USE OF NONINVASIVE CEREBRAL STIMULATION TECHNIQUES IN APHASIA: AN UPDATING

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ABSTRACT

Aphasia is a receptive and expressive communication disorder following to a cerebral accident (stroke, head injury, tumor). Classical speech and language therapy was not able to significantly contribute to the aphasia recovery. In the last decade two noninvasive cerebral techniques, transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS), have been used for the treatment of aphasic patients. In this paper I will report some of the main results in this field. The aim is to highlight both coherent and contrasting outcomes emerging from the use of these techniques and to understand their therapeutic potential in the treatment of aphasia.

Key words: aphasia, repetitive transcranial magnetic stimulation, transcranial direct current stimulation.

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Introduction

Aphasia is a communication disorder that affects normally right-handed individuals following an injury to the left hemisphere. Transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) are two noninvasive cerebral stimulation methods that can modify cognitive performance of neurological patients after strokes, degenerative diseases and tumors[1]. These stimulation techniques have been applied in the treatment of aphasia. In this review I will report the main results of more recent studies in which TMS and tDCS are used on aphasic patients.

TMS studies in aphasia

TMS induces an electric current at neuronal level employing magnetic fields. Trains of repetitive stimuli (rTMS) can be used to focally manipulate cortical activity and if applied to the scalp may have an excitatory or inhibitory effect on the underlying brain tissue depending on the parameters that are selected: low frequency rTMS (0.5-2 Hz) decreases, while high frequency (more than 3 Hz) increases the excitability and activation of cortical neurons. However, the effect does not only depend by the frequency but it may be related to the activation state of the stimulated cortex. Moreover rTMS is able to induce plastic long-lasting effects that remain after the end of the train and represent the potential for therapeutic application of the technique.

Most of the studies with aphasic patients (as a consequence of stroke to the left hemisphere) applied the stimulation at low frequency on the contralateral homologue areas[2-7]. Rational for application of this parameter was the theoretical framework of the interhemispheric inhibition in the aphasic brain. Interhemispheric inhibition model is borrowed from the researches on motor areas; this model predicts that after left hemisphere stroke, activation in right hemisphere is abnormally increased due to the loss of interhemispheric inhibition from the dominant hemisphere, producing a transcallosal inhibition towards the already damaged left areas. rTMS should modulate these interhemispheric relations, restoring a new balance. However, results of TMS application for rehabilitation of aphasia seem to be quite controversial (see Table 1).

Naeser et al.[2] found that 1 Hz rTMS on the right Broca's area improved linguistic performances

in four aphasic subjects, with benefit lasting up 2 months after rTMS.

Similarly, Barwood et al.[3] applied to right homologous Broca's area inhibitory (1 Hz) rTMS for 20 min daily, for 10 days. The results demonstrated improvement on naming performance and on the other aspects of expressive language and auditory comprehension in the stimulated group compared to the placebo control group until to 2 months post-stimulation.

Weiduschat et al.[4] used inhibitory rTMS on right Broca's area in post-stroke subacute aphasic patients. Together with a conventional speech therapy, a group of patients received 10 daily sessions of rTMS over the Broca's area, and a control group over the vertex. Results showed that experimental group improved significantly in the total score of Aachen Aphasia Test, whereas the control group did not. Furthermore, positron emission tomography revealed activation on the right hemisphere of the control group that was absent in the experimental group.

Hamilton et al.,[5] studied a patient with left hemisphere stroke and chronic non-fluent aphasia, who received 1Hz rTMS daily for 10 days on the dorsal posterior pars triangularis of Broca's area. This site was chosen based on a previous stimulation delivered to different sites of the right inferior frontal gyrus. Results showed an improvement in object and action naming, in picture description and in spontaneous speech, until 10 months after rTMS.

In another recent study Naeser and collaborators[6] showed that a low frequency rTMS of different parts of the right Broca's area produced an improvement or a worsening of performance in a naming test for a group of aphasic patients. In particular, suppression of right pars triangularis led to significant amelioration for accuracy and reaction times, whereas suppression of right pars opercularis produced a significant worsening in reaction times but not in the accuracy.

In a combined fMRI and TMS study, Turkeltaub and collaborators[7] presented a patient with sequential left and right strokes, who had received a treatment of inhibitory rTMS to the right pars triangularis of Broca's area, demonstrating an improvement in naming until 2 months after. Brain activity measured with fMRI was reduced at the TMS target but no increase of activity was detected in left hemisphere areas. When a right hemispheric stroke occurred, her language function was worsened respect to the other cognitive functions.

Finally, more recent studies[5-7] suggested that same frequencies of rTMS could have different effect for different sites of the same hemisphere; consequently, a more articulated model of the interhemispheric relationship, based on the complexity of neural representation of language, should be proposed. In fact, model of interhemispheric inhibition was adopted by findings on motor systems. The question is whether such a model of interhemispheric interaction can also applied to the functional language system that is constituted by a distributed cerebral network.

tDCS studies in aphasia

Unlike rTMS, tDCS is not able to directly stimulate neurons but acts by altering their membrane potential. The effects are determined by the polarity of stimulation: anodal stimulation increases excitability producing depolarization of the cellular membranes and cathodal stimulation decreases it provoking their hyper-polarization[8]. tDCS has principally been used to study motor and cognitive functions[9] and to evaluate its potential in therapeutic applications for different neurological diseases[1].

Recently, a new electrode placement, in which the active electrode is placed on the target area whereas the opposite is positioned on the homologous contralateral area, has been studied. The aim of this "dual" positioning was to strengthen the final effect throughout a cumulative and synergic effect of both stimulations.

tDCS has been applied to promote an improvement in aphasia after stroke and different results have been obtained (see Table 1). For example, after five days of anodic tDCS to the left Broca's[10] and Wernicke's area[11], paired with anomia treatment, better performance in naming was detected. Using anodic stimulation on the left Broca's area, Marangolo et al.[12] obtained a similar result with speech apraxia patients in a repetition task.

In contrast Monti et al[13], after a single session of cathodic stimulation of the left Broca's area in a group of patients, found an improvement in picture naming compared to sham and anodic stimulation on the same area.

Three tDCS studies carried out with right handed aphasic patients demonstrated language improvement after anodic stimulation of the left Broca's[10, 12] and Wernicke's areas[11], according to consideration that the perilesional regions of left hemisphere play a crucial role in aphasia recovery,

Study	Stimulated areas	Stimulation parameters	Aphasia type	Results
rTMS				
Naeser et al., 2005	Right Broca	10 daily session of 1 Hz rTMS	Global	Improvement in naming
Barwood et al., 2011	Right Broca	10 daily session of 1Hz rTMS and placebo	Nonfluent	Improvement in expressive language and comprehension after real rTMS
Weiduschat et al., 2011	Right Broca	10 daily sessions of 1 Hz rTMS and placebo	Broca, global, amnestic subacute	Improvement in Aachen Aphasia Test after real rTMS
Hamilton et al., 2010	Right Broca	10 daily session of 1 Hz rTMS	Nonfluent	Improvement in expressive language
Naeser et al., 2011	Right Broca	Single sessions of 1Hz rTMS	Nonfluent	Improvement in naming
Turkeltaub et al., 2012	Right Broca	10 daily session of 1 Hz rTMS	Nonfluent	Improvement in naming
tDCS				
Baker et al., 2010	Left Broca	5 daily session of anodal or sham tDCS	Anomic and Broca	Improvement in naming after anodal tDCS
Fiori et al., 2010	Left Wernicke	5 daily sessions of anodal or sham	Nonfluent	Improvement in naming after anodal tDCS
Marangolo et al., 2011	Left Broca	5 daily sessions of anodal and sham	Apraxia of speech	Improvement in repetition after anodal tDCS
Monti et al., 2008	Left Broca	Single session of anodal, cathodal, and sham	Broca and Global	Improvement in naming after cathodal tDCS
You et al., 2011	Left and right Wernicke	10 daily sessions of left anodal, right cathodal and sham	Global subacute	Improvement in verbal comprehension after right cathodal tDCS
Costa et al., submitted	Dual Broca and Wernicke	10 daily sessions of simultaneous left anodal and right cathodal and sham	Global with right stroke	Improvement in naming after left anodal and right cathodal on Broca's areas

Table 1

as sustained by some fMRI and PET studies. However, although this claim was experimentally supported, the possible contribution of right hemisphere in aphasia recovery was not taken into account by these authors.

Fiori and collaborators[11] delivered anodic tDCS to the left posterior language area; however they omitted to anodically stimulate right Wernicke's area because this montage had not been a significant effect on a nonword learning task carried out by healthy subjects in a their previous experiment. One could object that after a brain damage a functional reorganization, linked to the neuronal plasticity and depending on several factors (as onset and extension of the lesion, individual features, possibility of rehabilitation, and so on) could occur. Consequently same type of stimulation on brain damaged and healthy individuals probably could not be comparable.

Applying cathodic stimulation on the right Wernicke's area You et al.[14] reported an increase of correct responses in a verbal comprehension task for a group of 21 subacute aphasic patients. Anomia treatment associated with tDCS stimulation consisted in the execution of repetition, picture naming, reading aloud and verbal comprehension tasks. The results showed an improvement only in verbal comprehension for the patients undergone to cathodic stimulation of the right Wernicke's area whereas performance was comparable to the baseline in the other linguistic tasks.

Furthermore, anodic stimulation of the left Wernicke's area and sham stimulation did not provided significant results.

The authors interpreted the results as the action of transcallosal inhibition: reduction of neural activity in right Wernicke's area decreased the inhibition directed to the damaged hemisphere.

Recently, my research group[15] used a dual tDCS on a patient with severe aphasia following a right stroke to the middle cerebral artery. Before the experimental sessions a pilot study was carried out

in order to decide the best montage to use for the subsequent treatment. Cathodic stimulation of the right Broca's area (dominant for this patient) and contemporaneous anodic stimulation of the contralesional homologue area (left) for two weeks produced amelioration in naming task.

Conversely, the same montage on the Wernicke's areas did not significantly differ from the sham stimulation. As reported by other studies[6-7], our results demonstrated that lesional and contralesional regions could differently participate to the language reorganization.

Conclusions

In Table 1 are summarized rTMS and tDCS studies here presented. All rTMS studies applied inhibitory frequencies on right hemisphere producing amelioration in linguistic performance, in line with the interhemispheric inhibition model. More contrasting results are reported in tDCS studies: improvement of performance was obtained either with cathodic or anodic stimulation of both Wernicke's or Broca's areas. Overall this review underlines the potential therapeutic role of the cerebral noninvasive stimulation in aphasia rehabilitation; it also suggests considering the different functional reorganization of both hemispheres following to anatomical damage. Neuropsychological tests, functional images and pilot studies previous the experimental treatment will allow the best montage to use for each patient.

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