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A Pilot Study of the VirtuSphere as a Virtual Reality Enhancement

Nancy A. Skopp[1], **Derek J. Smolenski**[1], **Melinda J. Metzger-Abamukong**[1], **Albert A. Rizzo**[2], **and Greg M. Reger**[1]
[1]*National Center for Telehealth & Technology, Joint Base Lewis McChord, Tacoma, Washington, USA*
[2]*University of Southern California, Los Angeles, California, USA*

This pilot study assessed the utility and acceptability of the VirtuSphere, a cutting edge navigation platform designed to enhance presence in virtual environments. The VirtuSphere includes a 12-ft hollow sphere within which the user stands, and it rolls within a wheeled platform, in any direction, according to the user's steps. The pilot was a within-subject crossover design comparing the VirtuSphere to standard game controller navigation. The comparison was based on locomotion in Virtual Iraq, a virtual world resembling Iraqi war zones. Participants were 10 active duty soldiers not suffering from posttraumatic stress disorder. Results indicated that there were negligible differences in sense of presence, simulator sickness, and satisfaction across the two navigation systems. Although the VirtuSphere may provide entertainment value, these results do not provide initial support for the use of the VirtuSphere to improve constructs thought to be important to behavioral health applications of virtual reality. Potential improvements to the design of the VirtuSphere are discussed.

Research indicates that virtual reality exposure (VRE) therapy is an effective and promising treatment option for a range of anxiety disorders (Opris et al., 2012; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008). Due to the increased risk of posttraumatic stress disorder (PTSD) following military service in Iraq and Afghanistan (Sundin, Fear, Iversen, Rona, & Wessely, 2010), this treatment is recently of particular interest for the treatment of soldiers with PTSD (Reger & Gahm, 2008; Reger et al., 2011; Rizzo et al., 2011). In addition, concerns that military personnel may avoid treatment because of the stigma associated with seeking mental health care (Hoge et al., 2004; Tanielian & Jaycox, 2008) have caused speculation that VRE may be a more appealing form of treatment for young, technologically savvy service members (Reger, Gahm, Rizzo, Swanson, & Duma, 2009). VRE involves the use of multisensory virtual environments to augment the delivery of traditional exposure therapy. Prolonged exposure (Foa, Hembree, & Rothbaum, 2007) is a highly efficacious form of exposure therapy for PTSD that is based on emotional processing theory (Foa & Kozak, 1986). Emotional processing theory postulates that activation and emotional processing of fear structures is required to address pathological elements that maintain PTSD symptoms; fear structures are a program for survival made up of associations among stimuli, responses, and the meaning to the individual. VRE therefore may be superior to traditional exposure therapy for some patients because the multisensory nature of VRE is theorized to facilitate activation of disturbing memories and adequate levels of emotional engagement (Reger et al., 2011).

During VRE, the patient remains in a circumscribed area (usually seated, sometimes standing) and wears a head-mounted display (HMD). VRE typically involves 5 to 7 weeks of twice-weekly 90-min sessions (Rothbaum, Difede, & Rizzo, 2008). The patient accesses a virtual environment that resembles the setting of the index trauma that is recalled during exposure sessions. Movement within the virtual environment is typically attained through a video game controller. The patient does not physically move through the virtual environment but rather utilizes the game controller in combination with an orientation tracker to replicate head movements. A key feature of VRE is that it is designed to enhance exposure therapy treatment outcomes.

Additional technologies are now available that can be integrated with VRE and potentially augment soldiers' level of emotional engagement during exposure by increasing sense of presence, or the psychological sense of "being there" (Schrader & Bastiaens, 2012; Stanney et al. (1998). Such increased presence is postulated to create a more immersive experience potentially capable of increasing positive treatment

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Address correspondence to Nancy A. Skopp, Research Outcomes, and Investigations, National Center for Telehealth & Technology, 9993 West Hayes Street, Joint Base Louis-McCord, Tacoma, WA 98431, USA. E-mail: nancy.skopp@us.army.mil

outcomes. Furthermore, locomotion by a game controller results in a mismatch between the visual display and proprioceptive cues and may negatively impact immersion. Prior research has reported increased presence when walking types of locomotion (e.g., treadmill or walking in place) were used to navigate through a virtual environment (Peck, Fuchs, & Whitton, 2012; Slater, Usoh, & Steed, 1995). However, most walking locomotion approaches are limited to a constrained space within which the user is tracked.

The VirtuSphere is a cutting-edge technology that was designed to further enhance immersion and presence in virtual environments by allowing free movement through an unlimited virtual space. Specifically, the VirtuSphere consists of a 12-ft hollow sphere, which is placed on a wheeled platform to allow the sphere to rotate freely in any direction according to the user's steps. Using this system, the user is able to more naturally ambulate within virtual environments that are viewed by the user with a HMD, and this is believed to facilitate more complete immersion within the simulation. Moreover, the VirtuSphere's potential to increase the immersive experience in a virtual environment may significantly enhance the sense of presence within a computer-generated simulation. As such, the integration of the VirtuSphere with VRE and other VR therapies could ultimately increase treatment efficacy via enhanced presence.

Although the VirtuSphere holds the potential for more complete immersion and presence in virtual environments, thus far no research has examined with either service members or civilians. We conducted an initial pilot study to examine the feasibility and acceptability of the VirtuSphere immersion enhancement technology to provide much needed data on the usability and potential usefulness of this technology. Initial data were also collected on the extent to which the VirtuSphere is capable of enhancing VR presence and the extent to which it might produce simulator sickness. Last, this research generated initial parameter estimates to guide further research on this topic.

1. METHODS

1.1. Participants

To be eligible for the study, soldiers had to have had a history of deployment in support of the conflicts in Afghanistan and Iraq—Operations Enduring and Iraqi Freedom. Soldiers who met any of the following criteria were ineligible for participation: (a) positive screen (total score >50) on the Posttraumatic Stress Disorder Checklist (Weathers, Huska, & Keane, 1991), (b) endorsement of all five (yes/no) items on the panic disorder screen of Patient Health Questionnaire (Spitzer, Kroneke, & Williams, 1999), (c) self-report of strong propensity toward motion sickness (participants who responded "yes" to this question were excluded due to ethnical concerns about potentially inducing sickness in an individual known to suffer from motion sickness), (d) self-report of history of seizures, (e) self-report of history of head injury involving loss of consciousness greater than 15 min, (f) mobility problems or physical conditions that interfere with the proper use of the VR HMD or its peripherals, (g) self-report of pregnancy or breastfeeding, or a (h) self-report of a military medical profile limiting physical activities or duties. In addition, soldiers whose weight exceeded 230 lb were ineligible because of VirtuSphere weight limitations.

The sample included 10 active duty soldiers recruited from a large army installation. The average age was 28.4 ($SD = 5.1$); 90% were male; 90% reported race as White, and 10% reported race as Black. With regard to educational attainment, four of the soldiers completed high school or the equivalent, four completed some college, one completed an AA/technical degree, and one completed a bachelor's degree. Two soldiers had been deployed to Afghanistan, nine had been deployed to Iraq, and two soldiers had been deployed to "other" locations. Average weight and height were 183.3 lb ($SD = 22.0$) and 70.0 in. ($SD = 3.1$), respectively.

To recruit participants, team members briefed groups of soldiers on three separate occasions. At the end of the briefings, soldiers were asked to fill out a form with their names and contact information if they had initial interest in volunteering for the study; they were instructed to check the "not interested" box on the form, without identifying information, if they were not interested in volunteering. All soldiers were subsequently asked to place their completed forms in an envelope to preserve the confidentially of their responses and to reduce the possibility for coercion. A research assistant collected the envelopes and used these data to contact the soldiers who had indicated initial interest in volunteering for participation. A maximum of three telephone contact attempts were made; soldiers who did not respond after three attempts were considered to be no longer interested in participation.

Thirty-four soldiers indicated initial interest in volunteering for participation. Twenty-one of these soldiers did not participate because they could not be reached via telephone, were no-show for their appointments, or were unable to participate due to military duties. Individual written informed consent was obtained from all participants. Of the 13 soldiers who consented, three soldiers were excluded because they were ineligible (exceeded weight limit, self-reported medical problem). Thus, a total of 10 soldiers completed the pilot study.

1.2. Measures, Virtual Environment, and Equipment

Screening measures. To screen for PTSD and panic disorder, soldiers completed the Posttraumatic Stress Disorder Checklist– Military Version (Weathers et al., 1991) and the Panic Screen of the Patient Health Questionnaire (Spitzer et al., 1999), respectively. In addition, soldiers were asked to self-report histories of significant propensity for motion sickness, seizures, head injury involving loss of consciousness greater than 15 min, mobility problems, physical conditions that interfere with proper use of the virtual reality HMD or its peripherals, and a medical profile. Female soldiers were asked if they were pregnant or breastfeeding.

Presence. To assess presence, we administered the Presence Questionnaire (Witmer & Singer, 1998). The PQ is a 32-item questionnaire that is designed to assess presence in virtual environments. For the purposes of this study, Items 6, 15 to 17, and 21 were not scored because they were not relevant to the virtual environment (i.e., items pertained to auditory and tactile inputs, which were not presented in the virtual environments examined here). This measure has exhibited good internal consistency and correlates positively with immersive tendencies (Witmer & Singer, 1998). Participants completed the scale two times, once for each experimental condition. Coefficient alpha for the current sample was .85 for the game controller items and .94 for the VirtuSphere items. We also compared the items specific to the involvement subscale ($n = 12$) because this subscale had the strongest theoretical relationship with the underlying construct. Coefficient alpha for the subscale was .82 for the game controller and .90 for the VirtuSphere.

Simulator sickness. For the assessment of simulator sickness, we administered the Simulator Sickness Questionnaire (SSQ; Kennedy, Lane, Berbaum, & Lilienthal, 1993). The SSQ contains 16 symptoms of simulator sickness scored on four-point (1–4) nominal scale (i.e., *none, slight, moderate, severe*); examples of symptoms include: general discomfort, sweating, nausea, vertigo, confusion. The SSQ was supplemented with 12 items from the Motion Sickness Questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993) to provide full coverage of the range of potential adverse symptoms associated with use of the VirtuSphere, as exposure to virtual environments often induces motion sickness in some individuals (Kennedy & Stanney, 1996). The 12 Motion Sickness Questionnaire items related to more severe motion induced symptoms: stomach awareness, vomiting); these items were scored on the same 4-point nominal scale. As with the PQ, we administered the SSQ for both experimental conditions. Coefficient alpha was .95 for the game controller and .90 for the VirtuSphere item sets.

User satisfaction. To assess user satisfaction, we administered the Virtual Iraq Feedback Form (VIFF), which we developed as part of an earlier research project (Reger et al., 2009). This measure contains seven items scored on a 10-point scale (0–10) using three anchor points (*poor, adequate, excellent*). Examples of items composing this measure include, Did the graphics change or update effectively as you moved through the virtual reality environment? Please rate the navigation device in terms of ease of use? How would you rate your ability to pay attention to the computer environment? In addition, the VIFF contains two open-ended questions: What would you change about this way of moving around the virtual environment? If you could tell the developers of this way of moving around in the virtual environment one thing to change that would improve the overall experience, what would it be? Coefficient alpha for the seven ordinal items was .88 for the game controller and .93 for the VirtuSphere.

Virtual environment. *Virtual Iraq* was developed by the Institute for Creative Technologies to support VRE for PTSD (Rizzo, Reger, Gahm, Difede, & Rothbaum, 2009). The environment resembles the contexts soldiers typically experience during deployment to Iraq. Two environments, an Iraqi city and a desert/convoy scene, have been developed. For the purposes of this research, only the Iraqi city environment was used, as it provides a dismounted navigation context appropriate for testing the VirtuSphere. The Iraqi city environment includes a range of contexts, including desolate sparsely populated streets, derelict apartments and buildings, warehouses, a mosque, factories, junkyards, and battle-damaged vehicles. Another section of the city appears as a central gathering place with more foot and vehicle traffic, market vendors, other soldiers, monuments, and alleys populated with insurgents. The environment is laid out in city blocks so that participants can walk through the expansive city scenario.

Equipment. The *Virtual Iraq* system is designed to run on two networked notebook computers. One notebook runs the clinician's control application while the second notebook delivers the participants' image via an HMD and head orientation tracker. The HMD for this project was the eMagin z800, which uses OLED displays capable of 800×600 (SVGA) resolution with a 40° diagonal field of view and an IntertiaCube2 study for 3 degree-of-freedom (pitch, roll, and yaw) head orientation tracking. In this study, participants wore a backpack containing a laptop computer to which the HMD was connected. The computer was wirelessly networked to the control application. For game controller (GC) condition, the user navigated through the scenario using a USB gamepad device.

1.3. Procedure

All study procedures were approved by the Institutional Review Board at the military installation where this pilot was conducted. At each scheduled appointment, the research assistant greeted the soldier and escorted him or her to the research lab. The soldier was weighed, and once it was determined that the soldier did not exceed weight limit, he or she completed the initial screening measures and a self-report of exclusionary criteria.

Following safety instructions for the VR and VirtuSphere equipment, soldiers were given instructions and up to 10 min to practice and familiarize themselves with the virtual environment, the VirtuSphere, and the equipment prior to beginning the pilot. When a soldier indicated he or she was ready to begin, the trial commenced. Soldiers spent 10 min navigating through a predetermined route in the virtual environment according to two navigation conditions: (a) the VirtuSphere condition and (b) a GC condition in which soldiers stood on a base platform holding a mock M4 rifle with an attached computer game controller. Thus, the mock M4 rifle used in the GC condition allowed the participant to navigate the virtual environment by using a game controller mounted to the mock weapon. In each of the two conditions, soldiers wore an HMD with a head tracker that enabled the soldiers to turn in the direction of their gaze. The order with which each soldier were assigned to the two forms of navigation was randomly selected based on a random number generator. Each soldier was given 10 min to complete a specified (and identical) route using each navigational system, in turn. The research assistant provided verbal instructions to guide the soldiers through the same predefined course in the virtual environment. Immediately following each completed navigation through the virtual environment (i.e., GC condition or VirtuSphere condition), the soldier completed measures of presence, cyber sickness, and satisfaction.

1.4. Statistical Methods

We used both paired *t* tests and Wilcoxon signed rank tests to compare average scores of the outcome measures. All mean comparisons were evaluated using nine degrees of freedom, and effect size was calculated using the standard formula for Cohen's *d*. We also used graphical comparisons of scale scores to evaluate differences between the two treatments.

2. RESULTS

The average PQ scores between both conditions were indistinguishable (Table 1). Comparison of the Involvement/Control subscale of the PQ indicated that the presence associated with the VirtuSphere was lower than that associated with the game controller alone; this difference, however, was not statistically significant. There was a trend for an increase in reported sickness symptoms associated with the VirtuSphere use as compared to the game controller ($p = .06$, Student's *t* test; $p = .03$, Wilcoxon Signed-Rank test). Finally, participants reported lower overall satisfaction with the VirtuSphere use; again, this difference was not statistically significant.

Figures 1 and 2 depict the individual and population-average differences in overall presence and sickness symptoms between the VirtuSphere and the game controller. For the PQ, we observed that most participants reported a small decrease in presence between the game controller and VirtuSphere. Two participants had particularly large differences, but in conflicting directions, which most likely yielded the very small average decrease in presence observed in overall means. For simulator sickness, many participants had a low rating with the game controller; we observed only small increases in sickness symptoms when compared with VirtuSphere. Overall, neither condition elicited appreciable simulator sickness.

In addition, we examined data derived from the two free text items contained on the VIFF to assess the soldiers' comments about how the navigation with VirtuSphere and game controller could be improved (Tables 2 and 3). Some of the suggested improvements to the VirtuSphere navigation system included providing (a) more practice time, (b) a more stable interface to improve balance, and (c) greater freedom of movement. Suggestions for improving the game controller navigation included reducing the number of cords, conducting the session without lights to improve perception of the virtual environment, incorporating the controller into the pistol grip, and providing more complete sensory and audio output.

3. DISCUSSION

This study failed to detect significant differences in presence or simulator sickness among healthy soldiers who navigated through *Virtual Iraq* using a computer game controller compared with VirtuSphere navigation. There was a nonsignificant trend for increased simulator sickness after VirtuSphere use, relative to the game controller. However, because very low

TABLE 1
Comparison of Average Scale Scores of Presence and Sickness Between the Game Console and VirtuSphere Modes

	VirtuSphere	GC				
Scale	M (SD)	M (SD)	*d*	*t, df*	p^a	p^b
Presence (PQ)						
Overall	3.72 (0.80)	3.76 (0.54)	0.04	−0.13, 9	.898	.799
Involvement/Control	4.10 (1.02)	4.45 (0.65)	0.33	−1.04, 9	.327	.358
Sickness (SSQ/MSQ)	1.13 (0.17)	1.07 (0.14)	0.67	2.13, 9	.062	.028
Evaluation (VIFF)	6.61 (0.72)	7.34 (0.47)	0.28	0.87, 9	.405	.284

Note. *d* = Cohen's standardized mean difference; GC = game controller; PQ = Presence Questionnaire; SSQ/MSQ = Combined Simulator Sickness and Motion Sickness Questionnaire; VIFF = Virtual Iraq Feedback Form.

[a]Two-tailed *p* value associated with Student's *t* test. [b]Two-tailed *p* value associated with Wilcoxon Signed-Rank test.

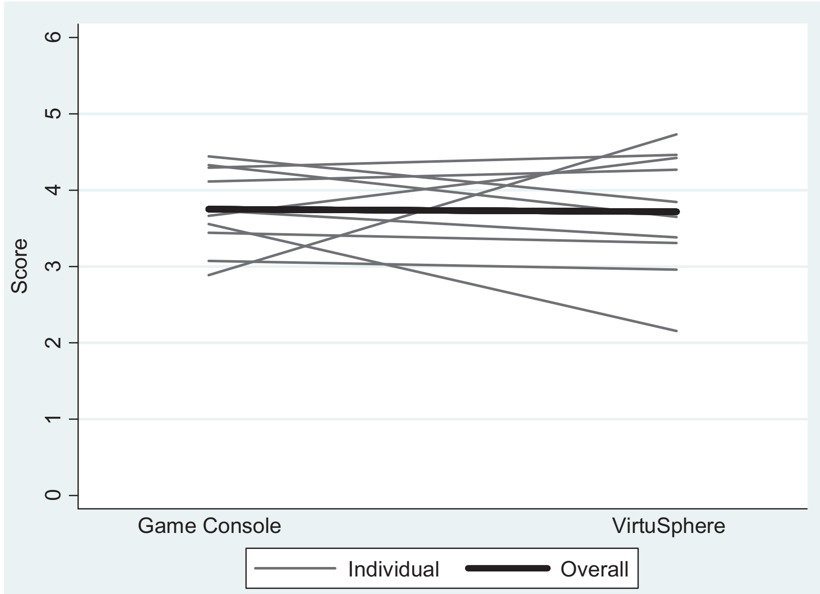

FIG. 1. Change in presence scores between the game controller and VirtuSphere platforms, individual and overall (color figure available online).

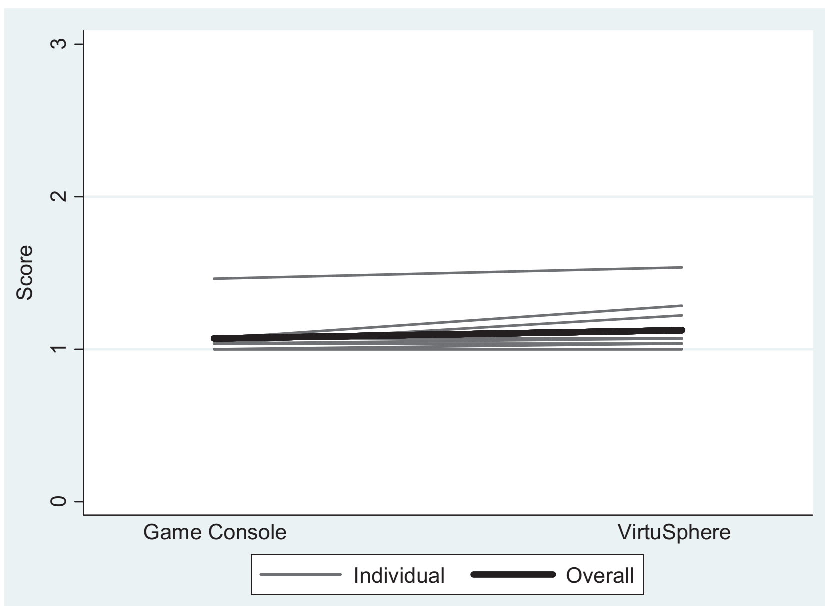

FIG. 2. Change in Simulator Sickness Questionnaire scores between the game controller and VirtuSphere platforms, individual and overall (color figure available online).

levels of simulator sickness were reported, the magnitude of this difference is small and of questionable clinical meaningfulness.

Similarly, most participants reported small decreases in both presence and satisfaction during VirtuSphere use, relative to GC use, but these differences were small and negligible. In short, this pilot study did not provide initial evidence that the VirtuSphere navigation peripheral meaningfully improves presence or increases simulator sickness relative to GC use. This should be confirmed with a wider sample because this pilot study excluded subjects who reported high susceptibility to motion sickness.

Prior research has found that patients' emotional engagement during exposure to the trauma memory is important to clinical outcomes (van Minnen & Hagenaars, 2002). In the context of VRE, the psychological sense of participating in the virtual environment is theoretically linked to its ability to act as an aid to memory activation. If a user does not have a sense of being present in the environment, the environment becomes

TABLE 2
Participants Comments on How to Improve Navigation With the VirtuSphere and Game Controller Platforms

What would you change about this way of moving around the virtual environment?

A. VirtuSphere
- "Interaction with locals."
- "More time to get used to walking with the head harness."
- "I love the concept but it's not very practical."
- "Be able to side step to the left or right to avoid being struck or the ability to step over walls."
- "Nothing it was one of if not the most real thing I have ever seen."
- "You would be unable to run or drop down. You must make slow deliberate movements."
- "I think just practicing and doing it more would make things easier."
- "Better rollers or slightly smoother outer surface so as to not get hung up."

B. Game controller
- "Turn the lights off so you can't see out of the virtual environment."
- "I would change moving head to change directions with another method."
- "Able to walk instead of using a controller."
- "Movement was easy, not much to change. I would use the control pad to turn left or right when moving versus the head-mounted display to turn while walking. That would allow you to walk straight forward but also to swivel your head to see around you."
- "Use the ball."
- "The controller on and how positioned and how to move forward/back."
- "Too many cords in the way."
- "Controller should be moved to the pistol grip or further back on heat shield."

TABLE 3
Participants Comments on How to Improve the VirtuSphere and Game Controller Platforms

If you could tell the developers of this way of moving around the virtual environment, one thing to change that would improve the overall experience, what would it be?

A. VirtuSphere
- "Interact with people."
- "It's too easy to fall over and lose your balance. Perhaps a treadmill."
- "The ability to move around and see everything in the environment is very good. After getting used to the movement inside the sphere it is very similar and accurate to being in that environment."
- "I really liked it."
- "Make the ball easier to control. Seems like it takes too much effort to start and stop. Hard to keep balance."
- "Better glasses."

B. Game controller
- "To interact with people and things."
- "I would change moving head to change directions with another method."
- "Full audio, sensory, everything bundled into one experience."
- "Being able to look to your left and right and around you without moving your direction of travel."
- "Let me walk pushing a button is not real."
- "Change the way the controller is mounted."
- "Try to fix it so you don't get stuck so much."
- "Create a wireless version."
- "Better glasses to improve total immersion and decrease peripherals."

less relevant to the treatment goals. Qualitative feedback from some participants and investigator observations of participants during VirtuSphere use raise concerns about the utility of the VirtuSphere for VRE. For example, some participants noted the need to make slow, deliberate movements or expressed concerns about stability and falling in the VirtuSphere. Although only one of the 10 participants fell, instability was observed in numerous participants. These challenges were likely due to the curved shape of the floor of the sphere and the inertia of the VirtuSphere's roll that did not modify step by step. One would speculate that a focus on keeping one's balance during VirtuSphere use in exposure therapy could negatively influence emotional engagement during treatment. A technical solution that facilitates rapid adaptation of the roll of the VirtuSphere to the speed of the user's locomotion would likely produce improved results.

Some participants complained that the VirtuSphere required additional practice for competence and speculated that additional time to learn might have improved their experience. The pilot allowed up to 10 min of advance rehearsal with an additional 10 min of VirtuSphere use to move through the preselected route in the virtual environment. Improvements in participants' VirtuSphere comfort and stability were observed by the investigators over time. However, as adequate mastery of VirtuSphere was not achieved for some participants within 20 min of use, it may not be a practical tool in the context of a time-limited, manualized exposure therapy treatment protocol. VirtuSphere applications that are not time constrained and allow for more practice may produce better results. For example, in settings with an unconstrained number of treatment sessions, it is possible that adequate learning trials could be conducted to effectively utilize the VirtuSphere to support therapy delivered over several sessions.

Limitations of this pilot study include the small sample. On one hand, not finding statistical significance with a sample of 10 may not be surprising. However, an equivalence test of the VirtuSphere versus the GC condition would require 1,051 research participants, assuming no appreciable difference exists and that a standardized difference of .10 is within the tolerable range to conclude equivalence. Moreover, based on the estimated effect size generated by this sample, future research would require a sample of 4,906 to have an 80% chance of detecting a significant standardized difference of .04 presence between VirtuSphere and GC conditions, if such a difference exists. Assuming our effect size is a reasonable estimate of the population parameter, the likely real-world meaningfulness of a difference in presence using the current VirtuSphere is likely to be negligible. Our study was also limited by a comparison of only two forms of navigation (GC and VirtuSphere), and these peripherals were tested with only one virtual environment (*Virtual Iraq*). Another limitation of our study was the availability of an M4 rifle only in the GC condition, which may have caused more users to rate presence in that condition more favorably for reasons not related to the virtual interface differences studied. Finally, this study did not use a clinical sample; hence, future research would have to determine the generalizability of these findings to soldiers with PTSD.

Virtual reality peripherals and equipment can be resource intensive investments. Recent applications of virtual reality in the treatment of anxiety disorders raise important questions about the relevance of a broad range of VR peripherals and equipment to the clinical treatment of anxiety disorders. Based on this pilot study, one would speculate that improvements to the VirtuSphere are required prior to meaningful application to the clinical treatment of PTSD populations. Our preliminary findings should not be construed as a general criticism of the potential utility of more realistic locomotion interfaces in other clinical VR systems. For example, there is some evidence that treadmill interfaces in VR may prove useful for gait training (Darter & Wilken, 2011; Gates, Darter, Dingwell, & Wilken, 2012).

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ABOUT THE AUTHORS

Nancy A. Skopp received her Ph.D. in Clinical Psychology from the University of Houston. Dr. Skopp is a Research Psychologist and Program Manager for the National Center for Telehealth and Technology (T2) and an Affiliate Associate Professor at the University of Washington Medical School Department of Psychiatry and Behavioral Sciences.

Derek J. Smolenski received his Ph.D. in Epidemiology from the University of Texas, Houston. He specializes in applied biostatistics, multivariate methods, and methods for causal inference in the context of behavioral and psychiatric epidemiology.

Melinda J. Metzger-Abamukong is a research assistant at the National Center of Telehealth & Technology (T2), as well as a member of the U.S. Army Reserves. Ms. Metzger-Abamukong received her B.S. in Chemistry from New Mexico State University.

Albert A. Rizzo received his Ph.D. in Clinical Psychology from the State University of New York at Binghamton. He is an Associate Director at the University of Southern California Institute for Creative Technologies and has Research Professor appointments with the USC Department of Psychiatry and Behavioral Sciences and the USC Davis School of Gerontology.

Greg M. Reger, Ph.D. is a clinical psychologist at the National Center for Telehealth and Technology's Emerging Technologies Program. He is a former army psychologist with significant research experience using virtual reality and other technologies to address a range of military behavioral health needs.