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The Effects of Computerized Smell of Memory

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The Effects of Computerized Smell on Memory

by

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We hereby certify that this dissertation, submitted by Brandon S. Spencer, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirements for the degree of Doctor of Philosophy.

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An Abstract of a Dissertation Submitted to Nova Southeastern University in Partial Fulfillment of the Requirements for the Degree of Doctor of Information Systems.

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It has long been recognized that there is a major correlation between smell and memory. Until recently, commercialized multi-sensory experiences involving olfaction were limited to non-computerized mediums. Companies that manufacture computerized scent technologies tout the educational benefits of their product, yet prior to this study, there appeared to be no scholarly research in regard to the efficacy of computerized scent-producing peripherals in educational environments. The aim of this research was to determine the odor memory enhancement benefits of incorporating olfactory, computerized peripherals into computerized multimedia-learning environments, from both a context dependent and context independent stand point. Specifically, within a multimedia environment, the goal of this study was to ascertain whether or not there would be a significant memory performance difference between subjects who were exposed to scents at both encoding and recall, over subjects who were exposed to scents at encoding only.

There were 61 subjects tested in a carefully designed and controlled experiment. Subjects were 6th, 7th, and 8th grade students from a local private school. Subjects were randomly assigned to one of three conditions: Administration of a multimedia presentation with computerized smell during the presentation but not during post-testing, administration of a multimedia presentation with computerized smell present during both the presentation and post-testing, or a control group that watched the multimedia presentation without smell and post-tested without smell. Subjects were pre-tested several weeks prior to commencement of the study and then given a post-test approximately 48 hours after viewing the presentation.

It was hypothesized that subjects in both experimental conditions would demonstrate an improvement in memory over the control group based on previous studies regarding odor memory. Although there was significant improvement within groups from pre-test to post-test, there was no significant difference found between groups. Based on these results, it would appear that in regard to this study, adding computer-generated scents to multimedia environments provided no measurable value as far as memory is concerned

There are a number of issues of which future studies in the area of computerized olfaction and memory should be mindful. These include the level of immersion, the duration of the presentation, the duration of aromas, the level of subject interactivity, the age of the subjects, the scent delivery method, the type of scent technology used, and the types of questions asked of subjects.

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Table of Contents

Abstract ii
List of Tables vi

Chapters

1. Introduction 1
Statement of the Problem Investigated and Achieved Goal 1
Relevance, Significance, and Need for the Study 3
Barriers and Issues 7
Elements, Hypotheses, Theories, and Research Questions Investigated 13
Limitations, and Delimitations of the Study 15
Definition of Terms 16
Summary 18

2. Review of the Literature 21
The Theory and Research Literature Specific to the Topic 21
Olfaction and Memory 21
History of Multimedia Smell 33
Computerized Olfactory Technologies 33
Smell and Education 35
Summary of What is Known and Unknown About the Topic 39
Contributions Made to the Field 42

3. Methodology 44
Research Methods Employed 44
Sampling Method 44
Participants 44
Site 45
Role of Researcher 45
Research Design 45
Variables 45
Experimental Groups 46
Specific Procedures Employed 46
Format for Presenting Results 50
Resources Used 50
Reliability and Validity 51
Summary 52

4. Results 55
Data Analysis 56
Findings 58
Summary of Results 59

5. Conclusion, Implications, Recommendations, and Summary 61
Conclusions 61
Implications 65
Recommendations 66
Summary 67

Appendixes
A. Material Safety Data Sheets 72
B. Subjects and Scores Groups A, B, and C 78
C. Trisenx Scent Dome 80
D. Testing Room Set-up 81
E. The Groups 82
F. The Multimedia Presentation 83
G. Pre-test/Post-test Quiz 90

Reference List 92

List of Tables

Tables

1. Group A Descriptive Statistics 56

2. Group B Descriptive Statistics 56

3. Group C Descriptive Statistics 57

4. Analysis of Variance 58

Chapter 1

Introduction

Statement of the Problem Investigated and the Goal that was Achieved

It has long been recognized that there is a major correlation between smell and memory. Not only has the marketing industry recognized the potential of incorporating smell into advertising as a marketing medium, but so have the entertainment and museum industries as well (Platt, 1999; Bonsor, 2001; Kaye, 2003). Until recently, commercialized multi-sensory experiences involving olfaction were limited to non-computerized mediums. Fueled by advances in multimedia and networking technologies, recent developments in computerized-olfactory technologies are abolishing this restriction. Although the technology is in its infancy, computerized-olfactory technologies are presently available at relatively low cost. Just as the marketing and entertainment industries are obvious beneficiaries of olfactory technology, based on historical and contemporary theoretical evidence regarding the human sense of smell and memory, it was reasonably assumed that the technology might prove useful if incorporated into traditional educational environments.

Although the connection between smell and memory has been well established, and companies that manufacture computerized scent technologies tout the educational benefits of their product (Trinsenx, 2005b; Trisenx, 2005c), before this study, there appeared to be no scholarly research in regard to the efficacy of incorporating computerized scent-producing peripherals into traditional educational environments. There are, however, numerous non-computerized studies on the subject of odor memory and olfaction. Many of these previous studies regarding odor memory have studied memory enhancement in terms of context dependency (see Schab, 1990; Cann & Ross, 1989; and Smith, Standing, & DeMan 1992; Herz, 1997). In regard to context dependency, the majority of these studies have found odor memory enhancement benefits to be contingent upon the presence of an odor stimulus at both the encoding stage and recall stage of a learning event (referred to as encoding specificity). However, context dependency has not been found in all odor memory related studies (Dinh, Walker, Song, Kobayashi, & Hodges, 1999; Jehl & Murphy, 1998). In many ways, this dichotomy is an inherent attribute of odor memory studies in general. Experts seemingly cannot agree on the underpinnings of observable olfactory phenomenon.

The aim of this research was to determine the odor memory enhancement benefits of incorporating olfactory, computerized peripherals into computerized multimedia-learning environments, from both a context dependent and context independent stand point. Specifically, within a multimedia environment, this study meant to ascertain whether or not there would be a significant memory performance difference between subjects who were exposed to scents at both encoding and recall over subjects who were exposed to scents at encoding only.

Using two experimental groups and one control group, each subject in this study was pre-tested, and then individually shown a short, learning task related multimedia presentation. The experimental group's version of the multimedia presentation included computer-generated, subject matter related scent cues, while the control group's version of the presentation did not. After 48 hours, a post-test (same as the pre-test) was individually administered to each subject in order to determine which group scored higher at recall.

Although there were significant improvements on test scores within groups, a statistical analysis demonstrated no significant improvement between groups. Ultimately, the findings from this study neither lend support for nor against context dependency or independency in computer-generated, scent-based multimedia environments. Based on these results, it would appear that adding computer-generated scents to multimedia environments provides no measurable value as far as memory is concerned. Because of this, further research in the area of computer-generated scent is warranted before any recommendations can be made regarding its inclusion into the traditional classroom.

Relevance, Significance, and Need for the Study

Most people spend a major portion of their lives in classrooms, learning everything from Algebra to Zoology. It is the goal of many governments and private organizations to make the learning experience more efficacious for students by discovering and implementing new educational techniques, an example of which is the early inclusion of computers in the classroom (Wood, Willoughby, Specht, Stern-Cavalcante, & Child, 2002). Educators must continue to be cognizant of advancements in technology that have the potential for creating more effective learning environments (Druin & Inkpen, 2001). For this reason, and based on the literature regarding odor memory, it was reasonably assumed that computerized olfactory technologies could be one of those advancements.

There is little doubt that multi-sensory intense applications create richer learning experiences (Sprinkle, 1999; Druin & Inkpen, 2001; Tan, Wahab, Goh, & Wong, 1998; Trisenx, 2005b; Trisenx, 2005c). As far as human memory is concerned, retention performance is enhanced when the encoding context is richer (Craik & Tulving, 1975), and olfactory stimulation has been shown to increase the vividness and clarity of mental imagery (Wolpin & Weinstein, 1983). It has long been demonstrated that the more information a person has during a learning event, the deeper the memory trace (Herz & Engen, 1996; Craik & Lockhart, 1972; Craik & Tulving; Davis, 1981). Therefore, it was reasonably assumed that multi-sensory environments, which include the sense of smell, would provide this additional information. It was further assumed that computerized olfactory technologies would not only increase the richness of the multimedia experience for the student, but that the technology would also serve as an educational aid to memory as well. This study attempted to answer the question, do computerized olfactory devices enhance memory, and if so, is that enhancement dependent on whether or not the original stimulus is present at both encoding and recall?

One of the most significant applications of the findings from this study revolves around the efficacy of incorporating scent technology into the classroom. Is the technology educationally useful, or is it a toy? From a memory enhancement perspective, if the idea for incorporating computerized scent technology into the classroom is to help students better learn and remember information for which they will later be tested on, the question as to whether or not the scent devices must be active during the exam must be answered (context dependency). For example, consider the botany student learning about specific plants as described by Trisenx (2005b) on their website. In the case of trees, identification is often based on phyllotactics (identification based on leaf configuration). Assume that a multimedia presentation has been developed that pairs the phyllotactic properties of a given set of trees with their respective and natural aromas. The student is expected to learn (identify) which tree is which based on these properties, and the learning session takes place individually in a computer lab. If odor is an effective memory enhancer, but only in context dependent situations, then any tree identification exam must also be administered in the presence of the original aroma. Individually testing each student would be very time consuming, and collectively testing an entire class with scent technology would be cost prohibitive. The results of this study demonstrate that chance could reasonably produce the same results given that a relationship between computerized smell and an improvement in memory exists. If it had been found by this study that the multi-sensory environment had more to do with odor memory enhancement than did the presence of the odor at testing (context independent), then this would have meant that reproducing the aromas at testing would not have been necessary.

The educational implications of computerized olfactory technology go well beyond that of the traditional classroom, which is an important consideration based on the results obtained here. Although a definitive recommendation for inclusion in the traditional classroom cannot be made based on these results, the technology itself could still be an effective educational aid in some niche fields. For example, scent technology could be incorporated into medical patient and haptic surgical simulators as a way to help students begin to recognize the important role that the sense of smell plays in the field of medicine (Spencer, 2006). In the medical field, certain disorders have specific odors associated with them, such as the smell of pears on a patient’s breath, which is indicative of diabetic shock, or the smell of bile during surgery, which is indicative of a ruptured organ. This same idea could be applied to other educational areas as well, such as during hazardous materials training (Cater, 1992, 1994), in museums (Daleair, 2005), and as an assistive technology for the disabled (Classen, 1999; Sprinkle, 1999; Winter, 1976).

Also, it is worth noting, scent related technology might be an effective tool in those educational environments that include children with attention deficit disorder (ADD). It has been demonstrated that adding aromas such as peppermint or Muguet to educational environments increases attention efficiency (Sullivan, Schefft, Warm, Dember, O'Dell, & Peterson, 1995; Barker, Grayhem, Koon, Perkins, Whalen, & Raudenbush, 2003; Warm, Dember, & Parasuraman, 1991). Based on this information, it could be reasonably assumed that an increase in attention efficiency might translate into an increase in memory, regardless of whether or not a child had ADD.

Lastly, the theoretical implications of this study revolve around the encoding specificity principle. If it had been found that odor memory enhancement was context dependent only, then this would have provided further evidence in support of the encoding specificity principle. If it had been found that odor memory enhancement was context *independent* in multimedia environments, then this would have provided further support for the idea that multi-sensory environments create richer memory traces, regardless of whether or not an odor stimulus is present at recall. Ultimately, in regard to memory enhancement, although subjects showed an overall improvement within groups, this study found no significant difference between groups. Based on this evidence, it could then be suggested that adding odors to multimedia environments, regardless of context, provides little additional value as far as memory enhancement is concerned.

Barriers and Issues

One of the major issues related to this study, and a barrier for future computer-scent related studies, revolves around the technology itself. Computerized scent technology is not perfect, and the computerized scent production device used in this study was no exception. Similar to the experiences of NASA, who also experimented with scent technology (P. Hogan, personal communication, September 5, 2003), saturation was an issue when it came to using scent technology during this study. Simply put, after exposure to one or more scents, the effects of subsequent aromas were greatly reduced. Some subjects reported being unable to differentiate between different aromas.

The issue of saturation is not technology specific, but instead is inherent to olfaction in general (Barfield & Danas, 1996). It is generally recognized that the human olfactory system is adaptive (Buck, 1996b; Schab, 1991). After a certain amount of odor exposure time has elapsed, a person will either become accustomed to an odor, no longer actively recognize it, or not recognize it as strongly. Davis (1977) refers to this as self-adaptation or cross-adaptation. Also, odor sensations persist longer than do the sensations for other sensory modalities (Herz & Engen, 1996), so it is counter-productive to bombard subjects with too many odors in rapid succession. Other scent technology manufacturers have developed less permeating distribution methods, such as air cannons that direct a short puff of scented air at a user's nose, but no method has found wide acceptance at this time (Kaye, 2004).

In addition to the issue of saturation, the scent device used in this study was also prone to software errors. For example, there were communication errors between software and hardware, the software program would not always release itself from system memory, and there were numerous false alarms regarding the need to replace the scent cartridge. The scent cartridges themselves are in need of design refinement, as they tend to leak, making all the aromas smell similar to one another.

Another issue regarding this study revolved around the general health of the subjects. Although there was an initial concern that some subjects might have allergies to the aromas generated by the scent device, nothing was reported on any of the consent forms and no such allergy related issue was experienced during testing. Nevertheless, even though the risk was minimal, it was still important to make sure that subjects were not allergic to any type of perfume related scent. Allergies themselves, which are generally hereditary, occur in approximately 20% of the population (Cleveland Clinic, 2005a), a fact of which future research in the area of computer-generated scent must be mindful. Air allergens typically cause reactions in the eyes, nose, and lungs of those affected. The most common allergy triggers are pollen, dust mites, mold, animal dander, insect stings, latex, certain foods, and certain medications (Cleveland Clinic, 2005b). The least common allergy triggers, but still important to consider, are allergic reactions to perfumes and fragrances. Exposure to airborne allergens generally causes minimal risk symptoms such as a runny nose, watery eyes, congestion, or sneezing.

In regard to perfumes and cosmetics, the list of common chemicals known to cause allergic reactions includes Acetone, Alpha-Pinene, Alpha-Terpineol, Benzyl Acetate, Benzyl Alcohol, Benzaldehyde, Camphor, Ethanol, Ethyl Acetate, G-Terpinene, Limonene, and Linalool (Tidwell, 2005). The Trisenx Scent Dome, which was the computerized scent device used during this study, comes with 20 pre-packaged oils (mixes of various compounds), two of which are labeled “Coffee” and “Chocolate.” The manufactures of the Scent Dome consider their scent formulas to be proprietary, thus the company would not provide specific information regarding whether or not their device contained any of the aforementioned chemicals. Although specific information was not provided, the company did supply material data sheets (see Appendix A). These material data sheets stated that, in regard to health hazards, both the Coffee and Chocolate aromas "may be irritating to skin, eyes, mucous membranes, throat, lungs [and are] harmful if swallowed." Based on this information, it was reasonably assumed that some of the chemicals associated with perfume allergies were also likely to be present in the Trisenx oil mixtures. As far as ingestion and skin contact were concerned, the oil vials of the Scent Dome were self-contained, so students did not have access to the liquid form of the aromas. However, as previously mentioned, the Trisenx scent cartridges do tend to leak, so skin contact is possible under certain circumstances.

Along these same general health related issue lines, although the testing itself did not create any health issues, several students were absent between testing sessions, which ultimately affected the sample size. Also, although two subjects reported having nasal congestion during testing, one of those subjects was in the control group and the other reported being able to smell the aromas regardless of the congestion.

It is also worth noting here that odor memory can be influenced by the connotations a person has associated with a specific odor (Herz & Engen, 1996). For example, Ehrlichman and Halpern (1988) demonstrated that subjects recalled significantly more positive memories in the presence of a pleasant odor, and significantly less positive memories in the presence of an unpleasant odor. If any of the subjects participating in this research had any personal aversion to chocolate or coffee, then the results of the post-test might have been affected.

Another issue related to this study revolved around the content appropriateness of the material presented to the subjects based on their level of cognitive development. While researching this issue, it was found that studies measuring age related olfactory memory generally approach the subject from an age degenerative standpoint, often comparing young adults to the elderly (Craik & McDowd, 1987; Kimmelman, 1993; Larsson, 1997). One study that did find odor memory differences between children and adults, a study by Lehrner, Walla, Laska, and Deecke (1999), did not test children in the 11 to 14-year-old age range (generally 6th, 7th, and 8th graders). However, when comparing the odor memory performance of 11 to 15-year-olds against that of 7 to 10-year-olds, Jehl and Murphy (1998) found those in the 11 to 15-year-old age range performed exceedingly better than 7 to 10-year-olds. Jehl and Murphy point out that, based on Piagetian concepts, 11 to 15-year-old children represent the fourth (and final) stage of cognitive development, which is referred to as the formal operational stage. Based on this information, it was reasonably assumed that the subjects that participated in this research were at the same cognitive developmental level as young adults, which meant that studies related to odor memory (encoding specificity, semantic mediation) could be generalized to 11 to 15-year-olds as well.

Lastly, in regard to the pre-test, treatment, post-test intervals, it would appear that the amount of time between initial testing and post-testing is not a significant issue when it comes to odor related memory. In regard to this study, an interval of 48 hours was given between administration of the multimedia presentation and the post-test. According to the historical research on odor memory, this interval could have been much longer and still not affected the results. For example, in one study (Winter, 1976), it was found that odor related memory primarily remained unchanged, even after 120 days. Cann and Ross (1989), citing the results of several odor memory related experiments, stated that a 15% long-term recognition loss for odors was found from 20 minutes to four weeks after testing, but that the loss only dropped an additional 5% after four months. Although there are a few researchers who question whether or not long-term odor memory is any different than other sensory modalities (Larsson, 1997), there are many more who substantiate the idea of consistency in regard to long-term odor memory (Chu & Downes, 2002; Herz & Engen, 1996; Rubin, Groth, & Goldsmith, 1984; Lawless & Engen, 1977; Lawless & Cain, 1975; Engen, 1987; Richardson & Zucco, 1989; White, 1998; Schab, 1991; Lyman & McDaniel, 1986; Engen & Ross, 1973; Danthiir, Roberts, Pallier, & Stankov, 2001; Aggleton & Waskett, 1999; Jehl, Royet, & Holley, 1997).

In regard to short-term odor memory, some studies have found the remembrance effects to be less stellar when compared to the short-term memory for other senses, such as vision (Engen, 1987; Richardson & Zucco, 1989; Schab, 1991; Engen & Ross, 1973; Danthiir, Roberts, Pallier, & Stankov, 2001). Some have argued that the difference between long-term and short-term odor memory is most likely due to the effects of differential encoding (Engen & Ross; Walk & Johns, 1985), while others (Herz & Engen, 1996; Schab) argue that much of the current empirical data on short-term odor memory is weak. As a differential encoding example, pictures can be described as having many attributes that serve as the basis for encoding a rich memory trace, while odors do not have this same richness. As time passes, the attributes associated with the visual stimuli are subject to deterioration when a person is exposed to other stimuli that share like attributes to the original stimuli. The opposite is true for odor memory because there are less perceptual features to initially encode into a memory trace (Engen & Ross; Walk & Johns; Schab; Lawless & Engen, 1977). This might lead to errors in short-term memory, but because odor memory tends to be resistant to interference, long-term memory usually remains intact. Regardless of the idea of differential encoding, some have argued that the same rules that govern the short-term memory for other human senses apply to olfaction as well (White, 1998; White & Treisman, 1997; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Rabin & Cain, 1984). In other words, as far as the senses and short-term memory are concerned, the question of whether or not olfaction is a unique memory system is beside the point, as a short-term memory store for olfaction does exist (Schab, Wijk, & Cain, 1991; Jehl, Royet, & Holley, 1994).

Although Winter (1976) and Ackerman (1991) describe odor memory related studies that spanned months, nearly all content dependent odor memory studies administered a post-test within 24 to 48 hours after initial testing (Schab, 1990; Smith, Standing, and DeMan, 1992). Because there appears to be no significant memory difference across time, and because past context dependent studies operated within a 48-hour post-test interval, a 48-hour interval between treatment and post-testing was selected for this research study as well. This is an important consideration, especially given the fact that the multimedia presentation/post-test interval between two subjects (subjects 35 and 51) was nine days due to illness. It would appear this gap had little significance on the overall test scores (refer to Appendix B), which was not unexpected.

Elements, Hypotheses, Theories, or Research Questions to be Investigated

The main theory that was investigated by this research, in regard to computer-generated aromas and odor memory, was the encoding specificity principle. The question was asked, does the encoding specificity theory hold true for all cases where odor was concerned, or is it possible that multimedia environments influence odor memory by creating a deeper memory trace during encoding, thus eliminating the need for the presence of the original odor at recall? To understand what was being asked by this question, and to understand the aim of this research, it is important to first understand the concept of encoding specificity. Schab (1990) defines the encoding specificity principle as follows:

> [The encoding specificity principle] assumes that salient elements of the context in which learning of target information occurs are encoded along with the target information as part of the memory trace. These contextual components may then function as retrieval cues to the target information when the same context is reinstated at testing (p. 649).

As previously mentioned, these types of learning situations, whereby odor memory enhancement is a product of the odor stimulus being present at both encoding and recall, are also referred to as being context dependent. The greater majority of studies regarding odor memory clearly support the encoding specificity principle and the concept of context dependency, but not all of them. In opposition to the encoding specificity principle is the idea of context *independency*. In context independent learning situations, an odor memory enhancement occurs regardless of whether or not the odor is present at recall. In other words, in context independent learning situations, the odor stimuli is present at encoding, but not at recall.

Based on this information, there were two major hypotheses that were tested by this study:

HYPOTHESIS 1: It was hypothesized that, based on the encoding specificity principle (Schab, 1990), and the results of previous context dependent studies regarding odor memory (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992), students exposed to an olfactory stimulus, both during a learning phase and a recall phase, would demonstrate a distinct memory advantage over a control group.

HYPOTHESIS 2: Taking previous context dependent studies one step further, it was further hypothesized that, based on the idea of a richer memory trace, a memory enhancement would occur for subjects exposed to the same olfactory stimulus during the learning phase, even though the odor stimulus was not present during the recall phase, when the olfactory stimulus was first presented in a multimedia environment (context *independent*).

It had been suggested, even in context dependent odor memory studies, that perhaps some logical pairing of odor stimuli with the subject matter could potentially enhance memory further, regardless of context dependency (Cann & Ross, 1989). Schab (1991) argued that odor memory might be better described as a combination of events, perhaps both semantic and environmental. It was further hypothesized that multimedia environments that include logically associated odors might be as effective, or perhaps even more effective, than those environments whereby the odor stimulus was not subject matter related, and this effectiveness might even preclude the idea of context dependency.

The aromas used during this study were both logically paired and subject matter related, yet no memory enhancement between groups was realized. If the post-test scores between the context dependent and context independent experimental groups of this study had been found to be similar, then this would have demonstrated that multi-sensory environments play a significant role in regard to odor memory, and that the encoding specificity principle could not be applied to all situations regarding odor memory.

There appear to be only two studies in support of odor memory context independency, one of which was conducted in a computerized, multimedia environment where several senses were being tapped at once. Both studies demonstrated that odor memory recall was not context dependent, and thus did not follow the encoding specificity principle (Jehl & Murphy, 1998; Dinh, Walker, Song, Kobayashi, & Hodges, 1999). It was hypothesized that, based on the results of these studies, and studies by Herz and Engen (1996), Craik and Lockhart (1972), and Craik and Tulving (1975), that a higher level of multimedia immersion would influence odor memory, regardless of the context. The research conducted here was intended to be a conceptual replication of the Dihn, et al. study.

Limitations and Delimitations of the Study

In regard to limitations and delimitations of this study, the majority of identifiable issues revolved around reliability and validity. For example, the subject pool used in this study was a convenience sample, which ultimately affects the generalizability of results. In addition, each group consisted of approximately 20 subjects (61 subjects total), and a larger sample might have had more of an influence on the results. Other issues affecting reliability and validity that have been identified include testing effects and diffusion of treatment. Refer to Chapter 3 for further details regarding reliability and validity issues.

Definition of Terms

1. *Context Dependent* – Based on the Encoding Specificity Principle, refers to situations where memory performance is enhanced when the contextual (or incidental) stimuli present during the initial learning phase is also present during the recall phase (Schab, 1990).
2. *Context Independent* – Opposite of Context Dependent, refers to situations where memory performance is enhanced even if the contextual (or incidental) stimuli present during the initial learning phase is absent during the recall phase.
3. *Cross-adaptation* – Term used to describe instances in which exposure to subsequent, differing odors creates a perception of lessening intensity (Davis, 1977).
4. *Dual Coding Theory* – States that an item can be encoded in a verbal-linguistic memory system, non-verbal-imagery memory system, or both (Lyman & McDaniel, 1986).
5. *Encoding Specificity Theory* – This principle describes memory in terms of its context. According to the principle, contextual cues are encoded into memories at the time of their formation. If the same (or similar) contextual cues are present during recall, then the memory is more likely to resurface (Schab, 1990)
6. *Episodic Memory* – Also referred to as Autobiographical Memory, Episodic Memory is the explicit memory of events that have been personally experienced (Larsson, 1997).

7. *Multimedia* – Any computerized program, presentation, or event that appeals to two or more of the humans senses: Touch, Taste, Sight, Hearing, or Smell
8. *Odor Memory* – Refers to both a person's memory for odors and memory that is evoked by, or associated with, odors (Herz & Engen, 1996).
9. *Olfaction* – The sense of smell, or the action of smelling.
10. *Proust Phenomenon* – Refers to autobiographical odor-evoked memories (episodic) that are often anecdotally described as being powerfully intense (Ackerman, 1991).
11. *Self-adaptation* – Term used to describe instances in which re-exposure to the same odor in succession creates the perception of lessening intensity (Davis, 1977).
12. *Scent Dome, The* – The name given to the computerized olfactory device developed by Trisenx (Trisenx, 2005a). The Scent Dome is the computerized olfactory device that was used in this study.
13. *Semantic Mediation* – Term given to memory retrieval enhancement that is considered to be more a product of paired association (verbally or visually mediated) than a direct link to something specifically encoded in memory (Herz & Engen, 1996).
14. *Semantic Memory* – One's general knowledge or experience with a specific subject, generally includes facts and conceptual information (Larsson, 1997).
15. *Senxware* – The name of the software used to interface with The Scent Dome (Trisenx, 2005a).

16. *Systems Memory Theory* – In regard to memory theory, this theory breaks human memory down into five interrelated memory systems (Larsson, 1997).
17. *Telemedicine* – Any medically related diagnosis or consultation between patient and caregiver that is conducted electronically over a telecommunications network.
18. *Trisenx* – Georgia based company currently marketing The Scent Dome computerized olfactory device.
19. *Verbal Mediation* - A form of Semantic Mediation whereby enhancements to memory are primarily the result of paired associations between what is to be remembered and linguistic labels (Schab, 1990).

Summary

The connection between smell and memory has been well established. Because of this, companies that manufacture computerized scent technologies tout its educational benefits (Trinsenx, 2004b) even though there appears to be no scholarly research in regard to the efficacy of computerized scent-producing peripherals in educational environments (prior to this study). Much of the previous research regarding odor memory has studied memory enhancement in terms of context dependency and the encoding specificity principle (see Schab, 1990; Cann & Ross, 1989; and Smith, Standing, & DeMan 1992), but not all studies. Based on the results of studies by Jehl and Murphy (1998) and Dinh, Walker, Song, Kobayashi, and Hodges (1999), it was hypothesized that odor memory enhancements might be context independent under certain conditions.

The goal of this research was to determine the odor memory enhancement benefits of incorporating olfactory, computerized peripherals into computerized multimedia-learning environments, from both a context dependent and context independent stand point. There were two major hypotheses tested by this study. First, it was hypothesized that, based on the encoding specificity principle (Schab, 1990), and the results of context dependent studies regarding odor memory (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992; Herz, 1997), students exposed to an olfactory stimulus, both during a learning phase and a recall phase, would demonstrate a distinct memory advantage over a control group. Taking previous context dependent studies one step further, it was further hypothesized that a memory enhancement would occur for subjects exposed to the same olfactory stimulus during the learning phase, even though the stimulus was not present during the recall phase, when the olfactory stimulus was presented in a multimedia environment (context independent).

The implications of this study are both educational and theoretical. In regard to education, computerized olfactory technologies have educational implications beyond that of the traditional classroom setting. The technology could be used for medical training (Spencer, 2006), for hazardous materials training (Cater, 1992, 1994), in museums (Daleair, 2005), and as an assistive technology for the disabled (Classen, 1999).

In regard to theoretical implications, if it had been found that odor memory enhancement was only context dependent, than this would have provided further evidence in support of the encoding specificity principle. If it had been found that odor memory enhancement was also context *independent* in multimedia environments, then this would have demonstrated that aromas add to the richness of the memory trace. As it stands, although there was a marked improvement within groups, there was no significant difference between groups, which demonstrates that in this particular case, the addition of smell to the multimedia environment had no discernable effect on memory.

Chapter 2

Review of the literature

The Theory and Research Literature Specific to the Topic

Olfaction and Memory

How does the human sense of smell work? The human physiology behind the sense of smell is actually rather complicated, and much work has been done recently to try to determine exactly how the human sense of smell works. When a person smells something, sensory neurons within the olfactory epithelium of the nasal cavity pick up on the odor's molecules (Buck, 1996a; Buck, 1996b; Sullivan, Ressler, & Buck, 1995; Zou, Horowitz, Montamayeur, Snapper, & Buck, 2001; Ranganathan & Buck, 2002). In short, these sensory neurons, which are re-generated approximately every 28 days, send signals to the olfactory bulb in the brain, which then relays signals to the olfactory cortex, which then relays the information to various cortical areas.

Part of this cortical area includes the limbic system, which is believed to be responsible for the emotional aspect of olfaction (Zou, Horowitz, Montamayeur, Snapper, & Buck, 2001; Sayette & Parrott, 1999; Davis, 1977; Herz, 1998). No other sensory system has direct access to the limbic system like the olfactory system. For this reason, it is generally believed that the limbic system projections into the amygdala and hypothalamus are directly related to the emotionally charged nature of odor memory (Cann & Ross, 2000; Chu & Downes, 2002; Glaser, 2001; Larkin, 1999; Gibbons, 1986; Herz & Engen, 1996; Ehrlichman & Halpern, 1988; Herz, 2005). Evidence of this biological connection has been demonstrated by both magnetic resonance imaging (Herz, 2004) and positron emission tomography (Herz, 1998).

Each sensory neuron within the olfactory epithelium is connected to the olfactory bulb by way of a single axon and to the mucus lining of the nasal cavity by way of multiple cilia (Buck, 1996a; Buck, 1996b; Sullivan, Ressler, & Buck, 1995). The cilium within the mucus lining contains odor receptors and the mechanisms necessary to translate sensory stimuli into usable signals. It is generally agreed that the organization of olfactory receptors within sensory neurons is not clustered, but is instead spatially organized, which is the result of genetic mapping. Much of the recent biological research regarding olfaction revolves around the idea of a spatial organization (for examples, see Buck, 1996a; Buck, 1996b; Sullivan, Ressler, & Buck, 1995; Zou, Horowitz, Montamayeur, Snapper, & Buck, 2001; Ranganathan & Buck, 2002; Malnic, Godfrey, & Buck, 2004). For a more detailed and scientific description of the physiology of olfaction, see Buck (1996b) or Kimmelman (1993). For a more detailed description for the layman, see Trisenx (2005c) or Herz and Engen (1996).

How does human memory work? There are actually many theories, both complementary and oppositional. Regardless of one’s position, Larsson (1997) makes the point that since there is a great deal of data to both support and oppose many types of memory theories, no theory can be out right rejected. In their simplest form, many memory theories break human memory down into three widely accepted classifications: sensory stores, short-term memory, and long-term memory (Craik & Lockhart, 1972). Systems theory, one of the more popular memory theories, breaks human memory down into five interrelated memory systems: procedural memory, perceptual representational system memory, semantic memory, working memory, and episodic memory (Larsson, 1997). According to systems theory, the ordering system of human memory is both phylogenetic (product of evolution) and ontogenetic (product of maturation). The more primitive memory systems, such as procedural memory and perceptual representational memory, can work independently of higher order processing, whereas the opposite is true for semantic, working, and episodic memory systems. Larsson defines the responsibility of each system as follows (p. 624): 1) Procedural Memory is expressed through skilled, behavioral, cognitive procedures, 2) Perceptual Representational System Memory is concerned with improving the identification of perceptual objects, 3) Semantic Memory is concerned with the acquisition and use of factual knowledge, 4) Working Memory registers and retains incoming information in a highly accessible form for a short period of time, and 5) Episodic Memory requires conscious recollection of personally experienced events acquired in a particular place at a particular time.

Even though the psychological and physiological underpinnings of human memory remain debatable, there have still been many studies and articles published over the years that demonstrate the link between olfaction and memory. These odor memory studies have typically fallen into one of three categories: stimulus-response type studies, associative learning type studies, or semantic mediation type studies (Herz & Engen, 1996; White, 1998). Those studies or articles on odor memory that do not clearly fit into one of these three categories generally approach the subject of olfaction from a multi-sensory, biological, or medical standpoint. Before describing each of these odor memory categories in turn, it is important to first note an important distinction between past research and the research conducted here.

In general, the two main tasks associated with the study of odor memory involve either odor identification or odor recognition (Larsson, 1997). Odor identification is typically concerned with semantic memory, while odor recognition is typically concerned with episodic memory. According to Tulving and Thomson (1973), semantic memory is generally considered the mental system responsible for the storage and utilization of conceptual, interrelational, and property specific knowledge of words, while episodic memory, which is generally concerned with the storage and retrieval of information regarding personally experienced events, looks at words as the focal elements of a given event. This study was neither an odor identification study nor an odor recognition study in the traditional sense. Subjects in this study were not asked to memorize paired-associate words for identification at a later time or asked to recall some autobiographical memory conjured up by a given odor. Instead, odors were ambiently administered during a multimedia presentation in order to measure the effects that those odors had on improving the subject's memory for facts from that presentation. The goal was to create as natural an environment as possible in order to test the effects of odor memory and context dependency. There appears to be only one other context dependent odor memory study that accomplished this in a naturalistic study, and that was a study by Aggleton and Waskett in 1999. Although the greater majority of odor related memory studies have been odor identification and odor recognition studies, these studies are still worth mentioning based on their theoretical relationship to the research conducted here.

In stimulus-response studies, subjects are typically presented with an odor stimulus that is intended to evoke some type of spontaneous, or episodic, memory (Herz & Engen, 1996). Although not an experiment in and of itself, one of the more famous elicitations of stimulus-response odor memory recall is exemplified by Marcel Proust in his book Remembrance of Things Past (Ackerman, 1991; Larkin, 1999; Kaye, 2001; Chu &

Downes, 2002; Engen, 1987). In this book, Proust describes the childhood memory of his Aunt's country home, a memory that was recollected while sitting down to have Madeleine cake with tea. The combined aroma of the cake soaked in tea was so strong and familiar to Proust, that the entirety of his childhood was laid before him in memory. These recollections became the impetus for the remainder of the book. Odor-cued autobiographical memories tend to be older than memories cued via other sensory modalities, and are often described as being emotionally charged (Chu & Downes, 2002; Herz & Cupchik, 1992). Because of this, odor-cued autobiographical memories are often referred to as demonstrating the effects of the Proust Phenomenon. For additional anecdotal accounts of episodic memory, see Laird (1935).

In another example of a stimulus-response odor memory study, subjects were given verbal label cues (the name of an odor) and asked to recall an autobiographical event associated with that odor (Chu & Downes, 2002). Afterwards, a second, extended autobiographical recall trial was attempted, whereas the original verbal label cue was presented to subjects, in addition to the actual odor, an irrelevant odor, or a visual cue. The results of the study demonstrated that when subjects where given the actual odor cues, a much greater amount of autobiographical detail was recalled, whereas when subjects were given visual cues or non-related olfactory cues, the recall for autobiographical events went down. One interesting aspect of this study was the fact that incongruent odors (ones not associated with the task at hand) actually had negative effects on the amount of detail recalled. Schab (1990) found similar results in an experiment using word lists and associated (and non-associated) ambient odors. Other stimulus-response odor memory studies, with similar results or conclusions, include

Rubin, Groth, and Goldsmith (1984), Engen (1987), Herz and Cupchik (1992), Herz (2004), Herz (1998), and Ehrlichman and Halpern (1988).

The second most common category of odor memory related studies are associated learning studies. Associated learning studies generally involve the administration of ambient odors, paired with some to-be-remembered item (TBR), at specific points during a given procedure (Herz & Engen, 1996; Pointer & Bond, 1998; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Lehrner, Walla, Laska, & Deecke, 1999; Schab, Wijk, & Cain, 1991; Jehl, Royet, & Holley, 1997). In a great many associated learning odor memory studies, the TBR item is typically the odor itself, but has also been a word list or visual item as well (Cann & Ross, 1989). Although associated learning studies are not the only category to do so, they often look at odor memory in terms of context dependency.

Context dependency, based on the encoding specificity principle, states that memory performance is enhanced in those situations where the contextual (or incidental) stimuli is present at both learning and recall (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992; Schab, 1990; Pointer & Bond, 1998; Tulving & Thomson, 1973). Schab (p. 649) writes, "[the encoding specificity principle] assumes that salient elements of the context in which the learning of target information occurs are encoded along with the target information as part of the memory trace [and] these contextual components may then function as retrieval cues to the target information when the same context is reinstated at testing." Tulving and Thomson (1973, p. 353) write, " . . . under the encoding specificity principle: What is stored is determined by what is perceived and how it is encoded, and what is stored determines what retrieval cues are effective in providing access to what is stored." This principle, according to Tulving and Thomson, is general enough to cover all instances of episodic memory.

There are a few associated learning studies that demonstrate context *independency*, a concept whereby a memory enhancement occurs regardless of the original contextual (or incidental) stimuli being present at both the learning and recall phases. For a more detailed look at the encoding specificity principle and its competing theories, see Tulving and Thomson (1973).

Historically, in contrast to the other senses and seemingly unique to olfaction, associated learning studies using olfactory stimuli have tended to support the notion of context dependency in regard to odor memory (Pointer & Bond, 1998; Herz & Engen, 1996; Herz, 1997). For example, in a 1992 study by Smith, Standing, and De Man, subjects were given a word list to memorize while being exposed to one of two non-related ambient odors that were passively administered. Two days later, some subjects were given a post-test with the original ambient odor being present, while other subjects were given a post-test with a completely different ambient odor than the original. This study found that when the same odor that had been present during the learning phase was present during the recall phase, memory was enhanced, but not vice versa. It is worth noting that in a similar study by Cann and Ross (1989), even though a different ambient odor presented to subjects at post-test did not enhance memory, it was found to increase the subject's overall participation.

In another study demonstrating context dependency (Aggleton & Waskett, 1999), patrons of the Jorvik Viking Center Museum in York, which incorporates odors into its exhibits, were tested up to six years later on their memory for information provided to them during their visit to the museum. There were three experimental groups in this study, and each group was post-tested twice. During the first post-test, group one received the original odors, group two received novel odors, and group three received no odors (control group). During the second post-test, group one received novel odors, group two received the original odors, and group three once again received no odors. It was found that group two, which received novel odors during the first post-test, and then original odors during the second post-test, showed significant improvement in memory test scores over the other groups. It is important to note, like the research conducted here, this is one of the few odor memory context dependent studies conducted in a naturalistic setting (not in a lab).

In the last example of a study demonstrating context dependency (Pointer & Bond, 1998), subjects were presented with a selected prose passage, that they were to memorize, coupled with either an olfactory stimulus cue (an odor), or a visual stimulus cue (a color). The aim of this study was to determine whether or not odor was an effective retrieval cue for more complex TBR items (instead of the typical word list). At recall, those subjects re-exposed to the original olfactory stimuli recalled the passage better than those subjects who had been given the visual cue, thus demonstrating the effectiveness of odor as a contextual cue for memory, even when the TBR item was more complex.

In contrast to those studies in support of context dependency are the studies conducted by Jehl and Murphy (1998) and Dinh, Walker, Song, Kobayashi, and Hodges (1999). Both studies demonstrate context *independency* in regard to odor memory. The focus of the Jehl and Murphy study was to determine whether or not the California Odor Learning Test (COLT), which was developed to assess the cognitive functioning of both impaired and healthy children, was able to detect developmental differences in odor learning and memory. In this study, subjects were first exposed to two sets of six odors during a single learning episode. After this learning episode, children re-called odor names either by free recall or category-cued recall. It was found that memory scores were higher for free recall than for category-cued recall. Odors were not reproduced at recall.

In the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study, a multi-sensory, virtual-reality office space experiment was conducted on 322 undergraduate students. This study showed that by increasing the modalities of sensory input (tactile, olfactory, etc.), the sense of presence for subjects was increased, as well as their ability to remember the placement of objects within the virtual environment. In the “reception area” of their virtual reality office, where there was a strategically placed coffee pot, the experimental group was exposed to the aroma of coffee via a small mask, while the control group was not. It was found that after post-testing, 95% of experimental subjects recalled the location of the coffee pot, versus a 59% recall rate for the control group. The smell of coffee was not re-produced at post-testing. The research conducted here attempted to conceptually replicate the findings of Dinh et al., but from within a less immersive environment.

The last major category of odor memory study relates to semantic mediation. Semantic mediation studies often question whether or not context dependent odor related memory enhancement is simply following the premise of semantic mediation, whereby the memory retrieval enhancement of odors is more a product of word or visual associations to the odors rather than a perceptual link to something specifically encoded in memory about the odor itself (Herz & Engen, 1996; Schab1990; Schab, 1991; Smith, Standing, & DeMan, 1992; Larsson, 1997; Lawless, 1997; Walk & Johns, 1985; Engen, 1987; White & Treisman, 1997; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Eich, 1978; Danthiir, Roberts, Pallier, & Stankov, 2001; Jehl, Royer, & Holley, 1994; Annett & Lorimer, 1995).

The most common type of semantic mediation is verbal mediation. An example of verbal mediation would be a situation in which a person mentally pairs an odor with its verbal (linguistic) representation, and then this representation serves as a mnemonic retrieval cue at post-testing. Many studies apply "dual coding theory" to the idea of semantic mediation, explaining that olfactory items are encoded in both a verbal-linguistic memory system, and a non-verbal-imagery system, which ultimately results in a stronger memory trace due to multiple, mental retrieval paths (Lyman & McDaniel, 1986, 1990; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Perkins & Cook, 1990; Jehl, Royet, & Holley, 1997; Annett & Leslie, 1996). According to the dual coding theory, odor names are stored in verbal-linguistic memory, whereas olfactory information is stored in a non-verbal-imagery memory system.

There are a number of widely recognized studies in favor of verbal mediation, such as Smith, Standing, and DeMan (1992), Schab (1990), Lawless (1997), Walk and Johns (1985), Lawless and Engen (1977), Larsson (1997), Rabin and Cain (1984), Lyman and McDaniel (1986), Eich (1978), and Engen (1987). Like all theories regarding odor memory, the overall evidence for verbal mediation is mixed. There are probably as many studies that argue against verbal mediation as there are that argue for it (Herz, 2000, 2003; Carrasco & Ridout, 1993; Herz & Cupchik, 1992; Danthiir, Roberts, Pallier, &

Stankov, 2001). There are still other studies that fall somewhere in the middle, neither taking stand for nor against verbal mediation (Engen, 1987; Chu & Downes, 2002; Richardson & Zucco, 1989; Lawless & Cain, 1975). These studies indicate that the association between odors and verbal descriptions is weak, and for odor memory recall to take place, the original odor stimulus must be present. According to Herz and Engen (1996), Lyman and McDaniel (1990), Jehl, Royet, and Holley (1997), and Davis (1981), verbal encoding will supersede sensory encoding if semantic information is available, but the linguistic component is not necessary (Herz, 2000; Herz & Cupchik; Richardson & Zucco, 1989). To put this idea another way, if a verbal or linguistic label is present during the encoding of an odor memory, then verbal mediation will play a factor at recall, and vice versa. Once mediational factors are exhausted, or they do or did not exist, then other perceptual, mental processes will take over. For additional information on studies that exemplify this idea, see Lehrner, Walla, Laska, and Deecke (1999) or Jehl, Royet, and Holley (1994).

In regard to semantic mediation and the research conducted here, it is important to note that semantic odor memory studies are generally concerned with odor identification (Larsson, 1997). Because this study was not an odor identification study, semantic mediation as an alternative explanation for memory enhancement is important to consider, but not of primary importance. Schab (1991) makes the point that if subjects are aware of an impending test of their memory, then they will use whatever means necessary to improve their performance, including internalized semantic mediation. For this reason, Schab argues that odor memory might be better described as a combination of events, perhaps both semantic and environmental.

Although not a category per se, there are a number of olfactory studies that do not neatly fit into the three aforementioned categories of stimulus-response, associated learning, or semantic mediation. Examples include Sprinkle (1998), who discusses the multi-sensory benefits of incorporating smell into the world of English literature; Glaser (2001), who discusses the olfactory deficit link between disorders such as Alzheimer's, Schizophrenia, and memory loss; Jones-Gotman and Zatorre (1988), who discuss the odor memory loss associated with certain types of brain surgery; and Moberg, Arnold, Doty, Kohler, Kanes, Seigel, Gur, and Turetsky (2003), who discuss odor hedonics in men with Schizophrenia. There are literally hundreds of studies related to the sense of smell and medically related conditions. For a clinical review of the many human disorders related to olfaction, see Kimmelman (1993).

It is worth noting, there are a handful of studies related to attention deficit issues that have implications in regard to incorporating computerized scent into the traditional classroom. For example, Sullivan, Schefft, Warm, Dember, O'Dell, and Peterson (1995) demonstrated that the presence of a fragrance could increase attention efficiency for those individuals who generally experience attention-maintenance issues. Similarly, Barker, Grayhem, Koon, Perkins, Whalen, and Raudenbush (2003) also found increases in task performance when the odor of peppermint was present, as did Warm, Dember, and Parasuraman (1991) with both peppermint and a fragrance called Muguet. Such findings have obvious educational implications (Trisenx, 2005c), especially considering the controversies surrounding Attention Deficit Disorder. If incorporating smell into educational environments helps children to concentrate, it might also be inferred that an increase in attentiveness might directly correlate to an increase in memory. Such a measurable effect was not realized with the research conducted here.

History of Multimedia Smell

Appealing to one's sense of smell via multimedia applications is not a new idea. In the 1950's, the documentary *Behind the Great Wall* provided the audience with 72 scent cues that were piped through a theatre ventilation system (Platt, 1999). In the early 1960's, Morton Heilig created the "Sensorama Simulator," a simulated motorcycle ride through the streets of New York City that appealed to all of the human senses except for the sense of taste (Heilig, 1962; Dinh, Walker, Song, Kobayashi, & Hodges, 1999). It was Heilig's goal to develop virtual training environments that would eliminate the risks associated with many dangerous professions. In the early 1980's, John Waters released *Polyester*, a movie in which audience members were provided with scratch and sniff cue cards to use at various times during the show (Platt, 1999). It was not until the late 1990's that real progress was made in the development of computerized olfactory technologies (Kaye, 2003).

Computerized Olfactory Technologies

One such late 1990's olfactory, computerized system was an electro-mechanical device created to produce various on-cue aromas activated by programmable personal computer (PC) events (Tan, Wahab, Goh, & Wong, 1998). This early version of scent technology made use of a mechanical design (stepper motor, solenoids, actuator, etc.) to provide atomized scent cues based on graphical user interface input. Other early scent technology systems used compressed air to disperse liquid scents or were wax based (Kaye, 2004).

As computerized olfactory technologies have become more commercially viable, new designs are becoming more sophisticated.

One of the more common types of computerized, olfactory designs makes use of a heated oil and fan system. The "Scent Dome," which is a device that is currently available for purchase from a Georgia based company called Trisenx (Trisenx, 2005b) and the device used for this study, is based on such a design. The Scent Dome (see Appendix C), which is approximately 5.5 inches wide, 8 inches long, and 2.5 inches tall, plugs into a standard COMM port (or USB port according to the manufacturer) and is powered by four "D" batteries or optional adapter (Bonsor, 2001). Each Scent Dome comes standard with one interchangeable scent cartridge (Trisenx). Each scent cartridge contains 20 distinct chambers, with 20 distinct vials of pre-selected scented oils, the combinations of which can create thousands of aromas.

Like the Tan, Wahab, Goh, and Wong (1998) mechanical device, the Scent Dome is also controlled by a graphical user interface. This proprietary software, called Senxware, allows the user to mix and match aromas by way of a virtual beaker, to specify their intensity, or to activate one of the pre-programmed aromas (Trisenx, 2005a). After a scent is created, and the Scent Dome software (or third party software) activates the unit for dispersion, the software communicates with the Scent Dome via a serial connection, at which time the selected chambers are heated up and the aroma is blown out of the Scent Dome by way of a small fan. The Scent Dome also comes standard with a software timing function, labeled "aromatherapy," that allows the device to be programmed to activate scents at specific intervals and for specific lengths of time.

In another contemporary scent technology design example, Aerome, a German Company, has developed a valve dispersion system that makes use of six glass tubes filled with granulates that each store a customizable aroma (Aerome, no date provided). After being activated by software, filtered and compressed air is forced through the selected glass tubes. Unlike the Scent Dome, which was designed to generally interface directly with a standard PC, the Aerome system has been primarily incorporated into proprietary, commercialized designs, such as standard or desktop sized multimedia kiosks (the perfuming industry, for example, currently uses this device).

Due to cost restrictions and general availability, the Trisenx device was the only device used in this study. At the time this research was conducted, the Trisenx device, with software, was available for $369 from the company website. Other companies with similar computerized scent production devices, at various stages of development, include Aromajet, British Telecom, Osmooze, AC2i, ScentIT, ScentAir, and DaleAir (Kaye, 2003; Kaye, 2004). These designs are either inkjet systems, wax based systems, airbrush systems, microencapsulated systems, or are similar to the Trisenx heated oil and fan design.

Smell and Education

In the Western World, the lower senses of smell, touch, and taste are not typically thought of as the most effective means for learning about the environment (Classen, 1999; Sprinkle, 1999). This Westernized idea is not found in all cultures. For example, the Warao people of Venezuela are taught to identify specific herbs, based on their aromas, to avoid the administration of pharmacologically fatal medicines (Classen). The Desana people, of the Amazon, whose name literally means “people who smell,” have an extremely complex multi-sensory, educational system. Not only do the Desana people classify things such as plants and animals based on their associated odors, but they classify other tribes by their collective odors as well. Gibbons (1986) also described a similar collective social odor system, but from a more Westernized viewpoint.

When it comes to the educational significance of incorporating smell into the learning environment, based on the literature, the educational entities most interested in scent technology, at this time, would appear to be museums (Singh, 2003; Kaye, 2003; Dale Air, 2005; Aggleton & Waskett, 1999). For example, the Natural History Museum of London features the odor of a pre-historic swampland in their dinosaur exhibits (Kaye; Dale Air), while the Jorvik Center museum in York features Viking related odors in many of their presentations (Aggleton & Waskett). Some of the more exotic aromas created for professional use include such things as "Alpine Laundry Powder," "Dragon's Breath," "Machine Oil", and even "Vomit" (Dale Air).

When it comes to the Western world, there are some obvious educational applications of smell, as well as some not-so-obvious educational applications. Some examples of obvious educational applications fall under the guise of emergency management training, such as teaching HAZMAT crews how to recognize hazardous materials based on their odors, or training firefighters to recognize, based on the aroma of a burning material, what extinguishing materials will be necessary to put out a fire (Cater, 1992, 1994). In addition, teaching people, including children (Winter, 1976), to recognize the smell of rotten food, or natural gas (Cater; Larkin, 1999), is another Western educational application of smell, as well as its incorporation into assistive educational technologies for the blind or deaf (Classen, 1999; Sprinkle, 1999).

The most obvious educational application of scent technology would be its inclusion into the traditional classroom. When touting the educational benefits of incorporating devices such as the Scent Dome into traditional, educational environments, Trisenx uses the example of a kindergartner learning to identify an apple, or the geology student learning about volcanoes (sulfur), or the botany student learning about specific plants (Trisenx, 2005b). Although this might be an obvious educational application of the technology to some, there are some not so obvious educational applications of the technology as well. Consider the field of medicine, for example, where certain odors are often indicative of specific medical conditions.

In traditional medicine, clinicians are trained to recognize the smell of pears (acetone) on a patient's breath as being indicative of diabetes (Winter, 1976; Ackerman, 1991; Gibbons, 1986). Syphilis, kidney failure, abscesses of the lung, uremia, scurvy, liver failure, rheumatic fever, diphtheria, pneumonia, and scarlet fever are also just a few of the conditions described by clinicians as having distinctive odors. In addition, odors that can be associated with surgery, such as infected wounds, human tissues, smoke (cauterization), and human body fluids such as blood or bile, have also been considered in terms of tele-present surgical applications (Keller, Kouzes, Kangas, & Hashem, 1995; Spencer, 2006). Computerized scent technologies could be incorporated into medical, educational settings as a novel way of introducing students to the finer nuances of medically associated odors.

Some of the more unusual educational applications of olfactory technology might include training dogs to sniff out bombs, drugs, and even termites, training soldiers to recognize the odor of the enemy (Gibbons, 1986), or to help people learn how to quit smoking (Sayette & Parrott, 1999). In regard to training dogs for example, if virtual odors could be accurately simulated, bomb or drug samples would not be needed to train the animals to recognize them (this would ultimately increase the number of private organizations with bomb and drug detection capabilities). In regard to solider training, although it might seem unusual, Gibbons reported that during the World Wars and in Vietnam, soldiers often smelled their enemy long before the opponent could be physically seen. Such a skill has obvious mortal implications. Lastly, in regard to smoking cessation, exposure to odors has been demonstrated to reduce the urge to smoke (Sayette & Parrott). It was reasoned that because cravings are initiated by non-automatic processes within the brain, and the act of olfaction requires a great deal of these non-automatic processes, that the odors were essentially squeezing out the psychological cravings for a cigarette.

Some other potential, non-traditional, applications of scent technology, although not directly related to the research conducted here, include such things as space station smell coding, where rooms or objects that exist in total darkness can be recognized by piped aromas (Cater, 1992); food spoilage testing, where technicians are trained to recognize rotten food shipments (Winter, 1976); to warn workers when it is time to clear a mine shaft (Barfield & Danas, 1996); to modernize test kits used to train children on what poisonous items to avoid ingesting; to help blind children learn (Sprinkle, 1999); to improve tests that assess cognitive functioning by testing odor memory, such as the California Odor Learning Test (Jehl & Murphy, 1998); and to influence mood (piped aromas have been used at Japanese companies, at London's Heathrow Airport, and even at New York's Memorial Sloan-Kettering Cancer Center [Glaser, 2001]).

Overall, there was, and continues to be, very little empirical evidence specifically supporting the efficacy of computerized olfactory peripherals in educational environments, and the findings of this particular study would argue against its efficacy. If computerized olfaction only provides entertainment value to students, then there is no educational basis for its incorporation into the traditional classroom. Based on the current literature regarding odor memory, deductions were made by Trisenx in regard to the efficacy of the Scent Dome as an educational tool. There is no apparent evidence that Trisenx bothered to conduct educational experiments like the experiment conducted here. The literature that Trisenx does provide (Trisenx, 2005c) on the scientific aspects of olfaction, education, and memory, is extremely weak and does not address odor memory issues such as encoding specificity, context dependency, semantic mediation, or dual coding. Whatever their reasoning, considering that they still advertise the educational connection, empirical evidence demonstrating the efficacy of olfactory devices in educational settings is still warranted.

Summary of What is Known and Unknown About the Topic

In summary, it is generally recognized that the sense of smell and memory are connected. In addition, the olfactory system is the only human sensory system with direct access to the physiological areas of the brain responsible for human emotions (Zou, Horowitz, Montamayeur, Snapper, & Buck, 2001; Sayette & Parrott, 1999; Davis, 1977; Herz, 1998). These systems include the limbic system, amygdala, and hypothalamus (Cann & Ross, 2000; Chu & Downes, 2002; Glaser, 2001; Larkin, 1999; Gibbons, 1986; Herz & Engen, 1996; Ehrlichman & Halpern, 1988; Herz, 2005).

Theories developed to explain the underpinnings of human memory generally approach the topic from a process view, often revolving around the classifications of sensory stores, short-term memory stores, and long-term memory stores (Criak & Lockhart, 1972). Systems Theory, one of the more popular theories, breaks human memory down into five interrelated memory systems: procedural memory, perceptual representational system memory, semantic memory, working memory, and episodic memory (Larsson, 1997).

Historically, the two main tasks associated with odor memory studies have revolved around either odor identification or odor recognition (Larsson, 1997). Odor identification studies are typically concerned with semantic memory, while odor recognition studies are typically concerned with episodic memory. The research conducted here was neither an odor identification study nor an odor recognition study.

The greater majority of studies related to odor memory fall into one of three categories: stimulus response, associative learning, or semantic mediation (Herz & Engen, 1996; White, 1998). Other miscellaneous studies approach olfaction from a multi-sensory, biological, or medical standpoint. Stimulus response studies typically present a subject with an odor stimulus intended to evoke some autobiographical memory (Herz & Engen, 1996), while associative learning studies generally involve the administration of ambient odors paired with some TBR item (Herz & Engen, 1996; Pointer & Bond, 1998; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Lehrner, Walla, Laska, & Deecke, 1999; Schab, Wijk, & Cain, 1991; Jehl, Royet, & Holley, 1997). A number of associative learning studies look at odor memory in terms of context dependency.

The idea of context dependency is based on the encoding specificity principle, which basically states that memory performance is enhanced in those situations where the contextual (or incidental) stimuli that was present during the learning phase is also present at recall (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992; Schab, 1990; Pointer & Bond, 1998; Tulving & Thomson, 1973). The greater majority of studies are in support of the idea of context dependency, but not all studies. Two studies that found opposite results were Jehl and Murphy (1998) and Dinh, Walker, Song, Kobayashi, and Hodges (1999). As previously mentioned, the research conducted here was meant to conceptually replicate the Dinh, et al. study.

Some studies question whether or not context dependent odor related memory enhancement is simply following the premise of semantic mediation, whereby memory retrieval enhancements are more a product of word or visual associations rather than a direct link to something specifically encoded in memory (Herz & Engen, 1996; Schab, 1991; Larsson, 1997; White, Hornung, Kurtz, Treisman, & Sheehe, 1998; Eich, 1978; Danthiir, Roberts, Pallier, & Stankov, 2001; Jehl, Royer, & Holley, 1994; Annett & Lorimer, 1995). Semantic mediation, with a linguistic component, is often referred to as verbal mediation and argued within the framework of dual coding theory. According to dual coding theory, odor memory traces are encoded in both a verbal-linguistic memory system and a non-verbal-imagery system, which ultimately results in a stronger memory trace (Lyman & McDaniel, 1986, 1990; White, et al., 1998; Perkins & Cook, 1990; Jehl, Royet, & Holley, 1997; Annett & Leslie, 1996). Like most theories regarding odor memory, studies related to the validity of semantic mediation are mixed.

Appealing to one's sense of smell via multimedia applications is not a new idea. Nevertheless, it was not until the late 1990's that computerized olfactory systems began taking shape (Tan, Wahab, Goh, & Wong, 1998). Now computerized scent production devices are commercially available from companies such as Aromajet, British Telecom, Osmooze, AC2i, ScentIT, ScentAir, Trisenx, and DaleAir (Kaye, 2003, 2004). Computerized scent production designs are either inkjet systems, wax based systems, airbrush systems, microencapsulated systems, or heated oil systems.

Currently, even though the educational entities most interested in scent technology appear to be museums (Singh, 2003; Kaye, 2003; Dale Air, 2005; Aggleton & Waskett, 1999), the technology does have other educational applications. These educational applications include areas such as HAZMAT training (Cater, 1992, 1994), telemedicine (Spencer, 2004, 2006), and incorporating the technology into the traditional classroom (Trisenx, 2005b).

The Contribution this Study makes to the Field

There is no direct evidence that commercially available scent production devices improve memory, regardless of the fact that companies like Trisenx hang their hat on the premise. Nevertheless, based on the theoretical evidence regarding odor memory and encoding specificity, it was reasonably assumed, even by computerized scent manufacturers, that in context dependent odor memory environments, memory would be improved if the odor stimulus were present at both encoding and recall. This study attempted to provide rigorous, scientific proof that computerized scent technologies are every bit as effective as passive scent technologies in the traditional classroom. Because the results of this study do not support such a conclusion, further research in the area of computer-generated scent is warranted before recommendations on the inclusion of scent technology in the traditional classroom can be made.

Chapter 3

Methodology

Because computerized scent technology manufacturers tout the efficacy of their devices in traditional educational environments, this research was designed to test their anecdotal presumptions in the traditional classroom. Specifically, the aim of this research was to determine the odor memory enhancement benefits of incorporating olfactory, computerized peripherals into computerized multimedia-learning environments, from both a context dependent and context independent standpoint, in a traditional classroom setting.

Research Methods Employed

Sampling Method

A local private school agreed to participate in this study and the sampling method was a non-probability, convenience sample. Although stratified random sampling would have increased the generalizability of results, it would not have been feasible based on subject availability (a stratified random sample would have required the participation of an entire school district).

Participants

The participants in this study were 6^{th}, 7^{th}, and 8^{th} grade students from a local private school called Holy Cross Lutheran, located in Wichita, KS. There were a total of 62 students who returned consent forms and participated in the study. One subject was not available for post-testing, thus 61 subjects were ultimately used in the sample. Refer to Appendix B for information regarding subject demographics.

Site

The study was conducted at Holy Cross Lutheran School in Wichita, KS. The pre-test was administered in the regular science classroom, while the treatments and post-tests were administered in the science supply room (approximately 32' x 12') directly connected to the main science classroom. Refer to Appendix D for photographs of the testing area.

Role of Researcher

In this study, the researcher was responsible for all aspects of the research. For example, the researcher explained the reason for the study to the students prior to pre-testing; the researcher developed the multimedia presentation; the researcher administered the pre-test, treatments, and post-test; and the researcher debriefed students on the overall results and premise of the study. In regard to the physical administration of the study, the researcher set up the testing equipment, managed the flow of subjects, and gave individual instructions to subjects prior to testing.

Research Design

The research design of this study was one factor, between groups, with a pre-test and post-test. Subjects were assigned to one of three conditions.

Variables

The independent variable (IV) in this study was exposure to a multimedia presentation with or without the presence of scents generated by a computerized olfactory scent-producing device. The dependent variable (DV) was each subject's level of recall about specific facts related to that multimedia presentation.

Experimental Groups

There were three conditions for this experiment, two experimental group conditions and one control group condition (see Appendix E). Experimental group A, which consisted of 21 subjects, was shown the multimedia presentation with smell and post-tested without it (free recall). Experimental group B, which consisted of 19 subjects after attrition, was shown the multimedia presentation with smell, and post-tested with smell. Both experimental groups were exposed to the same set of aromas. The control group, which consisted of 21 subjects, was shown the multimedia presentation without smell and post-tested without smell.

Specific Procedures Employed

Several weeks prior to the administration of the multimedia presentation, subjects were given a pre-test, as a group, in their regular classroom. Each grade level was administered the pre-test separately. Subjects were given approximately five minutes to complete the pre-test. Before the pre-test was administered, the researcher explained the purpose of the study to the subjects and explained that there would be no grade for the test. Subjects were instructed to guess on those answers for which they had no answer.

In regard to the purpose of the study and what information was given to subjects prior to pre-testing, the explanation given to subjects was scripted. Each grade level was given a brief explanation on the Doctoral process, the dissertation process, and some vague details regarding the study itself. Subjects were told that the goal of the study was to measure the effects of multimedia on memory, that the subject matter of the presentation would be on the processing of chocolate and coffee, and that the researcher would return after the results were tabulated to explain the study in greater detail.

Although the idea of incorporating computerized-scents into the multimedia environment was not specifically mentioned during this initial discussion, the parental consent forms did mention it, so some students were aware that olfaction played some role in the research.

The multimedia portion of this research experiment commenced on October 17, 2005, and ended November 2, 2005. Each participant was individually shown a PowerPoint presentation regarding the processing and importation of coffee and chocolate (refer to Appendix F). The presentation, which ran for 5.5 minutes (3.5 minutes on chocolate and two minutes on coffee), was transitionally timed based on voice narration by the researcher.

For the experimental groups, the aromas of coffee and chocolate were triggered during the PowerPoint presentation via the software-hardware interface between the Trisenx Senxware software and the Scent Dome olfactory device. Although the PowerPoint presentation could have been designed with Java plug-ins that automatically activated the Scent Dome at specific intervals during the presentation, the "aromatherapy" timing function was used instead. Using this function, the duration of each aroma was manually configured and then saved as a "smell file." During the administration of the multimedia presentation (for Groups A and B), the Scent Dome was programmed to run for six minutes (chocolate on for 180 seconds, off for 20 seconds, coffee on for 119 seconds, off for 41 seconds). Timing was based on the transition between topics (chocolate and coffee) and the PowerPoint and Senxware programs were activated simultaneously.

After 48 hours, subjects individually returned to the original testing area for administration of the post-test (pre-test and post-test were the same, refer to Appendix G for the set of multiple choice questions). The front side of the post-test included five questions related to the chocolate portion of the presentation, while the backside included five questions related to the coffee portion of the presentation. Each subject was given approximately five minutes to complete the post-test. Each subject had two minutes to complete the first set of questions (this was timed). The second set of questions was not officially timed, however all subjects finished within two to three minutes. Although Groups A and C did not receive aromas during post-testing, post-test timing was based on the activation cycle of the Scent Dome for Group B. During post-testing, for Group B, the Senxware software utility was programmed to activate the Scent Dome for a three-minute cycle (chocolate on for 90 seconds, off for 30, coffee on for 45 seconds, off for 15 seconds).

For experimental group A, the post-test was free recall, with no aromas present. For Experimental group B, aromas were passively present during post-testing. The control group, which was never exposed to any aromas, was required to free-recall on the post-test.

As far as scheduling was concerned, subjects were available for testing on Mondays and Wednesdays at various times throughout the day. Subjects participated one at a time. After one subject was done, that subject returned to class and the next subject was called. This turnaround time between subjects, which was between six and eight minutes, included short instructions, the presentation itself, time for the room to air out between groups (one to two minutes), and transition from classroom to testing area. Based on this schedule, approximately 29 students were tested during weeks one and two, and three students were tested during week three.

After being randomly assigned to conditions, subjects were then divided into three weekly groups. On day one of each week (Monday), subjects assigned to the control group were tested first to eliminate the potential effects of lingering odors in the testing area, followed by those assigned to experimental groups A and B, respectively. On day two of each week (Wednesday), control groups subjects were post-tested first, followed by subjects in experimental groups A and B, respectively. During the testing of control groups subjects, and subjects from Group A at post-testing, the Scent Dome was unhooked from the PC, removed from the shelf, and placed in an airtight box.

As each subject came into the testing area, they were asked to sit at the stool that was in front of the PC (this stool is labeled seat 1 in Appendix D). On day one (Monday), it was explained to students that they would be watching a short multimedia presentation on the processing of chocolate and coffee. It was also explained that the researcher would be sitting nearby (in seat 2), during the presentation, in order to be available to resolve any technical problems. During testing, the researcher worked vigorously on a laptop computer to appear engaged. The Scent Dome itself was situated on a shelf well below eye-view of the subject and never referred to. Refer to Appendix D for a photograph of the testing area that demonstrates the placement of the Scent Dome.

On day two (Wednesday), approximately 48 hours later, students were once again individually ushered into the science supply room to take the post-test. The only difference between the set up of the room during post-testing was that the PC monitor was no longer directly in front of the subject at seat 1. Each subject was then given a paper version of the post-test and instructions on how to complete the test. Specifically, subjects were told that they had two minutes to complete the first five questions, and that after the timer sounded, they could turn the test over to complete the next five questions. Nearly all subjects were done with the first five questions well before the initial two-minute interval expired. Before the post-test, each subject was reminded that there was no grade for the test and that a debriefing would take place several weeks after the results were tabulated.

Formats for Presenting Results

The unit of analysis for this study was each subject's individual score on the pre-test and post-test. Descriptive statistics are presented as well as a single factor, between groups analysis of variance. Excel was used to calculate both the descriptive and inferential statistics, and the results are presented in table format.

Resource Used

The major resources used to conduct this study included a scent device, a PC, and a room to conduct testing. The scent device was purchased from Trisenx at a cost of $369 plus shipping. A customized scent cartridge, which included chocolate and coffee scents only, was also used in this study. Trisenx provided this customized cartridge at no charge. The researcher also provided the PC needed to operate the multimedia presentation and the Scent Dome, in addition to a fan to help air out the room between subjects (it is worth noting that between subjects, both the door and windows to the science supply room where open for one to two minutes to facilitate scent disbursement).

Holy Cross Lutheran School agreed to participate in this study and provided access to the student subjects. Mrs. Betty Amey, the 6th through 8th grade science teacher, agreed to be the liaison between the researcher and the students. Testing took place in Mrs. Amey's classroom and the science supply room directly connected to her classroom.

Reliability and Validity

The fact that the subjects were drawn for a convenience sample might cause problems in regard to the generalizability of the results obtained by this study. Short of a stratified random sample, there was nothing that could have effectively been done to eliminate this threat. Based on the size and politics of the local Wichita, Kansas public school district, a stratified sample was not feasible. Although both genders were adequately represented by the sample, race was not. All the student subjects who participated in this study were Caucasian and very likely from middle to upper class families.

Testing effects might have been an issue in this study as well, since the pre-test and post-test asked the same set of questions. Exposure to the original set of questions might have played a role in the post-test score (pre-test-post-test sensitization). It was also assumed that a pre-test might lessen the effects of statistical regression, as those familiar with the subject matter prior to the pre-test could be weeded out of the sample. However, it was found that in all but one case, students who scored five points or more on the pre-test actually showed no improvement or scored less on the post-test.

Although the consent forms that students were required to take home did make mention of the fact olfaction would play a role in the research, the researcher did not discuss this idea with the students prior to testing. This non-disclosure might have ultimately produced a diffusion of treatment effect (groups discussing the study amongst themselves). It was observed that some male subjects from Groups A and B tried very hard to locate the source of the aromas during testing, while the same behavior was not observed with the females.

In regard to the content and age appropriateness of the PowerPoint presentation and test questions, Mrs. Betty Amey made recommendations on needed changes prior to testing. Recommendations primarily revolved around changing the wording of certain enigmatic concepts in order to maintain educational-level consistency across all age groups. All of Mrs. Amey's recommendations were implemented.

Summary

This research study took place at Holy Cross Lutheran School, a private middle school in Wichita, Kansas. Participants in the study were 61 middle school-aged science students. Pre-testing took place in the science classroom, while post-testing took place in the science supply room directly attached to the science classroom.

The research design for this study was one factor, between groups, with a pre-test and post-test. The researcher was responsible for all aspects of the study, from developing the multimedia presentation to administering the pre-test and post-test. The multimedia presentation was about how chocolate and coffee are processed. The pre-test and post-test, which included the same set of test questions, contained multiple-choice questions regarding factual information provided by the multimedia presentation.

The IV in this study was exposure to a multimedia presentation that either included, or did not include, odors generated by a computerized olfactory device (at either treatment or post-testing). The DV in this study was each subject's level of recall about the factual information provided in the presentation.

There were three conditions for this experiment, two experimental groups and one control group. Experimental group A was shown the multimedia presentation with smell and post-tested without smell (free recall). Experimental group B was shown the multimedia presentation with smell, and post-tested with smell. Both experimental groups were exposed to the same set of smells. The control group was shown the multimedia presentation without smell and tested without smell. Participants were randomly assigned to one of these three conditions.

The pre-test was administered several weeks prior to testing. The post-test was administered 48 hours after subjects viewed the multimedia presentation (with or without smell). Testing lasted three weeks. During weeks one and two, 29 subjects were tested. A total of three students were tested during the third week. Treatments were administered on Mondays and post-testing on Wednesdays.

The unit of analysis for this study was each subject's individual score on a pre-test and post-test. In addition to descriptive statistics, an analysis of variance was calculated as well. Excel was used to calculate these statistics.

In addition to the physical office space and subject pool needed to conduct this study, major resources used in this study included the Scent Dome, a PC, small fan, and a room for testing. The researcher provided the hardware, whereas Holy Cross Lutheran School provided the testing area.

In regard to the reliability and validity of this study, affective issues include convenience sampling, testing effects, and diffusion of treatment. Because the sample was not stratified, the results of the study cannot be scientifically generalized. Exposure to the original set of questions might have played a role in the post-test score (pre-test-post-test sensitization). It is also possible that students from different groups discussed the study amongst themselves, which might have influenced the results in some cases.

Chapter 4

Results

There were a total of 61 6th, 7th, and 8th grade students that participated in this study. Subjects were randomly assigned to one of three conditions: Administration of a multimedia presentation which included computerized smell during the presentation but not during post-testing (Group A); administration of a multimedia presentation that included computerized smell present during both the presentation and post-testing (Group B); and then finally a control group (Group C) which received no computerized smell. All Group A, B, and C subjects were pre-tested several weeks prior to commencement of the study and then given a post-test approximately 48 hours after viewing the multimedia presentation.

It was hypothesized that subjects in both experimental conditions (Groups A and B) would demonstrate an improvement in memory over the control group based on previous studies regarding odor memory. Overall, although there was significant improvement within groups between pre and post-test, an analysis of variance demonstrated no significant difference between groups. The average pre-test and post-test scores between groups were relatively consistent.

The data analysis, which is broken into segments by experimental groups, was calculated using Microsoft's Excel. This data analysis demonstrates descriptive statistics for each group and inferential statistics between groups. Subjects were scored on a 10-point pre-test/post-test scale. The questions on the pre-test and post-test were identical, multiple-choice, and related to the multimedia presentation (refer to Appendix G).

Data Analysis

Descriptive statistics for Group A are depicted in Table 1. Group A received scents during the multimedia presentation, but not during post-testing. The average pre-test score was 2.28 out of 10, while the average post-test score was 5.42 out of 10. The standard deviation was 1.70 and 1.83 respectively. For a list of scores by subject, refer to Appendix B.

Group A	*Pre-Test*	*Post-Test*
Mean	2.285714	5.428571
Standard Error	0.372526	0.39983
Median	2	5
Mode	3	4
Standard Deviation	1.707128	1.832251
Sample Variance	2.914286	3.357143
Kurtosis	-0.292676	-0.55178
Skewness	0.572631	0.09901
Range	6	7
Minimum	0	2
Maximum	6	9
Sum	48	114
Count	21	21

Table 1. Group A Descriptive Stats.

Descriptive statistics for Group B are depicted in Table 2. Group B received scents both during the multimedia presentation and the post-test. The average pre-test score was 2.42 out of 10, while the average post-test score was 5.52 out of 10. The standard deviation was 1.26 and 1.71 respectively. For a list of scores by subject, refer to Appendix B.

Group B	*Pre-Test*	*Post-Test*
Mean	2.421053	5.526316
Standard Error	0.289341	0.392685
Median	2	5
Mode	2	7
Standard Deviation	1.261207	1.711673

Sample Variance	1.590643	2.929825
Kurtosis	-0.19483	1.058998
Skewness	0.198566	-0.86718
Range	5	7
Minimum	0	1
Maximum	5	8
Sum	46	105
Count	19	19

Table 2. Group B Descriptive Stats.

Descriptive statistics for Group C are depicted in Table 3. Group C, the control group, did not receive scents at any time. The average pre-test score was 2.23 out of 10, while the average post-test score was 6.04 out of 10. The standard deviation was 1.26 and 1.56 respectively. For a list of scores by subject, refer to Appendix B.

Group C	*Pre-Test*	*Post-Test*
Mean	2.238095	6.047619
Standard Error	0.275203	0.341399
Median	2	6
Mode	3	7
Standard Deviation	1.261141	1.564487
Sample Variance	1.590476	2.447619
Kurtosis	-0.339636	-0.63807
Skewness	0.330493	-0.17312
Range	5	6
Minimum	0	3
Maximum	5	9
Sum	47	127
Count	21	21

Table 3. Group C Descriptive Stats.

The results from a single factor analysis of variance are depicted in Table 4. For this analysis, $F = .79$ with a $P < .45$. These results demonstrate that chance alone could reasonably produce the same results given that a relationship between computerized smell and an improvement in memory exists.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	4.610543	2	2.305271	0.791945	0.457799	3.155932
Within Groups	168.8321	58	2.910898			
Total	173.4426	60				

Table 4. Analysis of Variance.

Findings

Although it was predicted that both experimental groups would demonstrate an improvement in memory over the control group, there was actually no significant difference found between groups. Nevertheless, there was a significant difference within groups as demonstrated by the pre-test and post-test scores. According to these results, the addition of computerized smell to the multimedia environment was largely ineffective.

There are several significant alternative explanations for the results obtained here. First, it is entirely possible that the level of immersion experienced during a standard multimedia presentation is not significant enough for computerized scents to affect memory. Second, the scent delivery method used during this study may have been too passive. During the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study, an oxygen mask was used to administer the aroma. Third, when considering the fact that this study was an attempt to conceptually replicate the findings of Dinh et al., only one scent related question was asked of subjects during that study, whereas 10 scent related questions were asked of subjects in this study. Fourth, scent technology is not perfect. The device used during this study, the Scent Dome, was subject to both hardware and software related complications. Fifth, it is also possible that as a contributor to the richness of a memory trace, when coupled with faster functioning sensory modalities such as sight and sound, the efficacy of olfaction is superseded. Lastly, it is possible that a sampling error might have occurred and the subject pool was not truly representative of the population. Each of these alternative explanations is described in further detail in Chapter 5.

There were a few general observations made during this experiment that are worth noting here. First, nearly all subjects showed great interest in the multimedia presentation, regardless of the group that they had been assigned to. This interest might have been a product of the novel-learning environment, an inherent attribute of multimedia in general, a general interest in the subject matter, or a combination of the aforementioned.

Second, during the debriefing, which took place several weeks after post-testing, subjects expressed great interest in computerized olfaction. Whether substantiated or not, subjects reported the perception that depending on the subject matter, computerized olfaction would improve their ability to learn. Several students expressed an interest in purchasing the Scent Dome for personal use.

Summary of Results

Mean post-test scores between groups were relatively consistent at 5.42, 5.52, and 6.04 respectively. Although there was significant improvement within groups between pre and post-test, an analysis of variance demonstrated no significant difference between groups. Ultimately, the inferential statistic obtained here ($F=.79$ with $P < .45$) was not greater than the critical value (F Critical = 3.15). These results demonstrate that, under the conditions as designed for this research, computerized smell is largely ineffective in regard to improving memory in multimedia environments.

There are a number of alternative explanations that might explain the results obtained by this study. Examples include the possibility that the level of immersion experienced during a standard multimedia presentation is not significant enough for computerized scents to affect memory; that the scent delivery method used during this study may have been too passive; that too many scent related question were asked of subjects; that scent technology is not perfect; that olfaction might be superseded when other sensory modalities are appealed to; or that a sampling error occurred.

Lastly, there were a few observations made during this experiment that are worth noting. First, subjects expressed great interest in the multimedia presentation, regardless of group assignment. Second, although not supported by the results of this study, students felt as though the addition of computerized smell to the learning environment would help them learn, and several students expressed an interest in owning the Scent Dome.

Chapter 5

Conclusions, Implications, Recommendations, and Summary

Conclusions

The results of this study demonstrate that chance could reasonably produce the same results given that a relationship between computerized smell and an improvement in memory exists. Based on the results of this study, both hypotheses were rejected. There was no significant difference between groups in regard to computerized-scent enhancing memory.

HYPOTHESIS 1: It was hypothesized that, based on the encoding specificity principle (Schab, 1990), and the results of previous context dependent studies regarding odor memory (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992; Aggleton & Waskett, 1999; Herz, 1997), students exposed to an olfactory stimulus, both during a learning phase and a recall phase, would demonstrate a distinct memory advantage over a control group. This was tested via Group A, and the results demonstrated no distinct advantage over the control group (Group C) or Group B.

HYPOTHESIS 2: Taking previous context dependent studies one step further, hypothesis two stated that, based on the idea of a richer memory trace, a memory enhancement would occur for subjects exposed to the same olfactory stimulus during the learning phase, even though the odor stimulus was not present during the recall phase, when the olfactory stimulus was first presented in a multimedia environment (context *independent*). This hypothesis was primarily based on the results of a 1999 virtual reality study, by Dinh, Walker, Song, Kobayashi, and Hodges, that included appealing to one's sense of smell. This was tested via Group B, and the results demonstrated no distinct advantage over the control group (Group C) or Group A.

There are a few alternative explanations for the results obtained here. First, it is entirely possible that the level of immersion experienced during a standard multimedia presentation is not significant enough for computerized scents to affect memory. To put it another way, it is possible that adding computerized scent to a traditional multimedia presentation is not a significant enough change in richness to warrant an improvement in memory. Two examples help illustrate this. In the first example, the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study, subjects were exposed to the scent of coffee during a virtual office tour that also included tactile, auditory, and visual cues. The results of this virtual reality study indicated that increasing sensory modalities leads to an increase in one's sense of presence, which ultimately improves one's memory for objects within that virtual environment. It is important to note t hat in the Dinh et al. study, the aroma of coffee was administered via an oxygen mask that was worn by the subject. The extra level of virtual realism, in addition to the more active scent dispersion mechanism, might help to explain the differences between the Dinh et al. study and the research conducted here.

In the second example (Aggleton & Wasket, 1999), patrons of the Jorvik Viking Center Museum in York, which incorporates odors into its exhibits, were tested up to six years later on their memory for information provided to them during their visit to the museum. It was ultimately found that subjects receiving odors from the exhibit scored higher on a post-test than did the control group of patrons. The original odors were delivered in a naturalistic museum setting, which is as immersive an environment as is possible.

Also, referring back to the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study, subjects were exposed to only one aroma (coffee), and only one question related to the aroma was asked of each participant. It was a spatial orientation question (literally, "where is the coffee pot located") and not nearly as mentally demanding as the set of multiple-choice questions presented to subjects who participated in this study. These two studies might ultimately be testing different parts of the brain.

Although the research conducted here was also conducted in a naturalistic setting, it was far from immersive and perhaps not as ecologically valid as it should have been. Students did have regular access to the science supply room where testing took place, but in a context other than test taking. The room is generally used to fetch supplies to and from the classroom for various science related activities.

It is also possible that the findings obtained here are the result of a sampling error. Perhaps the sample was not large enough or not representative. This might explain why the well-established concept of encoding specificity was not supported by the results of this study.

These results might also indicate that the multimedia presentation and administration of computerized aromas was not long enough to affect memory. In this particular case, the multimedia presentation ran for 5.5 minutes and subjects were required to passively sit and watch the presentation. The study was designed this way due to time constraints. If subjects were allowed to progress from slide to slide at their own pace, then this might have influenced the results. Different exposure periods to both the multimedia presentation and/or the aromas might have changed the outcome, as well as different aromas (perhaps something less innocuous). It is also possible that computerized smell might be more affective with a younger group of subjects.

It is also possible that as a contributor to the richness of a memory trace, perhaps when odors are available by themselves they supersede other sensory modalities. Consider once again the context dependent study conducted by Pointer and Bond (1998). In this study, subjects were presented with a selected prose passage, that they were to memorize, coupled with either an olfactory stimulus cue (an odor), or a visual stimulus cue (a color). At recall, those subjects re-exposed to the original olfactory stimuli recalled the passage better than those subjects who had been given the visual cue, thus demonstrating the effectiveness of odor as a contextual cue for memory, even when the to-be-remembered item was more complex. Perhaps if there had been some combination of the visual and olfactory stimuli, results similar to the ones experienced by this study might have been realized.

Lastly, the design of the Scent Dome device, from a hardware perspective, might have affected the results of this study as well, but in a minor way. Although the Scent Dome was relatively affective during this study, as was discussed under the "Barriers and Issues" section of this report, the Scent Dome is an immature design and in need of refinement. The inter-changeable scent cartridges for use with the Scent Dome are designed with 20 separate chambers, each containing about one milliliter of scented oil in a small vial (refer to Appendix C for photographs of a scent cartridge). Each vial contains one small heating element intended to increase the volatility of the oil. During activation, one small fan, which is built into the Scent Dome base unit, is activated to circulate air through the center of the scent cartridge and ultimately into the room. There are two major flaws with this design that could have had some effect on the results of this study.

First, the scent cartridge itself is volatile without the heating elements and fan. In other words, a person can smell the device even when it is passively resting. In this particular case, the scent cartridge was customized with 10 chambers of chocolate aroma oil and 10 chambers of coffee aroma oil. The passive scent emitted from the cartridge was thus a combination of these two aromas.

Second, the scent cartridges themselves tend to leak in transit. There were three cartridges ordered for this study, two of the three arrived compromised. This flaw not only increased the passive scent being emitted during inactivity, but also influenced the aroma of other scents when the unit was active. One of the main reasons for this crossover is due to the fan design of the unit. Instead of a single fan mounted to the base unit and blowing through the center of a scent cartridge, the design would be more effective with if each chamber had its own fan. This type of design might even eliminate the need for the heating elements, since the oils themselves are clearly volatile without manipulation.

Implications

The implications of this study primarily revolve around three ideas. First, the results clearly demonstrate that additional research is warranted before recommendations regarding the incorporation of computerized scent into the traditional classroom can be made. Second, the results also indicate that off-the-shelf computerized scent technologies, like the Scent Dome, are in need of design improvements. Future studies in the area of computerized scent should seek to address these design flaws. Lastly, the results of this study raise additional questions regarding olfaction, context dependency, and encoding specificity. Future computerized scent-based studies exploring these topics should first incorporate the experimental design recommendations suggested in the next section before ruling out the original hypotheses posited by this study.

Recommendations

This study was meant to be a conceptual replication of the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study. Further research in this area might include a similar experimental design as the one conducted here, but within a more immersive environment. Questions developed to measure enhancements to memory should be more rigorous than the questions developed by Dihn et al.

For those attempting to replicate the results obtained by this study, or perhaps improve its design, there are several recommendations. First, using a larger set of test subjects is recommended. Second, allow students to interact with the multimedia presentation and work at their own pace. Third, consider using a different computerized scent technology other than the Trisenx device, develop a proprietary system, or modify an existing one. Also, instead of "hiding" the device, it might be more appropriate to place it in the open and explain to subjects what it does.

It would also be appropriate for future research in this area to approach the technology from a qualitative viewpoint in addition to a quantitative one. As was previously mentioned, it has been demonstrated that adding aromas to educational environments increases attention efficiency (Sullivan, Schefft, Warm, Dember, O'Dell, & Peterson, 1995; Barker, Grayhem, Koon, Perkins, Whalen, & Raudenbush, 2003; Warm, Dember, & Parasuraman, 1991). Even if an increase in attention efficiency does not directly correlate to an increase in memory, perhaps a measure of a subject's perceptions of computerized scent in the traditional classroom might shed some light on its effectiveness. If students are more interested in learning based on the inclusion of computerized scent technology in the classroom, then it might be an appropriate addition.

Lastly, computerized scent devices might be better served if employed in fields that more closely rely on the sense of smell, such as the medical field. For example, in regard to telemedicine, a similar study to the one conducted here could be developed to test the effects of incorporating smell into patient or haptic surgical simulators (Spencer, 2006). In this type of study, the independent variable could be either the presence or absence of medically related odors during virtual training, and the dependant variable could be performance on either subsequent virtual training events or real world events.

A similar, but less technologically driven medically related study possibility, might include resident doctors learning to recognize the various odors associated with common disorders such as diabetic shock or arsenic poisoning by way of computerized scents. Groups could include a computer scent-based multimedia presentation group, a text-based description group, and a passive odor-based group similar to the one described by Gibbons (1986). The independent variable could be the presence or absence of computerized smell, while the dependent variable could be performance on an odor-recognition test.

Summary

It has long been recognized that there is a major correlation between smell and memory. Not only has the marketing industry recognized the potential of incorporating smell into advertising as a marketing medium, but so has the entertainment and museum industries as well (Platt, 1999; Bonsor, 2001; Kaye, 2003). Although the connection between smell and memory has been well established, and companies that manufacture computerized scent technologies tout the educational benefits of their product (Trinsenx, 2005b; Trisenx, 2005c), before this study, there appeared to be no scholarly research in regard to the efficacy of incorporating computerized scent-producing peripherals into traditional educational environments.

Based on historical and contemporary theoretical evidence regarding the human sense of smell and memory, it was reasonably assumed that the technology might prove useful if incorporated into traditional educational environments. Odor memory studies generally fall into one of three categories: Semantic memory studies, stimulus response studies, or associated learning studies. Much of the previous research regarding odor memory has studied memory enhancement in terms of context dependency and the encoding specificity principle (see Schab, 1990; Cann & Ross, 1989; and Smith, Standing, & DeMan 1992). In regard to context dependency, the majority of these studies have found that odor memory enhancement benefits are contingent upon the presence of an odor stimulus at both encoding and recall (referred to as encoding specificity). Schab (1990) defines the encoding specificity principle as follows:

> [The encoding specificity principle] assumes that salient elements of the context in which learning of target information occurs are encoded along with the target information as part of the memory trace. These contextual components may then function as retrieval cues to the target information when the same context is reinstated at testing (p. 649).

However, not all odor memory related studies have supported the idea of context dependency. Two studies that found an improvement in odor memory in context *independent* situations were Jehl and Murphy (1998) and Dinh, Walker, Song, Kobayashi, and Hodges (1999).

The goal of this research was to determine the odor memory enhancement benefits of incorporating olfactory, computerized peripherals into computerized multimedia-learning environments, from both a context dependent and context independent stand point. This odor memory study was atypical in that it is not an odor identification nor an odor recognition study.

There were two major hypotheses tested by this study. First, it was hypothesized that, based on the encoding specificity principle (Schab, 1990), and the results of context dependent studies regarding odor memory (Cann & Ross, 1989; Smith, Standing, & DeMan, 1992; Herz, 1997), students exposed to an olfactory stimulus, both during a learning phase and a recall phase, would demonstrate a distinct memory advantage over a control group. Taking previous context dependent studies one step further, it was further hypothesized, based on studies by Jehl and Murphy (1998) and Dinh, Walker, Song, Kobayashi, and Hodges (1999), that a memory enhancement would occur for subjects exposed to the same olfactory stimulus during the learning phase, even though the stimulus was not present during the recall phase, when the olfactory stimulus was presented in a multimedia environment (context independent).

In order to test these assumptions, 61 6th, 7th, and 8th grade students from a local private school were tested. The research design for this study was one factor, between groups, with a pre-test and post-test. Subjects were randomly assigned to one of three conditions: administration of a multimedia presentation with computerized smell during the presentation but not during post-testing (Group A), administration of a multimedia presentation with computerized smell present during both the presentation and post-testing (Group B), and then finally a control group that did not receive any computerized smell (Group C).

The multimedia presentation was about how chocolate and coffee are processed. The pre-test and post-test, which included the same set of test questions, contained multiple-choice questions regarding factual information provided by the multimedia presentation. Subjects were pre-tested several weeks prior to commencement of the study, and then given a post-test 48 hours after viewing the multimedia presentation. Testing lasted three weeks. For this study, 29 subjects were tested during week one, 29 subjects during week two, and three students were tested during week three (treatments on Monday, post-testing on Wednesday). The unit of analysis for this study was each subject's individual score on a pre-test and post-test. In addition to descriptive statistics, an analysis of variance was calculated as well. Excel was used to calculate the statistics which are presented here in table format.

The results of this study demonstrate that chance could reasonably produce the same results given that a relationship between computerized smell and an improvement in memory exists. Based on the results of this study, both hypotheses were rejected. There was no significant difference between groups in regard to computerized-scent enhancing memory ($F = .79$, $P < .45$, F critical = 3.15). Although there was a performance improvement within groups, the mean post-test scores between groups were relatively consistent (Group A = 5.42, Group B = 5.52, and Group C = 6.04).

There are a few alternative explanations for these results. First, it is entirely possible that the level of immersion experienced during a standard multimedia presentation is not significant enough for computerized scents to affect memory. Second, referring back to the Dinh, Walker, Song, Kobayashi, and Hodges (1999) study which this research attempted to conceptually replicate, olfactory related post-test questions during that study were not as rigorous as the questions asked of subjects during this research. Third, although the research conducted here was also conducted in a naturalistic setting, it was far from immersive and perhaps not as ecologically valid as it should have been. Fourth, perhaps when encountered by itself, olfactory stimuli contribute more to the richness of a memory trace than if experienced with other sensory modalities. Fifth, the computerized olfactory device used during this research is in need of both software and hardware refinement.

The results of this study clearly demonstrate that additional research is warranted before recommendations regarding the incorporation of computerized scent into the traditional classroom can be made and implications regarding computerized smell and memory can be made. Further research in this area might include a similar experimental design as the one conducted here, but within a more immersive environment and with a more rigorous set of test questions. Other recommendations for future research include allowing students to interact with the multimedia presentation and work at their own pace, using a different computerized scent technology, taking qualitative measures, and being more open with subjects about the olfactory component of testing. Future research might also approach computerized scent technology from a medical standpoint, such as in the areas of medical simulation or emergency room medicine.

Appendix A

Material Safety Data Sheets

MANE

MATERIAL SAFETY DATA SHEET

HEALTH:
FLAMMABILITY:
REACTIVITY:

I - IDENTIFICATION

PRODUCT IDENTIFIER: **CHOCOLATE FRAGRANCE MF119384**

MANUFACTURER:

MANE, U.S.A.
60 Demarest Drive
Wayne, New Jersey 07470

EMERGENCY TELEPHONE NUMBER:

Daytime: (973) 633-5533
After Hours: (800) 424-9300

II - INGREDIENT INFORMATION

PROPRIETARY **FRAGRANCE** FORMULATION
CAS NO: Mixture

III - PHYSICAL DATA

PHYSICAL STATE: **Liquid**

VAPOR PRESSURE: **N/AV**

SPECIFIC GRAVITY: **(@ 25/25°C) :** N/A

VAPOR DENSITY (AIR=1): > 1

SOLUBILITY IN WATER: **slight**

BOILING POINT: **N/AV**

ODOR DESCRIPTION: Characteristic

IV - FIRE & EXPLOSION DATA

FLASH POINT: **137 °F**
(closed cup)
EXTINGUISHING MEDIA: **CO_2, FOAM, and DRY CHEMICAL**

FIRE FIGHTING PROCEDURES: Use standard procedures and preferred extinguishing media as stated above

UNUSUAL FIRE & EXPLOSION HAZARDS: **NONE**

HAZARDOUS COMBUSTION PRODUCTS: Burning liberates carbon monoxide, carbon dioxide and smoke

MANE

V - REACTIVITY INFORMATION

STABILITY: Presents no significant reactivity hazard. Normally stable even at elevated temperatures and pressures. Not pyrophoric nor reactive with water. Does not undergo explosive decomposition, is shock stable and is not an oxygen donor. Does not form an explosive mixture with other organic materials. Will not undergo hazardous exothermic polymerization.

INCOMPATIBILITY (Substances to avoid): **AVOID HEAT, STRONG OXIDIZING AGENTS**

VI – HEALTH HAZARD INFORMATION

THIS PRODUCT IS A MIXTURE FOR WHICH NO HEALTH HAZARD DATA EXISTS. THIS MIXTURE IS A PROPRIETARY BLEND WHOSE CONSTITUENCY IS CONSIDERED CONFIDENTIAL. THE HAZARDS ASSOCIATED WITH THIS MIXTURE ARE BASED UPON THE INDIVIDUAL HAZARDS OF ITS CONSTITUENTS PRESENT AT 1% OR OVER OR 0.1% OR OVER FOR CARCINOGENS.

POTENTIAL ADVERSE HEALTH EFFECTS FOR THIS PRODUCT:

***May* be irritating to skin, eyes, mucous membranes, throat & lungs.**

Harmful if swallowed.

VII – EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT: FLUSH WITH COPIOUS QUANTITIES OF WATER.

SKIN CONTACT: REMOVE CONTAMINATED CLOTHES. WASH EXPOSED AREA WITH SOAP AND WATER. IF IRRITATION PERSISTS, CONSULT PHYSICIAN.

INGESTION: DO NOT INDUCE VOMITING. CONSULT PHYSICIAN.

INHALATION EXPOSURE: GET VICTIM INTO FRESH AIR. CONSULT PHYSICIAN.

VIII – SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS SPILLED: CONTAIN LEAKS OR SPILLS WITH A NON-COMBUSTIBLE ABSORBENT MATERIAL.

WASTE DISPOSAL METHOD: INCINERATION OR SANITARY LANDFILL. IN ACCORDANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS.

IX – SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: NONE REQUIRED

VENTILATION: VENTILATION WHICH MEETS ACCEPTED STANDARDS IS RECOMMENDED.

SKIN PROTECTION: OIL RESISTANT GLOVES

EYE PROTECTION: SAFETY GLASSES OR SPLASH PROTECTIVE GOGGLES

OTHER PROTECTIVE EQUIPMENT: NONE REQUIRED

X - STORAGE AND HANDLING

STORAGE REQUIREMENTS: STORE IN A COOL, WELL-VENTILATED AREA

HANDLING REQUIREMENTS: USE GOOD INDUSTRIAL HYGIENE PRACTICES TO AVOID INHALATION AND CONTACT WITH SKIN AND EYES.

PRECAUTIONS: KEEP AWAY FROM HEAT AND FLAMES. KEEP CONTAINER CLOSED WHEN NOT IN USE.

MANE

XI – TOXICOLOGICAL INFORMATION

Toxicological tests have not been performed on this preparation, but a bibliography of toxicological data exists for all the raw materials used in this preparation. We would recommend that this preparation be handled with the usual precautions due to the unknown synergy possible on highly sensitive people.

XII – ECOTOXOCOLOGICAL INFORMATION

To the best of our knowledge, this preparation dos not contain any products that are environmentally toxic or not biodegradable. No ecotoxocological tests have been performed, and having no way to determine any eventual danger that may be due to a specific preparation, we recommend avoiding any voluntary or accidental spillage in the ecosystem.

XIII – DISPOSAL CONSIDERATIONS

Prohibit any dispersion in the environment (air, water, and ground)
Destroy wastes by incineration.
Destroy or recycle packaging according to local regulations.

XIV – TRANSPORTATION INFORMATION

Railway, surface, sea, air; hazard free except where specified (section 16)

XV – REGULATORY INFORMATION

XVI – OTHER INFORMATION

See technical data sheet of the product.

PERFUME PREPARATIONS ARE NOT INTENDED TO BE USED PRIOR TO DILUTION

This sheet is complementary to the technical data sheet of the product. The information is obtained from reputable sources and to the best of our knowledge is true at the date mentioned on this document and our responsibility cannot be claimed in case of abnormal use of the product.

MSDS PREPARED BY: Mane, USA
DATE: JUNE 1, 2005

MANE

MATERIAL SAFETY DATA SHEET

HEALTH:
FLAMMABILITY:
REACTIVITY:

I - IDENTIFICATION

PRODUCT IDENTIFIER: **COFFEE FRAGRANCE MF119382**

MANUFACTURER:

MANE, U.S.A.
60 Demarest Drive
Wayne, New Jersey 07470

EMERGENCY TELEPHONE NUMBER:

Daytime: (973) 633-5533
After Hours: (800) 424-9300

II – INGREDIENT INFORMATION

PROPRIETARY **FRAGRANCE** FORMULATION
CAS NO: Mixture

III - PHYSICAL DATA

PHYSICAL STATE: **Liquid**

SPECIFIC GRAVITY: **(@ 25/25°C) :** N/A

SOLUBILITY IN WATER: **slight**

ODOR DESCRIPTION: Characteristic

VAPOR PRESSURE: **N/AV**

VAPOR DENSITY (AIR=1): **> 1**

BOILING POINT: **N/AV**

IV - FIRE & EXPLOSION DATA

FLASH POINT: **152 °F**
(closed cup)
EXTINGUISHING MEDIA: **CO_2, FOAM, and DRY CHEMICAL**

FIRE FIGHTING PROCEDURES: Use standard procedures and preferred extinguishing media as stated above

UNUSUAL FIRE & EXPLOSION HAZARDS: **NONE**

HAZARDOUS COMBUSTION PRODUCTS: Burning liberates carbon monoxide, carbon dioxide and smoke

MANE

V - REACTIVITY INFORMATION

STABILITY: Presents no significant reactivity hazard. Normally stable even at elevated temperatures and pressures. Not pyrophoric nor reactive with water. Does not undergo explosive decomposition, is shock stable and is not an oxygen donor. Does not form an explosive mixture with other organic materials. Will not undergo hazardous exothermic polymerization.

INCOMPATIBILITY (Substances to avoid): **AVOID HEAT, STRONG OXIDIZING AGENTS**

VI – HEALTH HAZARD INFORMATION

THIS PRODUCT IS A MIXTURE FOR WHICH NO HEALTH HAZARD DATA EXISTS. THIS MIXTURE IS A PROPRIETARY BLEND WHOSE CONSTITUENCY IS CONSIDERED CONFIDENTIAL. THE HAZARDS ASSOCIATED WITH THIS MIXTURE ARE BASED UPON THE INDIVIDUAL HAZARDS OF ITS CONSTITUENTS PRESENT AT 1% OR OVER OR 0.1% OR OVER FOR CARCINOGENS.

POTENTIAL ADVERSE HEALTH EFFECTS FOR THIS PRODUCT:

***May* be irritating to skin, eyes, mucous membranes, throat & lungs.**

Harmful if swallowed.

VII – EMERGENCY AND FIRST AID PROCEDURES

EYE CONTACT: FLUSH WITH COPIOUS QUANTITIES OF WATER.

SKIN CONTACT: REMOVE CONTAMINATED CLOTHES. WASH EXPOSED AREA WITH SOAP AND WATER. IF IRRITATION PERSISTS, CONSULT PHYSICIAN.

INGESTION: DO NOT INDUCE VOMITING. CONSULT PHYSICIAN.

INHALATION EXPOSURE: GET VICTIM INTO FRESH AIR, CONSULT PHYSICIAN.

VIII – SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IF MATERIAL IS SPILLED: CONTAIN LEAKS OR SPILLS WITH A NON-COMBUSTIBLE ABSORBENT MATERIAL.

WASTE DISPOSAL METHOD: INCINERATION OR SANITARY LANDFILL. IN ACCORDANCE WITH LOCAL, STATE, AND FEDERAL REGULATIONS.

IX – SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION: NONE REQUIRED

VENTILATION: VENTILATION WHICH MEETS ACCEPTED STANDARDS IS RECOMMENDED.

SKIN PROTECTION: OIL RESISTANT GLOVES

EYE PROTECTION: SAFETY GLASSES OR SPLASH PROTECTIVE GOGGLES

OTHER PROTECTIVE EQUIPMENT: NONE REQUIRED

X - STORAGE AND HANDLING

STORAGE REQUIREMENTS: STORE IN A COOL, WELL-VENTILATED AREA

HANDLING REQUIREMENTS: USE GOOD INDUSTRIAL HYGIENE PRACTICES TO AVOID INHALATION AND CONTACT WITH SKIN AND EYES.

PRECAUTIONS: KEEP AWAY FROM HEAT AND FLAMES. KEEP CONTAINER CLOSED WHEN NOT IN USE.

MANE

XI – TOXICOLOGICAL INFORMATION

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XII – ECOTOXOCOLOGICAL INFORMATION

To the best of our knowledge, this preparation dos not contain any products that are environmentally toxic or not biodegradable. No ecotoxocological tests have been performed, and having no way to determine any eventual danger that may be due to a specific preparation, we recommend avoiding any voluntary or accidental spillage in the ecosystem.

XIII – DISPOSAL CONSIDERATIONS

Prohibit any dispersion in the environment (air, water, and ground)
Destroy wastes by incineration.
Destroy or recycle packaging according to local regulations.

XIV – TRANSPORTATION INFORMATION

Railway, surface, sea, air; hazard free except where specified (section 16)

XV – REGULATORY INFORMATION

XVI – OTHER INFORMATION

See technical data sheet of the product.

PERFUME PREPARATIONS ARE NOT INTENDED TO BE USED PRIOR TO DILUTION

This sheet is complementary to the technical data sheet of the product. The information is obtained from reputable sources and to the best of our knowledge is true at the date mentioned on this document and our responsibility cannot be claimed in case of abnormal use of the product.

MSDS PREPARED BY: Mane, USA
DATE: JUNE 1, 2005

Appendix B

Subjects and Scores Groups A and B

Group A S/NS (21)		PRE	POST	Group B S/S (19)		PRE	POST
Subject 1	Female, 6th Grade	0	8	Subject 22	Female, 6th Grade	1	5
Subject 2	Female, 6th Grade	5	4	Subject 23	Female, 7th Grade	3	7
Subject 3	Male, 8th Grade	6	5	Subject 24	Male, 6th Grade	2	5
Subject 4	Female, 8th Grade	3	6	Subject 25	Female, 8th Grade	4	1
Subject 5	Female, 8th Grade	1	7	Subject 26	Male, 7th Grade	3	7
Subject 6	Male, 6th Grade	0	5	Subject 27	Female, 6th Grade	4	4
Subject 7	Female, 8th Grade	1	5	Subject 28	Female, 6th Grade	2	4
Subject 8	Female, 7th Grade	3	6	Subject 29	Male, 8th Grade	2	7
Subject 9	Female, 8th Grade	5	4	Subject 30	Male, 8th Grade	2	7
Subject 10	Female, 6th Grade	1	7	Subject 31	Male, 6th Grade	1	5
Subject 11	Female, 6th Grade	0	5	Subject 32	Female, 6th Grade	2	5
Subject 12	Female, 7th Grade	2	6	Subject 33	Male, 8th Grade	4	8
Subject 13	Male, 7th Grade	2	9	Subject 34	Female, 8th Grade	2	4
Subject 14	Female, 6th Grade	1	3	Subject 35	Male, 6th Grade	5	5
Subject 15	Female, 7th Grade	3	4	Subject 36	Male, 6th Grade	2	6
Subject 16	Female, 7th Grade	1	2	Subject 37	Female, 7th Grade	1	7
Subject 17	Male, 7th Grade	2	3	Subject 38	Male, 6th Grade	0	7
Subject 18	Male, 7th Grade	3	7	Subject 39	Female, 7th Grade	3	7
Subject 19	Female, 6th Grade	4	4	Subject 40	Male, 8th Grade	3	4
Subject 20	Male, 6th Grade	3	6				

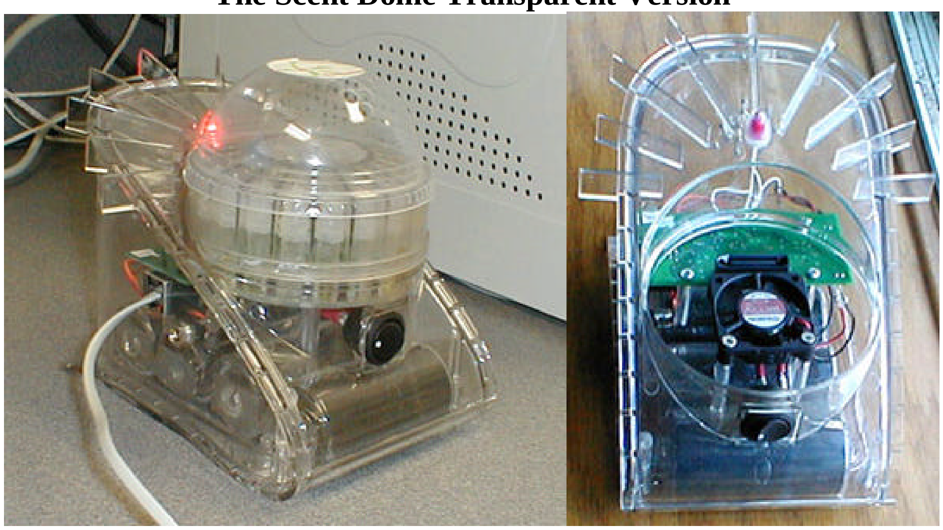
Subjects and Scores Group C

Group C CG (21)		PRE	POST
Subject 41	Male, 7th Grade	5	9
Subject 42	Male, 7th Grade	3	7
Subject 43	Female, 6th Grade	3	8
Subject 44	Male, 7th Grade	3	6
Subject 45	Female, 8th Grade	3	8
Subject 46	Female, 8th Grade	1	5
Subject 47	Male, 6th Grade	1	7
Subject 48	Male, 7th Grade	2	4
Subject 49	Female, 8th Grade	4	5
Subject 50	Female, 6th Grade	3	7
Subject 51	Male, 6th Grade	1	5
Subject 52	Female, 6th Grade	1	3
Subject 53	Female, 6th Grade	2	6
Subject 54	Female, 6th Grade	4	7
Subject 55	Female, 6th Grade	3	7
Subject 56	Male, 6th Grade	2	4
Subject 57	Male, 6th Grade	2	7
Subject 58	Female, 7th Grade	1	6
Subject 59	Female, 7th Grade	0	7
Subject 60	Female, 8th Grade	2	5
Subject 61	Female, 8th Grade	1	4

Appendix C

The Trisenx Scent Dome

The Scent Dome Transparent Version



Scent Cartridge Top View **Scent Cartridge Bottom View**

Appendix D

Testing Room Set-up

Appendix E

The Groups

Groups	Multimedia Presentation	Post-test
Experimental Group A	Smell	No Smell
Experimental Group B	Smell	Smell
Control group	No Smell	No Smell

Appendix F

The Multimedia Presentation

HOW CHOCOLATE IS MADE

To make chocolate, a person must start with Cocoa beans. Cocoa beans, which grow in pods on Cocoa trees, come from many different parts of the world, such as Central America, South America, Africa, and the Caribbean.

COCOA POD

COCOA POD

There is anywhere from 20 to 50 little beans in each pod, and it takes 400 beans to make one pound of chocolate.

After the Cocoa beans are harvested, they are heaped into big piles to ferment for 3 to 9 days.

FERMENTING BEANS

After fermentation, the Cocoa beans are spread out in the sun to dry. After they have dried, they are ready to be shipped.

DRYING IN THE SUN

DRYING IN THE SUN

The Cocoa beans first arrive in cities like New York, Amsterdam, London, and Hamburg before being shipped to other cities and towns.

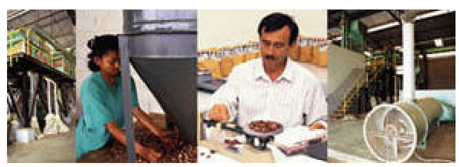
NEW YORK

LONDON

Now it's time to make some chocolate. Did you know that it takes 2 to 4 days to make an average size candy bar?

CANDY BARS

First, the Cocoa beans are sent through a cleaning machine to remove any dried pulp and pod pieces. After this, the beans are separated and combined.



THE CLEANING PROCESS

Next, the Cocoa beans are roasted in large rotary cylinders. This makes the outer shells brittle. After this, the beans are then sent through a "winnowing" machine that removes the outer shells. What is left are called "nibs."

WINNOWING MACINE

The nibs, which you can think of as the "meat" of the Cocoa bean, are then ground up into liquid chocolate and poured into molds.

THE NIBS

This liquid chocolate is then pumped into huge hydraulic presses that separate the Cocoa butter from the pressed cake, and then the pressed cake is pulverized into Cocoa powder.

HYDRAULIC PRESS

In order to make the Cocoa powder into chocolate, the manufacturer treats it with a processing agent, and then a certain amount of Cocoa butter is added back to the mix.

COCOA POWDER

At this point, different ingredients are added to the mix to make either dark chocolate, white chocolate, or milk chocolate, and then the mix is ground up by heavy rollers to prepare it for "conching."

CHOCOLATE ROLLER

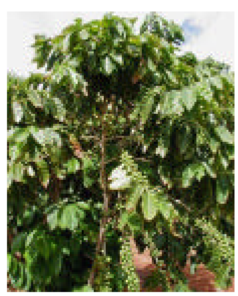
The conching process is where the chocolate gets its flavor. The conching machines use heavy rollers to "knead" the chocolate back and forth in order to improve its texture and remove unwanted chemicals.

Lastly, the mixture is sent through a tempering process, where it is heated and cooled, and then finally injected into molds of various shapes and sizes. After they put on the wrapper, now you have your chocolate bar!

MOLD INJECTION AND WRAPPING

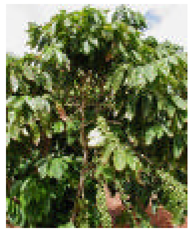
HOW COFFEE IS MADE

The process for making coffee is much simpler than the process for making chocolate. Coffee beans actually come from a tree that can grow up to 50 feet tall, but is usually pruned closer to 10 feet to make harvesting easier.



COFFEE TREE

Coffee, as a cash crop, is grown all over the world at high attitude, in countries with tropical and sub-tropical climates, such as Colombia, Ecuador, Brazil, and Kenya.



COFFEE TREE

The coffee beans themselves are actually the seeds from inside the coffee berry.

COFFEE BERRY

COFFEE BEAN

Because coffee berries are picked by hand, one of the most expensive processes involved in coffee production is harvesting.

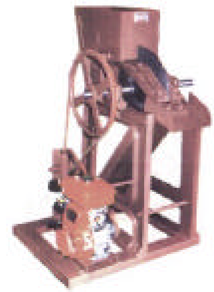
HARVESTING

One good coffee tree can produce up to 2000 coffee beans in a single year, which amounts to around 2 pounds of product.

COLOMBIAN COFFEE

The coffee bean itself makes up only 1/3 rd of the entire coffee berry, so the bean must be separated from its husk. This is done either by "wet processing" or "dry processing."

WET PROCESSING



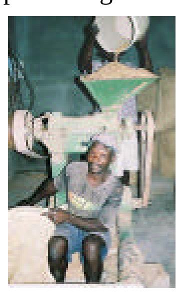
A DE-PULPER

With the wet processing method, a de-pulping machine uses water to help separate the coffee bean from the berry.

With the dry processing method, beans are dried in the sun for 2 to 3 weeks.

DRY PROCESSING

After the beans have dried, they are put through a "hulling" machine that extracts the coffee bean from the berry.



HULLING MACHINE

After the coffee beans have been processed, it is time to inspect them and ship them out.

BAGS OF COFFEE BEANS

After passing inspection, they are packaged up and shipped in bulk, where they eventually show up on store shelves in cans, bags, and dispensers.

FINISHED PRODUCT

Appendix G

Pre-test/Post-test Quiz

NAME_______________________________________

INSTRUCTIONS: You will not be graded on this quiz. Please answer each question by circling the appropriate response. If you do not know the answer, just take a guess.

1. How many Cocoa beans does it take to make a pound of chocolate?

A. 800 beans **B.** 200 beans **C.** 400 beans **D.** 50 beans

2. How long does it take for the Cocoa beans to ferment?

A. 7 to 10 days **B.** 2 weeks **C.** 24 to 48 hours **D.** 3 to 9 days

3. How long does it take to make an average size candy bar?

A. 1 week **B.** 2 to 4 days **C.** 24 hours **D.** Around 1 hour

4. The machine that removes the brittle outer shells from the Cocoa bean is called a:

A. Shucking Machine **B.** Hulling Machine **C.** Winnowing Machine **D.** Nibs Machine

5. Which Cocoa bean production process gives chocolate its flavor?

A. Conching **B.** Pressing **C.** Winnowing Machine **D.** Rolling

6. Coffee beans are actually seeds that grow inside of a coffee:

A. Pod **B.** Nut **C.** Tree **D.** Berry

7. How many coffee beans can a good tree produce in a single year?

A. 500 Beans **B.** 1000 Beans **C.** 2000 Beans **D.** 10,000 Beans

8. What is the most expensive process involved in coffee production?

A. Harvesting **B.** Shipping **C.** Grinding **D.** Packaging

9. The process for removing the coffee bean from its husk is called:

A. Emulsification **B.** Wet or Dry Processing **C.** Shelling **D.** De-husking

10. Using the dry processing method, how are the coffee beans dried?

A. Using huge ovens **B.** In the hot sun **C.** Using blow driers **D.** In bags

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