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Virtual Reality Mental Hygiene as a Mean to Reduce Psychosocial Stress during Space Expeditions

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Abstract

Long-distance and long-duration space expeditions will in the future give rise to different types of challenging tasks on how to maintain mental health for the crewmembers. This paper describes the application and feasibility of Virtual Reality Mental Hygiene (VRMH) as a means to reduce stress by members of the LUNARK expedition. The members of the expedition lived in confinement for 3 months in a moon habitat in the arctic regions of Greenland.

Keywords: Space psychology; Space psychiatry; Space expeditions; Virtual reality; Mental hygiene

Introduction

Long-duration space missions such as those to the Moon and Mars and beyond will in the future give rise to different types of challenging tasks on how to maintain mental health by the crewmembers. The isolation and confinement in a small crew in a confined space for long periods of time can lead to psychological and behavioral issues, such as depression, anxiety, irritability, and conflicts.

On Earth, the expeditions and exploration of Antarctica and the cave environment have been a useful analog to space expeditions and have provided valuable insights into the psychological effects of isolation and confinement, which are relevant to the study of long-distance and long-duration space expeditions. A well-documented phenomenon is "winter over syndrome", which is a phenomenon that could resemble subclinical depression, including somatic symptoms such as fatigue, headaches, and disturbed sleep patterns as well as psychological symptoms such as impaired cognition, anxiety, anger, and irritability. These effects can be particularly pronounced during the winter months, and researchers have found that factors such as lack of sunlight, limited social interaction, and monotony of daily routines can contribute to the development of mental health issues [1].

Another psychological phenomenon observed in crewmembers on long-duration space missions, as well as in other isolated and

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confined environments, is the "third quarter phenomenon". Crew members may initially experience a sense of relief or satisfaction upon reaching the halfway point of their mission, only to be confronted with the realization that they still have a significant amount of time left to go. This can lead to a sense of discouragement, anxiety, or even depression.

The third quarter phenomenon underscores the importance of developing effective strategies for maintaining the mental health and well-being of crewmembers on long-duration space missions. One approach that has been proposed is to focus on creating a sense of purpose and meaning for the crewmembers, by emphasizing the importance of their mission and the potential benefits that it could bring [2].

Another potential psychological stressor that has been identified as a concern for crewmembers on long-distance space missions is the "Earth-out-of-view phenomenon". The experience of seeing the Earth as a small and distant object can increase the crewmembers' sense of isolation and confinement and may contribute to feelings of loneliness, depression, or other adjustment disorders [1]. To mitigate the potential psychological effects of the Earth-out-of-view phenomenon, space agencies may need to develop strategies for helping crewmembers to maintain a sense of connection to their home planet. This could involve providing opportunities for crewmembers to communicate with loved ones on Earth, as well as creating virtual environments that simulate the experience of being on Earth. In addition to address the psychological challenges associated with the Earth-out-of-view phenomenon, it will also be important for space agencies to prioritize the overall mental health and well-being of crewmembers on long-distance space missions and there is a need for addressing how psychological and interpersonal distress can be reduced in future. This could include access to mental health professionals, implementing effective stress-management strategies, and ensuring that crewmembers have opportunities for social interaction and recreation. Additionally, providing opportunities for social interaction, recreation, and exercise can help to mitigate the psychological effects of isolation and confinement [2].

One way to find effective stress-management strategies and to achieve the goal of overall mental health during space expeditions could be to look at the nature and evolutionary development of the human brain. The modern human brain is a product of a long evolution, admirably adapted to life on Earth, but not adapted to the confinement, isolation, and machine-dominated environment that will characterize long-distance and long-duration space expeditions in the future.

The different substructures of the human brain have evolved over time and are associated with different functions and abilities. The different substructures of the brain reflect the different evolutionary periods, in which it was developed. Therefore, different parts of the brain have different abilities and functions and subsequently affect our experiences and how we cope in different situations. Structurally, the human brain has not changed much in the last 50.000 years.

The reptilian brain, which is the most primitive part of the brain, is responsible for survival-related functions such as aggression, fear, and territorial behavior. The mammalian brain, which is more evolved than the reptilian brain, is responsible for social behavior, emotions, and attachment. The most evolved part of the brain, the neocortex, is responsible for higher cognitive functions such as language, reasoning, and problem-solving [3, 4].

Humans have three major emotional regulation system; The threat system, the drive system, and The soothing system, and each system are indeed linked to different states of feeling, motivations, and behaviors. The threat system is activated when we perceive a threat, and it leads to feelings of fear, anxiety, and vigilance. The drive system is associated with the pursuit of rewards, and it leads to feelings of excitement, enthusiasm, and determination. The soothing system is associated with feelings of safety, relaxation, and contentment and our emotions are about safeness and neurophysiological through activation of the parasympathetic nervous system we are calmed with a behavior dominated by looking-after and soothing [3, 4].

Maintaining a healthy balance between these three systems is important for psychological well-being and resilience. Overuse or underuse of one system can lead to dysfunction, and it's important to develop adaptive coping strategies that involve all three systems inappropriate measures.

Understanding the link between these emotional regulation systems and the autonomic nervous system is also important for developing effective stress-management strategies. The sympathetic nervous system, which is associated with the fight-or-flight response, is activated by the threat and the drive systems, while the parasympathetic nervous system, which is associated with relaxation and restoration, is activated by the soothing system. By learning to regulate the autonomic nervous system, we can develop better strategies for coping with stress and maintaining psychological well-being in challenging environments like long-distance space expeditions [5, 6].

In prolonged stress situations, such as long-distance and long-duration space expeditions, the sympathetic nervous system can become overactive, leading to chronic stress and negative health outcomes. The chronic activation of the HPA axis can result in elevated cortisol levels, which can lead to immune suppression, memory impairment, and cardiovascular disease. In addition, chronic stress can also lead to negative changes in brain structure and function, including reduced gray matter in the prefrontal cortex, hippocampus, and amygdala, which are all important for emotion regulation and cognitive functioning. Therefore, it is important to find ways to reduce chronic stress and activate the soothing system during long-distance space expeditions to maintain crewmember mental health. It's important to promote a healthy balance between the sympathetic and parasympathetic nervous systems to mitigate the negative effects of prolonged stress.

One way to achieve this is through the activation of the soothing system and thereby activation of the parasympathetic nervous system. Our soothing system can be activated in various ways e.g. through positive interaction with other humans, slow-breathing, mindfulness, yoga, body awareness therapy, positive self-talk/letter writing, and visualization exercises. Further, specific stimulation of our senses, in particular, our tactile and proprioceptive, but also our visual and auditive senses, have been found to activate the parasympathetic nervous system. Therefore, in this study we wanted to explore the use of Virtual Reality Mental Hygiene (VRMH) as a means to reduce stress and anxiety for humans living in isolated, confined, and extreme environments (ICE), similar to a space expedition [5, 6].

Materials and Methods

Participants

The participants in the project were members of the LUNARK expedition. The two members of the expedition, Danish space architects Sebastian Aristotelis and Karl-Johan Sørensen, spent 61 days in a moon analog space habitat, located in the hamlet of Moriusaq, about 40 kilometers northwest of Thule Airbase. They operated under conditions that simulated what astronauts may experience during space missions, including performing tasks outside the module in space suits, similar to Extravehicular Activities (EVAs) or "moonwalks."

The effects of prolonged darkness in space, similar to the polar night experienced during the test phase of the expedition, were carefully studied as an important psychological stress factor for long spaceflights. The limited availability of sunlight can impact the circadian rhythms and overall mental well-being of astronauts, and strategies for mitigating these effects were explored during the expedition.

Additionally, limited communication with Earth, such as sending text messages of only 160 characters using a satellite phone, was tested to simulate the challenges of reduced real-time communication during space missions. This limitation in communication can lead to feelings of isolation and loneliness, and understanding the psychological impacts of such limitations is crucial for future long-duration space missions.

Intervention

With the purpose of creating a soothing earth habitat in a confined space, the VRMH was applied. The VRMH stimulation comprised three naturalistic 10-minute virtual reality nature films from Denmark with a 360-degree view. The videos were accompanied by the sound from the settings, all designed to activate the soothing system and the parasympathetic nervous system of the participants.

The VR headset used in the study was a pair of Oculus Go 64GB VR headsets, with a 5.5" LCD screen and a 2560 × 1440 total resolution, built-in speaker, 2600 mAh battery, and a 360-degree FOV (Field of View). During the study, the participants were instructed to use VRMH every afternoon. Further, the participants were instructed to be aware of any side effects when using the VR- glasses e.g., vertigo. Apart from vertigo, and on rare occasions nausea, there are no known side effects of using VR.

Assessment

Assessments comprised data collected from questionnaires and rating scales as well as galvanic skin response. Data from questionnaires and rating scales were administered at the start of the project and daily. For the daily monitoring of the general mental health of the participants, the project used a modified version of the WHO (Five) Well-Being Index (WHO-5).

The WHO (Five) Well-Being Index has 5 categories.

- I have felt cheerful and in good spirits.
- I have felt calm and relaxed.
- I have felt active and vigorous.
- I woke up feeling fresh and rested.
- My daily life has been filled with things that interest me.

Responses to the categories can be all of the time, most of the time, more than half of the time, Less than half of the time, Some of the time, At no time. All related to the last two weeks.

In the modified version, the same 5 categories were applied, using a visual analog scale (VAS). The participants filled out the modified version of the WHO (Five) Well-Being Index (WHO-5) before the VRMH stimulation and after, to examine if the VRMH stimulation has any impact on perceived mental health. To monitor possible changes in well-being, the difference in percentage scores was used; A ten % difference indicates a significant change (ref. John Ware, 1995).

In addition, biometric data of Galvanic Skin Response (GSR) were obtained during the VRMH stimulation via electrodes mounted on the fingers to electronically and continuously monitor and record changes in sweat production reflecting changes in the emotional level. The galvanic Skin Response (GSR) is a physiological measure that reflects changes in sweat gland activity and is commonly used as an indicator of emotional arousal. Emotional arousal can be triggered by various stimuli, both positive and negative, and is associated with changes in sympathetic nervous system activity, which is responsible for regulating many aspects of human behavior, cognition, and emotional states. The GSR signal is not specific to the type of emotion being experienced but rather indicates the intensity of the emotional response. Higher levels of emotional arousal, whether from positive or negative stimuli, tend to result in increased skin conductance, while lower levels of arousal result in decreased skin conductance. This makes GSR a valuable tool in studying emotional regulation and autonomic responses in different contexts, including in space missions where crewmembers may experience unique stressors and challenges to their mental health. Monitoring GSR can provide insights into how crewmembers are responding autonomously to their environment and can help researchers and mission planners better understand the impact of long-duration space missions on crewmembers' emotional well-being [7- 9]. GSR was measured with the Mindfield® eSense Skin Response Sensor. Measurements were done by placing two electrodes on two fingertips of the same hand while the measurement was recorded. Finally, the participant's experience of the use of VRMH was obtained from semi-structured interviews.

Results

Rating scales

Initially, 45 sessions with VRMH per participant were planned. Due to weather conditions, only 30 sessions were conducted per participant. Out of the 60 sessions, data were incomplete in 19 of the sessions, where the participant had either only completed the questionnaire at the beginning or at the end of the session or a single item was missing. Results from the completed sessions, have been analyzed and are summarized in the table below (Tables 1-3).

TABLE 1. **Paired t-test: Of the modified WHO_5 before and after use of VR.**

ID	Item	Pre(mean(SD))	Post(mean(SD))	95% CI	p-value
1	Cheer	5.44(1.96)	5.42(1.51)	-.64;.67	0.96
2		8.22(.72)	8.54(.73)	-.59;-.039	0.028
1	Calm	6.36(1.13)	6.36(1.79)	-.91;.91	1
2		7.96(.59)	8.5(.45)	-.87;-.10	0.004
1	Active	4.49(2.47)	4.09(2.27)	-.34;1.14	0.27
2		7.78(.84)	8.04(.76)	-.65;.12	0.17
1	Fresh	4.76(2.41)	4.39(2.41)	-.53;1.28	0.39
2		7.03(1.71)	7.42(1.48)	-1.02;.24	0.21
1	interest	4.40(2.08)	4.58(1.95)	-.66;.31	0.45
2		8.0(1.05)	8.12(.911)	-.38;.15	0.36

TABLE 2. **Percentages of Skin Conductance Responses (SCR) interval score during VRMH. Biometric data. The GSR measurement contained two components, the tonic static level and the phasic, fluctuation response, and these components gave total measurement for the Skin Conductance Responses (SCR). A higher number of SCR per minute is an indicator of higher stress. An SRC measurement between 0 and 5 SCR/minute is a relaxed state. From 6-9, SRC/min starts an animated state. From 10 SRC/min, a level of stress, and above 16 SRC/min a high level of stress.**

	0-5 SCR/MIN	6-9 SCR/MIN	10 SCR/MIN-15 SCR/MIN	>16 SCR/MIN
Participant 1	97%	2%	1%	0%
Participant 2	95%	1%	1%	3%

TABLE 3. **Paired t-test: Differences in galvanic skin response. Time-D is the time when the SCR is decreasing, and Time-I is the time when the SCR is increasing. Time-S the time when the SCR is stable.**

	Mean (SD)	95% CI	p-value
Time-D vs. Time-I	9.58 (3.54)	(10.72;8.42)	<.000
Time-D vs. Time-S	-10.55 (3.10)	(11.55;9.54)	<.000

Participants' perspective

The participant's statement about the use of VRMH: “The immersive quality of VRMH proved to be incredibly effective in providing a relaxed space for recovery and mental well-being during our LUNARK expedition in ICE (Isolated, Confined, and Extreme) environments. When other research tasks seemed to be a chore, going into the VRMH environment was a delight every day. Both the ritual of sitting down and relaxing (comparable with traditional meditation) and in combination with the scenic natural environment of the VRMH content was powerful experience. Before knowing the conclusions made from the biometric data collected from the experiment, we intuitively are very convinced about the positive effect and further potential of the technology.

Overall we are very confident in the future of VR as a countermeasure for space-induced stressors for astronauts, but we can also see Earth applications where similar countermeasure effects are relevant”.

Discussion

In this study, the application and feasibility of Virtual Reality Mental Hygiene (VRMH) were tested during the LUNARK expedition, a space analog expedition to the Arctic region of Greenland. VRMH has previously been tested in veterans with PTSD as well as psychiatric patients as a means to reduce stress and anxiety [10].

The results from the modified WHO-5, a measurement tool used to assess mental well-being, did not show a significant impact for most items, except for participant number 2 who had significant changes on two items: "I have felt cheerful and in good spirits" and "I have felt calm and relaxed" after the use of Virtual Reality Mental Health (VRMH) intervention.

There could be several possible reasons for this. The study may have had a small sample size, which could have limited the statistical power to detect significant changes in other items of the modified WHO-5. The modified WHO-5 may not have been suitable for capturing changes specifically related to the use of VRMH intervention. Measurement tools need to be carefully chosen and validated for the specific context and population being studied. It is possible that the modified WHO-5 was not sensitive enough to detect changes resulting from the use of VRMH intervention in this particular study and there could have been other confounding factors that influenced the results, such as individual differences in response to the intervention, external factors, or contextual factors that were not accounted for in the study design. The modified WHO-5 relies on self-report measures, which are subject to potential biases and may not fully capture the complexity of mental well-being.

The use of Virtual Reality Mental Health (VRMH) interventions showing a significant soothing impact on participants as reflected in the measurement of skin conductance response (SCR) suggests that VRMH may have a positive effect on regulating emotional arousal and nervous system activity. This indicates that the use of VRMH had a significant soothing impact on both participants and that the use of VRMH calmed their nervous systems. The calming effect observed in the participants' nervous system, as indicated by changes in SCR, may suggest that VRMH interventions could potentially be used as a therapeutic approach for managing emotional arousal and promoting emotional regulation.

By providing a virtual environment that is designed to be relaxing, calming, or otherwise emotionally supportive, VRMH interventions may help astronauts cope with the challenges of isolation, confinement, and other stressors associated with long-duration space missions or other environments where maintaining mental health is crucial. This was consistent with the participant's general experience of their use of VRMH during the LUNARK expedition. As the participant stated that the VRMH provided a space for relaxation and recovery and provided a space for mental well-being. Both the ritual of sitting down and relaxing (comparable with traditional meditation) and in combination with the scenic natural environment of the VRMH content had a positive impact. This suggests that VRMH may not only provide a means of relaxation and stress reduction but also offer a positive and enjoyable experience for individuals in Isolated, Confined, and Extreme (ICE) environments highlighting the potential benefits of VRMH for recovery and mental well-being in challenging environments such as space missions.

We have learned over the past 60 years, that humans can survive living on space stations in Low Earth Orbit (LEO), or spend time exploring the moon for shorter periods, but colonizing the moon or other worlds present unique challenges, not only in terms of surviving, but also in terms of thriving. Until now, space travel has usually been limited to a few weeks or a few months. In the future, man will be in space for several years at a time. A challenge that requires us not only to train and take care of the astronauts' physical health but also to ensure their mental well-being.

Earth has all the ingredients to protect and sustain life, not only physically, but also psychologically. Exploration missions that leave the Earth’s protective sphere, will have to overcome many challenges, from conditions in space. This includes issues like cosmic radiation and other hazardous environments and provides huge challenges of building and using habitats in space, which forces architects, engineers, and users to really think out of the box. The main focus is rightfully on the mission to survive, but to survive in the long run also implies that psychological health needs to be maintained and intact.

Long-distance and long-duration space expeditions will in the future give rise to different types of challenging tasks on how to maintain mental health by the crewmembers. Isolation and confinement during long-time space missions and the fact that crewmembers are forced to interact with each other in a small space will have a significant influence on the mental health of the crewmembers. It will be important to consider the psychological and interpersonal challenges of long-distance and long-duration space expeditions and develop strategies to support the mental health and well-being of the crewmembers. Understanding the nature and origin of the human brain and its emotional regulation systems can be a valuable tool in achieving this goal.

The LUNARK expedition serves as an important step towards understanding the human factors associated with long-duration space missions and lunar habitats and contributes to the advancement of space exploration by informing the design of future space habitats, mission planning, and astronaut support systems. The ability to maintain balanced mental health and good interpersonal relations are crucial for the personal well-being of the astronaut and for the success of the mission. The participants also expressed confidence in the future of VRMH as a countermeasure for space-induced stressors for astronauts and also recognized the potential of similar countermeasure effects for Earth applications. This suggests that VRMH may have broader applications beyond space exploration, and could be beneficial in other contexts where individuals face challenging environments or stressors. Clearly, the results from this study have limitations; there were only two participants in the study and no control group. It cannot be ruled out that the effect detected in the biological measurement could have come about through the procedure of sitting still for 15 minutes, however, the participant described that the VRMH gave them the possibility to escape the ICE condition and give them some private space, and that the use of the VRMH had a positive impact on them.

During the LUNARK expedition, a study of the influence of social isolation on the mental state of the two participants was conducted by an international research team from the Universities of Surrey and Milano-Biococca. The study revealed important findings about the influence of social isolation on the mental state of the two participants. The study showed that negative emotions such as depression, hopelessness, and helplessness became less frequent over time due to structured and scheduled social interaction. This suggests that the participants were able to adapt and cope with the challenges of social isolation through various means, including conversations about personal matters, joint leisure activities, and exercise.

Despite the decrease in negative emotions, the study found that the participants had an increased urge to make social contact. This highlights the importance of social connections and human interaction for psychological well-being, even in the context of ICE, VRMH interventions may have the potential to be used as an intervention to reduce loneliness and enhance the feeling of social connection. The immersive and interactive nature of virtual reality can provide individuals with a sense of presence and connection, even in virtual social environments, which may help to alleviate feelings of loneliness and social isolation [11].

The study also revealed that engaging in activities, such as joint leisure activities and exercise, was beneficial for the participants' mental states. These activities not only helped to alleviate negative emotions but also improved the perception of the flow of time, making the days seem less endless. This suggests that meaningful activities can play a significant role in maintaining mental well-being during prolonged periods of social isolation; this can also be a target for future use of VRMH.

Conversations about personal matters were found to be helpful in improving the mental state of the participants. This highlights the importance of communication and emotional expression in coping with social isolation. Having opportunities to share thoughts, feelings, and experiences with others can provide a sense of connection and support, even in isolated environments. Overall, the findings from this study suggest that while social isolation can pose challenges to mental well-being, engaging in activities, maintaining social connections, and having opportunities for meaningful conversations can help to mitigate the negative impacts of isolation. These findings highlight the importance of addressing social and psychological needs during prolonged periods of isolation, such as during long spaceflights or other isolated environments, to support the mental health and well-being of individuals [11].

One approach could be to use VRMH to create environments that simulate the sensory experiences of life on Earth and could be used to create immersive environments that provide crewmembers with a sense of connection to nature or to their home planet. Additionally, providing access to music, art, or other forms of cultural expression could help to enhance crewmembers' sense of well-being and connection to their humanity.

Conclusion

The VRMH study also revealed that there is a need for customization of the VR scenes that target the personal preference of the user. The participants of the LUNARK expedition called for VR recordings that were more personal, as one of the participants pointed out, it was fine with nature films, but he also missed films of an urban environment, which he described as "I have lived my whole life in an urban environment, it is my natural habitat”. It can be speculated if more personalized VR could enhance the feeling of social connectedness and the perception of the flow of time, through personalized VR films with daily scenes from the astronaut's life e.g., observing the family eating dinner, playing games, or sitting on his/she favorite café.

Further research and studies are needed to better understand the potential benefits of VRMH interventions in space exploration or other similar contexts. However, the findings from the LUNARK expedition suggest that VRMH may hold promise as a tool for promoting mental well-being and emotional regulation in challenging environments, such as long-duration space missions, where crewmembers may face unique psychological and interpersonal challenges, and the next step could be to test the feasibility of VRMH on a space mission to the International Space Station.

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