

Effect of olfactory stimulation on long-term memory retrieval via increased heart rate.

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Memory is an important tool in helping a person display appropriate behavior in various situations or conditions they may find themselves in throughout their lives. In order to utilize memories, one must first be able to process, store, and retrieve them via the brain. Two types of memory formation processes exist: the short-term memory process (STM) and the long-term memory process (LTM). STM is limited to a small number of chunks of information and is rapidly changing. Memories stored in STM are of events that have occurred extremely recently, and potentially may only be able to be recalled for a few moments after the actual event has occurred. An example of STM would be a case in which a person were to memorize a phone number from a phone book just long enough to place a call, but if someone else were to ask the caller to recite the phone number moments after hanging up the person would not be able to. STM has a capacity for how much information it can hold, and anything not deemed important enough is forgotten almost instantly. In contrast, LTM has the ability to store an infinite amount of information throughout one's life (10). The information stored in LTM is largely outside of conscious awareness in day to day life, but can be called into working memory to be used when needed. Some memories stored in LTM are easily accessible while others may be more difficult to recall consciously.

The process of memory is very dynamic, and not yet completely understood in the scientific world. Previous research has suggested that some stresses seem to have a substantial modulatory effect on LTM memory formation and retention (5, 7, 13). In several studies, it has been found that people who experience some stress (physiological, psychological or behavioural) then have an altered ability to respond to the environment around them (6, 7, 9, 10). In particular, research has suggested that olfactory stimulation has a positive effect on recall of various types of information stored in LTM. In a study by Suss, Gaylord, and Fagen, *et. al.* it was found that infants exposed to either a cherry or coconut odor while being trained to move a mobile were able to again move the mobile 24 hours later while being exposed to same odor. Infants exposed to the second odor (not the one they were originally exposed to) or no odor at all 24 hours after being originally trained were not able to recall how to move the mobile (14). In addition, researchers Lwin and Morrin have found that movie-theatre goers exposed to a scent while watching brand commercials prior to the feature film are more likely to recall the commercial when exposed to the same scent after a long-term delay than those who are not exposed to the scent after the delay (8).

The system of smell is unique because sensory information is transmitted directly to the amygdala and hippocampus without first going through the thalamus (2). This direct connection may explain the commonly observed relationships between smell, emotions, and memory (11). In our research, we will test the relationship between smell and LTM recall. We believe that, if a subject is exposed to an odor while memorizing trivial information, they will be more likely to recall this information (and be able to recall it more quickly) while being exposed to the same odor after a long-term delay. We believe subjects will be able to recall information more quickly when exposed to an odor because, as stated in previous research, individuals exposed to an odor are in a more alert state and thus possibly more apt to focus on LTM recall (4). We also believe the direct interactions between the memory and olfactory tracts in the brain will cause olfactory stimulation to allow LTM recall more quickly.

Along with LTM recall, olfactory stimulation has also been shown to affect heart rate in the human body. A particular study by Badia, et. al. monitored the effects of peppermint odor during sleep. This research showed increased heart rate in subjects exposed to peppermint compared to those not exposed to the odor (1). In addition to this olfactory research, memory research has also found increased heart rate to be positively correlated with memory recall when subjects are asked to recall shapes. (3). Because of this previously found evidence, we believe heart rate will be increased when a subject is exposed to an odor, and that this increased heart rate will assist in securing information in the subject's LTM.

Subjects exposed to no odor throughout the entirety of the experiment are the control group and will set the baseline levels of heart rate, LTM recall, and LTM recall rate. We hypothesize that subjects exposed to an odor during both the memorization and recall portions of the experiment (EG1) will have an increased heart rate during both the memorization and recall portions of the experiment, increased LTM recall, and an increased rate of recall when compared to the control group. We also hypothesize that subjects exposed to an odor only during the recall portion of the experiment (EG2) will have heart rates similar to subjects in the control group during the memorization phase of the experiment, but increased heart rates during the recall phase. We expect these subjects to have baseline LTM recall and rate of recall. The expected increase in heart rate for EG2 during the memorization phase is strictly based off of previous experiments that correlate the presence of an odor to increased heart rate (1).

Methods:

Each subject tested in this research was selected from the pool of Physiology 435 students at the University of Wisconsin-Madison. They were randomly assigned to one of three control/experimental groups: a control group (n=15), in which subjects were not exposed to smell during memorization or recall, experimental group one (EG1) (n=12), in which subjects were exposed to smell during both the memorization and recall phases, and experimental

group two (EG2) (n=12), in which subjects were exposed to smell during the recall phase but not during the memorization phase. (An additional test group in which an odor is present only during the memorization phase was not created in order to maintain the integrity of the study. Because each experiment lasted one hour, the odor would have needed to dissipate out of the experiment room in that time in order for the recall phase to be considered 'odorless'. Based off of previous research, two days has been used as a benchmark to completely clear an odor out of a room (8). Using different rooms for the memorization and recall phases was not allowed because a change in surroundings during the experiment could have had an undesired effect and skewed the results; as such, this group (EG3) was rendered impossible.) The odor used in this experiment was Glade "Apple Cinnamon". Only exposure to smell was varied in the different experimental/control groups; all other variables were kept constant. The same 20 pictures were used to test each participant. Each subject was not their own control (they were not tested in all 3 groups with different images) because the researchers believed this may have caused confusion in the subjects' memories (they may have attempted recalling images seen in a different portion of the experiment). Data measured from each participant in the study was their total LTM recall, their rate of LTM recall, and their heart rate (using a pulse oximeter).

Subjects were individually brought into a small room where they were given one minute (60 seconds) to memorize 20 black and white pictures printed out on a single 8x11" sheet of paper (Figure 9). During this time, their heart rate was recorded with a pulse oximeter. Measurements were taken before the memorization phase began and in 15 second increments thereafter (15 sec, 30 sec, 45 sec, and 60 sec). The subject was then allowed to leave the room and was brought back an hour (60 min) later to test their LTM recall of the memorized information. The subject was given one minute and 30 seconds to recall the pictures. Once again, their heart rate was measured right before the time period began and for every 15 second increment thereafter. Their reaction time and LTM recall ability were also recorded by counting the number of correctly recalled pictures in 15 second intervals, for example: number of pictures correctly recalled within 0-15 seconds, then 15-30 seconds, and so on until one minute and 30 seconds was reached. The subject also had the option of stopping the recall phase of the experiment earlier than one minute and 30 seconds if they could no longer recall any images. These subjects received a "0" for number of objects recalled in the time frames past the point of when they stopped the test. The total number of correctly recalled pictures was added up from each time interval (this assisted with determining the rate of recall). The number of incorrectly recalled pictures was also recorded.

From the heart rate data collected, an average heart rate was found for each individual for both the memorization portion of the experiment and the recall portion of the experiment. The researchers then subtracted the average memorization heart rate from the average recall heart rate for each subject to find the difference between the two. This was the measurement

used to compare heart rates between groups because it accounted for baseline differences in heart rates of each individual subject.

The measurement used to test total LTM recall was the number of objects each subject correctly recalled during the entire recall phase. Rate of recall was measured by dividing the number of images subjects recalled correctly during each fifteen second time interval of the recall phase by 15 seconds.

Measurements from each of the three physiological tests were subjected to statistical analysis (ANOVA) using Microsoft Excel and StatPlus. A p-value of 0.050 was decided to be the critical p-value determining whether or not a result from ANOVA testing was significant.

Results:

Using a pulse oximeter, we found the average difference in heart rate from the memorization phase to the recall phase. The control group had an average difference of 5.615 ± 5.61 , EG1 was found to have an average difference of 3.351 ± 3.68 , and EG2 was found to have an average difference of -0.101 ± 0.68 . Analysis of this data revealed no statistically significant differences occurred among these conditions ($p=0.399$) (Figure 1).

To measure LTM retention/recall, we scored the number of pictures correctly recalled one hour after the subjects were given 60 seconds to study 20 different shapes. The mean of pictures recalled during the control condition was 9.933 ± 3.20 . The mean of pictures recalled for EG1 was 9.75 ± 2.77 and the mean of pictures recalled for EG2 was 8.583 ± 2.27 . No statistical significance was found between EG1, EG2, and the control group under these conditions ($p=0.431$) (Figure 2).

While measuring rate of LTM recall, it was found that the control group had an average number of pictures recalled per second of 0.471 ± 0.172 during the 0-15 second time frame. During this same time frame, EG1 was found to have a rate of 0.494 ± 0.143 pictures per second and EG2 was found to have a rate of 0.361 ± 0.100 pictures per second (Figure 3). During the 16-30 second time frame, the control group had a rate of 0.156 ± 0.093 pictures per second, EG1 had a rate of 0.128 ± 0.112 pictures per second, and EG2 had a rate of 0.089 ± 0.052 pictures per second (Figure 4). During the 31-45 second time frame, the control group had a rate of 0.027 ± 0.042 pictures per second, EG1 had a rate of 0.022 ± 0.033 pictures per second, and EG2 had a rate of 0.067 ± 0.064 pictures per second (Figure 5). During the 46-60 second time frame, the control group had a rate of 0.009 ± 0.23 pictures per second, EG1 had a rate of 0.006 ± 0.019 pictures per second, and EG2 had a rate of 0.039 ± 0.045 pictures per second (Figure 6). During the 61-75 second time frame, the control group had a rate of 0.000 ± 0.000 pictures per second, EG1 had a rate of 0.000 ± 0.000 pictures per second, and EG2 had a rate of 0.011 ± 0.026 pictures per second (Figure 7). During the 76-90 second time frame, the

control group had a rate of 0.000+/-0.000 pictures per second, EG1 had a rate of 0.000+/-0.000 pictures per second, and EG2 had a rate of 0.006+/-0.019 pictures per second (Figure 8).

Significant differences between the groups for two time intervals were found for the rate of LTM recall test. During the 31-45 second time frame, it was found that the three groups showed a significant difference from each other ($p=0.049$). It was found that EG1 vs. EG2 was the source of statistical difference in this category ($p=0.043$). The control group vs. EG1 ($p=0.767$) and the control group vs. EG2 ($p=0.061$) did not show any statistically significant difference.

A statistically significant difference was also found between all three groups for the 46-60 second time interval ($p=0.019$). The control group vs. EG2 ($p=0.033$) and EG1 vs. EG2 ($p=0.026$) showed a significant difference, but the control group vs. EG1 did not ($p=0.695$).

No significant differences were found during the 0-15 second ($p=0.064$), 16-30 second ($p=0.172$), 61-75 second (0.106), or 76-90 second ($p=0.333$) time frames of the rate of LTM recall test.

Discussion:

Our initial findings show no evidence that the presence of an odor affects either heart rate or total LTM recall. Figure 1 attached shows that the difference between heart rates for the control group, EG1, and EG2 are not significantly different, and the subjects' results range from a difference of -14 BPM (EG1) all the way to 21.267 BPM (control group). Likewise, in Figure 2 it can be seen that the total number of pictures recalled for each group shows a similar result. These results are also not statistically significant.

These findings disagree with previous research, which has found that the presence of an odor does affect the ability of total LTM recall (8, 14) and also increases a subject's heart rate significantly (1). Because of these conflicting results, additional research needs to be done in this area in order to conclusively determine whether or not olfactory stimulation plays a role in these physiological variables. Our results may not have shown a statistically significant relationship for a number of reasons; our sample sizes for each group may have been too small and/or the odor (when used) may not have been concentrated enough to make a physiological change in the subjects. The pulse oximeters we used to record the heart rate were often jumpy in their readings, creating scattered heart rates (readings that would suddenly drop or rise dramatically) which may have affected the final average heart rate results. Future research should attempt to normalize these findings.

A statistical difference was found among groups in the measurements for LTM rate of recall. We hypothesized that subjects experiencing an odor in both phases (EG1) would have quicker rates of LTM recall, and that the subjects experiencing no smell throughout (control

group) or smell only during the recall phase (EG2) would have a baseline rate of LTM recall. Our results do not support this hypothesis.

Statistical differences between the three groups were found in the 31-45 second and 46-60 second time intervals of the recall phase. This implies that for the first 30 seconds of the recall phase, all three groups performed statistically the same in recalling objects. As time went on, however, differences began to emerge that were likely due to the changed variable in our study (the presence or lack of odor). Around the one-minute mark, statistical differences between the three groups once again disappeared; according to our data, this is when the majority of people in all three groups were no longer able to recall any objects (many subjects stopped the test themselves right around the one minute mark).

To figure out the source of the significant difference ($p=0.049$) in recall rate during the 31-45 second interval, ANOVAs were run comparing a single group to one other group. By p-values, it was determined that the control group and both experimental groups had insignificant differences, but that the difference between EG1 and EG2 was significant ($p=0.043$). These results are visualized in Figure 5.

The same process as stated above was used to find the source of the significant difference in the 46-60 second interval. The p-value between all three groups was 0.019, which means the difference between the groups in this interval was even more pronounced than the 31-45 second interval. ANOVAs between 2 groups at a time showed that the control group vs. EG2 and EG1 vs. EG2 both had a significant p-value ($p=0.033$ and $p=0.026$, respectively). This relationship is visualized in Figure 6. Data from EG2 is extremely different from both EG1 and the control group. In this time interval as well as in the 31-45 second time interval, subjects in EG2 are able to recall more objects than those in EG1 and the control group.

A previously discussed finding in this study was that the total number of objects recalled was not statistically different across the three groups (Figure 2). As such, we can infer that although subjects in EG2 were able to recall objects for a longer period of time than subjects in the other groups, they did not recall *more* objects than the other subjects. Instead, subjects in EG2 were simply slower at recalling objects than subjects in other groups were.

This finding leads us to believe smell does play a role in LTM recall. Subjects who experienced the same environment (presence or lack of an odor) during both the recall and memorization phases were not affected in their ability to quickly recall the images they had memorized an hour before. Subjects who did experience a change in environment (EG2) were hindered in their ability to recall objects as quickly as they may have been able to if the change in environment had not occurred. Our findings suggest that the rate of LTM recall is affected by a change in odor, not by simply the presence of an odor on its own. This finding leads to a new hypothesis, and hopefully to more research in the future.

Sources

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