to stress involves an increase in cortisol and catecholamine levels in humans, which prepares the body for physical exertion and increased metabolic activity (O'Connor et al., 2000). However, increased cortisol levels have been linked to detrimental influences on working memory recall, and as a result could potentially hinder academic performance (Kuhlmann et al., 2005). A specific example of high stress for most students coincides with preparing for and taking exams.

Students often enlist coping strategies before exams in order to reduce stress. A popular coping mechanism is avoidance, where the student distracts him/herself from the upcoming test, often via social media, entertainment, and/or technology (Stöber, J., 2004). It is likely that students use emotionally stimulating resources such as movies, TV shows, or video games as a distraction. As discussed in the article by Lang (1990), physiological arousal can be evoked by emotional content in TV commercials, and is often involuntary and unobserved by the person. Since movies, TV shows, video games, and other forms of media often contain emotional content, it is logical that they may also induce physiological arousal similar to the effects of a stressor. We aimed to test whether an emotionally arousing coping mechanism, such as viewing a startling video clip, could produce a stress-like response and if this was a detriment to performance regarding memory recall.

Mental stressors cause a measurable physiological change, as part of the fight-or-flight response, via activity of the sympathetic nervous system and hypothalamic-pituitary-adrenal axis. This response includes, but is not limited to: increases in heart rate, respiratory rate, sweating, and blood flow to major muscles, as well as the release of various stress hormones (Raff, H., & M. Levitzky, 2011). Similar to other stressors, a strong emotion like surprise could trigger a similar physiological response; that is, an increase in heart rate, an increase in respiratory rate, and an increase in electrodermal activity. Therefore, we hypothesize that the physiological response induced by a startling video will negatively affect memory recall in a way that mimics a direct stressor, i.e. fewer words will be recalled during the experimental condition.

Materials and Methods

Participants

For our study, we recruited four male and twelve female volunteers currently enrolled in Physiology 435 at the University of Wisconsin-Madison. Prior to beginning the experiment, participants signed a consent form that briefly described their involvement in the study. Subjects were asked to participate in two ten-minute sessions spaced one week apart.

Measurements

Subjects' respiratory rate and galvanic skin response were recorded continuously throughout the experiment using *Biopac Student Lab System BSL 4* software. Subjects were fitted with a Respiratory Transducer (*BIOPAC Systems Inc., Model SS5LB, California)* around the chest, and Electrodermal Activity Transducers (*BIOPAC Systems Inc., Model SS3LA/L, California*) were attached to the index and middle fingers of the right hand. Heart rate was also monitored using Pulse Oximeter/ Carbon Dioxide Detector (*Nonin Medical Inc., Model 9843, Minnesota*) placed on the left index finger. Heart rate was recorded manually every five seconds during baseline acquisition and during the recall task. Memory data reflected the number of correctly recalled words.

Controls

Pilot testing: In order to verify that a startling video could produce a physiological response, our group conducted pilot tests. Two members selected six suspenseful, startling videos to test on the other four group members. The tested group members had their heart rate, respiratory rate and electrodermal activity monitored throughout each video. The video with the most conclusive data and greatest activity for all three physiological measurements was selected to be the experimental video.

Positive control: For the positive control, our group mimicked stressful situations to demonstrate that the physiological measurements produced data when the subject was placed under stress. We had four participants partake in our positive control. Each participant had their heart rate, respiratory rate, and electrodermal activity measured while one group member asked a series of intrusive, personal questions. These questions made each participant uncomfortable enough to positively display that the physiological measurements worked under a stressful situation.

Negative control: For the negative control, our group cohesively decided to use a neutral video with very little visual or auditory stimulation. We chose a wood burning fireplace in order to create a non-stressful scenario.

Procedure

Participants were hooked up to a respiratory transducer around the chest, a pulse oximeter placed on the left index finger, and an electrodermal activity transducer with receptors placed on the index and middle finger of the right hand. The subjects were given a brief description of what the experiment entailed; that is, that they would be given a set of words to memorize, watch a video, and then be asked to recall the words. Baseline physiological measurements were taken for 90 seconds prior to starting the task. The volunteer was then given a list of twenty random words (identical for each participant) and asked to memorize them. After 90 seconds, the word lists were taken away and the control video was started. This video showed a fire in a fireplace as a neutral audio-visual stimulus. The video was shown for 15 seconds, followed by directions via Prezi to wait quietly for further instructions. The participant then sat in silence for 25 seconds to reach a total of 40 seconds. After completion of this task, physiological measurements were obtained while the subject was asked to orally recall as many words as possible from the previously memorized list. He/she was given 90 seconds to do so, and responses were written down by an assistant to aid the subject visually. After 90 seconds, the participant was asked to stop and data recording was terminated. The participant was then disconnected from all equipment and asked to keep the study confidential.

One week after the control testing, all participants were asked to return for a second round of testing. The procedure followed was identical to that listed above, save for the use of a stimulatory video rather than a neutral clip and a new list of words for the memory test. The experimental video depicted a snake jumping out at the camera, and was meant to be a startling audio-visual stimulus lasting for 17 seconds. This was followed by a waiting period, as indicated above, of 23 seconds to reach a total of 40 seconds. Word recall from the second list of random words was tested and physiological measurements were obtained as described above.

Data Analysis

Data from memory and physiological tests was analyzed using means and standard deviations within each category. Likewise, differences between recall measurements and baseline were calculated to assess participants' deviations from baseline. Paired student t-tests were also performed to determine if the experimental group was significantly different from the control group for each individual measurement.

Results

Paired student t-tests were used to analyze the differences in recall between control and experimental conditions in order to determine if the startling video impaired memory performance. Also, student paired t-tests were used to compare the differences in deviation from baseline recordings for physiological measures (EDA, respiration rate, heart rate). Means and standard deviations were calculated for each measure within these conditions. All statistics and hypothesis tests were performed with the entire sample size of 16 participants.

For memory performance, the mean number of words correctly recalled was 12.19 words (SD=2.79) for during the control condition and 12.75 words (SD=2.29) for during the experimental condition (see Figure 1). Additionally, participants recalled on average 0.56 more words during the experimental condition compared to the control condition. The paired t-test yielded a p-value of 0.415 (t=-0.839, df =15), indicating that our data is not statistically significant.

For EDA, differences for galvanic skin response were calculated by subtracting baseline recordings from measures taken during the recall portion of the experiment. The mean difference for galvanic skin response was -0.38 microsiemens (SD=0.98) for during the control condition and 1.01 microsiemens (SD=0.66) for during the experimental condition (see Figure 2). The paired t-test yielded a p-value of 0.055 (t=2.076, df =15), indicating that our data is not statistically significant but may describe a possible trend. These results indicate that on average participants showed a slightly greater deviation from baseline in their sweat response after watching a startling video compared to a control video but is still not statistically valid.

For respiration rate, measurements were recorded as breath cycles per minute. Differences were calculated by again subtracting baseline measurements from those taken during the recall portion of the experiment. The mean difference for respiratory rate was an increase of 5.46 cycles per minute (SD=3.89) for during the control condition and an increase of 3.50 cycles per minute (SD=2.81) for the experimental condition (see Figure 3). The paired t-test yielded a p-value of 0.028 (t=-2.435, df =15), showing that our data is statistically significant but does not disprove the null hypothesis because the participants physiological response increased in the control data more than in the experimental data. These results describe that on average participants increased their breathing rate more during the control condition than after watching the startling video clip.

For heart rate, differences were calculated by again subtracting baseline recordings from measures taken during the recall segment of the experiment. The mean difference for heart rate was an increase of 9.24 beats per minute (SD=7.23) for during the control condition and an increase of 5.24 beats per minute (SD=5.57) for the experimental condition (see Figure 4). The paired t-test yielded a p-value of 0.024 (t=-2.435, df=15), indicating that our data is statistically significant. These results report that after watching the startling video participants showed a less drastic increase in heart rate compared to the control condition, which does not disprove the null hypothesis.

In addition, we analyzed the recall scores independent of the video condition for each participant, and instead sorted individuals into groups that either showed a physiological response or did not. The mean was 12.78 words (SD=2.11) for those that showed a physiological response compared to a mean of 12.71 words (SD=2.69) for those that did not show a response. A t-test to compare these results yielded a p-value of 0.960 (t=0.051), indicating no significant difference between groups. Thus, a physiological response independent of audiovisual stimulation did not appear to alter memory performance.

We also analyzed the data set of recall scores between control and experimental conditions, but after removing 6 participants that failed to show a physiological response to the snake video. The mean number of correctly recalled words was then 13.44 words (SD=1.88) for during the control condition, and 12.78 words (SD=2.11) for during the experimental condition. A paired t-test between these new groups yielded a p-value of 0.489 (t=0.701, df=8), indicating that even after removing those that did not show a physiological response, there was no significant difference in recall scores between the control and experimental conditions.

Discussion

Experimental results were unable to confirm our hypothesis that a physiological response induced by a startling video would negatively impact memory test results. While EDA data showed some stress-like response, results were not significant. Respiration and heart rate were both more elevated during control tests than in experimental conditions, which is the opposite of a stress-like response to the audiovisual stimulation. Memory recall had no significant difference between the groups. Although the startling video produced stress-like physiological results in our initial testing, it did not appear to do so in our experimental data. This could be due to a number of factors. One key problem likely involved our pairing of control and experimental participants. Since we did the control testing first, it is possible that subjects were mildly stressed solely by participating in the experiment. When they returned to complete phase two of the testing (the experimental response), they may have been less tense due to familiarity of the experimental setup. Therefore, it is probable that a more relaxed state during the experimental run caused a decreased deviation from baseline. We had additional confounding factors due to experimental conditions not being entirely controllable. There were occasional unplanned interruptions and distractions from other people, and equipment was not a constant between days due to the student laboratory environment. While these problems may have impacted some of our data, they likely did not cause the final outcome alone. Because our results do not show a correlation between the startling video and the participant's physiological response, it is not possible to infer significant information from the memory test results. Even with manipulation of our data (data mining), we were unable to obtain significant results. The participants performed similarly on control and experimental memory tests, which reflected their similar physiological measurements.

Future experiments to test this hypothesis ought to include separate participant groups for control and experimental data collection, to remove the confounding comfort factor. A larger randomized sample of participants should be used for more effective results. The time period between memorizing the word list and recall should be longer, as the time used in this experiment may not have overcome working memory. Continuous rehearsal of information extends the amount of time it may remain in working memory, (Gazzaniga et al., 2013) thus the amount of time allotted for memorization of the word list should also be reduced.

References

Gazzaniga, Michael S., Todd F. Heatherton, and Diane F. Halpern (2013). *Psychological Science*. W. W. Norton & Company, Inc., New York.

Kuhlmann, S., Piel, M., & Wolf, O. T. (2005). Impaired memory retrieval after psychosocial stress in healthy young men. *The Journal of Neuroscience*, 25(11), 2977-2982.

Lang, A. (1990). Involuntary attention and physiological arousal evoked by structural features and emotional content in TV commercials. *Communication Research*, 17(3), 275-299.

T.M. O'Connor, D.J. O'Halloran, F. Shanahan (2000). The stress response and the hypothalamic-pituitary-adrenal axis: from molecule to melancholia. *QJM Jun 2000*, 93(6), 323-333.

Raff, Hershel, and Michael G. Levitzky (2011). *Medical Physiology: A Systems Approach*. McGraw-Hill Medical, New York.

Stöber, J. (2004). Dimensions of test anxiety: Relations to ways of coping with pre-exam anxiety and uncertainty. *Anxiety, Stress & Coping*, 17(3), 213-226.

Acknowledgments

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Figures

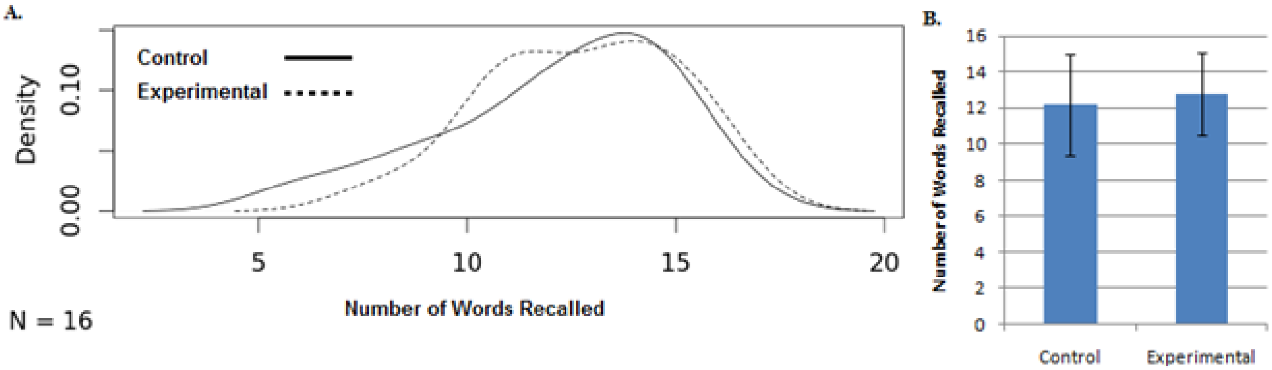


Figure 1. Memory Performance Scores

- **A.** This figure shows the estimated distribution of the number of words correctly recalled for both the control and experimental groups. Density curves were estimated from the given data and have been normalized to reflect the relative frequency. The density values themselves represent the relative proportional frequency of individual values within the data set. Both distributions appear very similar in shape and did not significantly differ.
- **B.** The figure shows the mean number of correct words recalled for both the control and experimental groups. Error bars represent one standard deviation from the mean in both directions. The means were not significantly different.

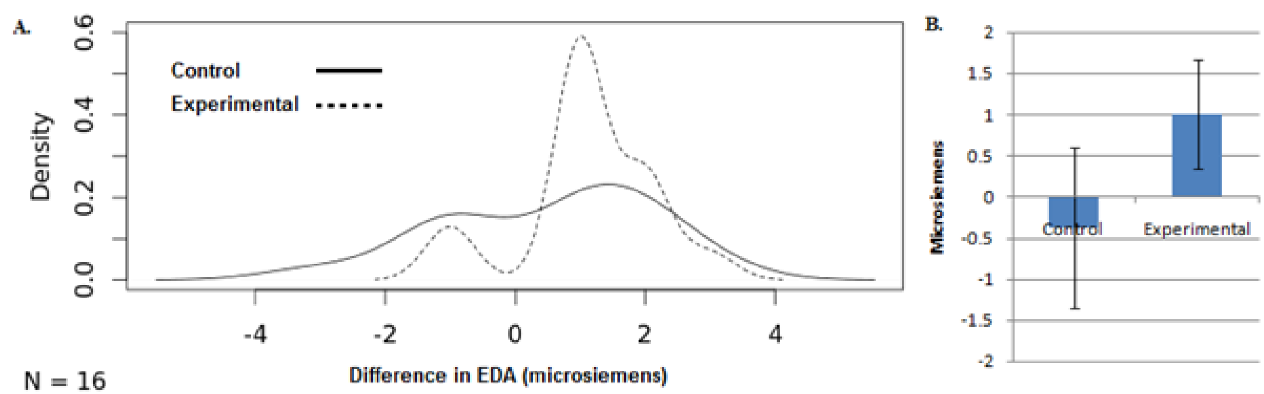


Figure 2. Differences in Electrodermal Activity (Recall-Baseline)

- **A.** This figure shows the estimated distributions for the EDA deviation from baseline for both the control and experimental groups. Differences were calculated by subtracting baseline measurements from those taken at the time of the recall task. Density curves were estimated from the given data and have been normalized to reflect the relative frequency. The density values themselves represent the relative proportional frequency of individual values within the data set. The distributions were not significantly different, but the experimental condition trended toward showing a greater increase when compared to the control condition.
- **B.** This figure shows the mean differences in EDA for both the control and experimental groups. Error bars represent one standard deviation from the mean in both directions. While not significantly different, the experimental mean difference trended toward being greater than the control mean difference.

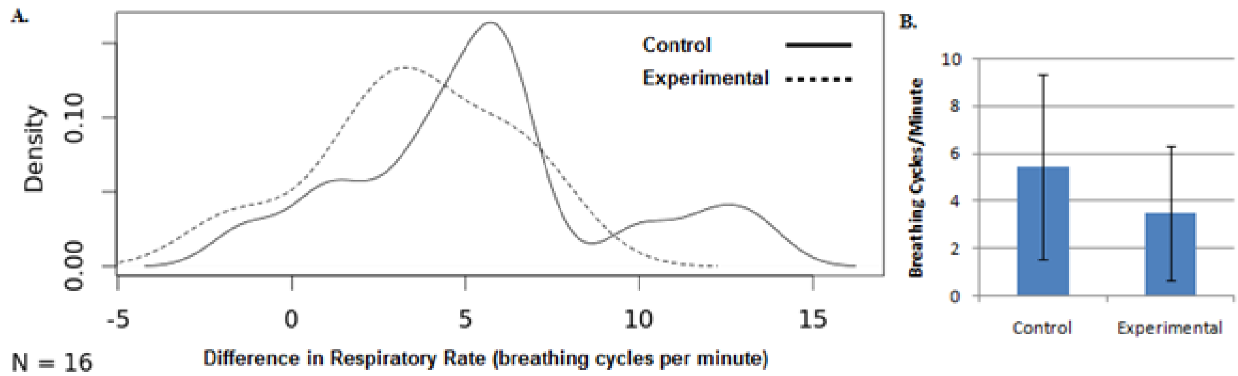


Figure 3. Differences in Respiratory Rate (Recall-Baseline)

- **A.** This figure shows the distributions for the respiratory rate deviation from baseline for both the control and experimental groups. Differences were calculated by subtracting baseline measurements from those taken at the time of the recall task. Density curves were estimated from the given data and have been normalized to reflect the relative frequency. The density values themselves represent the relative proportional frequency of individual values within the data set. The distributions were statistically different, with the control group showing greater increases in breathing rate than the experimental group.
- **B.** The figure shows the mean differences in respiratory rate for both the control and experimental groups. Error bars represent one standard deviation from the mean in both directions. The control mean difference is statistically greater than the experimental mean difference, indicating that the control condition increased breathing rate more drastically.

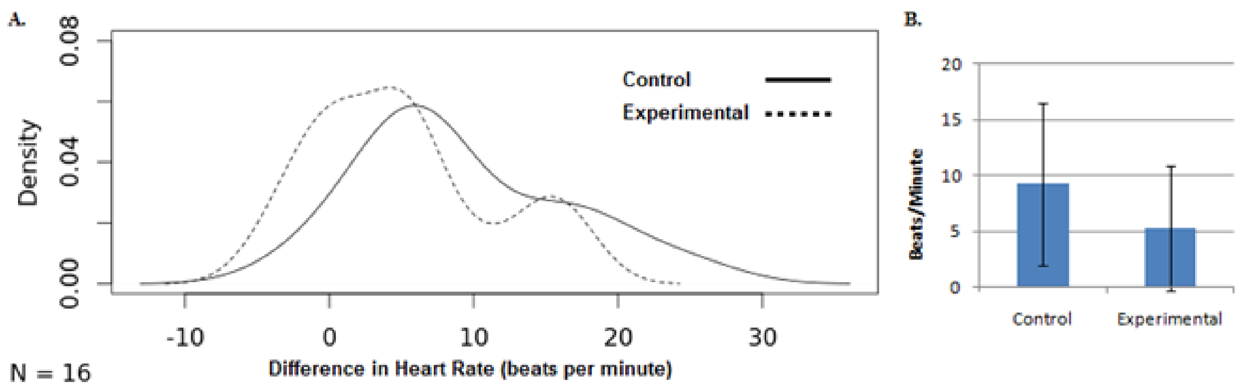
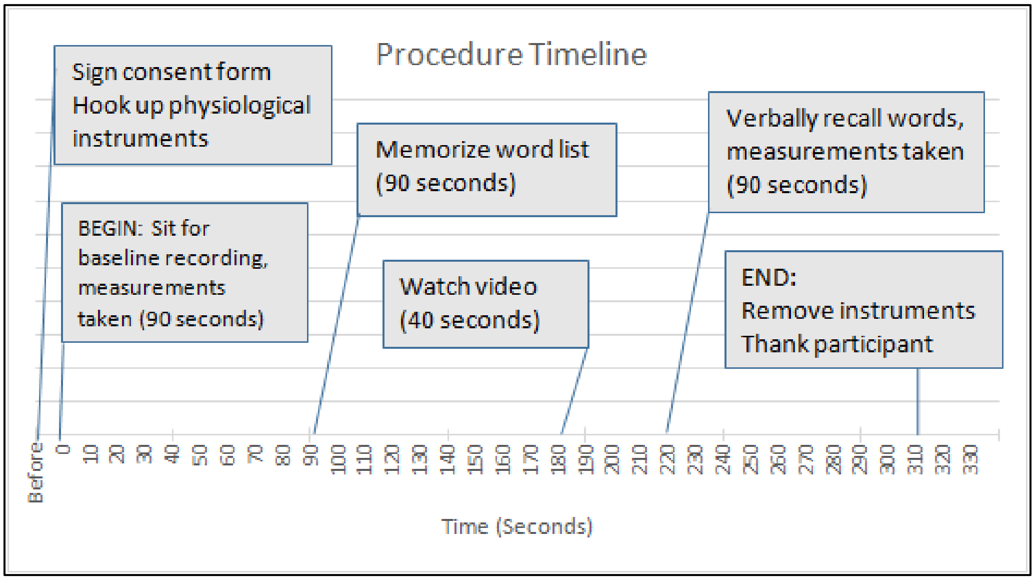


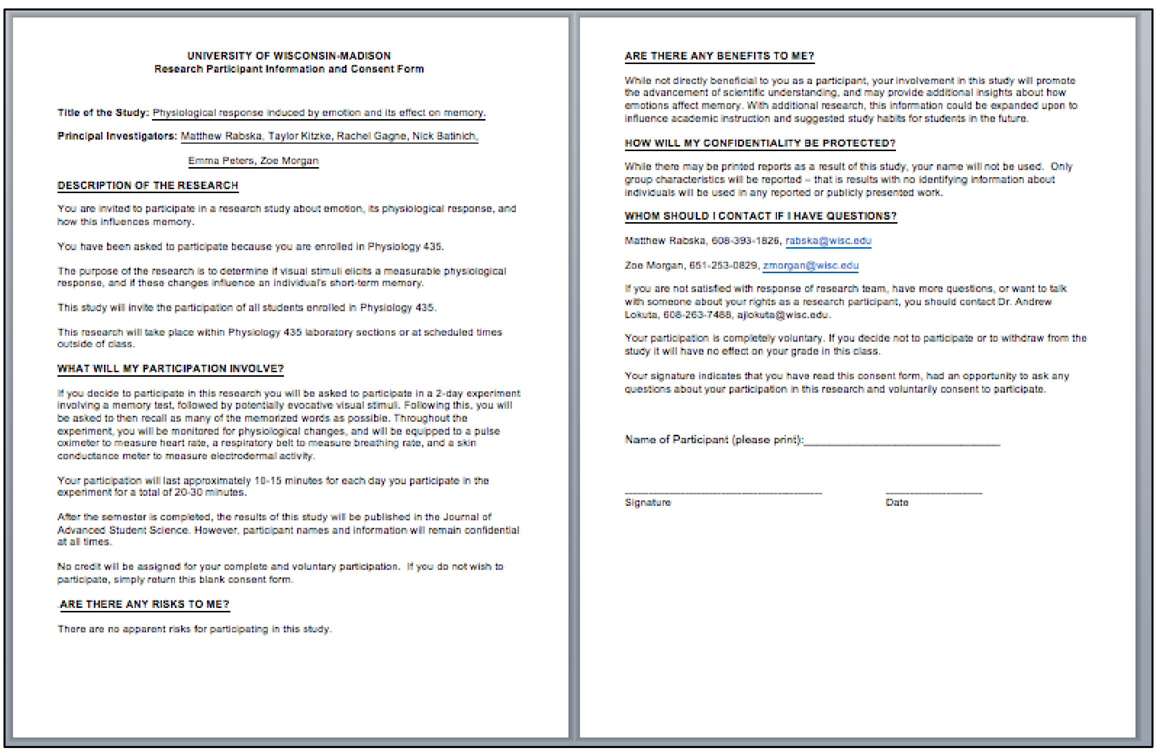
Figure 4. Differences in Heart Rate (Recall-Baseline)

- **A.** This figure shows the distributions for the heart rate deviation from baseline for both the control and experimental groups. Differences were calculated by subtracting baseline measurements from those taken at the time of the recall task. Density curves were estimated from the given data and have been normalized to reflect the relative frequency. The density values themselves represent the relative proportional frequency of individual values within the data set. The distributions were statistically different with the control group showing greater increases in heart rate.
- **B.** The figure shows the mean difference in heart rate for both the control and experimental group. Error bars represent one standard deviation from the mean in both directions. The control mean difference was statistically greater than the experimental mean difference, indicating that the control condition increased heart rate more drastically.

Appendix



Appendix A: Timeline of study illustrating the procedure throughout the experiment in units of time



UNIVERSITY OF WISCONSIN-MADISON
Research Participant Information and Consent Form

Title of the Study: Physiological response induced by emotion and its effect on memory.

Principal Investigators: Matthew Rabska, Taylor Kitzke, Rachel Gagne, Nick Batinich, Emma Peters, Zoe Morgan

DESCRIPTION OF THE RESEARCH

You are invited to participate in a research study about emotion, its physiological response, and how this influences memory.

You have been asked to participate because you are enrolled in Physiology 435.

The purpose of the research is to determine if visual stimuli elicits a measurable physiological response, and if these changes influence an individual's short-term memory.

This study will invite the participation of all students enrolled in Physiology 435.

This research will take place within Physiology 435 laboratory sections or at scheduled times outside of class.

WHAT WILL MY PARTICIPATION INVOLVE?

If you decide to participate in this research you will be asked to participate in a 2-day experiment involving a memory test, followed by potentially evocative visual stimuli. Following this, you will be asked to then recall as many of the memorized words as possible. Throughout the experiment, you will be monitored for physiological changes, and will be equipped to a pulse oximeter to measure heart rate, a respiratory belt to measure breathing rate, and a skin conductance meter to measure electrodermal activity.

Your participation will last approximately 10-15 minutes for each day you participate in the experiment for a total of 20-30 minutes.

After the semester is completed, the results of this study will be published in the Journal of Advanced Student Science. However, participant names and information will remain confidential at all times.

No credit will be assigned for your complete and voluntary participation. If you do not wish to participate, simply return this blank consent form.

ARE THERE ANY RISKS TO ME?

There are no apparent risks for participating in this study.

ARE THERE ANY BENEFITS TO ME?

While not directly beneficial to you as a participant, your involvement in this study will promote the advancement of scientific understanding, and may provide additional insights about how emotions affect memory. With additional research, this information could be expanded upon to influence academic instruction and suggested study habits for students in the future.

HOW WILL MY CONFIDENTIALITY BE PROTECTED?

While there may be printed reports as a result of this study, your name will not be used. Only group characteristics will be reported – that is results with no identifying information about individuals will be used in any reported or publicly presented work.

WHOM SHOULD I CONTACT IF I HAVE QUESTIONS?

Matthew Rabska, 608-393-1826, rabska@wisc.edu

Zoe Morgan, 651-253-0829, zmorgan@wisc.edu

If you are not satisfied with response of research team, have more questions, or want to talk with someone about your rights as a research participant, you should contact Dr. Andrew Lokuta, 608-263-7488, ajlokuta@wisc.edu.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study it will have no effect on your grade in this class.

Your signature indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate.

Name of Participant (please print):______________________________

______________________________ Signature

________________ Date

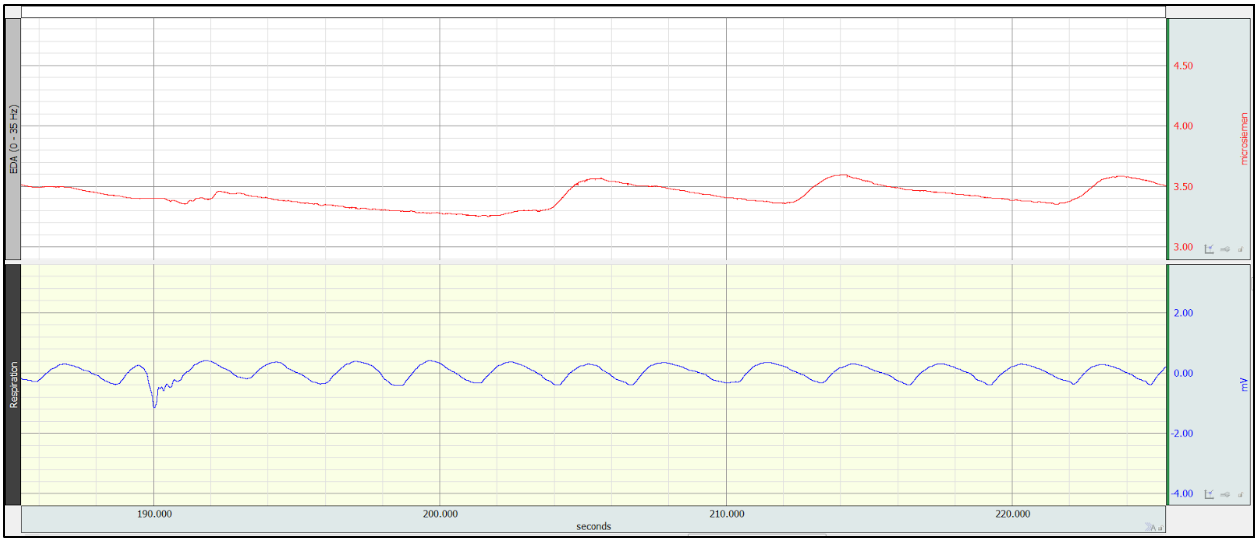
Appendix B: Screenshot of Subject Consent Form

Diamond	Skeleton	Garden	Printer
Web	Crystal	Restaurant	Bathtub
Mosquito	Sandwich	Stomach	Comet
Eraser	Drill	Highway	Banana
Brain	Eyes	Snail	Family
Bottle	Car	Drink	Spice
Window	Flower	Light	Desk
Meat	Sun	Church	Bathroom
Telescope	Train	Roof	Onion
Salt	Survey	Monster	Maze

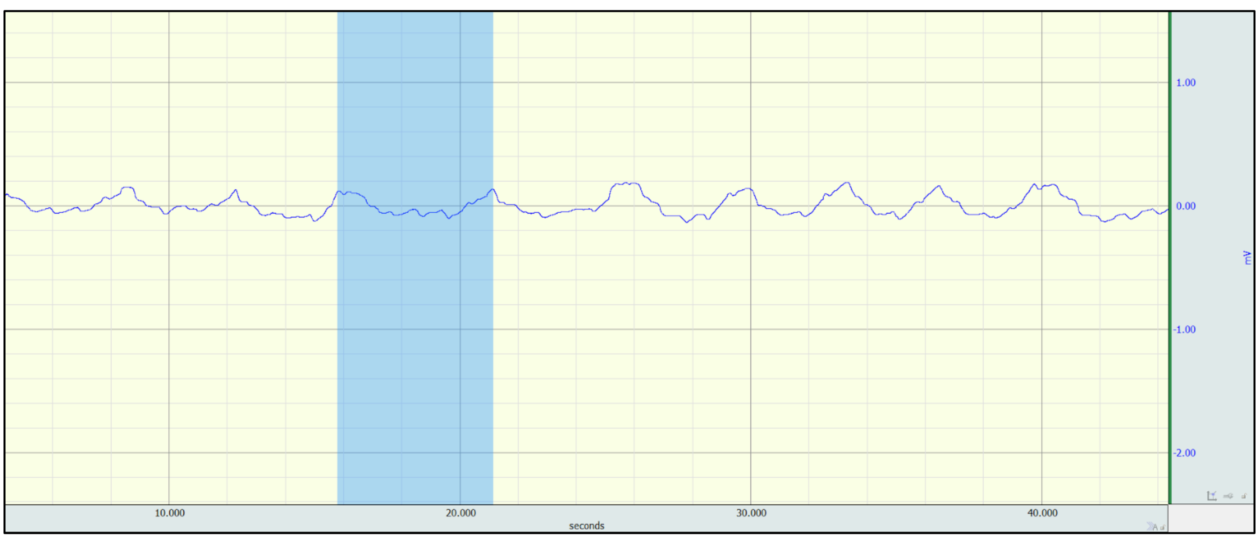
Appendix C: Screen shot of word list: The first word list (on left) is memorized during the control session. The second word list (on right) is memorized during the experimental session.

	Memory Test Score- Control	Memory Test Score- Experimental		
Participant Code	2/25/15	3/4/15	3/11/15	3/18/15
M005	9	15		
M006	6	10		
F007	12	14		
M008	15	14		
F009	14	14		
F010	8	8		
F011	12	16		
		Memory Test Score- Control	Memory Test Score- Experimental	
F012		14	13	
F013		13	11	
			Memory Test Score- Control	Memory Test Score- Experimental
M014			10	11
F015			16	16
F016			11	15
F017			14	11
F018			12	11
F019			14	12
F020			15	13

Appendix D: Participant Information: Summary table of dates of participation and memory recall scores.



Appendix E: Screenshot of BIOPAC analysis software of Respiratory Rate and EDA from a randomly chosen participant. The top graph (red) shows raw EDA data. The bottom graph (blue) shows raw respiration data.



Appendix F: Respiratory Cycle calculation: Screenshot of BIOPAC analysis software of respiratory rate. The blue highlighted section shows one cycle of respiration. Cycles per minute were used to calculate average respiration rate.