The Role of Virtual Reality in Providing Mental Healthcare to Astronauts Operating in Extreme Environments

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Paramount to the longevity of the human species is the colonization of other habitable worlds. Significant advancements in technology have made that dream possible, and space agencies across the globe are making plans to establish lunar research stations in the near future. With that being said, the well-being of astronauts in space should be the highest priority to increase the likelihood of mission success and safe returns. One often overlooked component of astronauts' survivability is their mental health. Astronauts undertaking missions to colonize other planets will be subjected to isolated, confined, and extreme (ICE) environments for long periods (Palinkas & Suedfeld, 2021). When experienced for extended durations, ICE environments can induce cognitive impedance, emotional instability, and an irregular sleep-wake cycle, which are often reported symptoms of being in space (Arone et al., 2021). Living and working in ICE environments can also hinder intrapersonal relationships between team members, shattering cohesiveness, effectiveness, and drastically decreasing the likelihood of mission success (Palinkas & Suedfeld, 2021). Reducing the stress and negative impacts of being in an isolated and confined situation is thus imperative to the survivability and the psychological well-being of astronauts. A viable solution to the mounting stressors of living in these conditions is giving astronauts access to restorative tools that will lessen the physical and mental symptoms that they may induce. Virtual reality has recently shown promise in being a remote medium for delivering mental health services, including restorative tools. This paper plans to examine the role virtual reality may play in improving the mood and reducing the stress of individuals stuck in ICE environments for extended periods of time.

Virtual Reality

History of Virtual Reality

Virtual reality (VR) technologies have been used as a tool in astronaut training since the 1980s in several space agencies across the globe. They have been useful as an effective and safe method of emulating spaceflight, weightlessness, and working around the limitations of physical training methods. Many astronauts are familiar with being in an immersive virtual experience whether it be through flight simulation or mission-specific training, making it a valid medium for delivering psychological services while in space. VR usage for astronauts may also provide a means of stress reduction caused by working in a confined space, be it through videogames, movies, physical exercise, team-building activities, simulated socialization with virtual agents, and relaxing nature scenes (Salamon et al., 2018).

Restorative Potential of Virtual Reality

Immersive virtual environments allow users an escape from their immediate surroundings, which is of use to astronauts struggling to acclimate to the boundaries of operating within an ICE setting. Bucolic, natural environments presented in virtual reality are notably efficient in offering viewers a restorative experience, one that may bring a period of respite for those presently in difficult situations (Lockard & Kaufman, 2019). An analysis was performed on a group of hospital patients diagnosed with cancer who were given virtual reality nature scenes during their standard chemotherapy procedures to reduce pain symptoms (Scates et al., 2020). A majority of the participants reported the experience elicited positive emotions with a statistically significant correlation between feelings of distractions and the immersive virtual nature scene (Scates et al., 2020). These findings are pertinent because using virtual reality technologies to create nature scenes may offer restorative effects to astronauts stuck in isolated, confined, and extreme scenarios.

Similar findings were found in an analysis of 19 individuals at Dartmouth College. An artificial isolated, confined, and extreme environment was created by having participants take a difficult 2-minute math exam designed to increase their stress (Anderson et al., 2017). During the exam, researchers simulated an isolated, confined, and extreme environment by repeatedly warning participants of time running out and monitoring them with close physical proximity (Anderson et al., 2017). Following the exam, participants in both the experimental and control groups sat in an empty classroom. Participants in the experimental group used a virtual reality headset to observe virtual nature scenes (Anderson et al., 2017). The results suggest that participants who experienced the virtual nature scene rather than the empty classroom exhibited a marked reduction of physical stress (Anderson et al., 2017). Despite its significant findings, this study is heavily limited by its short span. The test was too short because it failed to induce chronic stress in participants, and the virtual reality experience ended up taking longer than the test itself. Settings that are isolated, confined, and extreme are not necessarily dangerous in small periods, but continued exposure will most likely lead to negative emotions, behaviors, and cognitions (Arone et al., 2021). An astronaut tasked with completing a three-year embarkment to Mars, for example, would experience more stress as the time away from the comforts of Earth and their loved ones increased. A separate study that analyzed isolated individuals communicating with their family and friends through a 22-minute delayed messaging service found similar findings. A group of 6 were confined for a year at an indoor training facility in Hawaii that was designed to look like a Martian environment and spent their time performing activities similar to how they would if they were stationed on Mars. In the case of this experiment, this consisted of basic field work, exercising, cooking from shelf ingredients, and monitoring resource usage. They connected with friends and family members through an asynchronous emailing service and virtual agents in real-time. Researchers also utilized virtual environments to simulate experiences like gathering around a dinner table or taking a walk outdoors. The study found that being able to communicate with loved ones and escape the sensory monotony of the training facility through email and virtual reality enhanced the feeling of social connectedness and lessened the effects of isolation (Wu et al., 2016). Despite obtaining quantitative data that proves a significant relationship between the use of virtual environments and feelings of satisfaction, the results and conclusions drawn from this report rely partially on anecdotal evidence. As a result, there is no statistical connection between socialization through virtual environments and a decrease in the negative emotions or cognitions caused by living in an ICE environment.

While reviewing the literature for this topic, few other analyses that examine the efficacy of virtual reality for reducing stress in ICE environments were identified. It is necessary for further research to determine effective mediums of restorative mental healthcare for astronauts on long-term colonization missions. Virtual reality seems an appropriate means of delivering this psychological care to astronauts and viewing nature scenes appears to be an effective way of reducing stress. This paper seeks to determine whether renditions of nature scenes are more effective in reducing stress, restoring comfort, and improving mood for individuals operating in isolated, confined, and extreme conditions when viewed using a virtual reality headset versus a desktop monitor. Based on the literature, I believe that immersive virtual nature experiences viewed through a virtual reality headset will be more effective than observing the same scenes on a desktop monitor at lessening stress, uplifting disposition, and eliciting an impression of restorativeness of individuals operating in an ICE environment long-term.

Method

Participants

Participants in this study were healthy college-aged adults sourced from an American university through fliers, social network advertisements, and word of mouth. Candidates were screened to control for susceptibility to visually induced motion sickness (VIMS) caused by the head-mounted virtual reality device used in this experiment. A pre-screening survey was distributed online that asked candidates about previous medical and surgical history and to describe their prior experience with virtual reality, if any. A follow-up question inquired whether candidates had ever spent more than one week in an isolated, confined, or extreme environment. The replies to the pre-screening survey were assessed as open-ended questions, with candidates being encouraged to answer in detail to the best of their ability. Those with little or no experience using a virtual reality headset were included in the experiment (Anderson, et al., 2017). This was done to prevent inclusion of participants who may have developed a confidence in VR, which may skew later results where a survey inquires how comfortable they felt in the virtual experience. Similarly included were participants who had not experienced living more than a week in an ICE environment, as they may have developed coping skills which could disrupt the effects of the virtual reality experience. Of the pool of screened participants, those who had diagnosed mood disorders, psychiatric disorders, neurological illnesses, or history of neck mobility issues were excluded from this study (Kim et al., 2021). Also excluded were candidates who reported taking prescription medication for mental illness (Browning et al., 2020). 20

participants, 10 male, 10 female, were ultimately chosen of those screened. A small sample size was used to more accurately depict social spheres in space. Astronauts are typically grouped in small teams to promote better cohesion, and prevent overcrowding (Arone et al., 2021). All subjects signed a consent form indicating that they would be placed in a simulated isolated, confined, and extreme environment and that this may cause alterations in mood, stress levels and sleep-wake cycles, or they may experience negative emotions, cognitions, or exhibit negative behaviors.

Materials

For the duration of the experiment, participants resided in a transformed soundproof research laboratory that contained no windows nor exposure to natural light or the outdoors. It had simple white walls and was a relatively small room. It was barren apart from a small kitchenette that participants used to prepare meals from shelf ingredients, 2 treadmills, 8 sets of dumbbells (of varying weights), and resistance bands for use at any point, sleeping bags for rest, researcher-controlled overhead lights and room speakers, and a wall-mounted television with built-in speakers that allowed researchers to remotely play pre-recorded videos when necessary. There were 2 connecting rooms within the laboratory – a bathroom, and a “relaxation room” that participants used only once at the end of the first 2 weeks. The one-person bathroom contained a shower, a toilet bowl, and a sink and contained more than enough sanitization devices for 10 people for a month. The “relaxation room,” locked at the beginning of the experiment, was unlocked remotely for one-time use by all participants independently. Present in the room for both groups was an office chair, a computer monitor, and a desk. A Meta Quest 2, a standalone head-mounted display, was present for the experimental group. Standalone can be defined as it does not require a computer for operation and allows participants to use it with only the accompanying wireless controllers and rechargeable battery. A standalone device was necessary for this experiment to both preserve participant immersion and to emulate the limitations of being in space more accurately – possession of a non-tethered headset is more realistic and practical than the alternative. Participants in both groups wore noise-canceling, over-ear headphones while viewing the nature scenes to promote fuller sensory immersion. Fuller immersion has been linked to an increase in restorative effects of virtual nature simulations (Lockard & Kaufman, 2019). 360-degree, high-definition scenes were provided by Relax with Nature VR app by Atmosphaeres, that allows users to pick their own scene be it from beaches, cities, mountains, sunrises/sunsets, travel locations, etc. Scenes were viewed by the control group using the desktop monitor, and by the experimental group using the Meta Quest 2. All scenes lasted 15-minutes and contained both visual and audio stimuli relative to their setting. Participants in both groups selected their own scene, as there is evidence suggesting that viewers will garner more restorative effects from a better compatibility with the stimuli (Lockard & Kaufman, 2019). Before the beginning of the nature scene, members of the experimental group also viewed a 5-minute instructional video via the desktop monitor to confirm that their vision was unobstructed and the headset fit comfortably on their head (Anderson et al., 2017).

Measures

Restorativeness was measured once after everyone's nature experience using the Perceived Restorativeness Scale (Hartig et al., 1997). It contains 19 of the original 26 items and asks participants to quantify their experience in the current environment using a 7-point Likert scale that ranges from "not at all" to "completely" (Hartig et al., 1997). Items are separated into 4 categories – being away, which represents the period of relief from the stressors of the ICE environment, fascination, which describes the individual's immersion, coherence, how connected the individual felt to the nature scene, and compatibility, or how comfortable the user felt from the nature scenes (Hartig et al., 1997). 7 items were excluded from the questionnaire as they didn't fit the context of a virtual reality experience. Mood was measured twice, once 2 weeks after the onset of the experiment, and again at its conclusion through the Positive and Negative Affect Schedule (PANAS) scale (Watson et al., 1988). It contains 20 items that ask examinees to quantify their emotions on a 5-point Likert scale that ranges from "very slightly or not at all" to "extremely" (Watson et al., 1988). Quantative stress levels were recorded using Shimmer GSR+ sensor nodes worn on participants' index and ring fingers on their non-dominant hand to continuously measure skin conductance levels over the course of the experiment (Browning et al., 2020). Levels were averaged on a bi-weekly basis for an average level before the experience and after the conclusion of the experiment. Physiological stress levels require interpretation by the participant to determine whether the physical response was positive or negative (Browning et al., 2020). Qualitative stress levels were self-reported twice, once 2 weeks after the beginning of the experiment, and again at the end of the 4 weeks using the Perceived Stress Scale, which contains 10 items asking answerers to describe different physical and mental indications of stress using a 5-point Likert scale that ranges from "never" to "very often" (Cohen et al., 1983).

Procedure

The effects of immersive virtual nature experiences on physiological and mental indications of stress and emotional evocations for participants in isolated, confined, and extreme environments were examined with a mixed design. Subjects were first randomly assigned to one of two conditions: a virtual reality group or a control group. Both groups were given identical exerpiences in regard to environmental conditions, room arrangements, resource availability, group size, and time spent at the facility. Due to serious risks of long-term physical and emotional damage, placing participants in an isolated, confined, and extreme environment was impractical. Instead, an ICE environment was simulated by using artificial stressors that would increase participants' stress levels, without the risk to their safety or their health. Astronauts aboard spacecraft are subjected to incessant noise throughout the cabin and numerous sunrises and sunsets, which can disrupt sleep-wake cycles, increasing stress and altering mood (Arone et al., 2021). A research labatory was outfitted with the necssary materials to create a simulated isolated, confined, and extreme environment. The same lab was used for both conditions – groups were tested at different times. To induce stress on the participants, overhead lights were dimmed and brightened every 90 minutes to emulate the frequency astronauts may observe changes in sunlight. Similarly, overhead speakers in the rooms played ambient noise continuously, as heard by astronauts aboard the international space station. Participants shared the same common space, giving them little to no privacy except for bathroom usage to further simulate experiences by astronauts during spaceflight (Arone et al., 2021). Additional stress was induced by having participants monitor food consumption, and prepare their own meals using shelf ingredients (Wu et al., 2016). Participants spent 4 total weeks in the laboratory. At the end of the 2nd week, participants were instructed by pre-recorded video to enter into the "relaxation room" one at a time. Both groups were told to sit for the duration of the relaxation. Those in the control group viewed the scene using the desktop monitor and headphones, while those in the experimental grouped used the Meta Quest 2 headsets. Participants were given the Perceived Restorativeness Scale directly after the nature scene and then returned to the common area before sending in the next person. The 2 weeks following the relaxation was identical to the first in terms of environmental conditions, room arrangements, and available activities. The procedure above will obtain proper IRB approval before commencement.

Proposed Analyses

Data for this study will be simulated from randomly generated script in Excel. The study is mixed-design with a between-subjects variable: virtual reality experiences and a within-subjects variable: environmental stressors. My independent variable is relaxation technique – either through use of a virtual reality headset or a computer monitor to view the nature scene. My dependent variables are physiological stress, mood, and restorativeness. As a result, I plan to first perform a one-way repeated-measures MANOVA to assess how relaxation technique type affect physiological stress and mood. I am only running an analysis on physiological stress and not self-reports of stress because, as I mentioned earlier, the qualitative data I'm collecting on stress will only be used for determining whether increased electrodermal activity was caused by negative or positive reactions to the environment. I will determine if I violated the statistical assumptions of homogeneity of variance, sphericity, and normality for this MANOVA by performing Levene's test, Mauchly's test, and Shapiro-Wilk test, respectively. Descriptive statistics will also be provided, if the MANOVA proves statistically significant, in the write-up analysis to determine the direction of the relationship. I also plan to complete a two-sample t-test that compares the average restorativeness of participants in the control group to the average restorativeness to participants in the experimental group. This will allow me to better understand how virtual reality plays a role in providing a restorative experience to users observing virtual nature scenes. Tests will be performed to also discover whether the statistical assumptions of normality and homogeneity of variance for my two-sample t-test were violated. Descriptive statistics for the t-test will too be supplied to indicate the direction of the relationship.

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