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

**ABSTRACT:**

As space administrations 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 a evidence of progress since the neonatal space psychology research of the Space Race era, it is clear that 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**

**Extreme Environments:**

**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 radiation(Galts, 2018). 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, (Bychkov et al., 2021).

**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 (Meirhaeghe et al., 2020), 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 (Galts, 2018).

**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 (Connaboy, LaGoy, et al., 2020).

**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 (Ritsher, 2021). While these differences may seen small at first, over the course of many months in close proximity these differences can blow up. Russians have little concept of privacy, so much so that Russian does not have a word for it (Boyd et al., 2009). 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 (Boyd et al., 2009) In addition, sexism still occurs in space (Almon, 2019). This paper 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 (Oluwafemi et al., 2021; Ritsher, 2021)and how people should adhere to them, and perhaps it is for this reason that astronauts come to conflict with each other .

**Isolation and Confinement**

**Work Pressure**

**PROBLEMS:**

 Sleep deprivation

 Stress

 Depression

 PTSD can come back

Food related hazards

Home sickness

 Decreased crew cohesiveness

Virus reactivations

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 (Galts, 2018). Rats subjected to a simulated complex space environment (suspended tail, noise at 65 db, 1.5 hour light dark cycles, and confinement) for 21 days began presenting depression like behavior and increased oxidative stress levels (Min et al., 2021). These problems quickly compound upon themselves. Sleep deprivation can lead in increased risk of accidents (Davis et al., 2017), while high levels of work pressure among American crews (Boyd et al., 2009) 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 (Alfano et al., 2021). It would seem reasonable that this could translate into a spaceflight analog.

**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 (Korovin et al., 2021).

**Surveys:**

**MITIGATION TECHNIQUES:**

**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 (Ihle et al., 2021).

**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 (Salamon et al., 2018). 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 (Lu et al., 2020). 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 (Basu et al., 2021).

**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 (Harrison, 2010). 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 (Ferlazzo et al., 2014). 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 (Seguin, 2005). Additionally, have the astronauts be part of the pre flight design process, this way reasonable preferences can be built into the craft (Oluwafemi et al., 2021).

**Hypnotic Drugs**

Considering the high level of sleep depravation in astronauts, despite NASA regulations, use of hypnotic sleep drugs is pervasive (Barger et al., 2014).

**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 mission. The second piece is to provide comfort, perhaps a shared bonding experience among the crew. Special dishes could be added to fight homesickness (Bychkov et al., 2021).

**Improved medical management Specialized therapists – pyschologists occupational therapy**

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” (Doarn et al., 2019). Its for this reason there are strong recommendations to have astronauts trained in medical skills or have a doctor/surgeon as a crew member on board(Robertson et al., 2020).

**Software:**

Multiple software packages have been tested for use in long manned space missions. Packages like EARTH (Botella et al., 2016), WinSCAT (Connaboy, Sinnott, et al., 2020), and an online version of the Cognitive test battery (Casario et al., 2022) 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. This is good. Having astronauts with multiple capabilities and strengths lets a litany of different research happen during the same flight. However, in order 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) (Landon et al., 2017). This will provide a quantitative survey of the abilities each crew has, prevent overlap, and create an international standard with which to compare astronauts.

**Rewards**

**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 biosuit to measure blood pressure, O2 level, and electrophysiology (Roda et al., 2018). 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 (Suhir, 2021). 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 (Almon, 2019).

**Architecture design:**

New habitat architecture designs can be previewed in the Antarctic (Harrison, 2010). 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 (Romanella et al., 2020). This could either help astronauts train more efficiently, recover after space flight, or mitigate an during-mission event from becoming worse.

**Rewards:**

**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.