Brain's motor cortex uses multiple frequency bands to coordinate movement

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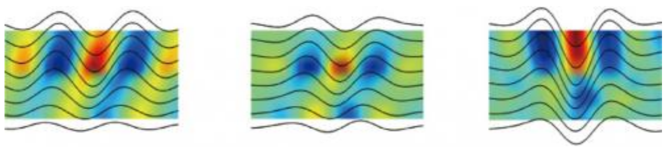

Figure 1: Typical slow gamma (left), fast gamma (center) and theta (right) brain-wave patterns measured during voluntary actions in rats. Credit: J. Igarashi et al.

Synchrony is critical for the proper functioning of the brain. Synchronous firing of neurons within regions of the brain and synchrony between brain waves in different regions facilitate information processing, yet researchers know very little about these neural codes. Now, new research led by Tomoki Fukai of the RIKEN Brain Science Institute reveals how one region of the brain uses multiple brain-wave frequency bands to control movement.

Control of movement requires activation of numerous muscle groups in correct sequence, a function achieved by the motor cortex. To investigate the contribution of brain waves to this process, Fukai and his colleagues inserted multi-channel electrodes into the motor cortex of rats to record brain-wave patterns as the animals learned to push, hold and then pull a lever to obtain a food reward. They also developed a machine-learning technique to extract spike sequences of individual neurons from the recorded waves.

Fukai and his colleagues found that brain waves of different frequencies appeared during distinct stages of the movements. Fast gamma waves, with frequencies of around 100 hertz, were most prominent when the rats pushed or pulled the lever, whereas slow gamma waves, with frequencies of 25–40 hertz, peaked when the rats held the lever to prepare for the next pull. Theta waves (4–10 hertz) peaked while the rats held the lever, and the initiation of the pulling movement coincided with a specific phase of these oscillations (Fig. 1).

Both frequencies of gamma waves were coupled to the theta waves such that the peaks of all three brain-wave frequencies occurred at the same time. The activity of different types of nerve cells in different layers of the motor cortex was also synchronized with specific brain-wave frequencies. Importantly, cells encoding different stages of the sequential movements fired in distinct phases of the theta waves.

The results suggest that theta waves play an important role in coordinating the neuronal activity underlying the planning and execution of voluntary movement. Theta waves are known to be important for the processing of spatial information in the hippocampus, but this is the first time that a similar code has been observed in the motor cortex.

"We are currently using machine-learning techniques to study how phase-locked spikes in different layers of the motor cortex encode motor information," says Fukai. "We are also studying whether a similar oscillatory coordination takes place in the prefrontal cortex during decision-making."

More information: Igarashi, J., Isomura, Y., Arai, K., Harukuni, R. & Fukai, T. "A ?–? oscillation code for neuronal coordination during motor behavior." The *Journal of Neuroscience* 33, 18515–18530 (2013)
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