THE PHYSIOLOGICAL RESPONSE TO AN AUDITORY CUE INDICATING TIME REMAINING ON A COGNITIVE PERFORMANCE TASK

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ABSTRACT

Previous studies have demonstrated that time constrained tasks lead to an increase in the physiological stress response and that elevated stress levels lead to poorer performance (Wahlstrom et al, 2002) (Clark et al, 1998). It remains unknown whether the practice of professors reminding students of remaining time on examinations could be leading to poorer performance. This study is investigating whether constant verbal reminders of the time remaining to complete a cognitive task leads to a greater physiological stress response and poorer performance than the control group. Thirty-two participants were recruited from Physiology 435 at UW Madison and randomly assigned to a control and experimental group. The participants were seated and baseline MAP and heart rate were collected, and the electrodermal activity (EDA) finger monitors were attached. The control group was told they had five minutes to complete the task and was then not disturbed for the remainder of the cognitive test. The experimental group, however, was notified of the time remaining in intervals until the five minutes expired. Statistical analysis found no significance for heart rate, blood pressure, and EDA between the control and experimental groups. Regarding performance on the word search, the data were significant with the experimental group finding an average of 5.44 words and the control finding an average of 7.25 words ($p=0.0357$). Increasing the authenticity of the exam setup and initial screening of participants are discussed as factors that may improve future studies.

Key Words:
STRESS, TIME CONSTRAINT, HEART RATE, EDA, BLOOD PRESSURE, TEST ANXIETY, WORD SEARCH

Introduction

Stress is a real or perceived threat to homeostasis that induces a physiological response to prepare the body for particular situations based off of past experience and temperament. (Gunnar & Quevedo 2007). While the response is variable, it has been shown that time-constrained examinations are one external stimulus that frequently induces psychological stress (Wahlstrom et al, 2002).

The Physiological Response to Psychological Stress

Psychological stress induces physiological responses in both the Hypothalamic-Pituitary-Adrenal (HPA) axis and the sympathetic nervous system. When stimulated by stress, the hypothalamus induces a hormone cascade that releases Adrenocorticotropic hormone (ACTH). Increased plasma levels of ACTH acts on the adrenal cortex to secrete cortisol which leads to increased salivary cortisol levels, increased heart rate, and blood pressure (Randall, 2010).

The sympathetic nervous system is the second component to the psychological stress response. While most organs are innervated by both the sympathetic and parasympathetic nervous systems, the sweat glands and the blood vessels in the skin are innervated exclusively by the sympathetic nervous system. When psychological stress activates the sympathetic nervous system, there is vasodilation of skin blood vessels and sweat glands are activated. Because these responses are involuntary and exclusively controlled by the sympathetic nervous system electrodermal activity is an ideal measurement of sympathetic activation and thus the acute stress response (Arnich et al, 2009).

Stress during Examinations

Previous studies have demonstrated that psychological stress pertaining to exams, often referred to as test anxiety, results in poorer performance (Clark et al, 1998). Clark et al (1998) assessed the anxiety levels of eighty-eight undergraduates and recorded their attempts to pass unit tests throughout the semester. Students with higher intrinsic levels of test anxiety have greater arousal of the sympathetic nervous system and took an average of 4.1 attempts to pass compared to the low anxiety group who took an average of two attempts to pass (Clark et al, 1998).

A specific factor contributing to stress during an exam is the time constraint component of the task. A previous study has shown that time-pressure with verbal provocation on a computer task demonstrated increased heart rate, blood pressure, and muscle activity compared to a control condition (Wahlstrom et al, 2002).

Practical Application

In university settings, it is common among professors and teaching assistants to announce the time remaining during an exam. But is it possible that this audible reminder of dwindling time is inducing greater stress among students thus resulting in poorer performance? A meta-analysis determined that high levels of arousal have debilitative effects on difficult cognitive tasks. Sensory inputs such as loud noises, bright lights, external distractors, and complex stimuli all lead to higher levels of arousal and present challenges in completing a cognitive task. Indications of arousal included higher levels of skin conductance, heart rate, breathing, and metabolic activity (Humphreys and Revelle 1984).

Conclusion

Previous studies have shown that subjects have a significant increase in their stress response when given a time constrained task, that higher levels of arousal lead to greater sympathetic activity, and that increased stress during exams lead to poorer performance. This experiment is examining whether subjects have a greater increase in their stress response when given a time-constrained cognitive task and are audibly reminded of the remaining time, versus when they are aware of the time constraint but left to complete the task without further arousal. We hypothesize that individuals who are frequently audibly reminded of remaining time while completing a cognitive task will exhibit significant increases in blood pressure, heart rate, skin conductance, and poorer performance on the task than those left to complete the task without audible time reminders. These measurements will allow us to assess each type of measurement both by itself and then collectively, to draw further conclusions on induction of stress and how stress affects performance. The control group, who received no audible reminders provides a baseline for the variation of heart rate, blood pressure and electrodermal activity to expect when individuals are asked to complete a time-constrained cognitive task.

Materials and Methods:

Participants

The participants for this study were undergraduate students enrolled in Physiology 435 at the University of Wisconsin - Madison. The sample included 32 students (n = 20 females and n = 12 males) ranging from 20 years old to 22 years old. Participants volunteered for the study and signed a consent form agreeing to the experimental procedure. There was no compensation given to participants. Participants were randomly assigned to either the experimental group or the control group to avoid bias.

Materials and Measurements

All participants were seated as heart rate and mean arterial pressure (MAP) measurements were taken on the non-dominant arm via the Omron 10 series+ blood pressure monitor (Model BP791IT manufactured by Omron Healthcare Co., Ltd, Lake Forest, IL). Baseline data were recorded and the device was left on for later measurements. Electrodermal activity (EDA), which is a measure of skin perspiration, was continuously measured on the non-dominant index and middle finger via the Biopac Student Lab Electrodermal Activity Finger Electrode Xdcr (Model SS3LA and Isotonic Recording Electrode Gel model 101, manufactured by Biopac Systems, Inc., Goleta, CA).

The words included in the elementary level wordsearch were selected from Physiology 435 class material. The words ranged from four letters to ten letters with an average length of 6.9 letters. The word search consisted of nine physiology-themed words, but participants were given a list of 10 words to find. Participants were asked to find 10 words in the puzzle to keep their stress levels high when they could not find the tenth word. Participants were also notified in the directions that if they found all 10 words they were eligible for bonus points in the class. Ten words fit well within the dimensions of the word search. The dimensions of the puzzle were 20 letters across by 15 letters down. Letters in the wordsearch could be shared. See **Figure 1** for the experimental word search. The instructions on the front side of the puzzle were as follows:

> Instructions: Find and circle as many of the words as possible. Search up, down, forward, backward, and on the diagonal to find these hidden words. You will be given five minutes to complete this puzzle. After speaking with Dr. Lokuta any participant who finds all ten words will be given **bonus points** in Physiology 435. The word search will be on the backside of this page.

Experimental Design

Baseline heart rate and MAP values were taken after the participant had entered the room and signed the consent form. Then, study participants were asked to complete a word search. Members of the *control* group were told that they had five minutes to find as many words as possible and were not spoken to for the duration of the word search. Members of the *experimental* group were told that they had five minutes to complete the same word search. The proctor then announced the time remaining in one minute intervals for the first three minutes, and then in 30 second intervals for the final two minutes. A proctor was present during the wordsearch for both the control group and experimental group.

Blood pressure and heart rate were measured immediately after the five minutes expired for both groups. Skin Conductance was continuously recorded throughout the trial and at this point was concluded. **Figure 2** shows the approximate schedule of events for the experimental procedure.

Positive Control

The positive control was used as evidence that the monitoring equipment was functional and capable of providing reliable measurements. Positive control was *not* used as a group that receives a treatment to achieve a known result. To evaluate the positive control of the experiment, physical activity was done in order to test the blood pressure and heart rate equipment. The participant's blood pressure and heart rate were taken before and after the physical activity, which consisted of 10 push-ups and 30 jumping jacks. The data supported our hypothesis that physical activity would increase blood pressure and heart rate. Evidence from this sample experiment is shown in **Table 1**.

An additional sample experiment was done to ensure correct functioning of the EDA equipment. The finger electrodes were plugged into channel two of the monitor and Biopac 4.0 software was opened on the computer monitor and set to a new experiment. Isotonic recording electrode gel was then placed on finger electrodes and the electrodes were placed on the subject's index and middle finger, the subject sat still for 180 seconds until his skin conductance remained constant and then rapidly rubbed hands together for four seconds. The data as seen in **Figure 3** is evidence that the EDA equipment will accurately record and detect skin conductance during the experiment.

Data/Statistical Analysis

We used an unpaired t-test to analyze MAP and heart rate prior to beginning the word search and after its completion. An one-way ANOVA was utilized to assess the relationship between verbal time reminders and skin conductance. All statistical tests were carried out with RStudio Software (v1.0.136).

To normalize the data set we decided to utilize percentage change of MAP and heart rate. Calculating the data this way will account for individual differences in baseline data. Additionally, for every data point of interest on the conductance test we took the average value over a five second interval to account for rapid fluctuation of measurements. For example, in the experimental group we analyzed five second periods immediately after a time announcement was given by recording the mean conductance and the change from peak to peak.

Results:

All results for the skin conductance data were calculated using a One-Way ANOVA. The results for the mean arterial pressure and the heart rate were calculated using the Welch Two Sample T-Test, which is an unpaired t-test. Statistical analysis found no significance difference for heart rate ($p=0.91$, **Figure 4**), blood pressure ($p=0.82$, **Figure 5**), and EDA ($p=0.366$, **Figure 6**). Regarding performance on the word search, the data were significantly different ($p=0.0357$).

For performance on the word search, (average number of words found) for the experimental group was 5.44 (SD = 2.83) and for the control group was 7.25 (SD = 1.69). The results were considered significantly different ($p = 0.0357$, **Figure 7**). For heart rate, the average percent change in heart rate for the experimental group was 0.027% (SD = 0.180) and for the control group was 0.033% (SD = 0.103). For blood pressure, the average percent change in mean arterial pressure for the experimental group was -0.008% (SD = 0.066) and for the control group was -0.002% (SD = 0.085).

Discussion:

The results showed blood pressure, heart rate and EDA differences between the experimental and control group to be insignificant. On average, the control group found a greater number of words in the word search, as well as a smaller standard deviation. This data proved to be significant, demonstrating better performance on the task and less deviation by the group with no auditory time warnings. Overall, physiological results did not support our hypothesis.

The 2002 Wahlstrom study that showed an increase in heart rate, blood pressure, and muscle activity during a time-constrained task differed from our experiment. Those participants were in their own work environment and had greater motivation to succeed on the task. We believe that our study may have generated insignificant results on the three physiological measurements because the conditions were not similar enough to an examination setting; and therefore all participants experienced less sympathetic arousal. While students were given motivation to find all words in the search by offering bonus points in Physiology 435, it was not enough to generate a drive to succeed on the task. The study was conducted in a closed room in which the participant was alone with two proctors and taking a word search. None of these factors were truly representative of an actual exam. The study may have found significant results if it had been conducted during an actual Physiology 435 exam in which students possess motivation to do well on the exam in a realistic setting.

Previous research has indicated that higher sympathetic nervous system arousal leads to poorer performance on a time-constrained task (Clark et al, 1998), a main tenet motivating this study. It should be considered, however, that the sympathetic arousal in the Clark study was a direct result of whether the participant had a high level of intrinsic test anxiety, rather than arousal created by the environment. Prominent psychologist, Albert Bandura, noted that people with anxiety rely more on their somatic and emotional states in judging their capabilities, and thus interpret their stress reaction as vulnerability to poorer performance (Bandura, 1994). This suggests that personality differences may have also been a factor in the performance of participants, which our study did not take into consideration.

To increase the significance of the results, further screening of participants should have been considered. At the University of Wisconsin - Madison, students can apply for a

McBurney VISA if they feel that they possess a circumstance that could negatively affect their academic performance. An example of a condition that qualifies for this visa is test anxiety. In relation to our study, participants with test anxiety could greatly affect average heart rate, blood pressure and EDA measurements. When performance is calculated, participants with test anxiety would perform worse than the average participant, thus lowering the average number of words found. Whether in the control or experimental group, it would facilitate support for the hypothesis that the experimental group would have poorer performance and impede the control group's results. Initial screening of test anxiety among students could have further defined our definition of qualified participants. In our results we had two participants that seemed to have intrinsically higher anxiety while in a test-like environment. These participants were considered outliers, but serve as an example of failing to screen participants in this manner.

To further support the findings of our study, an alteration in environmental factors would be a major point of emphasis for future studies. Factors would include hosting the exam in a lecture hall, having teaching assistants or professors as proctors, and including other students as confederates to facilitate a more authentic examination experience. In addition to environment, another improvement to our methods would be to deliver a more meaningful exam that participants could prepare for. Preparation may result in a greater investment in the student's performance resulting in higher personal expectations which may also lead to an elevated stress response during examination.

While our experiment only investigated the relationship between an auditory time reminder and its resulting physiological activity, it would be interesting to see if visual time reminders bared any significance to the stress response. Visual time reminders have an uncertainty associated with them as students may not notice when they are first presented, and therefore do not know how accurate it may be. This uncertainty could result in a heightened stress response. This could further shed light on the impact of specific external stimuli on physiological stress response. Because visual time reminders are also frequently used by professors, this relationship may be relevant for faculty at universities across the nation.

Figures/Tables:

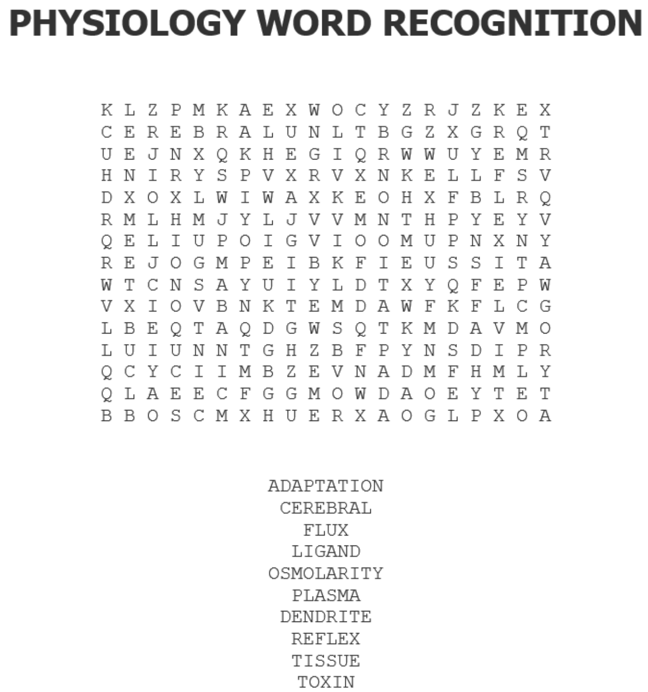

Figure 1: The experimental word search completed by the participants.

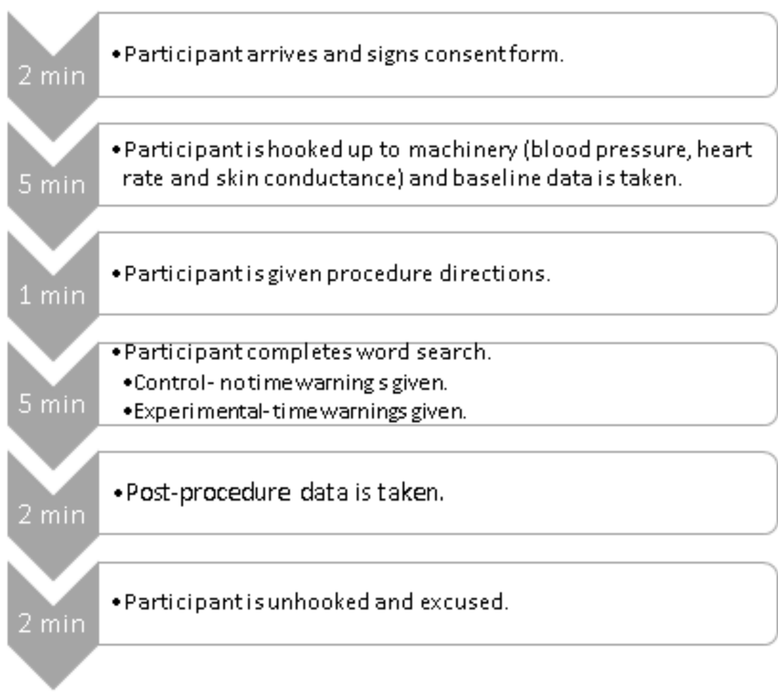

Figure 2: The approximate schedule of events for participants in this experiment.

	Mean Arterial Pressure	Heart rate
Before activity	92.67	75
After activity (30 jumping jacks and 10 pushups)	108.67	121

Table 1: Mean arterial pressure and heart rate was taken before and after physical activity to assure that machinery was functional in detecting change for the experiment.

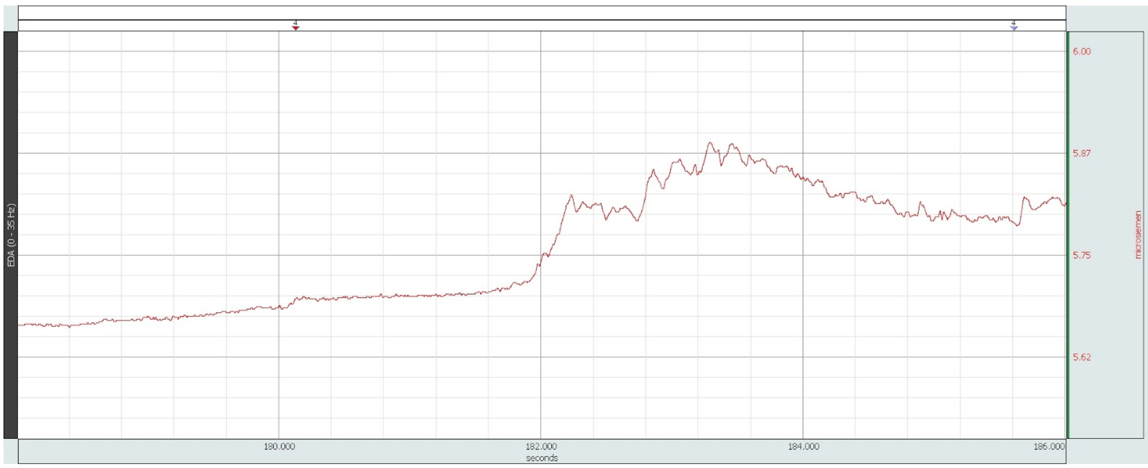

Figure 3: Data from the positive control of the EDA skin conductance monitor. At 180 seconds the subject began to rapidly rub their hands together to generate skin perspiration, and skin conductance measured in (microsiemens) increased until the subject stopped at 184 seconds.

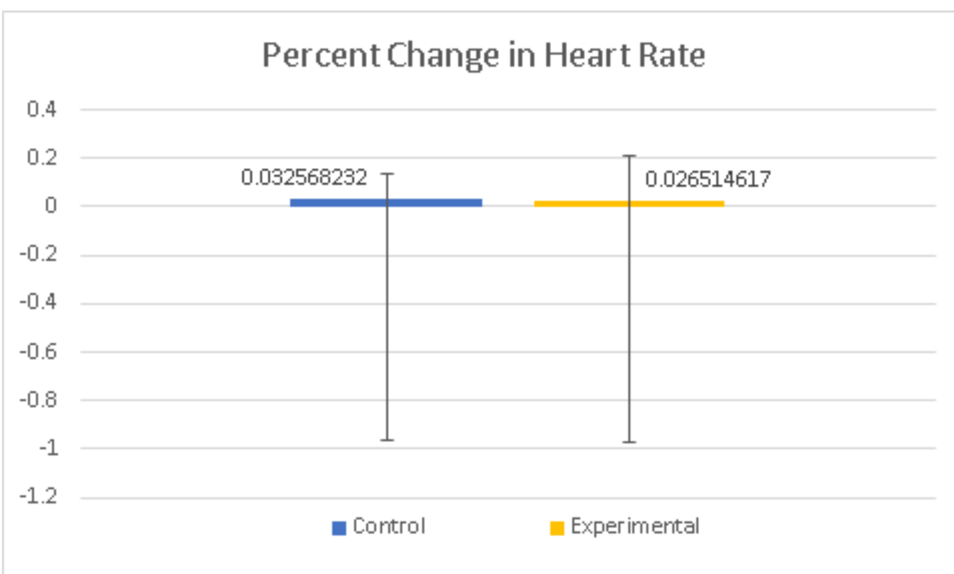

Figure 4: Percent change in heart rate for the experimental and control groups.

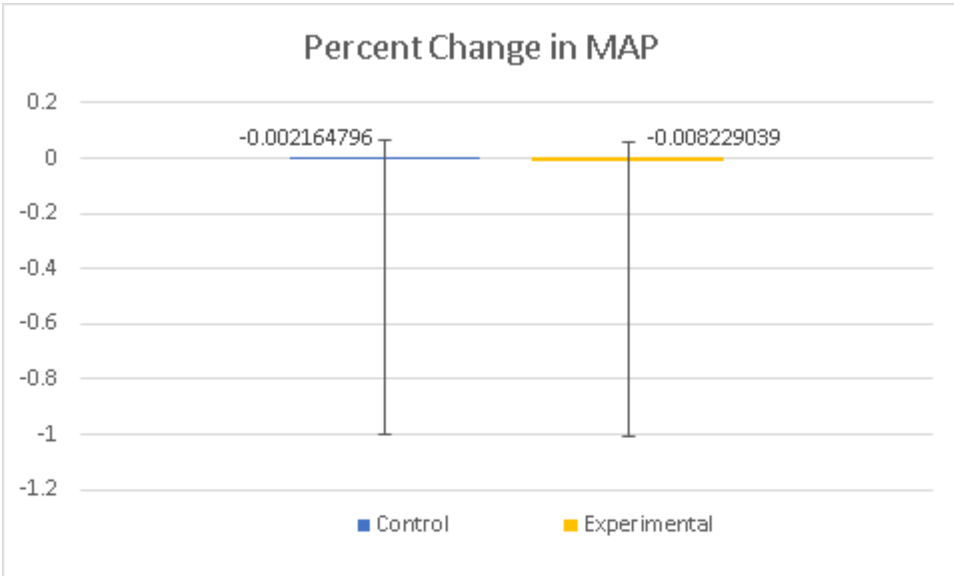

Figure 5: Percent change in mean arterial pressure for the experimental and control groups.

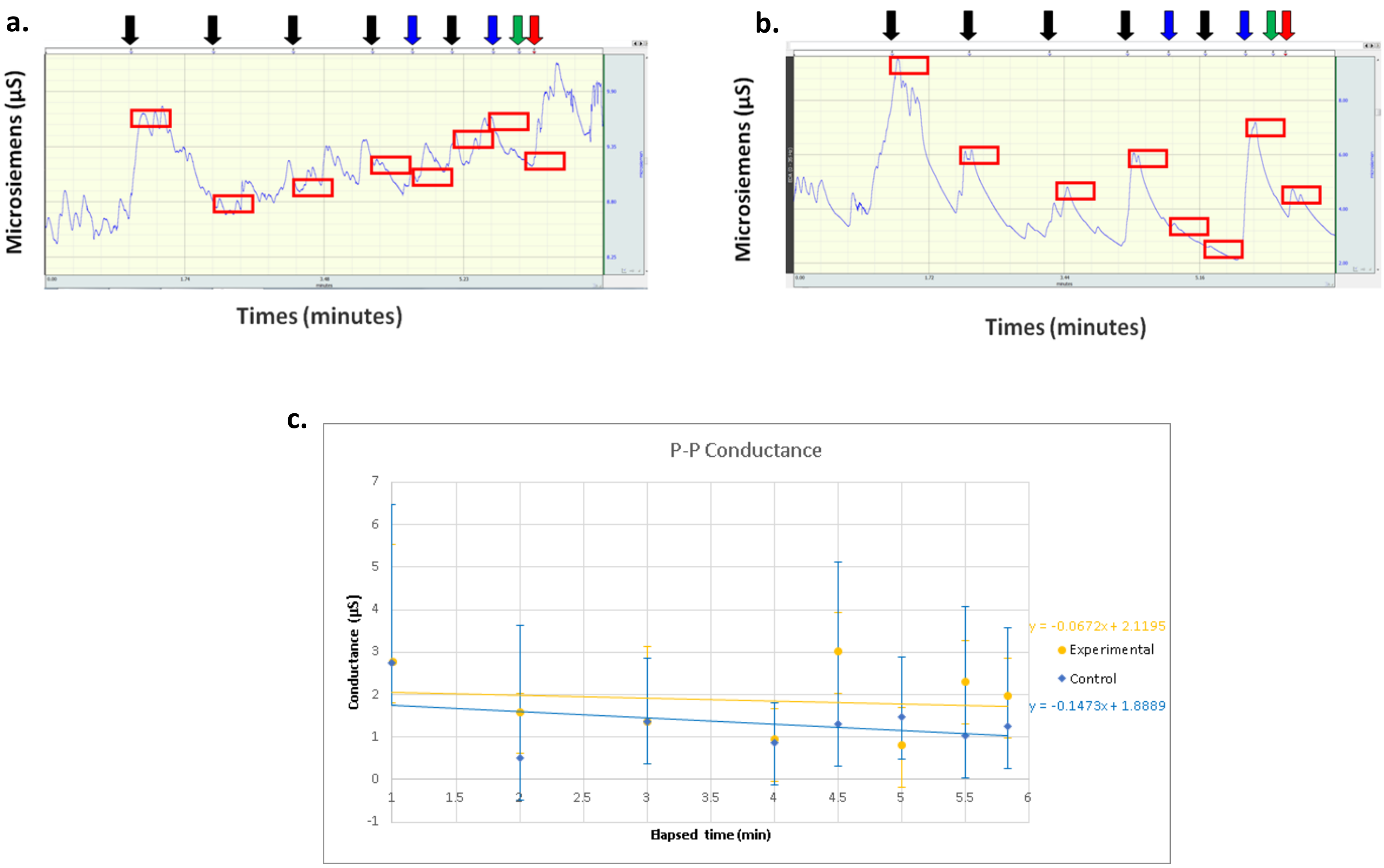

Figure 6a: Representative screen shot of EDA data from a *control* participant. Control participants were not given verbal time remaining reminders. The black arrows above represent where the time remaining reminder at each whole minute integer would have been given if the participant was in the experimental group. Similarly, the blue arrows indicate where the reminder would have been given at a thirty-second interval. The green arrow indicates where the reminder would have been given with ten seconds remaining. Finally, the red arrow indicates when the time was called and the study finished. **Figure 6b:** Representative screen shot of EDA data from an *experimental* participant. The black arrows above indicate the time remaining reminder at each whole minute integer. The blue arrows indicate the reminder was given at a thirty-second interval. The green arrow indicates the reminder was given with ten seconds remaining. Finally, the red arrow indicates the time was called and the study finished. **Figure 6c:** Change in P-P conductance over the duration of the experiment. The x-axis represents the elapsed time of the experiment, rather than the remaining time as stated in **Figure 6 a,b.**

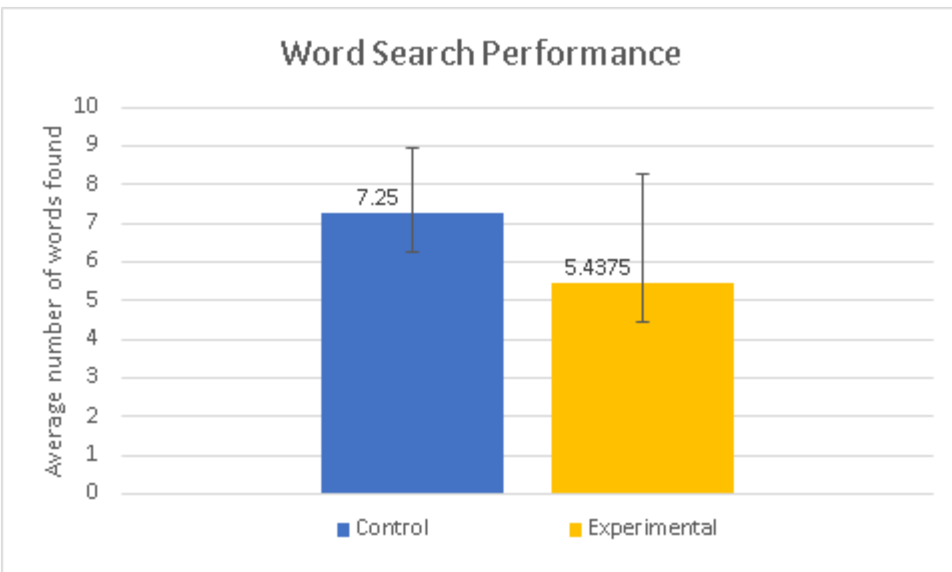

Figure 7: Average number of words found for both the experimental and control groups.

Citations

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