Distinguished Fellowship Award Brief

CEREBELLAR SUBSTRATES OF MOTOR LEARNING (2016 - 2018)

Fellow: David J. Herzfeld, PhD, Postdoctoral Fellow

Mentors: Reza Shadmehr, PhD, Professor, Biomedical Engineering, School of Medicine; Xiaoqin Wang, PhD, Professor, Biomedical Engineering, School of Medicine

Research Question: Anyone who remembers being a clumsy teenager knows that we sometimes don't move the way we intend, making a mistaken movement. The oldest region of the brain, the cerebellum, works continuously to correct these mistakes. How does the brain perform this amazing feat?

Interdisciplinary Approach: This project combines two complementary scientific fields: First, the field of motor control, which asks the question: "How do humans learn to move?" Second, this project incorporates neurophysiology, which asks how behavior is related to activity of neurons in the brain. Together, these fields allow us to directly address how the neurons of the brain learn following a movement error.

Potential Implications of Research: People move in surprisingly stereotypical ways. That is, even though there are many different ways to move, all healthy humans tend to move in the same way. This suggests that there is regularity in how the brain learns to move across people. Our goal is to understand how the brain performs this complicated task. If we understand how the brain learns, perhaps we can make people faster learners. These results could provide significant improvements in physical therapy and rehabilitation.

We are constantly making mistakes when we move. However, our brain has the amazing ability to learn from these errors. Whether it's accidently knocking over your coffee cup in the morning or missing the next step on your way up the stairs, the brain is able to learn from these mistakes to improve your movements. How does the brain learn to correct movement mistakes?

Research suggests that the cerebellum, the oldest part of the brain, is responsible for continually updating our movements following a mistake. People with damage to the cerebellum are unable to learn to correct their movement after a mistake, even though they are aware that they made a mistake. These results lead to two yet unanswered questions: How does the activity in the cerebellum contribute to making a movement, and how does this activity change after we make a mistake?

To begin to answer these questions, we focus on the simplest of all movements: movements of the eye. Humans make 2-3 eye movements every second, yet even these incredibly frequent movements often result in mistakes. For instance, if you are fatigued after a long day, your eye may fall short of where your brain intended to look. These movement errors are largely unconscious – your brain corrects for the mistake by generating a second eye movement in a fraction of the second. The cerebellum also learns from this error, unconsciously making the next eye movement a little larger, to correct the mistake.

How does the cerebellum learn? To answer this question, we use techniques from neurophysiology, which measure the activity of neurons directly from the brain of monkeys. In our task, we record from neurons in the cerebellum of monkeys while they correct for movement mistakes. Rather than waiting for the monkey to make a mistaken movement, in the laboratory we can make it appear that the brain made a mistake. In our task, the monkey looks at a dot on a screen. When this dot jumps to a new location, the monkey knows that its job is to make an eye movement to the new target location, tracking the target. However, unbeknownst to the monkey, during its eye movement, we shift the target slightly, making it appear to the monkey's brain that its eye movement over-shot the target. Over the course of many trials, the monkey's cerebellum learns that its normal eye movements are too large, and therefore reduces the size of the eye movement. We are specifically interested in how the neurons of the cerebellum accomplish this task.

In this project, we will record the activity of neurons in the cerebellum while the monkey experiences eye movement errors. By examining how the activity of neurons in the cerebellum changes as the monkey reduces the size of its eye movements, we can begin to answer the question of how the brain learns from error. While we are focused specifically on eye movements, we expect our results to be applicable to a number of different movements such as reaching and walking. By understanding how the activity in the cerebellum changes after an error, it may be possible to teach the cerebellum to learn even faster. Our results may provide a recipe for speeding learning for individuals that require physical therapy or rehabilitation.

For more information, please contact David J. Herzfeld (dherzfe1@jhmi.edu).