

The Effect of Stimulating and Soothing Smells on Heart Rate and Memory



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ABSTRACT

This study was performed to investigate the effect of smell on heart rate and short-term memory. Lemon and lavender were used as stimulating and soothing scents respectively, in order to determine if these odors increased or decreased heart rate and correspondingly improved or impaired memory. Sixty-seven participants from California State University, Sacramento were divided into three groups to test the hypothesis that the stimulating scent of lemon would enhance memory and increase heart rate, whereas lavender would reduce memory and decrease heart rate. However, the results from this study were not statistically significant to support this claim.

Our olfactory sense is unlike any other sensory modality. It is the only sense that is directly connected to the environment, has neurons that continuously regenerate throughout life, and has neuron axons that are unmyelinated. Having “unmyelinated axons” means that neurons’ axons are not surrounded by protective cells called “glial cells.” Glial cells make up myelin, which is a protective layer of cells around the cell axon that allows for fast transmission of information from one neuron to the next. Not being myelinated causes the sensory signal from the environment to the olfactory bulbs (the structure that perceives smells) to move slower, which is why there is a delay in our responses to smell, and why smells linger in our noses after the scent in the air has passed.

The olfactory system contains structures that are also components of the limbic system, the center that is in charge of emotion and sensory processing. Among these structures is the amygdala, which is involved with emotional processing, specifically fear; and the hypothalamus, which maintains homeostasis within the body; and the hippocampus, which is involved in forming new long-term memories. The olfactory system’s close location to the limbic system explains why certain smells bring back such strong, vivid, emotional memories. The first time we come in contact with a special smell

like the smell of one's grandparent or the smell of art paste, it gets stored in our memories so the next time we smell that scent we are taken back to a loved one's hugs or to preschool art class. The proximity of these two systems would also explain why certain odors can cause relaxation, increased or decreased heart rate, and many other physiological responses in the body.

Scholars have studied how heart rate affects cognition and memory (Jennings and Hall 1980; Luft et al. 2009; Hansen et al. 2007) and how olfaction can alter physiological responses (Xu et al. 2008; Duan et al. 2007; Herz 2009), but no research exists on the relationship between heart rate and memory as the result of a stimulating odor.

The most relevant literature to the present research is in aromatherapy studies. Aromatherapy is a therapeutic method in which aromatic essential oils are extracted from plants and commonly inhaled to enhance different responses. There exists no concrete evidence that either confirms or denies the therapeutic benefits of aromatherapy so there are skeptics to the idea. However, there is extensive research (Xu et al. 2008; Duan et al. 2007; Herz 2009) suggesting that certain essential oils can and do create physiological, emotional, and psychological responses. Sandalwood for example, produces a sedating, relaxing feeling, which tends to be useful for treating people with anxiety, depression and insomnia, while lavender is an uplifting scent that is soothing and helpful in minimizing stress, anxiety, negative emotions, and insomnia (Herz 2009). Rosemary has been known to clear the mind and stimulate memory, while clary sage is an uplifting odor that relaxes patients and helps with anxiety, depression, fatigue, and irritability (Herz 2009). Lemon has been found to improve memory but it does not have any other physical effects on patients (Harvard Women's Health Watch 2008). There have been studies that have investigated the effect of aromatherapy on depression (Yim et al. 2009; van der Watt and Laugharne 2008), irritability, dementia (Ballard 2007), and emotional diseases (Butje, Repede, and Shattell 2008), but no research connects stimulating scents with a direct influence on memory.

Although there have been studies on the effects of different odors on heart rate and on the effects of heart rate on memory and cognition, no research has been conducted on whether odors that increase heart rate also increase memory. The present study will use subjects from California State University, Sacramento to examine whether the stimulating smell of lemon and the relaxing smell of lavender, when presented to subjects, will cause their heart rates to increase or decrease and if there is a relationship between how well participants are able to recall information.

LITERATURE REVIEW

“Aromatherapy” is the use of essential oils that are extracted from plants through distillation in order to treat physical and psychological health issues. It is a branch of “phytotherapy,” which is the use of part of or an entire plant for medical purposes (Stelfitsch and Stelfitsch 2008). Essential oils have been utilized for therapeutic and medicinal purposes for centuries. Today, these oils are commonly used in massage oils, in baths, and are inhaled through steam or a diffuser to calm people, relieve irritability, aid in treating insomnia, and help with pain. There are many other uses for aromatherapy that are not as common, but when used by a specialist, a person who has been certified in the use of aromatherapy, it can be used to help treat inflammation, deodorize, increase blood flow to certain tissues in the body, or for many other beneficial purposes (Stelfitsch and Stelfitsch 2008). There are hundreds of essential oils that provoke different responses in people. Some of the odorants that have been prescribed to cause certain healing reactions include: sweet marjoram (to calm, sedate, and relieve an assortment of negative emotions like irritability, loneliness, and anxiety); sandalwood (also used to sedate, relax, and aid in treating depression, anxiety, and insomnia); and clary sage (to uplift, help relieve anxiety and depression, aid in fatigue, and calm irritable children). Two of the most popular scents studied in aromatherapy are rosemary, which stimulates memory and clears the mind, and lavender, which is uplifting, calming, and useful for reducing stress, anxiety, depression, and insomnia (Price 1991; as cited in Herz 2009). There is not enough evidence to scientifically prove the medical benefits of essential oils, but many studies have shown the effects that essential oils can have on people (Glaser and Graham 2008; Duan et al. 2007; Moss et al. 2003). Despite the studies done, the skeptics remain.

Some disbelievers of aromatherapy give the argument that the expectancy effect is the reason for the changes that researchers find in participants (Howard and Hughes 2008). In their study, Howard and Hughes (2008) suggest that studies that examined the consequence of lavender on participants are flawed. They suggest that researchers tell participants what changes the aromas should cause, or subjects are primed in some way to the purpose of the study. The researchers further argued that these actions influence such expected responses by the subjects. When people are aware that a certain smell is supposed to induce or reduce relaxation, they will become more or less relaxed depending on the expectation, and they will report as such. Howard and Hughes (2008) also suggest that many studies do not provide a placebo or blind experimental protocols to determine if a placebo effect exists or if experimenter expectancy causes the anticipated change. These researchers utilized a placebo in their study and manipulated

the expectations of the subjects (2008). They found that the participants who were primed to believe that the odor would make them more relaxed were more relaxed, and those who were told that the oil's scent would inhibit them from relaxing were least relaxed of all the conditions. The groups that were not primed measured in the middle of the two manipulated groups despite whether they were in the lavender or placebo conditions (Howard and Hughes 2008). Although expectations can produce fallacies in research, the Howard and Hughes' study is not comprehensive enough to disprove all lavender studies. In order to have a well-constructed experiment with valid data, one must control for such error as expectations. Controlling for fallacies is the foundation of valid research and many researchers control for these errors (Moss et al. 2002; Xu et al. 2008; Glaser et al. 2007). In addition, the olfactory system in humans is very complex.

Olfactory System

The olfactory system is the only sensory system that reaches directly to the cerebral cortex without first going through the thalamus (a structure that sends signals to different sensory locations and manages consciousness and alertness). When smells enter the nose, they activate olfactory receptor cells called cilia that take the signal from the nose to the olfactory bulb where the odor gets perceived. In the olfactory bulb, mitral cells pick up the odor signal and transport it down the olfactory tract where the signal is distributed to different parts of the limbic system (Chulder 2010). The limbic system is most commonly known for maintaining balance within the body through the use of hormones and the processing of emotions, but is also used in handling higher order sensory processes and in the formation of memories (Boeree 2009; Hesselink n.d.; Barker et al. 2003, 103-4). There are primary and secondary olfactory regions that include brain structures that are also components of the limbic system (including, but not limited to, the hippocampus, the amygdala, and the hypothalamus) (Duan et al. 2007).

The hippocampus is responsible for converting short-term memory into long-term memory, while the amygdala is essential in emotional processing and associating significance to sensory input (Hesselink n.d.), especially fear. Damage to the amygdala results in the flattening of emotion and no response to fear. It has been found that without the amygdala, people have difficulty discriminating between smells and matching a smell to the smell's name (Buchanan et al. 2003). The hypothalamus is one of the most active parts of the limbic system, and of the brain entirely. It is responsible for maintaining homeostasis within the body by receiving signals from all over the brain telling it about the body's blood pressure; how full the stomach is; skin temperature; information on the lightness and darkness of the environment;

and whether the body should be motivated to eat, drink, have sex, etc. The hypothalamus also provides information about ion balance and temperature of the blood and receives input from olfactory nerves along with numerous other functions (Boeree 2009; Barker et al. 2003, 98-9). In the process of sustaining hormones within the body, the hypothalamus controls the endocrine system by way of the pituitary gland (or master gland), which sends signals to other glands and tells them what, when, and how much to release. When certain fragrances enter the brain, they can trigger the hypothalamus, which then would activate the pituitary gland to release hormones that can induce autonomic changes compatible with relaxation and excitation (Duan et al. 2007). This interconnection of the olfactory system, the limbic system, and the endocrine system allows for support of the idea that if a smell is stimulating, then it might increase heart rate and improve memory.

The autonomic nervous system is a part of the peripheral nervous system, which connects the brain and spinal cord, also known as the central nervous system, to the limbs and organs. The autonomic nervous system is responsible for keeping the body in balance. It regulates heart rate, digestion, respiration rate, salivation, diameter of the pupils, urination, and sexual arousal. Duan and colleagues (2007) found—in their study about how odors affect the autonomic system—that lavender caused autonomic responses associated with relaxation. “Autonomic responses” refer to the automatic changes that occur within the body without conscious thought such as heart rate, blood pressure, etc. Some automatic changes that occur include slowing or increasing heart rate, increasing or decreasing blood pressure, and slowing or increasing breathing, but this study only looked at heart rate variability (HRV), how the heart varies from beat to beat, and blood pressure. Their results showed that after being exposed to lavender, there were no significant changes to blood pressure but HRV did appear to slow down in comparison with the control group (Glaser and Graham 2007).

Glaser and Graham (2007) examined the hormone levels, heart rate, and blood pressure in subjects who had been exposed to a physical stressor and then a stimulating odor (lemon) or a relaxing odor (lavender). They also examined how expectations influenced the results and found that those who were primed on what to anticipate from the different scents had higher heart rate increases after being exposed to the cold water stressor, and showed greater heart rate decrease during recovery than subjects who were blind to the conditions they were exposed to. Specifically, those in the unprimed conditions showed a more steady increase in heart rate after the stressor and a steady decrease in heart rate during the recovery. Diastolic blood pressure decreased from the “post-tape stripping” to “post-cold pressors” in participants who smelled lavender, while it increased in participants who

smelled lemon or water. “Post-tape stripping” was a painful stressor Glaser and Graham et al. (2007) used where they attached a piece of scotch tape to the participant’s forearm and then pulled it off; this was done to test skin recovery following exposure to an odor and to test the effect of smell on autonomic responses. The “post-cold pressor” is another stressful stimulus that Glaser and Graham et al. (2007) used. This was done by placing one of each subject’s feet, up to the ankle, in warm water for a minute and then immediately placing the same foot into cold water after the minute. For the systolic blood pressure, there were no significant changes in results. Norepinephrine was the hormone of interest in this research. It was found that after the cold stressor, norepinephrine levels decreased less when subjects smelled lemon compared to water and lavender, and norepinephrine levels remained higher than normal when participants smelled lemon but returned to pre-stressor levels when lavender and water were used.

“Norepinephrine” is a stress hormone that affects areas of the brain associated with attention and responding actions. In correspondence with epinephrine, another stress hormone, norepinephrine is a key component of the fight-or-flight response, directly increasing heart rate, activating the release of glucose for energy storage, and increasing blood flow to muscles (Glaser and Graham et al. 2007). In summary, all the studies examined discussed the different consequences of different essential oils on physiological responses on the body. There were also studies reviewed that explored the effects of odors on cognition, but there is no research that shows a connection between physiological changes and cognitive tasks or, more specifically, the connection between heart rate and short-term memory. The present study will hopefully bridge this gap and add to our understanding of how scents can induce physiological changes and enhance our memory.

METHODOLOGY

The researcher conducted a quantitative analysis on the connection between three levels of independent variables including: the stimulating scent of lemon, the soothing scent of lavender, and a control group. The dependent variables were heart rate and short-term memory.

All subjects in this experiment were administered the same two sets of memory tasks under different testing conditions. The testing conditions were distinguished by the smell in the room, while the subjects’ heart rate was being monitored using heart rate monitors. The letter memory task contained four trials in which subjects were asked to recall a group of four-, six-, eight-, and ten-letter sets, respectively; the second memory task was comprised of two trials of 20 random pictures. The heart rates of the participants were

gathered continuously throughout the experiment to determine if the scent the subjects were exposed to affected short-term memory as well as heart-rate levels.

Subjects

There were 67 participants in this study recruited from California State University, Sacramento by means of convenience sampling, but three had to be thrown out due to not following the instructions of the test or missing paperwork. Most participants were students from the Psychology Department; however, there were a few exceptions. One student was from Cosumnes River Community College, a handful of students were not psychology students, and one participant was not a student. There were 21 males and 46 females ranging in age from 18 to 56, with a mean age of 26 years and a standard deviation of 7.56.

Heart-Rate Assessment

A heart-rate monitor by Polar was used to track heart rate. The heart monitor consisted of a band that was wrapped around the participant's torso, under his/her clothes with the monitor in the middle of his/her chest, and under the breast bone, so that it could make direct skin contact and a clear heartbeat reading; a watch that corresponded with the monitor was worn on the participant's non-dominant hand so that heart rate could be monitored. After five minutes of sitting in the main room, and before entering the test room, a baseline heart rate was gathered. Another reading was taken five minutes after the participant entered the testing room but before any memory tasks took place to determine if a change occurred as a result of the room. There were subsequent heart-rate readings after each memory test and a final one at the end of the five minute rest period at the end of the experiment.

Memory Assessment

The memory tests consisted of letter and picture recall tests administered electronically through Microsoft PowerPoint 2007 using a Dell computer. The letter-recall test contained four rounds. It began with the subjects being asked to remember the four letters presented to them. After, this first round, each subsequent trial increased by two letters until the fourth trial when the maximum of ten letters was shown and asked to be recalled. At the beginning of each phase, a slide was shown telling the subjects to remember the upcoming letters, followed by a brief focal point and then the letters. The study items were presented for ten seconds proceeded by a 10-second task requiring the subjects to count backwards by twos from 20 to prevent them from repeating the letters over and over in their head, a practice known as maintenance rehearsal. Last, participants were given 20 seconds to write down all the letters they were able to remember.

The picture-memory test had two trials of 20 pictures presented on a slide for 30 seconds. Immediately after the 30-second study phase, participants had 45 seconds to write down all the pictures that they were able to remember. At the end of first trial, there was a prompt informing subjects that the next trial was about to begin, and they had another 30 seconds to try to remember 20 new pictures, followed by another 45 seconds to recall them.

Procedure

The testing stations used in this experiment were in room 209 in Amador Hall at California State University, Sacramento. Inside the room, there were seven separate computer rooms that each were about 50 square feet in size. Each room contained a Dell (Optiplex 960) computer with a keyboard, a desk, and a chair. Memory tests were administered through Microsoft PowerPoint software (2007). Before participants arrived for testing, the researcher used a diffusing stick to fill the testing area with either the smell of Aura Cacia 100% pure lavender or lemon essential oils, except for the control group room, which had no alterations. The door was then closed until the subjects arrived and were assigned to their rooms for testing. Prior to being fitted with a heart-rate monitor, subjects signed a consent form to participate in the study.

Participants were then attached to the Polar heart-rate monitors to track their heart rates throughout the duration of the study. After five minutes of being attached to the monitor, and before entering the study rooms, a baseline heart rate was gathered; upon entering the scented room, subjects sat for another 5 minutes to see if their heart rate was altered by the smell of the room. While they waited for further instructions, the subjects were allowed to read a psychology magazine that was in the room, or to sit and do nothing while they waited for the study to begin. After the five minutes of waiting in the study room had elapsed, participants began the tests. Heart rate was recorded after each memory task, and again five minutes after the conclusion of the final task. Data was then analyzed using SPSS-18 software on Dell computers.

To avoid the “practice effect” (the tendency to get better at a task after doing it over and over), half of each group started with the letter test while the other half started with the picture test. Following the conclusion of the research, subjects were asked if they had any questions and were given a debriefing form. They were all thanked for their participation by the researcher.

RESULTS

A one-way ANOVA was used to analyze the effect of scent on memory and heart rate. The recall for letters in each group was as follows: Control ($M = 22.27$, $SD = 5.55$), Lemon ($M = 22.14$, $SD = 6.29$) and Lavender ($M = 23.25$, $SD = 2.31$). However, there was not an overall main effect of scent on memory for letters: $F(2,61) = .49$, $p > 0.05$. Recall for pictures was similar. The results for this memory test were as follows: Control group ($M = 18.00$, $SD = 3.01$), Lemon group ($M = 18.95$, $SD = 4.44$) and Lavender group ($M = 19.48$, $SD = 4.23$). However, again, there was no main effect of scent on recall $F(2, 61) = .78$, $p > 0.05$. Heart rate also did not differ between conditions. The statistics were as follows: Control group ($M = 79.77$, $SD = 14.63$), Lemon group ($M = 82.62$, $SD = 13.57$) and Lavender group ($M = 76.86$, $SD = 11.33$) under pre-test conditions and during the testing procedure $p > 0.05$ (see Figure 1). There was a slight decrease in heart rate in the Lavender group compared with the Control and Lemon groups, and a slight increase in heart rate in the Lemon group compared with the Control and Lavender groups, but these observations were not statistically significant.

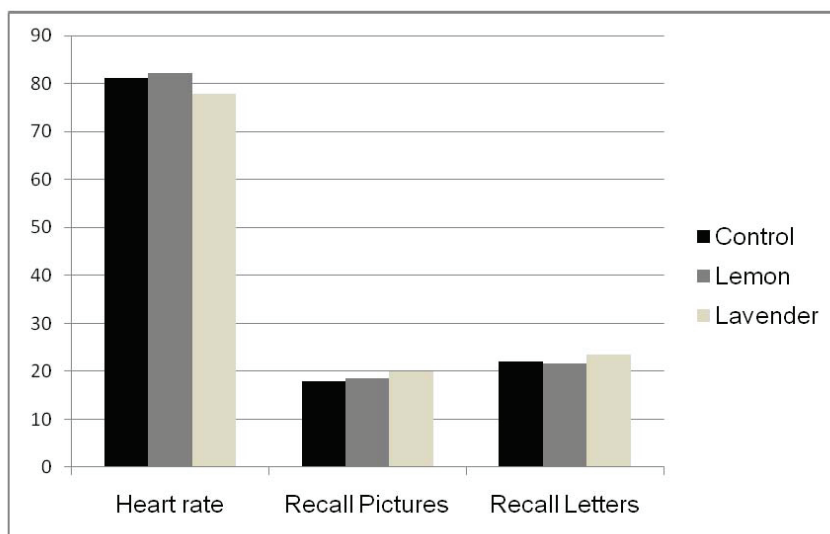


Figure 1. Comparison of (mean) heart rate, recall of pictures, and recall of letters for each condition

DISCUSSION

The results indicate there was no effect of essential oils on memory or heart rate. However, due to the complexity of the olfactory system, it is not surprising that subjects' short-term memory was not significantly altered by these scents, especially because of the fast adaptation that our olfactory

system goes through. Our olfactory system has a special chemical system that neutralizes the response of the olfactory receptors to odors. Due to these chemical adaptations, smells can seem to become 80% less powerful after only a few minutes of exposure (Dewey 2007). Perhaps long-term exposure for at least an hour may have resulted in a significant difference between the groups exposed to lavender and lemon. In addition, previous research indicates that priming the subjects' expectations of how a scent may affect them has a stronger influence on heart rate and arousal levels than the scent itself (Glaser and Graham 2007). Subjects were not primed in this experiment, but the idea of priming raises the issue of psychological aspects of smell. We recall items of the past via smells. For example, the smell of fresh cut grass may remind certain people of spring when they were children. Smells prime the memory for past events but they may not always affect short-term memory immediately. Perhaps if we used the same subjects and exposed them to the same scent during another memory test, they would do better than naïve subjects. Future research should investigate this idea. Although there were no statistically significant results, it is very interesting to note how heart rate slightly increased in the lemon condition and decreased in the lavender condition. Maybe this result is some indication that there was something happening, but other factors could have possibly counterbalanced these effects.

There were a few factors that could have played a significant role on these negative findings. When some participants were done with the memory tests, instead of waiting for the researcher to come back into the room, they got up to open the door or knock on the door to inform the researcher that they were done. This simple act, though seemingly trivial, would cause the subject's heart rate to increase in that instant, giving a higher reading than she/he would have normally had. Similarly, when other subjects were done with their tests, they sat for a few minutes before the researcher returned to the room for the heart-rate reading. This situation could have caused participants' heart rates to be lower than they were right after finishing the test because they had been sitting doing nothing. Some technical factors that could have resulted in the negative findings in this experiment were the facts that the lemon essential oil was nowhere near as strong as the lavender essential oil, and the lemon scent faded much faster. In the present study, it was much more imperative to make sure that the lemon smell was reapplied before a new participant entered the lemon room than it was with the lavender smell in the lavender room. Sometimes, after a participant left the lemon room, the smell was so faint that the researcher who knew the conditions could barely smell it; conversely, the lavender was overwhelmingly strong at times. Knowing that our olfactory systems adapt very quickly (Dewey 2007), if the

scent is not strong to begin with, it might have had even less of an effect; the weakness of the lemon odor along with the fast adaptation seem to be a valid explanation as to why there was no significant increase in heart rate in the lemon condition.

Heart rate is a difficult factor to measure because heart rate can vary so much. This experiment was an “across-subjects study,” meaning that different people were used for each condition. Future research will utilize within-subjects studies to get a more accurate idea of how the different scents really affect people. With fewer people needing to be used, a within-subjects group would probably reduce many of the external factors that could negatively affect results. Trying different everyday smells could also be considered in future research. For example, the researcher could use coffee as a stimulant instead of lemon, because many people use coffee to wake up in the morning. Running this experiment again with coffee and lavender as the scents, and using the same participants for a different set of memory tests would create a comparison of the original results and the new results to see if there is a main effect of priming. This is an important avenue to explore because if there were a connection between scent, heart rate, and memory, people from all different backgrounds and professions could enhance their own or other people’s memories for what they need to know by simply releasing a certain smell into the air. Students could better remember material for tests, grade-school teachers could have scents in the classroom to better help children learn reading or math, and even CEOs could have some smell in the air during meetings so that they and their employees leave the room remembering what was just discussed. Though seemingly trivial, this research may be the brink to memory enhancement.

CONCLUSION

The sense of smell is a unique sense in the way that it is interconnected with different functional systems in the brain, such as the emotionally centered limbic system and the hormone-regulating endocrine system, and in the way that the olfactory bulbs are attached directly to the cerebral cortex. Existing research found that certain smells can evoke changes in physiological responses as well as moods and cognitive processes, but the present research examined whether there was a relationship between a stimulating or soothing scent, heart rate, and short-term memory. The researcher hypothesized that the stimulating scent of lemon would cause an increase in heart rate and improve memory compared with the soothing scent of lavender, but the findings of this experiment did not statistically support this hypothesis. Due to the wiring of the brain and how the olfactory bulbs are connected to the

amygdala, which communicates with the hypothalamus, this researcher still thinks that smell may affect heart rate. With the exclusion of the limitations found in this present study, the current hypothesis may be supported in future research.

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