Medical Xpress

Study unveils changes in the brain during extended missions in space

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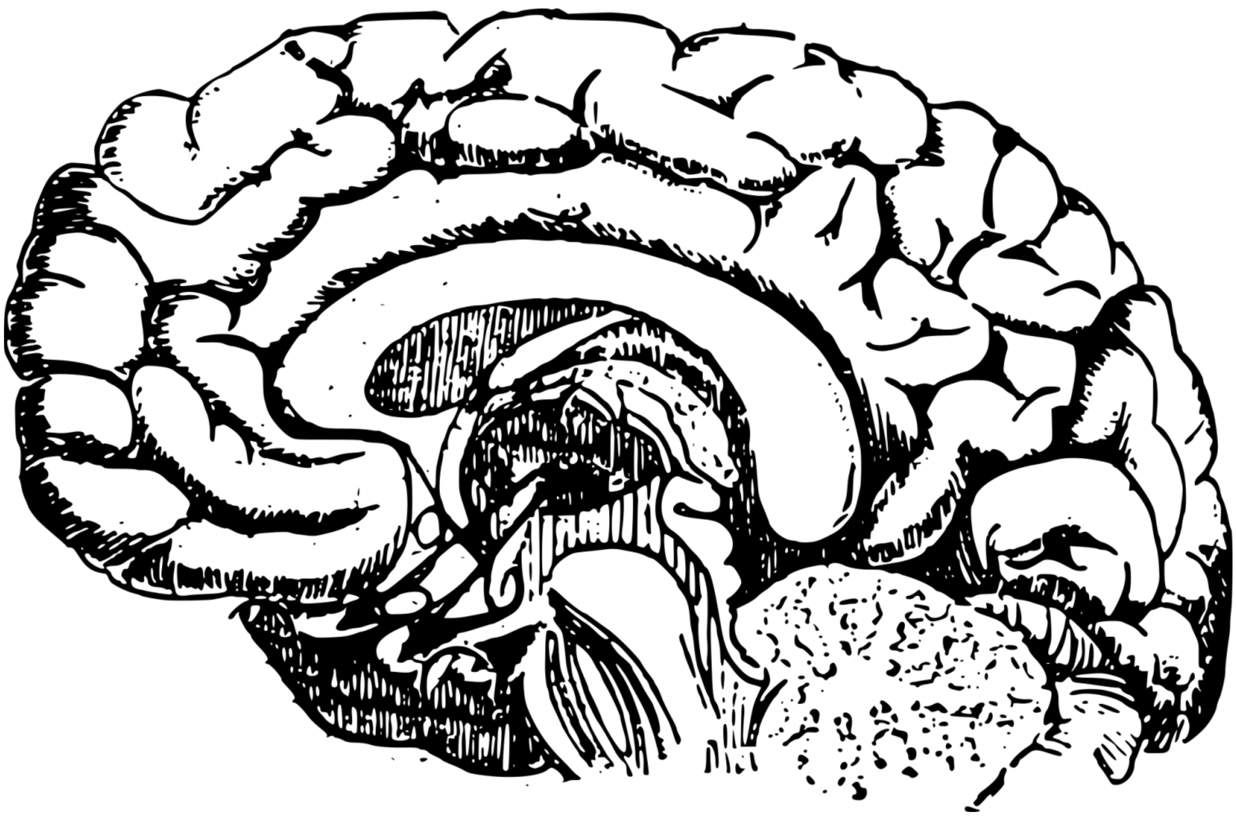

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It's been 55 years since NASA astronaut John Glenn successfully launched into space to complete three orbits aboard the Friendship 7 Mercury spacecraft, becoming the first American to orbit the Earth. The evolution of spaceflight, advancements in science and technologies and the progress of public-private commercial partnerships with companies such as Space X and Blue Horizons have strengthened NASA's goals and the public's confidence to move forward in discovery and human exploration.

More people today are poised to explore space than ever before; those who do will experience the effects of microgravity on the human body. Recognizing the need for data related to those effects, MUSC neuroradiologist Donna Roberts, M.D., conducted a study titled "Effects of Spaceflight on Astronaut Brain Structure as Indicated on MRI," the results of which will be featured in the Nov. 2 issue of the *New England Journal of Medicine*.

"Exposure to the space environment has permanent effects on humans that we simply do not understand. What astronauts experience in space must be mitigated to produce safer space travel for the public," said Roberts.

While living and working in space can be exciting, space is a hostile environment and presents many physiological and psychological challenges for the men and women of America's space program. For example, NASA astronauts have experienced altered vision and increased pressure inside their heads during spaceflight aboard the International Space Station. These conditions can be serious problems for astronauts, particularly if they occur in low-earth orbit aboard the International Space Station or far from Earth, such as on an exploration mission to Mars.

To describe these symptoms, NASA coined the term visual impairment intracranial pressure syndrome, or VIIP syndrome for short. The cause of VIIP syndrome is thought to be related to the redistribution of body fluid toward the head during long-term microgravity exposure; however, the exact cause is unknown. Given safety concerns and the potential impact to human exploration goals, NASA has made determining the cause of VIIP syndrome and how to resolve its effects a top priority.

Roberts is an associate professor of radiology in the Department of Radiology and Radiological Sciences at MUSC. Before attending medical school at MUSC, she worked at NASA Headquarters in Washington, D.C. Working with NASA's Space Life Sciences Division in the early 1990s, she was already aware of the challenges astronauts faced during long-duration spaceflights. She was concerned about the lack of data describing the adaptation of the human brain to microgravity and proposed to NASA that magnetic resonance imaging (MRI) be used to investigate the anatomy of the brain following spaceflight.

Roberts suspected subtle anatomical changes in the brains of astronauts during spaceflight might be contributing to the development of VIIP syndrome, based on her earlier work. From 2001 to 2004, Roberts led a three-year NASA-funded bed rest study, collaborating with other life sciences researchers at the University of Texas Medical Branch in Galveston. A South Carolina native, Roberts had just completed a two-year neuroradiology fellowship at the University of California at San Francisco.

For this study, she examined the brains and muscular responses of participants who stayed in bed for 90 days, during which time, they were required to keep their heads continuously tilted in a downward position to simulate the effects of microgravity.

Using functional MRI, Roberts evaluated brain neuroplasticity, studying the brain's motor cortex before, during and after long-term bed rest. Results confirmed neuroplasticity in the brain occurred during bed rest, which correlated with functional outcomes of the subjects.

As Roberts evaluated the brain scans, she saw something unusual. She noted a "crowding" occurrence at the vertex, or top of the brain, with narrowing of the gyri and sulci, the bumps and depressions in the brain that give it its folded appearance. This crowding was worse for participants who were on longer bed rest in the study.

Roberts also saw evidence of brain shifting and a narrowing of the space between the top of the brain and the inner table of the skull. She questioned if the same thing might be happening to the astronauts during spaceflight.

In further studies, Roberts acquired brain MRI scans and related data from NASA's Lifetime Surveillance of Astronaut Health program for two groups of astronauts: 18 astronauts who had been in space for short periods of time aboard the U.S. Space Shuttle and 16 astronauts who had been in space for longer periods of time, typically three months, aboard the International Space Station. Roberts and her team then compared the brain images of the two groups of astronauts.

Roberts and study investigators evaluated the cerebrospinal fluid (CSF) spaces at the top of the brain and CSF-filled structures, called ventricles, located at the center of the brain. In addition, the team paired the preflight and postflight MRI cine clips from high-resolution 3-D imaging of 12 astronauts from long-duration flights and six astronauts from short-duration flights and looked for any displacement in brain structure.

Study results confirmed a narrowing of the brain's central sulcus, a groove in the cortex near the top of the brain that separates the parietal and frontal lobes, in 94 percent of the astronauts who participated in long-duration flights and 18.8 percent of the astronauts on short-duration flights. Cine clips also showed an upward shift of the brain and narrowing of the CSF spaces at the top of the brain among the long-duration flight astronauts but not in the short-duration flight astronauts.

Her findings concluded that significant changes in brain structure occur during long-duration space flight. More importantly, the parts of the brain that are most affected - the frontal and parietal lobes - control movement of the body and higher executive function. The longer an astronaut stayed in space, the worse the symptoms of VIIP syndrome would be.

Roberts compared these findings with a similar medical syndrome experienced by women called idiopathic intracranial hypertension (IIH), which affects young, overweight women who present with symptoms similar to VIIP syndrome: blurry vision and high intracranial pressure with no known cause. A common treatment for IIH is to perform a lumbar puncture, whereby CSF is drained using a needle placed in the lower back - a procedure performed by a neuroradiologist such as Roberts. Presently, there is no protocol to perform a lumbar puncture in a microgravity environment.

To further understand the results of the study, Roberts and the team plan to compare repeated postflight imaging of the brains of astronauts to determine if the changes are permanent or if they will return to baseline following some time back on Earth. With NASA's Mars expedition mission set to launch in 2033, there's an urgency for researchers such as Roberts to collect more data about astronauts and understand the basics of human space physiology.

A journey to Mars can take three to six months, at best. In order to reduce travel time between the Earth and Mars, the two planets need to be aligned favorably, which occurs approximately every two years.

During this two-year time period, crew members would remain on Mars, carrying out exploration activities. The gravity on Mars is approximately one-third that of Earth. Considering travel to and from Mars, along with the time on the surface, the Martian expedition crew would be exposed to reduced gravity for at least three years, according to Roberts. What would that do to the human body? Could a human even survive that long in a reduced gravity environment?

NASA astronaut Scott Kelly spent 340 days living and working aboard the International Space Station, and astronaut Peggy Whitson recently completed a 288-day mission in space. To date, the longest continuous time in space was 438 days, a record held by Russian cosmonaut Valery Polyakov.

"We know these long-duration flights take a big toll on the astronauts and cosmonauts; however, we don't know if the adverse effects on the body continue to progress or if they stabilize after some time in space," Roberts said. "These are the questions that we are interested in addressing, especially what happens to the human brain and brain function?"

Study co-author and Department of Radiology and Radiological Science colleague Michael Antonucci, M.D., agreed. "This study is exciting in many ways, particularly as it lies at the intersection of two fascinating frontiers of human exploration - space and the brain."

"We have known for years that microgravity affects the body in numerous ways," he continued.

"However, this study represents the most comprehensive assessment of the impact of prolonged space travel on the brain. The changes we have seen may explain unusual symptoms experienced by returning space station astronauts and help identify key issues in the planning of longer-duration space exploration, including missions to Mars."

Roberts hopes to continue to collect long-term follow-up data on the astronauts already being studied. In addition, she is participating in a new bed rest study in Cologne, Germany, collaborating with Racheal Seidler, Ph.D., of the University of Florida and the German Space Agency. The study simulates astronauts living aboard the International Space Station, while being exposed to higher levels of carbon dioxide. Carbon dioxide scrubbers aboard the International Space Station clean and filter the air systems throughout the spacecraft, but some CO2 remains. Roberts will evaluate the blood flow to the brain, brain structure and other changes among study subjects.

With her team's hard work and dedication, Roberts hopes to establish MUSC as the go-to institution for further studies in clinical neuroimaging related to space exploration.

Provided by Medical University of South Carolina

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