**Review Article: Astronaut mental health. Current risks, monitoring, mitigation strategies, and planned research**

**Leon Tannenbaum**

**ABSTRACT:**

As space agencies begin preparations for longer term space missions, addressing the potential mental health problems that can arise in astronauts will become mission critical components for future missions. Early American mental health analysis began during NASA’s Project Mercury, astronauts with certain preferred characteristics; both physiological and psychological, would be labeled as “the right stuff.” No longer are our missions confined to short term flights in LEO (low earth orbit), but rather ones in preparation for a trek to the red planet. This review attempts to address causes and problems associated with the mental health of astronauts, while concluding with monitoring and mitigation strategies and possible avenues of future research. Problems include interpersonal disputes among astronauts, missing family, stress, loneliness, depression. These, among others, are problems already faced by astronauts on the ISS (International Space Station). Naturally there is an expectation that a future lunar or Mars mission would exacerbate these problems. It is vital that we provide our astronauts with mitigation methods such as: on staff psychologists, mixed VR/VR (virtual reality) architecture, adjusted exercise routines, special smells. These developments, while a good step forward, and evidence of progress since the neonatal space psychology research of the Space Race era, it is clear astronauts need more help before a mission to the red planet is appropriate.

**INTRODUCTION:**

Space exploration is very risky. Cosmic rays, micrometeorites, among other things, are constant dangers of human spaceflight. Nevertheless, just as relevant are the within vehicle dangers. Despite their extensive training and preparations, astronauts are still human and can fall victim to the dangers of mental health crises.

Interorganizational endeavors have presented both new opportunities and challenges to mission planners. No longer are space agencies building homogenous teams, but rather across the spectrum, different ethnic, educational, linguistic, national backgrounds. While this provides ample opportunity for joint learning and pride, cultural differences can quickly arise. Consider being an American astronaut on Mir immediately following the Soviet invasion of Afghanistan, flaring tensions could easily derail the mission, or worse bring the superpowers to a new zone of confrontation.

The invention of the semiconductor has brought a litany of new avenues of astronaut health monitoring. Previously, flight surgeons were limited to simple heart rate monitors, cumbersome ground-based machines, and surveys. Currently, mission control use miniature scanners, optical computer recognition technology (from cameras), and other technologies like speech recognition. The future of space monitoring looks to be in the field of advanced biosensors; in-flight data of mental health biomarkers could be vital in helping astronauts mentally survive the hardships of space.

Mitigation techniques encompass both psychological and physiological efforts. Online mental health software modules, modified lighting schemes, occupational therapy, and exercise have all been shown to boost moods in test subjects. As missions become longer and more dangerous, these techniques will need to be used in concert, providing astronauts a fighting chance in ICE (isolated, confined, extreme), environments

The purpose of this literature review is to identify the causes, problems being faced, monitoring methods, and possible solutions to the mental health challenges that astronauts face, and will continue to face in the years ahead. In sifting through academic, government, and industry research this paper will be divided into the four sections labeled in the previous sentence, and attempt to pinpoint the contemporary research, historical context, and ideas for the future to come.

**CAUSES**

**Radiation:**

Space is one of the most extreme environments humans have ever ventured into. Radiation and galactic cosmic rays are two of the deadliest dangers astronauts face. Without radiation shielding, astronauts on a Mars mission of approximately 30 months are exposed to approximately 900 millisieverts of radiation1. This is far above the radiation level that NASA allows its astronauts to be subject to during a career. Dangers of overexposure include carcinogenesis, central nervous system damage, and degenerative tissue damage, 2,3.

**Microgravity:**

Other than a select few, humans spend their entire life in a 1g environment. Understanding the human body’s adaptation to microgravity is imperative to mission success. While there is some research showing that microgravity provides a facilitatory effect on perspective taking abilities 4, it more dangerously: impedes early T-cell activation, alters the organization of the cell cytoskeleton, causes changes in the neuroendocrine system, sleep disruption, and among others, stress 1.

**Non-standard light cycle:**

Orbiting the earth so frequently the ISS is subject to non-24 light cycles. Without appropriate lighting mitigation, non 24-hour light cycles, cause disruption in human circadian rhythms which directly cause sleep deprivation, stress, and increases in workplace error 5.

**Heterogenous Crews:**

No longer are crews only men from one nationality. Men and Women from many different countries have participated in crewed spaceflight. Soviets, Americans, French, Israeli, Japanese, and many others have all come together on missions into outer space. However, astronauts are not made equally. American astronauts and Russian cosmonauts have very different upbringings. Russians value individualism much less than their American counterparts, while Americans are far more extroverted 6. While these differences may seem small at first, over the course of many months in close proximity these differences can blow up. For example, Russians have little concept of privacy, so much so that Russian does not have a word for it 7. In space, without understanding that Americans may simply want to be alone, could lead to sharp conflicts in the crew. In addition, these multicultural crews do not all speak English as a first language. While English has become a lingua franca, Americans must remember that slang and idioms are challenging to ESL speakers and need to be cognizant of the frustration it can place on their international counterparts who may not initially understand them 7.

Unfortunately, sexism still occurs in space 8. The paper referenced in the sentence previously has not documented a direct causality, on why women still face gender and sex bias in space. However, it is important to note, each country has views on gender norms 6,9 and how people should adhere to them, and perhaps it is for this reason that astronauts come to conflict with each other during missions. While there are some noted sex wise differences between men and women astronauts, there is little evidence to show that including women in crews is cause for higher incidences of interpersonal problems amongst crew members 10,11.

**Isolation and Confinement:**

Astronauts are locked in a small space, little areas for privacy, and have infrequent communication with people on Earth. Stress, territorial conflict, social monotony, can run rampant on the stations12. Similarly on earth in submarines or ice bases, common issues that develop are crowding, anger, social withdrawal, decreases in motivation and group cohesion 13.

**Inadequate Clothing:**

Mental health and physical comfort are never reduced when the astronaut has the appropriate apparel14. For astronauts taking part in extra vehicular activities, there are serious dangers from not being appropriately protected. The need for temperature and pressure regulation, radiation shielding, and tethering to the vehicle is vital for astronaut survival. Badly designed ones can directly cause exhaustion and injury2.

**PROBLEMS:**

Astronauts can quickly begin to face mental health stress immediately upon entering space. Microgravity in addition to immune system disruption, can begin to cause sleep disruption and stress 1. Rats subjected to a simulated complex space environment (suspended tail, noise at 65 decibels, 1.5-hour light dark cycles, and confinement) for 21 days began presenting depression like behavior and increased oxidative stress levels15. These problems quickly compound upon themselves. Sleep deprivation can lead in increased risk of accidents 16, while high levels of work pressure among American crews 7 can push astronauts to their mental limits. In earth side analogous studies, subjects in Antarctica who had long term exposure to cold developed changes in thyroid function, show casing as fatigue, depression, and sluggishness 17. It would seem reasonable that this could translate into a spaceflight analog.

The stress inducing nature of spaceflight, whether it be from microgravity, work pressure, or other environmental stressors, immune systems are directly compromised. Continuing studies into space induced immunity reduction have shown reduction in T cell/NK function, elevated plasma cytokine profiles, as well as persistent inflammation 18. Reactivation of herpes virus in space is common. Minimal preflight shedding of the herpes viruses Cytomegalovirus (CMV) and Epstein Barr Virus (EMV) and no preflight shedding of Varicella Zoster Virus (VZV), all demonstrated a marked increase in shedding inflight 18.

Work pressure is high for American astronauts 7. Americans simply haven’t found a way to resolve their high levels through any means yet, even after ISS alternations to make it a more user-friendly environment.

Ironically, long instructions and long manuals can be detrimental to work performance. In highly motivated individuals such as astronauts, unnecessarily long instructions (especially for a simple task) can be considered tedious, leading to frustration and irritation19.

**MONITORING:**

Equally as important as identifying mental health stresses are developing means of monitoring them. Currently monitoring methods include miniature scanners, optical computer recognition, speech recognition, surveys, and monitoring of biomarkers 20.

**Surveys:**

Surveys continue to be a key qualitative to quantitative measurement technique for monitoring of astronaut health. Profile of Mood States (POMS – short form), Visual Analog Scales (VAS), and Social Desirability Scale (SDS – 17), continue to be useful in modern research 21. However, it should be strongly noted that these surveys are not all encompassing, these surveys are quantitative and do not consider whether crew members are underreporting their distress, or if the surveys are appropriate for crew members of different backgrounds 21.

**MITIGATION TECHNIQUES:**

**Exercise:**

Exercise is a practically universally agreed upon as a mitigation technique, anecdotally and evidence based. Anecdotally, astronauts commonly agree that exercise reduces stress and maintains moral 22. A post mission analysis project on recommendations from the Apollo missions documents the explicit need that “exercise is a must.” 12,23

**Change outlook:**

Spaceflight can be an incredibly meaningful experience for those who have the chance to venture. Looking out the windows at the earth is said to be life changing. Astronauts show increases in appreciation for earth’s beauty, greater appreciation for its beauty and fragility 24.

**Virtual Reality:**

Virtual reality (VR) provides means for engaging astronauts in new fashions. In the same fashion that games provide new simulated environments for gamers, astronauts could be transported similarly to new environments. Even a short exposure could reduce stress 13. Mixed virtual reality can be an improvement on traditional VR. By adding special smells to the environment, astronauts can achieve a deeper level of immersion while simultaneously reducing stress levels. In mice with a 28-day hind limb unloading, limonene dispersion for the mice showed relief effects in their memory, learning ability, and physical health declines 25. These immersive, and eventually personalized VR environments could eventually become both new methods for crew training, mental health stimulation, and a new tool for psychological health 26.

**Specialized Architecture:**

Put bluntly, design architecture that is more amenable for astronauts. Habitats should: have enough volume for comfort and efficiency, enough room for storage, be easy to repair, be simple 27. Lighting can be another knob to play with. Cooler light seems to correspond with making future errors and perform multiple tasks at the same time 28. Some recommendations include having non-living areas be at temperatures of 18 degrees Celsius and muffling of noises to below 50-55 decibels; living areas should be at approximately 20-22 degrees Celsius with muffling of noises to below 35-40 decibels 29. Additionally, have the astronauts be part of the preflight design process, this way reasonable preferences can be built into the craft 9.

**Hypnotic Drugs:**

Considering the high level of sleep deprivation in astronauts, despite NASA regulations, use of hypnotic sleep drugs is pervasive 30. These drugs are heavily in use to try and reduce human error due to poor sleep and stress.

**Improved Nutrition:**

“Ideal food cannot ensure psychosocial comfort, while a grandma style pie can.” Space nutrition fulfills multiple roles. The first is clear, provide sufficient nutrients and calories for astronauts to complete their mission31. The second piece is to provide comfort, perhaps a shared bonding experience among the crew. Special dishes could be added to fight homesickness 2.

**Improved medical management:**

Astronauts could benefit from a reprioritization of skills taught or by the addition of an additional crew member to act as a designated medical officer (such as Dr. Leonard McCoy in Star Trek). Medical events are a serious threat to crew well-being and survival. Having specialized crew members to deal with medical issues that arise in space could heavily prevent mental health distress arising from “events not going to plan” 32. It is for this reason there are strong recommendations to have astronauts trained in medical skills or have a doctor/surgeon as a crew member on board33.

**Software:**

Multiple software packages have been tested for use in long manned space missions. Packages like EARTH 34, WinSCAT 35, and an online version of the Cognitive test battery 36 have been shown to be useful monitors of study members and useful enough at providing psychological support software.

**Crew selection:**

Crews are no longer homogenous. Having astronauts with multiple capabilities and strengths lets a litany of different research happen during the same flight. However, to prevent crew member clashing, space agencies need to be prudent about who is selected with each mission. A test battery in development needs to identify knowledge, skills, abilities, and other traits (KSAOs) 37. This will provide a quantitative survey of the abilities each crew has, prevent overlap, and create an international standard with which to compare astronauts.

**Additional Support:**

Astronauts need to have a mental health professional on staff 38. Tension preflight and mid-mission can boil over through pinging or teasing; and can rip apart the cohesion that is necessary for a safe and successful mission. Additionally, spouses could benefit from receiving personalized support, receiving similar care and guidance that military families are provided with who deal with separation and reunion38–40.

**FUTURE RESEARCH:**

**Advanced biosensors:**

As semiconductors become smaller and smaller, tech companies have begun attempting to design labs on a chip. Consider the ability for chips to be able to measure different biomarkers. Abbot Labs has created the i-STAT, that measures pH, pp Carbon Dioxide, electrolytes, glucose, and hematocrit; while MIT is designing a bio suit to measure blood pressure, O2 level, and electrophysiology 41. These devices can be lower weight, volume, and power consuming ways for monitoring astronauts on missions, rather than bringing aboard larger equipment.

**Predicting events:**

Proactive measures could be key in preventing astronauts from ever reaching a dangerous mental event. By testing astronauts in different situations, space agencies can begin predicting probabilities for human mental (or physical) failures for the situations, thereby building mathematical models for an analogous situation in microgravity 42,43. Using some combination of surveys, biosensors, monitors, fuzzy logic; the end goal is to have a viable model that can predict when an astronaut will have a failure point and prevent the mental distress from ever occurring 8,44,45.

**Architecture design:**

New habitat architecture designs can be previewed in the Antarctic 27. There astronauts can decide for themselves over a long period study what types of architectures will work in space, and which will not.

**Brain Stimulation:**

Noninvasive brain stimulation could be a safe way to artificially stimulate positive therapy into affected astronauts. These electrical pulses could, administered in different ways, potentially help train motor learning and non-dominant hands 46. This could either help astronauts train more efficiently, recover after space flight, or mitigate a during-mission event from becoming worse.

**Rewards:**

A novel concept for a reward system is being considered to provide temporal rewards to astronauts who complete novel tasks. The concept is to provide a secret reward inside an egg or a matryoshka doll to be opened at the same time on earth. The hope is to create a sense of non-verbal connection and communication with loved ones on earth, providing some means of well-being to astronauts on long missions away from fast communication with family and friends on earth 47.

**CONCLUSION:**

This paper has been an attempt to try and conglomerate some of the modern astronaut mental health problems and some of their mitigation strategies. Some causes and general mental health problems astronauts face were presented. Mental health monitoring and mitigation strategies were discussed, especially in ways that future space agencies could use in an operational and human performance context. It is clear further mitigation strategy research is necessary, continuing to keep astronauts mentally healthy is vital for mission success, their safe return home, and the continued success of space agencies across the globe.

1. Galts C. Houston, we have a doctor. *UBCMJ*. 2018;9(2):38-39.

2. Bychkov A, Reshetnikova P, Bychkova E, Podgorbunskikh E, Koptev V. The current state and future trends of space nutrition from a perspective of astronauts’ physiology. *International Journal of Gastronomy and Food Science*. 2021;24. doi:10.1016/j.ijgfs.2021.100324

3. Assad A, de Weck OL. Model of medical supply and astronaut health for long-duration human space flight. *Acta Astronautica*. 2015;106:47-62. doi:10.1016/j.actaastro.2014.10.009

4. Meirhaeghe N, Bayet V, Paubel PV, Mélan C. Selective facilitation of egocentric mental transformations under short-term microgravity. *Acta Astronautica*. 2020;170:375-385. doi:10.1016/j.actaastro.2020.01.039

5. Connaboy C, LaGoy AD, Johnson CD, et al. Sleep deprivation impairs affordance perception behavior during an action boundary accuracy assessment. *Acta Astronautica*. 2020;166:270-276. doi:10.1016/j.actaastro.2019.10.029

6. Ritsher JB. *Cultural Factors and the International Space Station*. Vol 76.; 2021.

7. Boyd JE, Kanas NA, Salnitskiy VP, et al. Cultural differences in crewmembers and mission control personnel during two space station programs. *Aviation Space and Environmental Medicine*. 2009;80(6):532-540. doi:10.3357/ASEM.2430.2009

8. Almon AJ. Developing predictive models: Individual and group breakdowns in long-term space travel. *Acta Astronautica*. 2019;154:295-300. doi:10.1016/j.actaastro.2018.04.036

9. Oluwafemi FA, Abdelbaki R, Lai JCY, Mora-Almanza JG, Afolayan EM. A review of astronaut mental health in manned missions: Potential interventions for cognitive and mental health challenges. *Life Sciences in Space Research*. 2021;28:26-31. doi:10.1016/j.lssr.2020.12.002

10. Goel N, Bale TL, Epperson CN, et al. Effects of sex and gender on adaptation to space: Behavioral health. *Journal of Women’s Health*. 2014;23(11):975-986. doi:10.1089/jwh.2014.4911

11. Vakoch DA, United States. National Aeronautics and Space Administration. *Psychology of Space Exploration : Contemporary Research in Historical Perspective*.

12. Palinkas LA, Suedfeld P. Psychosocial issues in isolated and confined extreme environments. *Neuroscience and Biobehavioral Reviews*. 2021;126:413-429. doi:10.1016/j.neubiorev.2021.03.032

13. Salamon N, Grimm JM, Horack JM, Newton EK. Application of virtual reality for crew mental health in extended-duration space missions. *Acta Astronautica*. 2018;146:117-122. doi:10.1016/j.actaastro.2018.02.034

14. Aspelund K. Textile needs and constraints for intravehicular activity in long duration space flight, part 3: Human factors and beyond mars. *AATCC Review*. 2017;17(4):44-49. doi:10.14504/ar.17.4.4

15. Min R, Chen Z, Wang Y, Deng Z, Zhang Y, Deng Y. Quantitative proteomic analysis of cortex in the depressive-like behavior of rats induced by the simulated complex space environment. *Journal of Proteomics*. 2021;237. doi:10.1016/j.jprot.2021.104144

16. Davis J, Burr M, Absi M, Telles R, Koh H. The contributions of occupational science to the readiness of long duration deep space exploration. *Work*. 2017;56(1):31-43. doi:10.3233/WOR-162465

17. Alfano CA, Bower JL, Connaboy C, et al. Mental health, physical symptoms and biomarkers of stress during prolonged exposure to Antarctica’s extreme environment. *Acta Astronautica*. 2021;181:405-413. doi:10.1016/j.actaastro.2021.01.051

18. Crucian BE, Makedonas G, Sams CF, et al. Countermeasures-based Improvements in Stress, Immune System Dysregulation and Latent Herpesvirus Reactivation onboard the International Space Station – Relevance for Deep Space Missions and Terrestrial Medicine. *Neuroscience and Biobehavioral Reviews*. 2020;115:68-76. doi:10.1016/j.neubiorev.2020.05.007

19. Goemaere S, Beyers W, de Muynck GJ, Vansteenkiste M. The paradoxical effect of long instructions on negative affect and performance: When, for whom and why do they backfire? *Acta Astronautica*. 2018;147:421-430. doi:10.1016/j.actaastro.2018.03.047

20. Korovin IS, Klimenko AB, Kalyaev IA, Safronenkova IB. An experience of the cognitive map-based classifier usage in astronaut’s emotional state monitoring. *Acta Astronautica*. 2021;181:537-543. doi:10.1016/j.actaastro.2021.01.022

21. Basner M, Dinges DF, Mollicone DJ, et al. Psychological and behavioral changes during confinement in a 520-day simulated interplanetary mission to mars. *PLoS ONE*. 2014;9(3). doi:10.1371/journal.pone.0093298

22. McKay CD, Standage M. Astronaut adherence to exercise-based reconditioning: Psychological considerations and future directions. *Musculoskeletal Science and Practice*. 2017;27:S38-S41. doi:10.1016/j.msksp.2016.12.011

23. Scheuring RA, Jones JA, Novak JD, et al. The Apollo Medical Operations Project: Recommendations to improve crew health and performance for future exploration missions and lunar surface operations. *Acta Astronautica*. 2008;63(7-10):980-987. doi:10.1016/j.actaastro.2007.12.065

24. Ihle EC, Ritsher JB, Kanas N. *Positive Psychological Outcomes of Spaceflight: An Empirical Study*. Vol 18.; 2021. http://www.ingentaconnect-

25. Lu Z, Wang J, Qu L, et al. Reactive mesoporous silica nanoparticles loaded with limonene for improving physical and mental health of mice at simulated microgravity condition. *Bioactive Materials*. 2020;5(4):1127-1137. doi:10.1016/j.bioactmat.2020.07.006

26. Basu T, Bannova O, Camba JD. Mixed reality architecture in space habitats. *Acta Astronautica*. 2021;178:548-555. doi:10.1016/j.actaastro.2020.09.036

27. Harrison AA. Humanizing outer space: architecture, habitability, and behavioral health. *Acta Astronautica*. 2010;66(5-6):890-896. doi:10.1016/j.actaastro.2009.09.008

28. Ferlazzo F, Piccardi L, Burattini C, Barbalace M, Giannini AM, Bisegna F. Effects of new light sources on task switching and mental rotation performance. *Journal of Environmental Psychology*. 2014;39:92-100. doi:10.1016/j.jenvp.2014.03.005

29. Seguin AM. Engaging space: Extraterrestrial architecture and the human psyche. In: *Acta Astronautica*. Vol 56. ; 2005:980-995. doi:10.1016/j.actaastro.2005.01.026

30. Barger LK, Flynn-Evans EE, Kubey A, et al. Prevalence of sleep deficiency and use of hypnotic drugs in astronauts before, during, and after spaceflight: AN observational study. *The Lancet Neurology*. 2014;13(9):904-912. doi:10.1016/S1474-4422(14)70122-X

31. Sirmons TA, Roma PG, Whitmire AM, et al. Meal replacement in isolated and confined mission environments: Consumption, acceptability, and implications for physical and behavioral health. *Physiology and Behavior*. 2020;219. doi:10.1016/j.physbeh.2020.112829

32. Doarn C, Polk J, Shepanek M. Health challenges including behavioral problems in long-duration spaceflight. *Neurology India*. 2019;67(8):S190-S195. doi:10.4103/0028-3886.259116

33. Robertson JM, Dias RD, Gupta A, et al. Medical Event Management for Future Deep Space Exploration Missions to Mars. *Journal of Surgical Research*. 2020;246:305-314. doi:10.1016/j.jss.2019.09.065

34. Botella C, Baños RM, Etchemendy E, García-Palacios A, Alcañiz M. Psychological countermeasures in manned space missions: “EARTH” system for the Mars-500 project. *Computers in Human Behavior*. 2016;55:898-908. doi:10.1016/j.chb.2015.10.010

35. Connaboy C, Sinnott AM, LaGoy AD, et al. Cognitive performance during prolonged periods in isolated, confined, and extreme environments. *Acta Astronautica*. 2020;177:545-551. doi:10.1016/j.actaastro.2020.08.018

36. Casario K, Howard K, Cordoza M, et al. Acceptability of the Cognition Test Battery in astronaut and astronaut-surrogate populations. *Acta Astronautica*. 2022;190:14-23. doi:10.1016/j.actaastro.2021.09.035

37. Landon LB, Rokholt C, Slack KJ, Pecena Y. Selecting astronauts for long-duration exploration missions: Considerations for team performance and functioning. *REACH*. 2017;5:33-56. doi:10.1016/j.reach.2017.03.002

38. Connors MM, Harrison AA, Akins FR. *Psychology and the Resurgent Space Program*.; 1986.

39. Santy PA. Psychological health maintenance on space station freedom. *Journal of Spacecraft and Rockets*. 1990;27(5):482-485. doi:10.2514/3.26169

40. Program HR. *Evidence Report: Risk of Adverse Cognitive or Behavioral Conditions and Psychiatric Disorders*.

41. Roda A, Mirasoli M, Guardigli M, et al. Advanced biosensors for monitoring astronauts’ health during long-duration space missions. *Biosensors and Bioelectronics*. 2018;111:18-26. doi:10.1016/j.bios.2018.03.062

42. Suhir E. Astronaut’s performance vs. his/hers human-capacity-factor and state-of-health: Application of double-exponential-probability-distribution function. *Acta Astronautica*. 2021;178:250-256. doi:10.1016/j.actaastro.2020.07.017

43. Pang L, Guo L, Zhang J, Wanyan X, Qu H, Wang X. Subject-specific mental workload classification using EEG and stochastic configuration network (SCN). *Biomedical Signal Processing and Control*. 2021;68. doi:10.1016/j.bspc.2021.102711

44. Alfano CA, Bower JL, Cowie J, Lau S, Simpson RJ. Long-duration space exploration and emotional health: Recommendations for conceptualizing and evaluating risk. *Acta Astronautica*. 2018;142:289-299. doi:10.1016/j.actaastro.2017.11.009

45. Stahl G. *Knowledge-Based Armchair Missions to Mars" Using Case-Based Reasoning and Fuzzy Logic to Simulate a Time Series Model of Astronaut Crews*. Vol 9.; 1996.

46. Romanella SM, Sprugnoli G, Ruffini G, Seyedmadani K, Rossi S, Santarnecchi E. Noninvasive Brain Stimulation & Space Exploration: Opportunities and Challenges. *Neuroscience and Biobehavioral Reviews*. 2020;119:294-319. doi:10.1016/j.neubiorev.2020.09.005

47. Lee CH, Balint T. Martian Delight: Exploring qualitative contact for decoupled communications. *Acta Astronautica*. Published online 2021. doi:10.1016/j.actaastro.2021.06.051