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How the brain controls movement under uncertainty

A new study by neuroscientists at the German Primate Center (DPZ) - Leibniz Institute for Primate Research in Göttingen shows that our brain deals with different forms of visual uncertainty during movements in distinct ways. Depending on the type of uncertainty, planning and execution of movements in the brain are affected differently. These findings could help to optimize brain-computer interfaces that, for example, help people with paralysis to control prostheses or computers with their thoughts alone (Nature Communications).

Imagine waking up thirsty at night and having to reach for a glass of water in the dark. Without a clear view, your brain has to estimate where the glass is and where your hand is - a challenge that often leads to imprecise movements. The brain processes two key pieces of information: It needs to know where the hand is and where to move it. But what happens if this information is inaccurate? Scientists from the Sensorimotor Research Group at the DPZ investigated this problem of visual uncertainty during movement control in their study with rhesus monkeys.

In the experiment, the monkeys moved a cursor on a screen - by hand using a kind of joystick. Two types of uncertainty were investigated: In target uncertainty, the target of the movement was represented by several scattered objects, so that it remained unclear where exactly the target was located. In the case of feedback uncertainty, the cursor was replaced by several scattered, small objects so that it remained unclear exactly where the user's own hand was located. In addition, the researchers tested the effects of feedback uncertainty while the monkeys controlled the cursor through a brain-computer interface, virtually by mere thought. In this case, only visual information is available as feedback about one's own movement, unlike natural arm movements where the body also senses the position of the hand via other sensory systems.

Different effects on movement

The results show that the brain reacts differently to uncertainty: Target uncertainty primarily affects planning and the start of the movement. If the monkeys did not know exactly where the target was, the movements were less precise from the start, i.e., planned imprecisely. This was also reflected in the activity of brain cells in the motor cortex. In contrast, the impairment of movements due to feedback uncertainty was only clearly evident when the monkeys were completely dependent on visual feedback - as in the case of control using a
brain-computer interface. In this case, the feedback uncertainty primarily affected the precise execution of the movement.
The researchers also found that neuronal activity in the motor cortex reflects both target and feedback uncertainty, but that these two forms of uncertainty are processed at different times. This suggests that the brain integrates information about the target and the hand position in different phases of movement control.

Relevance for brain-computer interfaces

The findings could help to improve brain computer interfaces (BCIs). This technology enables paralyzed people, for example, to control prostheses or computers with their thoughts alone. Since users of BCIs usually rely heavily on visual feedback, as this is often all they have at their disposal, they are particularly susceptible to uncertainties in the perception of their own movement. The integration of additional sensory signals could be a promising solution. For example, vibration motors, i.e., tactile feedback, could provide users with additional information about the movement of their hand and compensate for uncertainties. The research group led by Alexander Gail is already continuing the experiments and further developing the research approach as part of the new Collaborative Research Center SFB 1690.

Lukas Amann, neuroscientist in the Sensorimotor Research Group and lead author of the study together with Virginia Casasnovas, explains: "Our results show that the brain can compensate for uncertainty when alternative sources of information are available. This is a crucial factor for improving BCIs, as users are currently often limited to visual feedback. Additional sensory stimuli could help to make the control of neuroprostheses more precise and intuitive."

The study thus provides important insights into how the brain deals with sensory uncertainty - a basis for the further development of technologies that could help people with motor impairments.

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Gripping in case of uncertainty
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