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Using Virtual Reality for Long-Duration Space Missions

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Abstract. Many organizations around the world are pursuing space exploration with hopes of going further and further away from Earth. Spaceflight itself has significant implications on humans, meaning that it is important to understand the magnitude of effects that astronauts would feel during these missions. Some pressing concerns are the increased isolation due to social interactions as well as situational factors, which would lead to a decline in mental and physical health. Additionally, the possibility of substance abuse due to stress and access to medications can lead to significant reductions in mental health. To deal with these issues, virtual reality has presented itself as a unique solution that would help provide better overall mental health. The technology is frequently used in various clinical settings to deal with anxiety and depression, through techniques such as exposure therapy and cognitive behavioural therapy. Exposure therapy for anxiety with virtual reality targets anxiety-causing stimulus and works towards changing the patient's response, in a controlled setting. Cognitive behavioural therapy immerses the patient into a simulated world to provide them with experiences that mitigate the depression they are feeling. On the mission, exposure therapy would potentially be available to deal with stimulants of anxiety, while cognitive behavioural therapy would provide a happiness break. With further research in the field, virtual reality thus presents itself as a feasible opportunity to plan longer duration human space missions. This review compiles and investigates sources from literary research done in the respective fields.

Keywords. Virtual Reality, Space, Missions, Long-term, Mental Health, Depression

1. Introduction

Space exploration is a field that has been gaining momentum for some time now due to the likes of various organizations like SpaceX. Potential trips to Mars are being planned, and it is not long before discussions about sending humans beyond our neighbouring planets are discussed. To date, various probes and satellites have investigated planets within the solar system and beyond, but there is still that growing hope that human expeditions will potentially be more beneficial. It is important to acknowledge the feasibility of human space exploration to a distant planet or star, as there can be severe mental health implications on a long duration trip like this. Short missions to space have already shown to have major impacts on astronauts' emotional wellbeing and physical health, which makes the conditions of a long-term mission unimaginable. A possible solution to mitigate the risks associated with these missions is the use of virtual reality (VR) in a therapeutic manner during the mission. VR uses computer modelling

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and simulations that allow a person to interact in artificial and sensory environments. The technology is vividly used during astronaut training in the National Aeronautics and Space Administration (NASA), and there is a growing belief that it can have uses during actual trips. VR has to capability to combat the stressors that humans would feel during these lengthy expeditions.

2. The Difficulties of Space

Of the many obstacles that one would face during space travel, one of the most significant is isolation. Travel to Mars itself would take about seven months, one way, based on the recent journey of the Perseverance rover (NASA Mars, 2020). Venturing farther would mean even longer timelines, resulting in travel conditions such as intense isolation, which would be very difficult to stimulate. Social interactions that an astronaut would have with the rest of their crew could potentially lead to isolating circumstances. Although space crews are extensively trained and get to know the rest of their team quite well before a mission, there is a possibility of conflict in space. Differences between emotional expressivity between cultures can cause miscommunication (Kanas et al., 2009). For example, social behaviour norms such as how guests and others are treated can cause tension amongst the crew. Language barriers can cause tension and miscommunication as well (Kanas et al., 2009). At a surface level, it may seem like isolation is a part of the job description, however, it can have significant impacts on the crew. There have been analogous experiments at the Institute of Biomedical Problems in Moscow, Russia which stimulated the duration of space travel. The team found that during long periods of isolation, the hypothalamic-pituitary-adrenal (HPA) axis, which is responsible for the body's stress response, had increased activity (Pagel & Choukèr, 2016). Chronic stress leads to the dysregulation of the HPA-axis, which in the long term leads to a decline in fitness or immune health, as well as in neurodegenerative brain disease linked to HPA-axis dysregulation (Dunlavey, 2018). Increased stress is an issue because it is a common trigger for anxiety and often leads to the development of anxiety disorder. It was also seen that there was reduced physical activity which affected neuromuscular behaviour in the lower half of the body (Pagel & Choukèr, 2016). Reduced physical activity is concerning because there is a positive correlation between physical health and mental health, meaning that reduced physical activity leads to a greater chance of reduced physical wellbeing. Amplify these conditions for over two years, which is close to what a roundtrip to Mars would be, and there would be a very slim chance that crew members are not being mentally and physically impacted by the isolation.

During space flight, there are many pressures that members deal with such as sleep deprivation, gravity changes, and radiation. Along with that, all of their actions are highly scrutinized, and they are forced to live life away from friends and family. NASA has documented evidence of the prevalence of mental health problems during space flight. Across 89 shuttle missions from 1981 to 1998, there were over 1,800 in-flight medical events with US astronauts; most relating to anxiety and annoyance, with less than 2 percent as a cause of behavioural health (Morris, 2017). What adds to the concern is that space flights are equipped with medications, and often times their administration is not monitored. When medicine usage is documented, it can be seen that it is very high. The 2017 Dose Tracker experiment portrayed these results as pharmaceutical use by six crewmembers during their 5–6-month missions to the ISS was documented. An average of 453 medication uses was reported per crew member during their missions, which is approximately four medications per crew member, per week (Blue et al., 2019). Medications are administered on flights to manage injuries and frequently contain opioids, making them extremely addictive in an uncontrolled environment. Other times, many crew members take medications for common issues such as headaches or motion sickness.

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Being in a longer duration space flight means more opportunities to develop a dependence on substances because of an increased opportunity for usage. The reason for concern is because numerous population surveys in the US have found that about half of those who experience a mental illness during their lives will also experience a substance use disorder and vice versa (NIDA, 2021). The pattern of increased mental health decline and high drug usage amongst the overall population suggests a similar pattern in astronauts, which can drastically deteriorate their mental health, both during and after the mission. Overall, there are many complications associated with long-term space travel.

3. Virtual Reality as an Asset

Virtual reality is a continually growing field that has found its way into many industries. Simply put, it is the usage of technological systems to emerge a user into a virtual world that looks, feels, and sounds real. VR systems focus on the concept of immersion and perception to be present in a specific environment, as well as interaction with that environment (Cipresso et al., 2018). These systems vary in type as there are various levels of immersion, ranging from non-immersive systems which are cheap, to fully immersive systems which use output devices such as head-mounted displays (Cipresso et al., 2018). VR is gaining more popularity in clinical settings to help treat phobias, pain management, autism, and anxiety disorders. For example, in some early trials, VR was used for the treatment of acrophobia by slow exposure to virtual environments with footbridges, balconies, and a glass elevator with some sort of support for the patients to hold onto (Garrett et al., 2018). The results showed that the treatment modality was effective due to its ability to reduce the response to the stimulus. Similarly to help deal with post-traumatic stress disorder (PTSD), virtual environments have been created using VR to simulate complex traumatic scenarios under control (Garrett et al., 2018). Through this approach, the patients are provided with the opportunity to deal with their condition in a moderated setting, which reduces many risks.

A specific treatment associated with VR that would be beneficial for long-term space durations would be its ability to help with anxiety disorders. The most effective method is through exposure therapy, which is based on emotional processing theory, and states that memories of fears contain information about fear stimuli, meaning, and response (Maples-Keller et al., 2017). Hence the usage of VR is to activate and modify these fear memories through emotional processing by immersing the patient into a dimension with their stimulus, in a controlled setting. Due to this, most VR exposure treatments on anxiety disorders have been seen to have major declines in anxiety symptoms and present similar efficacy to traditional exposure techniques (Maples-Keller et al., 2017). These involvements of VR-related treatment with anxiety disorders would mean that crews could potentially get some assistant with the anxiety they would deal with onboard long-term missions. The way VR could be implemented is to provide exposure therapy during the mission. Prior to the mission, common stimulants for anxiety would be recognized and then during the mission, treatment would be administered to crew members when deemed necessary by the flight surgeon. Application of VR to counteract anxiety during these missions would help decrease the dependence crew members typically develop towards medications and overall lead to better mental and physical health. To what extent VR would be able to help cope with anxiety disorders in space is not known, but signs point towards a positive impact.

Depression that many astronauts face during space missions could also be mitigated through the use of VR. Cognitive Behavioural Therapy (CBT) is a common way used to help deal with depression, and it has the potential to be administered with VR. This would be achieved using a head-mounted display with a stereoscopic display that helps create the illusion

of a virtual environment. As for costs, mobile VR platforms cost as little as 240 USD, meaning that creating a version for the crew will not cause major financial stress (Lindner et al., 2019). There have been trials where patients with depression who also had strong self-criticism were treated using this modality. The way it was done was that first the patients would be placed into an adult body and expected to show compassion to a crying child. The roles would then be reversed and they would become the crying child, and an adult would console them and show them compassion, resulting in decreased self-criticism and depressive symptoms (Lindner et al., 2019). Another way in which CBT techniques can be used is to target anhedonia, the inability to feel pleasure. Through VR, the patients would engage in pleasurable activities such as virtual gardening and virtual animal interactions, in a way to alter their perspective about life (Lindner et al., 2019). Many astronauts become depressed in space expeditions for a variety of reasons, but a common one is an isolation and separation from family (Kanas, 2016). VR would potentially allow crew members to interact with virtual forms of their family and friends, even have conversations, which would greatly help deal with depressive symptoms. Alternatively, the technology might serve as an escape for the astronauts to get a break from their reality and do an activity that they love such as hiking or gardening, or just enjoy a serene environment. Overall, the implementation of VR during long-term space journeys would provide the mission with an asset that would help cope with the depression that many members will face.

4. Conclusion

All in all, space exploration is a vastly expanding field that will continue to gain traction in the future as well. There are risks associated with space missions, which get further amplified during longer-term missions. Isolation is one of the biggest causes of concern because crew members will be in an enclosed space with the same people, for a long period of time, leading to potential stressors. The isolation can lead to physical and mentally negative impacts on the crew. Along with that, the team will be away from their family for a long time and will have unrestricted access to medications, which would lead to the development of potential mental health problems like anxiety and depression. To combat some of these issues, VR has been brought forward due to its success in the treatment of mental health disorders in a clinical setting. The VR technology would be used to administer exposure therapy and CBT to the crew as needed, reducing the risk of negative effects of mental health on the mission. Although VR has not been proven in a space environment, current trials provide hope that it can be used to assist in maintained crew member health for longer-term space missions.

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