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This is Your Brain on Mars: What Space Travel Does to Our Psychology

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What happens to our brains, and our mental health, in space? As the US explores a potential mission to Mars, Nayef Al-Rodhan here looks at what we know so far about the mental and physical impact that space travel can have on the human body, as well as how to counteract it.

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What happens to our brains, and our mental health, in space? As NASA explores a potential mission to Mars, the question has become urgent.

America wants to go to Mars. In October 2016, the US reconfirmed its ambition to send people to the Red Planet by the 2030s. In the spring of 2017, the new US administration **expressed similar ambitions**.

Yet to successfully plan and conduct a mission to Mars, NASA needs to know how space affects human physiology in long-duration space travel.

Scott Kelly—the American astronaut to spend the longest amount of time in space—is helping NASA understand the physiological effects of a zero-gravity confined environment and radiation on the human body and mind.

NASA, which is **hiring astronauts** for its planned manned Mars mission and the International Space Station (ISS), will select candidates based largely on the findings of several on-going studies investigating radiation tolerance and psychological health.

Everything we know in the medical field about the human body and the human brain has been studied in an environment with gravity. Now, we are increasingly presented with the opportunity to study how the human body adapts or reacts to life in outer space.

For over a decade, **NASA's Human Research Program** has been discovering answers about what happens to the human body in space.

What we know so far is that space takes a toll on the human body both physically and mentally, and the risks associated with space travel vary in different environments—for example, between a space station and a spaceship travelling to Mars.

Physical issues include swollen faces (due to the fact that body liquids spread out more evenly), thinner bone density, mineral loss, a lack of sleep and sunlight, increased iron levels and distorted coordination. NASA's Vision Impairment and Intracranial Pressure **project** revealed that many astronauts experience deteriorated vision after missions caused by the affect of weightlessness on the brain and spinal fluid, with effects that can last for years.

According to NASA, astronauts who had spent long periods of time in space reported structural changes to the eye and **abnormally high cerebrospinal fluids** in the brain. Space flight has been demonstrated to squeeze on the fragile tips of the **optic nerves**.

There is also evidence that **galactic cosmic** radiation exposure increases an astronaut's**risk of heart disease**, cancer, central nervous system disorder and acute radiation syndrome, and that the **risk may be worse than previously thought**.

A paper in *Scientific Reports* showed that astronauts travelling to the moon were **four times more likely** to die of a cardiovascular disease compared to astronauts who flew beyond the Earth's protective magnetosphere.

The **estimates** showed that the dose of galactic cosmic rays irradiation to which Low Earth Orbit (LEO) and Apollo Lunar astronauts were exposed were not significantly different; however, there were differences in the absorbed dose due to the effects of the Earth's magnetosphere, which insulates the harmful effects of galactic cosmic rays.

In addition, scientists are increasingly investigating psychological issues related to space travel. Astronauts who will travel to the deep space destinations—Moon, Mars and beyond—will be typically isolated in a hostile and stressful environment with just a few others, without the option of returning to Earth or a quick rescue.

A series of high-profile incidents have flagged the importance of these issues. In 1976, the Soviet Soyuz 21 mission was halted after a "shared delusion" among crew members, who reported a suspicious odour that could never be identified.

In 1985, the Soviet Soyuz T14-Salyut 7 mission came to an **abrupt end** most likely due to factors of depression. In 2007, Lisa Nowak, an astronaut who had flown on the Discovery shuttle to the International Space Station, had a public outburst of rage and was diagnosed with a **brief psychiatric disorder** and depression.

Yet space flight also has positive psychological effects. An extensive **empirical study** published in 2006 listed some of the positive impressions of those who had travelled to space: a sense of appreciation and wonder at the Earth's beauty and fragility, improved interpersonal relations, and spirituality.

Life on Mars

So what really happens to our brains in space?

NASA's **Spaceflight Effects on Neurocognitive Performance** experiment compares astronauts' brains before and after living on the ISS for six months, using fMRI scans. Scientists found a reduction in the connectivity of motor and vestibular areas—essential in movement—after long space flights.

In zero-gravity environments the brain continues to send signals to the body as if it were in normal gravitational conditions. Sometimes, the body begins to think it is falling or upside down due to receiving signals from the inner ear or head fluid with no visual input to confirm the feeling.

After some time the brain more or less adjusts to the new environment, but back on Earth, the relaxation of reflexes can cause prolonged problems.

NASA is also conducting a **Behavioral and Performance Program**, which attempts to identify, characterize and prevent behavioral health issues linked to space travel. The study uses comparable situations on Earth—such as putting groups of people in isolation for extended periods of time—to investigate sleep and fatigue, team cohesion issues and possible adverse psychiatric conditions.

In 2014, a John Hopkins study found evidence of **cognitive impairment** as a result of the conditions that astronauts are exposed to, especially cosmic radiation which constantly bombards those in space. A **study** conducted by Andrew J. Wyrobek from University of California, Berkley, and Richard Britten from the Eastern Virginia Medical School showed that bombarding rats with high-speed graded doses of iron atoms disrupted their spatial memory.

In October 2016, a **UC Irvine-led study** found that exposure to galactic cosmic rays could induce long-term cognitive problems for astronauts, including chronic dementia. Several tests, which exposed rodents to fully ionized oxygen and titanium particles, found that the animals were suffering from both brain inflammation and reduced neural interconnectivity, even six months after initial exposure.

The animals also performed poorly in memory tests, demonstrating heightened anxiety and fear, with reduced ability to unlearn stressful and unpleasant associations.

These findings have understandably sparked concerns over the planned voyage to Mars, as astronauts will find themselves outside of Earth's magnetic field, which protects astronauts working aboard the ISS. They could face elevated levels of stress and anxiety, alongside impaired decision-making and multitasking capabilities—potentially in emergency situations which require an extremely high degree of autonomy.

This series of findings is corroborated by **other experiments**. At the Loma Linda University, a team of five researchers conducted experiments in which mice had their hindquarters hoisted off the ground for extended periods of time, and were also placed in the proximity of radioactive cobalt to mimic low level and constant exposure to gamma radiation.

The results of the experiment showed that the combination of these two procedures damaged the blood-brain barrier (which has a function to block most substances in the bloodstream from reaching the brain) more than if the brain had been exposed to only one of the procedures.

One protein in particular revealed these conclusions: the aquaporin-4, a water-regulating protein which increases in quantity when the blood-brain barrier is affected. Interestingly, there were also some behavioural changes that resulted from the increase in aquaporin-4, namely a higher tendency for risk-taking behaviour.

These issues pose a problem for NASA. Spaceships provide very limited protection from cosmic rays, which are only stopped by mass and can **pass through the hull of a spacecraft** and the skin of those on board.

Fitting an entire spaceship with a protective outer shield would not be financially viable. The idea of shielding an isolated part of a spaceship where astronauts spend a lot of time has been floated, which could feasibly resolve part of the problem.

Even so, astronauts would still be vulnerable to **solar particle events**, which are not easy to predict.

Manipulating astronauts' brains

One of the difficulties in studying the effects of space on astronaut cognition—specifically cosmic radiation—is that many factors affecting astronauts stem from a stressful spaceship environment. These factors include issues such as disrupted sleep, heavy mental workloads, high levels of carbon dioxide and microgravity. On average, astronauts sleep less than **6 hours** a night, and must concentrate and exercise for several hours per day.

A typical round trip to Mars will last about three years, meaning that astronauts will be confined to a small space with a group of people for an extremely long time, with no possibility to conduct real-time discussions with Earth teams, family and friends.

This can lead to conflict, depression and cognitive decline. There is also a concern that astronauts travelling to Mars will lack the comforting view of Earth currently seen on space station missions, which could increase psychosocial stresses and augment feelings of isolation. For these reasons, the **National Space Biomedical Research Institute (NSBRI)** is developing several additional research projects aimed at predicting behavioural problems and the best responses to them in space.

Efforts are being made to design both enhancement medication and therapeutic software to mediate the negative psychological effects that space can have on astronauts.

Computer programs are being developed to help astronauts cope with depression and conflicts on board the spaceship, including "problem-solving treatment" which makes astronauts analyze why they feel certain negative emotions such as animosity or stress.

Mind-enhancing supplements, which could improve memory, mood and energy, are being tested.

Pear Therapeutics, Inc., a biotechnology company, is working on a **project** that combines psychoactive medications as well as therapy software to address depression and cognitive functions. (Of course, lighter workloads and private communication with families back home can also serve as crucial mood improvers.)

Yet the use of cognitive enhancement psychoactive drugs has far-reaching consequences—and raises some ethical problems. While decreasing fatigue or stress can improve astronaut performance, it is an artificial remedy for emotions humans are endowed with as a result of **thousands of years of evolution**.

It is uncertain what consequences such tinkering could have—especially in the hypothetical situation where an astronaut develops an addiction, or is overmedicated.

In a situation where astronauts learn to resolve their interpersonal conflicts only with the help of computer therapy and psychoactive drugs, it also becomes difficult to predict what could happen if these services were disrupted. Would the astronauts be able to cooperate and keep working efficiently for months if they grew dependent on such therapies?

Space agencies are now increasingly striving to boost team performance by other means, such as by increasing crew sizes and diversity. NSBRI's are conducting **a unique study** devoted to investigating various leadership styles and team composition.

Into the future

Because space travel has captivated the imagination of humanity for centuries, having the possibilities and resources to send humans into space for longer periods of time is hard to resist.

These attempts will only multiply the research and questions into neuroscience and human physiology—and the ways in which our minds and bodies adapt to environments so remote and different from Earth, where our entire evolutionary history took place.

They will also lead to the consideration of more expensive technical solutions, such as the recourse to artificial gravity for Earth-Mars and Mars-Earth transfers, with faster travel (although costly in term of energy, it would be possible to reach Mars in less than three months), and comfortable large underground living facilities on Mars.

But if technology can ease the issues, it cannot solve the most important and basic questions about travel and life in environments so different from the ones to which humans have been accustomed since their emergence on the surface of their native planet Earth.

In the process, endeavours to travel to, and inhabit, distant planets will raise unprecedented questions in theology, ethics and **philosophy**, as well as environmentalism. The human capacity to venture out of the limits of this Planet is certainly going to raise some further questions about our own moral limitations, our relationship to Earth, and the notion of humanity itself.

About the Author

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