Olfactory Stimuli Increase Presence During Simulated Exposure

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Abstract. Exposure therapy (EXP) is an extensively studied and supported treatment for anxiety and trauma-related disorders. EXP works by exposing the patient to the feared object or situation in the absence of danger in order to overcome the related anxiety. Various technologies including head-mounted displays (HMDs), scent machines, and headphones have been used to augment the exposure therapy process by presenting multi-sensory cues (e.g., sights, smells, sounds) to increase the patient's sense of presence. Studies have shown that scents can elicit emotionally charged memories, but no prior research could be identified that examined the effect of olfactory stimuli upon the patient's sense of presence during simulated exposure tasks. **Methods:** 60 adult participants navigated a mildly anxiety-producing virtual environment (VE) similar to those used in the treatment of anxiety disorders. Participants were screened for olfactory dysfunction and history of seizures. Participants completed questionnaires pertaining to their (a) tendency to immerse themselves in activities and (b) current health. Visual exploration and presence ratings were collected throughout the experiment. **Results:** Linear Mixed Modeling showed statistically significant relationships between olfactory stimuli and presence as assessed by both the In group Presence Questionnaire (IPQ: R2 =.85, (F(3,52) = 6.625, p =.0007) and a single item visual-analogue scale (R2 = .85, (F(3,52) = 5.382, p = .0027).

Keywords: Exposure therapy · Presence · Augmented reality · Olfaction · Immersion

1 Introduction

Presence, when used to describe immersive feelings in virtual reality (VR), has been conceptualized and defined in different ways (for a review, see Lombard & Ditton1). Presence is most often described from the concept of transportation2, that is to say, people are usually considered "present" when they feel as if they are actually in the virtual world. Creative methods utilized for the purposes of increasing presence in virtual reality may include the use of tactile feedback, surround or 3D sound, and head mounted displays (HMDs) with high visual fidelity.

One benefit of elevated levels of presence is that when asked to recall, users remember the environment as if it was a real place instead of a simulated location [2]. Similarly, VR environments may produce the same emotions and physical reactions as

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their real-world counterparts when the level of presence experienced by the user is sufficiently high [1]. The ability to evoke similar emotions and physical reactions is particularly useful for clinical applications. For example, Hodges et al. [3] found that participants with clinical diagnoses of acrophobia reported increased anxiety when presented VR that included great heights. This ability to evoke real emotions from artificial environments has presumably led to the use of VR for the treatment of numerous anxiety disorders [4–6], as well as PTSD [7–10].

Exposure therapy (EXP) is a treatment that involves repeated presentations of feared situations or stimuli to overcome the patient's anxiety. For example, those who are fearful of dogs can eliminate their fear by repeated exposures to dogs in which the feared outcome (being bitten, for example) does not occur. Gradually, the anxiety of being around dogs will decrease and the patient learns that not all dogs are dangerous. This decrease is called habituation [11], and is analogous in humans to extinction models used in animals [12]. When conducting exposure therapy, multiple cues associated with the feared situations or stimuli are often incorporated to enhance extinction [13–15].

It is generally believed that the more senses are utilized by a medium, the greater its ability to generate a sense of presence [16–20]. In fact, many studies have examined the effect of screen size [21–24], sound [15], and multi-speaker systems [19] on presence. Tactile stimuli also increase presence [25], and have been used in the treatment of combat-related PTSD [26, 27]. It has also been suggested that olfactory delivery systems be introduced to VR [28]. Given the substantial research supporting the relationship between olfaction and strong emotional memory [29–33], it seems logical to explore the effect of olfaction on presence during virtual-reality assisted exposure therapy, as virtual reality is increasingly utilized and has been shown to be efficacious in the treatment of anxiety and trauma-related disorders [34–37].

However, the utility of olfactory stimuli (OS) to increase presence during simulated exposure therapy tasks is not yet known. In this investigation, we examined whether OS were associated with changes in presence within a virtual environment. We hypothesized that participants would experience higher levels of presence when engaged in VE's while receiving OS.

2 Methods

2.1 Sample

The sample consisted of 60 participants between the ages of 18 and 31 years of age ($M = 20.48$, $SD = 3.13$). Sixty-five percent (65 %) were male ($n = 39$), while ethnicity varied, including 38 Caucasians, 11 Hispanics, 6 African Americans, 2 Asians, and 3 who identified as Other (e.g., of mixed ethnic background). To be included in the study, participants were required to achieve a passing score on a brief test of olfactory function (see below). A history of seizures, epilepsy, or current prescriptions for beta-blocking or anxiety medications excluded individual participants from participating in the study.

2.2 Assessment Instruments

The Quick Smell Identification Test (QSIT; Sensonics, Inc., Haddon Heights, NJ) is a three-item multiple-choice test consisting of three microencapsulated odorant strips. The QSIT has been shown to be highly reliable over time ($r = 0.87$) and highly sensitive to identifying olfactory loss, particularly in those with severe olfactory deficits [38].

The Igroup Presence Questionnaire (IPQ) [39] is a 14-item self-report questionnaire designed to measure presence utilizing a 7-point Likert scale that loads onto three subscales; spatial presence (the sense of physically being in the VE), involvement (focus on the VE and involvement experienced), and experienced realism (subjective realism of the VE).

To determine presence during the experiment, participants were asked to rate their immersion on a visual-analogue scale (VAS). VASs have moderate to strong correlations with Likert based items [40]. VASs have superior metrical characteristics than discrete scales and can have a wider range of statistical methods applied to their measurements [41].

Participants were asked after scripted events to rate their presence during the exposure task. This rating was on a 7-point Likert scale to remain consistent with the Likert scale of the IPQ. The question, "How present do you feel?" was anchored at one (not at all) and seven (very much) prior to the start of each trial.

The Simulator Sickness Questionnaire (SSQ) [42] is a 16-item self-report scale used to rate common symptoms of simulator sickness on a 4-point scale. Such symptoms include general discomfort, headache, eyestrain, sweating, and vertigo. The SSQ was used for pre- and post-experimental assessment to assess symptoms commonly associated with VR use.

Visual Scanning (VS) was assessed as a behavioral index of presence as first hypothesized by Sheridan [43]. To assess VS, hidden "triggers" were anchored to the virtual avatar. When the participant explored the VE by turning their head or virtual body, a virtual beam swept across the trigger, resulting in a numerical score.

2.3 Procedure

Following consent, participants were asked to complete self-report measures (described above). Upon completion, each participant was assisted with the virtual reality equipment and encouraged to explore a virtual room in order to familiarize him/herself with the virtual reality controls and head mounted display (HMD). After a ten-minute familiarization period, participants were provided instructions regarding the upcoming task. Once questions had been addressed, the first exposure trial began. Participants were instructed to report problematic symptoms of simulator sickness at any point while in the VE.

During Trial 1 (T1), 50 % ($n = 30$) of participants received OS congruent with the VE; the other half of participants received no OS. After completion of T1, participants removed the HMD and headphones for a ten minute reset period, during which they completed additional self-report measures for T1. After the reset period concluded, experiment instructions were reiterated and Trial 2 (T2) began. During T2, 50 %

(n = 30) of the sample reversed olfactory condition, while the remaining participants remained in their T1 condition, meaning they either continued receiving scents, or they again received no scents. Upon completion of T2, participants completed self-report measures for T2, at which point their participation in the study concluded.

2.4 Virtual Reality System

The OS were ceramic pellets impregnated with scented oil (Dreamreapers Inc., Melrose Park, IL) consistent with the scent of smoke, garbage, cotton candy, and popcorn. Stimuli were delivered via air dispersion by a USB controlled Scent Palette (Virtually Better Inc., Decatur, GA).

The VE was modeled in 3D and controlled with the Unity3D engine (Unity Technologies, San Francisco, CA) and approximated an abandoned carnival at night. Participants were asked to imagine that they had lost their keys within the carnival, and were directed to retrieve them. The VE was presented to the subject using the Oculus Development Kit II HMD (Oculus VR, Irvine, CA) and high-fidelity stereo headphones (Audio Technica ATH-M50x; Audio Technica, Stow, Ohio). The VE was generated by a PC with an Intel® i5-4670 3.4ghz CPU, 16 gigabytes of RAM, and an Nvidia® GTX 780 Ti GPU. Participants navigated through the environment at their own pace and had full control over their movement utilizing a wireless Xbox 360 controller (Microsoft Inc., Redmond, WA). The participant had access to a virtual flashlight allowing them to explore any unlighted areas should they choose to examine the VE in greater depth. Participants were guided through the VE via location-based prerecorded narration. Congruent ambient sounds accompanied the visuals of the VE. At various locations within the VE, scripted events were presented to add realism to the VE. For example, an audio sample of an unseen object bumping into a metal garbage can was played as the participant passed a 3D garbage can. For those in the OS condition, this was augmented with the smell of garbage.

3 Results

3.1 Data Screening

Of 122 adults recruited via community announcements and the University of Central Florida, 62 were not included in the final analyses. Reasons include simulator sickness and discontinuation (n = 18), subthreshold ability to smell (n = 5), technical malfunctions (n = 38) and noncompliance with the experimental task (n = 1). Chi-squares and ANOVAs were conducted to determine if those excluded from the final sample were different proportionally to those included. No significant differences were found with the exception of gender; females were more likely to report their desire to discontinue or suffer from simulator sickness than males ($p = 0.012$).

Jackknife distance measures were calculated to identify multivariate outliers utilizing the critical value formula recommended in Penny [44]. Seven such outliers were identified, but demonstrated a negligible effect on p-values. These outliers did not possess enough influence to alter the significance of any analyses. Thus, the outliers were included in the final sample.

3.2 Statistical Analyses

All analyses were conducted on the final sample of 60 participants using JMP Pro 11.2.0 (SAS Institute Inc., Cary NC) after screening for data normalcy. All analyses defined significance utilizing a p-value of < 0.05.

3.3 Presence Ratings

Linear Mixed Model (LMM) analyses were utilized to assess change between trials for continuous outcome variables and within- and between-subject effects. Group membership served as a between-subjects effect, while trial and sex was assigned as within-subjects factors. IPQ scores were examined utilizing LMM predicted by sex, trial, gender, and group. There was a significant main effect for trial, $R^2 = .85$, ($F(1,52) = 6.3669$, $p = .0147$) and the group*trial interaction, $R^2 = .85$, ($F(3,52) = 6.625$, $p = .0007$). With regard to the main effect for trial, participants felt significantly more present during T1 than T2 ($LSM_{T1}=61.68$ & $LSM_{T2}=59.26$). With regard to the interaction, the Scent-No Scent (S-NS) group showed a disproportionate decrease in presence in T2 compared to other groups, while the No Scent-Scent (NS-S) group reported an increase in presence. This increase and decrease in presence (respectively) indicated that participants felt more presence when OS were present. The control groups maintained relative stability across trials, as the Scent-Scent (S-S) group on average declined by just over a single point (1.37, $LSM_{T1}=60.37$ & $LSM_{T2}=59.00$) while the No Scent-No Scent (NS-NS) group declined less than one point (.7, $LSM_{T1}=57.44$ & $LSM_{T2}=56.74$).

Examination of the VAS showed a significant main effect for trial, $R^2 = .81$, ($F(1,52) = 7.955$, $p = .0068$), also indicating that participants felt more present during T1 ($LSM_{T1}=73.48$ & $LSM_{T2}=67.25$). The group*trial interaction, $R^2 = .85$, ($F(3,52) = 5.382$, $p = .0027$) showed a disproportionate decrease in presence between T1 and T2 ($LSM_{T1}=79.43$ & $LSM_{T2}=61.32$) in the S-NS group compared to other groups. The NS-S group saw a gain in VAS scores during T2 ($LSM_{T1}=74.81$ & $LSM_{T2}=79.74$) which suggests that introducing OS increased perceived presence, even after one trial experienced within the VE.

3.4 Discussion

The purpose of this study was to explore the effect of OS on presence during a simulated exposure task. Results indicated across two separate measures (IPQ & VAS) that OS positively influenced the amount of perceived presence when administered, and that perceived presence decreased when OS were withheld. This finding supports our original hypothesis, and suggests that (a) the addition of scents may increase presence for participants during an exposure task, and (b) the removal of scents, once presented, likely results in a reduction of presence. These findings are very important, as EXP is enhanced when the number of cues utilized increases [13–15]. The inclusion of scents not only increases the number of cues, but may also increase the degree to which patients "buy in" to treatment, which is important because treatment credibility has been shown to increase treatment initiation [45].

One potential benefit of including OS may be increased generalization post-treatment. For example, in combat-related PTSD the scent of smoke may serve as a specific trigger. While traditional EXP may effectively reduce physiological reactivity in a patient with PTSD, the inclusion of smoke during EXP may allow broader generalization. Without scents included, everyday activities like camping or cooking may remain avoided at greater frequency than if congruent scents (e.g. smoke) had been included during the treatment. Conversely, it may be that scents affect the therapeutic process by facilitating memory recall of otherwise difficult-to-remember situations [46]. These results indicate that OS are not a detriment to presence and as such, the use of OS during EXP for disorders like PTSD or specific phobias should be considered. However, it appears that OS should not be discontinued once the user has experienced them due to reductions in reported presence. Additionally, OS may assist with treatment acceptability or in other words, patient "buy in" as anecdotal accounts of OS's effectiveness has already been described in the memory literature [47].

A last consideration that came from this study is the strong correlation between IPQ and VAS scores. This finding may indicate that simple scales can accurately assess presence, which may be beneficial for researchers who need less disruptive ways to assess momentary presence as interrupting tasks to assess presence can actually diminish presence.

4 Limitations

This study has several limitations. First and foremost, this experiment was conducted with participants who were not inherently anxious about the VE being presented. For example, our participants did not possess fears specific to the VE that would have been present in a clinical population, such as warfighters who have experienced combat. Future research may wish to utilize a clinical population. For example, soldiers or veterans in a convoy VE may better illustrate the influence of scents (e.g., diesel fuel or exhaust) on presence.

Our groups were also not optimally balanced for gender, due to gender differences in experiencing simulator sickness [48]. Women were much more likely to voice their desire to discontinue. After careful deliberation, the decision was made to recruit males only due to disproportionate attrition.

Overall, this study demonstrates the potential of olfactory stimuli used in exposure therapy, and indicates that OS may be effective in increasing presence during scenarios similar to those used in EXP. The score patterns for the reversal groups (S-NS & NS-S) trended in the hypothesized directions. If OS directly increases presence during individual sessions of EXP, the effect on treatment outcome must also be examined. Given the escalating patient care costs of anxiety disorders, the utilization of scents may positively impact treatment efficacy, through increased patient acceptability or greater habituation in-session. More research in this area is required.

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