THE PHYSIOLOGICAL EFFECTS OF ROSEMARY ON CONCENTRATION

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ABSTRACT

The use of essential oils has recently been gaining in popularity due its inexpensive costs and the research-based claims that they have the ability to cause beneficial physiological and cognitive effects on their users. It has been proposed that exposure to essential oils can alter one's physical state and improve cognitive ability. This study examines the physiological and cognitive effects that may arise from the use of one of the most popular essential oils: *Rosmarinus officinalis* L., or more commonly known as rosemary. Previous research holds that exposure to rosemary may cause increased sympathetic nervous system activity. It has also been demonstrated that increased physiological activity leads to increased cognition. These seemingly unrelated studies led to the hypothesis that rosemary will produce an increase in sympathetic activity and ultimately yield an increase in concentration. An experiment was conducted on the students of the University of Wisconsin-Madison. The participants were exposed to water or rosemary while taking a concentration test. Their heart rate, skin conductance, and respiratory rate were recorded. The results of our experiment were statistically insignificant, and did not support findings described in previous studies.

INTRODUCTION

Essential oils have had a staggering increase in popularity in recent years. This increase in reputation is, in large part, due to the prevalent claims given by researchers, physicians, and popular media that essential oils have the ability to alter one's mood, cognitive ability, or even physical well being. These assertions, in addition to the inexpensive, safe, and easy nature of the oils, have led to an overwhelming increase in acceptance of aromatherapy in modern day culture (McCaffrey, Thomas, & Kinzelman, 2009). Despite the recent increase in status, aromatherapy is not a new concept, but has in fact been widely accepted for thousands of years (Moss, Cook, Wesnes, & Duckett, 2003). With media becoming more influential on popular culture in recent years, an increasing demand for empirical evidence of the effects of aromatherapy on one's well-being has developed.

Rosmarinus officinalis L., more commonly known as rosemary, is a popular scent used in aromatherapy. Rosemary has been said to provide many physiological changes including physical transformations, such as hair growth and acne production (Sayorwan et al., 2013). More interestingly, the scent has been shown to produce cognitive changes, such as improvement in memory and enhanced arousal (Sayorwan et al., 2013 and Moss et al., 2003). Research on this effect in both animal and human trials has shown successful results. Moss et al. (2003) studied the effect of rosemary oil on mood and memory through the completion of a computerized cognitive assessment battery in a cubicle filled with the aroma. This experiment yielded impressive results, showing that rosemary enhanced performance on overall memory compared to controls and other aromas. Moss et al. (2003) also found that participants exposed to rosemary were more accurate in their assessments. Surprisingly, however, these participants did not have higher test scores compared to the control group, yet self-reported a more alert and content state, according to a subjective assessment (Moss et al., 2003). Despite the overwhelming evidence of the impacts of rosemary oil on cognitive processes, Moss failed to identify possible contributing physiological factors to this phenomenon.

Due to rosemary oil's reputation for providing stimulatory cognitive effects, Sayorwan et al. (2013) chose to examine the effects of the aroma on the human nervous system. The study gathered brain electrical activity via EEG signals, physiological measures, including heart rate, blood pressure, respiratory rate, and subjective moods of the participants. It was observed that heart rate, blood pressure, and respiratory rate significantly increased when exposed to rosemary (Sayorwan et al., 2013). Participants rated themselves as more refreshed, energetic, and alert after inhaling the aroma (Sayorwan et al., 2013). The inclusion of the brain electrical activity parameter also produced fascinating results. EEG signals displayed a decrease in alpha wave activity and an increase in beta wave activity in the frontal cortex. This type of brainwave activity is characteristic of a state of high arousal and alertness (Sayorwan et al., 2013). Overall, a significant stimulation of the sympathetic nervous system was observed when participants were exposed to rosemary oil, resulting in signs of both objective and subjective arousal.

Heightened autonomic nervous system activity and arousal have been linked to performance on mental skill tasks (Lackner et al., 2010). This includes tasks of concentration, attention, arithmetic skill, and memory. Lackner et al. (2010) studied the physiological effects of stressful mental tasks. This included The Cancellation Test of Attention and Concentration (d2-Test; Brickenkamp, 1962, as cited in Lackner et al., 2010), which requires participants to quickly and accurately identify certain characters in a sequence. This study displayed a consistent and significant increase in autonomic nervous system variables, such as heart rate, cardiac output, blood pressure, respiratory rate and skin conductance, during concentration tasks (Lackner et al., 2010). Another study, performed by Alan Beck (2013), examined heart rate during a balance concentration task and found similar heightened cardiorespiratory activity during completion of sustained attention tasks. Overall, tasks requiring increased concentration reliably produce an increase in sympathetic nervous system activity.

Popular media in recent years has shown increasing excitement for the cognitive effects of aromatherapy, including claims that rosemary oil has the ability to increase one's concentration. These statements have led to the overwhelming increase of essential oils being purchased for mental stress relief. In fact, a recent study has shown that nursing students felt less anxious and more focused on exams after inhaling the aroma (McCaffrey, Thomas, & Kinzelman, 2009). Despite the previously mentioned research of rosemary on physiological effects and concentration on nervous system activity separately, research is limited on the combination of the variables. The current study, therefore, is aimed at understanding the physiological effects of rosemary on concentration tasks. Based on previous research, it is predicted that rosemary will yield higher sympathetic nervous system activity, thus having a positive effect on concentration due to the heightened physiological state prior to completing a concentration task. This study will examine these effects by exposing participants to rosemary oil, recording their heart rate, respiratory rate, and skin conductance at baseline and after inhalation, as well as while completing a concentration task. We expect that the participants exposed to rosemary oil will have increased accuracy on concentration tasks secondary to the heightened cardiorespiratory activity prior to completing the task.

MATERIAL AND METHODS

Thirty five students, from the University of Wisconsin-Madison participated in this study: nineteen control subjects and sixteen experimental subjects. The participants were between twenty one and twenty two years of age and of both genders (23 females and 12 males), none of whom were aware of which experimental group they were a part of. Students who were congested, sensitive/allergic to the smell of rosemary, and/or dyslexic were excluded from this study.

In order to ensure that a change could be detected with the physiological equipment chosen, a positive control was obtained. With research group members as participants, a baseline heart rate, respiratory rate and skin conductance was taken for ninety seconds. Next, after running stairs for one minute, measurements were taken again for ninety seconds. When comparing the average results of each physiological components between the two measurement sets, a difference was found. The averages of heart rate, respiratory rate and skin conductance after exercise were all greater than the baseline averages. This result proved that, during the real experimental trials, the data recorded would portray a difference that could be analyzed for significance.

After students gave consent to participate in the study, they were briefed about what would be happening during the study (Diagram 1). They were then instructed to put the respiratory belt tight around their diaphragm, while a member of the research group put two skin conductance electrodes on the pointer and middle finger of the participant’s non-dominant hand, along with a pulse oximeter clip on the thumb of the same hand. Once all physiological measurement equipment was set up, each student was instructed to breath deeply, while a cup filled with liquid was held in front of their nose for ten seconds, and then to continue breathing normally for eighty seconds, after the cup was set down on the table in front of them. The liquid in the cup was different depending on which group the participant was a part of. For the control group, the cup was filled with water, while one part rosemary essential oil and one part water filled the cup for the experimental group. During the ninety second time period of taking in the scent and then breathing normally, pulse, respiratory rate and skin conductance were measured as baseline for the participant. A snapshot of a participant's respiratory and skin conductance data collected over a ninety second interval is displayed in Figure 1. Both respiratory rate and skin conductance were recorded continuously through BIOPAC, while heart rate was manually recorded every ten seconds by a research group member.

The next part of the study was explained to the student, after the baseline measurement was completed. When the student was told to do so, they flipped over the concentration test given to them upside down and then had ninety seconds to complete it by crossing out all of the letter "b's" they could find. During this ninety second interval, pulse, respiratory rate and skin conductance were measured again. The cup filled with rosemary or water remained on the desk next to the student during the entire period. Once the allotted time was over, the student was told to stop and the test was taken away to be scored by a research group member. The equipment was taken off of the participant, they were given a short survey to answer and then were free to go. The four question multiple choice survey asked participants of their reaction to the aroma they were exposed to and of their knowledge and experience with essential oils (Appendix I). Rosemary and control studies were conducted on separate days to avoid possible rosemary aroma in the room during a control study.

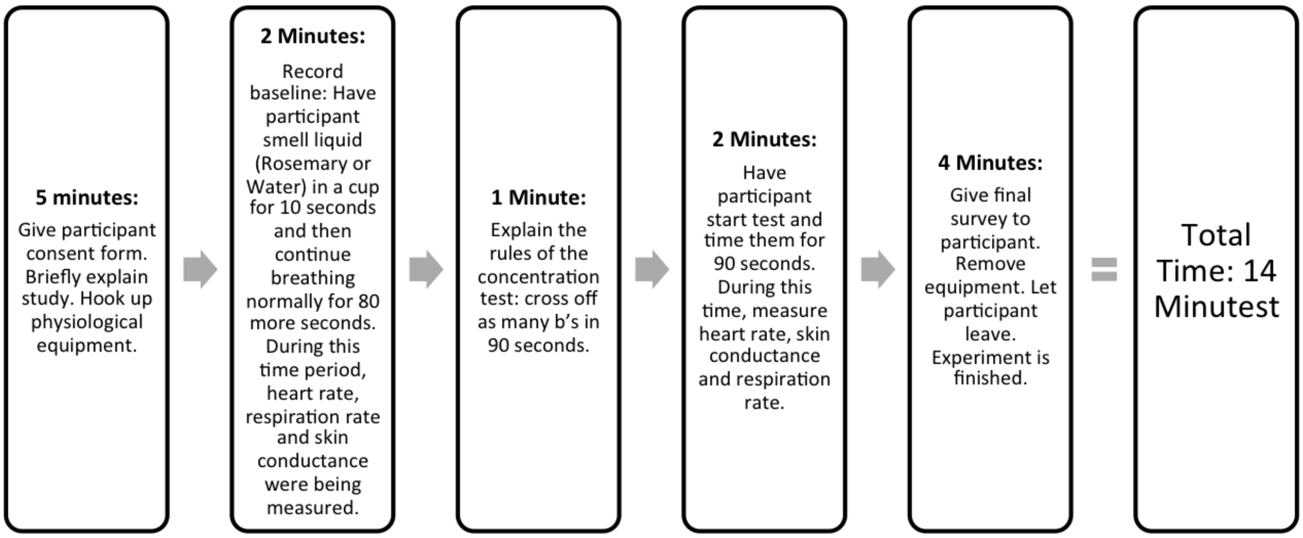
To analyze the physiological measurements taken, the two data sets taken from each student will be averaged separately, as baseline and test. Respiratory rate will be recorded as breaths per minute (BPM), which will be found by averaging the BPM at thirty, sixty and ninety seconds. Heart rate will be calculated by averaging the nine pulses recorded during one ninety second period. Lastly, the full ninety second measurement of skin conductance will be averaged.

Averaged data from all participants will then be compiled into two subgroups within both the control and experimental group: baseline and test. This data will be used to find the average difference between baseline and test for control and experimental groups. Statistical analysis will then be performed to decide if there is significant difference between both baseline and test for the separate groups and between the overall difference of each group.

For the concentration test, a student loses one point for missing a “b” and one point for crossing out a wrong letter. The score will then be found by subtracting the number incorrect from the total possible correct in the quantity of the sequence the participant finished in ninety seconds. A higher score correlates to greater concentration. The achieved scores will be compiled and averaged for the control and experimental groups. The average values will be analyzed for a significant difference in concentration.

Heart rate was measured by a Nonin Medical Inc Pulse Oximeter (Model 8000AA, 1 Meter Finger Clip Sensor, SN:119619502, Plymouth, MN). To manually record the pulse of the student every 10 seconds, an iPhone 6 timer was used. The other two physiological measurements were recorded using a BIOPAC System (MP36E1204002784, BIOPAC Systems, Inc, Golenta, California) that was hooked up to a Windows 7 system computer. The BSL Respiratory Effort Xdcr (BIOPAC Systems, Inc, Golenta, California) included the respiration belt (SS5LB, SN: 1602007568) to put around the chest to measure respiratory rate. The BSL EDA Finger Electrode Xdcr (BIOPAC Systems, Inc, Golenta, California) came with two skin conductance electrodes (SS3LA EDA, SN: 12123844), to strap around the pointer and middle finger of the same hand, and Isotonic Recording Electrode Gel (GEL101), to put generously on the pad of each finger before attaching the electrodes. A small cup was needed to hold the water or rosemary essential oil (100% pure *Rosmarinus officinalis*, NOW Foods, Bloomingdale, IL) for each study. The concentration test was composed of a randomized sequence of the letters b, d and p in a 1:3:4 ratio for a total of 700 letters. The sequencer was generated by Dave Reed, an Associate Professor of Computer Science at Creighton University (http://www.dave-reed.com/Nifty/randSeq.html).

Diagram 1: Timeline of Experimental Procedure



RESULTS

A statistical analysis was performed on the data acquired and no statistically significant values were obtained. The tests used to measure concentration were scored and a Welch Two Sample T-Test was completed to find evidence of an effect of rosemary treatment on test scores. In comparing the average test scores of the control and treatment groups, 38.947 and 38.313 respectively (Figure 2), no significant difference was found ($p=0.658$).

Skin conductance, measured in microsiemens, appeared to have a slight negative relationship to test scores, with a calculated slope of -0.197 (Figure 3). However, this analysis only produced a R-squared value of 0.0368. The average skin conductance was also measured against treatment group, which displayed a slightly lower average value at baseline for experimental compared to control, 6.208 and 8.245 respectively (Figure 4). The test condition showed only a marginal difference between the groups. A Welch Two Sample T-Test showed the effect of treatment on skin conduction to be insignificant (p=0.0635), although revealing a possible trend for inhalation of rosemary to lower skin conductance.

Heart rate was measured in beats per minute, which was averaged throughout the study and plotted against test scores. No relationship was reported, with a slope of -0.0431 and a R-squared value of 0.00438 (Figure 5). When comparing treatment groups, heart rate was, on average, lower in the experimental group compared to the control group at both baseline and test conditions (Figure 6). The Welch Two Sample T-Test showed this difference to be insignificant (p=0.252).

Respiration rate, in breaths per minute, was also measured throughout the study and the averages of the participants were plotted against test scores to determine a possible relationship. A modest positive relationship was seen between these two variables with a slope of 0.613 and a R-squared value of 0.0527 (Figure 7). Average respiration rate was also graphed against experimental condition, with the experimental group having a tendency toward lower average rates at both baseline and test condition (Figure 8). A Welch Two Sample T-Test showed the relationship of treatment on respiratory rate to be insignificant (p=0.0622).

A short survey following the study asked participants to describe their impressions of the scent as: pleasant, unpleasant, or neither (Figure 9). Thirteen of the participants from the aroma treatment group and three participants from the control group found the smell pleasant. Only one participant from each group labeled the smell as unpleasant. Lastly, fifteen from the control and two from the aroma group found the smell to be neither pleasant nor unpleasant.

Participants were also asked about their subjective reactions after inhaling the aroma. While majority of all participants reported no subjective change, more participants in the treatment group (9 of 16) expressed feeling a sensation to calmness or focus compared to the control group (3 of 19). These questions allowed an increased understanding about the participants' subjective experience.

DISCUSSION

Our hypothesis that inhaling rosemary oil would produce heightened sympathetic nervous system activity and would ultimately have a positive effect on concentration could not be proven by the study. First, we were unable to replicate findings from previous studies that demonstrated an increase in sympathetic physiological response with exposure to rosemary (Moss et al, 2003 and Sayorwan et al., 2013). In many ways, trends within our data suggest the opposite effect of rosemary on sympathetic activity. Although our data lacked significance, analysis revealed decreased skin conductance and decreased respiratory rate in those exposed to rosemary in comparison to the control.

Our results also indicate that there is no significant difference between the control and experimental group in average test scores, suggesting that exposure to rosemary is not correlated to greater concentration. These results contradict the findings that rosemary improves cognitive function as presented by Sayorwan et al. (2013) and McCaffrey, Thomas, & Kinzelman, 2009. Similar to Moss et al. (2003), many of the participants exposed to rosemary reported feeling more focused or relaxed despite an actual significant difference in test scores.

Based on previous studies, we expected to find that increased sympathetic physiological responses during a concentration test would correlate with higher test scores (Lackner et al., 2010 and Beck, 2013). While our data suggest that heart rate and respiratory rate increased while taking concentration tests, only higher respiratory rates appeared to be associated with higher test scores. No absolute conclusions can be drawn from this data because it lacks significance, however the results do not align with previous studies and should be considered in future research.

The findings from these three facets of our study have important implications for students. While the use of rosemary or other essential oils has become popular for increasing one's mental capacity, our study does not demonstrate this claim. This study also lacks evidence for an altered physiological state including heightened heart rate, skin conductance and respiratory rate in response to exposure to rosemary oil. This is valuable for students to consider as they seek out alternative ways to improve their study habits and ultimately their concentration skills.

In total, there are several factors that could have contributed to the results generated from our study. One variable that could have limited our study was the sample size. Due to time constraints, only thirty five individuals were tested. Perhaps, with a larger sample size, we would have generated statistically significant data. In addition, many of the participants in our study took part in other experiments prior to our study, possibly affecting the physiological factors measured in our experiment. This uncontrollable factor could have led us to falsely attribute certain physiological measurements to their respective treatment condition. Another obstacle we encountered was keeping the scent of the rosemary consistent for each participant in the experimental group. The rosemary scent became noticeably stronger in the room as more participants were tested throughout the day. This inconsistency in testing room environment may have affected the validity of our data. An additional challenging aspect of our experimental design was the test used to measure concentration. The test may not have been the most effective method for quantitatively determining concentration. Even though we ensured that participants did not have a history of dyslexia, perhaps certain individuals were innately better than others at differentiating letters from one another. A final limiting factor in our experimental design was in the administration of the test. Each participant was given ambiguous instruction prior to beginning the test. Albeit all participants were given the exact same assessment, we found that many individuals approached the test differently from others. Some individuals seemed to put greater emphasis on moving as quickly as possible through the test, consequently resulting in more mistakes. Others seemed to focus on minimizing the number of mistakes. In addition, many participants physically crossed off letters in different ways. These factors may have been eliminated if more information and instruction was communicated regarding the test and how it would be scored.

Future studies should focus on improving aspects of the experimental design and analysis in order to solidify whether or not a relationship exists between rosemary and concentration. First, researchers should ensure that the administration of rosemary scent is consistent throughout the study to successfully compare between and within participants. Additionally, we recommend that further studies use an alternative positive control. We suggest that a scent that is known to alter the physiological measures of interest in the study is used. This would ensure that the equipment is able to detect changes in physiological function similar to those expected in the study, which is vital for determining if a significant difference exists between the control and experimental group. Lastly, additional questions should be included in the post-study survey in order to better understand the participants' subjective experiences and provide a more in depth analysis of the results. It would be beneficial to know whether individuals recognized the scent as well as if they had previously used rosemary essential oil. The aforementioned changes and additions could lead to more significant results regarding rosemary's effect on concentration.

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APPENDIX I

1. How did you feel after being exposed to the scent? (circle all that apply)
a. Distracted
b. Focused
c. No change
d. Sick
e. Other:_________________________

2. Did you find this scent:
a. Unpleasant
b. Pleasant
c. Neither

3. Have you heard of using essential oils to increase concentration?
a. Yes
b. No

4. Do you use essential oils at home for increased cognition?
a. Yes
b. No

FIGURES

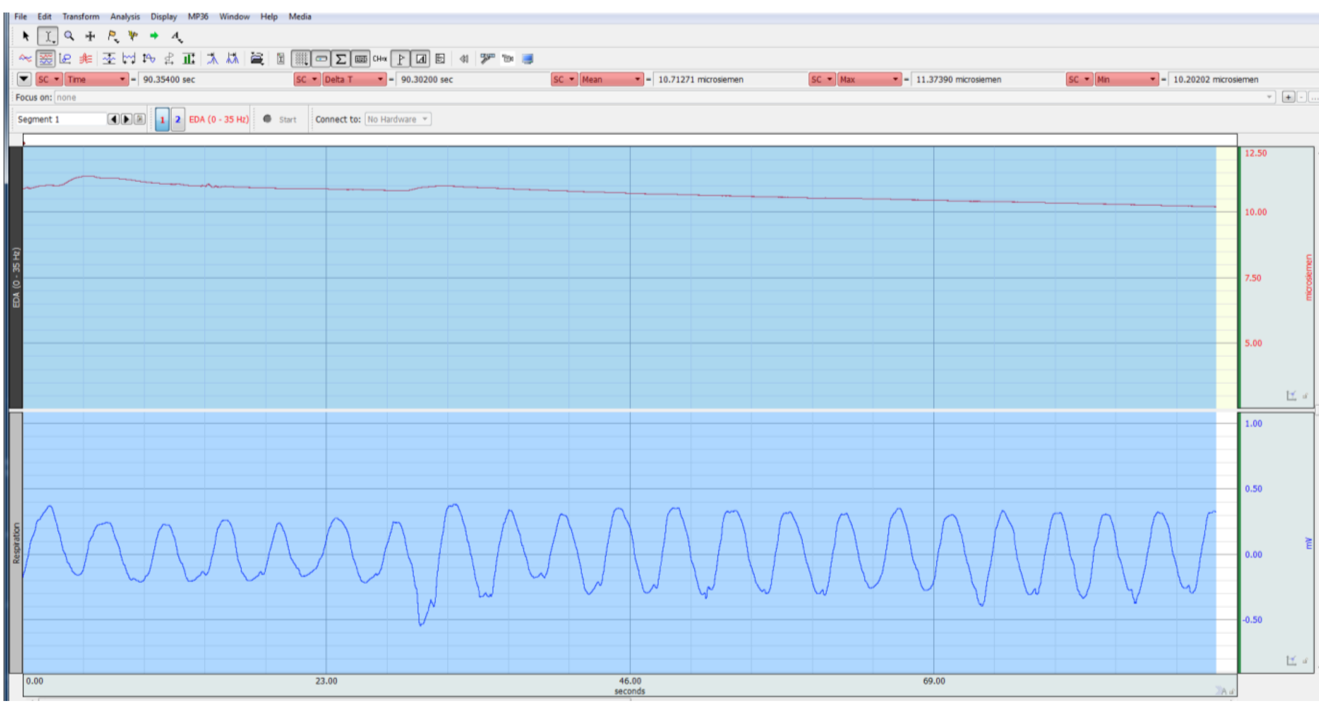
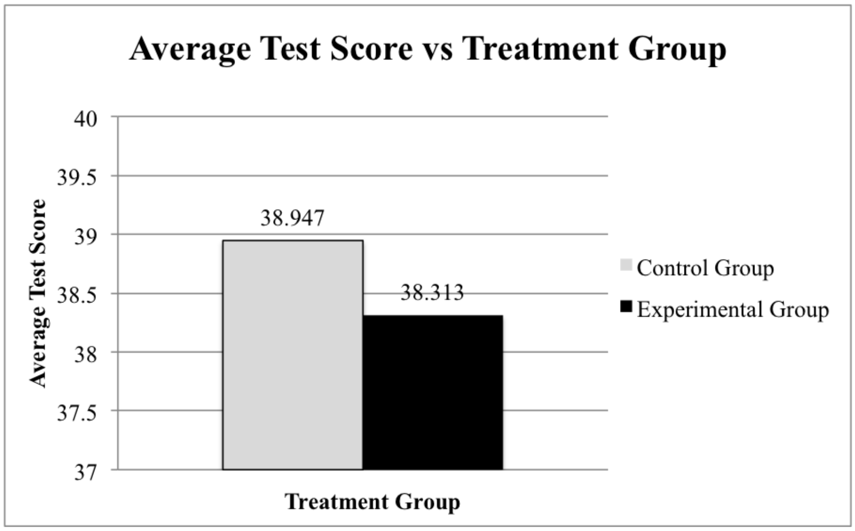
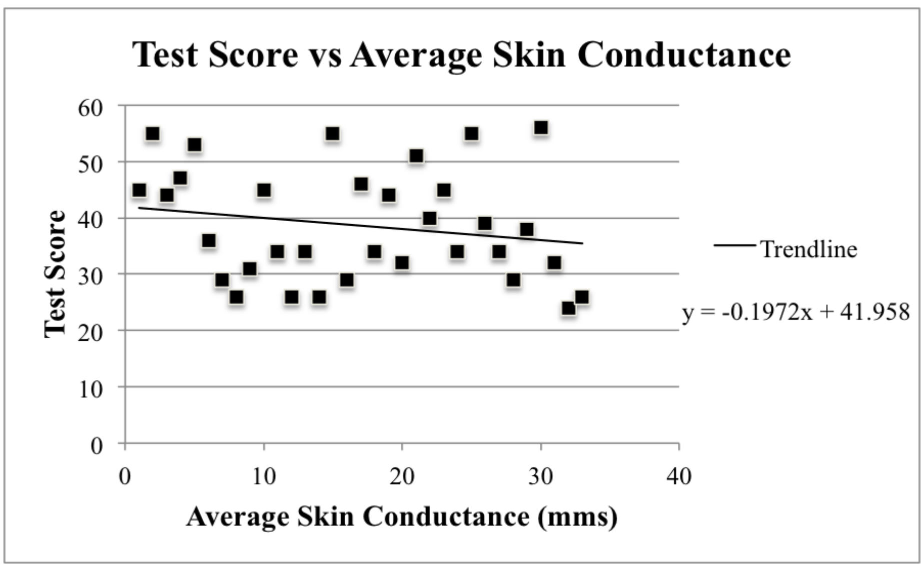


Figure 1 shows an example of collected skin conductance and respiration rate data



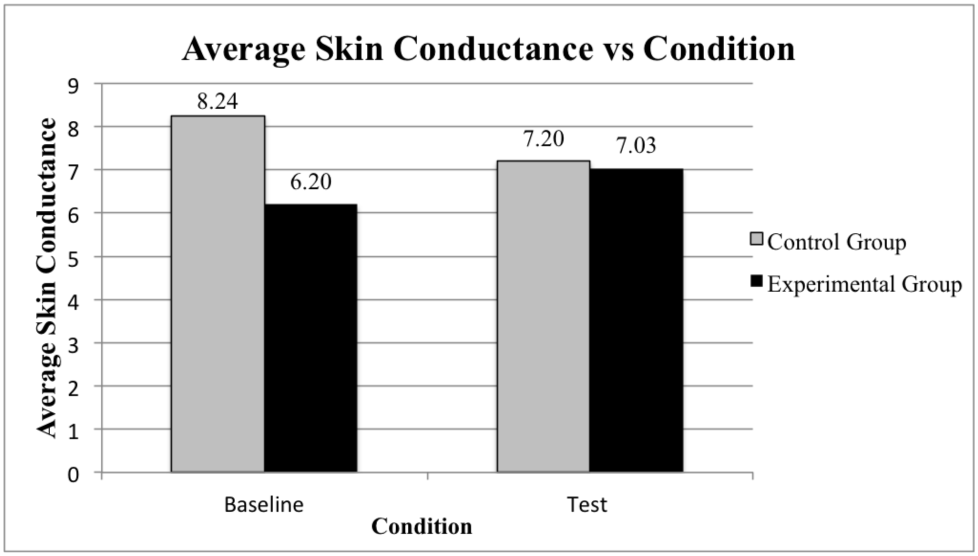
(StDev control=9.891, StDev Experimental=9.700)

Figure 2 Shows the average test scores for the control and experimental groups.



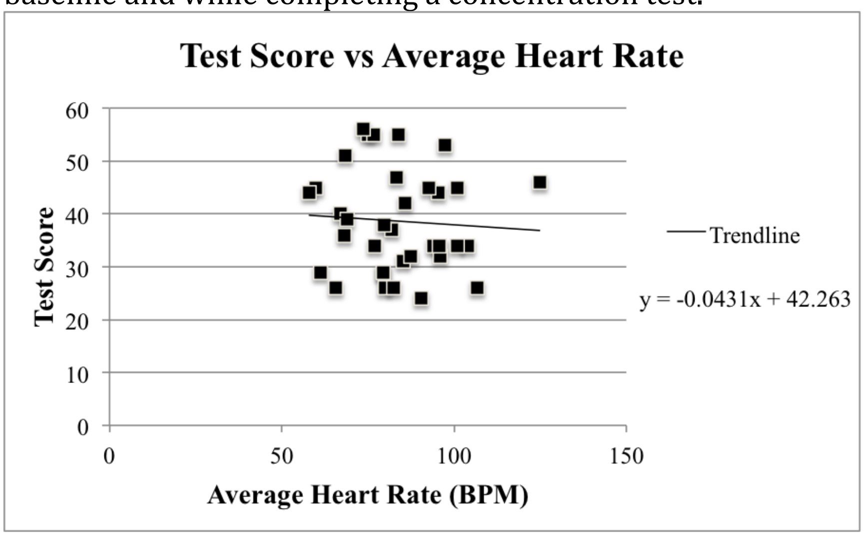
(R-squared= 0.0368)

Figure 3 plots each participant's average skin conductance while completing a concentration test against their test score. Data from both the control and experimental groups are included.



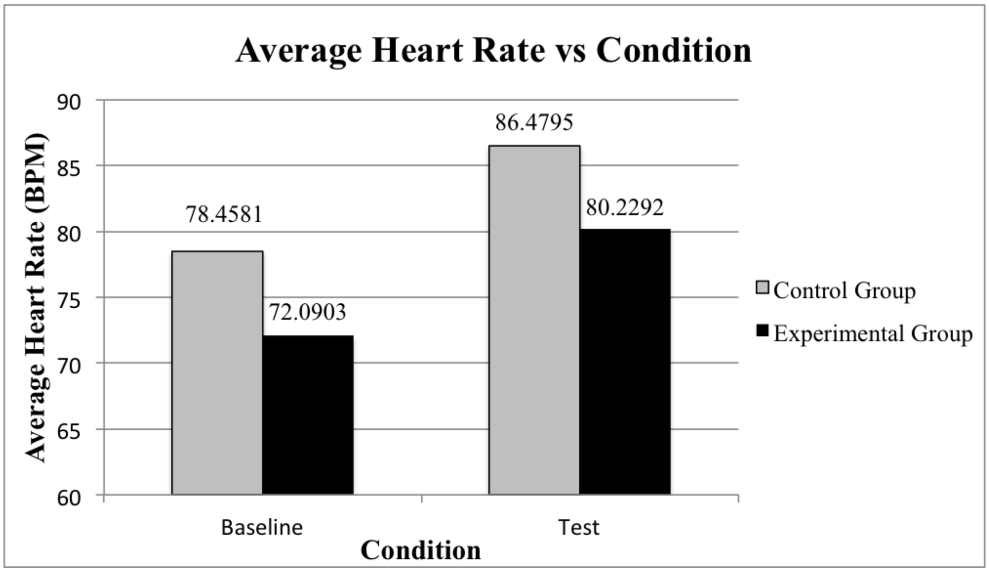
(StDev Baseline Control=2.562, StDev Baseline Experimental=2.595, StDev Test Control=2.644, StDev Test Experimental=2.863)

Figure 4 shows the average skin conductance for the control and experimental group at baseline and while completing a concentration test.



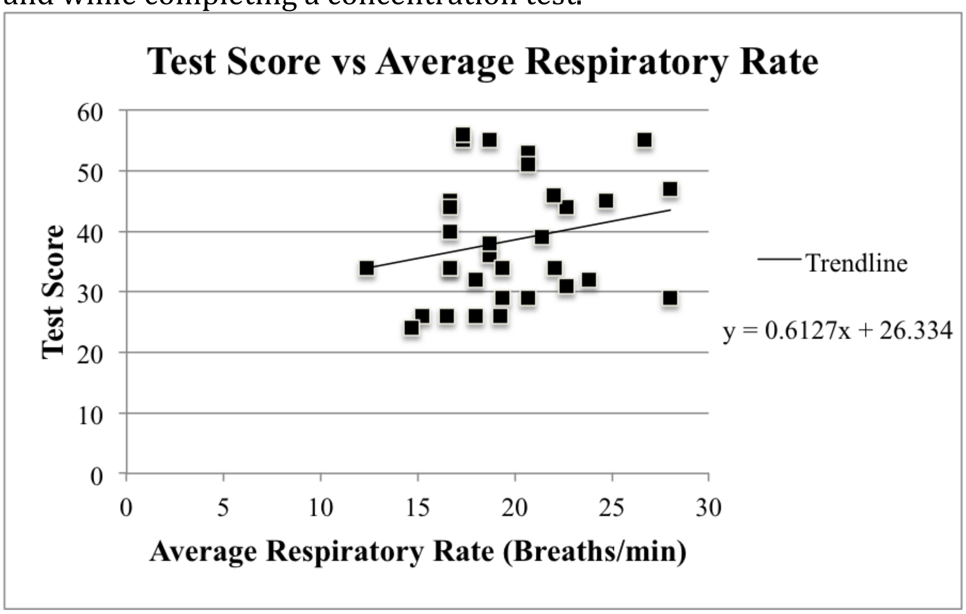
(R-Squared=0.00438)

Figure 5 plots each participant's average skin conductance while completing a concentration test against their test score. Data from both the control and experimental groups are included.



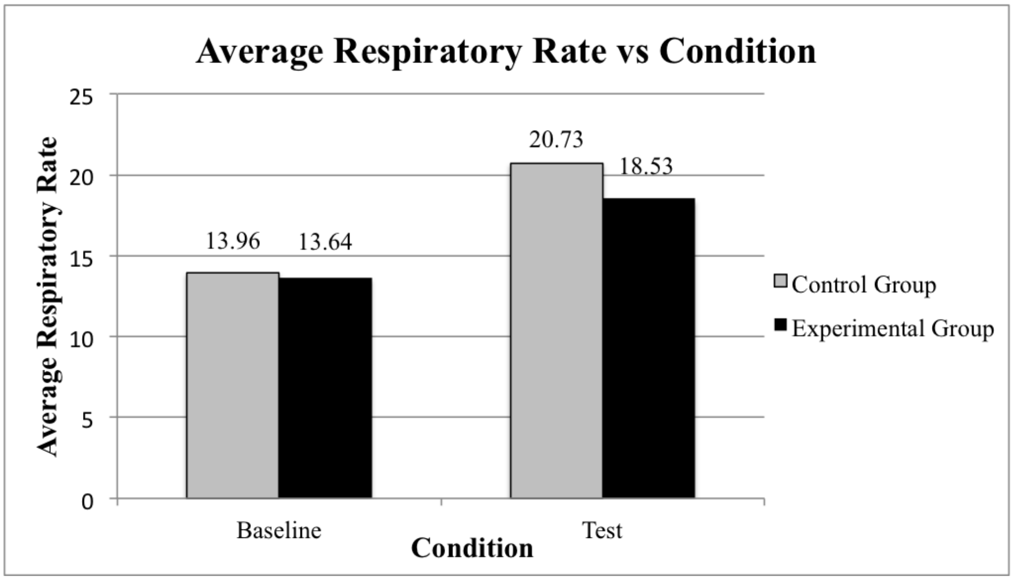
(StDev Baseline Control=10.456, StDev Baseline Experimental=14.209, StDev Test Control=15.174, StDev Test Experimental=14.119)

Figure 6 shows the average heart rates for the control and experimental group at baseline and while completing a concentration test.



(R-Squared=0.0527)

Figure 7 plots each participant's average skin conductance while completing a concentration test against their test score. Data from both the control and experimental groups are included.



(StDev Baseline Control=3.717, StDev Baseline Experimental=3.146, StDev Test Control=3.519, StDev Test Experimental=3.791)

Figure 8 Shows the average respiratory rates for the control and experimental group at baseline and while completing a concentration test.

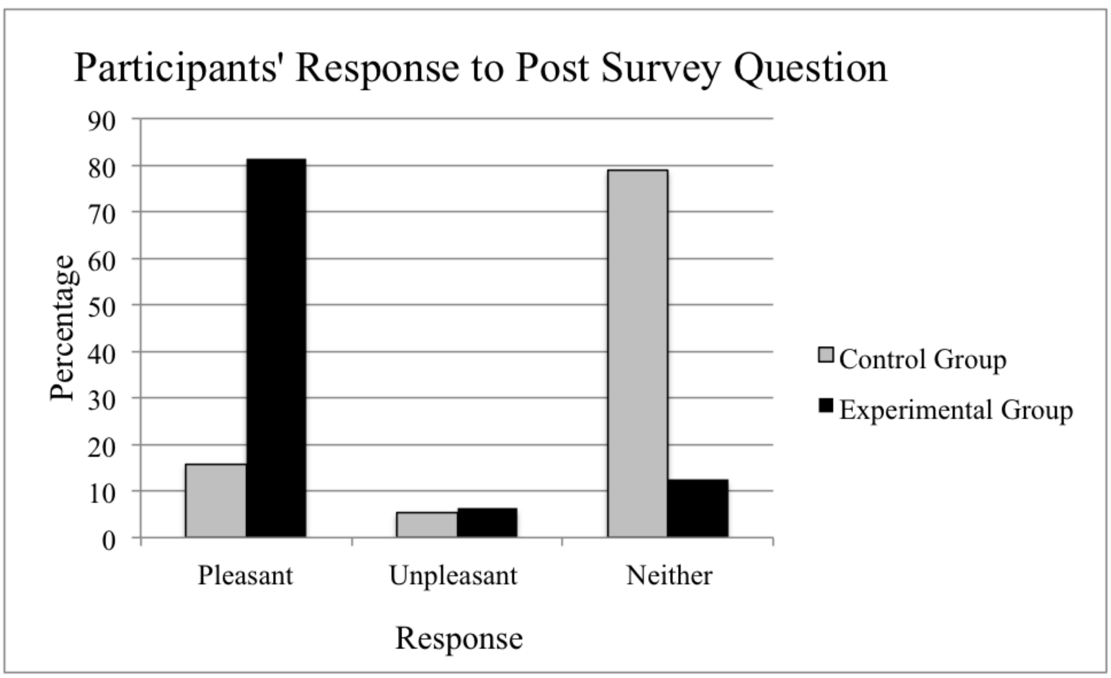


Figure 9 Depicts the proportion of respondents who described the smell of the exposed substance as pleasant, unpleasant or neither.