
The rationale of using non-invasive cortical stimulation as a tool to enhance motor learning

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Neuroplasticity

Neuroplasticity is the physiological mechanism that enables the brain to encode experiences and reorganize itself. It can be defined as the modification of existing neural networks in response to changes in behaviour or environment (Pascual-Leone et al., 2005; Rossini et al., 2007). Long-term potentiation (LTP) and long-term depression (LTD) are two forms of neuroplasticity respectively characterized by a persistent enhancement and decrease in synaptic transmission.

Several techniques that involve transcranial magnetic stimulation (TMS) can be used to measure brain plasticity noninvasively in humans. These include repetitive transcranial magnetic stimulation (rTMS), theta burst stimulation (TBS) and paired-associative stimulation (PAS). Neuroplasticity may be also induced using Transcranial direct current stimulation (tDCS), in particular, anodal cortical tDCS induces LTP-like changes while cathodal tDCS induces LTD-like effects (Nitsche & Paulus, 2001).

Exercise-driven neuroplasticity

The benefits of exercise on brain health have been recognized for centuries. Yet it has only been in the past two decades that scientific literature has stringently demonstrated the effect of exercise on brain health essentially by neurotrophic factors analysis. Animal studies have found that exercise elevates the levels of neurotrophic factors in select regions of the adult brain and spinal cord.

Rehabilitation techniques boosting neuroplasticity, through “motor learning” mechanisms, include a wide range of interventions, such as training with functional exercises, Constraint Induced Movement Therapy (CIMT), robot-assisted exercise and Virtual Reality. None of these approaches is able, however,

either to ensure a complete upper limb recovery in post-acute phase of stroke or to produce consistent dexterity changes in chronic phase.

Non-invasive brain stimulation as a tool to enhance motor learning

Since the '90s, the interest of the scientific world has oriented towards not-invasive neurophysiological methods that can modulate the excitability of neuronal circuits, "in vivo", thus enhancing the brain neuroplasticity after stroke in its early stages and expanding the therapeutic window also in the chronic phase. These methods, Repetitive Transcranial Magnetic Stimulation (rTMS) and Transcranial Direct Current Stimulation (tDCS), generate changes in the membrane potential of neurons, as follows:

- the cathodic current and the low frequency rTMS hyperpolarize neuronal membranes, and generate inhibitory effects,
- the anodic current and the high-frequency rTMS depolarize neuronal membranes and produce excitatory effects.

Through transcallosal connections, each hemisphere is supposed to exert an inhibitory activity on the contralateral one. After an acute hemispheric lesion, like in stroke, corticospinal excitability increases in the unaffected hemisphere and decreases in the affected one, since inhibition by the affected hemisphere on the healthy one is decreased because of the lesion. The increased excitability of the unaffected hemisphere could induce an overemphasized inhibitory activity on the affected hemisphere, thus providing an adverse functional impact. The lesioned hemisphere would therefore be twice penalized, first by the vascular lesion itself and then by this exaggerated transcallosal inhibition. The application of neuromodulation after a focal brain lesion aims to reduce interhemispheric imbalance, increasing ipsilesional excitability, reducing contralateral excitability and improving adaptive neuroplasticity.

The use of cortical stimulation, like tDCS, is claimed as a means to enhance standard upper limb rehabilitation effectiveness and expand the time window of the neuroplasticity phenomenon, thus ensuring a functional recovery even in chronic stages.

At present the best positive evidence of the effect of the tDCS on motor recovery after stroke exists mainly for patients with a chronic stroke suffering from moderate to mild impairment of one upper limb and in protocols in which tDCS is combined with physical therapies.

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