The Effect of Induced Stress on Fine Motor Accuracy

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Abstract

The stress response is a cascade of physiological changes resulting from activation of the sympathetic nervous system that occurs when one is subjected to a threatening situation. The physiological changes brought about by the stress response are well documented and understood, but it is unclear whether the stress response has any adverse effects on fine motor accuracy. This experiment explores the relationship between induced stress response and motor accuracy by inducing a stress response in subjects and analyzing their performance on a tracing task before and after the stressor. We analyzed the effectiveness of the stressor by measuring heart rate and electrodermal activity, using T-tests to confirm a statistically significant increase in each after exposure to the stressor. Tracing allowed us to measure the area spent outside of the line as a determinant of fine motor accuracy. Our results did not show significant evidence that an increase in heart rate or EDA (implying an increased stress response) were linked to a decrease in fine motor accuracy.

Introduction

The term stress is defined as a range of behavioral and physiological changes that occurs in response to an event that perturbs the homeostasis of an organism (Kim & Diamond, 2002). These physiological changes are carried out by a well-orchestrated release of stress hormones, and are widespread and nearly instantaneous throughout the body. Such physiological changes include, but are not limited to, increased heart rate, increased glandular activity, increased blood glucose availability to the brain and muscles, increased rate of respiration and decreased digestion (Raff & Levitzky, 2011). These common physiological changes have been coined the "fight or flight" response because they evolved as a survival mechanism allowing an organism to fight or flee a life-threatening situation. Unfortunately the body commonly induces the stress response in situations that are not life threatening, such as traffic jams or high-pressure tasks, and the previously life-saving physiological energy boost may result in decreased physical and cognitive ability (Mayer et al., 2002).

The stress response is a well-understood physiological process that is controlled by the activation of the sympathetic nervous system, a subdivision of the autonomic nervous system. A stressful stimulus is perceived by the sensory receptors of the eyes and ears and immediately sent to the relay center for auditory and visual input, the midbrain. From the midbrain the signal travels to the thalamus, and is then sent in two directions: to the areas of higher visual and auditory association in the cerebral cortex, and to the amygdala (Harvard, 2011). The amygdala is a small area of the brain that contributes to emotional processing. When a threatening signal reaches the amygdala, a distress signal propagates to the

hypothalamus (Fallon, 1992). The hypothalamus is often thought of as the homeostatic control center of the brain, as it regulates many of the visceral functions in the body. In the stress response, the hypothalamus sends signals through the sympathetic nervous system to the adrenal gland, specifically the adrenal medulla, which results in the release of epinephrine. As epinephrine circulates through the body, it brings about the physiological changes previously described (Joles & Baram, 2009). Previous research suggests that the neurotransmitters and hormones released during the stress response can potentially alter the function of the spinal circuits underlying motor performance, indicating that elevated neuroendocrine activity during heightened stress arousal may be a factor that can alter motor output (Noteboom et. al, 2001).

Our experiment aimed to investigate the relationship between an induced stress response and fine motor accuracy. We hypothesized that an increased stress response would result in decreased motor accuracy. To test this hypothesis, we instructed subjects to perform a tracing task in the presence or absence of a stressor. Tracing is a task that allowed us to measure the subject's accuracy by measuring the total area traced outside of the line. To ensure that subjects showed adequate amounts of stress response, we measured heart rate and electrodermal activity (EDA), a measure of electrical properties of the skin measured by sweat secretion. We conducted a T-test to confirm a significant increase in stress response after exposure to our stressor. We expected that the group exposed to the stressor would exhibit increased heart rate and skin conductance compared to the control group, indicating a heightened stress response. In our experiment, subjects initially performed a baseline trace. Then, half of the subjects were exposed to our stressor while the other half were not, and a subsequent tracing task followed. We then compared the individual's baseline and post condition tracing accuracy. From this, we analyzed: 1) if the individual showed an induced stress response, and 2) how the individuals tracing performance differed before and after the condition.

Materials

The physiological measurements taken required the following devices: a digital pulse oximeter from Nonin Medical Inc. (Model 9843) to measure heart rate with a finger sensor (placed on ring finger of non-dominate hand); BSL EDA Finger Electrode from BIOPAC Systems, Inc. (SS3LA) with Isotonic Recording Electrode Gel to measure EDA (placed on middle and first fingers of non-dominant hand). BIOPAC Student Lab 4.0 was used with BIOPAC MP36 to record EDA data on PC Windows 7 hardware.

A 15'' MacBook Pro was used to view the control video or play the experimental game. An optional wireless mouse was presented to subjects for use during the experimental game. Apple ear buds were used in both conditions with a volume set to 50%.

Two 8.5'' x 5.5'' sheets of paper with a printed dog outline were traced per participant. The participants traced these figures with a red pen. ImageJ software was utilized to measure the area in between the outer edge of the black line and the outer edge of the red pen.

Methods

Subjects

Participants included 29 physiology 435 students, ages 19 to 23. 10 were male and 19 female; all right- hand dominant.

Baseline Physiological Measures and First Motor Accuracy Test

Upon arrival, the pulse oximeter was placed on the ring finger, while the EDA was placed on the first and middle fingers of the non- dominant hand in order to measure heart rate and electrodermal activity respectively. After one minute, baseline measurements for heart rate and EDA were documented. Subjects were then given a black outline of a dog on a white piece of paper (Figure 1), a red pen, and told to trace the figure as quickly and accurately as possible using their dominant hand. This constituted the baseline trace for each participant.

Figure 1: This figure shows the dog outline that our subjects trace during baseline and post-stressor conditions

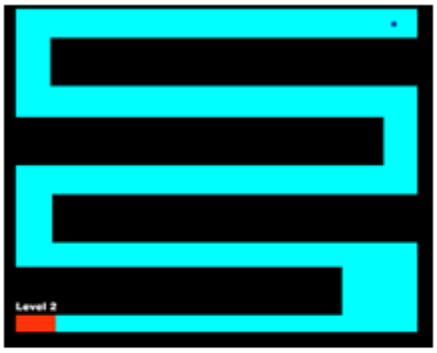

Figure 2: This shows the game that we use as our stressor – at the end of the 4th level, there is a surprise scary face and loud scream

Stressor and Control Conditions

After baseline measurements, subjects were instructed to insert ear buds. The "experimental" group played the online Exorcist Scary Maze Game (Figure 2). In this game, participants had to guide a blue square, via computer mouse, to the end of a maze without touching the maze walls. The game consisted of four levels. Before reaching the end of the fourth level, a scary face with a screaming sound appeared on the computer screen. This constituted our stressor. The "control" group watched a one-minute video of an aquatic scene, with sound. For both subject groups, the EDA data was collected continuously, allowing us to calculate experimental EDA maximums after the stressor. The heart rate value immediately after the completion of the game or control video was used as experimental heart rate.

Second Motor Accuracy Test

Immediately after playing the game or watching the video, subjects traced a second outline of the same dog as the baseline. This time, the figure was inverted in an attempt to limit muscle memory effects from repetition of the task. The images were scanned, and then ImageJ was then used to measure the total area from the outside of the black line to the outside edge of the red pen. We then compared the area spent outside the line between an individual's baseline and post condition trace. A timeline of our experiment is shown in Figure 3.

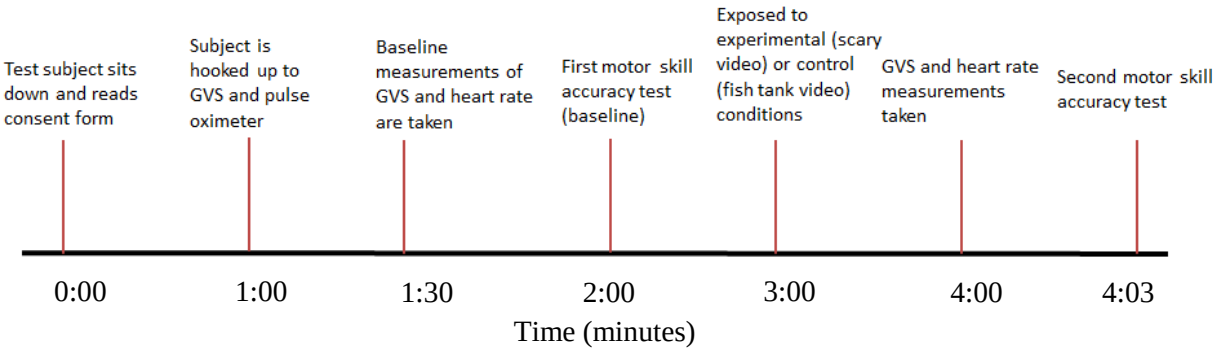

Figure 3 shows a timeline of our experiment. Time is shown in minutes and seconds. GVS refers to EDA.

Results

We first wanted to confirm the effectiveness of our stressor at inducing a stress response as measured by change in heart rate and electrodermal activity. Average heart rate was measured before treatment and immediately after treatment. Average baseline heart rate, which was measured before exposure to any conditions, was 76.48 beats per minute (bpm). Average baseline of the control group was 73.1± 8.5, while average baseline of the experimental group was 79.5± 16.4. After the control condition, average heart rate was 73.8± 8.3 bpm. After experimental conditions, heart rate significantly increased with an average of 101± 22.1 bpm. The increase in heart rate after treatment for the experimental group was significantly larger, increasing by an average 21.5 bpm, as compared to our control group, which increased by 0.7 bpm after treatment (p-value = 0.0002657). A density plot shows distribution of heart rate difference. The dashed line, our control group, displays a high peak around 0, signifying there was not much difference in heart rate before and after control conditions. The solid line shows a positive shift to the right, signifying a larger difference in heart rate after experimental conditions.

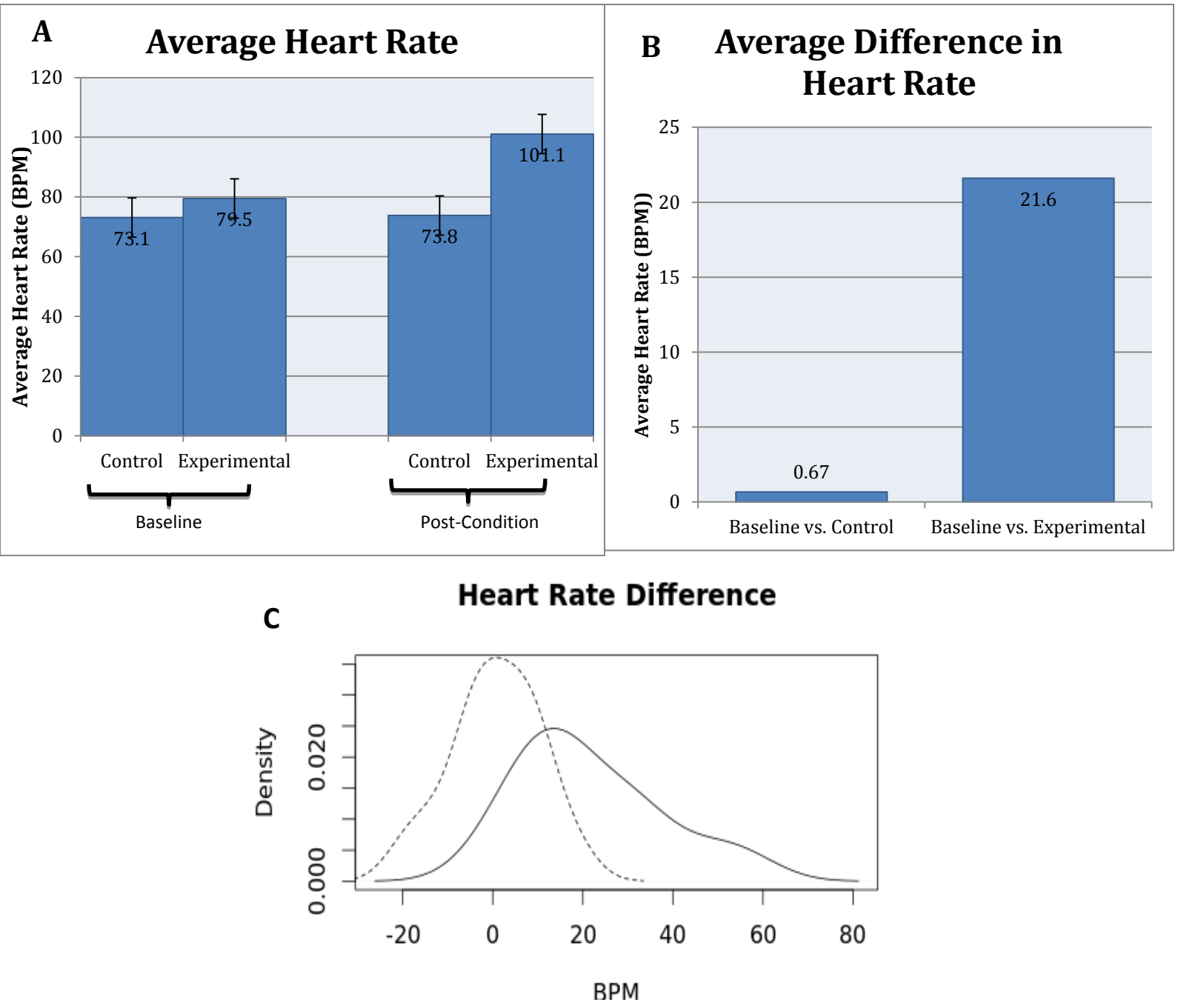

Figure 4: Three graphs showing results of heart rate are shown. Graph 4a shows average heart rate of baseline (76.48), control (73.1±8.5), and experimental (79.5±16.4). Baseline measurements were taken on all participants before participant was exposed to control or experimental conditions. The post-condition measurement was taken on control participants immediately following watching the aquatic scene and on experimental participants immediately following the scary video. Graph 4b shows the average difference in heart rate in control (2.69), and experimental participants (24.52), as compared to baseline. Values were calculated by subtracting baseline heart rate from the heart rate measured immediately after viewing aquatic scene or scary video. Graph 4c shows difference in heart rate in bpm (beats per minute) before and after treatment. Distribution of difference is plotted. Dashed line signifies control group and solid line signifies experimental group. The curve for our control group around 0 bpm displays a smaller increase in heart rate, whereas the right-shifted curve for our experimental group shows a larger and significant increase in heart rate. The Y-axis signifies density, which shows distribution of heart rate difference. A higher peak shows a higher density or a higher amount of participants.

EDA was the second measurement taken to ensure sufficient stress response. Baseline measurements were taken before exposure to any conditions. Control measurements were taken after exposure to the aquatic scene and experimental measurements were taken after exposure to the scary video. The difference in EDA was calculated by subtracting baseline measurements from the control or experimental measurements. Average control baseline measurement of EDA was 13.9± 5.6 microSiemens, while average experimental baseline is 12.4± 3.7 microSiemens. After control conditions, average EDA was 14.7± 5.0 microSiemens and after experimental conditions average EDA was 15.5± 3.5 microSiemens. The difference in the experimental group is significantly higher, increasing by a value of 3.19 microSiemens, as compared to our control group, which increased by a value of 0.77 microSiemens (p-value = 0.00027). A density plot shows the distribution of EDA difference in our participants. The dashed line signifies our control group, which shows high density around zero, meaning there was not much difference. The solid line signifies our control group which displays a positive shift to the right, displaying a larger EDA difference.

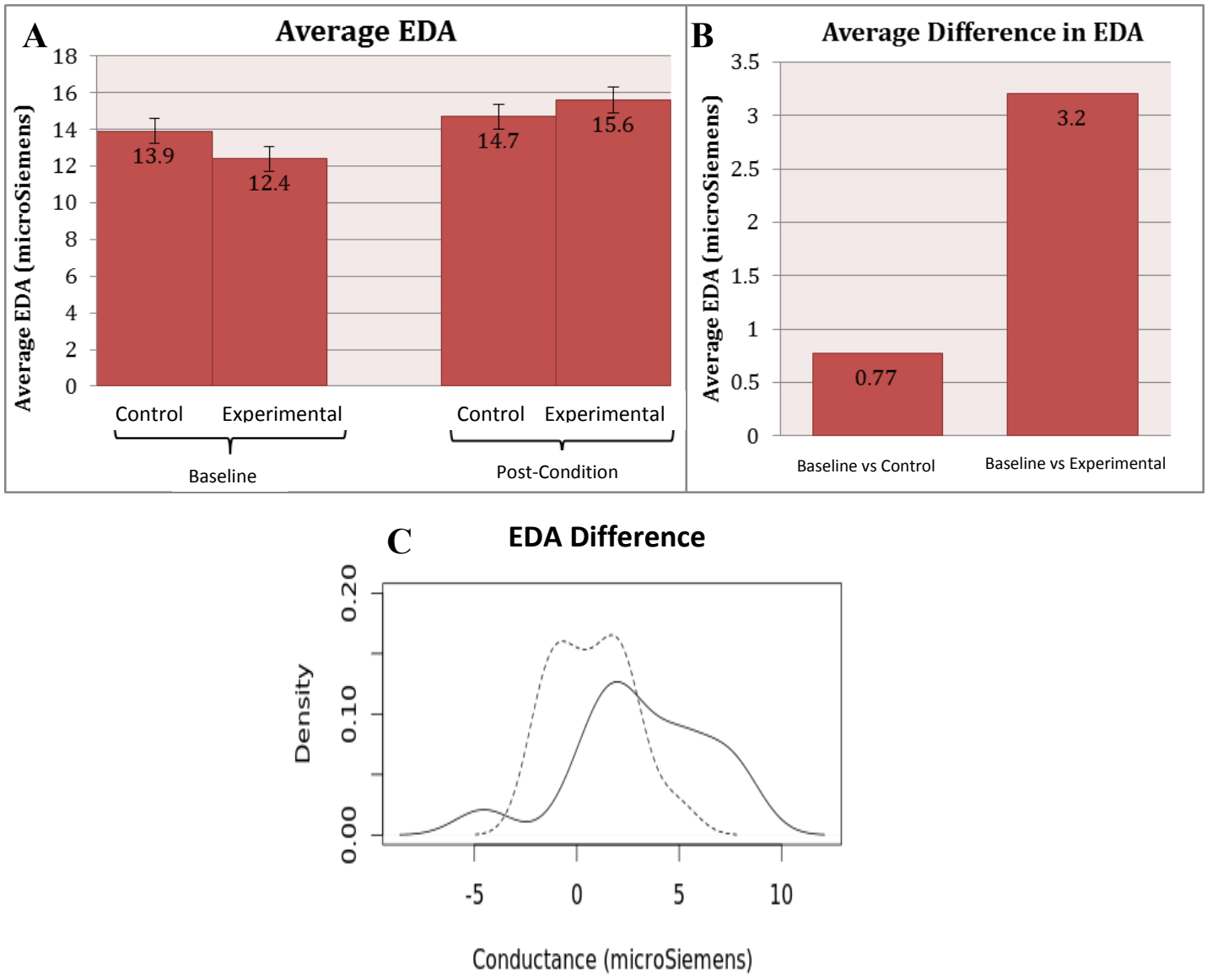

Figure 5: Three graphs showing results of electrodermal activity measured in microSiemens are shown. Graph 5a shows average electrodermal activity of baseline control (13.6± 5.6), and baseline experimental (15.5± 3.7). Baseline measurements were taken on all participants before participant was exposed to control or experimental conditions. Post-condition measurements were taken on control participants immediately following watching the aquatic scene and on experimental participants immediately following scary video. Graph 5b shows the average difference in electrodermal activity in control (0.4), and experimental participants (2.3), as compared to baseline. Values were calculated by subtracting baseline electrodermal activity from the electrodermal activity measured immediately after viewing aquatic scene or scary video. Graph 5c shows difference in electrodermal activity before and after treatment. Distribution of difference is plotted. Dashed line signifies control group and solid line signifies experimental group. The curve for our control group around 0 bpm displays a smaller increase in electrodermal activity, whereas the right-shifted curve for our experimental group shows a larger and significant increase in heart rate. The Y-axis signifies density, which shows distribution of electrodermal activity difference. A higher peak shows a higher density or a higher amount of participants.

Finally, we analyzed the effect of induced stress on fine motor accuracy by quantifying the area (in cm^2) spent outside of the line. We performed T-tests to compare the average area spent outside of the line between control and experimental groups. There was no statistically significant change in motor accuracy (p-value=0.1253). Both groups improved on tracing their second time, but on average the control group improved more than the experimental group. After treatment, the control group decreased their time spent outside of the line by 0.49 cm^2, while the experimental group decreased their time spent outside of the line by 0.11 cm^2 (Figure 6).

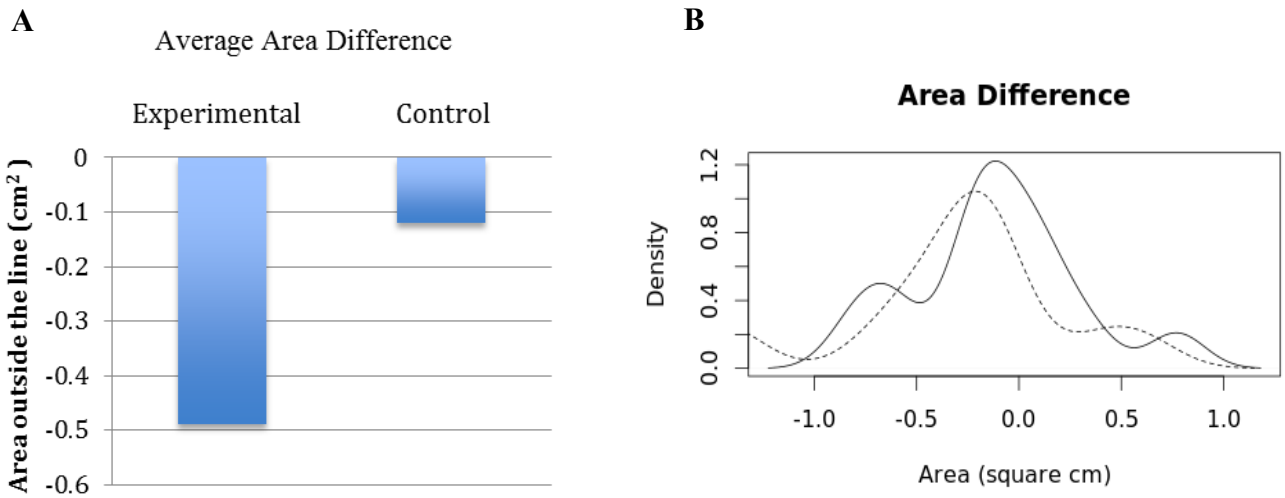

Figure 6: Graph 6a shows the average differences in area outside the line between baseline and post-conditions. Both groups improved, so the differences are negative. The control group decreased area spent outside the line by 0.49 cm^2. The experimental group decreased area spent outside the line by only 0.11cm^2. Graph 6b shows difference in motor accuracy before and after treatment. Distribution of difference is plotted. Dashed line signifies control group and solid line signifies experimental group. Motor accuracy is measured by area outside of the drawing in cm^2. Both curves are similar in size and magnitude and are mostly on the negative side of the graph, which signifies an increase in motor accuracy. The Y-axis signifies density, which shows distribution of area difference. A higher peak shows a higher density or a higher amount of participants.

Discussion

Based on our results, we reject our hypothesis that an increased stress response decreases fine motor accuracy. We successfully induced stress in the experimental group compared to the control group, as shown by the increased heart rate and EDA, yet the majority of subjects in both groups improved their motor accuracy on the second trace. However, it is important to note that the experimental group showed less improvement than the control group. These results may suggest that, since the control group improved their accuracy on the second test, it is expected that all subjects would perform better on their second test. Because the experimental group improved their accuracy less than the control group, this difference could be due to a decrease in motor accuracy caused by the increased stress response. However, it was not statistically significant ($p = 0.12$) that this stressor directly decreased motor accuracy. Depicted in Figure 7 is a picture of a drawing before and after exposure to control conditions and experimental conditions. It is possible to see how both participants improved yet the control participant improved more.

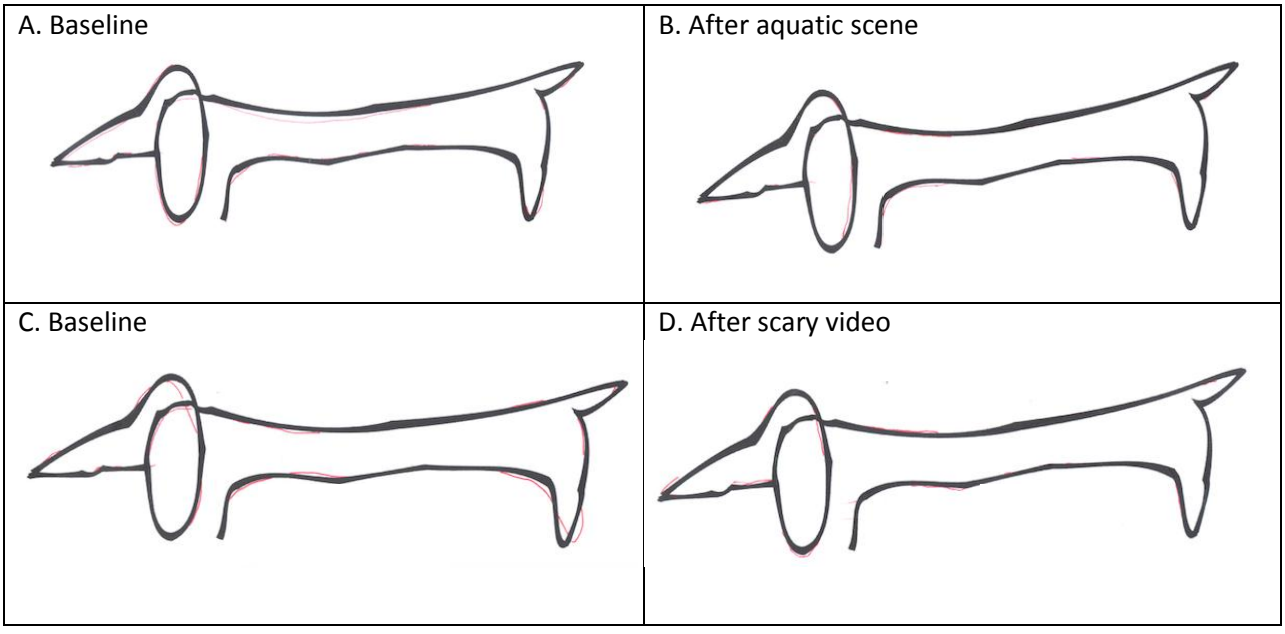

Figure 7. Figure shows baseline and subsequent drawings. Figure 7a shows baseline drawing and 7b shows the same participant's drawing but after exposure to control conditions, the aquatic scene. Figure 7c shows baseline drawing and 7d shows the same participant's drawing after exposure to the scary video. Both participants improve the second time due to what we believe is practicing the tracing, yet the participants exposed to control conditions improves more than the participants exposed to experimental conditions.

The lack of significant results may be attributed to potential flaws in our experiment. One of the main problems with our experiment is that the repetition of tracing likely led to an improvement from the first trace. Many college students do not regularly trace figures. Therefore, the novelty of tracing during the baseline measurement likely served as practice, resulting in the second trace being more accurate. We attempted to eliminate this problem by inverting the second figure in order eliminate potential muscle/visual memory without changing the figure itself. Future experiments may consider eliminating the baseline trace. Excluding the baseline trace would eliminate the apparent practice effects in our study and may result in the experimental group having significantly less motor accuracy.

One other primary flaw is subjecting the experimental group to a computer game involving hand movement, while the control group experienced only the visual and auditory aspects of a video. The continuous movement of the dominant hand in the experimental condition may have contributed to the improvement in the second trace. We chose to use the computer game because we were unable to find a video that induced enough stress. However, future experiments should better equate the sensory aspects of the conditions.

Another variable we should have controlled was the amount of time given for the subjects to trace the figures. We told the subjects to trace each dog "as quickly and accurately as possible", but the time varied between subjects, and this may have influenced the results. Specifically, a slower tracing speed, especially on the second figure, may have contributed to the general improvement seen among groups. Future experiments should set a time limit for the tracing.

Small sample size is also a contributing flaw. Our results show that there is possibly a correlation between induced stress and motor accuracy, but a larger sample size is needed to achieve significant results. Increasing the sample size would greatly increase the validity of our study as well.

Stress and motor ability is a topic that has been researched for years; however much of the existing literature on this topic discusses the effect of arousal on motor performance. Arousal encompasses stress, anxiety, and their interaction. The inverted- U hypothesis is largely associated, and it suggests that as arousal increases, performance improves up to a certain point, and then declines as arousal becomes overwhelming (Courts, 1942). Optimal performance typically occurs at a moderate level of arousal. However, individual personality differences can create ambiguous results, and the inverted-U hypothesis is not universal (Martens & Landers, 1970). Since our experiment only focuses on the stress aspect of arousal, the inclusion of anxiety in future studies may be a useful to better understand how motor accuracy is affected. More research on the influence of stress and anxiety on motor performance should be conducted to discriminate prominent individual factors and their effects.

In conclusion, the data disputes our hypothesis. However, future experiments, conducted in a manner where the above errors are eliminated, may provide evidence that stress alone decreases motor accuracy. A further understanding of how stress affects our daily lives, specifically our motor skill accuracy, may lead to deeper comprehension of stress and how to deal with it effectively.

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