Non-Invasive Neuromodulation in Cognitive Rehabilitation

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The functional deficit after a focal brain lesion is determined by the localization and the extent of the tissue damage. Since destroyed tissue usually cannot be replaced in the adult human brain, improvement or recovery of neurological deficits can be achieved only by reactivation of functionally disturbed but morphologically preserved areas or by recruitment of alternative pathways within the functional network. The visualization of disturbed interaction in functional networks and of their reorganization in the recovery after focal brain damage is the domain of functional imaging modalities such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Longitudinal assessments at rest and during activation tasks during the early and later periods following a stroke can demonstrate recruitment and compensatory mechanisms in the functional network responsible for complete or partial recovery of disturbed functions. Imaging studies have shown that improvements after focal cortical injury are represented over larger cortical territories, an effect which appears to be dependent on the intensity of rehabilitative training. It has also been shown that the unaffected hemisphere in some instances actually inhibits the recovery of ipsilateral functional networks and this effect of transcallosal inhibition can be reduced by non-invasive brain stimulation.

Non-invasive brain stimulation (NIBS) can modulate the excitability and activity of targeted cortical regions and thereby alter the interaction within pathologically affected functional networks; this kind of intervention might promote the adaptive cortical reorganization of functional networks after stroke. Non-invasive brain stimulation (NIBS) uses direct current (DCS: excitation under the anode, inhibition under the cathode) or repetitive transcranial magnetic stimulation (rTMS: excitatory at high frequency, inhibitory at low frequency). Since recovery from poststroke deficits seems to be more effective in patients who recover function in the ipsilateral perilesional area, NIBS trials aimed to activate this region: this effect can be achieved by excitatory NIBS (high frequency repetitive transcranial magnetic stimulation, rTMS; intermittent theta burst stimulation, iTBS; anodal transcranial direct current stimulation, tDCS) to reactivate the perilesional area or by inhibitory NIBS (low frequency rTMS or cathodal tDCS) to reduce increased activities in the contralesional homologous areas.

DCS as well as rTMS were applied in combination with rehabilitative measures in order to improve various symptoms after stroke, especially motor deficits (review in Hsu WY et al. 2012), aphasia (review in Mylius V et al 2012a) and hemispatial neglect (review in Mylius V et al 2012b). In these applications recovery was improved with combined treatment in comparison to standard therapy without NIBS. All types of NIBS were used in rehabilitation of motor deficits and aphasia after stroke and positive effects on recovery were observed. Among the different modalities low-frequency inhibitory stimulation in the contralateral non-affected hemisphere seems to be the most prominent approach.

Cognitive function in healthy older subjects could also be improved by various non-
invasive stimulation procedures (review in Hsu WY et al 2015), especially when
stimulation was delivered before the execution of the task and with multiple sessions of
stimulation. In Alzheimer’s disease patients a significant effect was found for the
cognitive outcomes, especially when stimulation was applied during the execution of the
task. In patients with mild cognitive impairment rTMS improved significantly
performance in memory tests, which was still persisting after one month (Drumond
Marra HLD et al 2015). In other neuropsychiatric disorders, eg depression,
dysfunctional cognitive control is associated with dysregulation of prefrontal cortex
activity and NIBS can ameliorate the condition (review in Demirtas-Tatlidede A et al
2013). However, further studies are needed to translate these techniques into clinical
practice.

References:

Hsu WY, Cheng CH, Liao KK, Lee IH, Lin YY. Effects of repetitive transcranial magnetic
Jul;43(7):1849-57.
Mylius V, Zouari HG, Ayache SS, Farhat WH, Lefaucheur JP. Stroke rehabilitation using
Hsu WY, Ku Y, Zanto TP, Gazzaley A. Effects of noninvasive brain stimulation on
cognitive function in healthy aging and Alzheimer's disease: a systematic review and
Drumond Marra HL, Myczkowski ML, Maia Memória C, Arnaud D, Leite Ribeiro P,
Sardinha Mansur CG, Lancelote Alberto R, Boura Bellini B, Alves Fernandes da Silva A,
Tortella G, Ciampi de Andrade D, Teixeira MJ, Forlenza OV, Marcolin MA. Transcranial
Magnetic Stimulation to Address Mild Cognitive Impairment in the Elderly: A
Randomized Controlled Study. Behavioural Neurology 2015;Article ID 287843.
Demirtas-Tatlidede A1, Vahabzadeh-Hagh AM, Pascual-Leone A Can noninvasive brain
stimulation enhance cognition in neuropsychiatric disorders? Neuropharmacology.
2013;64:566-578.