The hand as an instrument of cerebral plasticity

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Abstract

Why only the human hand is able to write, to draw and to play an instrument despite being anatomically equal to a monkey's hand? Why is so difficult, but also a real challenge for the rehabilitator , improve hand functioning after a lesion? In this paper we aim to describe proprioceptive and tactile upper limb information strategies given to patients in different conditions in order to improve upper limber function.

Keywords: *Hand, Muscle Vibration, Neuromuscular Taping, Plasticity, Proprioception.*

Why the human hand? And why only the human hand is able to write, to draw and to play an instrument despite being anatomically equal to a monkey's hand? And why the hands' function is characterized by tactile perception? And why not only motor movement? And finally why is touch so important?

The hand represents an excellent model in which to study one of the most intriguing issues in motor control: simultaneous control of a large number of mechanical degrees of free range of movement. Human hand is able to grasp objects of all shapes and sizes, to write, to paint, to sculpture and to play musical instruments [1]. But these motor skills are also associated with high tactile discrimination, which is possible thanks to skin receptors. These receptors play an indispensable role in kinesthesia [2]. It's enough to think that finger movement is possible through the contraction of forearm muscles whose tendons cross more than one joint; in this situation the muscle afferent information is potentially ambiguous but the proximity of skin receptors adjacent to each joint allow them to provide joint specific information [3].

Beyond this we have prehension, that is the act of reaching to grasp an object, which is performed with little conscious effort and appears as a seamless act. Prehension actually consists of two distinct but temporally integrated movements, a Reach and a Grasp, each mediated by different neural pathways which project from visual to motor cortex via the parietal lobe [4]. The Reach serves to bring the hand into contact with the target by transporting it to the appropriate location, whereas the Grasp serves to shape the hand for target purchase. As two distinct behaviors, the Reach and the Grasp may be subject to different evolutionary developments and adaptive specializations. The Reach is produced largely by proximal musculature of the upper arm and is guided by the extrinsic properties of the target (location and orientation), and is coded in egocentric coordinates relative to the reacher.

The Grasp is produced mainly by distal musculature of the hand and digits, while guided by the intrinsic properties of the target (i.e. size and shape), and can be coded in spatial coordinates intrinsic to the hand irrespective of the hand's location relative to the body. The visual attention is essential for identifying the terminal point of the Reach and is useful to integrate the Reach and the Grasp into a single prehensile act.

The anatomical plan of the somatic sensory system reflects an organizational principle common to all sensory systems: Sensory information is processed in a series of relay regions within the brain [5].

The primary somatic cortex S-I, the upper order of neurons of the somatic sensory system contains four cytoarchitectural areas: Brodmann's areas 3a, 3b, 1, and 2. Most thalamic fibers terminate in areas 3a and 3b, and the cells in areas 3a and 3b project their axons to areas 1 and 2. These four regions of the cortex differ functionally. Areas 3b and 1 receive information from receptors in the skin, whereas areas 3a and 2 receive proprioceptive information from receptors in muscles and joints. The secondary somatic sensory cortex (S-II), located on the superior bank of the lateral fissure, is innervated by neurons from each of the four areas of S-I and are required for the function of S-II. For example, when the neural connections from the hand area of S-I are removed, stimuli applied to the skin of the hand do not activate neurons in S-II. The S-II cortex projects to the insular cortex, which in turn innervates regions of the temporal lobe believed to be important for tactile memory [5].

The posterior parietal cortex (Brodmann's areas 5 and 7) areas receive input from S-I. Area 5 integrates tactile information from mechanoreceptors in the skin with proprioceptive inputs from the underlying muscles and joints. This region also integrates information from both the two hands. Area 7 receives visual as well as tactile and proprioceptive inputs, allowing integration of stereognostic and visual information. The posterior parietal cortex projects to the motor areas of the frontal lobe and plays an important role in sensory initiation and guidance of movement [5].

Perception and action have been considered for a long time as two serially organized steps of processing, with the former relying on sensory brain areas and the latter implemented by the motor cortex. A crucial role in perception is also played by cortical motor regions, especially when sensory Information is required for acting. An intriguing synthesis of this view maintains that "perception is not something that happens to us, or is within us: It is something that we do"[6].

The rehabilitation of the upper limb function in different pathological conditions is a real challenge for the rehabilitator and many approaches have been studied over the past years. In this paper we aim to describe proprioceptive and tactile upper limb information strategies given to patients in different conditions in order to improve upper limber function.

To optimize movement the nervous system must integrate sensory and motor inputs aiming at collecting information and correctly interpreting sensations.

NeuroMuscular Taping (NMT) is an innovative taping application based on eccentric and dilation stimulation of the skin, muscle tissue, tendons, neurological vessels, lymphatic and vascular pathways aimed at improving their functioning [7]. NMT provides passive stretching through the application of an elastic tape with eccentrical (opposed to concentrical) properties encouraging flexibility and coordination and bettering range of movement in patients suffering with excessive muscle contraction due to different clinical conditions. It has been claimed that the effects may be due to sensorimotor and proprioceptive feedback mechanisms [8]. An application of NMT to the upper limb of a 17 years old girl affected by hemiplegia was studied with Kinematic data during a reaching task before (PRE) and after 2 weeks of treatment (POST). Improvement in terms of movement duration, Average Jerk and Number of Unit Movements indices, indicating a faster, smoother and less segmented movement were observed in the treated limb. Improvements appeared regarding the range of motion in specific tasks of the upper limb joints, both at the shoulder and elbow joints. These results, associated with others, awaiting publication, seems to corroborate the key role of NMT as a sensitive input that may be integrated by the central nervous system and used for assisting motor program execution process known as Sensorimotor integration [8].

Muscle vibration is a strong proprioceptive stimulus, which, at low amplitude, preferentially produces afferent input able to reach the somatosensory and motor cortices. Increasing somatosensory input from the paretic hand by using somatosensory stimulation to enhance the human brain response to injury is a way to improve motor function [9]. Vibration may artificial generate a proprioceptive signal [10] able to induce long-lasting changes in the excitatory/inhibitory state of the primary motor cortex in healthy subjects [11] but also in post stroke patients [12].

In conclusion the hand is one of the most fascinating and sophisticated biological motor systems in which peripheral and central constraints has been identified [1]. The recovery of function is not only movement related but requires to identify all peripheral input necessary in able to induce a cortical reorganization.

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