Space Life Sciences Research Highlights

Studies of Artificial Gravity Yield Insights into Importance of Touch in Motor Control

Research by NASA-supported investigators challenges long-held assumptions about humans' ability to adapt to artificial gravity and provides new insights into the neurological mechanisms of motor control. This work also suggests that people with balance disorders might regain lost function by learning to use light fingertip touch cues.

Artificial gravity sounds like a concept straight out of science fiction. Indeed, fans of the 1968 movie *2001: A Space Odyssey* will recall that artificial gravity was a feature of the rotating spacecraft in the film.

Anyone who has been on one of those amusement park rides in which you spin around at high speed in a circular chamber, are pinned against the wall, and then the floor is retracted, has experienced artificial gravity.

Artificial gravity, however, is much more than a science-fiction plot device or a carnival gimmick. An effective means of creating artificial gravity may be the key to the success of long-term human exploratory missions in space. Research by James R. Lackner, Ph.D., and colleagues at Brandeis University in Waltham, MA, is challenging long-held assumptions about the ability of humans to adapt to and function in an artificial gravity environment.

Artificial Gravity Generates Coriolis Forces

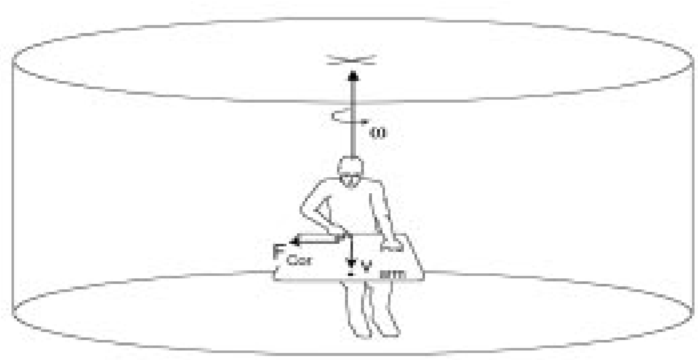
Long-duration space flight causes many changes in the human body. In the absence of Earth's gravity, muscles shrink, bones lose density, the heart pumps less blood, and the brain has to reorganize itself to function without gravitational cues. Experiments have shown, however, that artificial gravity—generated by rotating a spacecraft or a chamber within a space vehicle—may prevent some of these adverse effects.

In a rotating vehicle, the walls of the vehicle constrain objects to move in a circular path. It is this centripetal force exerted on objects by the walls which can be used to simulate the consequences of gravity on the human body. The faster the rate of rotation, the greater the force. The problem is that rotation also generates so-called Coriolis forces—inertial forces that cause moving objects to travel on a curved path rather than in a straight line. Because of Coriolis forces, reaching movements in a rotating environment are curved instead of straight, and moving the head causes motion sickness.

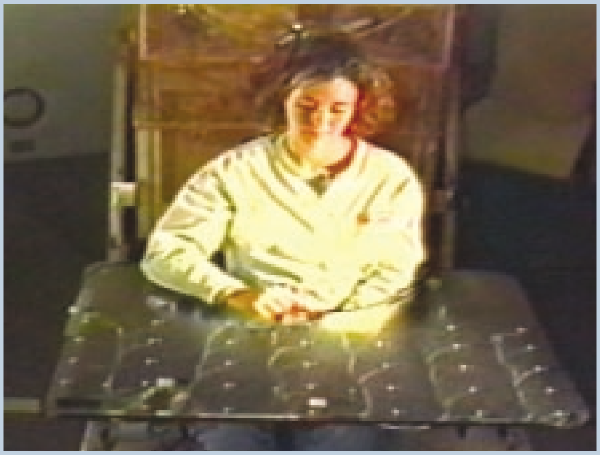
Studies conducted in the 1960s concluded that humans could not adapt to rotation of more than 3 rpm. Higher velocities led to progressively severe fatigue, motion sickness, and difficulty maintaining upright posture. Thirty years later, however, scientists have found that the study of Coriolis forces in a rotating environment provides important insights into the neurological mechanisms of motor control. These new insights have led in turn to renewed interest in artificial gravity.

Humans Can Adapt to Rotation

In a series of experiments performed in a rotating laboratory at Brandeis, Lackner and his associates have shown that humans can adapt to rotation of up to



Schematic illustration of an experiment in the Graybiel Laboratory slow rotation room designed to study adaptation to artificial gravity. The room is rotating (ω) to simulate artificial gravity, and the subject is ready to reach for a target straight ahead on the desktop. This situation permits studying an important side effect of rotating environments, the Coriolis force (F_{Cor}) produced when the arm (or any other object) moves (v) during rotation.



Photographic image of the rotating room. Close-up of the subject ready to perform a reaching movement.

10 rpm if the speed of rotation is increased gradually and if the subject makes repeated movements of the head, arms, and legs at each speed level.

"It turns out that humans can rapidly adapt to Coriolis forces," explains Lackner, director of the Ashton Graybiel Spatial Orientation Laboratory at Brandeis. When subjects can see their movements and they make the same reaching movement repeatedly from the same position, they adapt after about 10 reaches and no longer perceive the presence of Coriolis forces, he reports.

Even when the rotating room is kept dark so that subjects cannot see their reaching movements, adaptation still occurs as long as subjects can make fingertip contact with a surface. "Light fingertip contact is enough to permit adaptation even when subjects are denied visual feedback about their movements," says Lackner. Fingertip contact with a surface may also help astronauts recover more quickly from postural instability, which is common on returning to Earth from space.

Importance of Touch Cues

These studies show that touch is a much more useful source of sensory information than was previously realized, says Lackner. "Fingertips are extraordinarily sensitive devices. We have shown that light fingertip contact cues are profoundly important for stabilizing stance and locomotion and for providing a sense of orientation in weightless conditions. Light touch—at about 40 grams of force, less than a blind person uses to run their finger across a line of Braille—is not forceful enough to stabilize the body, but it *is* enough to send a signal to the brain about the body's position relative to the environment."

The researchers were surprised to learn that everyday movements performed on Earth—such as reaching out with an arm while simultaneously rotating the torso—generate greater Coriolis forces than are produced by reaching movements in a room rotating at 10 rpm. They believe this shows that the brain already compensates automatically for Coriolis forces.

Therefore, adapting to a rotating environment may be far less difficult than was previously thought. It may even be possible to "pre-adapt" astronauts to rotation. "The people who run the experiments in our rotating lab are adapted to rotating and non-rotating environments," notes Lackner. "They go back and forth every day without detriment."

Help for People with Balance Disorders

Light touch cues are also helpful to people with disorders of the vestibular system—the body's balance system—the investigators have found. In the dark or with their eyes closed, people with certain balance disorders have difficulty maintaining an upright position. "But if they are allowed to touch a surface with a fingertip, their stance is just as stable as that of normal subjects," says Lackner.

The investigators are exploring whether training in the use of light touch cues can help restore lost balance function. Because fingertip cues help returning astronauts recover from postural instability, they reason, it may be possible to retrain the brains of people with vestibular dysfunction to respond to fingertip signals.

References

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