THE NEW FRONTIERES IN APHASIA REHABILITATION: FROM TRANSCRANIAL BRAIN STIMULATION TO VIRTUAL REALITY

Barbara De Tommaso, Lucia Pecoraro, Rossella Muò, Simona Raimondo

Barbara De Tommaso, SLT, independent professional
Lucia Pecoraro, SLT, independent professional
Rossella Muò, SLT, ASL TO1, Rehabilitation Department, Turin
Simona Raimondo, SLT, "Città della Salute e della Scienza", Otolaryngology 2 Department, Turin

At present Transcranial Brain Stimulation (which includes Transcranial Magnetic Stimulation -TMS- and transcranial Direct Current Stimulation -tDCS) and Virtual Reality represent two main frontiers in aphasia clinical research.

Transcranial brain stimulation.

Transcranial brain stimulation was introduced and described for the first time during the second half of 1900. Since then, several studies have been conducted that have expanded its applications from a purely investigative use (directed to the study of brain mechanisms) to a targeted use in clinical treatment of cerebral disorders. A promising line of research, currently, is represented by the application of transcranial brain stimulation in *post-stroke aphasia*.

The main techniques used in this field are the **Transcranial Magnetic Stimulation** (**TMS**) and the **transcranial Direct Current Stimulation** (**tDCS**). Both modulate the mechanisms of brain neuroplasticity. As a function of parameters setting, an electric current causes a stimulation or an inhibition of cortical excitability. In summary, the therapeutic effect of TMS and tDCS in reducing aphasic disorders are believed to be related to the ability of the two techniques to induce beneficial changes in neuroplastic reorganization of the language areas after stroke (Horn et al., 2005; Turkeltaub et al., 2011). It's growing, in recent years, the evidence of the fact that, when conducted in combination with the speech therapy, these neuro-techniques are able to enhance the recovery of some language skills in the treated patients, both in chronic and post-acute phases (Bhogal et al., Breitenstein et al., 2009; Brady, Holland and Crinion, 2012).

The data collected in the last two decades have outlined some clear differences between TMS and tDCS that may determine the circumstances in which each of the two treatment modalities should be considered. Moreover, emerging theories in relation to the mechanisms of neuronal recovery after stroke may orientate the choice of the most appropriate approach for stimulation. We discuss below the peculiar characteristics of the two techniques and their applications in aphasia.

Transcranial Magnetic Stimulation TMS.

Technical specifications.

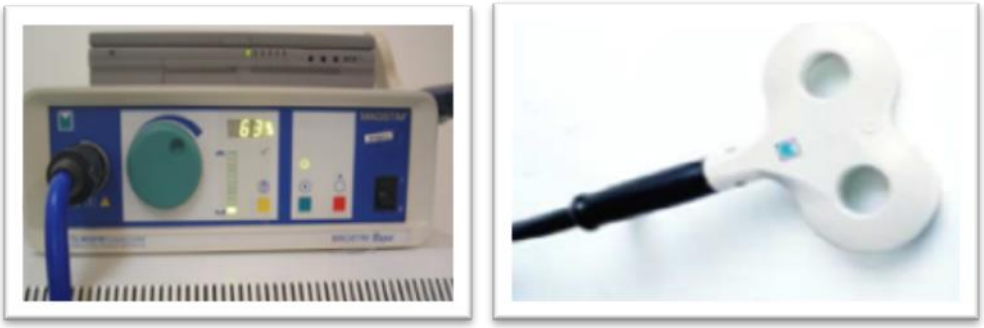

Fig. 1- Equipment for cerebral stimulation with rTMS coil (image from *Amsterdam Centre for the study of Adaptive Control in Brain and Behavior*)

The physical principle on which rests the TMS is the Faraday's law (law of electromagnetic induction). There are three main types of TMS: single pulse, double pulse (Paired-pulse TMS) and repetitive (rTMS). However, today the most widespread is the repetitive TMS , divided into "conventional " and " patterned " (Rossi et al., 2009). The first consists in a stimulation repeated at regular intervals (" trains " of stimulations) with a frequency ranging from 1 to 20 or more Hz, applied at the same point of the scalp. Conversely in the "patterned " type, stimulation is interspersed with short breaks . The duration of the effect is greater in the case of rTMS compared to single-pulse TMS in order of a few minutes.

The instrumentation used today is represented by a pulse generator and a coil current of stimulation (coil). Several authors (Rossi et al., 2009) show the presence of side effects and contraindications deserving of further study. The main side effects can be hearing loss if not used common earplugs, overheating brain, reduction or increase in mood, neck pain and/or headache. The main drawbacks are the presence of metallic implants in close contact with the coil, conditions that can cause or increase the risk of seizures (protocols unconventional stimulation TMS, conventional protocols of stimulation with high frequency rTMS stimulation parameters higher safe limits, personal history of epilepsy, vascular lesions, traumatic, tumor, infectious, metabolic or brain, taking medications that potentially reduce the seizure threshold, sleep deprivation and history of alcoholism), brain electrodes implanted, pregnancy and heart disease severe or recent.

TMS and aphasia.

Fig. 2 - Focal TMS stimulation in the right frontal site (image from *The Motor Control and Learning Laboratory - University of British Columbia, Vancouver, Canada, http://old.hkin.educ.ubc.ca/faculty/franksi/mcllab/labtour.html*)

The first studies about rTMS in aphasia made use of transcranial stimulation alone (Martin et al., 2009; Naeser et al., 2005b), and only recently the focus of interest has shifted to the combined treatment rTMS/Speech Therapy. The association demonstrated to be more effective than single rTMS stimulation (Martin et al., 2009b; Naeser et al., 2010).

The studies concerning the use of TMS in patients with fluent post-stroke aphasia are rather scarce (Kakuda et al., 2010b; Abo et al., 2012).

Finally, owing to the large interindividual variability of language features in patients with aphasia, the research on the application of TMS stimulation associated with traditional rehabilitation should include speech therapies modeled on the characteristics of the individual patient (Abo et al., 2012).

Transcranial Direct Current Stimulation (tDCS).

Technical specifications.

The use of tDCS in clinical practice dates back to the nineteenth century when Giovanni Aldini experienced direct electrical brain stimulation to treat patients with mood disorders.

The technique consists of the application on the scalp of weak electric currents (typically the intensity of 1-2 mA), for a few minutes, by means of two surface electrodes, impregnated with an isotonic saline solution. The typical configuration is a *bipolar* arrangement in which the active electrode is placed on the region to be stimulated and the reference electrode is positioned on the contralateral supraorbital region. Alternatively, the reference electrode can be placed on other sites, as the mastoid or shoulder (TCDS *monopolar*). Recently, tDCS high-definition (HD-tDCS) has been introduced that allows to increase the spatial resolution of the stimulation.

Fig. 3 - Portable stimulator DC, equipped with a pair of electrodes (supplier Scriphessco)

Cathodic TDCS (C-tDCS) is associated with a reduction of cortical excitability.
AnodicTDCS (A-tDCS) would lead to an increase of cortical excitability.
Repeated sessions of tDCS can induce plastic changes in performance persisting for months.
In a recent study, Rothwell (2012) supports the need to conduct tDCS simultaneously (on-line) with the functional treatment because the latter has the aim to focus the effects of tDCS on the appropriate neuronal circuits. That explains why almost all of the literature protocols adopted a combined approach Speech Therapy/tDCS (ST/tDCS).
Safety of tDCS.
Seizures are a very marginal concern (in none of the analyzed works they were cited). Data from different sources confirm that tDCS induces minimal side effects: weak tingling, itching, and a slight burning sensation.
tDCS and aphasia.
While most of the speech therapy treatments concerns of intensive training of naming abilities, literature includes many different configurations in the tDCS application. Trials were conducted with combined ST/tDCS stimulation of ipsilesional cortical areas (left areas) or with ST/tDCS stimulation of right, homologous, language areas. Cathodic TDCS or Anodic TDCS were applied.

Fig. 4 tDCS application (photo by Paul B. Fitzgerald, *Medicographia, 2011;33:202-208)*

The experimental design adopted in related studies are not directly comparable with each other, so - even in cases of an acceptable uniformity in clinical conditions of the participants - is difficult to draw firm conclusions. It would seem that, at least in cases of aphasia with moderate anomic disorders, the anodal

stimulation of left hemispheric areas is able to produce beneficial effects. But the question of whether the perilesional left areas are more or less crucial to the recovery compared to the corresponding areas of the right hemisphere, can only be addressed with studies involving a wider sample and homogeneous subjects and by adopting fMR to investigate neuroplastic changes in language networks, so to substantiate the purported effects of A-tDCS.

In conclusion, the evidence of a strengthening of the speech therapy effects induced by the association with neuro-stimulation techniques are encouraging, but the experimental observations are still under development and require further and more rigorous studies.
At the same time, the features of the research protocols suggest the opportunity for a greater involvement of speech therapists in experimental neurocognitive studies related to post-stroke aphasia. Moreover it has to be considered the possibility of including in the Core Competence of the Speech Therapist new stimulation techniques which are easy to apply, even if not yet widespread in our country.

Virtual Reality.
Virtual reality is a term referring to any type of virtual simulation created through the use of computers. The instruments used are video games (that are displayed on a standard screen), applications that require the use of special gloves equipped with sensors (wired gloves) and finally the World Wide Web. A review of VR applications shows that it can be considered a useful tool for rehabilitation (Sik Lànyi et al., 2006).
Scientific studies based on the use of virtual reality in aphasic patients proposed playing scenarios of daily living (inside home), oriented perspective functional to the acquisition of high frequency words, naming tasks, tasks of space exploration and indication, evocation of spatial tasks, writing tasks (Horvàth et al., 2009; Sik Lànyi et al., 2006).
Other studies show the use of a “virtual therapist” with the software ORLA-VT (Oral Reading for Language in Aphasia with Virtual Therapist) (Cherney et al., 2010) and a computer-based treatment based on observation and imitation (Lee et al., 2010). This works are based on the functional role of the matching mechanism observation- execution (Skipper et al., 2005) in learning by imitation of skills (production and understanding) through the use of avatars. Expected stimuli are progressively more difficult (monosyllabic words , two-syllable , sentences, etc.) with respect to the language skills acquired by the user (adaptation training) (Merzenich et al., 1996), including repetition of tasks and reading tasks.

References

- Abo, M., Kakuda, W., Watanabe, M., Morooka, A., Kawakami, K., Senoo, A. Effectiveness of low-frequency rTMS and intensive speech therapy in poststroke patients with aphasia: a pilot study based on evaluation by fMRI in relation to type of aphasia. Eur Neurol, 68(4), 199-208, 2012.
- Bhogal SK, Teasell R, Speechley M. Intensity of aphasia therapy, impact on recovery. Stroke; 34(4):987–993, 2003.
- Brady MC, Kelly H, Godwin J, Enderby P. Speech and language therapy for aphasia following stroke. Cochrane Database of Systematic Reviews, Issue 5, 2012.
- Breitenstein, C., Kramer, K., Meinzer, M., Baumgartner, A., Floël, A., & Knecht, S. Intense language training for aphasia. Contribution of cognitive factors. Nervenarzt, 80(2), 149–150, 2009.
- Cherney, L.R., Babbit, E.M., Cole, D., Van Vuurer, S., Hurwitz, R., Lee, J., Ngampatipatpong, N. Top Stroke Rehabil, 17(6), 423-431, 2010.
- Holland R. and Crinion J., Can tDCS enhance treatment of aphasia after stroke? Aphasiology, 26 (9), 1169–1191, 2012.

- Horn, S.D., DeJong, G., Smout, R.J., Gassaway, J., James, R. & Conroy, B. Stroke rehabilitation patients, practice, and outcomes: Is earlier and more aggressive therapy better? Arch Phys Med Rehabil, 86 (12 Suppl 2), S101-S114, 2005.
- Horvàrt, M., Dàniel, C., Stark, J., Sik Lànyi, C. Virtual Reality House for Rehabilitation of Aphasic Clients. Transactions on Edutainament III, Lecture Notes in Computer Science, 5940, 231-239, 2009.
- Kakuda, W., Abo, M., Uruma, G., Kaito, N., Watanabe, M. Low-frequency rTMS with language therapy over a 3-month period for sensory-dominant aphasia: Case series of two post-stroke Japanese patients. Brain Injury, 24, 1113–1117, 2010 b.
- Lee, J., Fowler, R., Rodney, D., Cherney, L.R., Small, S.L. IMITATE: An intensive computer based treatment fon aphasia based on action observation and imitation. Aphasiology, 24(4), 449-465, 2010.
- Martin, P.I., Naeser, M.A., et al. Overt naming fMRI pre- and post-TMS: two nonfluent aphasia patients, with and without improved naming post- TMS. Brain Lang, 111(1), 20–35, 2009 a.
- Martin, P.I., Naeser, M.A., Ho, M., Treglia, E., Kaplan, E., Baker, E.H., et al. Research with transcranial magnetic stimulation in the treatment of aphasia. CurrentNeurology andNeuroscience Reports, 9, 451–458, 2009 b.
- Merzenich, M.M., Jenkins, W.M., Johnston, P., Schreiner, C., Miller, S.L., Tallal, P. Temporal processing deficits of language-learning impaired children ameliorated by training. Science. 271(5245), 77–81, 1996.
- Naeser, M.A., Martin, P.I., Nicholas, M., Baker, E.H., Seekins, H., Kobayashi, M., et al. Improved picture naming in chronic aphasia after TMS to part of right Broca's area: An open-protocol study. Brain and Language, 93, 95-105, 2005b.
- Naeser, M.A., Martin, P.I., Lundgren, K., Klein, R., Kaplan, J.,Treglia, E., et al. Improved language in a chronic nonfluent aphasia patient after treatment with CPAP and TMS. CognBehav Neurol, 23(1), 29-38, 2010.
- Rossi, S., Hallett, M., Rossini, P.M., Pascual-Leone, A. Safety of TMS Consensus Group. Safety, ethical considerations, and application guidelines for the use of transcranial magnetic stimulation in clinical practice and research. , 120(12),2008-1039, 2009.
- Rothwell JC., Clinical applications of noninvasive electrical stimulation: problems and potentials. Clinical EEG and neuroscience; 43: 209-14, 2012.
- Sik Lànyi, C., Geiszt, Z., Magyar, V. Using IT to Inform and Rehabilitate Aphasic Patients. Informing Science Journal, 9, 2006.
- Skipper J. I., Nusbaum H. C., Small S. L. (2005). Listening to talking faces: motor cortical activation during speech perception. Neuroimage 25, 76–8910.1016/j.neuroimage.2004.11.006
- Turkeltaub, P.E., Messing, S., Norise, C. & Hamilton, R.H. Are networks for residual language function and recovery consistent across aphasic patients? Neurology, 76(20), 1726-1734, 2011.