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Press release

Minimum effort for maximum effect

Ten days after astronaut Thomas Pesquet take-off into space on the Proxima mission, many questions remain about human adaptation to gravity. The research team at Inserm Unit 1093, "Cognition, Motor Activity and Sensorimotor Plasticity" (Inserm/University of Burgundy), focuses on the manner in which movements that depend on this parameter are performed. For 30 years, it was thought that the brain, when giving motor commands, continuously compensated for the effects of gravity. In this study, the researchers reveal that it uses gravity to minimise the efforts our muscles have to make. These results have been published in *eLife*.

Many human and animal activities need our limbs to move in a precise manner. (Such is the case for professional dancers, who have perfect control of their bodies.) For a movement to be performed correctly, the brain has to generate muscular contractions while taking account of environmental factors likely to affect that movement. One of the most important of these is gravity. The brain develops an internal representation of gravity that it can thus use to anticipate its effects on our bodies. But how does that work? Until now, researchers thought that the brain compensated for the effects of gravity at every moment in order to direct a movement. But the Inserm researchers have proposed a new hypothesis. The brain may use the internal representation of gravity to take advantage of it and save energy.

In order to solve this mystery, the research team asked volunteers to perform arm movements under normal gravity and microgravity conditions. Under normal gravity, 15 volunteers performed right arm movements in 17 different directions.

Each movement was made up of two phases, which determined the total duration of the movement: an acceleration phase (e.g.: raising the arm if the initial trajectory is "upwards") and a deceleration phase (e.g.: stopping the arm on its pathway). This is known as temporal organisation of movement.

If the brain continuously compensated for the effects of gravity, as was thought, the acceleration and deceleration phases would be of constant duration. Under normal gravity, the acceleration or deceleration phase directed by the brain proved to be more or less, depending on the direction of the movement. This observation corroborates the hypothesis that humans have adapted to exploit gravity by modulating the duration of these phases in order to avoid making unnecessary demands on the muscles.

To confirm and validate these results, the researchers simulated weightlessness in an aircraft. The volunteers repeated the arm movements in the 17 directions. While at the beginning of the experiment, the manner of performing the movements was the same as on Earth, the phases of acceleration and deceleration gradually changed in duration.

Volunteer performing movements under microgravity conditions in an aircraft travelling in a parabolic arc

“This observation clearly shows that our brain captures information from the environment, reprogrammes itself and adapts to new gravity conditions,” explains Jérémie Gaveau, first author of this work. Once the brain has understood, it incorporates the new parameters and sends commands that allow movements to be performed with as little effort as possible.

“Comparing these results to those of computer simulations shows sophisticated behaviour on the part of the individual. Indeed, our movements are organised to take advantage of the effects of gravity, in order to minimise the efforts that our muscles need to make,” he concludes.

This is a genuine paradigm shift. This advance might ultimately be used to correctly programme the “brains” of humanoid robots or assist movement in disabled people.

Source

Direction-dependent arm kinematics reveal optimal integration of gravity cues
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