Science Education Collection

An Introduction to Motor Control

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Abstract

Motor control involves integration and processing of sensory information by our nervous system, followed by a response through our skeletal system to perform a voluntary or involuntary action. It is vital to understand how our neuroskeletal system controls motor behavior in order to evaluate injuries pertaining to general movement, reflexes, and coordination. An improved understanding of motor control will help behavioral neuroscientists in developing useful tools to treat motor disorders, such as Parkinson's or Huntington's disease.

This video briefly reviews the neuroanatomical structures and connections that play a major role in controlling motion. Fundamental questions currently being asked in the field of motor control are introduced, followed by some of the methods being employed to answer those questions. Lastly, the application sections reviews a few specific experiments conducted in neuroscience labs interested in studying this phenomenon.

Transcript

The control of motor behavior, or how the thoughts in our brains are translated into actions of our bodies, is one of the most important questions that can be asked by behavioral scientists. It is of fundamental scientific interest to understand how our nervous system can perceive and integrate sensory information and elicit a response through our musculoskeletal system. At the same time, an improved understanding of motor control will help us build better tools to help patients with motor disorders.

In this video, you will learn about the neurobiological basis of motor control, the fundamental questions of the field, some of the important experimental techniques, and a few specific applications of these techniques to study motor behavior.

To begin, let's take a look at what scientists currently know about the neurobiology of motor control.

Different parts of our nervous system seem to function hierarchically to control motor behavior. At the top of the neuroanatomical hierarchy is the motor cortex, consisting of the premotor and primary motor area. Coronal section through the motor cortex reveals that the primary motor area projects "upper motor neurons" down the spinal cord to control movements of different parts. Neurons that control specific body parts are localized to the same regions within the motor area, such that a "motor map" of the body can be roughly identified and represented in the form of a "cortical homunculus."

Anterior to the primary motor area is the premotor area, which is proposed to be involved in the control of task-specific complex movements. In addition to directly controlling movement, the premotor area is also suggested to play a major role in motor planning and learning.

Two other areas of the brain may play important integrative roles in motor control: the cerebellum and the basal ganglia. The cerebellum uses information from various sensory systems to fine tune aspects of locomotion, such as rhythm, gait, balance, and posture. It has also been suggested to play a role in motor planning and learning. The basal ganglia, which is rich in connections to the cortex and other parts of the brain, is thought to be involved in selecting one motion out of many to be executed. Major motor diseases, such as Parkinson's and Huntington's, have been attributed to lesions in the basal ganglia.

Further down the motor hierarchy is the brainstem and spinal cord. Upper motor neurons from the motor cortex travel down as the pyramidal tracts, which connects to the lower motor neurons that directly control motion. On the other hand, the extrapyramidal tracts receiving inputs from other brain regions are primarily responsible for modulating aspects of motion such as balance, posture, and coordination.

In addition to receiving instructions from the higher levels, motor neurons coming out of spinal cord are also responsible for the performance of involuntary spinal reflexes, like the knee jerk reflex, where sensory information directly dictates the motor response.

Now that we've reviewed the neural correlates of motor control, let's take a look at some of the major questions in the field of motor behavior.

While there are rough ideas about the roles of various brain regions in motor control, scientists are still trying to figure out what happens to these systems in movement disorders. Specific motor activities being investigated include balance and coordination, as well as dexterity. With improved experimental tools, some scientists are trying to pinpoint the localization of pathological events behind these disorders.

Another major question in the field is: how do our sensory perceptions influence our movements? For example, scientists are trying to understand how visual illusions, or targets with different perspectives, may affect voluntary and involuntary motions. They are also investigating how posture is adjusted when the subject is presented with different visual and motional cues.

Finally, scientists are also interested in studying how motor skills are acquired. This could entail trying to understand the length of time and the kind of feedback that is required to learn a motor skill, and how permanent is the learned skill.

After reviewing some of the main questions of the field, let's look at the experimental tools being used to answer these questions.

Rodents, such as mice and rats, are commonly used to perform tests that assess motor behavior. For example, basic locomotor function can be assessed with treadmill exercises or open-field activities, while having rodents exercise on setups, such as the balance beam and the rotarod, allows motor balance and coordination to be tested.

Alternatively, motor learning can be investigated in rodents using paradigms involving reaching for a food reward. Food handling tasks are also useful for assessing the animal's forelimb dexterity. These behavioral tests can be combined with interventions such as drug administration or surgery, in order to link a motor activity specifically to a particular neurological basis.

Finally, to observe the neurological changes that occur during motor activities, imaging and electrical measurement techniques can be applied. Techniques such as live-cell imaging, electroencephalography or EEG, and electromyography or EMG can be used to measure neuronal and muscle activities while the subject is performing a motor task.

Having looked at some common methods used in investigating motor control, let's discuss a few applications of these techniques.

As mentioned, behavioral tests can be combined with surgically induced injuries to study the link between specific neural lesions and motor behavior. In this study, researchers induced an injury to one side of the cervical spinal cord in rats, and then tested the effects on the animals' limb-use in locomotion and food handling tasks. These experiments help scientists understand the role of specific neural circuits in limb motor activity.

To study the role that sensory information plays in motor control, researchers can perform experiments where they present the subjects with specific sensory cues and observe their effects on motion. In this study, the participant was placed in an environment where the visuals surround and the support surface were programmed to move or sway. The subject's ability to adjust his or her posture and keep balance was then assessed.

Finally, some scientists are developing protocols where multiple modes of data collection are used simultaneously to get a more complete picture of motor control. In this study, scientists combined EEG, EMG, and motion-capture protocols in order to examine neural activity in participants performing real-world motor tasks.

You've just watched JoVE's video on the control of motor behavior. This video reviewed the current neurobiological understanding of motor control, key questions and prominent methods of the field, as well as a few applications of the methods to studying motor behavior. As always, thanks for watching!