The Effect of Continuous Unintelligible Talking Noise on Physiological Stress Response and Working Memory Recall

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Key Words: auditory stimulus, blood pressure, ECG, EDA, stress, working memory

Word count: 3,552

Abstract

Cognitive control allows us to function in a distraction-filled environment. Audible distractions compete for our attention as we attempt to focus on learning, recalling past events, or solving difficult problems. Previous studies suggest that noise triggers a surge of stress hormones, making it more difficult for the brain to complete complex cognitive tasks, particularly those that utilize working memory. In this study, we investigated the effect of background talking noise on physiological stress response and working memory task performance. We hypothesized that physiological stress would increase and cognitive performance would decrease when subjects were exposed to a continuous, unintelligible talking noise during a working memory task. Participants between ages 20-23 (n=26) were assigned randomly to one of two conditions: a control group with exposure to no auditory stimulus (n=13) and an experimental group with exposure to the unintelligible talking noise (n=13). Blood pressure, heart rate, and electrodermal activity (EDA) were monitored for the duration of the working memory task, and task performance was recorded. Results indicated no significant effect of the experimental stimulus on heart rate, EDA, or cognitive task performance. However, the data trended towards our hypothesis, which suggests that the distraction of unintelligible talking noise may elicit a weak physiological stress response without decreasing cognitive task performance. A significant difference in mean arterial pressure (MAP) between the control and experimental groups was found. Further research is needed to better characterize the relationship between distracting auditory stimuli, physiological stress response, and cognitive performance.

Introduction

When performing cognitive tasks that require intense concentration and memory, it is commonly assumed that either silence or white noise provides the most practical, productive environment. We go out of our way to ensure that exam environments are silent to allow students to properly focus. Libraries are often enforced quiet areas to allow others to read, study, or work effectively. While it has been shown that white noise enhances performance on working memory tasks (Carlson et al, 1997), the use of white noise in maximizing productivity is not often practiced. Similarly, results for the effects of music on memory vary depending on the individual's interest in the genre and familiarity to the song. Therefore, this study aims to examine the impact of an everyday noise on stress levels and cognitive performance, in an effort to determine the value of using quiet spaces for intense cognitive tasks.

The relationship between noise and stress has been well exhibited in previous studies. Noise is considered a psychosocial stressor, and the extent of its impacts depend largely on its recognition as an unpredictable, threatening event (Westman & Walters, 1981). Acute reactions to such noise upset the normal equilibrium of physiological functions by causing a central nervous system-mediated stress response (Rylander, 2004). Noise has been shown to activate the hypothalamic-pituitary-adrenal axis and the sympathetic nervous system, causing surges in stress hormones such as cortisol, epinephrine, and norepinephrine. Such stress responses, in turn, result in a number of physiological changes as well as deviations in homeostatic ranges including blood pressure, cardiac output, blood lipids, carbohydrates, electrolytes, and involuntary muscle contractions (Munzel et al., 2014). In these stressful situations, the brain switches from thoughtful, controlled behavior to reflexive behavior, which can be detrimental when completing complex cognitive tasks (Banis et al., 2012).

Working memory is involved in many common cognitive tasks, as it keeps pieces of important information briefly in mind until they are required for use. Remembering phone numbers and names and recalling newly learned information are some of the most common examples of working memory tasks. Previous studies have shown the impact of noise-induced stress on working memory capacity. Data collected from a study conducted in an office setting showed that performance on a working memory task, including recall of both written passages and numbers, was inhibited by both common background noise and human speech (Banbury et al.,1998). The recall task performance under these auditory distractions was found to be one-third the level of performance as when the task was conducted in a quiet setting. Another study found that speaking and laughing noises, when played over a lecture, reduced subjects' ability to later recall certain aspects of the lecture (Zeamer & Fox, 2013).

Past student research has focused on the relationship between various stress-inducing distractions and levels of physiological stress during working memory tests. Cannon et al. (2015) found that exposure to both auditory and non-auditory stimuli under test-taking conditions elicited significant physiological stress responses in the form of increased heart rate and EDA. Another study compared physiological stress levels and cognitive task performance with exposure to either white or ambient noise, with insignificant findings (Fox et al., 2015). This study aims to build on past research by analyzing a common mechanism of distraction which induces stress and inhibits working memory capacity in a typical classroom setting. Comparisons were drawn between the physiological stress levels and working memory performance of participants in a control group (no auditory stimulus presented) and an experimental group (a continuous, unintelligible talking noise presented).

We used three measurements to monitor the physiological stress response to acute continuous noise distraction, including blood pressure, electrocardiogram (ECG), and electrodermal activity (EDA). In past studies, an increase in blood pressure has been associated with poor cognitive performance (Elias, 1993). EDA and ECG were also used for recording the sympathetic nervous system activities associated with the stress response. Significant increases in both EDA and heart rate have been commonly cited as reliable physiological stress responses (Reinhardt, 2012). Each of these three physiological measurements were recorded throughout the duration of the working memory task. Baseline cognitive task scores and physiological measures (taken during the first trial in which no auditory distraction was presented) served as controls for participants' initial stress levels.

We expect that unintelligible continuous talking will act as a stress-inducing stimulus in the experimental group. We predict that this stimulus will impair subjects' ability to remain focused on the task, thus inhibiting their working memory and reducing the number of words they are able to recall. We also expect that this stimulus will induce significant changes in physiological measurements associated with stress, including an increase in both heart rate and EDA away from baseline, as well as an increase in blood pressure.

Materials and Methods

Participants and Groups

Twenty-six student volunteer participants at the University of Wisconsin-Madison between the ages of 20-23 were recruited at random for this study. All participants were asked to sign a consent form before their participation began. Subjects were asked to participate in two consecutive working memory tests, which took approximately 12 minutes to complete.

Before participating in the experiment, the participants were randomly assigned an identification number of one or two. This number determined which auditory stimulus would be presented during the second working memory test. Group one served as a negative control group, in which no auditory stimulus was presented. Group two served as an experimental group, in which participants heard 80 decibels of continuous, unintelligible talking noise retrieved from a YouTube video ("People Talking in BAR 9 Hours Long") throughout the entire second trial of the working memory test. All participants wore *Beats Studio Wireless Over-Ear Headphones* (Model BTONWIRELSBLK) throughout the duration of both trials of the working memory test.

Design and Procedure

The working memory test consisted of a 45 second memorization period immediately followed by a 45 second recall period. During the memorization period, participants were given a printed list of 30 words. All of the words were five letters long and fit onto one single piece of printer paper. During the recall period, participants were given a blank piece of paper and asked to write down as many of the previous words as they could. This same test was then repeated using a different set of 30 words.

The first trial of the working memory test began when the printed list of words was handed to the participant. ECG and EDA recordings started at this time and were monitored throughout the trial. No auditory stimulus was delivered during the first trial for any participant. The participant was given 45 seconds to study the list of words before it was removed. A blank piece of paper was then immediately presented to the participant, and they were again given 45 seconds to recall and write down as many words as they could. After the 45 seconds, the participant's paper was removed and scored. At this point, a second blood pressure reading was recorded and EDA and ECG monitoring were stopped and saved.

A second trial began shortly after the completion of the first trial. The process remained the same, except that the participant was presented with a new list of words for the task. The participants in group two received the 80 dB unintelligible talking stimulus during the second trial of the task. An outline of the general procedure is depicted in Figure 1-1.

Measures of Stress

Physiological measurements were taken by placing ECG and EDA electrodes and a blood pressure cuff on the participant. Both heart rate (in beats per minute) and EDA (in microsiemens) were measured using the *BIOPAC* Student Lab System BSL 4.0 (MP36, #MP36E1204002762, *BIOPAC* Systems, Inc., Goleta, CA, USA). Testing of these three physiological measurements on ourselves during feasibility trials confirmed their reliability as indicators of stress response. Sample ECG and EDA data recorded over time with the *BIOPAC* system is depicted in Figure 8.

Heart rate was measured with a *BIOPAC* Electrode Lead Set (SS2L) attached to three *BIOPAC* disposable electrodes (EL503) on the participant's right leg, left leg, and right wrist. Subjects' heart rates during the first 45 seconds of trial two were compared with their baseline heart rate obtained during the first 45 seconds of trial one. An increase in heart rate away from baseline was considered to be a positive indicator of stress.

EDA was measured using the *BIOPAC* EDA transducer (SS3LA/L), with fresh isotonic recording electrode gel (GEL 101) applied. Electrodes were attached to the index and middle fingers of the participant's non-dominant hand. EDA measures skin conductance as a function of sweat, which is induced by the sympathetic nervous system. The difference between the highest EDA value obtained over the 45 second recall period and lowest EDA value of the 45 second memorization period of trial one was found and compared to that of trial two. Five seconds on either side of each peak were selected, and the mean EDA value over the total ten seconds was calculated. EDA values from trial two were compared to their respective baseline EDA values from trial one in both the control and experimental groups. A larger difference in EDA values in trial two compared to the difference in EDA in trial one was considered to be a positive indicator of stress.

Blood pressure was recorded before the first task began, again after the end of the first trial, and a third time at the end of the second trial. Blood pressure was taken using an OMRON automatic blood pressure monitor (BP791IT, #2014004275LG, Omron Healthcare Co. Ltd., Lake Forest, IL, USA). The second and third blood pressure measurements were converted to MAP values. MAP values from trial two were compared to their respective baseline MAP values from trial one in both the control and experimental groups. A larger difference in MAP in trial two compared to the difference in MAP in trial one was considered a positive indicator of stress.

Cognitive task performance was plotted as a function of the change in each of the physiological stress measures between trial one and trial two for each participant.

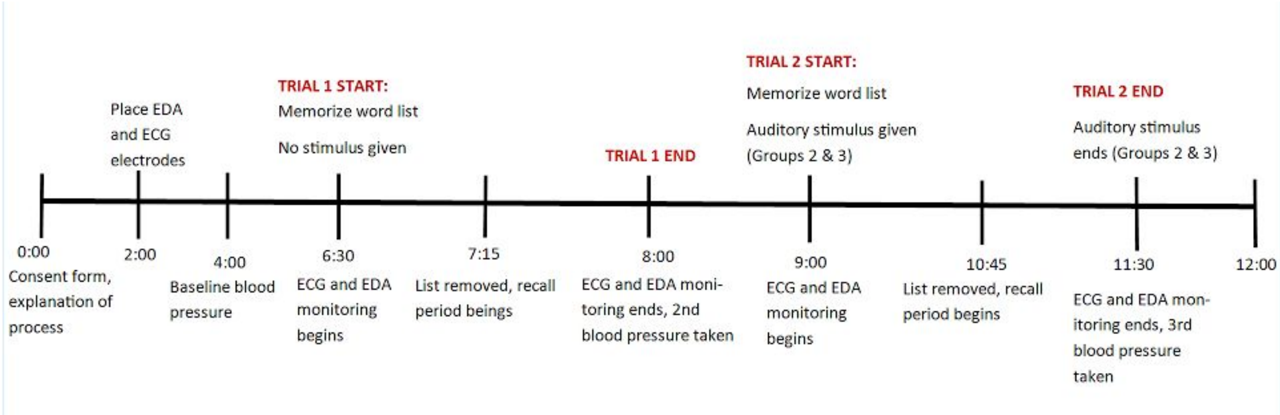

Figure 1-1: Timeline of Events

Results

Physiological Measures

According to the net change in EDA plot (Figure 6), the range in EDA within the control group was smaller than the range of EDA within the experimental group. However, a t-test produced a p-value of 0.7119, indicating no significant difference between our control and experimental groups with respect to EDA.

From the net change in heart rate graph (Figure 5), we note that the range in heart rate is greater for the control group than the experimental group. We observed that the standard deviations greatly overlapped, indicating no notable difference between our control and experimental groups. A t-test produced a p-value of 0.7265, confirming that there was not a significant difference between the two groups with respect to heart rate.

The graph showing net change in MAP (Figure 7) indicates that the range of values is greater for our experimental group than for our control group. A t-test produced a p-value of 0.0026, indicating a significance difference between the experimental and control groups with respect to MAP values.

Task Performance Measures

The net change in test scores observed between our experimental and control groups (Figure 4) showed that the range of words recalled in our experimental group was smaller compared to our control, indicating that participants recalled fewer words in trial two than they did in trial one. However, a t-test produced a p-value of 0.4428, showing no statistical significance between our control and experimental groups with respect to cognitive task performance.

A correlation was produced comparing the difference in heart rate to the difference in word count between trials of both the control and experimental groups (Figure 1). While there is a slight negative slope in the experimental group and a slight positive slope in the control group, the data is too inconsistent to draw any conclusions that cannot be attributed to chance.

In addition, we looked at the correlation between the difference in word recall and the difference in EDA (Figure 3). Neither the control nor the experimental groups demonstrated any correlation between the two variables, and as a result no significant difference was observed between the two groups.

The graph comparing the difference in MAP to the difference in words recalled (Figure 2) shows that the slopes of the control and experimental groups are both positive and in parallel. This suggests a positive correlation between mean arterial pressure and word recall.

P-values and confidence intervals for all t-tests describing the net difference in physiological measures and cognitive performance scores between the experimental and control groups can be found in Table 1.

Discussion

Statistical Analysis

Participants subjected to the auditory distraction did not perform worse on the word recall task from trial one to trial two. Though a statistically significant difference in MAP was observed across experimental and control groups (i.e. MAP increased more from baseline values in the experimental group than it did from baseline values in the control group), it was not correlated with a decrease in cognitive performance. No significant differences across groups were observed with respect to heart rate and EDA, though results trended towards our hypothesis that the distraction would elicit an acute stress response. These findings indicate that exposure to the auditory distraction may have produced some level of stress in participants in the experimental group. Several factors within the design and implementation of this study may provide explanation for the insignificant findings for the remaining variables tested.

Methodological Error

ECG recordings for data analysis were only utilized from the first 45 seconds of data collection for each test subject, rather than from the full 90 seconds of each trial. During the first 45 seconds, subjects were asked to memorize as many words as they could while in a still, seated position. During the 45 second recall period, the continuous writing by subjects with an electrode on their right wrist skewed the ECG data. No participants were left-handed, so many recordings showed heart rate artifacts during these 45 seconds. ECG was also affected by subjects tapping their fingers on the desk during recall, presumably to help them remember words as they were writing. Subjects #4-26 were instructed to refrain from this action.

Two outliers were noted among EDA data, both attributed to subjects pushing on the EDA electrodes throughout the trial. This created oscillations that were unable to be utilized for analysis. These oscillations were short and only present among the recordings of two participants, so maximum and minimum values were taken on either side of the skewed data. EDA recordings were analyzed using data from the entire 90-second trial.

The increases in ECG and EDA responses that we predicted in the experimental group were not significant. This could have resulted from the relief of the participant having finished the trial, inaccurate readings resulting from subject movement, an inherent lack of ability of the stressor to evoke an acute stress response, or subjects' increasing familiarity with the experimental procedure following the first trial.

To control for a difference in the intrinsic difficulty of each word list, the lists were used in alternating fashion. Half of the participants in both the experimental and control groups were given list one for the first trial and list two for the second trial. This process was reversed for the other half of the participants in each group, such that list two was used for the first trial and list one for the second trial. Despite the fact that each list contained 30 randomized five-letter words, we found that almost every test subject could recall more words from list two than list one. This phenomenon was observed regardless of which list was presented first. Future studies should consider methods for ensuring equal degree of difficulty between two or more lists of words used in a recall task.

Experimenter Error

The exact timing of each trial likely varied by about one second, as data collection in BIOPAC had to be stopped manually. Likewise, the time between trial one and trial two for each participant was not held constant, but was a matter of the time it took to save the data from trial one and prepare for trial two. These variations in overall experiment time may have contributed to each participant's ability to adapt to the situation or to experience a decrease in physiological stress before the second trial.

Inconsistent ECG calibration between different participants and experimenters may have also contributed to skewed ECG recordings, making several sections of the ECG data unusable for data analysis.

Variation in interpretation of the ECG and EDA recordings may have contributed to misrepresentation of experimental data. Individual researchers were assigned to analyzing either ECG or EDA data, such that inconsistencies were kept to a minimum within each type of physiological measure.

Experimental Conditions

The room in which this experiment was conducted was not isolated, but rather surrounded by other experiment rooms and was prone to unintentional disruption by other students in the area. Additionally, the temperature of the room and time of day varied slightly across the time frame in which this experiment was conducted. These factors may have contributed to variations in participants' stress levels and ability to focus on the task.

The participants of this study nearly all came from the Physiology 435 laboratory, and were all between the ages of 20-23. For the sake of efficiency and convenience, this study was rather limited in scope of participants. This cohort is not representative of the general population, and may have contributed somewhat to the skewing of physiological data for this study.

Lastly, the number of experimenters in the room with each participant varied in the beginning of the study. The first several participants partook in this study with five experimenters in the room, which may have contributed to increased stress levels and decreased cognitive task performance. This was later controlled for by having only two experimenters in the room at once for the duration of the study.

Future Studies

Future research on this topic should include several changes to study design and implementation in order to produce more significant results. First, increasing the number and diversity of participants for the study will yield more representative data. Second, the length of each trial could be lengthened and data from the recall period more specifically analyzed to ascertain more accurate relationships between the auditory stimulus and working memory task performance. Future experiments might also benefit from using a different type of working memory test in which variation in task difficulty can be more tightly controlled for. Use of an intelligible auditory stimulus might also produce more viable results, and would be an interesting variable for further study. Lastly, additional physiological stress measures might be utilized to increase validity of any physiological stress response inflicted by the auditory stimulus.

Our study contributes to the existing body of research on the effect of auditory stimuli on physiological stress and cognitive task performance, with evidence that a common background noise such as unintelligible talking may induce some level of physiological stress. The insignificance of the data among tested physiological measures and cognitive task performance suggests the need for further research on the topic. The findings from this study serve as a foundation on which future research can build to better understand the relationship between commonly distracting auditory stimuli, physiological stress response, and cognitive task performance.

Acknowledgements

We would like to thank Dr. Andrew Lokuta for his expertise and advice, as well as the PLVs and graduate students who assisted us with the methodology of this study. We also thank all of the participants who gave their time to partake in this study, as well as Alan Sayler for his assistance in data analysis.

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Tables

Measured Variable Change (Trial 2 – Trial 1)	t-value	p-value	Degrees of freedom	Confidence interval
Electrodermal activity	0.3751	0.7119	18.102	-0.8205 – 1.1774
Heart Rate	-0.3539	0.7265	23.347	-0.3553 – 5.2044
Mean Arterial Pressure	-2.4436	0.0226	23.102	-8.6636 - -0.7209
Words Correct	0.7804	0.4428	23.769	-1.2658 – 2.8044

Table 1: Two variable t-test without replication between control and treatment groups.

Figures and Legends

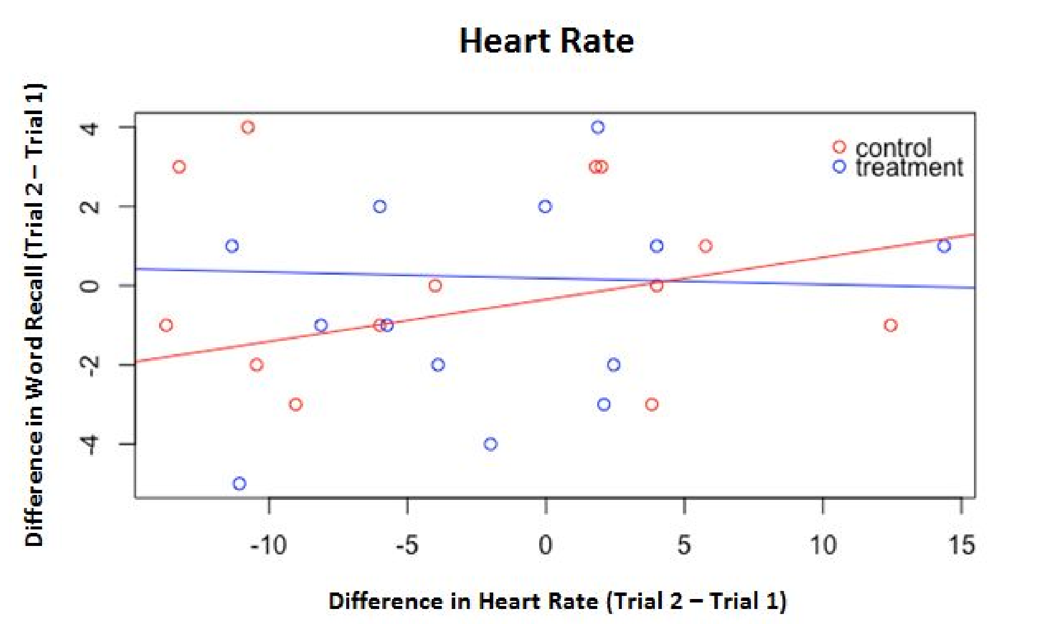

Figure 1: Difference in heart rate correlated to difference in word recall performance between control and treatment groups.

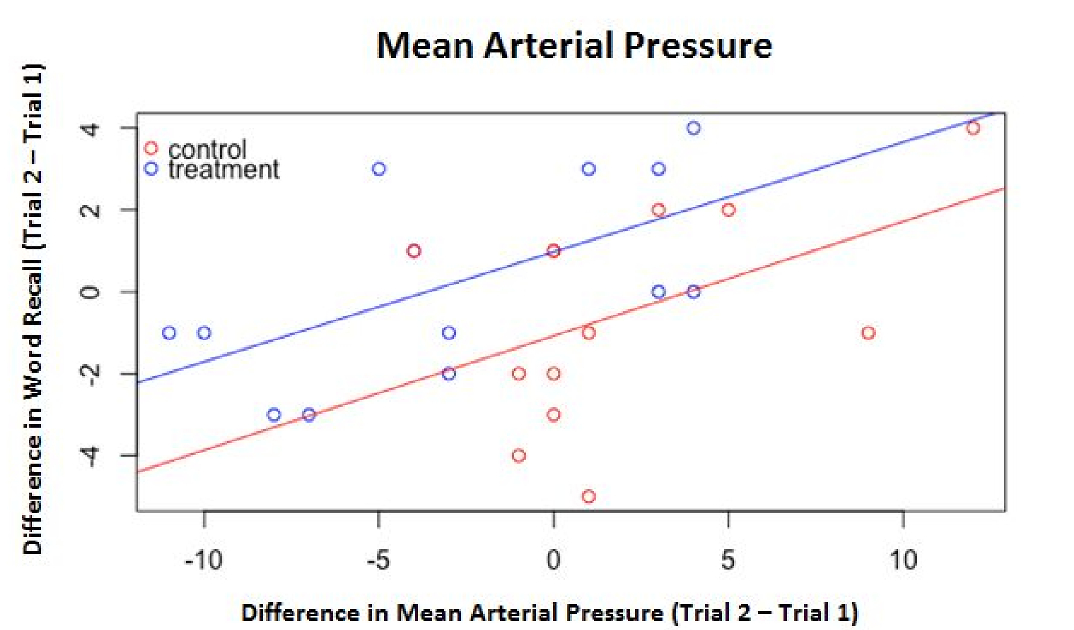

Figure 2: Difference in mean arterial pressure correlated to difference in word recall performance between control and treatment groups.

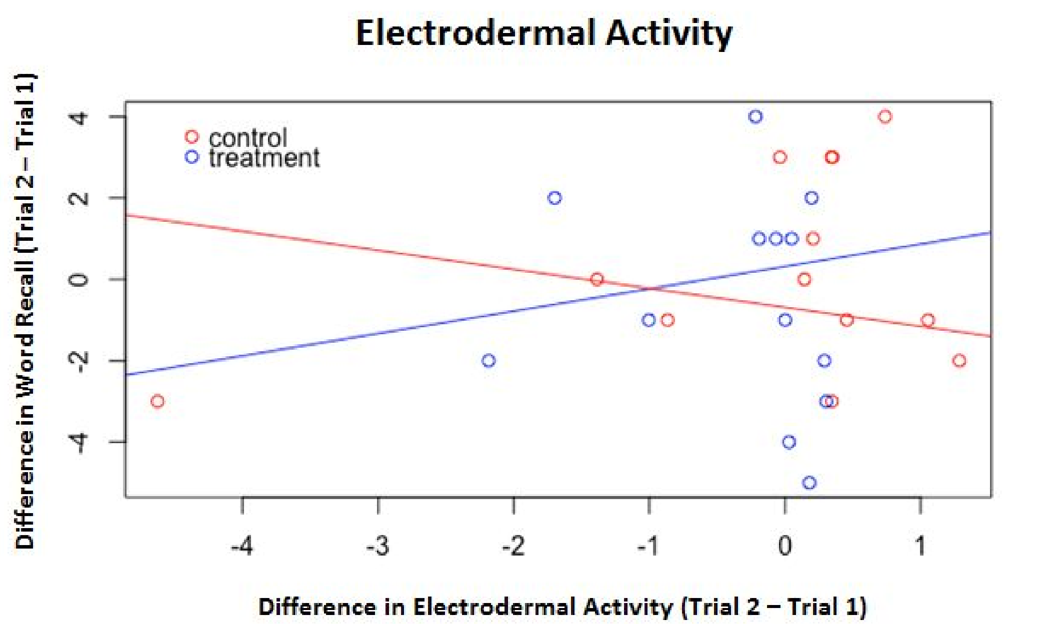

Figure 3: Difference in electrodermal activity correlated to difference in word recall performance between control and treatment groups.

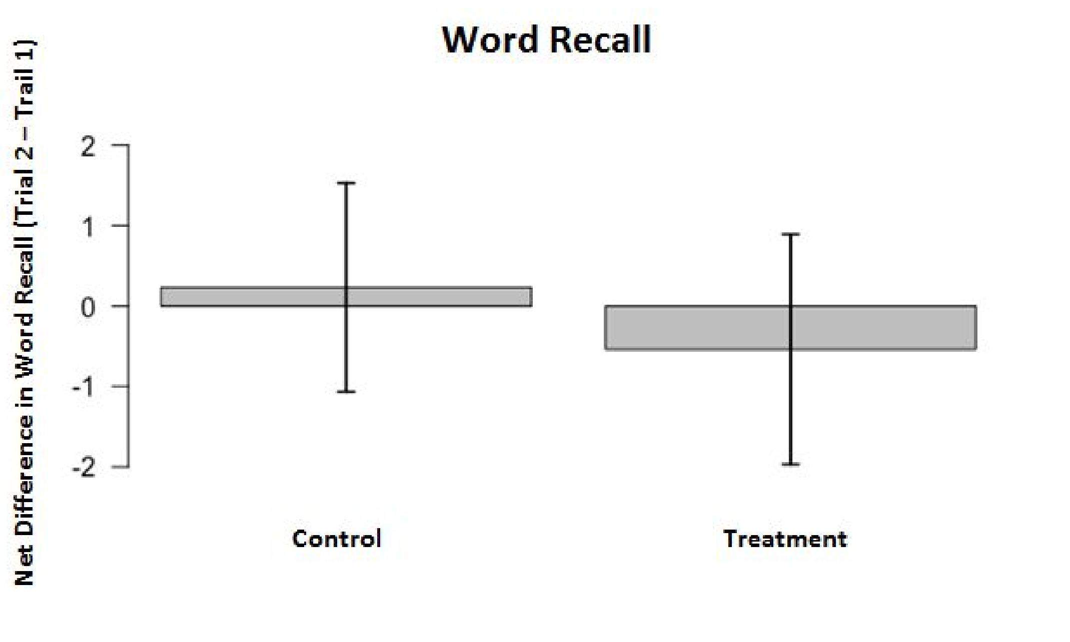

Figure 4: Net difference in word recall performance between control and treatment groups.

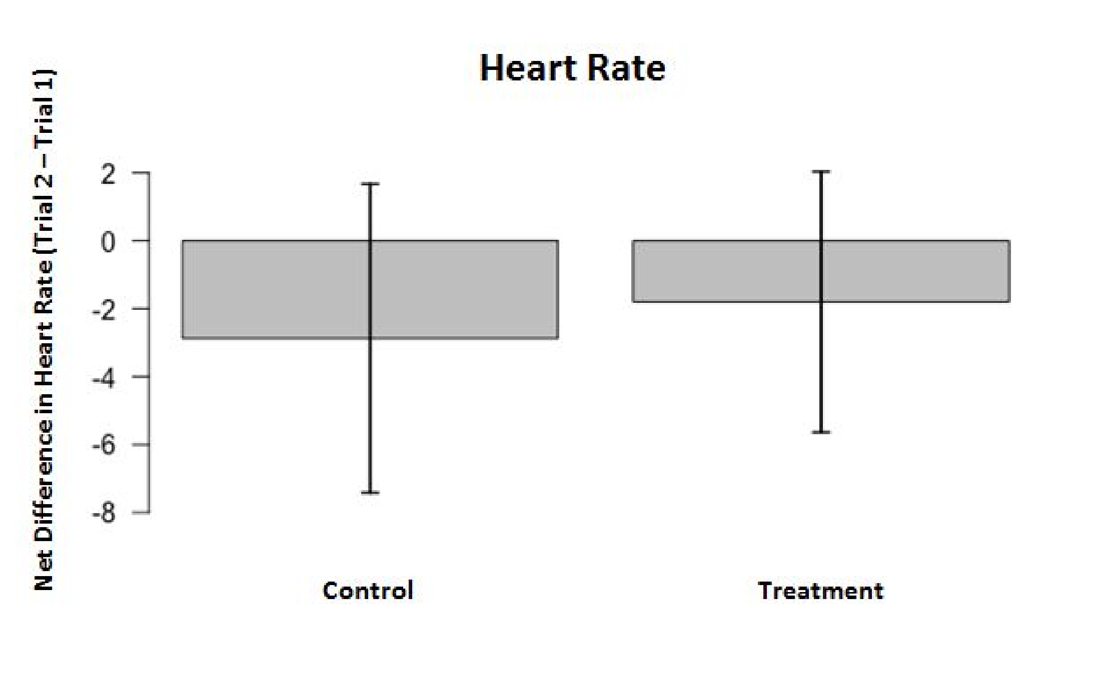

Figure 5: Net difference in heart rate between control and treatment groups.

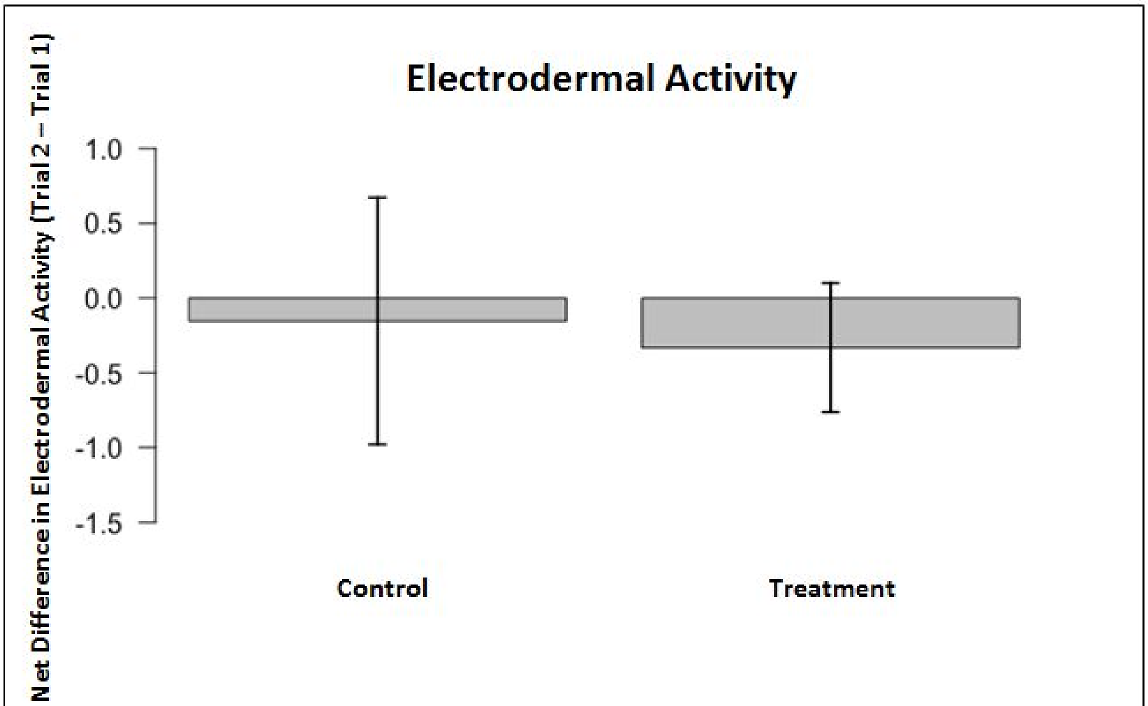

Figure 6: Net difference in electrodermal activity between control and treatment groups.

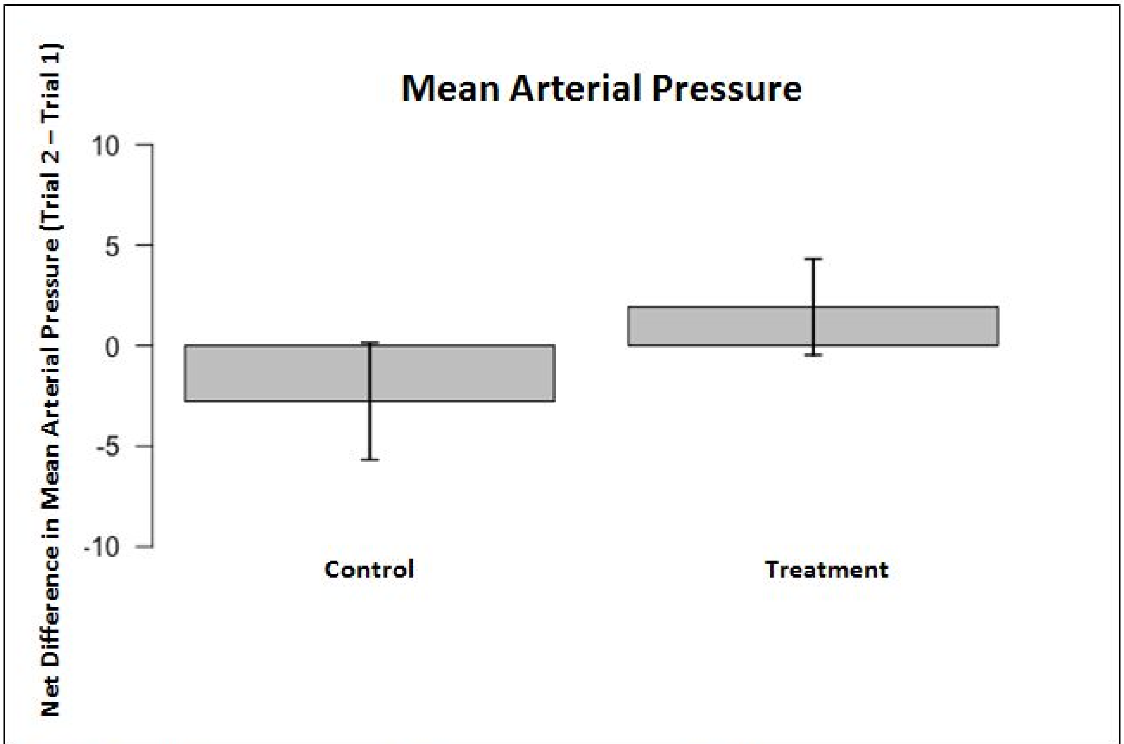

Figure 7: Net difference in mean arterial pressure between control and treatment groups.

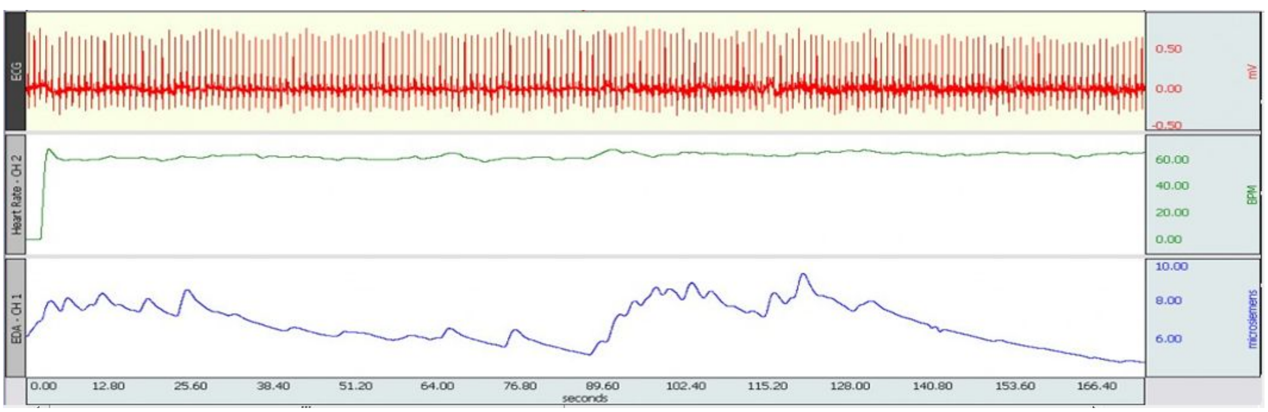

Figure 8: Sample ECG and EDA recordings using *BIOPAC*

Appendix

List 1

Learn	Cycle	Joker
Eight	World	Chewy
Shock	Young	Where
Blink	Women	Equal
Gauze	Other	Pixie
Hazel	Earth	Thumb
Night	Heard	Wrote
Group	Fuzzy	Quick
Watch	Sixth	Proxy
Toxic	Crazy	Chump

Check	Amaze	Vouch
Chalk	Hobby	Excel
Fluff	Flock	Flick
Cyber	Bunch	Porch
Pinch	Value	Cough
Major	Comic	Snack
Again	Enjoy	Polka
Caught	Junky	Scoff
Color	Eject	Finch
Great	Puppy	Gumbo