The Effects of Linalool and Peppermint Aromas on Cognitive Performance

Undergraduate Research Thesis

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Spring 2017

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Abstract

What if there was a way for people to perform better on tests, make less mistakes, and work more efficiently? Previous research has suggested that a person can achieve enhanced cognition and task performance simply by breathing the scents of certain natural substances. The amount of supporting research to back up these claims, however, is limited. This project seeks to understand the question of how peppermint and linalool (lavender) aromas affect cognitive performance. Its purpose is to provide a clearer understanding of the psychological and psychopharmacological effects (specifically regarding performance), if any, that these aromas can produce in human subjects. Subjects were evaluated in three separate conditions (no aroma, linalool aroma, and peppermint aroma) using the PEBL (Psychology Experiment Building Language) Math Processing Task, which involves answering simple math problems as quickly and accurately as possible. Results show that subjects exposed to the linalool aroma showed increased accuracy compared to their respective no aroma conditions, however, there was no effect on response time. Peppermint aroma did not have an effect on accuracy or response times compared to the respective no aroma conditions. These findings could have widespread application, including the ability to potentially increase accuracy or general task performance for people exposed to linalool. In addition, this study may open the door for further research on aromas to determine what other effects on humans or uses they could have.

Introduction

Whether you are a Wall Street executive, a medical student, or a child learning to read, anyone can benefit from having increased cognitive functioning. In a society full of opportunity, ever-changing technology, and a multitude of distraction, a cognitive boost can go a long way. Previous research has suggested that a person can achieve enhanced cognition and task performance simply by breathing the scents of certain natural substances (McCombs et. al, 2011; Raudenbush et. al, 2009; Sakamoto et. al, 2005). In this project, I explored the effects of linalool and peppermint aromas on cognitive performance, in order to gain a greater understanding of the potentials of aroma administration.

The notion that aromas, especially peppermint and lavender, can affect the brain is not a new concept. Peppermint, it is postulated, acts in an arousing manner—that is, it may increase alertness and task performance in subjects (McCombs et. al, 2011). This claim is supported by a team of researchers at Wheeling Jesuit University, who published a study on the effects of peppermint aroma on video game performance. According to the result of the experiment, participants (who were playing Wii Fit games) showed "greater improvements, such as completing significantly more levels" while playing in the peppermint condition than the control (no aroma) condition (McCombs et. al, 2011). They "reported less mental demand, perceived effort, and anxiety" compared to participants in the control group (McCombs et. al, 2011). The data also suggests that the "the scent administration promoted greater physiological arousal" (McCombs et. al, 2011). A second study, published by the same group of researchers, produced similar results.

In this experiment, subjects were asked to simulate driving while being administered two different aromas, one of them being peppermint. According to the results, peppermint administration "led to increased ratings of alertness, decreased temporal demand, and decreased frustration over the course of the driving scenario. In addition, peppermint scent reduced anxiety and fatigue" (Raudenbush et. al, 2009). These results suggest that peppermint administration may increase arousal and task performance. These studies provide excellent groundwork for this experiment as well as provide justification for the selection of peppermint as one of the chosen aromas.

The second experimental aroma, linalool, is the major psychoactive and olfactive component of lavender, and has been shown in past research to have sedative psychopharmacological effects (Souto-Maior et. al, 2011). A study published in the *International Journal of Neuroscience* by researchers in the United Kingdom depicted an experiment that used the Cognitive Drug Research (CDR) computerized cognitive assessment battery (which assesses attention, working memory, and long-term memory) to analyze cognitive performance in response to the lavender aroma (Moss et. al, 2003). According to the results, the lavender condition "produced a significant decrement in performance of working memory, and impaired reaction times for both memory and attention based tasks" (Moss et. al, 2003). In addition, it was indicated that the participants in the lavender condition "were significantly less alert" than those in the control (Moss et. al, 2003). Contrary to these findings, a second experiment, from Japan, found that lavender aroma increased subjects' ability to concentrate on a computerized task involving a moving picture that changes sizes (subjects were instructed to click the image at the point that it changes sizes), stating “although lavender is a sedative-type aroma, use . . . after accumulation of fatigue seems to prevent deterioration of performance in subsequent work sessions” and thus may help improve work performance (Sakamoto et. al, 2005). It should be noted, however, that this task was described as “monotonous,” not stressful (Sakamoto et. al, 2005). Due to the contradicting conclusions drawn from these experiments, it is the goal of this experiment to help bridge the gap between the findings to help deepen the understanding of the effects lavender (linalool) may have on cognitive performance.

Methods

Subjects

There were 19 subjects in the experimental (first leg) section of the study, seven men and twelve women. In the control section of the experiment, out of 16 subjects, five were men and eleven were women. Subjects had a large age range (from 18 to 71) and came from a variety of backgrounds. Subjects were enrolled using a database and gave their informed consent before beginning the experiment.

Stimuli

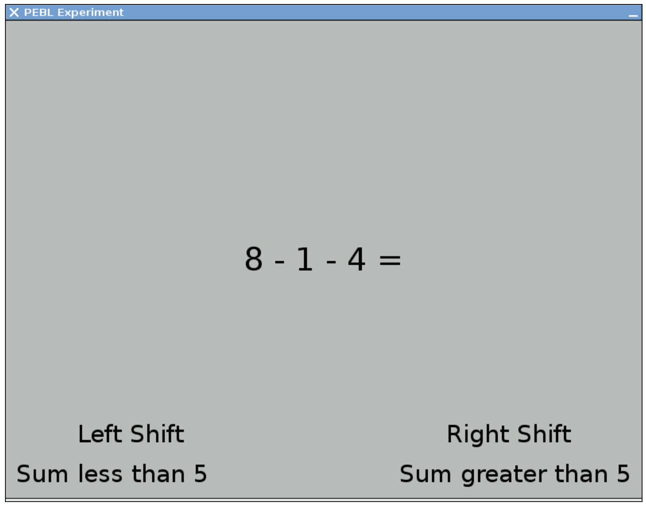
Pure peppermint and linalool essential oils were used during this experiment. For the peppermint condition, 50 mL of 35% peppermint/ethanol solution was created to allow diffusion via a custom-build olfactometer. In the linalool condition, a 25% linalool/miglyol solution was used. These solutions were pre-tested before the experiment began to make sure they were at the same perceived intensity level.

Methods

The design for the first leg of the experiment was as follows. The participants came to the laboratory individually to complete the experiment. After signing consent forms and being introduced to the experiment, participants entered the testing space (a small room with enough space for a desk with a computer and a chair) to complete a demographic questionnaire. This room had no aroma in it, however, a custom-built olfactometer delivered humidified, control breathing air (the same device used to administer the aromas in the experimental condition) into the environment, in order to keep consistency between the control and experimental conditions. Next, participants sat for approximately ten minutes due to evidence from past literature suggesting that exposure to aromas takes about this much time to take effect (Toda & Morimoto, 2011). After the waiting period, participants began a cognitive performance task using the PEBL (Psychology Experiment Building Language) Math Processing Task (Mueller & Piper, 2014). In this, participants were presented with random, simple math problems that they needed to mentally solve on a computer screen in three, three-minute blocks, and respond by saying if the answer to the problem is greater than five or less than five. Within each block, answers were greater than five approximately half of the time and less than five approximately half of the time, with the order of the individual problems randomized (please see image for clarification on the task). There was a time limit for each problem, ranging from one and a half to four seconds per problem, dependent on the number of integers present. Within each three-minute block, each problem had the same number of integers and the same amount of time to answer each problem, however, the number of integers varied from block to block, so that in both the control and experimental condition the participants completed a block with two integers, three integers, and four integers, with the order randomized. These integer conditions were considered easy, medium-difficulty, and hard respectively. Participants were given feedback on their accuracy after each problem, or, if they did not answer the problem in time, they were given a "Too Slow" message before the program automatically took them to the next problem. Participants were instructed to answer as many problems as they could in the block, as quickly and accurately as possible. The participants completed a "practice block" of one three-minute block, the integer condition of which was randomized and assigned to each participant to ensure that each integer condition was used the same number of times throughout the experiment. A one-minute break was also added in between each integer condition to avoid fatigue effects. To incentivize participants to perform well, they were told that their financial compensation was based on their performance (this was not true, each participant received the full amount of payment regardless of how well they do at the task). This deception was necessary to keep the participants motivated, thus ensuring consistent results.

After completing the first set of three blocks (the control, no aroma condition) of the experiment, the participants were moved to another room to complete a questionnaire on how they felt (perceived arousal, etc.) during the that treatment. Following the 10-min aroma exposure period, subjects then completed the same math task in the presence of either peppermint or lavender aroma. To eliminate potential carryover effects of the aromas, the participants came in on a second day to complete the experiment with the other aroma (they completed the control condition twice). After both days were completed subjects received compensation. Data for this leg was analyzed based on accuracy and response time.

To control for learning effects, a second group of subjects were recruited for a control experiment (second leg) in which subjects underwent the exact same process except they were not exposed to aromas in either room. Subjects completed this control condition in a single session. This was done to further understand whether the effects we saw in the first leg were due to the structure of the experiment (i.e. learning effects), or if the effects were due to the aromas themselves. Data for this leg was also analyzed based on accuracy and response time.



This is a screenshot of the PEBL Math Processing Task (Mueller & Piper, 2014).

Data Analysis

Univariate ANOVAs were conducted to determine significance.

Results

Response Time

Response time is the time (in ms) required for each subject to answer each problem and is considered an aspect of cognitive performance because it shows how quickly the subjects were able to record a response. A comparison of subjects' response time in the peppermint aroma condition and its respective control condition revealed that response time significantly decreased with the administration of peppermint aroma. Specifically, we saw significance overall ($p<.01$) and in the 4-integer condition ($p<.05$) (*Figures 1 and 2)*. In the linalool aroma condition we also saw a significant decrease in response time compared to its respective control, specifically overall (p<.001) (*Figures 3 and 4)*. Finally, in the second leg of the experiment, we saw that when the first room control (no aroma) was compared to the second room control (also no aroma), we saw a significant decrease in response time in the second room. Specifically, we saw significance overall (p<.001), in the 2-integer condition (p<.05), the 3-integer condition (p<.01), and the 4-integer condition (p<.01) (*Figures 5 and 6)*. In each case, response time increased as the number of integers increased, which is consistent with expectation because it takes longer to solve more difficult problems.

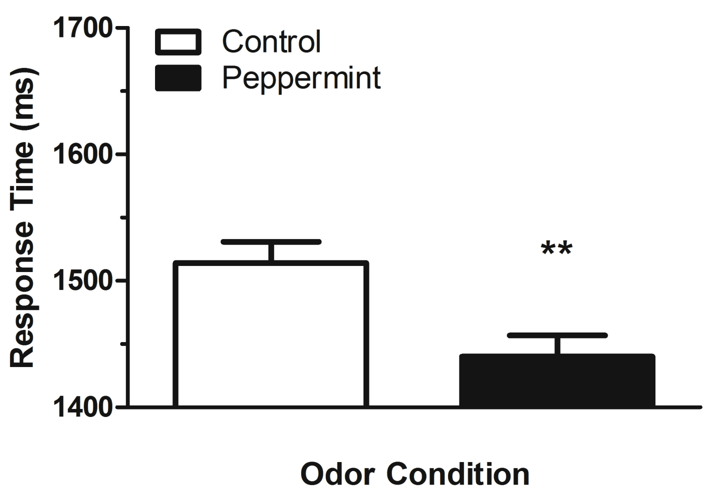


Figure 1: Mean response time (ms) per problem overall. We see a significant decrease in response time overall (across all conditions).

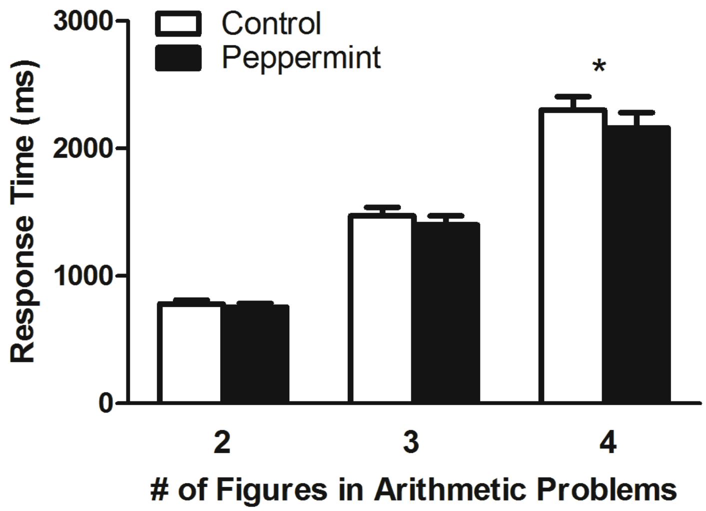


Figure 2: Mean response time (ms) per problem vs. integers. Response time increased as the number of integers increased (consistent with expectation). Specifically, we see a significant decrease in response time in the 4-integer (hard) condition as compared to its respective control.

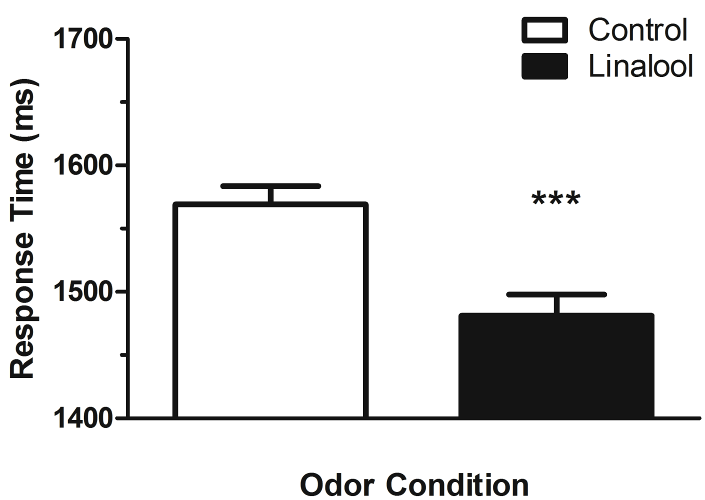


Figure 3: Mean response time (ms) per problem overall. We see a significant decrease in response time overall (across all conditions).

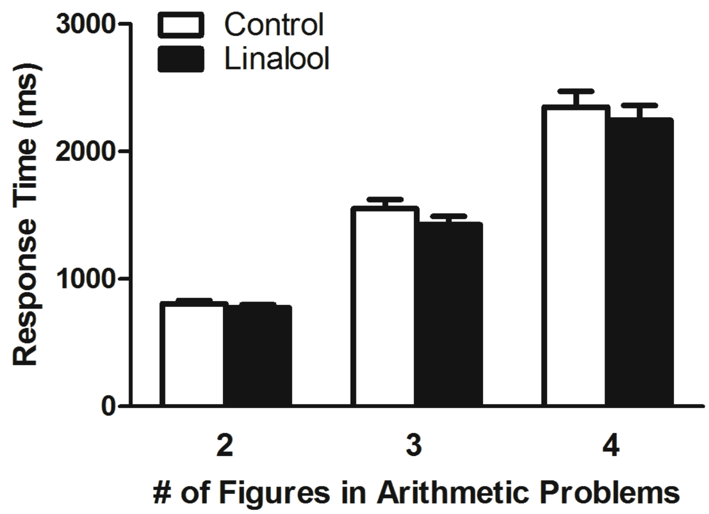


Figure 4: Mean response time (ms) per problem vs. integers. Response time increased as the number of integers increased (consistent with expectation). We do not see significant changes in response time at the level of individual integer conditions.

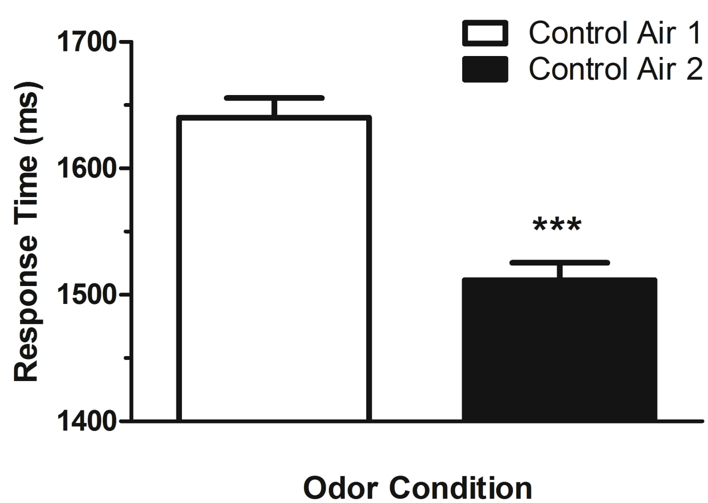


Figure 5: Mean response time (ms) per problem overall. We see a significant decrease in response time overall (across all conditions).

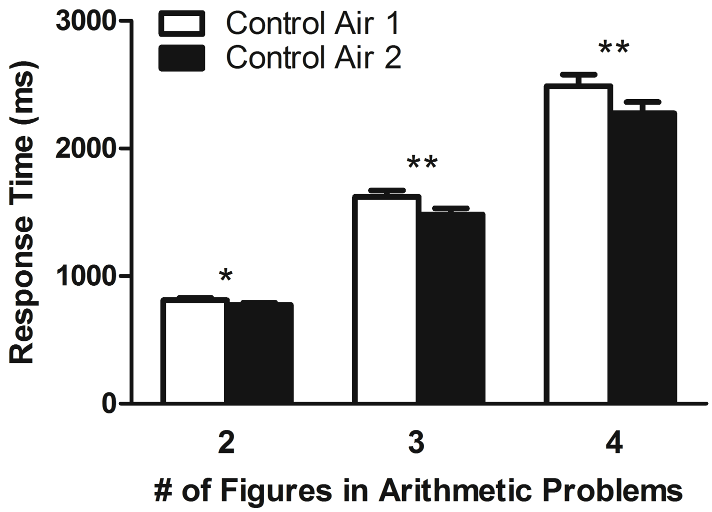


Figure 6: Mean response time (ms) per problem vs. integers. Response time increased as the number of integers increased (consistent with expectation). We see a significant decrease in response time in the 2-integer (easy), 3-integer (medium-difficulty), and 4-integer (hard) conditions as compared to their respective controls.

Proportion of Correct Responses

The proportion of correct responses, i.e. the accuracy of a subject, was determined by the amount of correct responses out of the number of problems attempted in a block. This is seen as a crucial aspect of cognitive performance because it determines if a participant is able to obtain better results under a certain condition. In the peppermint aroma condition there was seen to be no significant differences when compared to its respective control (*Figures 7 and 8)*. In the linalool condition there was seen to be a significant increase in accuracy compared to its respective control. Specifically, significance was established overall ($p<.001$), in the

2-integer condition (p<.01), and in the 4-integer condition (p<.05) (*Figures 9 and 10)*. Finally, in the second leg of the experiment, we saw that when the first room control (no aroma) was compared to the second room control (also no aroma), there was no significance overall but there was significance in the 2-integer condition (*Figures 11 and 12)*. In each case, accuracy decreased as the number of integers increased, which is consistent with expectation because more difficult problems are harder to solve.

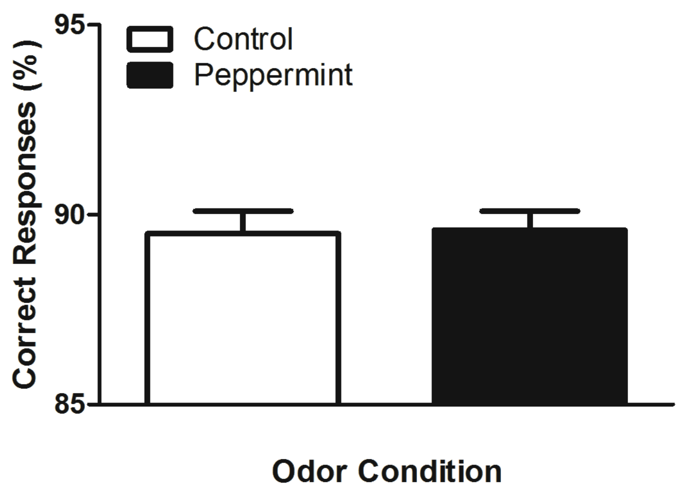


Figure 7: Mean proportion of correct responses per block overall. We do not see a significant change in accuracy overall (across all conditions).

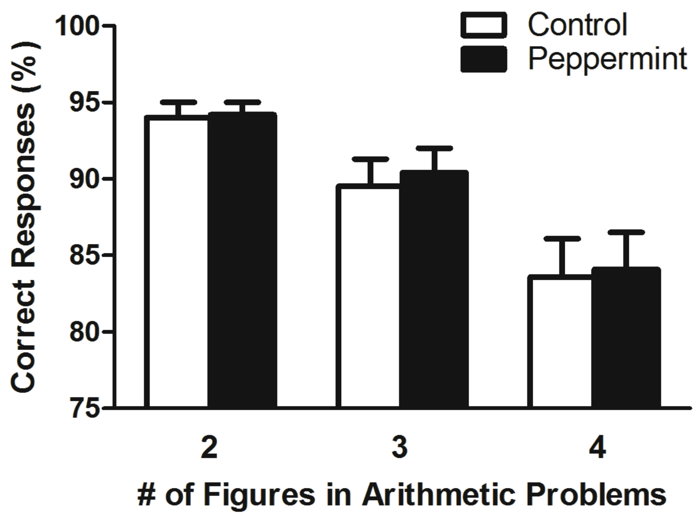


Figure 8: Mean proportion of correct responses per block vs. integers. Accuracy decreased as the number of integers increased (consistent with expectation). We do not see significant changes accuracy at the level of individual integer conditions.

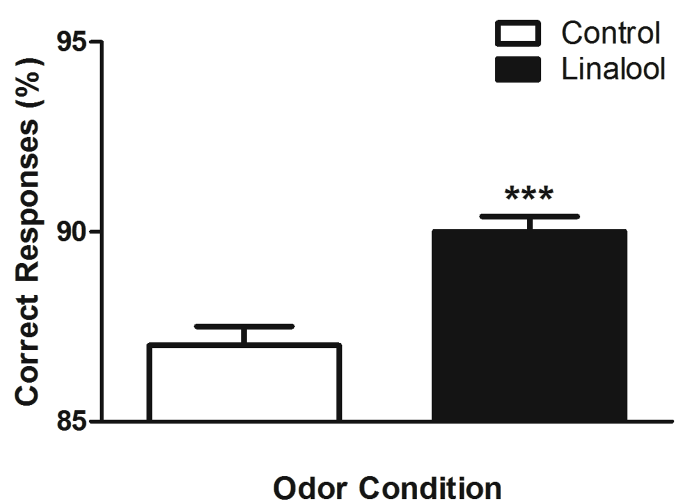


Figure 9: Mean proportion of correct responses per block overall. We see a significant increase in accuracy overall (across all conditions).

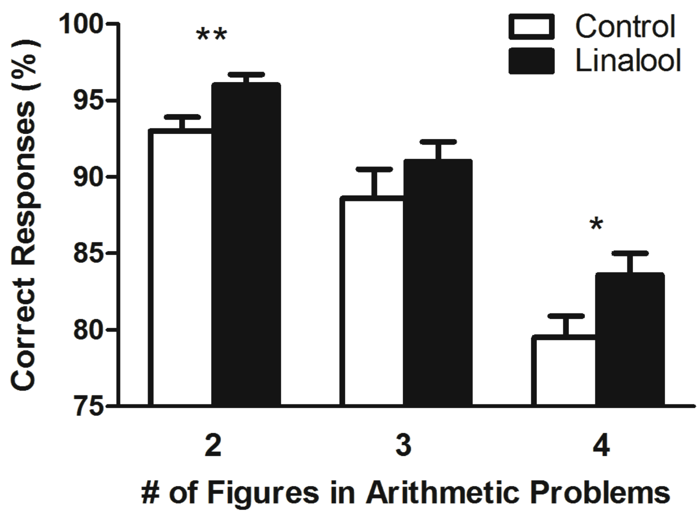


Figure 10: Mean proportion of correct responses per block vs. integers. Accuracy decreased as the number of integers increased (consistent with expectation). We do not see significant changes accuracy at the level of individual integer conditions.

Figure 11: Mean proportion of correct responses per block overall. We do not see a significant change in accuracy overall (across all conditions).

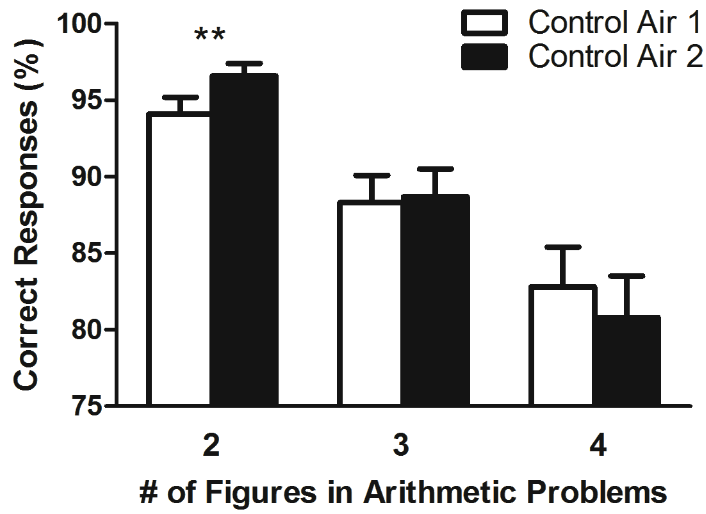


Figure 12: Mean proportion of correct responses per block vs. integers. Accuracy decreased as the number of integers increased (consistent with expectation). We see a significant increase in accuracy in the 2-integer (easy) condition as compared to its respective control.

Discussion

Conclusions

Peppermint aroma is postulated to increase “physiological arousal” (McCombs et. al, 2011). In 1908, Yerkes and Dodson established a connection between physiological arousal and cognitive performance, indicating that there is an optimal level of arousal (not too much and not too little) required to perform at one’s best (Yerkes and Dodson, 1908). As such, we hypothesized in this study that participants in the peppermint condition would have facilitated cognitive performance compared to controls because they would be pushed into a more optimal (increased) state of arousal. On the other hand, linalool has been shown to evoke a relaxed state characterized by a decrease in arousal. Therefore, we hypothesized that participants exposed to linalool aroma would have impeded cognitive performance (Moss et. al, 2003). Results for this experiment, however, indicate that these hypotheses may not be correct.

Though at first glance, due to the fact that both peppermint and linalool aromas significantly decreased response time compared to their respective controls, one may conclude that both aromas increase performance by allowing the participant to respond faster to questions. We believe, however, that that these changes in response time may have been due to learning effects. When we compare the results in the first leg to those in the second leg of the experiment we see that participants who received no aroma (control) in both rooms also saw a decrease in response time. This tells us that the decrease in response time we saw with the peppermint and linalool may be due to something besides the aromas themselves. Due to the fact that, in order to eliminate possible pharmacological carryover effects of peppermint and linalool administration, the aromas were always administered after their respective no aroma (control), and that we too see a decrease in response time going from the first to the second room in the second leg control experiment, we can posit the notion that these effects were due simply to the fact that the aromas were administered in the second room of the experiment. That is, that these effects may have been due to the constructs of the experiment, and are the potential results of a learning effect, where participants did better under the aroma conditions simply because those conditions came second, after they had already gotten used to and "practiced" the task at hand. We therefore do not have enough evidence to suggest that either peppermint nor linalool aromas have any effect on response time.

For proportion of correct responses (accuracy), on the other hand, the fact that we had non-significant results in our second leg control experiment but did see a significant increase in proportion of correct responses with linalool in our first leg experiment strengthens the idea that linalool aroma does cause a significant increase in cognitive performance. We believe these results may be explained, at least in part again by the Yerkes-Dodson Law, which suggests there is an optimal level of stress and arousal (an inverted U-shaped curve) that impacts performance—not enough stress and we are uninterested or too relaxed, too much stress and we are anxious (Yerkes and Dodson, 1908). Because the PEBL Math Processing task can be considered stressful, it is possible that the administration of a sedative-type aroma like linalool pushes the participant from a position of too much stress to a more optimal (lower) level of eustress. Do to these findings, we can conclude that the administration of linalool aroma can increase cognitive performance, via an increase in accuracy, in similar tasks.

Limitations

It should be noted that there were some limitations to the study. Aspects of the study, such as pleasantness of the aromas (due to individual preference), familiarity, and preconceived notions about how the aromas may affect the individual may have played a role in how the subjects actually performed. In addition, it is important to note that the results only hold for cognitive performance tasks specific to the task in this experiment, and cannot be extrapolated to include other aspects of performance.

Future Directions

There are multiple directions this research could be taken in the future. First, it would be interesting to explore how other aromas (for example, vanillin) compare to the results of the peppermint and linalool groups. Next, it would be interesting to investigate if we see similar results with other measures of cognitive performance, such as if we had students analyzing literature, thinking through word problems, or solving a puzzle. Finally, it would be interesting to see the effects orally ingested linalool, perhaps in the form of a hard candy, would have on cognitive performance.

Acknowledgements

I'd like to give a special thanks to Dr. Simons for being my guide and mentor not only for this project, but also for the latter half of my undergraduate college career. I'd like to give an additional thank you to the wonderful members of my lab, who have been equal parts supportive, helpful, and fun to be around. Finally, I'd like to thank Ohio State's Undergraduate Research Office for providing me with the resources and summer fellowship that allowed me to take up this project.

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