Creating realistic computational models of the cerebellum

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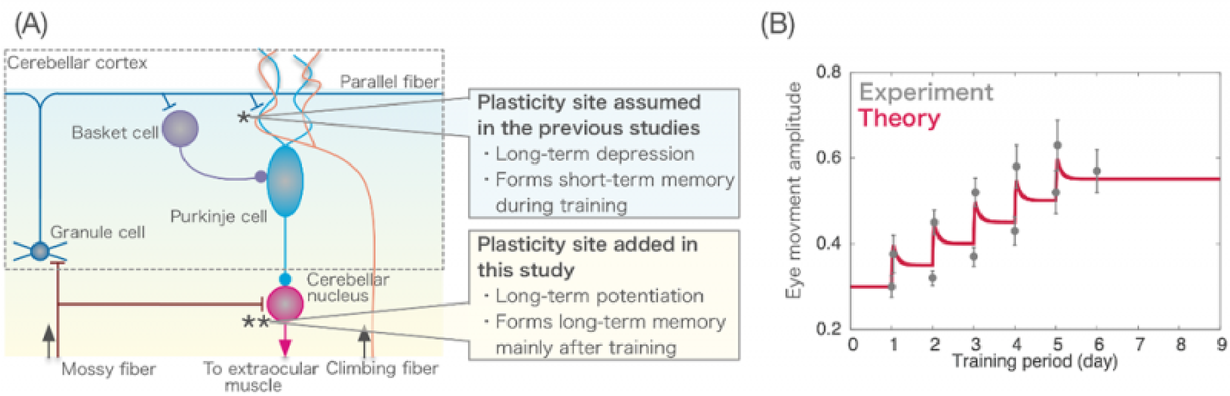

(A) Schematic diagram of the cerebellar circuit in OKR adaptation, an eye movement reflex. We built a theoretical model that incorporates dual plasticity at parallel fiber-Purkinje cell synapses and mossy fiber-cerebellar nuclear cell synapses. (B) Comparison of mouse experiments (gray dots with error bars) and a computer simulation result (red line). Animals are given daily 1-hour training followed by dark rearing for 23-hours. The eye movement amplitude increases by 1-hour daily training and decays naturally after training, indicating the formation of short-term memory. The amplitude also gradually increases day by day, indicating the formation of long-term memory. The horizontal axis represents the training day, and the vertical axis the amplitude of the eye movement. Reproduced from a press release of Ref 2. (http://www.uec.ac.jp/eng/news/announcement/2014/20150226-2.html)

In spite of gigantic advances in medical science over the last century there are still huge gaps in our knowledge of the inner workings of the human brain. For example, how do people in their eighties still remember sights, sounds, and fragrances from their childhood; what are dreams; and why certain people can master many different languages and others have their hands full with just one? Underscoring the deep interest in uncovering the functions of the brain, multi-billion dollar projects have been launched in the USA, EU, and Japan to address these and much deeper aspects of the brain.

Importantly, in the quest for answers to such questions one of the fundamental issues for neuroscientists is developing effective scientific approaches to elucidate the mysteries of the human brain—an organ known for its innate inaccessibility.

At UEC, Tokyo, Tadashi Yamazaki is focusing his efforts on the cerebellum or 'little brain' in Latin. Notably, in terms of relative size, the cerebellum is approximately 10% of the brain but it contains 80% of the neurons. So computational models based on the cerebellum could potentially be effective in describing the functions of the whole brain.

"The functions of the cerebellum are much better understood than the much larger cerebrum," says Yamazaki. "For example we know that the cerebellum plays a major part in coordinating and integrating information from our senses with activation of joints and muscles to produce movement. So in my research I use the wealth of scientific data and information already available about the cerebellum to create realistic computational models of the structure and functions of the cerebellum. Our models provide many insights into how the cerebellum and even the other parts of the brain work for building a complete whole-brain model on a computer."

Recent findings by Yamazaki and colleagues include the use of a graphics processing unit (GPU) to create a 'real time cerebellum' comprising of over 100,000 neurons that trained a robot to hit a ball bowled in real-time [1]. These results are important for robotics research where teaching robots to move precisely is critical for many applications.

Furthermore, in research related to memory, Yamazaki and colleagues created a theoretical model of memory consolidation in the cerebellum. These results offer insights into why 'practice makes perfect' in motor learning, offering an innovative approach to developing new learning methods and intelligent robots [2].

Yamazaki is also pursuing projects with national research institutes and local hospitals in Japan on the development of brain-style artificial intelligence; neuron circuit simulations based on the shapes of cells; and rehabilitation based on the simulation of brain and body movement.

More information: [1] Tadashi Yamazaki et al. Realtime cerebellum: A large-scale spiking network model of the cerebellum that runs in realtime using a graphics processing unit, *Neural Networks* (2013). DOI: 10.1016/j.neunet.2013.01.019

[2] Tadashi Yamazaki et al. Modeling memory consolidation during posttraining periods in cerebellovestibular learning, *Proceedings of the National Academy of Sciences* (2015). DOI: 10.1073/pnas.1413798112

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