

## Using Biological and Environmental Malodors to Enhance Medical Simulation Training

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### ABSTRACT

The U.S. Army Simulation and Training Technology Center (STTC) is performing research to improve the realism of the look, feel and smell of trauma simulations. STTC research results have generated improvements in the look and feel of man-worn or simulator-worn prosthetic injuries. Olfactory cues play an important role in memory and training. However, very few research studies have focused on olfactory stimulation in training situations. STTC olfactory research requirements include identifying simulated odorants that are safe to use and store, have a long shelf life, are usable in both indoor and outdoor training environments, and disperse quickly. Three STTC olfactory research programs generated results from technology evaluations, explored the benefits and cautions of odor usage, and led to ideas for more in-depth studies.

### ABOUT THE AUTHORS

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### INTRODUCTION

Medical care givers may benefit from realistic immersive training. Multimodal simulation immerses students by stimulating multiple senses. While visual and auditory stimuli have long been effectively incorporated into immersive training environments, olfactory stimulation has lagged behind, due in large part to factors such as cost and the immature state of olfactory technologies.

Olfactory simulation devices are being designed and developed to enhance immersion in medical training simulations. The addition of olfactory simulation can potentially enhance the perception of immersion, facilitate learning and expand the breadth of skills that can be trained.

One application is training combat medics within realistic warfighting scenarios. Exposing trainees to particular smells may help avoid the shock of first smelling the odors on the battlefield. Preparing for all the sights, sounds, smells and feelings associated with combat may help provide Soldiers with the strength required to face adversity, fear and hardship.

### BACKGROUND

Olfaction is an important, yet underappreciated sense. Malodors, or unpleasant odors, can be a powerful stimulus on the battlefield. Stress inoculation may have applicability to odors and the link to memory cues. Simulation and Training Technology Center (STTC) is researching ways to introduce malodors to military first responders to assist in increasing the fidelity of their training.

#### Memory and Odors

The sense of smell can have an impact on experiences and interaction related to task performance. Most people can remember a time when a pleasant aroma recalled a fond memory. On

the other hand, the malodor of sour milk just as powerfully can bring back a more negative memory. Each of these examples can elicit positive or negative feelings. Just as decreased vision or hearing could possibly lead to a decrease in skill performance and training, the sense of smell could lead to an increase or decrease in skill performance and corresponding emotional responses (Herz & Schooler, 2002).

Memories have a higher emotional component when the cue to recall that memory is based on odor and less emotional when the cue to recall that memory is based on vision (Herz & Schooler 2002). In other words, according to Herz and Schooler, visual and verbal cues do not have as high an emotional connection as odor cues. The emotional component of memories from odors is often referred to as the Proust Phenomenon. The Proust Phenomenon is the "ability of odors spontaneously to cue autobiographical memories which are highly vivid" (Chu & Downes, 2000 in Washburn et al. 2003). Someone smelling an odor associated with an event may link memories to that event more so than someone just seeing or hearing the event.

Herz and Engen (1996) state that odor memory is linked to both "memory for odors and memory that is associated to or evoked by odors" (p. 300). Research has found that familiar odors, correctly identified, are remembered more than those that are not familiar and therefore not identified correctly (Rabin & Cain, 1984 in Herz and Engen, 1996). Further, odor labeling can form better odor memory (Lyman & McDaniel, 1986, 1990 in Herz and Engen, 1996).

One of the possible reasons for the connection between the olfactory system and memory may be that the "primary olfactory cortex forms a direct anatomical link with the amygdale-hippocampal complex of the limbic system" (Herz & Engen, 1996, p. 300). Further, the authors note the olfactory system has only two synapses that separate the "olfactory nerve from the amygdala which is critical for expression and experience of emotion" (Aggleton

& Mishkin, 1986 in Herz & Engen, 1996, p. 300) and “human memory” (Cahill, Babinsky, Markowitsch, & McGaugh, 1995 in Hertz and Engen, 1996, p. 300). Additionally, the olfactory nerve is separated by three synapses from the hippocampus, “involved in the selection and transmission of information in working memory, short- and long-term memory transfer, and various declarative memory functions” (Eichenbaum, in press; Schwerdtfeger, Buhl, & Gemroth, 1990; Staubi, Ivy, & Lynch, 1984, 1986 in Herz and Engen, 1996, p. 300). The authors mention this connection to emphasize the differences in the olfactory system from other sensory systems regarding its shortened synaptic connections and its impact on memory.

According to Herz’s and others’ research, if medics are trained to correctly identify familiar odors they will remember that odor better. By association, it may be possible to desensitize medics by establishing memories of the odors during training so that when malodors are experienced on the battlefield, a medic’s response will be less stressful because they have existing memory of that odor.

Because odors elicit a higher emotional response, the addition of odors to the sights and sounds of an immersive training environment might provide an increase in task effectiveness, therefore improving skill performance or stress inoculation.

### **Adding Odors to Medical Training Simulations**

Adding odors to a training simulation might better prepare the medic to handle all the aspects of their duties on the battlefield. Research has shown that experiences help “develop the ability to discern and identify certain odors that signal important information necessary for appropriate task identification and response whereas training in these areas could reduce the time an individual would normally need to develop these skills” (Washburn, 2003, p. 24).

A student medic may smell the malodor of simulated burnt flesh in a training environment, and subsequently correctly treat the simulated patient’s wound. When that same medic smells burnt flesh in an actual combat situation, s/he remembers the correct procedure used in training; thus is more readily able to treat the injured patient in the combat situation without the potential distraction of smelling burnt flesh for the first time. This hypothesis led to the inclusion of olfactory cues as an element of the STTC Severe Trauma Simulation Army Technology Objective (ATO).

### **Impact of Wartime Malodors**

The U.S. Army teaches Soldiers preparing to deploy to combat operations that they will likely encounter multiple malodors during combat operations (Army, 2008). Wartime negative effects of malodors are noted in the following situations:

- “According to his son, Haig visited the front trenches only once because the smell of mass death made him sick, and he felt that he could not effectively command when this occurred” (Kastenberg, 2005, p. 25).
- “The nurses reported sights, smells, and sounds of war that were pleasant, unpleasant, or horrible” (Dittmar, Stanton, Jezewski, and Dickerson, 1996 in Wynd, 2006, n.p.).

### **Stress Inoculation**

Stress inoculation training (Jaremko, 1984) is a “cognitive-behavioral approach for preventing stress-related disorders” (p. 544). As such, it has a specific clinical definition. While the mission of the STTC does not involve clinical diagnosis and interventions, but rather technologies to augment training, it is important to note that military medical training sites routinely inject stressors into training scenarios (Jones, 2007; Fleischman, 2007; McCarthy, 2003). Jaremko (1984) indicates that “combat must be considered one of the major stressors a human can face” and indicates that “stress prevention and reduction” techniques were becoming increasingly common (p. 549). Given the Jaremko article was written in 1984, an era of relative calm for the military, one can extrapolate an even greater need for the application of stress reduction for today’s U.S. military.

### **Simulating Odors**

The history of simulated odors dates back at least to the 1950s, when competing movie producers vied to release the first motion picture with odors that would “play” at the appropriate time (Avery, 2008). While these were little more than publicity stunts, significant research has gone into the science of simulating odors. Attempts have been made to analyze odors based on “building blocks”, in much the same way that all colors can be created by combining the three primary colors. (Avery, 2008). Today, the most common approach to decomposing

an odor is through the use of gas chromatography-mass spectrometry (Hertz, 2007 and Avery, 2008) which basically analyzes a substance to determine its composition. Once identified, the odor of that substance can be simulated by creating a chemical compound with similar properties.

Researchers recommend “adding olfactory stimulation to virtual environments to enhance the sense or presence, in the environment” (Washburn et al., 2003 p.19). Using life-like smells is expected to increase knowledge acquisition and retention (Greswell, 2009, p. 81).

The “Virtual Iraq” program helps treat post traumatic stress disorder (PTSD). Participants are exposed to the “scent of body odor with the smell of exotic spices and garbage” in a virtual reality simulation of Iraq (Kaufman, 2008, pp. 57-58). The Virtual Iraq program demonstrates that malodors and smells associated with battle situations are currently incorporated into training.

### **Olfactory Simulation Delivery Challenges**

Olfactory simulation challenges include determining the proper amount of odors to disperse. Using synthetic odors indoors and outdoors requires differing amounts to properly simulate the odor. Ventilation systems in indoor training environments may carry odors to unintended parts of the facility. Finally, the sense of smell takes longer to process but does tend to last longer than other senses (Herz and Engen, 1996). Dispersal amount (in terms of quantity, concentration, time of dispersal, and time dispersed in terms of the training event) are parameters to be considered when using odors in a training event (Washburn et al., 2003).

Odor experiences can be either “specific (i.e. a sample odor sprayed or sniffed directly from a source) or ambient (i.e. a general odor in a room)” (Washburn et al. 2003 pp. 19-20). The application of either method may produce differing results, while odors specifically smelled could be more concentrated in nature. The ability to disperse malodors slowly and control the amount can help to reduce the lingering effects.

### **PTSD Safety Concerns**

Because of the strong connection between odors and memory, STTC has taken a cautious approach with testing odors at military training sites. While the majority of trainees at most sites are not combat

veterans, the majority of instructors have experienced malodors in “real world” environments. Subjecting instructors to the odors could trigger post-traumatic stress disorder-type reactions. Indeed, one senior (E-6) instructor who sampled an early burnt flesh simulated odor was observed going pale and shaking. However, another combat veteran in a non-medical field who has smelled the same simulated odor multiple times compares it to “burning bacon” and did not indicate any concerns. Clearly, more research is needed to determine how to prevent the effect of malodors in training situation from invoking PTSD - type reactions in combat veterans.

### **Severe Trauma ATO**

In October 2006, the STTC launched a three-year ATO to explore severe trauma simulations. The goal was to provide simulations that more accurately replicated the look, feel, and odor of injuries seen on today’s battlefield. Enhanced severe trauma simulations were intended to provide resistance to stressors for the caregiver at the point of injury.

Initial research on the severe trauma ATO was limited to the “look and feel” requirements, with little research in odors. However, by providing medics and Soldiers the opportunity to train in high-fidelity situations, the transfer of skills may increase.

### **OLFACTORY CUES RESEARCH EFFORTS**

STTC hypothesized that adding medical training simulations might help immerse Warfighters in all aspects of a life-like training situation. Furthermore, with odor showing to have such a strong tie to memory, the realism added by the inclusion of odors in the training environment might be effective in evoking memories of successful training evolutions to odors experienced later in combat situations.

### **Olfactory Cues Research Requirements**

STTC submitted a call for papers in the fall of 2008 focusing on the creation of olfactory cues simulation technologies. The requirements posed by the STTC included:

- Delivery of relevant ambient or environmental odors and trauma-related odors in a training environment.
- Use in both indoor and outdoor training environments with odors used in an indoor environment dissipating and odors used outdoors

being strong enough to pervade the training area but not overwhelm trainees and instructors.

- Use of chemicals that are safe to personnel and cause no harm to surfaces they contact, including vegetation. STTC further stipulated that odors must be removed from clothing after a “minimal number” of washings, with one washing being the objective.
- Chemicals must be safe and easy to store, with a shelf life of one year as a threshold and two years as an objective.
- Personnel must be able to prepare the scents with a minimum of contact.
- Odors should be associated with relevant sources and be scenario-driven. For example, the odors related to an eviscerated bowel should originate from a source at or near the eviscerated bowel; diesel odors likewise should appear to originate from a vehicle.

The call for papers resulted in three contracted research efforts that sought to address the problem with different approaches. Odors localize to Human Patient Simulators (HPS), embedded wearable wounds with congruent odors and ambient odors.

#### Odors Localized to Human Patient Simulators

The first approach focuses on delivering biological odors from a human patient simulator. The HPS can simulate smells associated with battlefield injuries using canisters designed to contain and disperse odors engineered into simulators. The canisters are controlled by physiologically-based computer control software that manages the simulated patient’s behavior, injury and moulage. Thus, this approach matches well with the need to release biologically-based odors by increasing the level of fidelity and realism for the trainee.

An initial pilot test was performed at the Medical Education Training Center (METC), a joint-training center in San Antonio, TX to examine initial usability and fidelity of odors emitted for a HPS. The HPS was matched with an abdominal evisceration wound with congruent odor. The audience for the testing consisted of flight medics, pilots, doctors and nurses, some who have recently returned within the last six months from Afghanistan. The group was a mixture of officer and enlisted personnel at various levels. Nineteen participants received a pre-scenario questionnaire consisting of 13 yes/no questions. They were exposed to a scenario involving an HPS, in particular, the Stand-Alone Patient Simulator (SAPS) known as iStan with an abdominal

evisceration scenario and then took a post-scenario questionnaire consisting of 11 yes/no questions.

#### Summary of Feedback:

Table 1 and Table 2 highlight initial test results. While only 37% were combat veterans, over 63% had previously seen an abdominal evisceration. This could be due to participants working in hospital-based positions.

In the pre-test, Table 1, the majority of the participants had not been exposed to simulated trauma smell/malodor trainings. The test group responded positively when asked if they wished they had more exposure to trauma wounds and smells/malodors during training which could make training more effective. When treating trauma, remembering the malodor may also help identify the injury and odor relationship.

**Table 1. HPS Pre-Test Questionnaire**

Pre – Test Questions	Yes	No
Are you a combat veteran?	0.37	0.63
Would seeing simulated wounds be worthwhile?	0.84	0.16
Would smelling simulated trauma wounds be worthwhile?	0.74	0.26
Have you ever been exposed to trauma smells during combat?	0.53	0.47
If you answered yes to question 4 - Did you feel nauseated or uncomfortable at the smell of your first encounter with a patient with severe trauma?	0.16	0.84
The first principle of trauma care is hemorrhage control?	0.74	0.26
Did the sight of simulated trauma cause you to hesitate?	0.11	0.89
Do you wish you had more exposure to trauma wounds and smells in training?	0.79	0.21
Combat medical training is more effective when conducted in a realistic environment?	0.89	0.11
Have you ever seen an abdominal evisceration wound?	0.63	0.37
In treating real trauma, do you remember the smell?	0.74	0.26
From your perspective, are smells associated with trauma wounds capable of causing a person to react adversely?	0.68	0.32
Have you been a participant before of simulated trauma smell trainings?	0.05	0.95

Following the abdominal evisceration wound-and-odor-match, the test participants completed a post-test questionnaire in which the responses are shown in Table 2. It appears that responses were positive or neutral to the use of odors adding value to the training and the importance of realism. This illustrates that the combination of iStan along with a

visual and olfactory simulation had some training relevance.

**Table 2. HPS Post-Test Questionnaire**

<b>Post – Test Questions</b>	<b>Yes</b>	<b>No</b>
Did you find the training exercise valuable?	0.58	0.42
Did you believe the trauma wound smell added value to the training?	0.58	0.42
A physiologically based simulator is better than a partial task trainer in trainings?	0.58	0.42
The simulated abdominal evisceration wounds was realistic?	0.58	0.42
Did the smell of the trauma wound evoke any bad memories?	0.21	0.79
Combat medical training is more effective when conducted in a realistic environment.	0.79	0.21
Were the simulated smells similar to the real thing?	0.63	0.37
Was the simulated trauma wound anatomically correct?	0.63	0.37
Did the simulated trauma wound make the training better?	0.42	0.58
Did the simulated trauma smell cause a delay in treating the patient?	0.11	0.89
If the trauma smell trainer were available for your training would you see benefit to this training tool?	0.84	0.16
Did you find the training exercise valuable?	0.68	0.32
Did you believe the trauma wound smell added value to the training?	0.05	0.95

### HPS Conclusions

Participants initially stated that simulated trauma wounds would be helpful in training. However, upon completing the exercise participants expressed mixed results. Still, participants did state the benefit of using a trauma smell trainer, if available. This result is in juxtaposition with the final question about trauma wound smells adding value to the training.

More research is needed with a larger sample size to determine if the odor was strong enough or dispersed long enough during the exercise. It is also important for future testing to address levels of experience and various job duties. Additionally, more specific questionnaires could be designed to inquire as to why differences exist between pre- and post-test results.

### Embedded Wearable Wound Odor

The second approach is also oriented toward biological odor requirements. It is unique in that it seeks to match odors to realistically looking wearable wounds. These wounds can be worn by human role players or by human patient simulators. As an example, skin ulceration will be paired with the smell of ulcerated flesh. This approach may support surgical simulations and live tissue replacement simulations.

### Embedded Wearable Wound Odor Results

An exercise was performed to demonstrate the use of wearable wound odor technology. The objective of the exercise was to record the immediate impressions, comments, and suggestions from professional and certified paramedic and EMT/fire fighters from the City of Winter Park, Florida. Observers focused on feedback on the appearance of the simulated wound and odors that emanated from the simulated injury.

The five simulated odors demonstrated included: blood, decaying flesh, burned flesh, excrement, and ulcer. The five corresponding simulated wounds included: mutilated muscle laceration, decaying/rotting flesh, burn, perforated small bowel and vascular ulcer.

The wounds were applied onto a live actor or mannequin body part. Each wound was sprayed initially with equal sprays of the corresponding aerosol simulated odor. The exercise lasted 3 hours at which all wounds remained adhered to the surface. Before each group entered the room, approximately 3-5 sprays had to be added to each wound. Five groups of five paramedics and or EMT/fire fighters smelled the five different simulated odors. The room was ventilated and the air conditioning was operational during the exercise. When the exercise was complete, the ScentWave machine aired the room with a deodorizing scent in order to neutralize the remaining odors the room.

### Summary of Feedback:

Table 3 highlights the feedback obtained from the wounds matched with the simulated odor testing.

**Table 3. Feedback from Odor Testing**

<b>Burned Flesh</b>
Needs to be more pungent; some said it smelled like cooked bacon. It was also noted that the burned flesh was missing the burned hair smell.
Many said the burned flesh simulated wound looked realistic.
Someone commented that it looked like a lightning burn.
<b>Ulcer</b>
Most people commented that the ulcer smelled like an ulcer, however it needed to be more pungent.
When a vascular ulcer occurs on the foot, the entire foot should be red and that redness would continue through the leg (e.g. like a trail of redness starting at the wound).
Another group said the veins should be light red to dark red going down to the ulcer.
The wound should be oozing with liquid and puss.
Overall, the ulcer looked extremely realistic.
<b>Blood</b>
The laceration looks realistic especially during the pumping of the blood.
Most everyone described the smell of blood having an iron/copper smell.
Our smell is linked to a perfume scent which tends to smell sweeter than what a fresh bloody wound smells like.
Blood smell isn't as strong as the other odors.
The wound was said to smell like baker's yeast that rotted.
<b>Decaying Flesh</b>
Prosthetic wound looked realistic.
Smell was highly realistic and closely resembled the smell of the wound.
One person commented that it needed to smell a little more like fecal matter.
<b>Excrement (Perforated Bowel)</b>
Needs to be more pungent; one should be able to smell it when entering the room.
Looks really realistic and exactly like what an evisceration should look like.
Smells exactly like the real wound.

**General Findings:**

- The odors were pungent but the paramedics and fire fighters are used to encountering more extreme presentations where they smell the odor of the severe wound upon entering a room versus within a few inches of the wound.
- Since we were testing all five odors in one room, we diluted the simulated odors more than normally recommended to avoid "cross-contamination" of the odors.
- According to the Winter Park Fire Department paramedics and fire fighters that evaluated the simulated wounds and odors, the physical appearance of all the wound prosthetics were the most realistic representations available for training purposes. They also added that they would use the simulated wounds and odors to enhance training exercises such that they could more easily immerse trainees in scenarios.

**Ambient Odors**

The final approach developed the capability to disperse odors into a room or outdoor training area from a stand-alone wireless computer-controlled device. This approach is well suited to release ambient/environmental odors such as diesel fuel and rotting garbage.

The ultimate goal of the Severe Trauma Simulation ATO is to provide training applications to assist medics to better cope with the stress of combat. It is challenging to track medics who have used the applications in training and follow up to determine whether the simulations helped.

A focused training effectiveness evaluation was developed in which the independent variable was time to complete a task, and the dependent variable was pre-exposure to malodors.

Experiments were conducted at the Defense Medical Readiness Training Institute (DMRTI), a joint-service school at Camp Bullis in San Antonio, TX. DMRTI's provides pre-deployment training to military medical professionals (e.g., physicians, physician assistants, nurses, and dentists). While military medical professionals at this level are not expected to provide point-of-injury care, they are subjected to this type of battlefield care so they can better understand the challenges that the medic who treated the patient overcame.

**Ambient Odors Study Methods**

Students who participated in an indoor training exercise were randomly assigned to one of three groups. The first group had no exposure to any simulated odors, and provided a baseline time to complete a task. The second group was exposed to odors only during the actual training exercise. The third group was exposed to odors the day before the training exercise, and again during the training exercise.

Observers timed students applying a tourniquet to a human patient simulator. The hypothesis was that the group pre-exposed to the odors prior to the training exercise would perform the task faster than the group that was exposed only during the training exercise.

Researchers performed an initial pilot test followed months later by a more controlled experiment.

### Ambient Odors Testing Results - Pilot Testing

Descriptive statistics shows the mean, standard deviation and standard error resulting from this experiment, as shown in Table 4. A One-Way Analysis of Variance (ANOVA) was conducted to evaluate the relationship between pre-exposure to malodors and the time to apply a tourniquet on a training mannequin during a simulated exercise, as shown in Table 5. The independent variable, pre-exposure to malodors, was presented to one group while a second group received no pre-exposure to malodors. The dependent variable was time to apply a tourniquet while malodors are present in the training environment. A third group, the baseline group, received no pre-exposure to malodors and no malodors during application of the tourniquet.

**Table 4. Descriptive Statistics Pilot Test**

	N	Mean (sec.)	Std. Deviation	Std. Error
1 (Baseline)	2	76.50	31.82	22.50
2 (Control)	2	82.50	48.79	34.50
3 (Experimental)	4	90.00	32.14	16.07
Total	8	84.75	31.05	10.98

The ANOVA was not significant,  $F(2,45) = 2.95$ ,  $p = .06$ . The comparison of the three means did not reveal significant differences,  $F < 1$ . Therefore, the results of the one-way ANOVA did not support the hypothesis that pre-exposure to malodors will have an effect on the time to apply a tourniquet.

**Table 5. One-Way ANOVA Pilot Test**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	256.5	2	128.25	2.95	.06
Within Groups	6491	45	1298.2		
Total	6747.5	47			

The results of the pilot study highlighted the need to control many external factors to better determine if pre-exposure to malodors is related to improved performance of tasks when that odor is present in the simulated or actual environment. These factors included increasing the sample size, eliminating several multi-modal stress cues, reducing the effects of practice.

With the pilot study, a group of 3-5 students entered a darkened room that contained mannequins with simulated injuries. The performance timing was a group measurement, not an individual measurement. The group assessed the patient (mannequin) and then made a determination of how to treat the patient.

Timing of performance included the time to assess the patient, the time to find the tourniquet in the aid bag in near darkness and then time to apply the tourniquet. The large variability in the performance times was due to the complexity of the performance measurement. The group could have improperly assessed the patient and treated the wrong wound or they could have had difficulty finding the tourniquet in the aid bag. The experimental design was then changed for the subsequent controlled experiment so that that individual performance measurement was taken. This helped to increase the sample size and also get a true individual measurement. Additionally, subjects were only measured on the time to apply the tourniquet.

In the pilot study, the simulated tactical environment included multiple stress cues. These included loud aircraft noise, loud gun fire, screams, Middle Eastern chanting, smoke, darkness and a squad leader role player. Sometimes, the squad leader role player would provide instructional cues to groups that were taking too long to assess or treat their patient. These stress cues probably had an effect on the group's performance with treating the mannequin and were not related to the fact that they had pre-exposure to malodors. The experimental design was again changed for the subsequent controlled experiment so that these stress cues were eliminated.

Finally, in the pilot study, the subjects experienced the training exercise twice, a familiarization day and a training day. Performance was measured on both days, but some of the difference in performance between the first and second days could be attributed to practice and familiarization during the training exercise. For the controlled experiment, the subjects only performed the tourniquet application once and the performance measurement was taken then.

### Odor Detection, Identification and Recognition

One anecdotal result that was observed was when subjects were asked if they smelled anything in the room while the olfactory system was delivering malodors, many subjects did not remember smelling anything. Table 6 shows how subjects were in each group, how many perceived an odor and how they rated that odor.

**Table 6. Odor Perception**

Group	Number of Respondents	Number Perceived Odor	Rate	Mean Intensity
1	14	3	21%	17.50
2	15	5	33%	22.00
3	29	8	28%	23.89

**Ambient Odor - Controlled Experiment**

Table 7 shows the mean, standard deviation and standard error resulting from this experiment. A one-way ANOVA was conducted to evaluate the relationship between pre-exposure to malodors and the time to apply a tourniquet on a training mannequin. The independent variable, pre-exposure to malodors, was presented to one group while a second group received no pre-exposure to malodors. The dependent variable was time to apply a tourniquet while malodors are present in the training environment. A third group, the baseline group received no pre-exposure to malodors and no malodors during application of the tourniquet. The ANOVA was not significant,  $F(2,45) = 2.95, p = .06$ , as recorded in Table 8. Therefore, the results of the one-way ANOVA did not support the hypothesis that pre-exposure to malodors will have an effect on the time to apply a tourniquet. No follow up tests were evaluated since the ANOVA was not significant.

**Table 7. Descriptive Statistics Controlled**

Group	N	Mean (sec.)	Std. Deviation	Std. Error
1 (Baseline)	9	41.33	30.70	10.23
2 (Control)	19	26.37	6.72	1.54
3 (Experimental)	20	31.50	10.39	2.32
Total	48	31.31	15.83	2.28

**Table 8. One-Way ANOVA Controlled**

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1368.89	2	684.45	2.96	0.06
Within Groups	10407.42	45	231.26		
Total	11776.31	47			

**Odor Detection, Identification and Recognition**

It appears that the subjects in the controlled experiment perceived an odor at double the rate that the pilot study did. These results are shown in Table 9.

**Table 9. Odor Perception**

Group	Number of Respondents	Number Perceived Odor	Rate	Mean Intensity
1	9	1	11%	40.00
2	19	11	58%	26.36
3	20	13	65%	40.77

**Ambient Odor Conclusions**

Based on the results of the controlled experiment, pre-exposure to malodors may not affect performance. This experiment was based on the research that malodors do have an impact on performance as evidenced in the research performed by Herz, 2005.

When the results of this experiment are examined, there are multiple possibilities as to why no relationship between malodors and performance was evidenced. Perhaps the concentration and intensity of the stimulus was not strong enough. If these variables were measured at multiple levels, perhaps a relationship with performance would be demonstrated.

Related to concentration and intensity is the length of exposure to the odor during pre-exposure and exposure. The average time of pre-exposure was 3 minutes and the average time for exposure during the tourniquet application was close to 32 seconds. Perhaps performance would have been impacted if a more lengthy task (time to perform) were measured.

Another possibility was the fidelity of the stimulus (burnt human) was not realistic or it was not a smell that the subjects had experienced before, i.e. no memory of the smell and therefore, could not identify it. The hedonic valence of the odor was not high for the subjects in this experiment. It was curious that not one subject from the controlled experiment identified the odor as "burnt human" or anything close to that description.

## **Ambient Odor Recommendations**

One variable not measured with this experiment was immersion. It has been demonstrated that olfactory simulation adds to the immersion of the simulation. One aspect that was apparent in the pilot study was that the multiple stimuli presented during the training scenario helped the students to be immersed into that scenario, so much so that the malodors were not detected. A research question could be related to how much immersion is added to a training scenario when olfactory simulation is present.

Another recommendation would be to conduct this experiment again but incorporate a task that takes longer to perform. Possibly if the subjects were exposed to the malodor for a longer period of time, the affect on performance would be more apparent.

One topic that was not addressed was the congruity of the cues. Research could be conducted that examines the relationship of the congruity of cues to impact on performance.

The prototype hardware and software still needs to be evolved. One possibility would be to modify the design so that through the Bluetooth operation, a smartphone could be used to control the olfactory simulation. A role player or instructor/operator could control the simulation from anywhere within the training scenario.

## **SUMMARY**

It is still unknown whether pre-exposure to malodors prior to an event will improve performance versus the first exposure taking place during the event. The emotional connection to memories that are odor-based may play a role in supporting pre-exposure to malodors. Adding malodors to hands-on immersive training may increase the fidelity of a life-like training situation. Supporting pre-exposure to odors may help to properly identify injuries and reduce the potential distraction of being exposed to malodors on the battlefield.

Three differing efforts at the STTC are currently researching the application of odors. All three approaches are unique in nature and explore the issue from the domains of: 1) the addition of biological odors from a patient simulator, 2) releasing the biological odor from simulated injuries and 3) dispersing the odors into a training area from a computer-controlled apparatus. Future pilot studies may help to identify which method works the best

under varying conditions and the relationship between task performance.

The usage of malodors has not yet been extensively studied and cautions regarding the dispersal of malodors should be taken. Each individual reacts differently and it is unknown which malodors are more offensive or attach emotional responses as compared to others.

## **FUTURE RESEARCH**

### **Job Assignment Suitability**

Simulated malodors might be useful as a job assignment selection tool. Early exposure to simulated malodors (e.g., during recruit training or “boot camp”) could identify those who cannot tolerate malodors. Those who are unable to tolerate the odors in a training environment may be more likely to have issues with the malodors in combat.

Tolerance of relevant malodors could hypothetically be a selection factor for determining whether a candidate becomes a military medic. A military medic’s memory of events, and emotional response to that memory, could differ from that of another medic present at the same event depending on the sensory stimuli they received.

### **Task Performance**

Future research could identify the relationship between task performance and odor-cued memories. Task performance could be explored in terms of retention of pre-exposure to malodors and memory. Studying the addition of malodors at varying points of instruction might provide information on placement of odors and its relationship to task performance.

In order to truly evaluate simulated malodors for effectiveness in training medics, several rather extensive experiments should be performed. The pilot test at DMRTI and METC are important first steps. However, even with sufficient sample size, it might only show that pre-exposure to malodors can improve performance.

Of more importance is examining the role between memory and odors (in general) related to task-performance. As mentioned earlier, such an experiment could be performed by exposing one group of students to a malodor while they repeatedly perform a task. The control group would not be pre-

exposed to the odor but would also repeatedly perform the same task. Both groups would then perform the task while exposed to the odor during a training exercise in which the particular task was only one task to be performed.

Another interesting experiment would involve retention. Assuming that pre-exposure to malodors improves performance, research could be conducted to determine how much time between pre-exposure and task performance can lapse before the pre-exposure memory fades.

Finally, another relevant research topic would involve varying the training interventions offered students while pre-exposed to malodors to determine if pre-exposure supports performance improvement regardless of the particular training intervention. Research would involve pre-exposing the student to a particular malodor and determining if the various forms of training (classroom lecture, computer-based training, or hands-on practice) make any difference in performing a task (e.g. tourniquet application).

Related to the training interventions topic would be more academic research regarding the general role odors (not just malodors) have in performance and retention for various types of tasks.

The tourniquet application task referenced here is primarily a psycho-motor skill. Potential research questions include:

- Could exposure to pleasant odors improve performance in cognitive skills?
- Could exposure to malodors deter students from negative behavior?

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