What is it like to be in weightlessness ?

An episode with Steven Jillings

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Abstract

In this episode, Dr. Steven Jillings reviews the recent progress on the scientific study of conscious experiences in weightlessness.

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The video and audio version of this episode are available on https://aliusresearch.org/bulletin06-jillings-podcast.html

For as long as humankind can remember, we've been astounded by the mysteries of outer space. Major advancements in our understanding of the physical world in the last few centuries have led to technological developments that enable us to travel farther and farther away from Earth's surface. Although many engineering, infrastructural, and physical aspects of space travel have been successfully established, how the human body reacts and copes with such extreme conditions was and still is much less known. Of the various aspects of spaceflight, weightlessness is probably the most remarkable difference experienced by space travelers. Because biological organisms have evolved throughout a long period of time under Earth's gravitational conditions (known as 1G), their anatomical and physiological systems have developed to work optimally within this condition. Humans, therefore, experience a profound change when in weightlessness, both in terms of unconscious physiological mechanisms as well as in terms of subjective feelings.

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Starting from the first human space mission in 1961, a new scientific research domain has emerged to unravel the ways in which the human body reacts and adjusts to weightlessness in order to ensure successful and healthy missions in space. Several approaches to studying the effects of weightlessness on the human body exist. The most obvious way to study the effects of weightlessness is to take measurements of astronauts while they are free-floating during their space mission. Such measurements, however, are restricted to either subjective reports or to measurements with relatively simple equipment that can be transported to space. A second approach is to perform experiments on-ground before and after spaceflight, which has the advantage of access to the full range of laboratory equipment, but has the disadvantage that measurements are not taken in a weightless condition.

A common limitation for both spaceflight experimental approaches is that few people go to space, leading to a slow pace of knowledge gain on the effects of weightlessness on the human body and mind. To overcome this limitation, experimental settings on Earth have been developed to simulate various aspects of spaceflight. One example is parabolic flight, which is the only way to create weightlessness on Earth. This is realized by an airplane making parabolic trajectories, where passengers experience weightlessness for 20-25 seconds during the top part of the parabola (Karmali & Shelhamer, 2008). In this setting, researchers can conduct in-flight experiments, as well as before/after study designs, although the passengers are only weightless for a short consecutive period.

At the start of the free floating phase, disorientation and nausea may occur, which in some cases may lead to vomiting (Young et al., 1984). This is true for both spaceflight and the short-term spells of weightlessness induced by parabolic flight (Glasauer & Mittelstaedt, 1997). Weightlessness can further lead to visual and bodily illusions, such as the inversion illusion, where one's sense of uprightness is lost (Gabriel et al., 1967). The reason for these experiences is that the brain is unable to make sense of conflicting signals coming from the eyes and the vestibular or balance system. On Earth, our vestibular system detects head position changes, which relies in part on the existence of gravity as a vertical reference. As a consequence, humans in weightlessness are unable to distinguish up from down based purely on their senses (Senot et al., 2012).

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It also seems that these altered perceptions are confined to the spatial environment and not to the sense of embodiment. A study in Russian cosmonauts found that 98% of the tested cohort experienced disorientation, while no one reported on altered perception of body ownership or embodiment (Kornilova, 1997). Additionally, the physical laws governed by gravity on Earth are hardwired within our brain to facilitate predictions of object movements in the environment and to generate quick motor responses to interact with the moving object (Indovina et al., 2005; Senot et al., 2012). Sensorimotor functions in a condition where the known laws of physics do not seem to apply will therefore be required to update and adopt new strategies, such as the trajectory of goal-directed arm movements (Gaveau et al., 2011).

Finally, studies using parabolic flight have shown that weightlessness might trigger altered arousal responses based on observing increased stress hormone release and elevated high-frequency neurological activity. On the other hand, after being exposed to several parabolas, a suppression of this neurological activity was found, suggesting that the participant has got somewhat familiar to the state of weightlessness. Prolonged stays in outer space further trigger changes in astronauts' conscious experiences.

Astronauts typically have poor sleep quality due to a floating "position" during sleep (Wu et al., 2018). Accumulation of sleep deficit may then affect high-demanding cognitive tasks and cause mood changes. Despite all these operational difficulties and triggers of the brain's autonomic responses, weightlessness is generally considered to be a profound and fun experience. Sally Ride said she believes experiencing weightlessness, along with viewing the Earth from a great distance, are for any astronaut the most fun aspects of spaceflight (https://kidadl.com/articles/inspirational-astronaut-quotes).

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With the prospect of future long-duration missions to the Moon and Mars, it will be important to understand how different G-levels (1/6G on the Moon and 1/3G on Mars) during such missions influence conscious states and adaptability. A remarkable observation in light of transitions into different gravitational environments are the consistent reports that astronauts who have been to space before adapt more quickly to the space environment (Reschke et al., 1998). Upon return to Earth, these experienced astronauts also acclimatize quicker to Earth's gravity than their novice counterparts. Although there will always be a time window required for adaptations, a period where astronauts are most vulnerable in terms of performance, this observation suggests that human beings are capable of learning to live and work in a space environment. Nevertheless, the unfamiliarity of microgravity and other gravitational states will always have a profound effect on a vast range of brain functions, as the hardwired brain computations that have accumulated and have been optimized throughout one's life on Earth are seriously challenged during spaceflight.

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