The Hazards of Space to Humans

Before humankind can actively explore space, there are a few things that need to be considered (Grant D. Tays, 2021). Besides the technological capabilities required to have humans in space for longer periods of time, the other part, that is just as vital, is the human factors. Space exploration efforts are being hindered by three significant challenges humans face during long-duration space travel: radiation, physiological changes, and psychological changes.

History

People in space have always had their challenges. It all started with Yuri Gagarin on April 12, 1961. Figure 1 and Figure 2 show images of Yuri showing his military uniforms between 1957 and 1961. Yuri was the first person to orbit Earth aboard Vostok 1. This accomplishment just snowballed into the history of space flight we see today. This led to two big records: the longest continuous time in space and the longest cumulative time in space by any one person. The longest time any one person has spent in space continuously was 438 days. This record was set by Valery Polyakov who stayed aboard the Mir space station from January 1, 1994, until March 22, 1995 (Pearlman, 2015). The record for longest cumulative time in space was set by Gennady Padalka who, to this day, has accumulated 878 days in space over 5 flights (Space Facts, 2023). But this does not come without risks, of course. There are three main categories of risks when it comes to having humans in space: Radiation, Physiological, and Psychological.

Figure 1

Image of Yuri Gagarin

Figure 2

Image of Yuri Gagarin

Radiation Effects

On Earth, humans are typically exposed to 2.4 milli-sievert (mSv) per year from several different places such as the Earth itself, fallout and remnants of nuclear fallout/testing, coal and nuclear plants, x-rays at the doctor's office or hospital, etc. (IAEA, n.d.). In space, astronauts get exposed to a range of radiation amounts depending on the altitude they are at. It can be anywhere from 50 to 2,000 mSv (Perez, 2019). For comparison, 1 mSv is equal to around 3 chest x-rays. Whether it is galactic cosmic rays (GCR) or solar particle events (SPE), space radiation can cause several issues for humans. Some of these include radiation sickness, cancer, degenerative diseases, and lower immunity capabilities.

According to the United States Environmental Protection Agency (2023), radiation sickness is the common name for acute radiation syndrome. For someone to get radiation sickness, the exposure would have to be extensive. Minimally, someone would have to get 75 rad[1] in a somewhat short time interval of minutes to hours to get radiation sickness. On Earth, this is the equivalent of getting 18,000 chest x-rays across your entire body within that time span. Other events that can cause this level of radiation explosion while on Earth are nuclear explosions, highly radioactive material ruptures close by, and accidental handling of radiative material. Being exposed to radiation can cause some long-term effects as well like cancer and cardiovascular disease.

Cancer caused by radiation happens because ionizing radiation damages the DNA within cells. Normally human bodies can repair those damaged cells, but with constant

[1] Rad is the United States' standard measure for radiation units. Internationally, it is Gray (Gy). 1 Gy is equivalent to 100 rads.

exposure (like an astronaut would have in space), that damage is not being repaired. When the cells die, they ultimately become cancerous and end up spreading as cancer does.

Physiological Effects

Physiological effects include a list of risks such as telomeres mutation/shortening, body mass loss, bone density loss, folate increase, inflammation (leading to artery wall thickening), gene mutation, gene expression, protein level instability, hypotension, fluid shifts, and visual impairments. Bone density loss is contributed to being in microgravity specifically. It has been observed that there is a rate of loss around 1 – 1.5% per month while in microgravity (Institute of Medicine, 2014). This is significant because in postmenopausal females (when bone density loss is a common occurrence), the average rate of loss is around 2-3% per year. Mitigation efforts include drinking enough water, diet (focused on nutritional intake), and exercise. Hypotension is thanks to microgravity as well, where blood ends up staying in the upper part of the body. This, by itself, can cause facial edema. As the person returns to Earth and gravity, the blood pools much lower and ends up causing orthostatic hypertension.

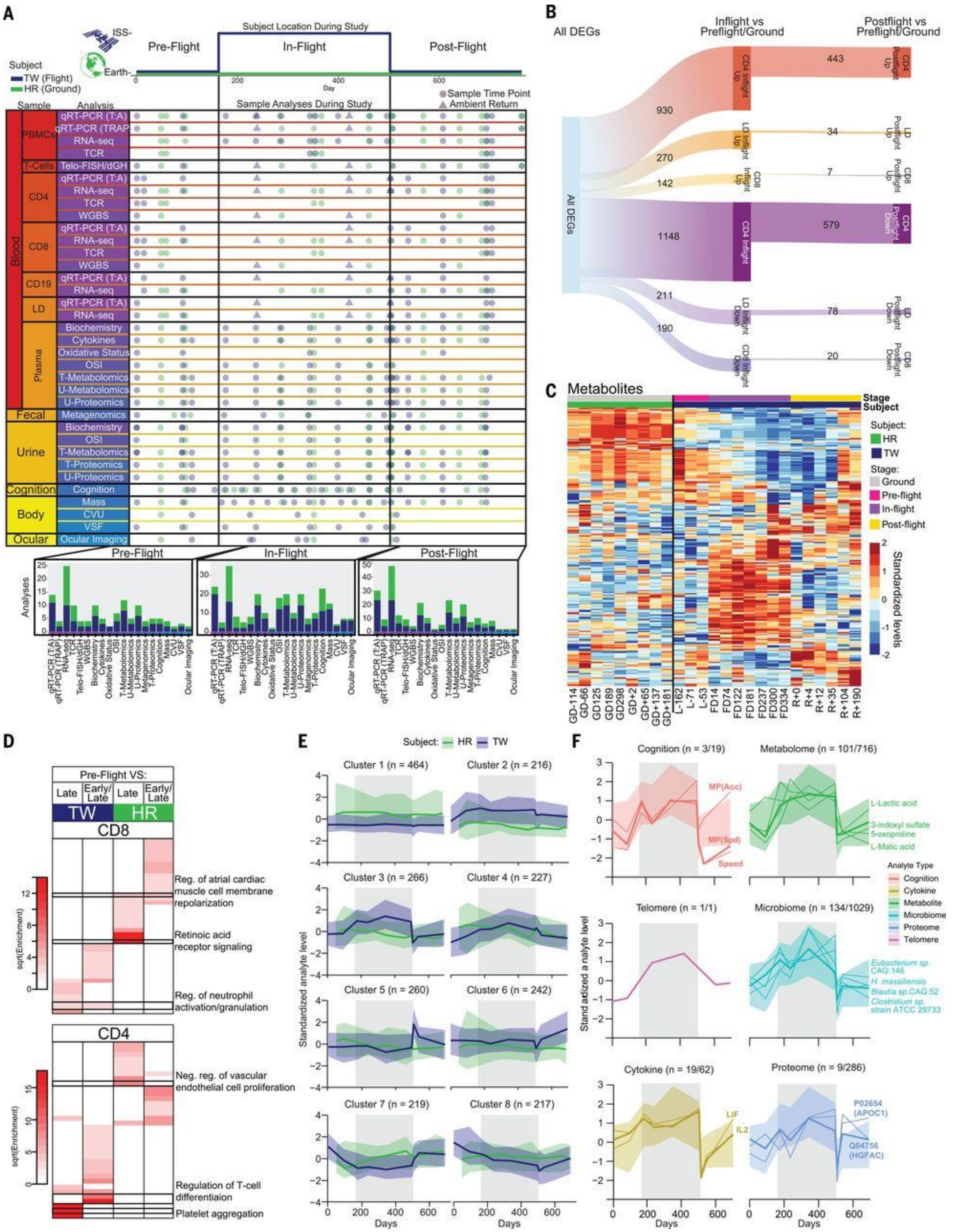
Visual impairments have been documented on multiple occasions both on the International Space Station (ISS) and the Mir Space Station (Institute of Medicine, 2014). Of the collective reports that focus on eye health of astronauts, the overall findings saw that hyperopia (or far-sightedness), scotomas (or blind spots), and papilledema (elevated intracranial pressure) were common occurrences. These were associated with fluid shifts (due to microgravity), diet, radiation exposure, and elevated carbon dioxide levels. To mitigate these visual impairment issues, there has been an extensive research effort by NASA to monitor and combat the after-effects once the astronauts are back on Earth.

Gene mutation, telomere mutation/shortening, and gene expression issues are attributed to radiation exposure primarily. Radiation has a way of getting into cells and either changing them or damaging them. When radiation is not damaging the cells, it is changing them, even if slightly. A great example of this was NASA's Twins Study back in 2016. This study was done with a set of genetically identical twins (Mark and Scott Kelly) over the course of 25 months[2]. What made this an ideal research opportunity was the fact that they were both astronauts. This allowed NASA to study how the human body reacted to spaceflight and being in space for extended periods of time (Parks, 2018). Parks (2018) explained that the data collected and analyzed during the Twins Study (as seen in Figure 3) showed a few important things: telomere lengths changed during a mission[3], decreased body mass while in orbit, increased folate while in orbit, microgravity impacted cognitive functions[4], vaccine immunity was not impacted by the space environment, microgravity increased inflammation within the body[5], microgravity affected the microorganisms within the human gut[6], gene mutations are triggered by spaceflight[7], gene expression relied on certain environments to

[2] The actual time spent in space by one of the twins was 340 days, but they were both monitored for a total of 25 months to get pre-, in-, and post-flight data.
[3] Telomeres lengthen during flight and time in space but rapidly shorten within about 48 hours of coming back within Earth's gravity. This has been hypothesized to be attributed to intense exercise and restricted diet during the mission.
[4] It was hypothesized that the twin that went into space (Scott) had declining cognitive function when returning to Earth due to Earth's gravity.
[5] As seen by blood tests that measured lipids and cytokines.
[6] The biggest difference was a decrease in Bacteroidetes numbers while in space – but they did come back to normal levels upon touchdown.
[7] Test results showed that hundreds of gene mutations were experienced by Scott during the mission. 93% returned to normal after the fact, but a surprising amount of them did not.

Figure 3

Data collected pre-, in-, and post-flight during the 25 months of the NASA Twin Study



react the way they are expected to[8], thickening of artery walls[9], and the regulation of fluids via proteins increased[10].

Psychological Effects

The psychological effects include cognitive effects once out of microgravity, degradation of fine motor function, gross motor function, and hand-eye coordination, dual-tasking, and isolation. As seen in NASA's Twin Study, cognitive function is affected by leaving and reentering Earth's gravity. Another concern is central nervous system (CNS) issues. CNS issues are attributed to radiation exposure, but they tend to cause psychological changes such as degradation of both fine and gross motor functions (Zarana S. Patel, 2020). Hand-eye coordination and dual-tasking capabilities fall under the category of cognitive function – so by extension, they are considered psychological effects. Impacted hand-eye coordination and dual-tasking capabilities can be detrimental to astronauts and the missions they are on.

Isolation is a very broad term for what has ended up being a slightly taboo subject for astronauts up until recent years. There was a reluctance to report certain psychological symptoms for fear of being removed from the mission and future projects (Institute of Medicine, 2014). Despite that, there has always been a consensus that irritability and anxiety are normal occurrences when it comes to isolation issues for astronauts. NASA has made

[8] The two aspects that were unexpected during this part of the study were the gene expressions near the telomere length regulation and collagen production regulation areas.
[9] Unfortunately, it's still unclear if this was due to the space environment or specific to genetics within the individual.
[10] The specific biomarker that was focused on was aquaporin 2. Aquaporin 2 is meant to help regulate water being transferred around within the body which gave indications of hydration status. This was associated to abnormally high levels of plasma sodium (which is a dehydration indictor), but overall, this is hypothesized to be attributed to fluid shifting and ultimately microgravity.

mitigation efforts to recognize and combat psychological side effects attributed to isolation. The mitigation comes in the form of analog missions to monitor isolation effects on the psyche. One specific study in 2014 had six crew members isolate themselves for 520 days to simulate a mission to Mars. This study concluded with one crew member showing depression and mood swings towards the end of the mission, two crew members showing signs of sleep regulating issues which attributed to majority of the conflicts during mission between crewmembers, and the other crew members showing no behavioral or adverse psychological symptoms (Zarana S. Patel, 2020).

Conclusion

Studying and conquering the radiation, physiological, and psychological challenges humans face are vital to our long-duration space travel abilities for the future. Without proper mitigation efforts, long-duration space travel just will not be a viable possibility for humans. Theoretical concepts of artificial gravity have been a topic of conversation when talking about possible long-term space travel without many of the current risks and issues that are seen during missions. Artificial gravity, while the technology is not there yet, is a viable concept when considering that it would negate the risks attributed to microgravity. The only mitigation efforts humanity can truly make when it comes to radiation exposure is advancement of technology and material being used for space crafts and space suits. Neither are easy tasks, but they are at least being considered and studied in hopes of safer space travel for astronauts.

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