Reliability and Feasibility Considerations in the Assessment of a Malodor Adaptation Technique: A Pilot Study

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ABSTRACT  Research often links barriers to optimal human performance of a complex medical task to malodor exposure. Olfactory adaptation, or desensitization to an odorant, may ameliorate performance degradation. Olfactory adaptation is traditionally measured by detection threshold and perceived intensity. Nontraditional measures including stress, confusion, and escape behavior may better reflect impacts on performance but face validity concerns. This article describes a pilot study undertaken to determine what measurements and techniques are best suited and logistically feasible to explore olfactory adaptation with respect to performance of a relevant task. Results of the pilot study confirmed validity of selecting an experimental adaptation period a length of time between two previously published results. The study also validated traditional detection threshold and perceived intensity measures and data collection techniques. Electrodermal activity data, a nontraditional measure of stress, proved more promising than inconsistent heart rate or blood pressure. Nontraditional measures of confusion/bewilderment also produced inconsistent outcomes. Perceived workload data were collected for timing purposes; a more homogeneous population may produce more significant results. While preliminary results indicate adaptation may contribute to better complex task performance, follow-on research may proceed using traditional and newly validated measures with the number of subjects necessary to provide statistical confidence.

INTRODUCTION  Malodors are regularly encountered in both clinical and field medical settings. In combat environments, malodor commonly refers to the “stink of the battlefield” often associated with death.2 A survey of U.S. Army combat medics deployed to Iraq or Afghanistan taken between November 2009 and May 2010 indicated 42.4% experienced exposure to the “sight, sound, or smell of dying men and women.” A similar study of U.S. Army Nurse Practitioners reported a 22% rate of exposure to the sight and/or smell of dying men and women.3

Odors are perceptions of odorants through the olfactory system, eliciting a response.6 Malodors may have physiological7–11 as well as behavioral12,13 effects that could impede or directly degrade performance.14,15 In some individuals, malodors may induce elevated levels of desire to escape12 from or avoid13 an environment. Initial exposure to intense malodors may affect performance on complex tasks,14 but may not affect performance on a “simple” test.14 Performance of short-term memory tasks may also suffer in the presence of a malodor.15 Some malodor concentrations considered “irritating” induced “increased levels of tension, depression, anger, fatigue, and confusion.”16 Other malodor effects include increased heart rate17,18 and increased startle reflex.19,20 Hesitation, performance degradation, and elevated escape behavior may adversely affect the complex medical task of aiding battlefield casualties during the “Platinum Ten Minutes”21 and the “Golden Hour.”22

Surgical masks, widely used in clinical environments, serve to prevent blood, mucus, saliva, or other liquids from passing between patient and victim.18 Outside of clinical environments, rescue workers regularly wear surgical masks19 and respirators20 to block the odor of death and decay. Respirators offer more protection from odors than surgical masks,21,22 with some manufacturers reporting filtration ability between 0.1 and 0.3 μm for respirators meeting “commonly used” “N95” specifications.23 N95 respirators are not without side effects. Wearsers experience significantly higher heart rate, temperature, and relative humidity than wearers of surgical masks and also report feeling tight, itchy, fatigued, odorous, and salty.24 Alternatively, a gas mask offers significantly more protection against a broad range of airborne threats, including chemical, biological, and radiological weapons, and battlefield pollutants.25 A change of filter cartridges is recommended when a contaminant can be detected by smell.26 Gas mask negative side effects include inhibited inhalation and exhalation27–30 limited communication ability29,31 and restricted vision.31

Malodor adaptation techniques may mitigate the aforementioned malodor effects in such situations where masks are not a feasible alternative. Olfactory adaptation, a “marked reduction in sensitivity to an odor stimulus,”32 may occur through prior
exposure to the odor. Other than one example in the literature involving research in participants’ homes on long-term exposure to pleasant odors, the vast majority of the literature on olfactory adaptation was performed under laboratory-like conditions. Although limited, study of the human olfactory system is gaining attention with a 2004 Nobel Prize going to groundbreaking human olfactory research.

The level of olfactory adaptation is traditionally measured by detection threshold—concentration at which a participant detects the presence of the odorant—and perceived intensity—participant’s estimated intensity of the odorant.

The duration of exposure to the stimulus, or odorant, and its concentration are major factors in adaptation, as with all senses. Given prior exposure to an odorant, individuals may see both a reduced perceived intensity and detection threshold. As an individual’s adaptation to an odorant’s concentration increases, the individual’s probability of detection of a weak stimulus decreases. The length of prior exposure period necessary to elevate an individual’s detection threshold or “adapt” to the odor may vary from 15 to 20 seconds to 20 minutes.

Recovery from adaptation (or return of an individual’s sensitivity to a malodor) often occurs quicker than the adaptation process, but both repeated and prolonged exposure can increase both adaptation’s effect and the recovery period.

The available literature does not explore adaptation techniques used to mitigate the harmful effects of malodors on complex performance by medical personnel, nor does the literature discuss the use of nontraditional measures such as confusion/bewilderness, escape/avoidance, and stress. Thus, one purpose of this pilot test was to determine the feasibility and validity of traditional and nontraditional measures in assessment of a malodor adaptation techniques to reduce negative outcomes while improving positive outcomes. The literature also does not give a clear indication as to an appropriate adaptation period for a given malodor. Determining the time needed for a treatment to achieve malodor adaption is critical for potential success; as a result of lack of definitive guidelines, the pilot study took the mid-point of multiple studies or 10 minutes, as a beginning point to test. Finally, use of nontraditional measures in a nontraditional setting is ripe for error and possible emergence of issues not foreseen. A pilot study provides an opportunity for identification of implementation issues.

METHOD

Design and conduct of the pilot study explored reliability and validity considerations including subject prerequisites, experimental design, task, malodor conditions, experimental artifacts, and traditional and nontraditional data collection measures and protocols.

Subjects’ prerequisites included the education level and math skills necessary to perform the complex test using a calculator and the ability to detect smells, generated by the use of “Sniffin’ Sticks.” Subjects were informed of Material Safety Data Sheets and International Fragrance Association safety certification, signed informed consent form, and completed a demographics form. Subjects could not participate if they reported post-traumatic stress disorder, previous exposure to the smell of burnt or burning human flesh, were pregnant, not feeling well/sick, or used tobacco products.

The experimental design considered two factors (olfactory adaption and malodor presence), and with malodor at two levels (absent/present). The design randomly assigned subjects to one of four conditions: Group A (odor/odor), Group B (odor/no odor), Group C (no odor/odor), or Group D (no odor/ no odor). A total of 24 subjects, six per group, participated in the study.

The complex task focused on math conversions and decimal place accuracy as well as tablet, liquid, and injection dosage taken from nursing skills testing.

Burnt flesh served as the malodor since as precedent burnt flesh is deemed offensive by civilian firefighters and used in therapeutic treatment of post-traumatic stress disorder for combat veterans.

Experimental artifacts included two tents that contained odor or no odor conditions. A table and calculator inside each tent enabled subjects to take the complex task used in the experiment. A ScentAir dispenser generated the odor at a standard rate. The amount of time of odor dispensing served as an indicator of actual odor intensity.

Traditional olfactory adaptation measures and protocols included subjects reporting detection of the odor during each trial. As appropriate, after a trial, subjects reported perceived intensity of the odor using a seven-point Likert scale and through questions on air quality using Atmospheric Quality Scale (AQS) and task load using the NASA TLX (Task Load Index) Likert scales. Nontraditional data collection measures and protocols included Profile of Mood States (POMS) instrument containing questions related to confusion/bewildenment levels. Nontraditional olfactory adaption objective measures of stress included heart rate and blood pressure taken via an Omron model BP742 blood pressure monitor (Omron Healthcare, Lake Forest, Illinois) and increased electrodermal activity (EDA) using the Affectiva Q-Sensor (Affectiva, Waltham, Massachusetts). Measures of escape/avoidance behavior explored included: (1) if subjects left the experiment early, (2) the length of stay by subjects in an environment with a malodor, and (3) if subjects would voluntarily participate in a follow-on experiment involving the same odor.

The sequence of activities, data collected, and protocols implemented may be seen in Table I. As noted in Table I, after the preliminary data collection, conduct of experiment involved an observer accompanying each subject individually to the first tent and after 2 minutes turning on a ScentPop (ScentAir, Charlotte, North Carolina) odor machine. Depending on the group to which a subject was assigned, the machine presented the odor of burnt flesh or no odor. After 12 minutes (10 minutes with the ScentPop running), the observer led the subject from the tent to a neutral area, measured blood pressure and heart rate, and administered the TLX and AQS. After gathering those measurements,
the observer led the subject to a second tent to repeat the complex task again with odor or no odor conditions administered according to the subject’s Group assignment. Mean time between tents was 5 minutes, with all but two participants entering the second tent between 4 and 7 minutes after leaving the first tent. After the second tent, subject blood pressure and heart rate were taken, and TLX and AQS, along with a final POMS, were administered. Subjects were then debriefed, thanked, and released.

RESULTS
Statistical significance is not the objective of the pilot study but rather feasibility of protocols and validity of measures in terms of directional consistency with expectations established in literature.

Evidence of Olfactory Adaptation
Table II contains difference in group means between Tent 2 and Tent 1 traditional olfactory adaptation measures and protocols for scent detection threshold time, perceived intensity, and test scores.

As expected, Group A (odor/odor) adapted to the malodor from first to second exposure. The basis of this conclusion is that detection threshold average increased approximately 73 seconds while perceived intensity as measured in the AQS decreased an average of one rating in the 7-point scale. Other groups performed as expected, but revealed the need for stronger control on test methodology. Recommended controls include (1) a 30-minute tent airing period and/or four tents to avert confounding of trials resulting from residual odors and (2) tents needed greater separation to avert malodor escape and confounding of the no odor tent. Third, in terms of scores obtained while taking the complex test in each tent, Group A (adaptation group) saw the mean test score increase, whereas Group C (the no adaption treatment group) saw a mean test score decrease. The contrast between Group A to Group C indicates a trend to support the hypothesis that participants who experience a malodor adaptation treatment saw better complex task performance than participants subjected to the same odor who did not experience the treatment. The no odor/no odor Group D controls for learning and did show an improvement in the complex test results but the improvement was not as large an improvement as Group A. The odor/no odor Group B showed a large performance improvement indicating, as expected, that when participants are not exposed to a malodor, they may perform better on a similar task than when they are exposed to a malodor.

Confusion/Bewilderment
Table III contains difference in group means between the nontraditional olfactory adaptation post- and pretest POMS Survey Confusion/Bewilderment score.

The overall mean POMS score was 42.5, on a range of 35 to 64. Consistent with the initial hypothesis, Group A participants saw small or no changes to their POMS Confusion/Bewilderment scores. However, the other 3 groups were inconsistent; Groups B and D both showed an increase, whereas Group C participants showed no change. This may have been the result of the aforementioned control issues or

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**TABLE I.** Sequence of Activities, Data Collected, and Data Collection Protocols

<table>
<thead>
<tr>
<th>Activity Sequence/Data Collection Protocol</th>
<th>Pretest Data Collection</th>
<th>Enter Tent, Initiate Test and Scent Pop</th>
<th>Exit Tent, Wait in Neutral Area</th>
<th>Enter Tent, Initiate Test and Scent Pop</th>
<th>Exit Tent, Perform Post-Test Data Collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>POMS (Confusion/Bewilder)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>AQS (Perceived Intensity)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>TLX (Task Load)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Heart Rate and Blood Pressure</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>EDA Monitor Attached</td>
<td>Monitor Attached</td>
<td>Time Scent Detection Threshold</td>
<td>Subject Early Exit Escape Time</td>
<td>Subject Early Exit Escape Time</td>
<td>Monitor Detached</td>
</tr>
<tr>
<td>Subject Reports</td>
<td>Time Scent Detection Threshold</td>
<td>Subject Early Exit Escape Time</td>
<td>Subject Early Exit Escape Time</td>
<td>Subject Early Exit Escape Time</td>
<td>Subject Early Exit Escape Time</td>
</tr>
<tr>
<td>Observer Reports</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**TABLE II.** Difference in Group Means Between Tent 2 and Tent 1

<table>
<thead>
<tr>
<th>Group</th>
<th>Odor Detection (Seconds)</th>
<th>Perceived Intensity (AQS)</th>
<th>Test Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Odor/Odor)</td>
<td>72.8</td>
<td>-1.0</td>
<td>1.33</td>
</tr>
<tr>
<td>B (Odor/No Odor)</td>
<td>285.2</td>
<td>-0.8</td>
<td>1.17</td>
</tr>
<tr>
<td>C (No Odor/Odor)</td>
<td>-406.8</td>
<td>1.2</td>
<td>(.025)</td>
</tr>
<tr>
<td>D (No Odor/No Odor)</td>
<td>142.0</td>
<td>0.2</td>
<td>.25</td>
</tr>
</tbody>
</table>

**TABLE III.** Difference in Group Means Between Post- and Pretest POMS Survey

<table>
<thead>
<tr>
<th>Group</th>
<th>Confusion/Bewilderment POMS Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (Odor/Odor)</td>
<td>1.6</td>
</tr>
<tr>
<td>B (Odor/No Odor)</td>
<td>3.0</td>
</tr>
<tr>
<td>C (No Odor/Odor)</td>
<td>No Change on Any of 6 Subjects</td>
</tr>
<tr>
<td>D (No Odor/No Odor)</td>
<td>3.0</td>
</tr>
</tbody>
</table>
may call into question the relevance of the POMS for this particular study as discussed further below.

Workload
The NASA TLX is planned for use in the experiment but as a result of heterogeneity of subjects, only used in the pilot study to determine time needed in the actual experiment to complete the survey.

Escape/Avoidance
No one left the experiment early. Only Groups A and C (those subjected to the odor in the second tent) were asked to participate in a follow-on experiment; only two of the 12 said they would not. For the primary experiment, all subjects will be asked this question as such: Would you be willing to participate in a follow-on study involving the same odor, if we can find a time that fits your schedule? (This wording should eliminate time constraints as a reason not to participate.)

Stress
Table IV contains nontraditional olfactory adaptation stress measures and protocols using difference in group means for blood pressure and heart rate.

<table>
<thead>
<tr>
<th>Group</th>
<th>Second Reading—Baseline</th>
<th>Third Reading—Second Reading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Systolic</td>
<td>Diastolic</td>
</tr>
<tr>
<td>A (Odor/Odor)</td>
<td>−2.8</td>
<td>−7.8</td>
</tr>
<tr>
<td>B (Odor/No Odor)</td>
<td>−6</td>
<td>2.8</td>
</tr>
<tr>
<td>C (No Odor/Odor)</td>
<td>−1.7</td>
<td>−1.8</td>
</tr>
<tr>
<td>D (No Odor/No Odor)</td>
<td>1.2</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Group A blood pressure and heart rate dropped after the first malodor tent, perhaps indicating relief rather than malodor-induced stress, but increased after the second malodor tent, which would be inconsistent with the notion of relief but consistent with the notion of malodor-induced stress though not consistent with malodor adaptation. Group B systolic and diastolic pressures and heart rate were internally inconsistent throughout. Group C blood pressure and heart rate dropped slightly after the first no odor tent, possibly indicating relief or indicating no change in stress levels. After the malodor second tent, results were internally inconsistent. Group B, who were not exposed to odor, unexpectedly showed increased stress after the first tent. Was there anticipatory stress about the second tent? After the second no odor tent, Group D readings uniformly declined perhaps indicating relief but certainly not malodor-induced stress or malodor adaptation. Given internal inconsistency in results, interpretation confusion between relief, malodor-induced stress, anticipatory stress, and malodor adaptation, and the time required to check blood pressure and heart rate, the pretest results did not support further use.

EDA data were vast as it collected data on an individual throughout the experiment requiring graphing to visualize change in participant reading over the course of the experiment.

FIGURE 1. Horizontal axis is 24-hour time, and the vertical axis is the Q-Sensor EDA reading, in microsiemens for a participant from Group A, with times in tent shaded.
The Assessment of a Malodor Adaptation Technique

Table V. Pilot Test Assessment of Data and Collection Protocols Feasibility and Validity

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Pilot Test Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional Data</td>
<td></td>
</tr>
<tr>
<td>Subject reported detection threshold</td>
<td>Group A indicates presence of olfactory adaptation as expected</td>
</tr>
<tr>
<td>AQS (perceived intensity)</td>
<td>Group A indicates presence of olfactory adaptation as expected</td>
</tr>
<tr>
<td>Nontraditional</td>
<td></td>
</tr>
<tr>
<td>Performance of a complex task</td>
<td></td>
</tr>
<tr>
<td>POMS (confusion/bewilderment)</td>
<td></td>
</tr>
<tr>
<td>Blood pressure/heart rate</td>
<td>Discrete measures indicate groups behaved inconsistently. Literature is also inconclusive on measures. Further, methodology was invasive and disruptive to the experiment.</td>
</tr>
<tr>
<td>Electrodermal Activity</td>
<td>Continuous data throughout the experiment could logically be interpreted as groups behaving consistently with expectations.</td>
</tr>
</tbody>
</table>

Continuous measurement of the stress using EDA did show promise as it tracked logically with expectations; therefore the stress outcome variable as measured by EDA will remain in the future experiment. The elimination of the aforementioned measurement instruments will reduce cost, implementation scope, and burden.

CONCLUSION

This pilot test confirmed traditional data and collection protocols for perceived intensity and detection threshold for malodor olfactory adaptation research. Further the pilot test sought to explore the feasibility and validity of nontraditional techniques to define olfactory adaptation as a technique to alleviate human performance issues. As the pilot study indicates, performance of a complex relevant task (unlike a task not relevant to the participant audience) shows promise to improve in an olfactory adaptation condition. In addition, nontraditional outcome variable such as stress as measured by EDA appear to be promising while blood pressure and heart rate did not. Further research into the value of the confusion/bewilderment outcome variable and appropriate measurement instruments remains. Given these insights, the main experiment is currently underway with results expected to be published in late 2017.

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