Effects of Personally Relevant Distractions Versus Generalized Distractions on Physiological Measures and Reading Comprehension

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Abstract

Multitasking is increasingly prominent in the daily life of a college student. Technology plays a vital role in this as students regularly use laptops and cell phones. This study seeks to evaluate any significant differences in physiological responses to personally-relevant and external distractions via cellphones, and the effects of these distractions on reading comprehension. The hypothesized result of this study was that the personally-relevant distraction would have an increased effect on physiological reactions, while also correlating with lower reading comprehension scores. Thirty participants completed four reading comprehension tests, each with a different treatment: no distraction, participant-proctor conversation, personal phone call, and background phone call. During each of these tests, participants' electrodermal activity, eye movement, and heart rate were measured. The results of this study were not statistically significant, so no conclusion can be drawn regarding whether distractions elicit strong physiological responses in the context of reading comprehension.

Introduction

In today's society, multitasking, also known as cognitive flexibility, has become the norm, especially when it comes to college students and technology (Carrier, et al. 2009; Lep, et al. 2014). Whether it is checking an email while taking notes in lecture, or sending a text while completing an assignment, media multitasking has become a seemingly unavoidable aspect of being in college. There is an incredibly high prevalence of technology on campuses throughout the US, with 96% of undergraduate students reporting owning a cell phone in the most recent Pew Report (Cotton & Junco, 2011). Interrupting cell phone rings during a note-taking task have also been shown to lower test scores (End, et al. 2010). Those who multitask may choose to do so as a way to prevent the occurrence of other potential distractors or due to their own inability to concentrate on any singular assignment (Sanbonmatsu, 2013). Research has shown that the repeated alternation between tasks of different media, cell phones, and literature can result in less efficient note-taking and comprehension due to a delay in motor skills (Wei, 2014). Multitasking is also known to split cognitive processing, which decreases the brain's ability to store information (Naveh-Benjamin, et al. 2000). Further, cell phones have been shown to significantly hinder students' focus, and negatively impact their final grade in a course as a consequence (Kuzenekoff & Titsworth, 2013).

Despite the negative cognitive impact of multitasking on learning being fairly well established, little research has been done on the physiological effects of multitasking and distraction. Additionally, there is a gap in the literature regarding certain types of distractions, i.e. those that are personally relevant, and determining if they have a different impact on an individual than distractions that are less individually involved. This study will examine the physiological effects of varying types of distractions on learning, and the effects of these distractions on reading comprehension.

In order to quantify the physiological response of each participant, heart rate (HR), electrodermal conductance of the skin (EDA), and eye movement were quantitatively measured. HR was measured at various points throughout the study to detect the change in arousal of the participant caused by a certain stimuli. This measurement is useful to compare conditions of similar stimuli to see their effect on the participant's arousal. EDA was measured to observe if, upon perception of the stimulus, there was a response by the sympathetic nervous system in the form of more active sweat glands (Jang, et al. 2015). Any change in perspiration was detected and acts as a possible indicator that a sufficient arousal had been present. Changes in the amount of eye movement were recorded in order to examine any significant increase in eye movement above baseline values while being exposed to specific stimuli. An ample distraction was expected to cause a spike in eye movement by the participant in order to determine who was calling or to identify if the ring was from their phone or another phone present, resulting in a loss of focus from the assigned reading.

It was hypothesized that audible ringing or vibration of the participant's cell phone would cause the greatest distraction, measured by changes in the physiological tests, and correlate with the least number of questions answered correctly on the reading comprehension test due to the cell phone being a personal stimulus. It was anticipated that eye movement would increase upon ringing as participants would look toward their phone by second nature, either to see who was calling or to react to the call. Similarly, it was expected that HR and EDA would increase due to the initial surprise and anticipation of a personal phone call. It was further hypothesized that the third party cell phone will not elicit as great of a physiological response from the participant since it is not a personal stimulus.

Methods

Participants

Participants for this study were students enrolled in Physiology 435 at UW-Madison. There were 30 participants (M= 7, F=23) ranging from ages 19-22. The participants were tested in the mid morning through early evening. All were regular cell phone users.

Materials

HR, EDA, and eye movement by an electrooculogram (EOG) were all measured on a participant who performed a reading comprehension task while exposed to varying distractions. A BSL Shielded Electrode Assembly (SS2L, BIOPAC Systems, Inc.) with General Purpose Electrodes (Part #: EL503, EL503-10, BIOPAC systems, Inc.) was used to measure the eye movement over a period of time. A Domestic Pulse/Oximeter/Carbon Dioxide Detector (Model #: 9843, Nomin Medical, Inc., Plymouth, MN) with Finger clip sensor (Model #:8000K2, Nomin Medical, Inc., Plymouth, MN) measured the heart rate in beats per minute over a period of time. A BSL EDA Finger Electrode Xdcr (SS3LA, BIOPAC Systems, Inc.) was used with Isotonic Recording Electrode Gel (GEL101, BIOPAC Systems, Inc.) to record the change in electroconductance on the skin of the participant's first and second fingertips over time. The reading comprehension passages and test questions used were obtained from http://www.testprepreview.com/modules/reading1.htm, with each passage ranging between 4 and 7 short paragraphs, and the number of questions ranging between 5 and 7 questions per passage. In addition, three cell phones were required: one from the participant and two from the researchers.

Procedure

To prepare, three researchers were present in the room throughout the study, each with a specific role. One researcher recorded the times on the data collection graph that corresponded with each trial (start and finish) as well as the time that the distraction was presented. Another researcher recorded HRs for each trial at 0, 20, 40 and 60 seconds. The third researcher instructed the participant, timed each trial, and handed the participant reading passages and comprehension questions. Once the participant entered the room, he or she was asked to read and sign the consent form as well as indicate their cell phone number. The participant was not forced to participate in the study and had the option to stop at any point throughout the study. Before any data was collected, the participant was informed that an additional purpose of the study was to measure the effects of cell phone anxiety and was asked to place their phone on the table in front of them, as well as switch it from the silent mode to loud/vibrate if necessary. This was stated in order to diminish any suspicions regarding why we asked them to place their phone on the table. The participant was not told whether or not they would receive a phone call during the study in order to allow for a more natural response to the ringing. There were no instructions given regarding whether or not the participant could silence their phone while receiving the call, so some ignored the ringing and others silenced it. The phone rang for a period of 20 seconds across all participants in both conditions C and D. The participant was connected to the physiological measurement devices while the experimenters explained the instructions of the study. An HR monitor was placed on the dominant hand index finger and the EDA device was placed on the non-dominant hand first and second fingertips. In addition, six EOG electrodes were placed on designated areas on the participant's face: three spaced evenly on the forehead, one on each temple, and one below the right eye (Figure 1). Multiple electrodes were used to monitor various directions of eye movement. This combination of electrodes was able to detect the degree to which horizontal and vertical movement of the eyes occurred. After the participant was properly connected, we tested the data collection to ensure that each device was working correctly.

There were four trial conditions conducted during the study that varied in one component, twenty seconds into the reading. Each trial allotted one and a half minutes for the participant to complete the reading, and they were able to stop reading before the time period ended. Each trial had its own reading passage with corresponding comprehension questions, and the readings paired with each trial were constant across all participants. After each reading section, the participant handed the reading back to the researcher in exchange for the corresponding comprehension questions. The participant then had two minutes to answer the questions. The participant recorded all answers on a half sheet of paper. After the completion of the fourth trial, the participant returned the answer sheet to the researchers, was disconnected from all measurement devices, and thanked for their participation. Figure 2 denotes the overall timeline for this process.

The first trial (A) acted as the negative control and there was no distraction present at twenty seconds, so therefore it was used as a baseline for the experiment. The second trial acted as the positive control (B), in which the researcher began a conversation with the participant twenty seconds into the timed reading and finished the conversation after one minute. The questions for condition B were scripted and therefore held constant across all participants. For the third trial (C), the researcher called the participant once on their cell phone twenty seconds into the reading. If the call went was not ignored by the participant, the phone would stop ringing within about 20 seconds. Finally, during the fourth trial (D) the researcher's phone rang/vibrated on the same table as the participant for 20 seconds.

The positive control condition was conducted prior to the experimental conditions with each physiological measurement device. This was done to ensure that changes existed in the output measurements during the distracted phase compared to the non-distracted phase. This test demonstrated that the devices used could confidently detect when our participant was distracted.

Data Analysis

Data analysis was conducted using R Studio. A one-way ANOVA was utilized to examine the relationship between experimental conditions and the physiological variable being measured (EDA, EOG, HR). In order to analyze potential changes between baseline (A) and the other experimental conditions, analyzed values were calculated as a difference between baseline and each condition. Data points for EDA and EOG were selected by taking the average peak value at the time of distraction. Data points for HR were calculated as a mean of the four HR measures throughout the study. A variation of paired T-Tests were used to analyze the relationships between reading comprehension tests and the experimental condition, and these values were calculated as a difference between baseline and each condition as well.

Results

Heart Rate

The average baseline (condition A) HR was 78.77 beats per minute, with a range of 58-102 beats per minute across participants. There was no statistically significant relationship between the experimental conditions and HR ($p > 0.05$). The mean difference in HRs for condition B (0.773 +/- 5.20), condition C (-2.098 +/- 6.05), and condition D (-1.352 +/- 7.43) were found in comparison with the baseline value, condition A (Figure 3).

Electrodermal Activity

The average baseline EDA was 20.201 microsiemens, with a range of 0-85.21 microsiemens across participants. There was no significant relationship between experimental condition and skin conductance ($p > 0.05$). The average skin conductance differences for condition B (-0.286262+/-3.55), condition C (0.582+/-1.29), and condition D (0.547+/-1.84) were calculated as differences from condition A, which was used as baseline (Figure 4).

Electrooculogram

The average baseline EOG was 0.473 mV, with a range of -.216-9.99 mV across participants. There was no significant relationship between experimental condition and eye movement ($p>0.05$). The mean eye movement differences for condition B (0.005+/-2.65), condition C (-0.103+/-1.69), and condition D (-0.306+/-1.73) were calculated as differences from condition A, which was used as baseline (Figure 5).

Reading Comprehension

The average baseline reading comprehension score was 43.33% correct, with a range of 0-85.71% correct across participants. A statistically significant difference was found in reading comprehension scores between our negative control, condition A, and positive control, condition B ($p=0.0022$), with condition A displaying higher scores. No statistical significance was found between the negative control and the other experimental groups. The average percent of correctly answered questions on the reading comprehension test during conditions B, C, and D in comparison to the baseline scores from condition A were -17.142 +/- 27.92, -3.996 +/- 33.60, and -11.329 +/- 25.38 respectively (Figure 6).

Discussion

None of the hypotheses in this experiment were supported, meaning no true conclusions can be drawn regarding whether distractions elicit strong physiological responses in the context of reading comprehension based on this study alone. The significant difference in reading comprehension scores between conditions A and B displayed that the positive control was effective in the cognitive aspect of the experiment, but a possible correlation between that and physiological responses is in this study could not be determined. Although this study did not produce significant results regarding the relationship between distraction and the three physiological responses measured, it is possible future studies could find that HR, eye movement and skin conductance are in fact able to measure an internal response to a distraction.

Heart Rate

Analysis of the HR data did not produce significant results ($p > 0.05$), meaning distraction did not have an effect on HR. The study showed, though not significant, that on average HR decreased during conditions where a cell phone was utilized compared to testing conditions where cell phone use was not included. Perhaps the presence of a cell phone and the constant distractions they elicit have become commonplace and are more comforting than distracting to individuals, opposing the original hypothesis.

Electrodermal Activity

Distraction did not show significant effects on the EDA data of the participants ($p>0.05$). During analysis of the data, there were spikes in skin conductance observed on the EDA stream almost immediately after the distraction occurred, and although results were not significant, this physiological measurement responded the quickest and most consistently with the distractions, indicating that EDA was a valid physiological measurement for this experiment. A screenshot (Figure 7) of the EDA stream is included to show the typical graph seen across participants, with the peak indicated in the image occurring almost simultaneously with the distraction. Although the trend of the total study was not significant, participant 29 modeled the hypothesized trend with the highest conductance found during the positive control, the second highest while their personal phone was ringing and the lowest conductance, but still higher than the negative control, was found while an outsider's phone was ringing (Figure 8).

Electrooculogram

The EOG results found were inconclusive between all experimental conditions, meaning distraction did not directly impact eye movement ($p>0.05$). Although the results were insignificant, the peaks corresponded with the timing of the distraction indicating there was a physiological response in the participant across conditions, supporting the validity of this measurement (Figure 7).

Reading Comprehension

The lack of a significant relationship between reading comprehension scores and experimental condition ($p>0.05$) displayed that distraction did not have an effect on reading comprehension scores in this study. However, participant 13 displayed the hypothesized trend scoring the lowest percentage of questions correctly answered in the positive control and increasingly higher scores when their personal phone rang, an outsider's phone rang, and the negative control in that order (Figure 9). The results did show participants on average scored slightly lower when there was an outsider phone ringing compared to when their personal cell phone rang although the results are not significant. This trend may indicate that a person is able to ignore their phone because they assume it is not an important call, and audio and visual stimulation from an unexpected, outsider's phone that the individual is trying to identify may end up being more distracting, which opposes the original hypothesis.

Limitations

There were several limitations in this study. There were only 30 participants, and the potential of gaining significant results could have been hindered due to the small sample size. Additionally, these 30 participants were not randomly selected, decreasing external validity and potentially contributing to the lack of significance as well.

The reading comprehension task used to evaluate any relationship between distraction and physiological response overall illustrated more limitations of this study. Order effects may have been induced because the researchers did not randomly vary the sequence of the experimental conditions across participants, and the sequence of the readings themselves could have impacted the results. Also, there were very obvious floor effects in the reading comprehension questions, threatening the construct validity of the reading comprehension task since it was not possible to tell whether the low scores were impacted solely by experimental condition. Another limitation was the lack of control over the presence of cell phone notifications the participant received other than the experimental phone call required for condition C. There could have been more overall distracting notifications rather than only the phone call in any of the 4 conditions, potentially impacting the data. In addition, the cell phone reception for each participant varied based on the individual's cell phone service provider and therefore altered the reliability of condition C, as condition C did not work in some cases because the participants' phones would not ring.

There were also some difficulties with the physiological measurements themselves. Since certain participants had greater sweat responses than others, the EOG electrodes did not stick as well in some cases, decreasing the reliability of the EOG measurement since data could not be accurately corrected without perfect adherence of the electrodes to the skin. Also, this study required multiple wires to be connected to the participant at a given time, and the fact that there were electrodes connected to their face and devices covering three of their fingertips could have been a confounding distractor that was not accounted for. In addition, it is possible that some measurement changes were due to movement artifacts instead of physiological changes in the participant due to the conditions researched. Altering the methods to account for these limitations will make for a stronger future studies on the physiological effects of distraction.

Conclusions

In order to have a greater potential for gaining significant results, the experimental design would need to be altered in several parts of the experiment. The reading comprehension questions and passages would need to be more thoroughly screened by ensuring that the questions for each passage could be answered correctly in the time allotted without any distractions. In addition, more questions in each passage would enable the experimenters to more accurately distinguish comprehension across the experimental conditions. Likewise, the two experimental conditions would be randomly selected for each participant to eliminate order effects. Also, cell phone service would be screened in the space where the study is conducted with multiple service providers and the participants cell phone would be tested before the study began to ensure functionality in the space. The participants would also be asked to wait until they had stopped sweating excessively, if necessary, or excluded from participating in the study if their sweat caused the electrodes to not stick sufficiently to their face. As stated earlier, the experimental set-up may have been a distraction in itself to many of the participants, so different measurements should be used in the future to measure the physiological response to possible distraction in the participant. If the experiment is conducted in the same three conditions, it would be beneficial to include a longer acclimation period at the start of the trial so the participants could get used to the physiological measurements attached to them.

Research on technological distractions should be further investigated as technology is part of almost every aspect of daily life today. Cell phones, personal and others', are only one example of the control technology has in parts of our lives. The effect of technology in a professional setting (i.e. on their productivity, amount of time spent working, ability to get a promotion, etc.) would be useful information for the working technology user. Future studies could also implement the physiological measurement of reaction time. According to the Biopac Manual, reaction time is the delay between a stimulus and when the reaction occurs (Kremer, P-1). This relationship between distraction and reaction time could be useful in studying how distractions can impact attention span.

Research done regarding the hypothalamic-pituitary-adrenal (HPA) axis' response during a stress provides a possible explanation for the results regarding reading comprehension while a distraction was present. This research has found that acute, short term stressors can increase a person's ability to learn (Duncko et al., 2007). A distraction during a timed and graded activity, like the research conducted in this study, can elicit a stress response in a participant. The amount of stress a distraction, like a personal cell phone, causes in an individual should be studied in order to more completely relate this study with the HPA axis stress hypothesis.

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Figures

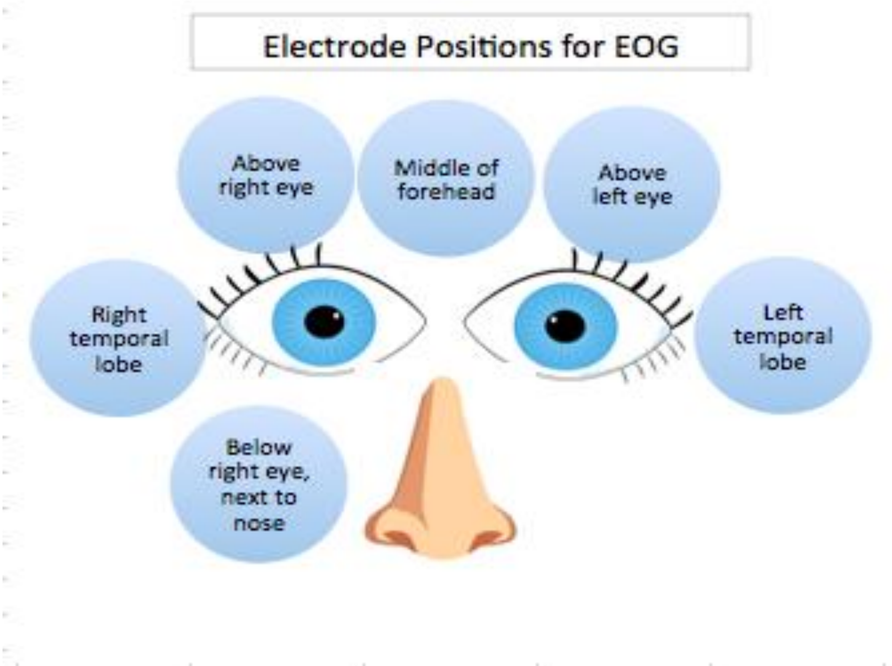

Figure 1: Electrode positions for EOG.

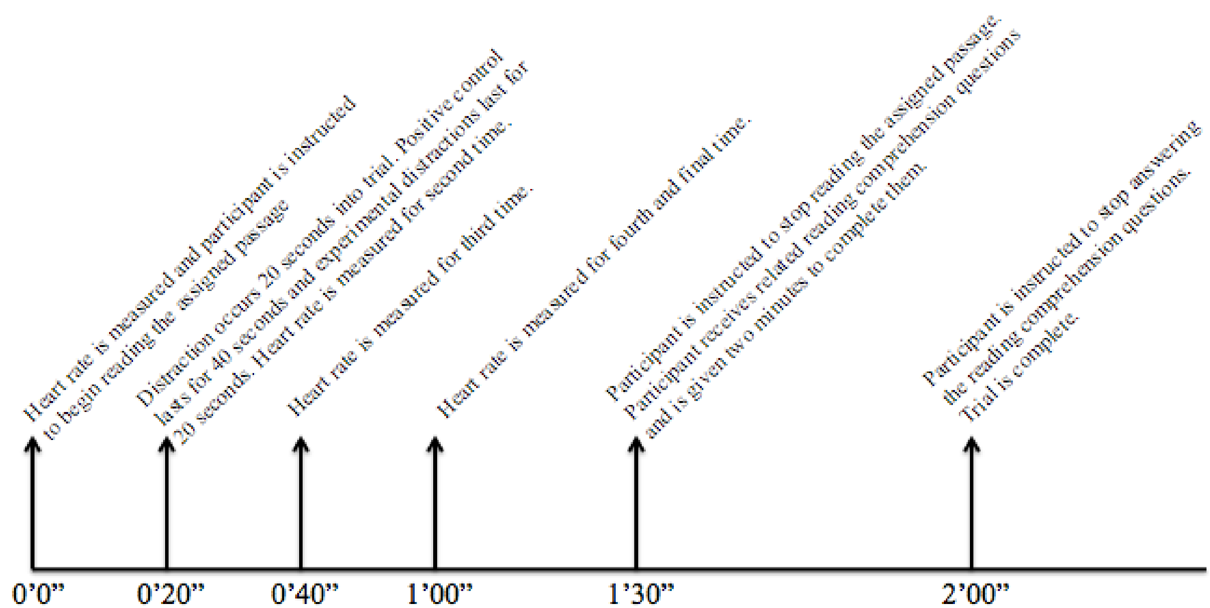

Figure 2: General timeline of events participants experience in a single trial. EOG and Electrodermal Activity are measured continuously throughout the entire experimental procedure.

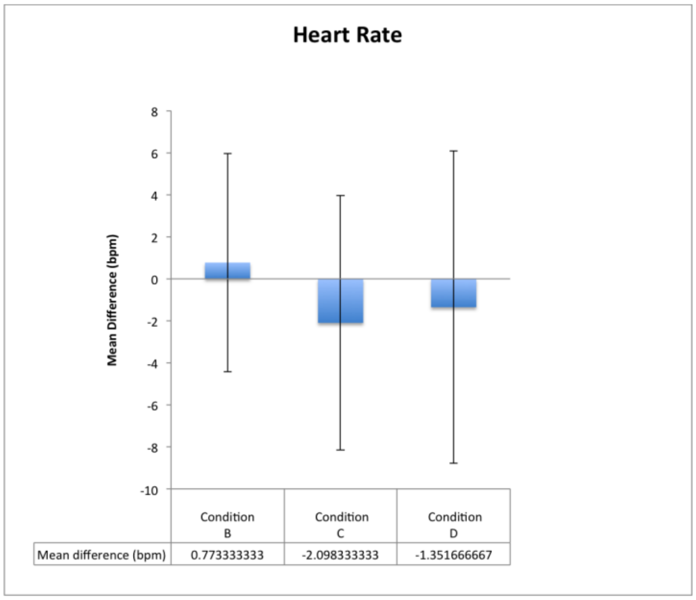

Figure 3: Mean differences from baseline (condition A) in heart rate dependent upon experimental condition, with the x-axis representing baseline determined from condition A.

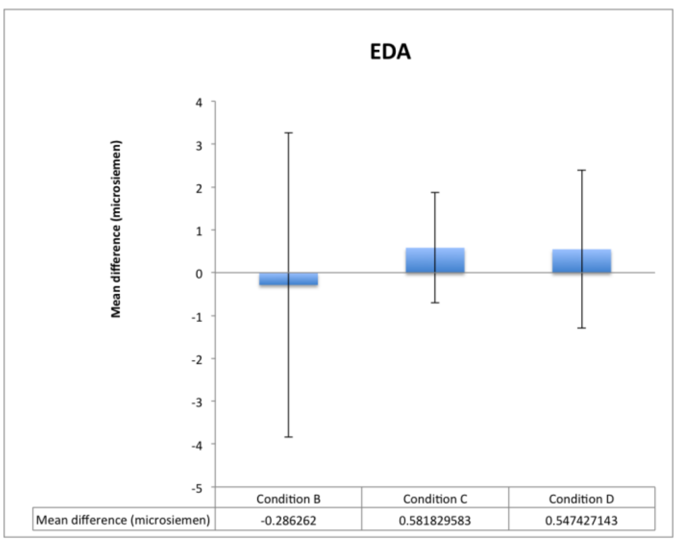

Figure 4: Mean differences from baseline (condition A) in skin conductance dependent upon experimental condition, with the x axis representing baseline determined from condition A.

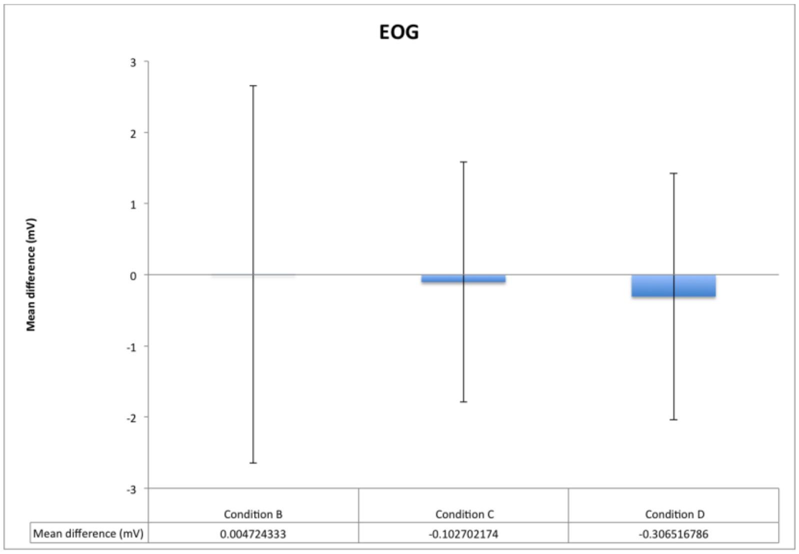

Figure 5: Mean differences from baseline (condition A) in eye movement dependent upon experimental condition, with the x axis representing as the baseline determined from condition A.

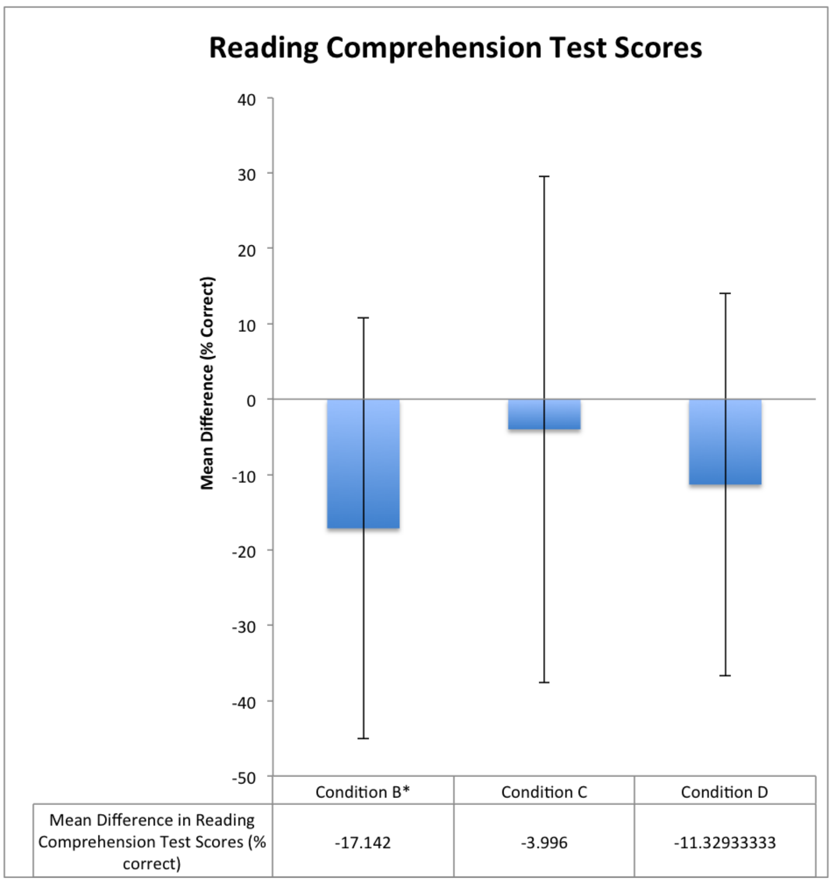

Figure 6: Mean differences from baseline (condition A) in reading comprehension test scores dependent upon experimental condition, with the x axis representing baseline determined from

condition A. The asterisk next to condition B signifies its mean is significantly different from baseline.

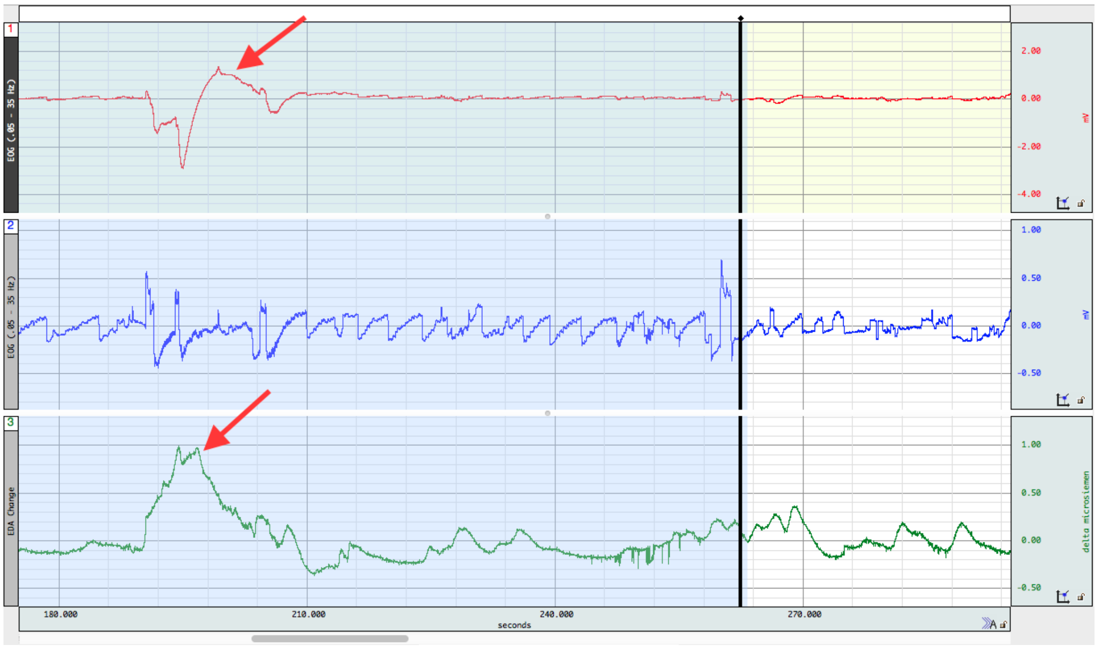

Figure 7: A screenshot of the threads viewed by experimenters. The arrows indicate the peaks that were measured as a change from the baseline initially measured in the experiment. These peaks coincided almost simultaneously indicating that they infact measured the physiological response, however the results found were not significant. The top portion of the graph refers to EOG, and the bottom portion represents EDA. For EOG, the x-axis represents time (s), and the y-axis is measured in millivolts (mV). For EDA, the x-axis represents time (s), and the y-axis measures change in microsiemens (ΔμS).

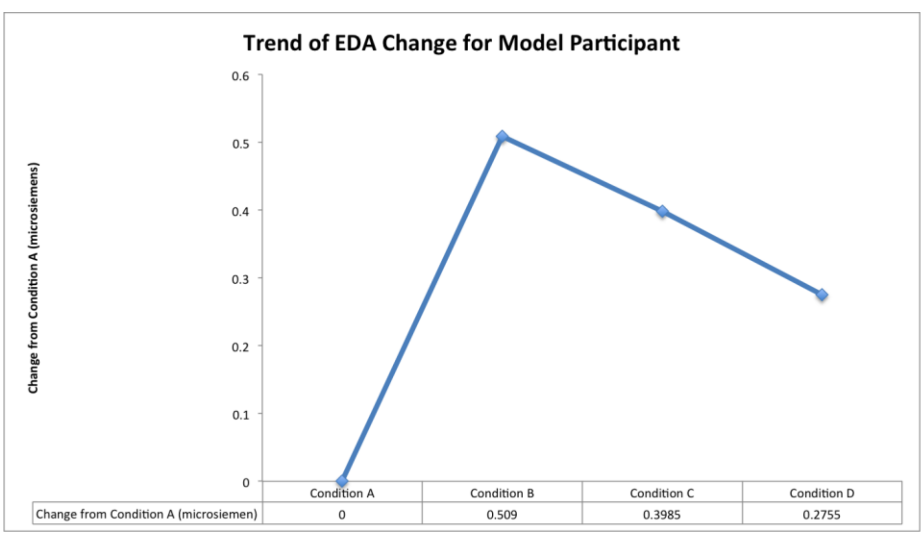

Figure 8: Representation of the hypothesized trend of the EDA change from baseline (condition A) throughout the experiment by one model participant.

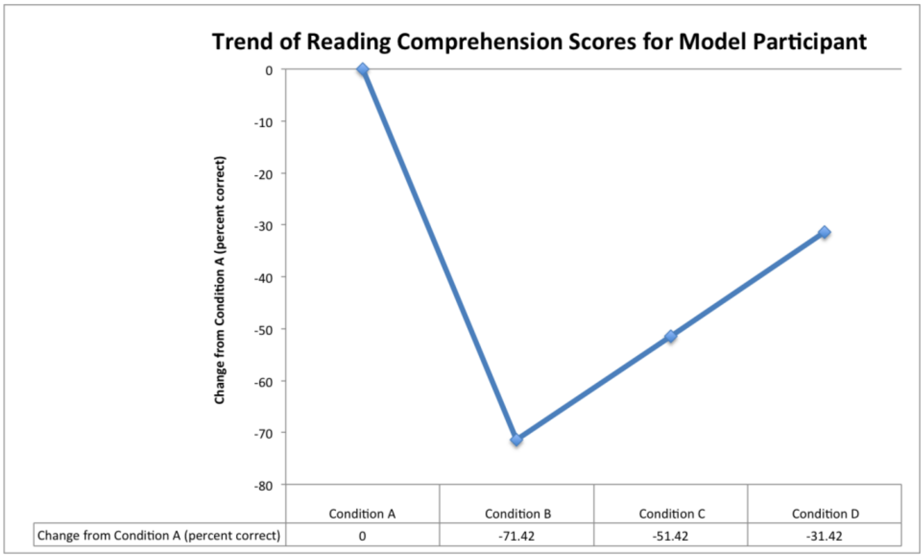

Figure 9: Representation of the hypothesized trend of the change of reading comprehension scores from baseline (condition A) throughout the experiment by one example participant.

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