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5-María Virginia Pinzón Fernández
6-Nelson Adolfo López Garzón

INFORMATION CIRCULAR: Brain and Microgravity

About the authors:
1. Medical Student- Universidad de Cauca - School of Health Sciences - Department of Physiological Sciences - Corporación Del Laboratorio al Campo (DLC)- Grupo de Investigación en Salud (GIS) Popayán – Colombia.
2. Medical Student- Universidad Nacional de Colombia - School of Health Sciences - Department of Physiological Sciences - Corporación Del Laboratorio al Campo (DLC)- Grupo de Investigación en Salud (GIS) Popayán – Colombia.
3. Nursing Student- Universidad de Cauca - School of Health Sciences - Department of Physiological Sciences - Grupo de Investigación en Salud (GIS) Popayán – Colombia.
4. Doctor-Universidad Javeriana- Department of Physiological Sciences - Grupo de Investigación en Salud (GIS) - Popayán – Colombia.
5. Bacteriologist- Associate Professor- PhD candidate in medical anthropology; School of Health Sciences - internal medicine department - Grupo de Investigación en Salud (GIS) Popayán – Colombia.
6. Internal Medicine - Nuclear cardiologist; - Associate Professor- PhD candidate- School of Health Sciences - internal medicine department - Grupo de Investigación en Salud (GIS) Popayán – Colombia

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Possible acute and late risks to the **central nervous system** (CNS) from galactic cosmic rays (GCR) and solar particle events (SPE) are **concerns for human exploration of space.**

Poor evidence of cerebral alterations exists in the astronauts.
The studies are in animals, with the target to evaluate the astronauts.

The central nervous system risks may include: altered cognitive function, reduced motor function, and behavioral changes, all of which may affect performance and human health. Late CNS risks may include neurological disorders such as Alzheimer's disease (AD), dementia and premature aging.

In the past, the risks to the CNS in adults exposed to low to moderate doses of ionizing radiation (0 to 2 gray (Gy), where 1 Gy = 100 rad or 1 Joule absorbed per kg) have not been a major consideration, as this is the typical dose fraction used in radiotherapy and does not produce widespread cell killing or frank tissue degradation.

The late CNS risks are possible degenerative neurological disorders such as Alzheimer's disease, dementia, and premature aging.

Neuronal loss



Microgravity

Scientists are studying how microgravity will affect developmental signals from the neuron to the muscle. It is possible that gravity is required for the neuron to form functional motor end plates and behave normally.

Crewmembers also experience a disruption in their proprioceptive system, which tells where arms, legs and other parts of the body are oriented relative to each other.

Astronauts in space for weeks to months can run into trouble. Calcium in bones secretes out through urine. As the bones weaken, astronauts are more susceptible to breaking them if they slip and fall, just like people with osteoporosis. Muscles also lose mass.

Microgravity may affect human muscle and spinal cord cells by changing the number of cells during the cell division stage of development or by altering the shape and size during change in development.

Central nervous system risks include changes in Space

- Vigilance and reaction time
- Motor function
- Behavior and mood
- Changes in cognition
- Learning
- Spatial orientation
- Circadian regulation
- Risk decision making
- Processing speed
- Short-term memory

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Spaceflight Effects on Neurocognitive Performance

https://www.nasa.gov/mission_pages/station/research/experiments/1007.html

Vestibular Function- microgravity :

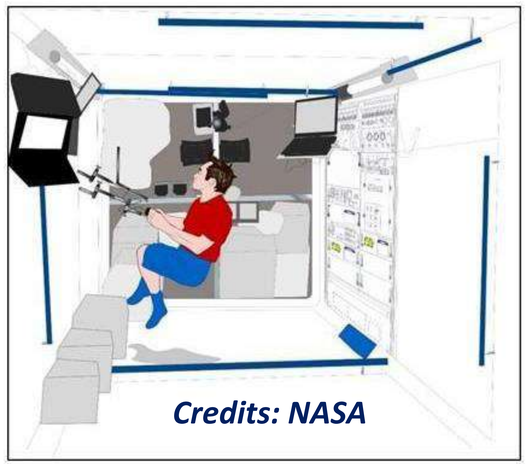
In the weightless environment of space, tilting the head does not stimulate the otoliths. Signals from the otolith organs conflict with the semicircular canals and the visual signals that are being sent to the brain. The microgravity environment of space affects astronauts in significant ways.

In the weightless environment of space, tilting the head does not stimulate the otoliths. Signals from the otolith organs conflict with the semicircular canals and the visual signals that are being sent to the brain.

The microgravity environment of space affects astronauts in significant ways. They may experience dizziness, get space motion sickness, and be unable to differentiate up from down. They sometimes become disoriented because they cannot fully perceive where their limbs are located.

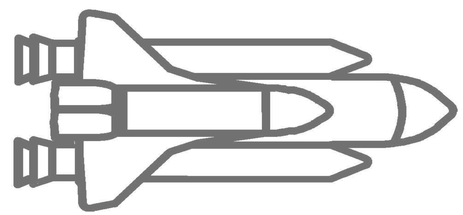
Astronauts experience similar sensations of dizziness and disorientation during their first few days in the weightless environment of space. Upon returning to Earth's gravity, they must re-adapt and frequently have difficulty standing upright, stabilizing their gaze, walking, and turning corners.





Credits: NASA

During spaceflight, the control of movement is altered to account for the fundamental change in gravity. This can lead to motion disturbances and difficulty controlling motion following transitions in gravity levels (e.g., transition to Earth, lunar or Martian surfaces). Spaceflight has also been anecdotally reported to affect cognition.



Spatial Orientation- microgravity:

The process by which we align, or position, our bodies in relation to objects or reference points in a three-dimensional space is called spatial orientation. To maintain this sense of "where we are," our somatic sensory system processes signals from our vestibular, visual, tactile, and proprioceptive (a sense of the movements and positions of the limbs) systems. In space, astronauts must maintain their spatial orientation without the "down" direction signal which gravity provides on Earth.

Astronauts have to adapt to the sensory disturbances produced by microgravity. Some depend heavily on vision, while others orient their bodies in relation to external references, such as equipment racks or the floor of the spacecraft.

Recommended Reading: *NASA (Laurie J. Abadie, Charles W. Lloyd, Mark J. Shelhamer, NASA Human Research Program) - see link:* https://www.nasa.gov/hrp/bodyinspace

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THE WORLD IS WAITING FOR THE RESULTS OF GRIP STUDY.

Scientists are also learning how an astronaut's nervous system may be impacted by different gravitational environments such as the moon, asteroids or planets. The GRIP study from ESA (European Space Agency) is exploring how space residents interact with objects by monitoring their grip and load forces.

Microgravity provides a unique environment to study dexterous manipulation. The grip force/load force coordination is adapted to a 1G Earth environment, and it is observed that grip force control exhibits characteristics such as up/down asymmetries in peak acceleration and grip force, and is maintained during short-term exposure to microgravity during parabolic flight. The GRIP experiment studies the long-term adaptation of grip force/load force coordination (effect of weight vs mass, optimization of movement kinematics and dynamics, and grip force during controlled collisions), and to study the interaction between cognitive and proprioceptive cues, with respect to control of grip force and movement kinematics, for "upward" vs. "downward" movements.

Credits: NASA



NASA Image: ISS056E009784 - Alex Gerst, Expedition 56 Flight Engineer (FE), participates in the GRIP study in the Columbus Module. GRIP is an ESA-sponsored experiment that is researching how the nervous system adapts to microgravity. Observations may improve the design of safer space habitats and help patients on Earth with neurological diseases.

Credits: NASA



NASA Image: ISS056E009783 - Alex Gerst, Expedition 56 Flight Engineer (FE), participates in the GRIP study in the Columbus Module. GRIP is an ESA-sponsored experiment that is researching how the nervous system adapts to microgravity. Observations may improve the design of safer space habitats and help patients on Earth with neurological diseases.

SPACE APPLICATIONS

Data from the GRIP experiments may also be used to identify potential hazards for astronauts as they move between gravitational environments. These studies could also contribute to the design and control of intelligent haptic interfaces to be used in challenging environments such as deep space, planets and their moons, or asteroids.

See the following topics: *Credits: NASA*

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WE RECOMMEND THAT YOU READ THE RESEARCH REPORT THOROUGHLY.

Credits: NASA-

Human Research Roadmap

https://humanresearchroadmap.nasa.gov/Risks/

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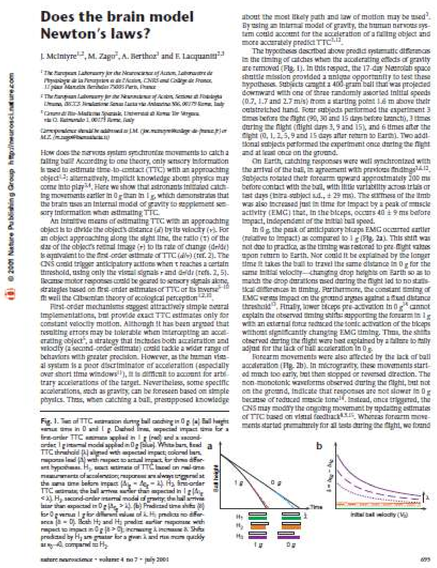

Does the brain model Newton's laws?

J. McIntyre[1,2], M. Zago[2], A. Berthoz[2] and F. Lacquaniti[2,3]

[1] *The European Laboratory for the Neuroscience of Action, Laboratoire de Physiologie de la Perception et de l'Action, CNRS and Collège de France, 11 place Marcelin Berthelot 75005 Paris, France*
[2] *The European Laboratory for the Neuroscience of Action, Setsore di Fisiologia Umana, 00125 Fontalonne Sersa Lucia via Ardeatina 306, 00179 Roma, Italy*
[3] *Centro di Bio-Medicina Spaziale, Università di Roma Tor Vergata, via O. Raimondo 1, 00173 Roma, Italy*

Correspondence should be addressed to J.M. (joe.mcintyre@college-de-france.fr) or M.Z. (m.zago@hsantalucia.it)

How does the nervous system synchronize movements to catch a falling ball? According to one theory, only sensory information is used to estimate time-to-contact (TTC) with an approaching object[1–5]; alternatively, implicit knowledge about physics may come into play[2,6]. Here we show that astronauts initiated catching movements earlier in 0_g than in 1 g, which demonstrates that the brain uses an internal model of gravity to supplement sensory information when estimating TTC.

An intuitive means of estimating TTC with an approaching object is to divide the object's distance (d) by its velocity (v). For an object approaching along the sight line, the ratio (τ) of the size of the object's retinal image (r) to its rate of change ($\dot{r}$) is equivalent to the first-order estimate of TTC (d/v) (ref. 2). The CNS could trigger anticipatory actions when τ reaches a certain threshold, using only the visual signals r and $\dot{r}$ (d/v) (refs. 2, 5). Because motor responses could be geared to sensory signals alone, strategies based on first-order estimates of TTC or its inverse[7–10] fit well the Gibsonian theory of ecological perception[11,12].

First-order mechanisms suggest attractively simple neural implementations, but provide exact TTC estimates only for constant velocity motion. Although it has been argued that resulting errors may be tolerable when intercepting an accelerating object[5], a strategy that includes both acceleration and velocity (a second-order estimate) could tackle a wider range of behaviors with greater precision. However, as the human visual system is a poor discriminator of acceleration (especially over short time windows[13]), it is difficult to account for arbitrary accelerations of the target. Nevertheless, some specific accelerations, such as gravity, can be foreseen based on simple physics. Thus, when catching a ball, presupposed knowledge about the most likely path and law of motion may be used[1]. By using an internal model of gravity, the human nervous system could account for the acceleration of a falling object and more accurately predict TTC[14,15].

The hypotheses described above predict systematic differences in the timing of catches when the accelerating effects of gravity are removed (Fig. 1). In this respect, the 17-day Neurolab space shuttle mission provided a unique opportunity to test these hypotheses. Subjects caught a 400-gram ball that was projected downward with one of three randomly assorted initial speeds (0.7, 1.7 and 2.7 m/s) from a starting point 1.6 m above their outstretched hand. Four subjects performed the experiment 3 times before the flight (90, 30 and 15 days before launch), 3 times during the flight (flight days 3, 9 and 15), and 6 times after the flight (0, 1, 2, 5, 9 and 15 days after return to Earth). Two additional subjects performed the experiment once during the flight and at least once on the ground.

On Earth, catching responses were well synchronized with the arrival of the ball, in agreement with previous findings[14,15]. Subjects rotated their forearm upward approximately 200 ms before contact with the ball, with little variability across trials or test days (intra-subject s.d., ± 29 ms). The stiffness of the limb was also increased just in time for impact by a peak of muscle activity (EMG) that, in the biceps, occurs 40 ± 9 ms before impact, independent of the initial ball speed.

In 0_g, the peak of anticipatory biceps EMG occurred earlier (relative to impact) as compared to 1 g (Fig. 2a). This shift was not due to practice, as the timing was restored to pre-flight values upon return to Earth. Nor could it be explained by the longer time it takes the ball to travel the same distance in 0_g for the same initial velocity—changing drop heights on Earth so as to match the drop durations used during the flight led to no statistical differences in timing. Furthermore, the constant timing of EMG versus impact on the ground argues against a fixed distance threshold[5]. Finally, lower biceps pre-activation in 0_g[3] cannot explain the observed timing shifts: supporting the forearm in 1 g with an external force reduced the tonic activation of the biceps without significantly changing EMG timing. Thus, the shifts observed during the flight were best explained by a failure to fully adjust for the lack of ball acceleration in 0_g.

Forearm movements were also affected by the lack of ball acceleration (Fig. 2b). In microgravity, these movements started much too early, but then stopped or reversed direction. The non-monotonic waveforms observed during the flight, but not on the ground, indicate that responses are slower in 0_g because of reduced muscle tone[16]. Instead, once triggered, the CNS may modify the ongoing movement by updating estimates of TTC based on visual feedback[4,5,17]. Whereas forearm movements started prematurely for all tests during the flight, we found

Fig. 1. Test of TTC estimation during ball catching in 0_g (a) Ball heights versus time in 0_g and 1 g. Dashed lines, expected impact time for a first-order TTC estimate applied in 1 g (red) and a second-order, 1 g internal model applied in 0_g (blue). White bars, head TTC threshold (k) aligned with expected impact; colored bars, response lead (k) with respect to actual impact, for three different hypotheses. H_1, exact estimate of TTC based on real-time measurements of acceleration; responses are always triggered at the same time before impact ($\Delta_0 = \Delta_{0g} = k$). H_2, first-order TTC estimate, the ball arrives earlier than expected in 1 g ($\Delta_{1g} < k$). H_3, second-order internal model of gravity; the ball arrives later than expected in 0_g ($\Delta_{0g} > k$). (b) Predicted time shifts [δ] for 0_g versus 1 g for different values of k. H_1 predicts no difference ($\delta = 0$). Both H_2 and H_3 predict earlier responses with respect to impact in 0_g ($\delta > 0$); increasing k increases δ. Shifts predicted by H_3 are greater for a given k and rise more quickly as $v_0 \to 0$, compared to H_2.

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Risk of Acute (In-flight) and Late Central Nervous System Effects from Radiation Exposure
https://humanresearchroadmap.nasa.gov/Risks/risk.aspx?i=102

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