Improving Learner Performance through Olfactory Intervention

Aaron Loewer

Abstract

Sensory inputs in educational environments can influence learner performance. Specifically, the sense of smell (olfaction), with its neurological connections to emotion can be utilized to enhance learner performance and reduce learner anxiety. The purpose of this paper is to review aroma-based learning research in order to answer the following research questions: Can a pleasant ambient aroma enhance learner performance when released in an instructional environment? What is the influence that a pleasant aroma might have on learner anxiety? The results in most of the studies reviewed backed the use of pleasant aromas in learning environments. Two possible explanations are that some pleasant aromas have been shown to enhance connections between the learner and subject matter, while they also contribute to reductions in human anxiety.

Introduction

Olfaction, or the sense of smell, is a powerful, emotionally tied capability (Herz & Engen, 1996). This paper demonstrates that humans can learn to use olfaction to enhance performance in diverse environments and situations. Various behaviors or tasks exist in which dealing with olfactory information is a key element. For example, a car driver who perceives the odor of an overworked engine is presented with olfactory cues to change driving behavior, such as shifting to a higher gear, or to provide maintenance to the car by checking levels of radiator fluid or oil. The smell of worn out brake pads can also prompt behavioral or maintenance choices like shifting to a lower gear so the engine can slow the car's momentum, or checking the thickness of the brake pads to see if repairs are needed.

Food preparation is another area of activity that provides multiple instances where olfaction can aid performance. When selecting foods, chefs can use their olfactory sensitivity to perceive the ripeness of fruits such as pineapple and cantaloupe, or the freshness of milk or eggs. While baking or cooking, olfactory hints inform the cook as to whether or not an item has been cooked long enough, or too long. Prior to serving food, chefs use their sense of smell to evaluate food odor and taste as "perception of odors and flavors [has] similar neural bases" (Phillips & Heining, 2002, p. 204). Hence, the plugging of one's nose can be an effective approach when taking in foods or medications that taste unpleasant.

In a few cases, human behavior is unconsciously influenced by olfaction. One well-documented example is mate selection. Thornhill and Gangestad (1999) demonstrate that females not taking birth control pills are able, through olfaction, to detect males who will provide genes that will generate the healthiest possible posterity (p. 191). While males do not possess this ability, they do however possess the ability (along with females) to judge expected body scent attractiveness based on portrait attractiveness (1999).

The influence that pleasant aromas can have on learner performance has been tested in numerous studies (Aggleton & Waskett, 1999; Baron, 1990; Baron & Kalsher, 1998; Cann & Ross, 1989; Deethardt, 2003; Diego, Jones, Field, Hernandez-Reif, Schanberg, Kuhn, McAdam, R. Galamaga & M. Galamaga, 1998; Ehrilichman & Halpern, 1988; Epple & Herz, 1999; Herz, 1997; Ludvigson & Rottman, 1989; Nagai, Wada, Usui, Tanaka & Hasebe, 2000; Smith, Standing & de Man, 1992). However, little is known in the instructional technology field about such findings. Consequently, some instructional technologists may be limiting themselves to designing and redesigning performance interventions without considering an important element of instruction—the use of olfactory abilities in triggering conscious and subconscious cues.

The research questions for this review are two basic questions that instructional technologists need to know in order to effectively incorporate olfactory stimulation into their designs: Can a pleasant ambient aroma enhance learner performance when released in an instructional environment? What is the influence that a pleasant aroma might have on learner anxiety? The first question is important because designers need to know whether or not olfactory intervention even works, and whether or not it has been proven to work in various settings. The second question is based on the importance of emotions in olfactory research. As will be explained further, olfactory connections with the limbic system indicate that interventions involving pleasant aromas may reduce anxiety as experienced by learners.

Theoretical Basis

Four principles explain the theoretical importance of reviewing studies that examine the influence of olfaction on learner performance and anxiety. Anxiety is defined by Merriam-Webster (2006) as an "abnormal and overwhelming sense of apprehension and fear often marked by physiological signs (as sweating, tension, and increased pulse), by doubt concerning the reality and nature of the threat, and by self-doubt about one's capacity to cope." The four theoretical principles are discussed in the following order: environment, context, inputs, and affordances.

According to Blanchard and Thacker (2006), the environment is one of the key factors determining human performance. Their model claims that performance is the product of three factors: (a) motivation, (b) KSA (knowledge, skills, and attitudes), and (c) environment. They explain "it is the combination of these factors that determines the person's performance. The likelihood of engaging in any activity, then, is limited by the weakest factor (….) If the environment does not support the activity or blocks it, then it doesn't matter how motivated or knowledgeable you are – you won't do it" (p. 76). Granted, Blanchard and Thacker (2006) are speaking of more than just the sensory inputs in the environment, such as organizational structure and culture, but they are also clear regarding the importance of the surroundings in which performance is taking place.

Environmental contexts that are increasingly similar during acquisition, retention and retrieval (Anderson, 1995) can enhance performance during these neural activities. On the other hand, lack of contextual cues could lead to a decrement in performance. Driscoll (2000) states "When context changes from learning to application or practice, learners often fail to transfer the knowledge they acquired in one context to the other, related context" (Driscoll, 2000, p. 154). Furthermore, she states that "context plays an important role in learning. In familiar contexts, learners can relate new information and skills more easily to what they already know than if the learning context is unfamiliar" (p. 154).

The problem of transfer can sometimes exist when learning environments or contexts are dissimilar from those in which recall takes place. High-end simulations can be employed to reduce contextual gaps, but for simulations to truly reflect all aspects of a learning/performance environment, all sensory inputs should be considered. Gibbons and Fairweather (1998) emphasize that when representing information "the designer must be aware of the alternatives for communicating through all of the sensory channels: graphic and motion graphic, tabular, verbal and non-verbal auditory, tactile, kinesthetic, and olfactory" (p. 318). Making the point clear, Engel (2000) emphatically titles her book, *Context Is Everything*.

The importance of communicating and representing information leads to the cognitivist concepts of "inputs" and "means" as discussed by Driscoll (2000). "The results of learning are to be explained through inputs (largely external to the learner) and means (largely internal to the learner)" (p. 156). Regarding inputs that are external to the learner, Gibson's (1966) ecological perception theory introduces the concept of affordances. "The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill" (Gibson, 1986, p. 127). In other words, "affordances are an object's properties for which it can be used in a particular moment – they are an object's invitations. For instance, a door handle possesses the initial affordance of grasping and, secondarily, turning" (Loewer, 2006, p. 24). Gibson (1986) summarizes:

> The perceiving of these mutual affordances is enormously complex (. . .) is based on the pickup of the information in touch, sound, odor, taste, and ambient light. It is just as much based on the stimulus information as is the simpler perception of the support that is offered by the ground under one's feet. For other animals and other persons can only give off information about themselves insofar as they are tangible, audible, odorous, tastable, or visible. (p. 135)

In summary, various theorists and practitioners emphasize the importance of four theoretical principles: environment (Blanchard & Thacker, 2000), context (Driscoll, 2000; Engel, 2000; Gibbons & Fairweather, 1998), inputs (Driscoll, 2000), and affordances (Gibson, 1966; 1986). While not necessarily mentioned in the studies examined in this review, each principle contributes to the theoretical basis for examining olfaction-based learning studies. Designers and developers who consider these principles during the ISD process may find grounds to produce instruction that incorporates olfactory cues along with inputs to other sensory modalities.

Literature Review

This review consists, first, of summaries of two previous reviews of olfactory research. Afterward, the review of individual studies that pertain to the research questions is presented. Two integrative reviews were located in which the relationship between cognition and olfaction was examined, these are Richardson and Zucco (1989) and Herz and Engen (1996). Unfortunately, both pairs of reviewers failed to present their findings in a concisely summarized manner.

Richardson and Zucco (1989) reviewed previous research on the following topics: Subjective description of odors, odor detection, odor identification, memory for odors, and brain damage leading to loss of olfactory ability. The reviewers did not include studies that examine the influence of olfaction on variables pertinent to this review such as anxiety, mood, associated memories and learner performance. Like many studies in olfaction, Richardson and Zucco (1989) focused primarily on the human abilities (or disabilities) of remembering, describing and categorizing odors.

Herz and Engen (1996) reviewed previous research on the following topics: (a) memory for odors (including long and short-term odor memory), (b) verbal abilities to describe odors, (c) olfactory imagery, (d) distinctiveness of odor memory, and (e) memories evoked by odors that are autobiographical or context-dependent.

Their review lends itself much more to the topic of this paper, in particular, summaries of research conducted on human memories evoked by odors. They summarized "the first direct examination of odor-evoked memory" (p. 306), as found in Herz and Cupchik (1995) where the researchers "used a paired-associated incidental learning paradigm to examine whether odors evoked more emotional memories than verbal cues" (Herz & Engen, 1996, p. 306). They found that the odor and verbal cues were equal in their ability to elicit correct responses but that the odor cues had a "higher emotional intensity" (p. 306).

Regarding context-dependent memory, Herz and Engen (1996) pointed to four studies in which an ambient odor is present during study and testing. These studies are Cann and Ross (1989); Herz (1997b); Schab (1990); Smith, et al., (1992). Herz and Engen (1996) also explained the cause of powerful emotions that are generated by olfactory experiences:

> The primary olfactory cortex forms a direct anatomical link with the amygdala-hyppocampal complex of the limbic system. Only two synapses separate the olfactory nerve from the amygdala, which is critical for the expression and experience of emotion (Aggleton & Mishkin, 1986) and human emotional memory (Cahill, Babinski, Markowitsch & McGaugh, 1995). Only three synapses separate the olfactory nerve from the hippocampus, involved in the selection and transmission of information in working memory, short- and long-term memory transfer, and various declarative memory functions (Eichenbaum, in press; Schwerdtfeger, Buhl & Gemroth, 1990; Staubli, Ivy & Lynch, 1984, 1986). No other sensory system makes this kind of direct and intense contact with the neural substrates of emotion and memory, which may explain why odor-evoked memories are unusually emotionally potent. (p. 300)

Additional literature examined for this review included books, journal articles, web sites and personal vitae of researchers. Search terms included various combinations of the following: affect, anxiety, aroma, biofeedback, blood pressure, cognition, fragrance, heart rate, knowledge, learning, memory, nasal, nose, odor, olfaction, performance, perception, scent, sense, and smell.

Databases for locating sources were accessed primarily through the library at Utah State University. They included: Digital Dissertations, Education Full Text, ERIC via EBSCO Host, ERIC via the US Department of Education, PsychINFO via EBSCO Host, and Biological Sciences. An associate accessed numerous full-text articles at the Jean and Alexander Heard Library at Vanderbilt University and sent them to the researcher.

Inclusion Criteria

The following were established as inclusion criteria for this review: Research must be conducted on recall of memories and/or learned content and skills, as opposed to research on recall of odor names, or odors themselves. This criterion alone caused the exclusion of the majority of articles cited in the aforementioned Richardson and Zucco (1989) review. Additional criteria included researcher documentation of: random assignment to treatment and control groups, odors used in treatment groups, odor release methods, sample size, and age of subjects.

Originally, the researcher required documentation of effect size, but Herz (1997a) was the only researcher to include such findings, thus the criterion was adjusted. Although attempts were made to calculate effect sizes from results of other studies, the reported data was generally insufficient. Gathering other data was also unsuccessful. For instance, R.A. Baron was asked to provide data for items such as male to female participant ratios in Baron (1997), but he had "disposed of the data for that study a long, long time ago" (R.A. Baron, personal communication, December 6, 2005).

The results in most of the studies reviewed backed the use of pleasant aromas in learning environments. Two possible explanations are that some pleasant aromas have been shown to enhance connections between the learner and subject matter, while they also contribute to reductions in human anxiety.

Sample

Twenty-five articles were identified for inclusion in the review, many of which contained multiple studies. The studies were categorized according to the order of the research questions: (a) olfactory studies on learner performance, and (b) olfactory studies on learner anxiety. It should be noted that some of studies examined both performance and anxiety, thus, they were included in both categories.

Olfaction and Learner Performance

Olfactory studies on learner performance show that pleasant aromas such as peppermint, rosemary and lavender can be used to enhance connections between learning and testing. For example, Schab (1990) found that memory retrieval during a test can be aided if the same aroma is present in both the encoding and testing conditions. He also showed that learner performance can be further enhanced when the aroma is related, or congruent with the task at hand. For example, if a female student is learning about the biology of apples, her ability to recall specific content might improve if an apple scent is present during both encoding and retrieval.

Similarly, Aggleton and Waskett (1999) found that congruent aromas distributed in a Viking museum enhanced participants' ability to perform delayed recall of Viking-related content. They remembered "the types of clothing and jewelry worn by the Vikings, the types of foods eaten, the nature of the buildings and the classes of items sold in Viking York" (p. 3).

Baron and Kalsher's (1998) examination of the effects of a lemon fragrance on simulated driving performance is another example. Subjects were divided into four groups in which two treatments were administered—a lemon scent, or a gift, to randomly assigned groups. The researchers found that performance was best achieved in the scent condition in which no gift was received.

Eighteen studies (mean sample size 58.7) that examined the effects of pleasant aromas on performance were included in this section of the review. They are: Aggleton and Waskett (1999); Baron and Kalsher (1998, Study 1); Baron (1990); Cann and Ross (1989); Deethardt (2003); Diego, et al., (1998); Ehrilichman and Halpern (1988); Epple and Herz (1999); Herz (1997a, Study 1); Herz (1997a, Study 2); Herz (1997b, Study 1); Herz (1997b, Study 2); Ludvigson and Rottman (1989); Nagai et al., (2000); Schab (1990, Study 1); Schab (1990, Study 2); Schab (1990, Study 3); Smith, et al., (1992).

Twenty-one tasks were completed by participants in the 18 studies (Figure 1). The frequencies of these tasks were: Cognitive (8), Word recall (6), All others (4), Procedural (3). The most common aromas used in the performance studies (listed alphabetically) were almond, apple, chocolate, cinnamon, jasmine, lavender, lemon, peppermint, pine, and rosemary.

In the 18 studies listed above, all findings were statistically significant in favor of using pleasant aromas in performance situations except two: Deethardt (2003), and Ludvigson and Rottman (1989). The Deethardt (2003) study examined participants' ability to recall paired word associates where words were matched with specific aromas from seven combinations of dry teas, spices and incense. Ludvigson and Rottman (1989) had participants complete analogies, math problems, and vocabulary recall while being exposed to aromas of cloves and lavender.

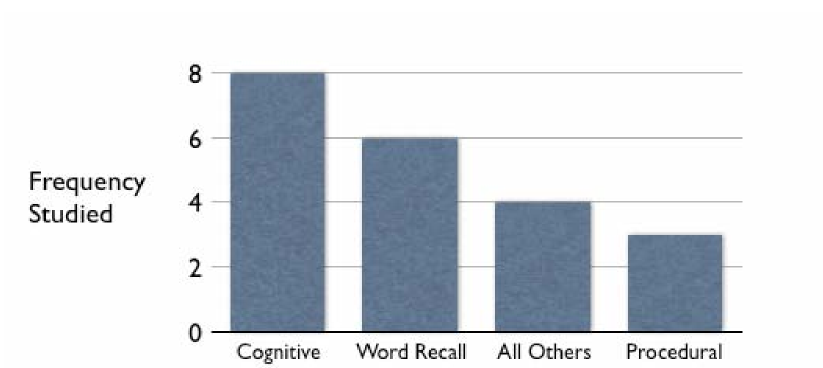

Figure 1. Types of tasks completed by participants in performance studies.

Unfortunately, only two studies (by the same researcher) included a report of effect size, both of which used violet leaf in the scent condition. Herz (1997a, Study 1) reported an effect size of .11 when participants completed word recall tasks while experiencing public speaking anxiety. Herz (1997a, Study 2) reported an effect size of .42 when participants completed word recall tasks while experiencing test anxiety. While these effect sizes may not be large, they are effect sizes that show significant, positive results.

The results of olfaction-based performance studies may be explained by Smith, et al., (1992) who cite Tulving's (1983) encoding specificity principle where "verbal memory performance is enhanced when the contextual, or incidental, stimuli present at the time of retrieval are the same as those which were present during the initial learning" (p. 339).

Olfaction and Learner Anxiety

As a result of direct links between olfactory processing and the limbic system (which some researchers claim to be the biological source of human emotional response), odors can strongly influence emotions. Kringelbach (as quoted by Hoelgaard, 2004) states that while other sensory inputs pass through the thalamus, the same "does not happen with olfactory input – that goes straight to the emotional response centre" (¶ 9).

Olfactory studies on learner anxiety (indicated by both self-report and physiological data) show that subjects' moods and attitudes can be influenced by both pleasant and unpleasant fragrances. For instance, Baron (1997) and assistants approached passersby in a shopping mall in areas where half of the passersby were in the presence of pleasant aromas (coffee shops, bakeries). The passersby were asked to complete a favor, either to provide change or the time of day for one of the assistants. Findings indicated "a higher proportion of passersby helped the accomplice when pleasant fragrances were present than when they were absent and that this was true for both" (p. 501) genders. Participants also filled out mood questionnaires (some before, and some after completing the favor). Subjects in the presence of the aromas reported being in a more favorable mood than subjects not exposed to the aromas.

While the majority of olfactory researchers measure anxiety using self-report questionnaires, some also employ physiological assessments. Diego et al., (1998) used both self-report and EEG (electroencephalogram), also known as a brain wave test, to monitor subjects' brain activity when given three minutes of aromatherapy. Two aromas, lavender (which is considered to be relaxing) and rosemary (stimulating) were used in the experiment. Data gathered using EEG showed that the lavender-exposed group experienced increased drowsiness while the rosemary-exposed group experienced increased alertness. These data were also consistent with subjects' self-report of mood. Both groups performed math computations (pre- and post-aromatherapy) and results showed that both groups performed faster after the aromatherapy. Interestingly, the lavender group was more accurate in its math responses than the rosemary group, suggesting that relaxation may assist concentration (p. 223).

Nagai et al., (2000) examined the influence of participant-selected aromas (and their documented intensities) during a psychomotor task. They used a blood pressure monitor and a polygraph system which monitored "respiratory movement, electrocardiogram, pulse wave of the left middle finger, and skin temperatures of the forehead and the left forefinger" (p. 228). Results indicated that during a rhythmic handgrip exercise, diastolic blood pressure was significantly lower for the odor group than the non-odor group.

Twelve studies (mean sample size, 93.1) were included in this section of the review. As mentioned earlier, some overlap existed between the performance studies and anxiety studies, thus some experiments were included twice. They are: Baron (1990); Baron (1997); Baron and Kalsher (1998, Study 2); Baron and Thomley (1994); Diego et al., (1998); Herz (1997a, Study 1); Herz (1997a, Study 2); Herz (2004); Lehrner, Eckersberger, Walla, Pötsch and Deecke (2000); Ludvigson and Rottman (1989); Sanders, Diego, Fernandez, Field, Hernandez-Reif and Roca (2002, Study 1); and Spangenberg, Crowley and Henderson (1996).

Eighteen variables were examined in the 12 studies. Results in 13 of the 18 variables examined confirmed that pleasant aromas could reduce human anxiety. The non-significant affects came as a result of two aromas investigated: Lemon (1) and Violet leaf (4). Interestingly, a lemon scent was used in Baron and Kalsher's (1998, Study 1) simulated driving performance study, finding lemon to significantly enhance performance yet in Study 2, the lemon aroma did not positively influence participant affect.

From the total number of affects reported, the frequencies at which specific types of affect were examined included the following: affective state after study (3), mood (3), emotional arousal (2), pleasure (2), relaxation (2), state anxiety (2), depression (1), emotionality of odor-evoked memories (1), affective evaluations of a store's appeal (1), and trait anxiety (1). The most common aromas used in the twelve studies (listed alphabetically) were lavender, lemon, orange/orange citrus, rosemary and violet leaf.

Amidst ongoing research, little is known of the affective domain. Martin and Reigeluth (1999) state that they "believe there are compelling reasons for including affective development in all types of learning environments" (p. 507). Goleman (1994) summarizes possible reasons for the importance of affective research and instruction.

> [The] architecture of the brain gives the amygdala a privileged position as an emotional sentinel, able to hijack the brain. [Sensory] signals from the eye or ear travel first in the brain to the thalamus, and then – across a single synapse – to the amygdala; a second signal from the thalamus is routed to the neocortex – the thinking brain. This branching allows the amygdala to begin to respond before the neocortex, which mulls information through several levels of brain circuits before it fully perceives and finally initiates its more finely tailored response. (p. 17)

One group that is exemplary in affective examination is the Affective Computing Group (http://affect.media.mit.edu/) at Massachusetts Institute of Technology, which describes its work in the following way:

> Our research develops new technologies and theories that advance basic understanding of affect and its role in human experience. We aim to restore a proper balance between emotion and cognition in the design of technologies for addressing human needs. (¶ 1)

One of their current projects challenges learners to "focus on a topic such as math in the presence of strong emotions (problems at home, or feelings for the teen across the room)" (http://affect.media.mit.edu/projects.php, ¶ 6). The objective is to teach students how to apply meta-affective skills for handling emotionally heightened situations.

Another branch of affect research promotes physiological data gathering in order to assess emotional conditions of learners. Moss (2003) asserts that heart rate, respiration, muscle tension and hand temperature are manifestations of anxiety, all of which can be physiologically gathered. As mentioned previously, some of the studies reviewed in this paper documented the use of physiological anxiety assessment (Diego et al., 1998; Nagai et al., 2000; Sanders et al., 2002). Peek (2003) explains that in gathering physiological data, instrumentation is used to "(a) monitor a physiological process of interest, (b) measure (objectify) what is monitored, and (c) present what is monitored or measured as meaningful information" (p. 45). As such, increasingly accurate information can be gathered from research participants, whereas self-report mechanisms may be unreliable, or the actual reporting by the participant may be biased.

Conclusion

One of the purposes of this conference is to strengthen connections between new technologies and educational goals. Where the goal of educators in most sectors is to create learning experiences that enhance learner performance, new technologies employed to achieve such a goal may be found in the domain of physiological assessment. If one of the first objectives of a designer is to understand the audience then physiological data can provide valuable details about learners, their possible levels of anxiety, and their experiences in various instructional environments.

The concepts of environment, context, inputs, and affordances, as previously discussed, demonstrate the importance of strengthening connections between acquisition, retention and retrieval (Anderson, 1995) through olfactory intervention. Incorporating olfactory interventions into the "selection, sequencing and posing of problems" (Foshay & Gibbons, 2003, p. 22) may augment an instructor's ability to foster contextual connections in learners.

A sample of the growing body of olfactory research literature has been presented in this review. Specifically, literature has been evaluated regarding the influence of olfaction on learner performance and anxiety. Twenty-five articles, some of which contained multiple studies, were located and included in the sample. Overall, many studies point out the fact that not only do olfactory stimuli serve as adequate cues for recall, they also serve as potent cues for recall of highly emotional memories.

To directly answer the research questions, the majority of the studies reviewed show that pleasant aromas can enhance learner performance. Additionally, many of the studies reviewed have also shown pleasant aromas may decrease human anxiety. The level of influence that aromas had on anxiety was not examined, but it is reasonably safe to conclude that various pleasant-smelling aromas may assist learners with relaxation during encoding and recall. Without such assistance, these experiences may remain cognitively, or affectively uncomfortable to learners. While this review focuses primarily on olfaction as an emotionally-tied human sense (Herz & Engen, 1996), there is much that the field might also gain through additional research that shows how olfactory stimulation might be combined with other sensory stimulation to improve performance and decrease anxiety.

References

Aggleton, J.P., & Mishkin, M. (1986). The amygdala: Sensory gateway to the emotions. In R. Plutchik & H. Kellerman (Eds.), *Emotion: Theory, research and experience. Vol 3: Biological foundations of emotion* (pp. 281-296). Orlando, FL: Academic Press.

Aggleton, J.P., & Waskett, L. (1999). The ability of odours to serve as state-dependent cues for real-world memories: Can Viking smells aid the recall of Viking experiences? *British Journal of Psychology, 90*, 1-7.

Anderson, J.R. (1995). *Learning and memory: An integrated approach* (1st ed.). New York: John Wiley & Sons, Inc.

Baron, R.A. (1990). Environmentally induced positive affect: Its impact on self-efficacy, task performance, negotiation and conflict. *Journal of Applied Social Psychology, 20*(5), 368-384.

Baron, R.A. (1997). The sweet smell of…helping: Effects of pleasant ambient fragrance on prosocial behavior in shopping malls. *Personality and Social Psychology Bulletin, 23*(5), 498-503.

Baron, R.A. & Kalsher, M.J. (1998). Effects of a pleasant ambient fragrance on simulated driving performance: The sweet smell of…safety? *Environment and Behavior, 30*(4), 535-552.

Baron, R.A. & Thomley, J. (1994). A whiff of reality: Positive affect as a potential mediator or the effects of pleasant fragrances on task performance and helping. *Environment and Behavior, 26*(6), 766-784.

Blanchard, P.N., & Thacker, J.W. (2003). *Effective training: Systems, strategies, and practices.* Upper Saddle River, NJ: Pearson, Prentice Hall.

Cahill, L., Babinski, R., Markowitsch, H.J., & McGaugh, J.L. (1995). The amygdala and emotional memory. *Nature, 377,* 295-296.

Cann, A. & Ross, D.A. (1989). Olfactory stimuli as context cues in human memory. *American Journal of Psychology, 102*(1), 91-102.

Deethardt, M.R. (circa 2000). The effects of olfactory stimulation on short-term memory. Retrieved June 24, 2003 from http://clearinghouse.mwsc.edu/manuscripts/347.asp

Diego, M.A., Jones, N.A., Field, T., Hernandez-Reif, M., Schanberg, S., Kuhn, C., McAdam, V., Galamaga, R., & Galamaga, M. (1998). Aromatherapy positively affects mood, EEG patterns of alertness and math computations. *Intern. J. Neuroscience, 96*, 217-224.

Driscoll, M. (2000). *Psychology of learning for instruction* (2nd ed.). Boston: Allyn and Bacon.

Engel, S. (2000). *Context is everything: The nature of memory.* New York: W.H. Freeman.

Ehrlichman, H. & Halpern, J.N. (1988). Affect and memory: Effects of pleasant and unpleasant odors on retrieval of happy and unhappy memories. *Journal of Personality and Social Psychology, 55*(5), 769-779.

Eichenbaum, H. (in press). Olfactory perception and memory. In R. Llinas & P. Churchland (Eds.), *The mind-brain continuum.* Cambridge, MA: MIT Press.

Epple, G. & Herz, R.S. (1999). Ambient odors associated to failure influence cognitive performance in children. *Developmental Psychobiology, 35,* 103-107.

Foshay, W.R., & Gibbons, A.S. (2003). *Learning, teaching and designing problem solving: An assessment.* Unpublished manuscript. Retrieved October 4, 2006 from http://www.foshay.org/PDFs/Learning,%20Teaching,%20and%20Designing%20Problem%20Solving%202a%20-%20Fosh.pdf

Gibbons, A. & Fairweather, P. (1998). *Computer-based instruction: Design and development*. New Jersey: Educational Technology Publications.

Gibson, J.J. (1966). *The senses considered as perceptual systems*. Boston: Houghton Mifflin.

Gibson, J.J. (1986). *The ecological approach to visual perception.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Goleman, D. (1994). *Emotional intelligence: Why it can matter more than IQ*. New York: Bantam.

Herz, R.S. (1997a). Emotion experienced during encoding enhances odor retrieval cue effectiveness. *American Journal of Psychology, 110*(4), 489-505.

Herz, R.S. (1997b). The effects of cue distinctiveness on odor-based context-dependent memory. *Memory & Cognition, 25*(3), 375-380.

Herz, R.S. (2004). A naturalistic analysis of autobiographical memories triggered by olfactory visual and auditory stimuli. *Chemical Senses, 29,* 217-224.

Herz, R.S., & Cupchik, G.C. (1995). The emotional distinctiveness of odor-evoked memories. *Chemical Senses, 20,* 517-528.

Herz, R.S., & Engen, T. (1996). Odor memory: Review and analysis. *Psychonomic Bulletin & Review, 3*(3), 300-313.

Hoelgaard, T. A. (2004). Emotional Learning. Retrieved March, 2005, from http://www.lld.dk/publications/quarterlyonline/2004-issue3/emotionallearning/en

Lehrner, J., Eckersberger, C., Walla, P., Pötsch, G., & Deecke, L. (2000). Ambient odor of orange in a dental office reduces anxiety and improves mood in female patients. *Physiology & Behavior, 71,* 83-86.

Loewer, A.J. (2006). *Comprehensive final examination,* Unpublished manuscript, Utah State University, Logan, UT.

Ludvigson, H.W. & Rottman, T.R. (1989). Effects of ambient odors of lavender and cloves on cognition, memory, affect and mood. *Chemical Senses, 14*(4), 525-536.

Martin, B., & Reigeluth, C.M. (1999). Affective education and the affective domain: Implications for instructional-design theories and models. In C. M. Reigeluth (Ed.), *Instructional Design Theories and Models: A New Paradigm of Instructional Theory (Vol. II)* (pp. 485-509). Mahwah, NJ: Lawrence Erlbaum Associates.

Merriam-Webster Online Dictionary (2006). Retrieved September, 2006 from http://m-w.com/dictionary/anxiety

Moss, D. (2003). Anxiety Disorders. In D. Moss, A. McGrady, T. C. Davies & I. Wickramasekera (Eds.), *Handbook of mind-body medicine for primary care.* (pp. 359-375). Thousand Oaks, CA: Sage.

Nagai, M., Wada, M., Usui, N., Tanaka, A., Hasebe, Y. (2000). Pleasant odors attenuate the blood pressure increase during rhythmic handgrip in humans. *Neuroscience Letters*, 289, 227-229.

Peek, C.J. (2003). A primer of biofeedback instrumentation. In M.S. Schwartz and F. Andrasik (Eds.), *Biofeedback: A practitioner's guide* (pp. 43-87). The Guilford Press: New York.

Phillips, M., & Heining, M. (2002). Neural correlates of emotion perception. In C. Rouby, B. Schaal, D. Dubois, R. Gervais, & A. Holley (Eds.). *Olfaction, taste, and cognition* (pp. 196-208). New York: Cambridge University Press.

Richardson, J.T.E., & Zucco, G.M. (1989). Cognition and olfaction: A review. *Psychological Bulletin, 105*(3), 352-360.

Sanders, C., Diego, M., Fernandez, M., Field, T., Hernandez-Reif, M., Roca, A. (2002). EEG asymmetry responses to lavender and rosemary aromas in adults and infants. *International Journal of Neuroscience, 112,* 1305-1320.

Schab, F.R. (1990). Odors and the remembrance of things past. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*(4), 648-655.

Schwerdtfeger, W.L., Buhl, E.H., & Gemroth, P. (1990). Disynaptic olfactory input to the hippocampus mediated b stellate cells in the entorhinal cortex. *Journal of Comparative Neurology, 194,* 519-534.

Smith, D.G., Standing, L., & de Man, A. (1992). Verbal memory elicited by ambient odor. *Perceptual and Motor Skills, 74*, 339-343.

Spangenberg, E.R., Crowley, A.E., & Henderson, P.W. (1996). Improving the store environment: Do olfactory cues affect evaluations and behaviors? *Journal of Marketing, 60,* 67-80.

Staubli, U., Ivy, G., & Lynch, G. (1984). Hippocampal denervation causes rapid forgetting of olfactory information in rats. *Proceedings of the National Academy of Sciences, 81,* 5885-5887.

Staubli, U., Ivy, G., & Lynch, G. (1986). Studies on retrograde and anterograde amnesia of olfactory memory after denervation of the hippocampus by entorhinal lesions. *Behavioral Neurology & Biology, 46,* 432-444.

Thornhill, R., & Gangestad, S.W. (1999). The scent of symmetry: A human sex pheromone that signals fitness? *Evolution and Human Behavior, 20,* 175-201.

Tulving, E. (1983). *Elements of episodic memory.* New York: Oxford University Press.