ABSTRACT

EFFECTS OF PLEASANT AMBIENT ODOR AND VERBAL PRIMING ON MEMORY RECALL

by Jennifer Ret

Previous research suggests that odors emitted into a learning environment may facilitate recall, and that telling people they are being exposed to something that will help them remember may further enhance the effects of the odors. The study examined the effects of a pleasant olfactory cue and verbal priming statements on a memory recall task. Two hundred eleven undergraduates were assigned to 1 of 4 conditions: odor/priming, odor/no-priming, no-odor/priming, or no-odor/no-priming. The odor participants were exposed to a pleasant scent during learning and recall. The priming participants were also alerted to the odor and told it had memory enhancing properties. Although no significant differences were detected between the odor and no-odor groups, women who were exposed to a priming statement recalled significantly more correct letter sequences than women who were not. This unobtrusive, highly cost-effective intervention should be investigated further with younger students to determine its potential in the classroom.
EFFECTS OF PLEASANT AMBIENT ODOR AND VERBAL PRIMING ON MEMORY RECALL

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Effects of Pleasant Ambient Odor and Verbal Priming on Memory Recall

Aromatherapy and essential oils marketed for a broad spectrum of human ailments have begun to draw a great deal of attention in both the popular and scientific literature. From lavender-scented baby wash to aromatherapy massage services, the lay public has taken a considerable interest in the use of scent and odor for all sorts of purposes. *Prevention* (2005) recently published an article about the effects of spraying vanilla scent on the mattresses of incubators housing premature babies. It described a study in which a group of French scientists had discovered that the smell of vanilla not only increased respiration of the infants, but also decreased the occurrence of sleep apnea. Thus far, these interests have generally been limited to odor’s ability to relax, soothe, or stimulate. However, there is a growing body of evidence which suggests that the properties of certain odors can also facilitate the ability to recall information when presented in both the learning and recall environments.

Compared to the fields of other perceptual kinds of memory (i.e., auditory/verbal, visual) olfactory memory research is relatively young (Issanchou, Valentin, Sulmont, Degel, & Koster, 2002). To date, most work has focused on memory for odors themselves, odor names, the interaction between mood and odor, the role of odors in episodic memories, and the pathology of olfactory perception as a result of age or illness (Bhalla, Marcus, & Cornwell, 2000; Carrasco & Rideout, 1993; Ehrlichman & Halpern, 1988; Goldman & Seamon, 1992; Gottfried, Smith, Rugg, & Dolan, 2004; Herz & Cupchik, 1995; Murphy, Nordin, & Acosta, 1997; Nordin & Murphy, 1998; Potagas et al., 1998). However, there is a growing body of research that points to the effectiveness of certain odors for enhancing retention and recall of learned information (e.g., Schab, 1990; Smith, Standing & deMan 1996; Crosthwaite & University of Dayton, School of Education, 1997; Gilbert, Knasko, & Sabini, 1997; Herz, 1997; Moss, Cook, Wesnes & Ducket, 2003).

*Basic Physiology of Smell*

The olfactory system has three main parts: the olfactory mucosa, the olfactory bulb, and the olfactory brain. At the very top of the nasal passages is the olfactory cleft, which is lined with the olfactory epithelium and a thick, mucus covering (Engen, 1991). Together, the olfactory epithelium and the mucus that covers it make up the olfactory mucosa. The olfactory epithelium, occupying the space of about 5 cm², contains approximately 10 million olfactory
receptor cells (neurons), which are regenerated about once each month (Engen, 1991; Kalat, 1998). Interestingly, this density of sensory receptors is matched only by the visual system.

At the ends of the neurons, embedded in the mucous lining, are small hairs called cilia that are believed to contain the actual receptor sites for odor molecules. Like the receptor cells of other sensory systems, the olfactory receptors gather information from the environment and transform it into an electronic signal the brain can understand. In the olfactory system, the receptors include details about the quality and strength of environmental odors in their message. The new, electronic information is then passed along to the appropriate sensory area of the brain in order to be processed further. In the olfactory system, the first stop in the brain is the olfactory bulbs (Engen, 1991). The olfactory bulbs are the enlarged ends of the olfactory lobes, which extend like soft antennae from the anterior cerebral hemispheres. The messages received here from the receptors in the olfactory mucosa are coded according to which neurons they are received from and what the electronic information from the receptors says about the odor. This “translated” message is then sent out to the areas of the brain associated with olfaction, again in an electronic form, through different routes (fiber tracts) depending on the destination of the information.

The olfactory brain includes several neuroanatomical structures. One of these is the hypothalamus, which controls many motivated human behaviors including eating, drinking, sleeping and sexual behavior. The hypothalamus also regulates the pituitary gland, an important part of the endocrine system. Of particular interest to the present study however, is the connection between the olfactory neurons and the amygdala, which is thought to play a major role in the mediation of human emotions and which also has direct connections to the hippocampus, the hub of human memory function. Researchers have demonstrated the strength of this connection through studies involving the pairing of odors with positive and negative words and images (Herz and Cupchik, 1995), and by presenting odor cues associated with personally meaningful memories during functional magnetic resonance imaging (fMRI) (Herz, Eliassen, Beland & Souza, 2004). This secondary connection between the olfactory and memory systems, bridged by the amygdala, provides the anatomical basis for the current study.
Olfaction and Memory

The effects of odors upon memory performance have been investigated in the literature for the last two decades and several key studies have helped to build the foundation for the present research. In a landmark investigation by Schab (1990), three separate experiments were conducted to examine the relationship between odors presented in both learning and testing environments. Participants were given a set of words to learn and then recall at two separate sessions during which either consistent (the same odor at learning and recall), inconsistent (one odor present at learning and a different odor at recall), or no ambient odors were present. When the odors were consistent between sessions, the subjects performed significantly better at recalling the words than when inconsistent ambient odors were present, or when no odor was present in either condition. No mention of the odors was made to the participants during the study, demonstrating that the improvement was not facilitated by any verbal memory cues. Another independent study also demonstrated that a consistent odor cue at learning and relearning sessions can lead to superior memory for a novel word list than disparate odors between sessions (Smith, Standing & deMan, 1996).

In order to further analyze the effects of odor presence on various aspects of performance, Moss, Cook, Wesnes, & Duckett (2003) employed a computerized cognitive measure called the Cognitive Drug Research (CDR) task. The CDR is a computerized instrument that is designed to allow investigators to look more closely at various dimensions of memory and to determine which ones are specifically impacted in a given condition. The researchers presented participants with two essential oils, rosemary and lavender, during the task. These oils were selected because of their purported opposite effects on cognitive performance. While rosemary is believed to increase reaction time, lavender has been shown in a number of studies to have a marked sedative effect (e.g., Knasko, 1992; Ludvigson & Rottman, 1989). As expected, results showed a significant decrement in the participants’ reaction time scores as a result of administration of lavender, presumably because of its sedative properties, but a significant boost in the overall memory performance type with exposure to rosemary. Interestingly, the researchers also found a decrement in the memory speed domain of the CDR with exposure to both odors, as compared to no-odor controls using the same task. The odor groups in this study both reported a significantly more contented mood following the challenging test battery than the control groups. This combination of results may indicate that the effects of
odor administration are somewhat limited, or that perhaps the odors themselves created a more positive or soothing atmosphere, and as a result, the participants were slowed to a more comfortable pace, allowing them to better focus on the tasks at hand. In both this study and the Schab study (1990), the researchers specifically avoided mentioning the presence of odors, presumably because these experiments were designed to analyze only the effects of the odors on various behaviors rather than the expectancy of odors. Although these studies provide a wealth of information about the effects of the odors themselves on performance, they do not tell us how perceptions of presented odors might affect performance.

The Olfactory Placebo Effect

The theory of the “placebo effect” is that human behavior changes based upon our expectations. If we are told that we will be getting a drug that will help us, we improve, even if the drug is really just a sugar pill with no medically significant properties at all (i.e., it is a placebo). In reality, the improvement occurs because of the participant’s perception of the “drug.” Similarly, this effect can occur in psychological or educational studies when a group is told they will be getting the benefit of a treatment when there is actually nothing at all being done. We can “subtract out” the placebo effect by comparing these participants (those who were told they would be getting treatment but who actually didn’t) to those who really did get treatment.

In order to investigate the effects of expectancy in the realm of olfactory research, several studies have deliberately alerted study participants to the presence of odors in a learning environment. The goal of alerting participants to treatment, a procedure commonly known as priming, is to draw the attention of the learner to various cues in the environment. One olfactory priming study randomly assigned volunteers to one of three odor groups; peppermint, osmanthus (a sweet, floral scent), or a no odor control group (Herz, 1997). Participants were placed in experimental environments wherein the corresponding smell was present. Researchers then provided the participants in these scented environments with words to remember, specifically mentioning the presence of the odors at the time of learning and then later at a delayed recall session. Results indicated that participants in the osmanthus group recalled more words than those in the peppermint or control groups, but that both odor groups recalled significantly more words than those in the no odor group. By using a priming procedure in which participants were
specifically alerted to the presence of the odors, researchers could ensure that the participants perceived the memory cues that had been provided for them, however, there was no control for a placebo effect. That is, individuals in the control group were not given the same verbal indications about the presence of an odor (priming statements), which may have, in and of themselves, aided in recall by serving as an additional, different type of memory cue to aid in later performance.

Researchers have demonstrated the strength of olfactory placebo effects by generating perceptions of feigned odors in large groups of individuals. By pouring a clear “mystery” liquid (actually distilled water) onto a cotton ball and merely suggesting an associated odor, then passing the cotton around a lecture audience, one investigator found that 75% of the audience members actually reported perceiving the odor they’d been told about (Slosson, 1899). In another study, O’Mahony (1978) found that people could be convinced of the presence of olfactory cues via the broadcast of tones on radio and television, and that some listeners even reported changes in olfactory odors when an “ultrasonic tone” (actually no tone) was played. These studies demonstrate the power of suggestion in the realm of olfaction and lend credence to the idea that olfactory placebo effects do in fact exist.

Olfaction and Sex Differences

Another current line of research associated with the biology of smell functions in humans is that of sex differences as it pertains to memory for and naming of odors. A literature review by Brand and Millot (2001) indicated that sex seemed to be an important factor in all olfactory abilities, with women generally being superior to men, especially in terms of odor identification and memory for odors. However, in the overwhelming majority of studies investigating the differences between men and women and their ability to recall target odors from a set, all gender effects disappeared when verbal memory strategies were controlled for (Brand & Millot, 2001; Choudhury, Moberg, & Doty, 2003; Larsson, Finkel, & Pedersen, 2000; Larsson, Lovden, & Nilsson, 2003; Oberg, Larsson, & Backman, 2002). In support of the notion that the female olfactory advantage has more to do with verbal capabilities than with a keener sense of smell, these same studies found that women tended to be better able to identify odors verbally than men. Therefore, it seems that memory for odors may not be impacted as strongly by sex or biology as by the ability to use language to recall target odors.
Interestingly, it appears that males and females may respond differently to priming statements regarding olfactory stimulus cues as well. One study specifically targeted the interaction between gender and priming by randomly assigning 40 male and 40 female participants to either a priming condition or a non-priming condition (Gilbert, Knasko, & Sabini, 1997). Based on their assignment, participants were told that the purpose of the study was either to examine how well people focus on clerical tasks (no priming), or to examine how the “presence of an odor” would affect their performance on a clerical task (priming). The members of these two groups were then assigned to one of three odor conditions, pleasant (osmanthus), unpleasant (ammonia) or no-odor. Each group was asked to complete a clerical task called digit deletion while exposed to its specific odor condition. In order to examine placebo effects, participants in the no odor-priming condition were told that “a large number of the American public can not smell this particular odor— you know, just like some people cannot wiggle their ears. It’s okay that you don’t smell it—we believe it may affect your performance even if you can’t.” Women performed significantly better on this clerical task than men when given a priming statement, regardless of whether the actual odor in the room was pleasant, unpleasant or feigned. Conversely, men performed significantly better than women when there was no priming statement given.

In combination with what is known about women’s ability to identify and recall odors more effectively than men, evidently by using verbal cues to assist them, it is worth investigating the sex-differences in olfactory priming in the context of a more educationally relevant task such as spelling. Perhaps women’s increased susceptibility to priming as well as their efficacy in making verbal-olfactory connections could lead to better performance than men on a task when they are provided with both of these types of memory cues. The present study seeks to explore this possibility in addition to investigating the effectiveness of these cues when provided in the context of an educationally relevant task, such as learning and recalling a set of novel words, much like a spelling test. We will also seek to further the limited research in the area of memory recall using olfactory context cues to analyze the effect of priming participants prior to their exposure to an odor intended to be used as a context cue, and to compare the effects of priming on memory performance among men and women.
Thus, the present study will address 3 major research questions: 1.) Will participants who are specifically informed about the presence of an odor in their environment and its memory-enhancing properties prior to learning and recall (primed for odor exposure) perform better on a language-related memory task requiring both immediate and delayed recall than those who are not told about the odors?, 2.) Will participants in experimental groups, regardless of whether they are primed or not, perform better at recall than participants in the no-odor + no-priming group?, and 3.) Will women perform better than men on a language-based memory task when primed for odor exposure?

Methodology

Participants and Setting

A total of 230 undergraduate students took part in the study (mean age = 19.3 years, SD = 1.31). Of these, 35.6% were males, 37.3% were freshmen, 32.6% were sophomores, 14.3% were juniors, and 15.7% were seniors. The mean GPA for the group was 3.34 (SD=.48). Students were recruited from courses in various disciplines at a Midwestern university and were offered a small amount of extra credit by their instructors in exchange for their participation in the study. Participants were given a choice of eight appointment slots and were asked to sign up for the one that was most convenient for them. They were told to set aside one hour on each of two days (48 hours apart) in order to take part in the study, and that it would require them to “learn some words” and tell the experimenter a little bit about themselves. Students recorded their name and contact number in a slot on the sign up sheet and they were contacted via e-mail three days before the study and by phone the night before the study to remind them to attend. Participants were assigned to one of four experimental conditions based upon room availability and the study appointment times they chose: (1) odor + priming (n=46), (2) odor + no-priming (n=62), (3) no-odor + priming (n=69), or (4) no-odor + no-priming (n=53).

Two similar experimental rooms were used. Both measured approximately 30’ X 30’, were windowless, and each was furnished with long tables and chairs. Room temperature was approximately 70°F. Moderate lighting was provided by overhead fluorescent bulbs. The door to the experimental environment remained shut unless participants were entering or leaving the room before or after a session. A machine called a diffuser, which is used to emit ambient odors, was present in the experimental environment regardless of the odor condition. The experimenter neither touched nor made any reference to the diffuser while the participants were in the room.
Regardless of the experimental condition, any questions directed to the experimenter regarding an odor in the room and/or the diffuser, were answered with “all of your questions will be answered once we have completed the study.”

**Dependent Variable**

*Immediate Recall.* At the immediate recall session (5 minutes after initial learning), participants were asked to complete a free recall test (see Appendix C), which consisted of a single sheet with 20 blanks printed on it. They were given 5 minutes to recall as many of the animal names as they could that had been presented to them at the start of the session and write them on the free recall test. The students were told that the words did not have to be in any specific order and that they should spell the words the best they could. These instructions were also printed on the free recall test as a reminder. The tests were scored by graduate assistants following the session. Scores were obtained for both the number of words spelled correctly, called errorless spellings (ES), and correct letter sequences (CLS). ES was calculated by summing the number of words written on the free recall test that exactly matched any of the words on the initial word list, allowing for 20 possible points. If the same word was written on the free recall test more than once, credit was only awarded to one instance of the word, even if the others were spelled correctly.

CLS were calculated by considering each word written on the free recall sheets. Credit was awarded for beginning the word with the correct letter (1 point) and ending the word with the correct letter (1 point), and each correct letter-join in between was awarded one point. A letter-join was defined as a letter and the letter immediately to the right of it. This allowed for a total of 125 possible points. For example, if the student responded with “ibes” for the list word “ibex”, she received 1 point for beginning the word with the letter “i,” one point for the i-b join and one point for the b-e join, but 0 points for the e-s join and 0 points for ending the word with the letter s instead of x. So, out of 5 possible points available for the word ibex, the participant would have received 3. White and Haring (1980) designed the CLS scoring system to serve as a more sensitive measure of recall than the dichotomous ES scoring system described above. Indeed CLS is often used in studies of writing fluency and spelling instruction specifically for this purpose (e.g., Deno, Marston & Mirkin, 1982; Vaughn, Schumm, & Gordon, 1993).
Because one of the goals of the study was to determine the effectiveness of odor as a recall cue, it was logical to use the most sensitive means available.

Delayed Recall. Identical free recall tests were distributed at the delayed recall session (48 hours after initial learning, see Appendix D) and were scored by graduate assistants following the delayed session. Again ES and CLS scores were obtained for each participant using the same methods described above.

Design
Experimental Conditions

Odor + priming. Twenty drops (mL) of osmanthus oil were dispensed into the diffuser with a pipette, and the diffuser was turned on 15 minutes prior to the scheduled arrival of the participants and remained running until the experimental condition ended, both in the immediate and delayed conditions. Additionally, a priming statement (see Procedures, below) was administered at the immediate and delayed recall sessions. Osmanthus was chosen because it was characterized as a pleasant odor and had improved participants’ performance in a prior study (Herz, 1997), and because of its rarity, it was expected to be novel for many participants, making it unique to the learning environment.

Odor + no-priming. Participants in this group were exposed to the odor, using the procedures described above, however, the priming statements delivered to the odor + priming group at the immediate and delayed sessions were omitted. Instead, the sessions began with the distribution of pens and pencils and administration of the directions for the learning period (see Procedures, below). This was followed by distribution of the demographic survey (see Appendix B), for which the participants were given 5 minutes, and 5 minutes for the free recall test. At the delayed recall session 48 hours later, 20 drops of osmanthus oil were placed in the diffuser. It was turned on 15 minutes prior to the scheduled arrival of the participants and ran until the experimental condition ended. Participants were asked to wait quietly outside of the experimental environment in an open seating area and they were shown in after everyone had arrived. The free recall test was distributed and participants were given 5 minutes to complete it, after which the tests were collected and odor questionnaires (see Appendix E) were handed out.
The participants were dismissed from the research study after the questionnaires were completed and returned.

*No-odor + priming.* At the immediate recall session for the no-odor + priming condition, the diffuser was simply placed in the experimental environment prior to the arrival of the participants but osmanthus oil was not dispensed into it and the diffuser was never turned on. After participants were shown into the experimental environment and provided with pens or pencils, they were exposed to the priming statement described in the Procedures section (below). The procedures for the learning period, demographic survey and free recall test were the same as in the other conditions. At the delayed recall session 48 hours later, the diffuser was again placed in the experimental environment but was not turned on and did not contain the osmanthus oil. The participants were again exposed to a statement very similar to the one written below, they were given 5 minutes for the free recall test, and they were provided with the odor questionnaire. Using this no-odor + priming group, the present study specifically examined the placebo effect, specifically whether or not it was actually more powerful than the olfactory cues themselves.

*No-odor + no-priming.* In the immediate recall session for the no-odor + no-priming condition, the diffuser was placed in the experimental environment without the osmanthus and was not turned on. The priming statement was omitted and the researcher simply gave the directions for the learning period, the demographic survey and the free recall test. At the delayed recall session, the diffuser was placed in the experimental environment without osmanthus oil and was not turned on. The researcher gave the directions for the free recall test, allowed 5 minutes to complete it, and afterwards distributed the odor questionnaire.

Because it was important to determine whether or not participants actually perceived the odor cue that had been provided for them, and since they were not allowed to discuss the cue with the researcher during the course of the study, an important item on the odor questionnaire was related to the participants’ ability to detect the odor. Specifically, the question read, “Did you notice a distinct odor in the room?” Participants were forced to choose either yes or no. This measure helped to ascertain the integrity of the independent odor variable since it could not be directly assessed during the study.
The present study utilized a four group, 2x2x2 randomized experimental design in which there were two levels of odor (odor and no-odor), two levels of priming (priming and no-priming) and two levels of recall (immediate and delayed). All participants had an equal chance of being assigned to any of the four groups. Since the study was experimental (the independent variables were deliberately manipulated while the others were held as constant as possible), an analysis of variance (ANOVA) was used to compare the means of the four groups, with the null hypothesis being that all four groups would be equal and the alternative being that at least one of the four groups would recall more words in either the delayed or immediate recall condition than the others. Since there were more than two groups, and multiple comparisons would thus need to be made, the ANOVA procedure introduced less chance of making a Type I error than multiple t-tests would have. The immediate and delayed scores were analyzed separately using two individual one-way ANOVAs.

Procedures

The experimental procedures used in this study were approved by the Miami University Institutional Review Board for human participants.

Informed consent was obtained from participants outside of the experimental environment just prior to the start of the study. This was to ensure that they remained unaware of the odor inside the experimental room until the study began. After everyone had arrived, and informed consent had been obtained, participants were then led into the experimental room. Students were given either a pencil or pen at the start of the session if they had not brought one. Individuals in the odor + priming group were then exposed to the following statement by the experimenter:

“We are conducting a series of studies to test the effectiveness of certain odors and their ability to enhance memory recall in college students. There has been a particular odor released into this room prior to your entrance. You may or may not be able to smell it – you know, like some people can wiggle their ears and some people can’t. Other studies have shown these odors to be effective for enhancing memory recall whether or not you can smell them. Please take a few moments...and take a few deep breaths...and notice the particular odor in the room at this time (allow 30-second pause). Now, we’ll begin the study.”
Afterwards, they were presented with a word list (see Appendix A) made up of 20 novel animal names taken from a face-name mnemonic technique study (Carney & Levin, 2001). All words were nouns between four and nine characters in length. Students were also given two blank sheets of unlined paper and were instructed to learn the 20 animal names over the next ten minutes using the “most effective learning strategy available” to them at that time. They were told that they could use the blank pages to help them if they chose. These 10 minutes were termed the learning period. At the end of the learning period the experimenter collected the word list and the blank sheets of paper.

Participants were then given 5 minutes to complete a demographic survey (see Appendix B) which included questions about age, estimated GPA, and class, as well as allergies, colds and sinusitis, and the participants’ earliest memories of school. This was used as a competing task to interfere with their continuing to rehearse the words and as a means to collect demographic information on the participants.

Next, participants were presented with the free recall test containing 20 blanks as described above. The instructions to recall as many words as they could in 5 minutes, to print them on the page and to spell them the best they could, were read to the participants by the experimenter from the free recall test. The tests were collected at the end of the five-minute period and students were reminded to return 48 hours later for the second session. In order to control for practice effects and to isolate the effects of the odor and the priming, however, they were not told that they would be required to recall the same list of words.

At the delayed recall session, twenty drops (mL) of osmanthus oil were dispensed into the diffuser using a pipette, and the diffuser was turned on 15 minutes prior to the participants’ scheduled arrival and ran until the experimental condition ended. The participants were asked to wait in an open seating area until everyone had arrived, after which they were directed into the experimental environment.

At the start of the delayed session, participants were exposed a statement very similar to the one provided at the first session. Next they were given the identical free recall test described above and were asked to recall as many of the words as they could from the first session. The same rules for spelling and order were in place. Researchers collected all recall sheets at the end of the 5-minute period and the students were given a twenty-item odor questionnaire, which
asked about their perceptions of the experimental environment, specifically the odor. After participants completed this short survey, they were dismissed from the research study.

In the odor conditions, participants were exposed to osmanthus odor during both the immediate and delayed recall sessions, and this odor was present throughout the entire condition. In the priming conditions, participants were exposed to the priming statement written above at the start of both the immediate and delayed recall sessions. At the immediate recall session all participants, regardless of the experimental condition to which they had been assigned, were given 10 minutes to learn the list of 20 novel animal names, 5 minutes to complete a demographic survey, and 5 minutes to complete a free recall test (recall as many of the animal names as they could). Forty-eight hours after the immediate session, they returned to the same experimental environment and they were given 5 minutes for another free recall test, after which they were asked to complete an odor questionnaire.

After the odor questionnaires were collected at the end of the delayed session, participants were fully debriefed and told the purpose of the project was to determine if the presence of an olfactory stimulus in the learning and/or testing environment affected the recall of 20 novel words 48 hours after being introduced to them. Each group was told that they were assigned to one of four groups based upon the date/time for which they had signed up to participate, and that based on the findings, researchers would examine which learning condition allowed for the most words recalled. Participants were given the researchers’ names and contact number if they were interested in receiving the results from the study. Each person was then allowed to leave the experimental room and their participation in the study was terminated.

Reliability
In order to establish the reliability of both the ES and CLS scoring systems, inter-scorer agreement was calculated. Thirty percent of the free recall tests from the immediate recall condition and thirty percent of the tests from the delayed condition were randomly selected and scored by both the primary investigator as well as a graduate assistant. Inter-scorer agreement ranged from 97%-100% (mean = 98.6%) for ES scores and from 87%-100% (mean = 90.2%) for CLS scores.

Results
Only the data acquired from those participants who attended both the immediate and delayed recall visits and who met all of the criteria for participation in the study was included in the analyses. Eighteen of the recruited participants failed to return for the delayed recall session and their data were excluded from the analysis. One participant reported that she was pregnant after taking part in the first session, and because of the strong effects odors may have upon pregnant women, this participant’s data was also excluded from the analyses. The final composition of each experimental group is reflected in Table 1. In order to verify that groups were relatively equal prior to the start of the experiment, their reported grade point averages were compared, with no significant differences between the groups $F(3, 174)=1.19 \ (p=.316)$. Additionally there were no significant differences between the groups with regard to reported seasonal allergies $F(3, 210)=1.20 \ (p=.312)$ or colds $F(3, 209)=2.30 \ (p=.08)$.

Research Questions 1 & 2: Will participants who are primed for odor exposure perform better than those who are not, and will participants in experimental groups perform better than participants in the no-odor + no-priming group?

The first two research questions addressed the effects of priming and odor on the participants’ ability to recall words from the word list during an immediate recall session (5 minutes after learning) as well as a delayed recall session (48 hours after learning). In order to detect any significant differences that existed between the four groups, a univariate analysis of variance (ANOVA) was conducted for ES scores, reflected in Table 2, and CLS scores, reflected in Table 3. ES scores did not differ significantly among the four groups in the immediate condition $F(3, 210) =1.23 \ (p=.30)$, nor in the delayed condition $F(3, 210) =1.16 \ (p=.325)$. Results for CLS scores also showed no significant differences between the groups in the immediate $F(3, 210) =0.95 \ (p=.419)$, or the delayed conditions $F(3, 210) =1.49 \ (p=.216)$. A graphic depiction of the means for each of the four conditions is presented in Figures 1 (ES scores) and 2 (CLS scores). Exploratory post-hoc tests were conducted using Tukey’s Least Significant Difference (LSD) method and revealed that participants in the no-odor/priming group produced significantly more CLS at the delayed recall session than those in the no-odor/no-priming group ($p=.043$). The post-hoc test results did not yield any significant differences between the four groups in the delayed session using the ES scores, nor in the immediate session with regard to either CLS or ES scores. It is important to note that, although no main effects
were detected for odor or priming, the ANOVA procedure did elucidate an interaction effect between these two factors, as reflected in Figures 3 (ES scores) and 4 (CLS scores).

Research Question 3: *Will women perform better than men when primed for odor exposure?*

In order to answer the third research question regarding the effects of priming and odor on the different genders, a separate ANOVA was run to analyze the ES and CLS scores in the immediate and delayed conditions for males and females. For males, no differences between the four groups were detected using either ES scores $F(3, 72) = 1.54$ (p=.211) or CLS scores $F(3, 72) = 1.53$ (p=.215) in the immediate condition. For males in the delayed condition, no differences were found using the ES scores $F(3, 72) = .358$ (p=.784) or the CLS scores $F(3, 72) = .621$ (p=.604).

For females, no significant differences between the four groups were detected using the ES scores in the immediate $F(3, 137) = .663$ (p=.576) or the delayed condition $F(3, 137) = 2.18$ (p=.093). Among the four groups, females’ immediate CLS scores were not significantly different $F(3, 137) = .611$ (p=.609). However, females’ CLS scores were significantly different among the groups at the delayed session $F(3, 137) = 3.57$ (p=.016). Post-hoc tests of this result using the Tukey’s LSD method revealed that females exposed to priming statements in the absence of an odor (no-odor + priming) achieved higher ES scores than women exposed to priming statements in the presence of an odor (odor + no-priming, p=.04) and women exposed to neither an odor nor a priming statement (no-odor + no-priming, p=.04). Additionally, the women exposed to priming statements in the absence of an odor recalled significantly more CLS at the delayed session than the women in any other group (no-odor + no-priming p=.005, odor/no-priming p=.023, and odor/priming p=.017).

In order to determine whether or not the priming improved female performance over male performance in the immediate and/or delayed conditions, the performance of females in the groups receiving the priming statements (odor + priming and no-odor + priming) was compared to the performance of males in the groups receiving no priming statements (odor + no-priming and no-odor + no-priming). The results of this ANOVA indicated that there were no significant differences between the groups’ ES scores in the immediate $F(3, 116)=1.72$ (p=.17) or delayed conditions $F(3, 116)=1.57$ (p=.19). Additionally, there were no differences in the groups’ CLS scores in the immediate $F(3, 116)=1.62$ (p=.19) or delayed conditions $F(3, 116)=2.0$ (p=.11). Despite these insignificant overall findings, further exploratory analyses were conducted using
the Tukey’s Least Significant Difference method which revealed that at the immediate session, the females in the no-odor + priming group recalled significantly more exactly-spelled words (p=.027) and significantly more CLS (p=.049) than men in the no-odor + no-priming group. These exploratory analyses did not detect any significant differences between delayed performance (using either the ES or the CLS scoring system) of the females who received priming statements and the males who did not.

Discussion

The results of this investigation partially support the use of ambient odors, specifically osmanthus, as memory aides for simple verbal recall tasks. Tests of statistical significance did not detect main effects for priming or odor exposure on exact spelling scores or correct letter sequences when members of both genders were considered. This is contrary to the literature in this area, which indicates that individuals do indeed perform better on tasks such as this when provided with an olfactory cue in addition to other cues. The interaction graphs (Figures 3 and 4) illustrate several trends in the data, which are important to note. Participants who were not primed tended to recall more complete words (higher ES scores) with an odor than without an odor. In contrast, participants who were primed tended to recall more complete words (higher ES scores) without an odor present than with an odor. It appears that when considering partial words (CLS scores), these trends are not so pronounced, perhaps because of the increased variability introduced by the CLS scoring procedure. These trends in the data do seem to support the current literature, although there were no statistically significant main effects.

Results of the data acquired from female participants indicated that there was a significant difference in women’s delayed recall scores. More specifically, women who were exposed to priming statements, regardless of whether or not the odor they were told about was actually present, recalled significantly more correct letter sequences 48 hours after learning than women who were not exposed to these statements. This result serves to further support previous findings and indicates that women may indeed be more suggestible than men when it comes to performance on simple verbal tasks such as memorizing and recalling a list of novel words. This also suggests that there may be a placebo effect working to increase women’s scores. That is, the mere suggestion that they were receiving treatment (or, in this case, being exposed to a
feigned memory-enhancing odor) may have improved their performance. And in turn, it appears that this effect was a more powerful memory aid for women than the odor itself.

Contrary to the literature (Gilbert & Knasko, 1997), men did not show a decrement in performance when provided with a priming statement. Instead, men in all four groups performed similarly, regardless of odor or priming statements.

The literature in this area also suggests that women exposed to priming statements (regardless of the presence of an odor) tend to out-perform men who are exposed to priming statements. However, in this study, such an effect could only be detected with exploratory analyses and only in the immediate recall condition, 5 minutes after learning. This gain does not appear to be maintained over time.

It is possible that these disparities may be due to the fact that a large number of participants reported that they did not detect an odor in the experimental environment. In the odor + priming group, 79% of the participants indicated that they detected a “distinct” odor in the room during the study. In the odor + no-priming group, only 35% reported that they detected the odor, which was incidentally the exact same percentage reporting an odor in the no-odor + priming group. In the control condition (no-odor + no-priming), only 16% of the participants reported detecting an odor. This important limitation should be considered for future research; perhaps running pilot studies in an experimental environment in which various titrations of an odor are emitted into the air until the appropriate “detectable” titration is determined (say 90% of participants report smelling a distinct odor), after which the current experimental design could be implemented with the appropriate titration.

Additional limitations may include the low percentage of male participants. Of the 211 students who attended both visits, only 35% were male. It is possible that the effects of the odor and/or the priming statements were not detected because of this lack of power. Lastly, because of scheduling constraints, one room was used for the no-odor conditions and a different one was used for the odor conditions. This may have introduced a systematic variable into the analysis that may have interfered with the results. Future research should attempt to keep the experimental environment exactly the same across conditions, with the exception of the odor of course.

*Future Directions*
Since it appears that the priming statements themselves may have served as a more effective cue for recall than the odor itself, at least for female participants, it would be helpful to know exactly what it is about the priming statements that makes them helpful. Is it necessary that they be related to odor, as ours were? Would feigned high-frequency tones or infrared lights (those that can’t be detected by humans) also facilitate recall for female participants?

The use of ambient odors in the classroom, to assist in the knowledge acquisition process, has the potential to be a powerful intervention strategy. Not only is it cost-effective in terms of both money and teacher time, but it is unobtrusive to classroom procedures. The use of odor as a context cue to aid in memory recall has thus far shown strong potential in the research literature, and the present study will investigate this potential even further using an educationally relevant task. Although this research study is primarily theoretical in nature, and does not have a direct implication for teachers at present, as the method is refined, we may learn more about the most effective ways to utilize this unique sensory modality to aid in memory tasks both in and out of school. Thus far, no researchers have documented the use of this combination of techniques in school-age children, which may be helpful in determining if there is any difference between the performance of adults and that of children under these conditions. In this case, the task could be a more realistic, school-centered one, such as a real list of spelling words or state capitals.

Additionally, because of the emotionality often connected to odor memory, as described in the introductory section and in Herz’s research with autobiographical memories (2004) it is possible that recall of words with more “emotional” weight than these novel animal names may be better facilitated with odor cues. That is, if the words themselves are more emotion-laden than these nouns, perhaps the benefit of olfactory cues would be more apparent at recall. Likewise, although this particular odor had been shown to improve students’ performance on memory tasks by other research groups, it is possible that its novelty was actually an impediment to recall. Perhaps if the odor were more familiar to the participants, they may link the words to other established memories, which may also help to facilitate recall.
References


Table 1.

*Number and sex of participants taking part in both immediate and delayed conditions.*

<table>
<thead>
<tr>
<th></th>
<th>Priming</th>
<th>No-Priming</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Odor</td>
<td>11</td>
<td>28</td>
</tr>
<tr>
<td>No-Odor</td>
<td>18</td>
<td>45</td>
</tr>
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</table>
Table 2.

*Mean ES scores at immediate and delayed recall in all four conditions.*

<table>
<thead>
<tr>
<th>ES Scores</th>
<th>Immediate Recall</th>
<th>Delayed Recall</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odor</td>
<td>No-Odor</td>
<td>Odor</td>
<td>No-Odor</td>
<td>Odor</td>
</tr>
<tr>
<td>Priming</td>
<td>8.8</td>
<td>9</td>
<td>5.9</td>
<td>6.8</td>
<td>7.35</td>
</tr>
<tr>
<td>No-Priming</td>
<td>9</td>
<td>7.7</td>
<td>5.9</td>
<td>5.6</td>
<td>7.45</td>
</tr>
<tr>
<td>Mean</td>
<td>8.9</td>
<td>8.35</td>
<td>5.9</td>
<td>6.2</td>
<td>7.4</td>
</tr>
</tbody>
</table>
Table 3.

*Mean CLS scores at immediate and delayed recall in all four conditions.*

<table>
<thead>
<tr>
<th>CLS Scores</th>
<th>Immediate Recall</th>
<th>Delayed Recall</th>
<th>Mean</th>
<th>Mean</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Odor</td>
<td>No-Odor</td>
<td>Odor</td>
<td>No-Odor</td>
<td>Odor</td>
</tr>
<tr>
<td>Priming</td>
<td>75.6</td>
<td>78.2</td>
<td>54.4</td>
<td>62.8</td>
<td>65</td>
</tr>
<tr>
<td>No-Priming</td>
<td>79.4</td>
<td>70.9</td>
<td>56.6</td>
<td>51.4</td>
<td>68</td>
</tr>
<tr>
<td>Mean</td>
<td>77.5</td>
<td>74.55</td>
<td>55.5</td>
<td>57.1</td>
<td>66.5</td>
</tr>
</tbody>
</table>
Figure 1.

*Mean ES scores among all four conditions.*

![Mean ES Scores among all four conditions](image_url)
Figure 2.

*Mean CLS scores among all four conditions.***
Figure 3.
Interaction effects between odor and priming on mean ES scores in immediate and delayed conditions.
Figure 4.

*Interaction effects between odor and priming on mean CLS scores in immediate and delayed conditions.*
Appendix A

Animal Word List

Directions: You will have ten minutes to learn the following words using any strategy needed. You may use the scratch paper provided to write in. All materials will be removed after ten minutes.

addax
peccary
tamandua
mandrill
tana
bobac
loris
tamarin
okapi
babirusa
corsac
muntjac
hamadryas
chamois
entellus
kinkajou
coati
tenrec
ibex
capybara
Appendix B

Demographic Survey

Please complete the following information:

Study ID Number: _________________________________

Class for credit (if applicable): ________________________________

Professor’s name: ________________________________

Age: _______  Gender: Male  Female  (Circle One.)

Ethnicity:  African-American  Asian-American  Hispanic  White

          Other ___________________________

Major: ________________________________

Classification:  Freshman  Sophomore  Junior  Senior

Approximate Cumulative G.P.A.: ___________

Do you have either skin or respiratory allergies? ___________

    If yes, please explain. ____________________________________________________________

Do you currently have a cold or sinusitis? ___________

Please describe your first memory of school:

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

________________________________________________________________________________

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Appendix C: Free Recall Test (Immediate Recall)

Animal Word List
Directions: Please PRINT the words that you learned at the beginning of the session. They do not have to be in any specific order. Also, spell the words the best you can. You have five minutes.

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Appendix D: Free Recall Test (Delayed Recall)

Animal Word List
Directions: Please PRINT the words that you learned from the first session. They do not have to be in any specific order. Also, spell the words the best you can. You have five minutes.

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Appendix E: Odor Survey

Please think back to **SESSION 1** (two days ago) and answer the following questions:

1. Did you notice a distinct smell in the classroom? (Circle one.)  
   - YES  
   - NO

2. How would you rate the smell in the room? (Circle one.)  
   - Recognizable  
   - Unrecognizable  
   - Don’t Know

   Please describe the smell. __________________________________________________  
   __________________________________________________

3. Were you distracted by the smell in the room? (Circle one.)  
   - YES  
   - NO

   If YES, (Circle One)  
   - Positively Distracted  
   - Negatively Distracted

4. How do you think the smell in the room affected your ability to remember the words? (Circle one.)  
   - Increased Greatly / Increased Somewhat / Decreased Greatly / Decreased Somewhat / Not At All

5. Please circle the word that best describes your satisfaction with the classroom facilities:  
   - A. Lighting  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT  
   - B. Smell  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT  
   - C. Temperature  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT  
   - D. Acoustics  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT  
   - E. Color  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT  
   - F. Comfort  
     - PLEASANT  
     - NEUTRAL  
     - UNPLEASANT

6. Please tell us which strategies you used to help you remember the words after we first showed you the list (Session 1). Check ALL that apply  
   - Repeating the words over and over to yourself either quietly out loud or in your head _____  
   - Writing the words over and over _____  
   - Other (Please describe in detail) __________________________________________________

   __________________________________________________
Please answer the following questions with only today’s session (SESSION 2) in mind:

1. Did you notice a distinct smell in the classroom? (Circle one.)  YES  NO

2. How would you rate the smell in the room? (Circle one.)  Recognizable  Unrecognizable  Don’t Know

   Please describe the smell.___________________________________________________
   _______________________________________________________________________
   _______________________________________________________________________

3. Were you distracted by the smell in the room? (Circle one.)  YES  NO

   IF YES, (Circle one.)  Positively Distracted  Negatively Distracted

4. How do you think the smell in the room affected your ability to remember the words? (Circle one.)  

   Increased Greatly / Increased Somewhat / Decreased Greatly / Decreased Somewhat / Not At All

5. How many words do you think you correctly recalled today?  _____/20

6. Please circle the word that best describes your satisfaction with the classroom facilities:

   1. Lighting  PLEASANT  NEUTRAL  UNPLEASANT
   2. Smell    PLEASANT  NEUTRAL  UNPLEASANT
   3. Temperature  PLEASANT  NEUTRAL  UNPLEASANT
   4. Acoustics  PLEASANT  NEUTRAL  UNPLEASANT
   5. Color     PLEASANT  NEUTRAL  UNPLEASANT
   6. Comfort   PLEASANT  NEUTRAL  UNPLEASANT

**General Questions:**

1. Did you perceive the room odor to be the same for Session 1 and Session 2?  YES  NO

2. Have you practiced recalling the words over the past 48 hours?  YES  NO

3. Have you discussed the words with anyone else?  YES  NO
4. In general, how would you rate your ability to smell? (Circle one.)

   Excellent  Good  Fair  Poor  I can’t smell at all

5. Are you currently a smoker?  YES  NO
   If YES, _______cigarettes per day
   _______packs per month

6. Are you currently taking any prescribed medication? (Circle one.)  YES  NO
   If yes, please list the medications you are taking:

7. Is it possible that you could be pregnant, or are you pregnant? (Circle one.)  YES  NO