How does the brain work? The 100-billion neuron question

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To study aggression in children, Lisa Gatzke-Kopp uses a mobile neuroscience laboratory, equipped with EEG machines and testing equipment. The exterior of the mobile unit is painted with a kid-friendly design.

(PhysOrg.com) -- For centuries, the brain has been the subject of countless philosophical and scientific debates. Recently, many discoveries and theories have cropped up around how the brain works, and those theories are helping us better understand the brain's role in health and behavior.

"There is no scientific study more vital to man than the study of his own brain. Our entire view of the universe depends on it." Francis Crick, co-discoverer of the structure of the DNA molecule and author of that quote, was not alone in his desire to understand the brain, which has 100 billion neurons. For centuries, the brain has been the subject of countless philosophical and scientific debates. Recently, many discoveries and theories have cropped up around how the brain works, and those theories are helping us better understand the brain's role in health and behavior. Several researchers in the College of Health and Human Development work to understand different functions and conditions that are influenced by the brain, including aggression, movement and iron deficiency.

The Neural Center of Aggression

Research has shown that children who exhibit aggressive behavior are at risk for developing violent or other risky behaviors later in life. Many schools have adopted strategies to reduce or prevent aggressive behaviors in children, but these strategies vary in their success. Lisa Gatzke-Kopp, assistant professor of human development and family studies, seeks to understand why intervention strategies can be unsuccessful, and she's looking at the children involved in these interventions to find out.

"There are many factors that can lead to aggressive behavior, and that differs from person to person. This makes treating at-risk children a little tricky," said Gatzke-Kopp. She cautioned that, when it comes to treatment, "one size definitely does not fit all. We don't yet understand how to predict what treatment approach will work best for which child."

Gatzke-Kopp thinks that the answer may be found in understanding more about how individual children's brains respond to the environment. Using electroencephalography (EEG), Gatzke-Kopp is measuring changes that occur in the brain when a child makes mistakes on an assessment test. In adults, there is an almost immediate neurological response that indicates awareness that a mistake has been made. This is critical in the learning process and helps individuals adapt their behavior. If children have not developed this automated brain response to their mistakes, investigators hypothesize that this could increase the risk for developing aggressive or violent behavior.

Gatzke-Kopp also is assessing different cardiac responses when children receive rewards. The responses she’s measuring, such as heart rate variability, are known to be controlled by the brain, so this should provide additional insight into the factors of aggressive behavior. In addition, Gatzke-Kopp is measuring children’s emotional reactivity after viewing a series of emotionally evocative film clips and studying how children react physically to different emotions. This can further the understanding of the systems children use when learning to cope with or control their emotional states.

The aggression intervention Gatzke-Kopp studies is called Promoting Alternative THinking Strategies (PATHS), which was developed by Mark Greenberg, holder of the Edna Peterson Bennett Chair in Prevention Research and director of the Prevention Research Center for the Promotion of Human Development, and Karen Bierman, distinguished professor of psychology and associate director of the Prevention Research Center.

“I hope to find out what’s going on in children’s brains when they don’t respond to interventions,” said Gatzke-Kopp. “Ultimately, we’ll be able to use that knowledge to develop something that works for every child who needs help dealing with their aggressive behavior.”

New Ways of Doing Old Skills

Sometimes, researchers can tell a lot about the brain by looking at a person’s behavior. This approach -- known as behavioral neuroscience -- can show researchers how the brain works. This is particularly handy when figuring out ways to help stroke victims, or people who suffer from brain damage, learn new ways to complete movement tasks they previously had been able to do. That’s exactly the type of work done by Robert Sainburg, associate professor of kinesiology and neurology.

The traditional view of movement is that is controlled by one half of the brain: the right half of the brain controls the left half of the body, and the left half of the brain controls the right half of the body. But Sainburg has a different hypothesis, which he has confirmed in his lab. Both halves of the brain contribute to movement: the left half is responsible for trajectory (the shape and speed of a movement we make) and and the right half is responsible for stabilizing the limb in a given position.

Sainburg has seen evidence of this by conducting experiments that separate those two aspects of movement. He puts his subjects in a virtual reality environment and asks them to complete simple motor tasks, such as moving an arm from point A to point B. People with damage to one half of the brain will exhibit specific deficiencies in these two aspects of movement.

“When we move,” said Sainburg, “we first plan where we want to go, then we translate that plan into muscle activations, which ultimately produce forces and movement. During movement, we also rely on sensory feedback to adjust our movement.” What Sainburg is trying to understand in his experiments is where, in this process, damage to specific brain structures might affect movements.

In some experiments subjects are in a nearly frictionless environment, created with tiny air jets that push against a surface, creating a lift (the same mechanical concept that allows an air hockey puck to glide across a surface).

“This reduced-friction environment has two purposes,” said Sainburg. “First, it allows us to study movements without fatiguing our subjects due to demands of gravity and friction. Second, this makes it easier for us to mathematically model the movement. To account for friction, one would need to place sensors at every point of contact with the table surface.” Sainburg also conducts studies on three-dimensional movements, which do not use air jets.

Based on how a person performs simple movement tasks in Sainburg's lab, he can assess the extent to which brain damage has limited a person's ability to move. Patients with right brain damage tend to have difficulty stopping their movements at a given position, while patients with left brain damage have difficulty controlling the shape and speed of their movements.

Sainburg's goal is to help people regain their ability to move. The next step in the recovery process would be to learn new ways to complete movement tasks. Along with researchers at Penn State Milton S. Hershey Medical Center, Sainburg currently is in the developmental stage of new approaches to learning movement skills.

Restless Mice

You're lying down, getting ready to fall asleep at night, when suddenly you have the unbearable urge to move. Twitch a leg, get up and move, do anything but stay still, your body tells you. So you move and everything seems fine again. However, as soon as you lie down, you feel the urge to move again. This is a common symptom of restless legs syndrome (RLS), and Erica Unger, research associate in the Department of Nutritional Sciences, has been investigating the link between levels of iron in the brain and RLS.

"One of the difficulties when it comes to researching RLS is that you're relying on what people tell you they are feeling," said Unger. In mice, who cannot communicate having an urge to move, the research becomes even more difficult. There is a way around this, though -- by observing patterns of behavior.

The mice Unger looks at share a key similarity as people who have RLS:

each exhibits the same pattern of activity during a given 24-four-hour period. As in humans, most animals' days are broken down into sleeping periods and waking periods. If you graphed the amount of movement an animal makes in a given day, there is a large amount of activity during the animal's awake period, and movement declines as sleep approaches. In RLS patients and the mice that Unger has been investigating, there is a surge of activity before sleep.

Unger and a colleague, Byron Jones, professor of biobehavioral health, found another similarity between these mice and most RLS patients -- they are both iron deficient in the brain. "The iron deficiency observed in the brain appears to be comparable to what we see in the RLS brain. It's remarkable how similar they are," said Unger.

Iron is regulated differently in the brain than it is in the rest of the body. Testing iron levels in someone's hand, for example, would turn up similar results as testing iron levels in that person's foot, but the iron levels in the person's brain could be totally different. The reason for this is because the brain regulates iron levels independent from the body, which also means that taking an iron supplement every day might not be very productive in relieving RLS symptoms. In fact, although people who suffer from RLS show signs of brain-iron deficiency, many do not show the typical hallmarks of iron deficiency outside of the brain.

Unger has been investigating the underlying causes of RLS symptoms and is focusing on how to treat the symptoms observed in the mouse model. Her technique relies on the brain's dopamine system. Dopamine, a chemical in the brain, is important in many daily functions, including learning and sleeping. It also plays a large role in movement, which is how it ties into Unger's research.
The brain creates dopamine regularly, and this process is dependent on iron. In someone with an iron-deficient brain, this process could become disrupted, and actions in the body that are fueled by dopamine can be

affected. Two of those processes, sleep and movement, are affected in people with RLS.

By using this mouse model of RLS, Unger should have a better understanding of not only how RLS can be treated, but how and why the brain regulates iron differently than the rest of the body.

No Simple Answer

As researchers find out more about the brain, it is becoming clearer that there will be no simple answer to the question, "How does the brain work?" However, with their cutting-edge methods and innovative experiments, Gatzke-Kopp, Sainburg, Unger, and several other researchers in the College of Health and Human Development are finding answers to more specific questions centered on brain function. These answers are not only furthering our understanding of the brain, but they are leading to new ways to help people.

Provided by Pennsylvania State University

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