Literature Review

Astronauts' Mental Well-being During Long Duration Space Missions

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Literature Review

Isolation and Confinement

#1. Isolation – A Concept Analysis.

This document reviews definitions of isolation, citing The Merriam-Webster Dictionary as "the condition of being alone" and WordNet.com as a state of separation that involves feeling disliked or alone. It traces the term's origin to the Latin "insulatus," meaning "made into an island," as per an online etymology dictionary (Gilmartin et al., 2013). The author also discusses how isolation is portrayed in popular literature and art, typically depicting individuals forced into isolation by social circumstances, punishment, or contagion fears, highlighting the theme of physical or emotional separation (Gilmartin et al., 2013). Gilmartin outlines that the term "isolation" varies across different fields but generally refers to the separation of one entity from another in science. She defines isolation as a state where an individual experiences reduced sensory and social input, often alongside constraints on their physical space or mobility. It is also suggested that studies based on this definition could enhance our understanding and improve life for those in isolation (Gilmartin et al., 2013). Gilmartin points out three main attributes of isolation—sensory deprivation, social isolation, and confinement—and notes that its effects can lead to anxiety, depression, mood disturbances, anger, loneliness, and other negative health outcomes (Gilmartin et al., 2013).

#2. Isolation / NASA Experiments in Closed-Environment Living Advanced Human Life Support Enclosed System.

The book examines the importance of managing environmental cues in sealed habitats for long-term human missions in harsh conditions. It discusses sociokinetic analysis, developed at NASA's Johnson Space Center in 1997, as a method for architects to create spaces that promote mental health, productivity, and good interactions among inhabitants—key to mission success (Lane et al., 2002). This analysis method involves detailed studies of how groups use their environment and the strategic use of data from these studies to improve habitat design. Additionally, the book details how statistical analysis of resident usage patterns and thorough documentation of habitats can guide enhancements in environmental design cues (Lane et al., 2002). The authors emphasize that the psychological and social well-being of inhabitants in space habitats is heavily influenced by design elements such as lighting, color schemes, and spatial layout. Incorporating natural light, comfortable spaces, and aesthetically pleasing environments can improve mood and reduce stress and anxiety among crew members (Lane et al., 2002). They mention that layout also plays a crucial role in shaping social interactions by strategically placing boundaries between private and semi-private spaces, it can affect how individuals interact fostering a harmonious atmosphere crucial for mission success (Lane et al., 2002).

Furthermore, the book discusses how environmental design impacts productivity by addressing factors like noise levels, lighting conditions, and the ergonomic setup of workspaces, which can influence concentration and overall work performance. “Optimizing these elements can minimize distractions and promote a productive environment” (Lane et al., 2002). The text also explores the impact of environmental factors on physical health, noting that air quality, temperature control, and exposure to natural elements are pivotal, and that poor conditions in these areas can lead to health issues and discomfort, affecting both productivity and overall well-being (Lane et al., 2002). Additionally, they highlight that the design of the habitat influences inhabitants' sense of control over their environment for which providing options for personalization, privacy, and autonomy within the space empowers individuals can enhance their mental health and productivity by contributing to a sense of agency (Lane et al., 2002).

#3. Psychiatry Issues Affecting Long Duration Space Missions

The review analyzes anecdotal reports from extended manned space missions and studies conducted in space analog environments on Earth to gather insights into psychiatric issues associated with space travel. It identifies several key psychological challenges faced by astronauts, such as adjustment reactions, psychosomatic issues, asthenia, mood and thought disorders, and post-mission personality and family problems (Kanas, 1998). To address these challenges, the analysis recommends a range of countermeasures that include stringent pre-launch selection and training processes, continuous monitoring and psychological support during the mission, and comprehensive debriefings with crew members and their families after the mission. The use of psychoactive medications is also noted as beneficial, though the analysis acknowledges that the effects of microgravity on drug pharmacokinetics remain poorly understood and require further study (Kanas, 1998).

#4. Environmental Stress

The document examines the concept of environmental stress, exploring stress caused by factors like noise, crowding, substandard housing, and traffic congestion. It discusses the transactional model of stress, which looks at the interaction between individuals and their environment, and the allostatic load theory, which describes the body's efforts to maintain stability under stress (Bilotta et al., n.d.). It also outlines the effects of environmental stress on health, including physiological and psychological responses such as increased cortisol levels and heightened annoyance. Additionally, it covers coping strategies and the importance of analyzing the physical characteristics of challenging environments to understand the impact of prolonged exposure to environmental stressors (Bilotta et al., n.d.).

The document identifies several prevalent environmental stressors and their impacts on human health, and crowding is defined based on the subjective feeling that there are too many people in a space relative to one's comfort level (Bilotta et al., n.d.). The analysis further explores how chronic exposure to environmental stressors can adversely affect the immune system, leading to diminished immunological responses. It links stress to increased inflammatory and cardiovascular responses, suggesting significant implications for overall health (Bilotta et al., n.d.). The document emphasizes that prolonged stress, especially from environmental sources, is particularly damaging, potentially leading to severe health outcomes due to impaired immune functions. This analysis underscores the critical need for addressing these environmental stressors to mitigate their harmful health effects (Bilotta et al., n.d.).

#5. Risk of Performance and Behavioral Health Decrements Due to Inadequate Cooperation, Coordination, and Psychosocial Adaptions within a Team

The document analyzes the risks of performance and behavioral declines in teams, underscoring the necessity of cooperation, coordination, communication, and psychosocial adaptation for high team performance (Landon, 2022). It points out factors like intragroup conflict, lack of shared mental models, and poor teamwork as contributors to performance decrements (Landon, 2022). Strategies recommended include careful selection of team members based on key competencies such as teamwork, motivation, and adaptability, along with traits like emotional stability and flexibility in leadership roles (Landon, 2022). The analysis demonstrates that poor cooperation, coordination, communication, and psychosocial adaptation negatively impact team dynamics and performance, and that inadequate communication leads to misunderstandings and conflicts that disrupt team cohesion and trust. These communication gaps also hinder decision-making, causing delays and errors, and that ultimately, these factors can compromise mission success and safety, as well as hinder the achievement of team objectives (Landon, 2022).

#6. NASA Space Flight Human-System Standard: enabling human spaceflight missions by supporting astronaut health, safety, and performance. *(Childress et al., 2023)*

This article delves into the challenges of isolation and confinement that crewmembers face during extended space flights. Living and working within small, enclosed environments with other crewmembers can lead to interpersonal and behavioral health issues, despite meticulous crew selection and rigorous training (Childress et al., 2023). Factors such as heavy workloads, disruptions in circadian rhythms and sleep patterns, and limited communication with Earth contribute to potential performance declines, adverse health outcomes, and, in some cases, the jeopardization of mission objectives (Childress et al., 2023). In response, NASA has implemented several methods to monitor the behavioral health of crewmembers during space flights. They have also developed technologies and tools aimed at early identification of potential issues, allowing for timely and appropriate interventions or treatments to mitigate these risks (Childress et al., 2023).

#7. ***Self-Care in Space. Interview to Dr. Bell***

This article focuses on an interview with Dr. Suzanne Bell, an organizational psychologist at NASA, in which she discusses the significance of self-care practices and coping strategies for astronauts dealing with the stressful environments of space (Pogosyan, 2024). Dr. Bell underscores the significance of self-care for astronauts to maintain their physical, mental, and emotional health during space missions, and she emphasizes that self-care involves managing health and readiness to contribute effectively to the team and mission (Pogosyan, 2024). A crucial aspect of this is self-regulation, indicates Dr. Bell, where astronauts must control their emotions and behaviors under varying circumstances. An example she mentions is that astronauts on the ISS must handle intense workloads and switch smoothly from high-energy activities like spacewalks to routine tasks such as eating or resting, and that these self-care and regulation skills are vital for their success and well-being on long-duration missions (Pogosyan, 2024).

The analysis examines the most effective emotion-regulation techniques for astronauts, highlighting the comprehensive training they receive. This training equips astronaut candidates with traditional emotion-regulation skills such as reappraisal and problem-focused coping, which are crucial for managing emotions under depleted circumstances, typical of long-duration space missions(Pogosyan, 2024). Additionally, the analysis emphasizes the importance of social support as a primary coping mechanism for astronauts aboard the International Space Station (ISS), and that they benefit from real-time access to family, friends, Mission Control, and psychological support services, all of which play a critical role in maintaining their mental health and resilience in the challenging environment of space (Pogosyan, 2024). Nonetheless, researchers are currently exploring a significant challenge in space research which is the impact of long-term isolation on social support, particularly relevant for future Mars missions. These missions will face up to a 22-minute communication delay each way between the crew and Earth, rendering real-time support and interaction unfeasible (Pogosyan, 2024). Dr. Bell indicates that this delay necessitates a reevaluation of current coping strategies used by astronauts on the International Space Station (ISS), which rely on immediate communication. Consequently, there will need to be a fundamental shift in how social support is provided and utilized in these extended missions, requiring new approaches to maintain astronaut mental health and team cohesion in the face of prolonged isolation (Pogosyan, 2024).

#8. Behavioral Health and Performance. OCHMO-TB 016 Rev B. *(Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search, n.d.)*

In this technical brief it is depicted how Space flight takes place in a highly challenging environment with distinct stressors, and that typical behavioral health issues in this setting may involve stress, depression, anxiety, interpersonal difficulties, and grief (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). It is noted that while these conditions may be temporary and treatable with time or intervention, there is a risk they could develop into more severe psychiatric disorders. Therefore, identifying and addressing the predictive and contributing factors of behavioral health is essential to prevent the onset of distress (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.).

The analysis outlines key factors impacting crew members' behavioral health during space missions, encompassing physical challenges such as injury risks from electrical shocks, environmental hazards like radiation, physiological changes including altered immune responses, and essential preparedness needs like food and medication (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). Specific concerns focus on Isolation, and it highlights potential cognitive, behavioral, and psychiatric disorders, underscoring the need for effective team cooperation, coordination, and communication to mitigate isolation effects. As well as work-related factors where issues include sleep loss, circadian rhythm disruptions, and stress from fluctuating workloads, which significantly impact crew health and mission success (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). “Reported Behavioral Health Issues during Spaceflight:

•Soyuz T10-Salyut 7 (1984): Crew reported possible hallucinations to mission control.

•Soyuz T14-Salyut 7 (1985): Depression may have contributed to evacuation and early termination of the mission.

•2 of 7 (29%) of NASA Shuttle-Mir astronauts reported depressive symptoms. (Human Research Evidence Report, April 11, 2016)

•An STS Payload specialist became despondent when their experiment failed. The crew reported concerns about the potential for dangerous behavior, including opening a hatch. As a result, the STS hatches were fitted with locks.

•Delayed notification to a Russian crewmember of a family member's death led to acute social withdrawal, depression, and isolation.

•Soyuz 21 reportedly ended prematurely due to unspecified "interpersonal issues" with the crew."

The document outlines comprehensive strategies to address behavioral health issues and enhance crew performance during spaceflight missions, categorized into five key areas: Selection, Training, In-Flight Psychological Support, In-Flight Neurobehavioral Monitoring, and Family Psychological Support (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). For missions longer than six months or outside low Earth orbit (LEO), it is recommended to enhance support for families, significant others, and friends, and to improve crew-ground communication. It includes "Repatriation" in which briefings are held for astronauts and their families pre-flight and about six weeks before landing, and additional support is provided to facilitate astronauts' smooth reintegration into their family and work lives after the mission (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.).

For extended missions or those outside of low Earth orbit (LEO), it is advisable to employ additional, minimally invasive monitoring strategies to objectively assess the psychological and behavioral conditions within the mission environment. These strategies are crucial for preserving astronaut well-being and performance by tackling the diverse psychological and neurobehavioral challenges they face during missions (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). Within the strategies it is mentioned "The Habitat Design Guidance" which addresses key strategies to alleviate various psychological stressors faced by crew members during missions. Specific recommendations include, Personal and Private Space, Privacy in Waste & Hygiene Areas, Sleep Quality and Quantity, additionally, each crew member should also have individual control over their sleep environment to promote adequate rest and maintain well-being throughout the mission (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.).

The document also includes strategies to enhance sleep and well-being in space by addressing environmental factors like noise, temperature, vibration, and light with tailored sleep accommodations including clothing and ear plugs. It stresses the importance of efficient spatial organization by placing stowage strategically and managing workload through individual development plans that ensure space and resource allocation for various activities (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). The analysis highlights the necessity of individual controls for environmental conditions in living and working spaces to improve comfort. It also recommends communication enhancements in private quarters for better connection with family, emphasizing the need for privacy and emotional support (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). Regarding crew composition, the document points out that habitat design should consider team size, roles, and cultural backgrounds. It advocates for clear hygiene separation within the habitat and suggests incorporating safety features like alternative escape routes and radiation shelters. Additionally, it outlines the need for protocols for handling crew mortality that minimize risks to other crew members, ensuring these measures are socially and culturally appropriate (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.).

#9. NASA SPACE FLIGHT HUMAN SYSTEM STANDARD VOLUME 1: CREW HEALTH

The document describes the development of health standards for space crew, based on robust scientific and clinical evidence, including previous mission experiences, research, and current medical practices. The framework for setting these standards is modeled after the United States Occupational Safety and Health Administration (OSHA) but is specifically adapted to address the unique health challenges of space exploration in line with NASA's mission needs. This ensures the standards are both effective and specifically relevant to the conditions in space (*NASA Technical Standard*, 2022). The document states that health standards developed are intended for all NASA human space flight programs, not just specific ones. While current programs like the Space Shuttle and ISS already comply with these standards, they are particularly crucial for longer missions beyond low Earth orbit (LEO), such as to lunar outposts or Mars. These standards are most applicable to the in-flight phase of space missions, with a heightened importance for extended missions where the prolonged exposure to the space environment poses greater health risks (*NASA Technical Standard*, 2022).

The document outlines the "Behavioral Health and Performance" strategies necessary for supporting the psychological well-being of crew members, key ground personnel, and their families throughout space missions. It specifies the implementation of psychological support programs, as detailed in the Program MORD "Medical Operations Requirements Documents"

(*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.). These programs include continuous monitoring and assessment of psychological status, weekly Private Family Conferences (PFCs) with two-way communication, crisis intervention when needed, and facilities for relaxation, recreation, entertainment, and social communication. These measures aim to maintain mental health and enhance the overall well-being of everyone involved in the mission (*Ochmo-Tb-016-Behavioral-Health.Pdf - Google Search*, n.d.).

#10. Artemis Campaign Development (ACD) and Medical Operations Requirements Documents (MORD) (*Artemis Campaign Development (ACD) Medical Operations Requirements Documents (MORD)*, n.d.)

The document outlines the role of a Behavioral Health and Performance (BHP) provider in the Artemis Campaign Development, detailing their responsibilities for each mission. These responsibilities include preflight preparation for crew and their families, in-flight monitoring and support, necessary interventions and countermeasures, and postflight re-adaptation (*Artemis Campaign Development (ACD) Medical Operations Requirements Documents (MORD)*, n.d.). The rationale for having a BHP provider is to ensure optimal behavioral and emotional health and readiness in the high-risk, high-stress environment of space missions. This professional is required to be licensed in psychology or psychiatry, and also needs extensive experience in aerospace psychology or psychiatry since this professional is crucial in providing support and consultative services to the crew, their families, and management from launch through the completion of the mission (*Artemis Campaign Development (ACD) Medical Operations Requirements Documents (MORD)*, n.d.).

Biophilia

#11. 14 Patterns of Biophilic Design - Improving Health & Well-Being in the Built Environment

"Biophilia is humankind's innate biological connection with nature. It helps explain why crackling fires and crashing waves captivate us; why a garden view can enhance our creativity; why shadows and heights instill fascination and fear; and why animal companionship and strolling through a park have restorative, healing effects." (Browning, 2014). The text analyzes biophilic design, highlighting its historical significance and interdisciplinary relevance. It details how this design philosophy isn't new but a formalization of historical and scientific insights, demonstrating a deep-rooted human need to connect with nature (Browning, 2014). The term "biophilia" was introduced by Eric Fromm and popularized by Edward Wilson, reflecting a longstanding interest across various scientific fields (Browning, 2014).

The text outlines the development of biophilic design principles, particularly highlighted during a 2004 conference and further explored in a 2008 book by Kellert, Heerwagen, and Mador. It emphasizes Stephen Kellert's identification of numerous methods for creating biophilic experiences and the user experience categories defined by William Browning and Jenifer Seal-Cramer. The discussion notes significant growth in the integration of neuroscience and architecture over the past decade, with green building standards increasingly adopting biophilic elements to enhance indoor environmental quality and connection to place (Browning, 2014). Recently, biophilic design is being promoted as a solution for various societal issues, such as reducing workplace stress and improving student performance, patient recovery, and community cohesiveness (Browning, 2014).

The text outlines the "Nature Design Ecosystem" as a framework for Biophilic Design, defining 'nature' as including both living organisms and non-living components of an ecosystem. It categorizes Biophilic Design into three areas: Nature in the Space, Natural Analogues, and Nature of the Space, providing a structured approach to incorporating diverse natural elements thoughtfully into the built environment (Browning, 2014). For the purpose of this study I mainly focused on the first category of Biophilic Design -Nature in the Space.

Nature in the Space directly incorporates physical elements of nature into spaces, including plants, water, and animals, as well as natural forces like breezes and sensory experiences such as sounds and scents. It encompasses seven biophilic design patterns: 1. Visual Connection with Nature: Views to elements of nature. 2. Non-Visual Connection with Nature: Sensory stimuli that reference nature. 3. Non-Rhythmic Sensory Stimuli: Unpredictable connections with nature. 4. Thermal & Airflow Variability: Natural environmental changes in a space. 5. Presence of Water: Enhancing experiences through water interactions. 6. Dynamic & Diffuse Light: Natural light variations. 7. Connection with Natural Systems: Awareness of natural processes. **Natural Analogues** involves using non-living and indirect evocations of nature through design elements like artwork, furniture, and décor, involving three patterns: 8. Biomorphic Forms & Patterns: Nature-inspired forms and patterns. 9. Material Connection with Nature: Minimally processed natural materials. 10. Complexity & Order: Detailed, nature-like spatial hierarchies. **Nature of the Space** focuses on spatial configurations reminiscent of natural settings, featuring four patterns: 11. Prospect: Clear, unimpeded views. 12. Refuge: Spaces that offer protection and withdrawal. 13. Mystery: Partially obscured views that encourage exploration. 14. Risk/Peril: Safe interaction with apparent risks.

#12. Ulrich and Parsons 1992 – Influences of Experiences with Plants on Well-being and Health. *(Ulrich & Parsons, 2020)*

Ulrich (2020) states that much of the support for biophilia is based on studies involving one or more of three key mind-body systems—cognitive, psychological, and physiological—which have been examined to different extents through both laboratory and field research. He explains that these studies aim to understand how an individual's health and well-being are influenced by their surroundings (Ulrich & Parsons, 2020). In the text, the author discusses various theories from social and natural sciences on the benefits of passive interactions with nature, like exposure to plants, and argues that despite their diverse approaches, these theories consistently predict positive impacts on psychological and physiological well-being from such natural encounters (Ulrich & Parsons, 2020). Within his argument, he underscores that this cross-disciplinary consensus highlights the universal importance of integrating nature into environments to enhance human health, and implies that the presence of natural elements is beneficial for overall wellness (Ulrich & Parsons, 2020).

Ulrich (2020) mentions that a common theme among these theories is that exposure to environments with vegetation, as opposed to urban or built settings devoid of natural elements, generally supports recovery from stress. While overload and arousal theories may vary, they both suggest that environments characterized by visual complexity, noise, intensity, and movement can overload and tire human sensory systems, or cause excessively high levels of psychological and physiological arousal (Ulrich & Parsons, 2020). " Both theories imply that restoration from stress or perceptual fatigue should be fostered by settings having stimuli, such as plants, that are low in intensity and incongruity, and have patterning that reduces arousal and processing effort" (Ulrich & Parsons, 2020).

Ulrich (2020) argues that initial emotional reactions, rather than cognitive responses, are the primary human response to nature, influencing subsequent thoughts, memories, and behaviors. This aligns with current research on emotions, cognition, and neurophysiology. The Kaplans build on William James' concept of "involuntary attention," suggesting that nature captivates people's attention effortlessly, which aids in recovering from mental fatigue caused by tasks requiring intense and prolonged focus, and this demonstrates the restorative effects of nature through automatic psychological engagement (Ulrich & Parsons, 2020). Ulrich (2020) includes that from an evolutionary standpoint, the calming effect of observing natural scenes, such as an aquarium with fish, stems from nature's ability to captively hold attention. This natural engagement diverts individuals' focus away from self-centric and anxiety-inducing thoughts towards a more outward and peaceful awareness, akin to a meditative state (Ulrich & Parsons, 2020). This theory suggests that the inherent qualities of natural settings play a crucial role in reducing stress by redirecting and maintaining human attention effortlessly, thus fostering a tranquil mental environment (Ulrich & Parsons, 2020).

"A stress reaction is the process of responding psychologically, physiologically, and often with behaviors to a situation that is taxing or threatens well-being" (Ulrich & Parsons, 2020). The text discusses stress in terms of its effects on human performance and health, noting that while short-term stress can enhance performance and cognitive function, long-term stress is generally harmful and should be managed to prevent negative outcomes. It also emphasizes that while aesthetic preference is a significant emotional response, it is only one part of a broader spectrum of emotions—such as fear, anger, sadness, and interest—that are crucial for understanding the psychological aspects of stress and restoration (Ulrich & Parsons, 2020).

Ulrich (2020) mentions that research spanning over 100 wilderness studies consistently highlights psychological restoration and stress reduction as key benefits, as seen in studies by figures like Driver and Knopf (1975) and Knopf (1987). Moreover, the author mentions that Hartig, Mang, and Evans (1987) specifically controlled variables like physical exercise and psychological "escape" in their experiment. They induced stress in participants using a demanding cognitive task and then had them either read magazines, listen to music, walk in an urban area, or walk in a nature-rich environment. Results showed that individuals who walked in nature experienced more positive feelings compared to those engaged in other activities, underscoring the uniquely restorative effect of natural environments (Ulrich & Parsons, 2020).

CUPOLA – Ulrich (2020) indicates that research has shown that visual contact with natural elements through windows is restorative and generally preferred over windowless environments, which are often disliked and associated with increased stress, particularly in workplace and healthcare settings. Studies have found that office workers with limited or no access to external views were more inclined to decorate their spaces with nature-themed posters, possibly as a way to compensate for the absence of natural scenery (Ulrich & Parsons, 2020, as cited in, Heerwagen and Orians, 1986).

Ulrich's analysis (20200 examines research by Wise and his team, who interviewed a diverse group of Western astronauts and Soviet cosmonauts regarding their interior decor preferences for space vehicles and facilities. These environments, described as isolated, cramped, hazardous, and stressful, provide a unique setting to explore the psychological impact of interior design. The study highlights the importance of incorporating nature-themed elements to enhance psychological comfort and mitigate stress in these challenging environments (Ulrich & Parsons, 2020, as cited in Wise and Rosenburg, 1988). The summary provided by the researchers highlights a collective preference among astronauts and cosmonauts from various national backgrounds for incorporating more natural elements into the stressful conditions of space habitats. The findings indicate a nearly unanimous request for the inclusion of plants, natural colors, landscape images, and natural woods (Ulrich & Parsons, 2020). This preference underscores a universal human affinity for nature, transcending cultural and national boundaries, particularly in technologically advanced environments like space stations. The report also notes the documented success of such strategies in Soviet space missions, where natural scenes and working gardens were effectively used to maintain crew morale on the Salyut and Mir stations. This analysis suggests that the integration of natural elements in space habitats can play a critical role in enhancing the well-being of those in isolated, high-stress environments. (Wise et al., 1990).

The text highlights that stress and restoration are not solely psychological phenomena but also have crucial physiological components. These components manifest in reactions or activity levels across various bodily systems, such as the cardiovascular system (Ulrich & Parsons, 2020). Ulrich (2020) noted that data derived from recording these physiological responses is widely acknowledged in the scientific community as credible indicators of stress and restoration. Furthermore, the author highlights that the use of physiological methods is valuable for detecting influences on well-being that may escape individual conscious awareness and are not easily captured through verbal assessments like ratings or questionnaires (Ulrich & Parsons, 2020), and suggests that physiological data can provide a more comprehensive understanding of the impacts of stress and restoration beyond what individuals can articulate.

Ulrich (2020) mentions that Wise and Rosenberg (1988) conducted a study to assess the impact of nature decor on alleviating physiological stress and enhancing work productivity among astronauts in a space station. In the experiment, astronauts individually performed stressful tasks in a simulated crew cabin at a NASA center, where they were exposed to one of four visuals: a savanna-like scene, a mountain waterfall, a "hi-tech" abstract, and no picture for control (Ulrich & Parsons, 2020). They found out that although the mountain waterfall was aesthetically favored, the savanna-like scene was found to be significantly more effective in reducing stress according to physiological data (skin conductance) (Ulrich & Parsons, 2020). Additionally, they noted that this scene seemed to reduce stress even when subjects were not directly looking at it or were possibly unaware of its presence, for instance, the authors Wise and Rosenberg suggested that the savanna scene might induce a positive emotional state that continuously buffers against stress during tasks (Ulrich & Parsons, 2020).

The author mentions that the analysis of physiological studies suggests that methodologies relying solely on verbal ratings or evaluations related to the presence of plants in physical settings, such as satisfaction or pleasantness ratings, might not adequately capture the full impact of plants on well-being (Ulrich & Parsons, 2020). Ulrich (2020) includes that the reviewed research indicates that brief interactions with vegetation can effectively facilitate recovery from mild stress, and that this implies that the advantages of observing natural elements like trees, flowers, and other forms of vegetation are likely more significant when individuals are under considerable stress or confined for extended periods (Ulrich & Parsons, 2020). The document includes that such conditions are typical in environments like healthcare facilities, prisons, and certain high-stress occupational settings, and that extended exposure to natural views in these contexts could consistently bolster psychological and physiological health, improve functionality, and potentially influence behaviors in ways that might be observable in health-related metrics (Ulrich & Parsons, 2020). The author concludes that this highlights the critical role that sustained contact with nature can play in enhancing well-being and health in various stressed and restricted environments, and suggest the usage of "compact, self-contained unobtrusive units that record or transmit data" that can be worn by individuals as they experience natural settings for research purposes. (Ulrich & Parsons, 2020).

Ulrich (2020) describes cognitive functioning as encompassing mental agility, memory, and the ability to think, learn, and express ideas logically or creatively. He notes that directed attention is essential for completing repetitive tasks like routine paperwork, reading, and calculations, as well as for functioning effectively in dynamic environments, such as navigating busy streets. He adds that directed attention is energy-intensive, and that over time, it can lead to mental fatigue and a depletion of cognitive resources (Ulrich & Parsons, 2020), as cited in, Kellert et al., 2008, and van den Berg et al., 2007). The author also indicates that frequent interactions with nature provide chances for mental recuperation, allowing higher cognitive functions to rest. Consequently, people who regularly participate in these restorative experiences usually demonstrate a better ability to perform tasks that require concentrated attention, in contrast to those dealing with cognitive fatigue (Ulrich & Parsons, 2020).

Psychological Health and Well-being: Psychological responses encompass our adaptability, alertness, attention, concentration, emotion and mood. This includes responses to nature that impact restoration and stress management. For instance, empirical studies have reported that experiences of natural environments provide greater emotional restoration, with lower instances of tension, anxiety, anger, fatigue, confusion and total mood disturbance than urban environments with limited characteristics of nature (e.g., Alcock et al., 2013; Barton & Pretty, 2010; Hartig et al., 2003; Hartig et al., 1991).

Horticultural Therapy

#13. HATA- American Horticultural Therapy Association

Horticultural therapy (HT) "is the engagement of a client in horticulture activities facilitated by a trained therapist to achieve specific and documented treatment goals" (*AHTA Definitions and Positions*, n.d.)

#14. Horticultural Therapy Program for People with Mental Illness: A Mixed-Method Evaluation

When considering the functional abilities of participants, therapists need to establish clear, practical, and quantifiable goals across emotional, social, physical, and intellectual areas. The outcomes of Horticultural Therapy (HT) are designed to foster a sense of achievement (Siu et al., 2020). To enhance engagement and the therapeutic process in HT, several key practices are recommended: (1) Each participant is responsible for the care of at least one type of plant throughout the therapy; (2) participants are encouraged to actively observe and engage with the growth process of their plants; and (3) therapists should leverage the multi-sensory properties of plants during the sessions (Siu et al., 2020).

The author explores the multifaceted therapeutic benefits of horticulture for individuals with mental illnesses, such as schizophrenia and depression. The text outlines that horticulture provides emotional relief by reducing stress and psychiatric symptoms, stabilizing mood, and enhancing feelings of tranquility, spirituality, and enjoyment (Siu et al., 2020). It also highlights the physical benefits, particularly in reducing fatigue and revitalizing cognitive functions like attention, and form a psychosocial perspective, Siu (2020) notes that horticulture increases self-efficacy, self-esteem, and overall quality of life. The narrative also emphasizes the social benefits, pointing out that horticultural therapy fosters group cohesion and a sense of belonging.

The document underscores the practical benefits as well, explaining that engaging in horticulture leads to a sense of accomplishment and productivity, and for individuals with disabilities, it offers an opportunity to develop sustainable vocational skills (Siu et al., 2020).

#14. Agriculture for Space: People and Places Paving the Way

In this article, Wheeler (2017) examines the development of agricultural systems for space, a concept dating back to the early 20th century with Tsiolkovsky. Central to these systems is the use of photosynthetic organisms to produce oxygen and food, a practical research that began in the 1950s and 60s with pioneers like Jack Myers, who studied algae for oxygen production and CO2 removal for the US Air Force and NASA (Wheeler, 2017). The text emphasizes that space agriculture has both contributed to and benefited from advances in terrestrial controlled environment agriculture, with ongoing potential for future development.

The author reviews significant developments in agricultural systems for space life support, beginning with NASA's initiation of the Controlled Ecological Life Support Systems (CELSS) Program around 1980 (Wheeler, 2017). The narrative spans global efforts, including Japan's Controlled Ecological Experiment Facility (CEEF) for integrated closed-system studies, the European Space Agency's MELiSSA Project focusing on ecological recycling methods for space life support, and advancements at the University of Guelph, where a Canadian team developed sophisticated plant production chambers for space crop testing by 2000 (Wheeler, 2017). It is also mentioned the most recently, Beihang University's Lunar Palace 1, a closed life support facility featuring an agricultural module for sustaining three humans, exemplifies the ongoing international commitment to developing sustainable life support systems for space (Wheeler, 2017).

#15. Eating in Space—From an Astronaut's Perspective

Included in this paper are the observations and experiences of two astronauts, one from the Skylab mission era and one from the Shuttle era. The authors discuss enhancing astronauts' meal satisfaction and nutrition by tailoring menus to individual preferences and dietary needs (Kerwin & Seddon, 2002). They suggest that introducing new food items and maintaining variety can prevent boredom and improve meal enjoyment. Essential to this is meeting the nutritional requirements necessary for astronauts' health and performance (Kerwin & Seddon, 2002). They highlight that implementation of feedback mechanisms, such as food tastings by astronauts, is recommended to refine choices and boost satisfaction. Including familiar comfort foods that can also uplift morale and offer a taste of home (Kerwin & Seddon, 2002). Additionally, they mention that viewing food preparation and consumption in microgravity as engaging learning experiences can help astronauts adapt to eating in space. The author concludes that continuous updates to food systems based on astronaut feedback are crucial for improving meal options and overall nutrition during space missions (Kerwin & Seddon, 2002).

#16. Gardening for Therapeutic People-Plant Interactions during Long-Duration Space Missions

Odeh and Guy (2017) review existing literature on people-plant interactions, particularly focusing on how these interactions are relevant to space exploration and their psychosocial and neurocognitive benefits in daily life. The review advocates for the use of plants to provide therapeutic benefits during long-duration space missions, especially important for missions venturing to distant locations where ground-based support is minimal (Odeh & Guy, 2017). They highlights that evidence sufficiently suggests that active engagement with plants, such as through farming and gardening, can offer therapeutic benefits for behavioral health and cognitive function, and this perspective supports integrating horticultural activities into space missions as a strategic approach to mitigating potential psychosocial and neurocognitive challenges faced by astronauts (Odeh & Guy, 2017).

"While there is evidence for these benefits in ambient Earth-bound environments, we are not aware of a single study that demonstrates whether or not the therapeutic benefits would carry over into a spaceflight environment disconnected from the natural sensory stimulation and input provided by plants." (Odeh & Guy, 2017). The authors examine the unique challenges of living in a spacecraft for extended periods, highlighting how this environment diverges significantly from typical Earth-based living conditions (Odeh & Guy, 2017). The text identifies several critical characteristics of spacecraft that complicate long-term habitation: the absence of gravity, the disruption of natural diurnal cycles, isolation, confinement, proximity to a hostile environment, and the lack of a natural biophilic interior (Odeh & Guy, 2017). Each of these factors is discussed in terms of how they contribute to the difficulty of sustaining human life and well-being in space, emphasizing the need for innovative solutions to mitigate these challenges in future space habitation designs (Odeh & Guy, 2017). Key issues such as space motion sickness, altered body fluid distribution, and vestibular dysfunction are highlighted as factors that can adversely affect psychological well-being in space (Odeh & Guy, 2017). The text also references E.O. Wilson's Biophilia Hypothesis, which posits an inherent human need to connect with nature in the context of the absence of natural environments in space, which according to this hypothesis, could further deteriorate mental health (Odeh & Guy, 2017). They also suggests that these challenges could lead to mental health disorders and reduced cognitive performance in flight crews during extended space missions, posing risks to crew cohesiveness, command structures, and decision-making, ultimately jeopardizing the safety and success of the mission (Odeh & Guy, 2017).

The authors examines various inflight countermeasures designed to improve the environment and well-being of crew members during long-duration space missions and highlight two primary measures: enhancing interior design to provide a richer sensory environment, which is intended to alleviate attention fatigue and stress while fostering learning and participation in therapeutic activities; and promoting leisure activities that engage crew members during their off-duty time (Odeh & Guy, 2017). Despite spatial constraints in spacecraft, the article proposes the integration of plants not just as a nutritional resource but also as a therapeutic intervention (Odeh & Guy, 2017). The text discusses the challenges of replicating natural environments in space and propose simulated nature experiences as a viable alternative. They argue that during extended spaceflights and extraterrestrial habitation, plants can play a crucial role beyond providing nutrition and recycling resources (Odeh & Guy, 2017). The authors emphasize that plants are essential for maintaining behavioral health, cognitive function, and overall physical health of the crew, thus making them integral to supporting sustainable life in space environments (Odeh & Guy, 2017).

The author synthesizes a substantial body of quantitative research that demonstrates how various gardening and horticultural activities have positively impacted the mental health of diverse populations (Odeh & Guy, 2017). Odeh and Guy (2017) cited Clatworthy et al. (2013) highlighting observed general improvements in mental health outcomes, while specific reductions in anxiety, depression, negative mood states, and perceived stress are noted across multiple studies by Lee et al. (2004), Kam and Siu (2010), Gonzalez et al. (2011a, b), Wichrowski et al. (2005), Van Den Berg and Custers (2011), Yun and Choi (2010), and Kotozaki et al. (2015). The authors also mention that further corroborating these findings, Kaplan's seminal work (1973) and later studies by Berman et al. (2008), Annerstedt and Wahrborg (2011), Coon et al. (2011), and Keniger et al. (2013) provide evidence that not only do interactions with or immersion in nature alleviate mental health issues such as anxiety, depression, mood disorders, and stress, but they also enhance self-esteem, directed attention, and cognitive functions (Odeh & Guy, 2017).

The author synthesizes findings from a meta-analysis conducted by Bowler et al. (2010), which reviewed 25 studies and consistently found positive impacts of nature exposure on increasing feelings of energy and decreasing feelings of anxiety, anger, fatigue, and sadness. In the context of long-duration spaceflight, the authors note the significant challenges astronauts face, including isolation and extreme environmental conditions, which heighten the risk of interpersonal conflicts (Odeh & Guy, 2017). Such conflicts can adversely affect various aspects of astronauts' mental health, including sleep, attention, anxiety, depression, and stress. Further supporting the importance of nature exposure, Odeh and Guy (2017) references studies by Cho and Mattson (2004), Son et al. (2004), and Gonzalez et al. (2011b), which demonstrate that interactions with plants and access to plant-rich environments contribute to enhanced social integration, group cohesion, and overall social functioning. The text argues that these interactions could be crucial in mitigating the interpersonal and psychological risks astronauts face during extended missions, suggesting a therapeutic role for plant-rich environments in space travel (Odeh & Guy, 2017).

In the text it is discussed the broader implications of cultivating food in space, suggesting that beyond nutritional value, there are significant psychological and biological benefits, and that this perspective is illustrated through the experiences of Cosmonaut Valentin Lebedev during his 1990 space mission (Odeh & Guy, 2017). The authors note that Lebedev recorded feelings of loss and sadness in his diary when the plant cultivation areas known as Oazis, Fiton, and

Svetoblock were no longer active, and that Lebedev's emotional response to the absence of the plants underlines the satisfaction and emotional enrichment he derived from caring for them (Odeh & Guy, 2017). The authors argue that the astronaut's experience points to a possible innate human need to nurture, indicating that the presence of plants in space could fulfill more than just physical dietary needs by also providing psychological comfort and a sense of purpose (Odeh & Guy, 2017). Moreover, the author uses Lebedev's reflections to argue that engaging in horticultural activities could help mitigate feelings of emptiness and improve the overall well-being of space crews (Odeh & Guy, 2017).

The authors analyze another anecdote involving astronaut Peggy Whitson, who experienced a significant emotional reaction upon seeing soybeans growing in the Advanced Astroculture TM (ADVASC) Experiment on the International Space Station (ISS) (Odeh & Guy, 2017). They mention that Whitson, conveyed in an email to her family and friends how unexpectedly pleasing the sight of six soybean plants was to her, and noted that seeing something green for the first time in over a month had a profound psychological impact, highlighting the intensity of her reaction (Odeh & Guy, 2017). The authors conclude that Whitson's reflections suggest that the presence of plants in space not only serves practical purposes such as food supply but also plays a critical role in maintaining psychological health (Odeh & Guy, 2017). On addition to this, they suggest that her comments imply that for longer missions, such as a potential journey to Mars, having a garden could be essential for astronauts' emotional well-being (Odeh & Guy, 2017). The authors use this account to emphasize the importance of incorporating elements of terrestrial life into space environments to enhance the psychological state of crew members during extended missions.

One more story the authors include in the text is from Astronaut Don Pettit who offered anecdotal support for the presence of plants in space through his blogs and other writings, where he affectionately describes his interactions with a zucchini plant (Odeh & Guy, 2017). Assuming the zucchini's perspective in one of his blog entries, Pettit conveyed the plant's significance to him on the International Space Station. He highlighted the comfort he derived from the zucchini's "earthy green smell," which provided a stark, pleasant contrast to the "engineered machinery" that dominates the space environment (Odeh & Guy, 2017). In the text is also depicted the significant attention drawn by Scott Kelly's 2016 tweet, which celebrated the first flower grown in space, highlighting its impact on both media coverage and public interest (Odeh & Guy, 2017). Odeh and Guy (2017) describe how originally, Astronaut Kjell Lindgren began the experiment on the ISS's Veggie plant growth platform, but Kelly assumed responsibility for the zinnia plants. The narrative emphasizes Kelly's pivotal role in salvaging the experiment by overcoming a fungal growth issue that allowed the plants to bloom successfully, and in subsequent discussions, including a NASA interview, Kelly articulated the lessons learned from the experiment and underscored the educational value of cultivating plants in space (Odeh & Guy, 2017). The text mentions that Kelly spoke of his personal dedication to the plants' recovery and his plans to harvest them on Valentine's Day, demonstrating his emotional connection to the plants and underscoring the human aspect of space exploration (Odeh & Guy, 2017). The authors use this example to illustrate the broader implications of bioregenerative life support systems, such as those that include growing plants, for long-term human space missions.

Odeh and Guy (2017) analyze the global fascination with the first zinnia flower grown on the ISS, noting the event's significant online impact, with nearly 80 million Google search hits recorded by November 25, 2016. They mention that this widespread interest underscores the profound psychological effects that growing plants in space has on observers, suggesting a deeper emotional or symbolic resonance (Odeh & Guy, 2017). The authors argues that this enthusiasm among astronauts and cosmonauts for botanical activities in space provides a compelling rationale for quantitative research to further explore the impacts of plants on crew mental health and well-being under spaceflight conditions (Odeh & Guy, 2017). Additionally, the text highlights the dual benefits of plant cultivation in the ISS's Veggie plant growth facility—not only does it aid in essential processes like carbon and oxygen recycling, but it also offers psychological relief to astronauts who participate in their care. This aspect is particularly emphasized in the work of Vessel and Russo (2015), who point out the therapeutic potential of horticultural activities aboard the ISS (Odeh & Guy, 2017).

The authors discusses the potential of future research into plant-mediated psychosocial effects to fill current gaps in NASA's Human Research Program, and suggest that such studies could focus on identifying factors and validating countermeasures that aim to enhance both individual and group psychosocial health, as well as cognitive performance, during long-duration (Odeh & Guy, 2017)comprehensive studies in the area of human-plant interactions which is essential for more precisely quantifying treatment effects and for advancing our understanding of the fundamental impacts that nature and plants have on human well-being (Odeh & Guy, 2017). The author advocates for this research direction as critical to fill the gap in the notable limitation in the research on the benefits of people-plant interactions, particularly within the context of the Biophilia Hypothesis, where the influence of plants in participants' everyday lives can obscure the studies' findings (Odeh & Guy, 2017). Additionally, they argue that there is a lack of clarity regarding the duration of benefits derived from nature experiences or interactions with plants, and that by eliminating this background influence, researchers could better ascertain and amplify the true effect size of the benefits resulting from people-plant interactions (Odeh & Guy, 2017).

The authors conclude suggesting the use of a proper experimental design that includes setups with and without plants in analog LDSM ICE (isolated, confined, and extreme) environments on Earth where the experiments can be employed to accurately assess the real impact of being around, cultivating, and enjoying the benefits that plants offer (Odeh & Guy, 2017).

#17. Initial survey on fresh fruit and vegetable preferences of Neumayer Station crew members: Input to crop selection and psychological benefits of space-based plant production systems

In this document, the authors explore the unique experiences of crews living in the confined environments of Antarctic stations, likening their experiences to those of early space missions. The text highlights significant anecdotal evidence that underscores the psychological benefits derived from installing plant production systems at these stations (Mauerer et al., 2016). A particular case study from the South Korean King Sejong Station is mentioned, where a detailed investigation was conducted following the setup of a plant growth facility, providing empirical support for these benefits. Furthermore, the author discusses the EDEN ISS project, which involved researchers from Wageningen University in the Netherlands where was developed a crop selection procedure that specifically considered food acceptability among other factors (Mauerer et al., 2016). It is mentioned that this research led to a survey aimed at examining the personal preferences of former crew members of various German Antarctic stations, and that these individuals, having lived under remote and isolated conditions, provided insights into food acceptability and the psychological advantages of crop production in spaceanalogous environments (Mauerer et al., 2016). The paper emphasizes the importance of understanding these aspects to better prepare for the psychological and sustenance needs in similar future space missions. The authors mention that a survey conducted among crew members of German Antarctic stations, highlighting its role as an initial effort to map out their food production preferences was a foundational survey that not only established a baseline of preferences but also raised additional questions to refine future evaluations of food preferences and psychological impacts of on-site food production in remote settings (Mauerer et al., 2016). The authors acknowledg differences expected between terrestrial and microgravity environments, and point out that the isolated conditions of the Neumayer Antarctic stations closely mimic those of early manned space missions, making them a suitable analogue for study (Mauerer et al., 2016). The text also emphasizes that incorporating more detailed demographic data about the crew members, such as gender, nationality, age, and specifics of their Antarctic stays, would enhance the utility of future surveys.

#*18.* Artemis

NASA's Artemis program aims to return astronauts to the lunar surface and establish a sustained presence there. The program, named after the Greek goddess of the moon, Artemis, reflects its connection to the Apollo program, which first landed astronauts on the Moon on July 20, 1969 (Mann & updated, 2022). As described on NASA's website, Artemis is a mission designed to employ advanced technologies to enhance lunar research and set the stage for eventual manned missions to Mars (*What Is the Artemis Program?*, 2022). The narrative specifically highlights Artemis 3, planned to explore the previously unvisited South Pole of the Moon, and that the astronauts on this mission will be tasked with finding and utilizing lunar water, investigating the Moon's geology, and developing techniques for living and working on another celestial body (*What Is the Artemis Program?*, 2022). Notably, the Moon is described as being only three days away from Earth, emphasizing the logistical feasibility of these missions. Furthermore, the article discusses the importance of testing technologies on the Moon that will be crucial for future Mars missions, which could involve round trips lasting up to three years, and they underscore the dual objectives of the Artemis program -advancing lunar exploration and preparing for deeper space exploration goals (*What Is the Artemis Program?*, 2022).

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