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Research paper

Transcranial direct current stimulation to improve naming abilities of persons with chronic aphasia: A preliminary study using individualized based protocol

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ABSTRACT

Background and purpose: Transcranial direct current stimulation (tDCS) is a noninvasive tool to facilitate brain plasticity and enhance language recovery after stroke. Our study aims to develop an efficient protocol for individualizing tDCS to treat naming deficits within chronic aphasia patients.

Method: Seven patients with chronic aphasia participated in this preliminary study. All participants performed a baseline naming assessment. Next, the best stimulation area (either Broca or Wernicke), best side (either left or right hemisphere), and best type of stimulation (either anodal or cathodal) were assessed with tDCS during four individualized pre-intervention sessions. The location and type of stimulation that produced the greatest improvement for each patient were used in subsequent treatments. Treatment included six stimulation sessions (2 mA, 10 min), three treatments per week, two weeks in a raw. Naming abilities were assessed immediately after treatment, as well as one month and three months after treatment. Sham (placebo like) tDCS was administered to all participants three months post treatment.

Results: Treatment led to significant improvement in percentage of correct responses compared to baseline, whereas sham led to no equivalent improvement. Improvement was still present three months after treatment.

Conclusions: An individually-tailored protocol of 2 mA, 10 min tDCS was found to improve naming abilities of individuals with chronic aphasia. If proved to be effective in larger studies, our findings may have important clinical implications for the use of tDCS in enhancing language abilities after stroke.

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1. Introduction

A relatively new area of research is associated with the clinical implications of neuromodulation of the cortex by transcranial direct current stimulation (tDCS) to facilitate brain recovery after stroke. tDCS is a noninvasive, painless cortical neuromodulation technique that modifies spontaneous neuronal excitability through a tonic depolarization or hyperpolarization of resting membrane potential (Nitsche & Paulus, 2000). Depending on the polarity of the current flow, brain excitability can either be increased (anodal tDCS) or decreased (cathodal tDCS). The beneficial implications of tDCS within stroke patients were found in the motor domain as well as in the cognitive and language aspects. In the motor cortex, anodal tDCS over the affected hemisphere and cathodal tDCS over the unaffected hemisphere have been shown to improve motor function after stroke (Boggio et al., 2007; Fregni et al., 2005). In the cognitive domain, anodal tDCS over the left dorsolateral prefrontal cortex has been shown to enhance working memory (Jo et al., 2009) and to improve attention after stroke (Kang, Baek, Kim, & Paik, 2009). In the language domain, several studies attempted to examine the use of tDCS to enhance language skills. In healthy subjects using tDCS was found to enhance proper naming retrieval (Ross, McCoy, Wolk, Coslett, & Olson, 2010), matching picture to invented trained words (Fiori et al., 2011; Liuzzi et al., 2010), to increase the number of words generated by healthy persons during a verbal fluency task (Iyer et al., 2005), and to improve both accuracy and response time on a picture naming task (Fertonani, Rosini, Cotelli, Rossini, & Miniussi, 2010; Sparing, Dafotakis, Meister, Thirugnanasambandam, & Fink, 2008).

Within stroke aphasic patients, one of the frequent language deficits is Anomia-the crucial impairment to name pictures or objects. It significantly reduces a person's ability to communicate and deliver a message and therefore causes frustration to both patient and caregivers. In the last decade, several studies examined the use of tDCS with or without concurrent speech therapy, in order to improve the impaired naming abilities of aphasic patients after stroke. For instance, Monti et al. (2008) administered tDCS (2 mA, 10 min) over the left inferior frontal gyrus (IFG) to eight chronic non-fluent aphasic patients. Patients were assigned to either an anodal-tDCS or a cathodal-tDCS group. Active (AtDCS or CtDCS) and sham tDCS were tested in random order, allowing at least 1 week to elapse between sessions. The subjects and the examiner were blinded to the type of stimulation. Results suggested that cathodal-tDCS significantly improved performance accuracy on a picture naming task (33.6% improvement relative to baseline), whereas anodal stimulation had no such effect. Monti et al. (2008) argued that the improvement in naming abilities was due to tDCS-induced depression of cortical inhibitory inter-neurons that led to disinhibition and consequently to improved function of the damaged language areas. Baker, Rorden, and Fridriksson (2010) reported that it was anodal-tDCS rather than cathodal-tDCS that improved naming abilities in ten chronic aphasia patients. The authors administered anodal-tDCS (1 mA, 20 min) for five days and sham tDCS for another five days, with concurrent computerized naming treatment. tDCS positioning was guided using a priori functional MRI results during an overt naming task. Naming accuracy of treated items improved following anodal-tDCS as compared to sham-tDCS (36 vs. 15 correctly named items, respectively), and lasted one week post treatment. Recently, Vestito, Rosellini, Mantero, and Bandini (2014) found long lasting effects after anodal tDCS administered. The participants all who had post stroke chronic aphasia received 10 days of anodal tDCS on the left frontal (perilesional) region. During each tDCS treatment the patients had to complete a picture naming task. The results showed significant improvement in naming ability compared to baseline up to 5 months after the end of treatment. Moreover, Fiori et al. (2011, 2013) found improvement in naming abilities following anodal tDCS that was applied to posterior cortical regions such as Wernicke's area by the superior temporal gyrus (STG) (Fiori et al., 2011; 2013). It appears that the few studies that looked at tDCS in aphasia have examined the effects of treatment after differing periods of times, have stimulated various brain regions in the left hemisphere, and have used different stimulation type (cathodal vs. anodal tDCS). Some of this inconsistency might be resolved if treatment takes into account the different possibilities for language reorganization within the damaged brain, as well as the connectivity between the two cerebral hemispheres during language processing.

In recent years a growing body of evidence suggests that not only is the left hemisphere involved in language recovery, but that the right is involved as well. This idea is not new (Barlow, 1877; Basso, Gardelli, Grassi, & Mariotti, 1989; Gowers & Barker, 1886; Kinsbourne, 1971). Imaging studies have also suggested that recovery involves the right hemisphere as well (Blasi et al., 2002; Buckner, Corbetta, Schatz, Raichle, & Petersen, 1996; Cappa et al., 1997; Musso et al., 1999; Thulborn, Carpenter, & Just, 1999; Weiller et al., 1995). This is further supported by studies that examined right hemisphere activation post therapy (Crosson et al., 2005; Peck et al., 2004; Raboyeau et al., 2008). A recent study examined whether applying tDCS over the homolog right IFG rather than the left IFG could enhance naming abilities as well (Flöel et al., 2011). The results showed that application of anodal tDCS over the right IFG significantly improved naming accuracy, and the effect lasted two weeks post treatment. However, the mechanisms underlying right hemisphere involvement in language recovery are not yet fully understood. Heiss and Thiel (2006) describe paths of brain plasticity during aphasia recovery after stroke using hierarchical model. According to this model, best recovery is obtained when the original activation within the left hemisphere is restored. However, such activation will be found only when brain damage is relatively circumscribed. Incomplete, but often satisfactory improvement of language function can occur when primary functional centers in the left dominant hemisphere are damaged, but there is still preserved activation of areas surrounding the lesion. At the bottom of this hierarchy model lays only limited recovery that can be achieved when ipsilateral network components are severely damaged. Then, an activation of contralateral homologous regions occurs, enhancing partial interhemispheric compensational language processing in these areas. However, this involvement of the contralesional areas contributes to some improvement in language functioning but usually it is not as efficient as intrahemispheric compensation (Heiss & Thiel, 2006). Consistent with the hierarchical model Schlaug,