Psychological Challenges of Spaceflight

A Report from the Psychology Proto Task-Force developed as part of an exercise organized and sponsored by the Human Space Program's Overview Round Table.

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Abstract

On October 6, 2021, the Psychology Proto Task-Force (PPTF) presented at the Overview Round Table within a series of inaugural interdisciplinary presentations coinciding with the launch of the Human Space Program. It is exploring the psychology of space migration, emphasizing how we can support people to survive, adapt, and thrive on future missions to Mars and beyond. As we expand further into the solar system, we stand on the precipice of change: unprecedented missions like this will bring unique challenges and opportunities. Mobility, adaptation, and collaboration have ensured our survival on Earth; seemingly each step of our evolution has moved us closer to expanding beyond our natural habitat. Successful migrations beyond Earth will rely on our ability not only to acclimatize and sustain physical and mental health off world, but also to optimize it. This paper, co-authored by several members of the PPTF, explores some of the anticipated challenges and stressors of deep space missions and off-world migrations. Various members of the task force may subsequently make further recommendations geared towards their expertise.[1]

Keywords: Human Space Program, Psychology Proto Task-Force, Space Health, Space Human Factors, Deep Space, Mars Missions, Future of Space Exploration, Psychology, Wellbeing.

Introduction

To date, no human being has journeyed out into deep space or set foot on Martian soil. This means that we do not have a first-hand account of how people will respond when they eventually live and work in extreme habitats like these. While we can make assumptions based on the evidence we have gathered on environments that resemble deep space and off-world landscapes, they only provide a glimpse into what these missions are likely to entail. Despite the gaps in empirical knowledge, we must try to draw conclusions about the challenges that off-world habitation and deep space missions present. One way to achieve this is to explore the evidence from isolated and confined environments (ICEs), extreme and unusual environments (EUEs), and the International

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[1] The subject matter in this report was developed by the authors as part of an exercise organized and sponsored by the Human Space Program's Overview Round Table.

Space Station (ISS).[2] These unique terrestrial and low Earth orbit (LEO) environments will allow us to make initial predictions about physiological, performance, and psychosocial adaptation on extraterrestrial missions, which in turn will assist with planning and preparation for planned missions, including:

1. Selecting appropriate candidates and teams.
2. Predicting crew performance.
3. Selecting appropriate support strategies.
4. Establishing baselines for a wide range of human cognitive, social, and emotional factors.
5. Testing the viability of exponential technologies (VR, AR, XR, and AI) as novel tools that can help to mitigate psychological challenges during ICE missions.
6. Developing and training interpersonal or intrapersonal conflict management strategies.

In the Summer of 2021, The Human Space Program (HSP) charged the Psychology Proto Task-Force (PPTF) with exploring the psychology of space migration, with an emphasis on how we can support people to survive, adapt, and thrive on future missions to Mars. On October 6, 2021, the PPTF presented its findings at the Overview Round Table meeting as part of a series of inaugural PPTF presentations. This paper summarizes some of the findings of that presentation. In future publications, members of the PPTF may opt to extend this work by making recommendations based on their areas of expertise or interest.

Anticipated Challenges

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Psychological research demonstrates that if you place a well-adjusted person in an isolated, confined, or extreme environment with a small group of people over a long period of time, you are likely to witness the unraveling of the individual and the crew.[3]

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[2] Ilya Whiteley and Olga Bogatyreva, *Toolkit for a Space Psychologist to Support Astronauts in Exploration Missions to the Moon and Mars* (Bath, UK: Cosmic Baby Books, 2018; first published Frome, UK: Systems Engineering and Assessment, 2006).

[3] Fatin Atrooz, Tzuan A. Chen, Brian Biekman, Ghalya Alrousan, Johanna Bick, and Samina Salim, "Displacement and Isolation: Insights from a Mental Stress Survey of Syrian Refugees in Houston, Texas, USA," *International Journal of Environmental Research and Public Health* 19, no. 5 (2022): 2547; David T. Lardier, Micah N. Zuhl, Kelley R. Holladay, Fabiano T. Amorim, Raina Heggenberger, and Kathryn E. Coakley, "A Latent Class Analysis of Mental Health Severity and Alcohol Consumption: Associations with COVID-19-Related Quarantining, Isolation, Suicidal Ideations, and Physical Activity," *International Journal of Mental Health and Addiction* (2022): 1-24, doi.org/10.1007/s11469-021-00722-9; Lisa M. Mann and Benjamin R. Walker, "The Role of Equanimity in Mediating the Relationship between Psychological Distress and Social

However, over the decades, ICE experiments and the National Aeronautics and Space Administration (NASA) have shown that small teams of people can cope reasonably well for periods of 3-12 months.[4] While these experiments show that with adequate support and training, highly disciplined government-trained astronauts or other trained professionals, for a period of time, can adapt reasonably well to extreme terrestrial environments and to LEO, deep space and habitation missions present a myriad of unprecedented health and psychosocial challenges.

Spacefarers who journey out beyond our immediate cosmic neighborhood will face extreme isolation for longer periods of time, as they will find themselves thousands of miles away from planet Earth and all that is familiar. As they move beyond the relative safety of LEO, they will need to contend with extreme environmental stressors such as increased radiation and altered gravity (e.g., hypergravity and hypogravity), placing them under significant risk. As it stands, external Earth-based support, such as communication with Mission Control, will also be disrupted on such missions. The crew will also have to contend with knowing about the dangers inherent in their immediate environment, which will inevitably create additional pressures.

Arguably, beyond the immediate survival and safety concerns, the success of future deep space and planetary habitation missions will largely depend on the psychological well-being and physiological health of the crew.[5] Although these missions are unprecedented, evidence from the ISS, ICE, and EUEs highlight several internal and external challenges that could play an important role in mitigating health. These predictors fall under four discrete yet interdependent categories,[6] with a fifth additional category titled existential and consciousness added for further consideration.

1. Physiological and health: vestibular problems, space sickness, kidney stones, sleep disturbances, hypoxia, intracranial hypertension, hypercalcemia, loss of bone density and osteoporosis, metabolic changes resembling changes caused by aging and illness.
2. Performance: disorientation, visual illusions, attention and memory deficits, error proneness, cognitive decline, psychomotor problems, and low stamina.
3. Psychological and psychiatric: adjustment, sleep, somatoform, psychotic, and affective disorders, suicidal ideation and plans, asthenia, and grief.

Isolation during COVID-19," *Journal of Affective Disorders* 296 (2022): 370-79; Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

[4] Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

[5] Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

[6] Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

4. Interpersonal: tension, paranoia, withdrawal, territorial behaviors, lack of privacy, affect displacement, aggression and microaggression, conflict and disagreements, and romantic relationships.
5. Existential and consciousness: lack of freedom, facing death and mortality, insignificance, loneliness, meaninglessness, lack of hope and purpose, disturbances in sense of self and consciousness.

Before humans can realistically accomplish the vision of becoming a multiplanetary species and identify appropriate protocols, interventions, and countermeasures that will help them to survive, acclimate, and perhaps even thrive in extreme environments, the risks and challenges associated with psychosociological factors must be identified and addressed. Although it is not in the scope of this paper to provide a comprehensive review of the health and psychosocial challenges and stressors, the authors attempt to summarize some of the key areas of concern.

Medical and Health

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In the first instance, environmental hazards that place crew safety and survival under significant risk will need to be overcome. As it stands, there will be considerable disruption to communication on future missions beyond LEO, which means crews will need to be autonomous and independent from Earth's Mission Control support.[7] Furthermore, data from NASA suggests that the risk of astronauts sustaining medical illnesses or life-threatening injuries dramatically increases over time, suggesting that there will be more medical emergencies on long-duration missions beyond LEO.[8]

Some health concerns remain unresolved, and questions remain unanswered pertaining to space medicine. For example:

1. We are still in the early phase of studying and collecting data pertaining to human factor predictions. Such predictions are difficult to make along with all the challenges of long-term physiological effects for astronauts, which are still relatively unknown.
2. The recent success of the private civilian space sector and the potential for non-government-trained astronauts offers more challenges and questions on crew selection criteria, e.g., who is considered "fit for the mission" if they only want experiences as space tourists? The differing

[7] NASA, "NASA Space Flight Human-System Standard Volume 1, Revision B: Crew Health," January 5, 2022, standards.nasa.gov/standard/nasa/nasa-std-3001-vol-1.

[8] Andrew W. Kirkpatrick, Chad G. Ball, Mark Campbell, David R. Williams, Scott E. Parazynski, Kenneth L. Mattox, and Timothy J. Broderick, "Severe Traumatic Injury During Long Duration Spaceflight: Light Years Beyond ATLS," *Journal of Trauma Management & Outcomes* 3 (2009): article 4, doi.org/10.1186/1752-2897-3-4.

intensity and fidelity of training, based on what category of astronauts they are (space agency astronauts, civilian astronauts, and future space tourists) could have an unknown impact on their psychological well-being during the mission.

3. Medical personnel and capabilities on board the spacecraft will need to respond adequately to trauma/emergency and to cope with the adaptive responses of the human body in space.
4. Altered gravity environments, including the onboard environment in the ISS, can alter the potency and efficacy of specific medications.[9]
5. Medical procedures and protocols have yet to be developed sufficiently to include surgical interventions, and astronauts lack training to perform such procedures.
6. Understanding the role of genomics and proteomics is necessary to develop personalized medicine to ensure optimal health and well-being, and to support and maintain the peak performance of astronauts.
7. Understanding the impact of a range of altered sensory perceptions because of upregulation and downregulation of sensory receptors is necessary.
8. The distribution of the increased intracranial pressure caused by microgravity can vary in individuals. As a result, the differing regions of the brain that are affected by the increased pressure can have a variety of idiosyncratic manifestations that have yet to be fully understood.[10]

Space health and wellness research will help to resolve some of these questions and will contribute to innovative solutions. Bioastronautics, bioengineering, and human systems integration, for example, can complement other psychosocial applications to help astronauts during long-duration missions, planetary surface exploratory expeditions, and settlements, as well as building sustainable habitats on the Moon, Mars, and beyond.

Stress

Annahita Nezami

Stress can be conceived of as the activation of a cascade of bodily responses that are triggered when we face undesirable situations or conditions (internal, external, or both). Typically, when we face an undesirable situation, we experience varying degrees of dysregulation, and our body responds by activating specific physiological responses in a

[9] Johannes Kast, Yichao Yu, Christoph N. Seubert, Virginia E. Wotring, and Hartmut Derendorf, "Drugs in Space: Pharmacokinetics and Pharmacodynamics in Astronauts." *European Journal of Pharmaceutical Sciences* 109 (2017): S2-S8, doi.org/10.1016/j.ejps.2017.05.025.

[10] Alex P Michael and Karina Marshall-Bowman, "Spaceflight-Induced Intracranial Hypertension." *Aerospace Medicine and Human Performance* 86, no. 6 (2015): 557-62, doi.org/10.3357/AMHP.4284.2015.

bid to maintain homeostasis (internal equilibrium). All the energy from the internal motion, or co-motion, is siphoned through our behavioral and affective responses.

Stress can be experienced either positively (eustress) or negatively (distress) and can manifest as acute, episodic, or chronic. The nature, intensity, and duration of stress will mediate valence. There is also a distinction to be made between environmental, biological, and psychological aspects of stress. For example, we may be more prone to a particular stress response due to the characteristics and traits we inherit from our parents, the surrounding environment can help shape our personality and ultimately how we respond to stress, and finally, the biological response to stress—the fight-or-flight response, is pervasive and ubiquitous amongst all animals with complex nervous systems.[11]

Generally, stressors that are acute, intense, and an immediate threat to homeostasis result in a short-term suppression of pain known as stress-induced analgesia—a widely studied phenomena that is a part of the body's defensive fight-or-flight response. In contrast, exposure to prolonged or chronic stress, referred to as stress-induced hyperalgesia (i.e., an exacerbation of pain), increases the occurrence of psychological and psychosomatic symptoms.[12] In this way, homeostasis and the fight-or-flight response form the bedrock of stress and research.

A myriad of precipitating and perpetuating factors may lead to psychological disturbances on future extraterrestrial missions. A framework that places psychological health on a health-ease versus dis-ease continuum will help to create a basic structure, organize presenting symptoms, and ultimately help to provide a treatment pathway. On one end of this continuum is normative responses to stress that could lead to adverse cognitive and behavioral outcomes; on the other end, more pervasive physical or mental health conditions can develop if the stressor remains and adverse conditions are not detected and mitigated early. In this example, adaptation and effective functioning, even in the presence of stress, discomfort, and disease, can be considered a state of wellness or health-ease.[13]

Psychiatric Illness

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NASA's Behavioral Health and Performance (BHP) division differentiates between adverse behavioral conditions and psychiatric disorders in the following manner: a behavioral condition is any decrement in mood, cognition, morale, or interpersonal

[11] Mustafa al'Absi, Motohiro Nakajima, and Stephen Bruehl, "Stress and Pain: Modality-Specific Opioid Mediation of Stress-Induced Analgesia," *Journal of Neural Transmission* 128, no. 9 (2021): 1397-407. doi.org/10.1007/s00702-021-02401-4.

[12] Ryan K. Butler and David P. Finn, "Stress-Induced Analgesia." *Progress in Neurobiology* 88, no. 3 (2009): 184-202, doi.org/10.1016/j.pneurobio.2009.04.003.

[13] Aaron Antonovsky, "Perceiving the World as Coherent," in *Health, Stress, and Coping: New Perspectives on Mental and Physical Well-Being*, ed. Aaron Antonovsky (San Francisco: Jossey-Bass, 1979), 123-59.

interaction that adversely affects operational readiness or performance, whereas a psychiatric disorder is one that meets the Diagnostic and Statistical Manual of Mental Disorders, fifth edition (DSM-5) criteria for diagnosis of a disorder. The DSM-5 defines a mental disorder as "a syndrome characterized by clinically significant disturbance in an individual's cognition, emotion regulation, or behavior that reflects a dysfunction in the psychological, biological, or developmental processes underlying mental functioning."[14]

From this premise we propose that acute disturbances on a mission to Mars might include:

1. Oscillations in mood; irritability, mood swings, low mood, despondency, and indifference.
2. Sleep disturbances; disruption to quality of sleep, excessive naps, interrupted sleep and nightmares.
3. Visual illusions and unformed/pseudo-hallucinations.
4. Dissociation; including derealization, depersonalization, or amnesia.
5. Grief; relating to loss of reference points, loss of normalcy, loss of meaning, and loss of connection.
6. Displacement and homesickness.
7. Fatigue and withdrawal.
8. Emotional suppression.
9. Deviant behavior; referring failure to conform to group norms and expectations.
10. Psychosomatic; including chronic pain, fibromyalgia, recurring migraines, or infections.
11. Learned helplessness; referring to the psychological effects caused by the uncontrollability of events that are beyond control.
12. Changes in executive functions; including spatial and motor-skills, significant modifications in movement, posture, and orientation.
13. Time effects; including disruptions to circadian rhythm and third-quarter syndrome (the decline in performance during the third quarter of missions in ICE, regardless of actual mission duration).

Pervasive psychiatric disorders on a mission to Mars might include:

1. Schizophrenia and other psychotic disorders (e.g., formed hallucinations, paranoia).
2. Mood or anxiety disorders.

[14] American Psychiatric Association, *Diagnostic and Statistical Manual of Mental Disorders*, 5th ed (DSM-5). (Washington, DC: American Psychiatric Association, 2013); Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

3. Phobias (e.g., claustrophobia or acrophobia).
4. Dissociative disorders.
5. Adjustment and sleep disorders.
6. Complex grief.
7. Break-off.
8. Unspecified space syndromes

To conclude, research suggests that chronic stress and uncontrollable adverse events can lead to acute psychological disturbances, and can gradually develop into more serious psychiatric disorders. Challenges pertaining to diagnosis and treatment of space syndromes are likely to arise in earlier missions, as the crew will encounter unfamiliar or perhaps entirely new psychiatric issues. The first pioneers will be part of a human experiment, documenting the psychological and physiological impact of travelling beyond LEO. Additionally, there is a risk that crew members may conceal symptoms or delay reporting them altogether due to fear of erroneous assumptions being made about their capacity or for fear of being labeled unfit for future missions.[15] To avoid compromising day-to-day operational duties and overall mission success, and for the crew to feel confident and to act competently during instances that require diagnosis, prognosis, or treatment, effective psychological systems, protocols, and interventions will need to be agreed upon and implemented.

Psychosocial

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Crew members on prolonged missions beyond LEO are likely to encounter more extreme forms of social isolation and boredom, which can exacerbate psychosocial and Interpersonal issues. As it stands, the crew will have to sacrifice normalcy in every sense of the word, with limited personal space and privacy, living under increased surveillance, sacrificing many creature comforts and earthly luxuries, missing out on social life, and having limited contact from family and friends. As such, problems that seem minor on Earth can easily escalate, and frustration and tension can easily grow between crew members in ICE.[16]

In 1979 Henri Tajfel proposed the widely acclaimed social identity theory, which asserts that human beings use categorization as a means to make sense of the surrounding world. In relational encounters, we tend to categorize people into ingroups or outgroups. The classical view argues that this system of categorization is hard-wired into us. Although it

[15] Nathaniel P. Morris, "Mental Health in Outer Space." Scientific American Blog Network. *Scientific American*, March 14, 2017. blogs.scientificamerican.com/guest-blog/mental-health-in-outer-space/.

[16] Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

is adaptive in some ways, categorizations can lead to the formation of maladaptive biases, which can gradually lead to conflict.[17]

Since its conception, empirical support for Tajfel's theory has grown. A recent neuropsychological study on group biases found that participants displayed higher levels of empathy when they viewed a painful event occurring to a hand labeled with their own religion (*ingroup*) than to a hand labeled with a different religion (*outgroup*). The study found that when we observe another person in pain, brain regions are activated that are involved in the sensation of our own pain (mirror neurons). However, it seems this neural mirroring is not constant; rather, it is modulated by our beliefs about their intentions, circumstances, and group allegiances.[18]

In relation to crew composition, the benefits and risks of homogeneity and individual differences will need to be considered, including personality, culture, and neurodiversity. For example, it will be critical, particularly during earlier missions involving smaller crew sizes, to select members who are self-autonomous: who can work alone, be decisive, and quickly adjust to new or difficult environments, and members who are resilient and flexible: who are able mentally or emotionally to cope with changes in circumstance or with crises and quickly to return to baseline.[19] It is also important to factor in how individual members respond to emotional and physiological stress; for example, do they suppress emotions and become easily irritable, and how do they perceive and respond to their internal state (interception).

The biosphere experiments provide a good example of how groups of people can respond in ICE environments. In 1987, the Biosphere Research and Development Center, an Earth system science research facility in Arizona, was established. Two experimental closures were conducted, the first from 1991 to 1993 (Biosphere 1), and the second in 1994 (Biosphere 2), before a change in ownership resulted in alleged interference with the Biosphere 2 study, which led to the termination of the experiment. The experiment provided a snapshot into some of the interpersonal challenges that could arise in ICE, as well as ecological life within biospheres and for long-term habitation in space. Amongst other outcomes, the first biosphere experiment led to low team morale, partly due to poor nutrition and lack of oxygen, and division and discord between group members. Although there was some conflict amongst the team, they were able to work together to achieve the experiment's primary goals, to protect the biosphere. Despite their personal differences, all the crew reported feeling a strong affinity with the biosphere and the natural world. This intimate connection enabled the crew to discern and respond to even

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[17] Henri Tajfel and John C. Turner, "An Integrative Theory of Inter-Group Conflict," in *The Social Psychology of Intergroup Relations*, ed. William G. Austin and Stephen Worchel (Monterey, CA: Brooks/Cole, 1979), 33–47.
[18] Don A. Vaughn, Ricky R. Savjani, Mark S. Cohen, and David M. Eagleman. "Empathic Neural Responses Predict Group Allegiance." *Frontiers in Human Neuroscience* 12 (2018): 302.
[19] Whiteley and Bogatyreva, *Toolkit for a Space Psychologist*.

subtle changes in the living systems.[20] The biosphere experiments demonstrate some of the common issues that can arise in ICE. They also show us how a sense of purpose can play an important role in strengthening team cohesion and perhaps could be a potent antidote for existential issues that arise out of extreme isolation and boredom.

In deep space environments, well-being will be affected by the management of social relations. This can be considered via two interrelated analytical frames: first, the architectural and material dimensions of humans living off-earth and second, the social conditions of such living. There has been a lot of conversation about the physiological effect of leaving Earth as a home planet. However, for most of history, human beings have not been aware of their place on a planet. Nor do most people consider their relation to the Earth, as the daily lived experience is that of a localized environment on a static plane. We are therefore best served to think about the phenomenology of the environment rather than the empirical reality of planets. In this sense, we can learn from existing missions and analogues in extreme environments. In places such as Antarctica, crew dynamics have been noticeably affected by the rhythm of the day. On the state-of-the-art UK research facility, Halley VI, built on a floating ice shelf in the Weddell Sea, the crew stays on the same schedule (GMT), whereas on the French/Italian Concordia mission, the crew members work to their own schedules, leading to a fracturing of team bonds.

In off-Earth living, as in Antarctica, one is heavily reliant on the technical infrastructure of the habitat to live. There is no going outside without suitable equipment. As such, people will have to develop a healthy symbiotic relationship with technology. Different cultural groups have different thresholds of where the body ends and where cyborg or technical intervention begins. For example, robots are used frequently in care homes in Japan, but they would be rejected in Europe as impersonal.[21] Further the regulation and management of our bodies would be under the surveillance and control of such architectural regimes, and this has implications for sense of self, sense of control, governance, privacy, and one's relation to authority.[22]

Then there is the question of the habitat itself. Homes around the world look very different to each other. Each house is both a reflection of and aids particular social relations. Homes keep the sacred from the profane, separate people from each other and bring them together. They reflect our understanding of self, kin, family, hierarchy, and order. With this in mind, any habitat would need to have the flexibility to adapt to changing social conditions through a physical partibility in the structure of the habitat itself.

Third, the ethno-physical conditions of off-Earth living need to be considered. Here Earth analogues do not provide adequate insight. The human body has evolved on the

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[20] Jane Poynter, "Biosphere 2," TEDx, 2009; www.ted.com/talks/jane_poynter_life_in_biosphere_2.

[21] Michael Shea, "User-Friendly: Anthropomorphic Devices and Mechanical Behaviour in Japan." *Advances in Anthropology* 4, no. 1 (2014): 41-49.

[22] Victor Buchli, *An Anthropology of Architecture* (London: Taylor & Francis, 2013).

Earth in terms of physiology, but also in terms of psychology and sociology. In alternative gravity environments the body acts differently, meaning body language and one's relationship to one's body in terms of tiredness, emotion, and such things changes. We need to ensure that clear communication occurs to smooth the disruptive effect of changing ethno-physics.[23]

The question must be asked of what population size is best so that diversity and social cohesion can be maintained. Bio-anthropologists such as Robin Dunbar have suggested that humans are only capable of around 150 meaningful relationships,[24] although others have argued for over 250. In habitats with a high degree of crew interdependence, Dunbar's Number becomes important. Small crews should be in odd numbers to resolve conflict; crews above forty will need administrative staff and division of labor (a cook, a cleaner for example). Habitats should be scalable, partible, and adaptable.

As previously discussed, long-duration journeys to space will require prolonged confinement and isolation from friends, family, and home. These stresses have potential psychosocial impacts on social behavior, cognition, and consciousness. These factors and the adaptation processes that will need to occur not only physically and psychologically, but also socially will need to be considered in habitat and mission design and crew selection.

Existential

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The human condition dictates that the majority of us, in our own way, have to contend with the ultimate existential givens of life relating to isolation, death, freedom, and meaning. Existential crises can broadly be characterized by the belief that we are insignificant in the grand scheme of life and that life lacks any real purpose or meaning, and they can be accompanied by feelings of anxiety and depression. Existential crises can occur at different stages during the human life span, commonly resulting from our inability to accept, integrate, or resolve the existential givens.[25]

Beyond the daily environmental stressors and the interpersonal challenges that the crew(s) and settlers will experience, they will also encounter existential matters. Historical accounts reveal how some people respond to existential crises. Together, these accounts are indicative of past patterns and help us translate collective action into a type of narrative. This type of knowledge and understanding, alongside the empirical data from

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[23] Aaron Parkhurst and David Jeevendrampillai. "Towards an Anthropology of Gravity: Emotion and Embodiment in Microgravity Environments," *Emotion, Space and Society* 35 (2020): 100680.

[24] Robin Dunbar, *How Many Friends Does One Person Need? Dunbar's Number and Other Evolutionary Quirks* (London: Faber & Faber, 2010).

[25] Rollo May and Irvin Yalom, "Existential Psychotherapy," in *Current Psychotherapies*, ed. Danny Wedding and Raymond Corsini (Itasca, IL: F. E. Peacock, 1989), 363-402.

ICE, will be invaluable for developing an accurate predictive model for future deep space and habitation missions.

Captain Sir John Franklin's lost expedition is one historical story that dramatically portrays how human beings respond during severe isolation and life-threatening circumstances. In 1845, two British ships led by Franklin, HMS *Erebus* and HMS *Terror*, departed to go on a voyage of Arctic exploration, travelling to the unnavigated sections of the Northwest Passage in the Canadian Arctic. The expedition ended with a devastating disaster after both ships and a total of 129 men became icebound. The crew faced a harrowing time trying to survive, and the evidence suggests that the men endured extreme suffering, overcoming many challenges, before circumstances turned dire, which led some to cannibalism. Eventually, all 129 men sadly perished, largely due to the severe weather conditions and lead poisoning.[26]

World War II was a global event that was highly stressful and traumatic for those involved. Wartime historical records offer further clues to how people and groups respond during existential crises. Some of the military personnel who served on the front line lived in extreme conditions in army barracks or bases for prolonged periods of time, often finding themselves isolated and removed from ordinary social activities. One example of the effects of extreme isolation during the war is the Maunsell Forts. As part of the British defense network, a dozen temporary quarters were constructed in the Thames Estuary for military personnel to help protect important ports and shipping channels. A selection of these forts were called Maunsell Forts, named after the designer, Guy Maunsell. Living conditions on the Maunsell Forts were said to be extreme, with around a hundred soldiers stationed there during the war, rotating between six to eight weeks on the forts and ten days on land in between deployments. Psychologists recommended that the men take up hobbies as a way to distract themselves: painting, knitting, or building models. However, over time, living in a confined space, and the extreme isolation and boredom became almost unbearable, and when the mission was terminated some required psychiatric treatment—the fortresses were aptly named "Fort Madness."[27] There are also historical accounts of times of crises that show people coming together, of bravery and heroism, and of collective positive action.

How will the human mind and body respond to being hurled out into deep space, untethered and removed from its natural habitat? The crew on deep space and habitation missions will inevitably have to deal with existential concerns, both on a daily basis and as points of crises. At best, these issues will cause mental discomfort, and at worst they can lead to psychiatric disorders. Before any planned mission departs this Earth, existential matters will need to be thoroughly considered and mitigated.

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[26] Douglas Wamsley, "Silas Enoch Burrows and the Search for Sir John Franklin." *Interdisciplinary Journal of Maritime Studies* 8, no. 2 (2018): 26.

[27] Frank R. Turner, "The Maunsell Sea Forts. Part Two: The World War Two Army Sea Forts of the Thames and Mersey Estuaries," 1995, Imperial War Museum, www.iwm.org.uk/collections/item/object/ 1500097795.

Neuropsychology and Consciousness

Oscar O'Farrill

The perspective of social neurocognition can provide potential foundations and frameworks to consider the variables implicit in the processes of cognitive and executive functions. The intra- and interpersonal relationships and social behaviors and the complex dynamic systems that withhold the sociocultural representations and master narratives have a multidirectional influence over the configuration of the self, the ego(s), and consciousness. Derived from the most recent research with imaging of functional brain/neuronal anatomy, the conceptualization and analysis of two dissociable macro-scale brain networks are postulated:

1. Mirror neuron system (MNS): mirror neurons focused on understanding external actions, as well as identifying the actions that other people carry out. The MNS has shown correlations with higher cognitive abilities such as understanding intentions, learning and memory, social learning, consciousness and awareness, language, imitation of patterns and behaviors, and some characteristics of empathy.
2. Default mode network (DMN): a complex anatomically defined neuron system that is activated when individuals do not focus their attention on the environment.[28] The DMN possess potentially to influence the perception of external emotion, empathy, mentalization, morality, the ability to explain, predict and interpret desires, beliefs, intentions and emotions in other people, and the functioning of social working memory, introspection and mind wandering.[29]

The knowledge base surrounding the neuroanatomy of the MNS and the DMN and their role in the cognitive construction of the self and consciousness, and its correlation with social cognition is rapidly changing, with the aforementioned perspectives providing direction for future exploration. With the advancement in functional neuroimaging technology, such as EEG, fMRI, infrared stimulation, and computational technologies such as AI, complex dynamic system data analysis, and deep transcranial and direct current simulation, it will be possible to create computational models of complex dynamic systems. Therefore, the neurocognitive perspective of social interactions can simulate multinational and interdisciplinary crew dynamic scenarios to undertake a deep and

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[28] Randy L. Buckner, Jessica R. Andrews-Hanna, and Daniel L. Schacter. "The Brain's Default Network: Anatomy, Function, and Relevance to Disease." *Annals of the new York Academy of Sciences* 1124, no. 1 (2008): 1-38.

[29] David M. Amodio and Chris D. Frith, "Meeting of Minds: The Medial Frontal Cortex and Social Cognition," *Nature Reviews Neuroscience* 7 (2006): 268–77, doi.org/10.1038/nrn1884; Ahmad Abu-Akel and Simone Shamay-Tsoory, "Neuroanatomical and Neurochemical Bases of Theory of Mind," *Neuropsychologia* 49, no. 11 (2011): 2971-84, doi.org/10.1016/j.neuropsychologia.2011.07.012.

thorough analysis of individual and collective disorders, traditions, practices, cognitions, and consciousness, to be matched and designed to develop a non-violent perspective on social conflict management and resolution processes for interpersonal and intrapersonal relationships on long-term spaceflights.

Hupfeld et al. demonstrated at least two co-occurring patterns during spaceflight involving the effects of microgravity on the brain and behavior called *dysfunction* and *adaptive plasticity*. Evidence has shown that microgravity can have adverse effects including shifting the intracranial fluid, gray matter variations, and white matter decrease, mostly due to sensory and perceptual reconfiguration, reweighting, re-pathing, and neural compensation due to the lack of external stimuli during space flight. This complex analysis of the brain and the subsequent behavioral changes has been described as "Spaceflight Perturbation Adaptation Coupled with Dysfunction."[30] This experience has opened a wider spectrum of possibilities to collect more data on the potential influence of gravity and social dynamics on long-term space travel and post-flight recovery.

The entropic brain hypothesis proposed by Robin L. Carhart-Harris et al. postulates that "the quality of any conscious state depends on the system's entropy measured via key parameters of brain function."[31] The studies analyzed the relationship between rapid eye movement (REM) states, brain waves, and biological brain system dynamics, as the potential configuration and reconfiguration of metacognition, neurological repatterning, neurogenesis and MNS strategic stimulation, energy efficiency and management of the DMN, and its correlation with states of consciousness induced by flow states, sound-waves, meditation, entheogens, psychedelics, and near-death experiences. The findings direct us towards a responsible and ethical design and analysis of psychological and psychiatric treatment with practices and substances that can facilitate access to primary states of consciousness and transcendental experiences.[32] In this regard, ongoing pilot studies carried out by universities and international organizations are analyzing the potential of combining modern psychotherapy with entheogen ancestral ceremonial rituals and traditional healing practices, suggesting significant decreases in the perception of depression and anxiety, PTSD processing, addictive behaviors, familiar and social conflict management, and increased self- and social perception of emotional well-being, belief in accessing expanded states of consciousness, enhanced sensory perceptions of self and cognition, perceived sacred and spiritual experience, feelings of unification with

[30] K. E. Hupfeld, H. R. McGregor, P. A. Reuter-Lorenz, and R. D. Seidler, "Microgravity Effects on the Human Brain and Behavior: Dysfunction and Adaptive Plasticity," *Neuroscience & Biobehavioral Reviews* 122 (2021): 176-89, doi.org/10.1016/j.neubiorev.2020.11.017.

[31] Robin Carhart-Harris, Robert Leech, Peter Hellyer, Murray Shanahan Murray, Amanda Feilding, Enzo Tagliazucchi, Dante Chialvo, and David Nutt. "The Entropic Brain: A Theory of Conscious States Informed by Neuroimaging Research with Psychedelic Drugs." *Frontiers in Human Neuroscience* 8 (2014), doi.org/10.3389/fnhum.2014.00020.

[32] Carhart-Harris et al., "The Entropic Brain."

the whole, sense of profound self-love and the people of the surroundings, finding new purposes for life, and feelings of being part of a pure limitless self and consciousness.[33]

Conclusion

The evidence to date suggests that long-duration travel beyond LEO will present multiple interpersonal and intrapersonal challenges, potentially giving rise to strained social dynamics, as well as psychosomatic and psychiatric illnesses. Before we can live and work on the Moon and Mars, or journey even further out into deep space, we will need to develop medical and psychosocial protocols and procedures that help crew and settlers to survive, adjust, acclimate, and even thrive. To offer optimal psychosocial support on planned missions, it will be necessary to establish an integrated framework that aims to predict, prevent, and resolve critical challenges. To achieve this, the PPTF recommends the following:

1. A meta-analysis of extant empirical evidence and a clear explanation of the predicted changes that result from space travel and the mechanisms that produce the change.
2. The collection and analysis of relevant ancestral and indigenous knowledge.
3. The collection and analysis of relevant historical accounts.
4. The creation of a biopsychosocial predictive model for early deep space and planetary habitation missions for *small crews* based on collated datasets (ancestral and indigenous, ISS, and other extreme terrestrial environments).
5. The use of predictive model(s) to create and test breakthrough mental health advancements and treatments with high ecological validity.

A comprehensive framework and a strategic plan will improve the focus of research and clinical trials and will help to generate effective solutions that look to prevent and mitigate psychosocial issues.

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In the first instance, AN would like to express her appreciation to the authors, who devoted their spare time to write this paper. We would also like to say a heartfelt thank you to Frank White and the team behind the Human Space Program, and to the other members of the PPTF, including Lisa-Marie Persaud, Kevin P. Russell, and Blanka Deroko.

[33] Oscar O'Farrill, "Neuropsychosocial Effects of Ancestral Traditional Practices as Treatment for Symptoms of Anxiety, Depression, PTSD and Addictions, and the Promotion of Emotional Wellbeing and Expanded States of Consciousness," unpublished manuscript, 2022.

Whilst it was not in the scope of this paper to present all of the original findings of the Proto Task-Force, we hope this paper serves as a foundation for members to expand upon.

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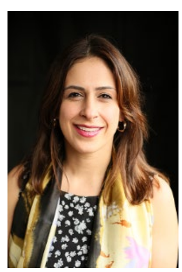
Editors' Notes: In early 2020, Frank White, author of *The Overview Effect*, began hosting a weekly zoom call since dubbed the Overview Roundtable, which has served as a think tank for a diverse group space enthusiasts from a variety of industries. In the summer of 2021, White convened a number of proto task forces made up of members of the roundtable. Each proto task force presented a report to the roundtable. In the fall 2021 *Journal of Space Philosophy* (volume 10 number 2), we published the findings of the Ethics Proto Task Force by Nielsen et al. In this issue, we add two more papers: this report from the Psychology Proto Task Force by Nezami et al. and later in the issue, the Education Proto Task Force Report by Wagner et al. This article on the Psychological Challenges of Spaceflight looks beyond survival and avoiding disease to explore how we might create contexts for humans to thrive—and even achieve peak performance—as we expand beyond our natural habitat on Earth. Medical, psychiatric, and psychosocial elements (including culturally dependent home designs and body language) are all considered in this thorough report. ***Gordon Arthur and Mark Wagner.***

About the Authors



Dr Annahita Nezami, CEO and co-founder of VROE, where she oversees the design, research and clinical aspects. Annahita is an international speaker, researcher and chartered psychologist providing consultation, training and therapy. Her areas of interest include space health and the Overview Effect, wellbeing, neuroscience, trauma, depression, performance, and altered states of consciousness. Annahita serves as an advisor to multiple organisations and was elected as a fellow of the Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA). She has been a guest lecturer at various establishments such as Deakin University, Australia, Central St Martin's, London, and University College, London; she was invited to talk about mental health and the

Overview Effect on BBC Radio 4 and TEDx; and she has published papers and articles with Springer and other media outlets.

Dr David Jeevendrampillai is an Anthropologist of Outer Space. As a research fellow on the ERC funded ETHNO-ISS project, his current research examines the formation of a planetary subjectivity via the view of earth from space. He is interested in the anthropology of the future, technology and modernity, the politics of place and emergent conceptions of the human and the body, particularly in relation to technology and data. His interests encompass but are not limited to discussions on land rights, post-cosmopolitanisms and colonialism. He is interested in bringing together the wide array of academic disciplines involved in space science to engage in critical discussions around outer space.

Sucheshnadevi Patil is a Founder and CEO of Humans in Space! She is currently developing digital health tech products at her startup. She is an NSF I-CORPS Fellow Candidate for 2022 . She was a part of IIAS Scientist-Astronaut Training. Her company, Humans in Space, focuses on building health tech products for a healthy human future on earth and in space at humansinspace.co. She is trained as an engineer and biotechnologist professional and has worked at the world's topmost medical center TMC Houston. She has been a health researcher at Baylor College of Medicine, Houston Methodist Research Institute, and MD Anderson Cancer Center with a passion to advance research into human health and diseases. She has built innovative methodologies and mechanisms for improving health. She has also contributed as a space-health researcher and published a research paper, which she presented in Washington, DC at the International Astronautical Congress on the Genetic Habitability of Exoplanets, worked as a space health researcher collaborator, and studied human health effects psychology and body metabolism in an analog mission at the LunAres Research Station. Her work has been published by South African SpaceOps.

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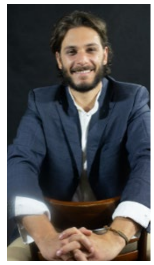
Her research focuses on analog astronautics, space medicine, med tech, human factors, and exponential technologies. She is the CEO of the Mars-Moon Astronautics Academy & Research Sciences (MMAARS), training analog astronauts and building the Mars-Moon Settlement Analog Training Settlement in the Mojave Desert, California. She is CEO of AvatarMEDIC, Inc., which aims to disrupt and democratize healthcare access by converging XR/AR/AI, haptics, robotics and drones. A veteran analog astronaut and commander of multiple analog astronaut missions, she pioneered the first Martian station-to-station simulation training and MMAARS Space Medics training programs. She has commanded missions from low- to high-fidelity locations in Nepal, Antarctica, Africa, and America's Mars-Moon Analog Astronaut Exploration Expeditions project. She trained at the National Institutes of Health (NIH), National Cancer Institute (NCI) in clinical research medicine, drug discovery and molecular therapeutics. She is a graduate of the International Space University and the recipient of a Google Scholarship to attend Singularity University's (GSP15). She founded the Clinic, LLC, an integrated wellness and telemedicine center in Los Angeles, California.



Oscar O'Farrill is a Psychologist from the Universidad Iberoamericana Mexico. He gained an MSc in Cognitive Psychology and Learning at the Latin American Faculty of Social Sciences in Argentina and the Autonomous University of Madrid, and he is an enthusiast for life. He is founder, clinical psychotherapist, speaker, and lead researcher of the Ecosystem for Human Development and Consciousness Studies. He has experience as a consultant in Educational Innovation and Social Development for schools, unschooling projects, NPOs, companies and organizations, collaborating with several research teams in universities such as Newcastle University, UNAM, Universidad de la Plata, Universidad Iberoamericana, and PENT FLASCO. He is a current member of the Psychology Proto Taskforce of the Overview Round Table and the Human Space Program. In the sports field, he has worked as a high-performance psychologist for male and female athletes of various disciplines and ages. He was a player and coach of the National Rugby Team and National Ice Hockey Team, acquiring diverse distinctions as MVP, captain, and leadership roles. He is a musician, singer-songwriter, metaverse psychologist and sound therapist, having performed at various festivals, concerts and workshops in Europe, Mexico, and Argentina.

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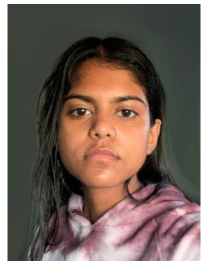
- Neurocognition, expanded states of consciousness and emotional well being.
- High-performance development and sports psychology.
- Artistic expression and flow states of the mind.
- Mind, self and brain theories and quantum physics.
- Space travel, mental health, and mental performance.
- Smart communities for elder care.

Feel free to follow him on social networks to keep in touch: linktr.ee/oscarmetapsychology; calendly.com/capsico-org.



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