How the Emotional Motor System Controls the Pelvic Organs

Gert Holstege, MD, PhD

ABSTRACT

Introduction: The brain has two goals: survival of the individual and survival of the species. It ensures that the body resides in safe circumstances and can obtain sufficient drink and food. It also has to produce and protect offspring. Its most important tool is its motor system, which consists of the voluntary and emotional motor systems.

Aim: To explain how the brain uses its emotional motor system to control the pelvic organs.

Methods: Anatomic and physiologic data in cats and humans are used to find out how this motor system works and what parts of the brain and brainstem are involved.

Main Outcome Measures: Main outcome is that the brain control of the pelvic organs is a specific descending system.

Results: The pelvic organs are innervated by the sacral parasympathetic motoneurons, which are controlled by a specific group of neurons in the pontine brainstem, the pelvic organ stimulating center (POSC). Through long descending pathways, this POSC generates micturition, defecation, and sexual activities by stimulating different groups of sacral parasympathetic motoneurons. In turn the POSC is driven by the periaqueductal gray (PAG), which receives, through the sacral cord, precise information regarding the situation in all pelvic organs. In addition, the PAG receives instructions from higher brain levels such as the amygdala, bed nucleus of the stria terminalis, and various regions of the hypothalamus. Notably, in humans, the most important brain region having access to the PAG is the medial orbitofrontal cortex, which is deactivated in women with hypoactive sexual desire disorder.

Conclusion: In women with hypoactive sexual desire disorder, deactivation of their medial orbitofrontal cortex produces a decrease in PAG-POSC activation, causing absence of vaginal vasocongestion and lubrication and decreased sexual behavior in general. It often leads to major problems in their personal circumstances. The question is whether new drugs can cure this.

Sex Med Rev 2016;4:303–328.

Key Words: Pelvic Organ Stimulating Center; Pelvic Floor Stimulating Center; Periaqueductal Gray; Hypoactive Sexual Desire Disorder; Urge-Incontinence; Parasympathetic

INTRODUCTION

The brain has two objectives: survival of the individual and survival of the species. This is true not only for the total brain but also for the brainstem. The brainstem, including the mesencephalon (midbrain), is a complete brain with somatosensory, auditory (inferior colliculus), visual (superior colliculus), vestibular, and motor systems. Animals in which the cortex and diencephalon are cut off can live on, albeit at a lower level.[1] The cortex cerebri can be considered a copy of the brainstem, also with somatosensory, auditory, visual, vestibular, and motor parts. The olfactory part (smell) was evolutionary developed later and only has access to the cortical and diencephalic parts of the brain. A major difference between the brainstem and the cortex is that the cortex contains a great many more neurons than the brainstem, which enable the various cortical systems to function much more precisely with a much larger amount of memory. This memory allows the individual to interpret much better the impact of the incoming information.

The brainstem and the cortex play a role in the control of the pelvic organs. In this report, the basic systems involved in this control are discussed. Because these systems are part of the basic motor systems in general, these basic motor systems (voluntary and emotional) also are discussed.

Received March 17, 2016. Accepted April 29, 2016.

The University of Queensland, Queensland Brain Institute, Department Asia Pacific Center for Neuromodulation, Brisbane, Queensland, Australia

http://dx.doi.org/10.1016/j.sxmr.2016.04.002

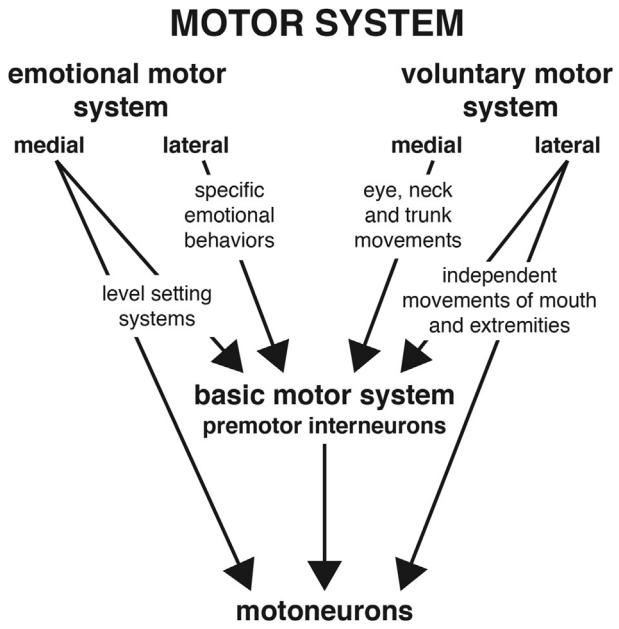

Figure 1. The motor system consists of two subsystems, the voluntary and the emotional motor systems. These subsystems have access to premotor interneurons and motoneurons.

TWO MOTOR SYSTEMS

In all mammals including humans, two different motor systems exist (Figure 1).[2] The voluntary motor system allows the individual to move its body parts voluntarily, whereas the emotional motor system controls basic motor activities such as blood pressure, heart rate, respiration, and the activities of the pelvic organs.

Voluntary Motor System

The most well-known motor system is the voluntary motor system, which in humans mainly originates in the motor cortex. This voluntary motor system consists of medial and lateral components (Figure 1, right).

Medial Component of the Voluntary Motor System

Evolutionarily speaking, the medial component is already present in the caudal brainstem, where the dorsomedial tegmental field controls posture (ie, back and trunk musculature), as found in fish and most other animals without limbs. Control of neck and eye movements also belongs to this medial component and the same system controls the movements of back, trunk, neck, and eyes.[3–5] The motor cortex controlling posture and neck and eye movements can be considered a copy of this system, but with many more neurons. This part of the cortex still uses the same brainstem output system to control basic posture and head and eye movements.

Lateral Components of the Voluntary Motor System

Limbs were a later evolutionary development than the posture control systems, which meant that the motor system controlling limb movements also developed later and became located further rostrally in the brainstem, in the mesencephalon. This motor system is the magnocellular red nucleus, which, through the rubro-bulbospinal tract, has access to the premotor interneurons of the limbs in the spinal cord and to oral muscle premotor interneurons of the facial nucleus in the brainstem.[6] In mammals such as cat and monkey, the red nucleus also maintains direct connections with the motoneurons, but only to a limited extent.[7,8]

The motor cortex in mammals is basically a copy of the red nucleus as far as it projects to the caudal brainstem and spinal cord (ie, the cortico-bulbospinal tract is a similar system as the rubro-bulbospinal tract). The major difference in humans is that the cortico-bulbospinal tract contains many more fibers than the rubrospinal tract in monkeys and other mammals. In humans, the motor cortex maintains direct connections with motoneurons innervating the mouth, face, tongue, arms, hands, and legs. For example, the direct corticospinal connections with the motoneurons innervating the hand muscles enable humans to play the piano, and the direct projections to the mouth, tongue, pharyngeal, and laryngeal muscles allow humans to produce speech (Figure 2, right), a motor activity only possible in this species. The precise movements allowing playing the piano or speech are based not only on the many cortico-bulbospinal fibers but also on the very large number of cortical neurons in the premotor cortex. They can be considered the necessary motor memory for performing very precise movements such as playing the piano or producing speech. The memory neurons for producing speech are known as the *area of Broca.* However, the production of sound is not generated by the voluntary but by the emotional motor system (Figure 2, left).[9,10]

Innervation of the Pelvic Organs

The voluntary motor system does not have direct control of the pelvic organs, but rather, only some control of the striated muscles of the pelvic floor. The pelvic floor motoneurons are located in the nucleus of Onuf, which innervate all parts of the pelvic floor, including the external urethral sphincter and the external anal sphincter.[11–13] Interestingly, the motor cortex cannot contract these muscles separately, but only as a unit. Furthermore, the motor cortex cannot continuously keep contracting the pelvic floor muscles, which means that a strong uncontrolled urge for micturition or defecation cannot be stopped for a long time, leading to urge-incontinence.[14] The real control of the pelvic organs is by the emotional motor system.

Emotional Motor System

The emotional motor system differs completely from the voluntary motor system. An interesting example is mouth movements (Figure 3). Mouth muscles are under very strong control of the voluntary motor system, allowing humans to produce speech.[15] Interruption of the motor cortex projections to the mouth muscle motoneurons leads to an inability to move the mouth, including showing teeth. However, there exists