



MOVEMENT AND NEUROSCIENCE

Dance and the Brain

Toes tap, wrists flick, arms extend, but it is the brain that dances. Many parts of the brain act together to turn a body's motion from discrete movements into a fluid, physical art form. Creative dance works are experienced by both the dancer and an audience member. Watching or executing a moment of dance, several regions of the brain may become active: they may speedily calculate spatial orientation, readjust motor signals, or attach emotional responses to the choreography.

Our brains are the directors of our bodies' orchestra of movement, allowing dancers — be they professionals on stages or amateurs in living rooms — to move precisely in time and space. Exactly how the brain manages dance was the topic of discussion at the annual "Dialogues Between Neuroscience and Society" presentation at Neuroscience 2008. Renowned dancer, choreographer, and conductor Mark Morris of New York talked with neuroscientists about the intersection of dance and brain science.

Practice Makes Perfect

Researchers have long sought to discover exactly how exquisite body movement is controlled, learned, and appreciated by others. Morris, who began his dance training at the age of 8, explained that practicing the same steps repeatedly helps decrease the body's response time to create seamless motion in time with music.

"By the time you've done a particular sequence thousands of times it feels like nothing. It's like driving or something where you're just there. You just got there and you don't have to consciously look at your feet," Morris said. "Ideally, dancers aren't thinking 'five six seven eight, now's my entrance,' they just do it. It's the thing where a fish doesn't know it's in water. That's how it is in dancing."

Orchestrated or planned movements start in the motor cortex. This region is divided into sections, with each governing a different part of the body. Signals from the motor cortex travel down 20 million nerve fibers in the spinal cord to an arm or finger, telling it to respond in a particular way. The more minute the movement,

the greater the area in the motor cortex devoted to the movement.

To achieve a rhythmic, well-coordinated style of dance, the brain must coordinate all this effort for joints to act in proper order and muscles to contract to perfect degree. A cluster of brain cells called the basal ganglia plan movement, while the cerebellum takes sensory input from the limbs and refines signals in the cortex to smooth out motion.

A Sixth Sense

Each limb of the body is defined in part by its distance to everything else. The ability to understand our position in space is called proprioception — the sense of how far your arms reach when you stick them out — while kinesthesia is the sense of arms and legs in motion in that space.

This sense of physical self-awareness can extend beyond the body to clothes and props, or even other people. For a trained dancer, Morris said in his Dialogues appearance, such body awareness is like a sixth sense.

"To dance in front of thousands of people you have to have a lot of confidence, and that means a great deal of physical awareness," explained Morris. "You somehow do this calculation of where the



Above: Mark Morris' company partners professional dancers with students who have limited mobility due to Parkinson's disease. The classes enable students to experience new forms of movement and self-expression.



Above: Mark Morris, a celebrated dancer and choreographer, spoke at the Dialogues Between Neuroscience and Society lecture at Neuroscience 2008.

person is behind you. Our broad conception of proprioception is, 'This is me here.'"

The Joy of Dance

Even for individuals who struggle to coordinate the most basic movement, dance is still a superb release and learning experience. The degenerative disorder Parkinson's disease (PD) destroys basal ganglia

neurons, causing tremors, stiffness, and halting movements, hardly the hallmarks of a dancer.

Yet, Dance for PD, a joint project between the Mark Morris Dance Group and the Brooklyn Parkinson Group, offers people with Parkinson's the chance to engage in ballet, tap, jazz, and modern dance exercises. In sessions, patients learn from movement experts how they can use their senses and brains to control movement.

While there is growing interest in understanding how and whether dance could benefit PD patients physiologically, the classes appear to improve mood and concentration. Further insight and advances, however, may yet reveal new treatments for human disorders in different ways, including through dance and rhythm.



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Captivating Rhythm

Rhythm is universal — all over the world, people respond to a steady tempo. Strong beats drive people to dance. Even young children seem to instinctively know how to move to music.

Perhaps we are all so sensitive to rhythm because it drives so much of our biology. Our hearts beat rhythmically, and we wake and sleep to circadian rhythms. These intrinsic rhythms are associated with rhythmic activity in the brain. Perhaps it is fitting that rhythmic brain activity is vital to produce the movements that comprise dance.

Even small changes to these natural rhythms can have dire effects on the whole animal. Diseases like depression and injuries like repeated concussions can throw rhythms off balance, ultimately resulting in changes in cognition, mood, and behavior.

In living creatures, specialized neuronal circuits called central pattern generators (CPGs) produce rhythmic behaviors, like walking, swimming, breathing, and chewing. The cells found in these circuits produce electrical discharges in an “oscillatory” pattern that repeats.

Model Nervous System

Researchers have learned much about CPGs and the rhythmic activity of the nervous system by studying crustaceans, like crabs and lobsters. Compared with most mammals, these animals have simpler nervous systems, so they are attractive models for understanding how neural circuits produce rhythmic behaviors.

Researchers, including SfN Past President Eve Marder, have been particularly interested in the stomatogastric nervous system (STG) in these animals. The STG is the part of the crustacean central nervous system that controls the movement of the stomach. The STG contains about 30 nerve cells that are organized into two different rhythmic CPGs. Researchers have mapped the connections between these cells, and the resulting web-like network can be studied to obtain insights into how larger neural networks function.

Constantly Active

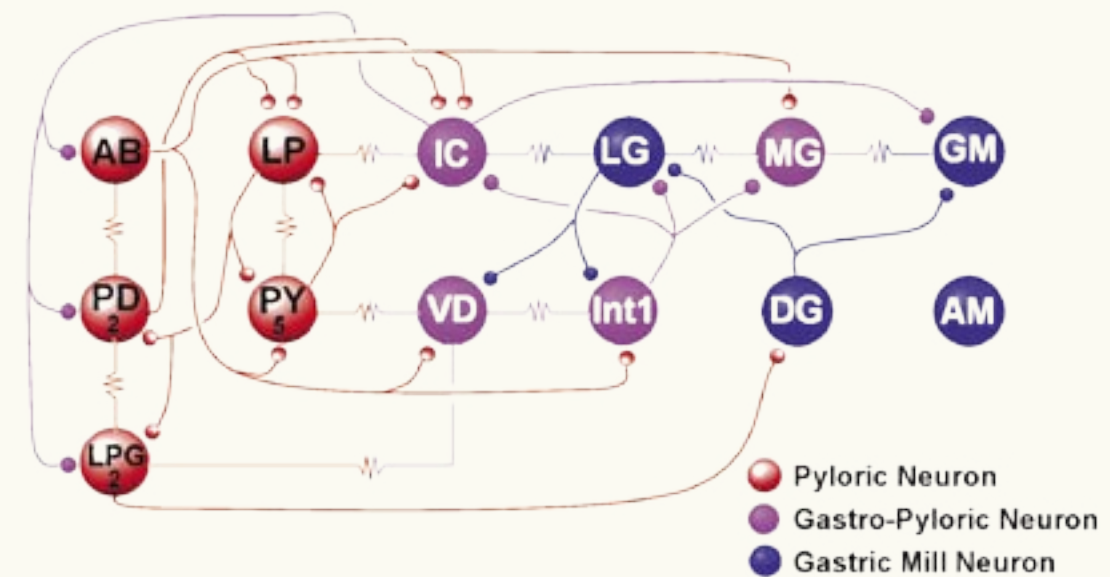
Where does the rhythmic activity of CPGs come from? Even when they are removed from the body, groups of STG nerve cells maintain



Top: Lobsters have simplified neural pathways, which makes them good models to study the circuitry of the nervous system. **Right:** Even in relatively simple nervous systems, brain cells form complex connections. These connections, often illustrated in circuit diagrams, like the one shown here from the crab stomatogastric nervous system, form the foundations for behavior and much of physiology.

their rhythmic firing patterns. These findings demonstrate that the rhythmic activity is intrinsic to the CPG. Rather than wait for something to trigger their activity, these circuits are constantly active.

These crustacean studies reveal an important principle about all neural networks: the nervous system is constantly active. It does not wait passively for a stimulus



to turn it on. The nervous system is active day and night, whether an organism is asleep or awake, although the patterns of activity are different during sleep than when the animal is awake. Research indicates that sensory stimuli modify internally generated activity. For example, the animal’s ingestion of food alters the firing rhythm of STG cells and ultimately increases movement in the stomach. Similarly, the presence of a predator changes CPG firing rhythm, resulting in swimming behavior aimed at escape.

Changing Tempo

Sensory stimuli are not alone in modifying rhythms. Natural and not-so-natural chemicals modify CPG rhythms as well. Dr. Marder’s lab has shown that chemicals called neuromodulators fundamentally alter the activity produced by neuronal circuits so that the circuits can produce different behaviors. For example, one substance might increase a rhythm’s rate and amplitude, while another substance might silence the rhythm.

Because of the network structure of brain circuits, changing the rhythm of one brain cell can influence many others. In fact, throughout the nervous system, individual neural networks interact,

forming one master network web. So, seemingly remote modifications can affect the whole animal.

By showing how small changes in the chemical environment can affect many nerve cells and the behaviors they produce, these studies offer insight into the dramatic effects of disorders like depression. Upsetting the balance of brain chemicals changes the state of brain circuits, profoundly altering mood and behavior.

In studying cellular rhythms in crabs and lobsters, researchers are discovering the mechanisms driving our rhythms — those in dance, thought, and sleep.