TOPICAL REVIEW

# Considerations on physiological mechanisms of spinal cord movement performance according to cerebral stimuli

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**Abstract**

**The process of communication between brain and spinal cord remains unclear. Therefore an attempt supported by spinal cord stereotaxy was made to disclose the physiological mechanisms underlying the cooperation between the brain and spine as generated by the spinal cord. The initializing stimulus was the discovery of motoneuron location in all spinal cord segments providing an organic substrate for spinal cord stereotaxy. What remains to be clarified are the anatomical structures of spinal cord, participating in the feedback between brain and spinal cord. Therefore two possible hypotheses were proposed by the authors.**
**One of them is closely related to the analytical synthetical mechanism of real objects and thoughts depiction in the memory of the brain and in form of concrete ideas it forms the basis for concrete thinking.**
**In case of spinal cord another more probable mechanism should be considered: the process of analysis and synthesis between the participating spinal motoneurons. The mutual neuronal spinal cord connections are capable of depicting the movement pattern, and the movement is transferred by means of the described spinal cord pathways to the memory of the brain as a concrete movement idea. From here the ideas are transferred according to the individual needs backwards by means of another described spinal cord pathway back to the spinal cord, and the spinal cord is the final effector.**
**The process of thinking is the physiological correlation of technical software, but in form of abstract thinking it is transferred to the form of abstract thinking. *(Fig. 3, Ref. 7)*. Full Text (Free, PDF) *www.bmj.sk*.**
**Key words: movement mechanism, spinal cord and brain cooperation, spinal cord stereotaxy.**

Spinal cord is an integral part of the central nervous systems assuring the movement performance for all cerebral levels. Therefore it is logical to assume that the realization of movement is elicited by the most diverse stimuli not only from the internal milieau, but especially from the surrounding environment and also on demands established inside the human brain.

However when the spinal cord is interrupted, for instance in case of traumatic injury, the communication between spinal cord and brain ceases and therefore the communication is maintained by ascending and descending connecting neural pathways. The communication has a defined anatomical substance permitting therapeutic intervention in case of functional disturbance affecting the functional structure. Even when minimally invasive surgery is considered, spinal or cerebral stereotaxy should be discussed (1).

Such interventions should be supported by knowledge on spinal cord motor structures, so far not completed.

Based on results of experiments conducted on cats having the same arrangement of the spinal cord as humans it has been proven that spinal cord gray matter was arranged in nine layers defined by the character of neural cells, therefore resembling cerebral cortex. Spinal cord receives stimuli via posterior spinal horns and only a limited amount of stimuli reaches motoneurons directly. These stimuli are probably responsible for antenatal foetal movements similar to spinal reflexes. During individual

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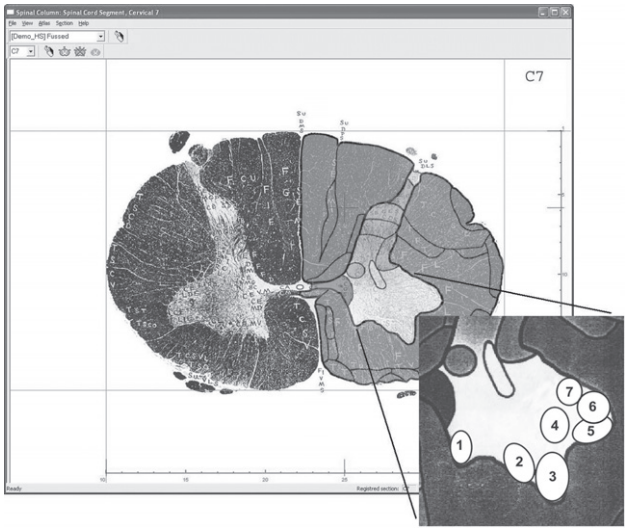


**Fig. 1. The empty area in the anterior spinal cord horn in the prepared topometric map (C7 spinal segment) reflect motoneuron distribution for the individual muscles according to the original experimental study conducted by prof. Čierny. 1 – mm. spinospinales, errectores trunci, 2 – m. serratus anterior, 3 – m. latissimus dorsi, m. teres major, m. subscapularis, 4 – mm. pectorales, m. coracobrachialis, 5 – m. triceps brachii, 6 – mm. extensores carpi et digitorum manus, 7 – mm. flexores carpi et digitorum manus.**

maturation the movement is performed in mediated fashion by neural pathways between brain and spinal cord, and spinal motoneurons control the individual muscles.

Clinical observations enabled to locate the projection of individual muscles to defined spinal cord segments and based on the data from embryonic development Bok (2) to locate extensor muscles to the ventral circumference of anterior spinal horns and flexors to the posterior circmference. But the exact location of motoneurons being appropriate for individual muscles has not been found.

However a precise atlas based on macrohistological slices of the spinal cord has shown (3) that spinal anterior horns contain up to six groups of motor cells, bordered by neural fibers. They were supposed to represent motoneurons functional mission but without further specification.

Not earlier than at the end of the 20th century the research dealing with motoneurons location was finished after several decades and the topographic distribution of motoneurons in cervical and thoracic segments of cat spinal cord has been discovered by means of tigroid motor cells degeneration after the interruption of nerve fibers supplying the individual muscles (4).

These data have supplemented the approximate location of motoneurons in lumbar and sacral spinal cord segments obtained from pathological studies in poliomyelitic patiens (5). After the transfer of these findings into Riley atlas the first complete spinal cord topometric maps for the purposes of spinal cord stereotaxis have been constructed (Fig. 1).

However for the physiological idea about spinal cord movement reaction to the stimuli from higher cerebral levels including the dominant regions the adequate information about the communication between the brain and spinal cord is still missing.

At present it is possible to present two hypothetical pathways of spinal cord function (I, II) similar to the transfer of real object and features of the surrounding world to the brain. From the philosophical point of view this process is considered to be the reflection of the surrounding world in our consciousness. In physiological terms the reflection gains clear shape, for instance a simply defined apple becomes a stimulus for the brain through the visual analyser, and similarly by means of its smell for the olfactory analyser, or by tactile sense when touching its surface, or by means of the sound and taste when biting it.

The individual stimuli are formed in different brain structures, but the cerebral simultaneous synthetic activity connects immediately the excited sites and a virtual picture of the apple is created and subsequently stored in the memory as a concrete idea of a real apple. After its transformation into a more general level it represents an abstract concept,word, substantive, an apple (Fig. 2).

### The 1st hypothetical pathway of spinal cord function

Even though the brain perceives the stimuli from its surrounding by a limited number of sense systems, the set of concrete ideas is immense, as well as the set of movements generated by the spinal cord.

However the movement is transferred into reality by means of muscles, tendons, and joints activity. These structures contain specific receptors and possibly by means of posterior columns ascending the neural pathways the spinal cord transmits analytical information to the brain. The synthetic cerebral activity creates the virtual picture of movement. The picture is stored in memory as a concrete idea and after conditioned transformation it is changed into an abstract concept, a verb,,. Therefore the spinal cord does not only perform the movement, but also depicts it. Due to movement fluency the brain uses successive synthesis, therefore the final depiction resembles a movie. The uniqueness of the movement system enables to name the motoric system more precisely as kinestetic (6). Therefore not only the synthetic structure of a defined movement is stored in the memory, but also the entire sequencies of adapted or acquired movements, expressing the activity in time.

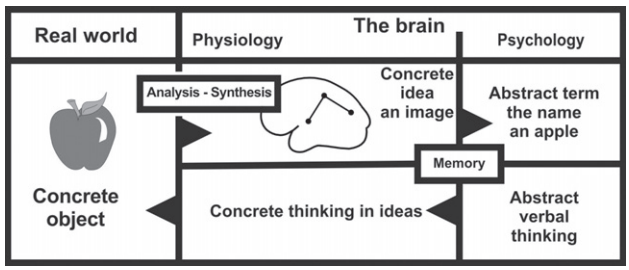


**Fig. 2. With the help of senzory organs brain performs analysis and synthesis of a real object for object depiction. The final image is stored in memory as an concrete idea and after transformation as an abstract term.**

Based on the acquired concrete ideas and abstract concepts stored in memory the brain forms a response to the stimuli meeting the aims and needs of organism by transmitting the signal to the spinal cord via descending pathways so that spinal cord can perform the movements.

The mechanism forming the response to the stimulus is physiologically related to our thinking and in technical terms is probably comparable with software construction. Though distant from reality, abstract thinking is fast, therefore able to recall immediately the principal features of the prepared reaction from the different viewing angles including phantasy (for instance we are going to the summer house) and it is only virtual in brain memory.

Realization of the selected response is completed by concrete thinking in the range of real images, for instance car starting, driving on the road, etc. Concrete thinking is slow, but objective. Both forms of thinking mutually combine one with another, but the corticospinal tract for movement reactions is probably employed only in concrete thinking.

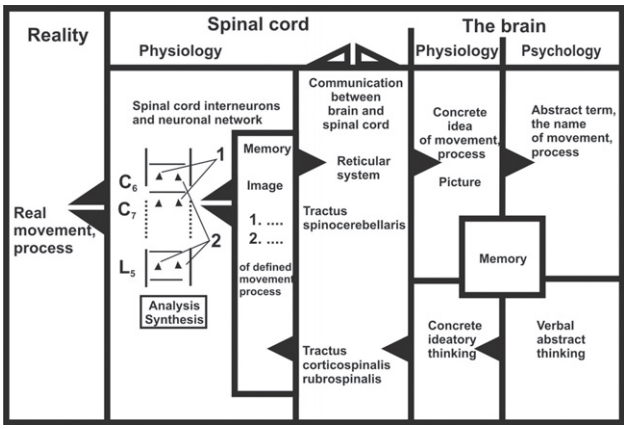


**Fig. 3. With the help of motoneurons spinal cord realizes movement analysis and with the help of neuronal network syntesis is completed, a procewss stored in the network mentioned above is displayed like in memory. The picture is shifted to the brain and it is stored in brain memory in the form of defined movement or process idea and after transformation like abstract term, the name of movement, process.**

**The 2nd hypothetical pathway of spinal cord function**

However, movement is the principal manifestation of life since embryonic life; therefore it is possible to admit that the communication between spinal cord and brain is still different, though some common points must be admitted. Spinal cord is a cerebral pre-degree and therefore it can be expected that it is able to perform some synthetic activity and must contain a certain form of memory function.

A large amount of motoneurons in different spinal segments participate in every movement performance, but the spinal cord alone is already able to perform synthesis of these analytic movements into the final performance and due to its fluency in a certain frequency to create the synthesis successively through the entire duration of the activity.

Activated motoneurons on various levels of the spinal cord must establish mutual connections. And these mutual connections are realised by paving the neural pathway through the neural network formed by tangles of neural fibers in the vicinity of spinal gray matter, especially anterior horns forming more than one half of spinal cord cross-section area. The cause may reside in the fact that the most complex cerebral operations related to the performance of movements take place here: to bring the picture of movements to the brain and to elicit it repeatedly.

The structure of connections within the neuronal network can be conceived for every movement as a multidirectional multiangular polygon, or graph, that can be used even in virtual images of real objects and phenomena. Provided that the knots of the graph resemble the motoneurons and its sides reflect its mutual interconnections, then it is possible to depict the immense movement variability by the graph. Any of the graph pathways reflect a definite movement stored in the neural network like in memory. And because the memory at lower cerebral levels is continuosly evolving and transferring (maybe by means of reticular system located closely to the corticospinal tract) to the higher functional levels, the movement is being imprinted in the brain in the same manner, so that the movement is carried out in the opposite direction by the spinal cord. Therefore the feedback circuit is able to carry out any movement and to learn it with the possible help of eventual visual initiation and control. A defined idea of movement is stored in memory and for transformation purposes is marked with the name of particular activity – for instance biking (Fig. 3).

Because the movement takes place in time and space, the evaluation is based on speed and direction, expressed as an adverb, adverbium and adjective after the substantiation of the verb. After that the muscle tension related to the quality of movement is being imprinted to the memory together with the movement. Other neural structures and pathways participate in the performance of movements, especially when talking about the communication between the spinal cord and somatotopically arranged cerebellar structures connected to higher brain structures by means of spinocerebellar tract. Cerebellar structures are further connected to the higher brain structures by means of the dentatorubrothalamic tract. The rubrospinal tract located also in the vicinity of corticospinal tract, intervenes in the quality of movements, because even nucleus ruber contains features of simple somatotopic organization.

The reactive momevement is similarly performed, for instance as a reaction to visual, acoustic or pain stimuli, or movements forced by requirements related to work, sport or music. The mechanisms of movements reflect the complex functioning of articulatory organs.

When the muscles controlled by the spinal cord complete a defined act, then the movement of articulatory organs perform speech in form of sound signals, abstract terms, words.

These new signals began to mark everything that human beings perceived from the outer environment as well as from the inner world and started to use these signals not only for mutual contacts, but also for themselves.

The word then became the abstraction of reality, the fundament of specific human thinking, and the instrument of higher orientation in the outer world and inside themselves. It has made the connection with other human brains possible, namely to exchange the thoughts and ideas and to protect themselves in cooperation with other similarly thinking brains.

Words permit to recall entire experience and knowledge, recorded in individual human memory associated with the individual per se, and outer world. They express thoughts in grammatical terms and sentential connections, by which the brain evaluates the most diverse stimuli from the present, past and expected future, and prepares the optimum reaction, referred to as rational activity. The optimum response is carried out by spinal cord activity in concrete ideas (7). The movement of muscles innervated from spinal motoneurons enables also the transfer of words into their graphic form, letters and makes them accesible for signify.

There is a tencency to describe the objective difficult cerebral activity trend from the subjective point of view as a topic of psychology, with the soul being a mystery, because it is not submitted to objective scientific analysis, but only to subjective one. But the confluence of both can be expected, because even the simple conditioned reflex is on the one hand an objective true fact and on the other hand it can be perceived as entirely based on one's own feeling and hesitations, based on subjective conditions.

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