New prospects of transcranial electrical stimulation (tES): from bench to bed side

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Over the last decade, the field of neuroscience has experienced the introduction and rapid development of non-invasive brain stimulation techniques. These techniques include transcranial magnetic stimulation (TMS) (Rossi et al., 2009) and transcranial electrical stimulation (tES) (Nitsche et al., 2008), which interact non-invasively with spontaneous brain activity and, by implication, with related sensory-motor and higher order cognitive behavior. The establishment of non-invasive brain stimulation techniques to evaluation the underling functional mechanisms of the central nervous system constitutes a significant breakthrough in basic as well as in clinical neuroscience. The principal aim of this workshop is to meet and discuss the new knowledge gathered about these innovative approaches. Specifically the discussion will be focused on the potential role of tES in different fields from animal studies to clinical application in psychiatry and neurological rehabilitation.

The recently revived technique of tES (Nitsche & Paulus, 2000; Priori, 2003) involves the application of weak electrical currents (~1-2 mA) directly to the head for several minutes (~5-30 minutes). The stimulation is delivered by a battery-driven current stimulator through a pair of electrodes. These currents generate an electrical field that modulates neuronal activity according to the modality of the application, which can be direct (transcranial Direct Current Stimulation, tDCS), random noise (transcranial Random Noise Stimulation, tRNS) or alternating (transcranial Alternating Current Stimulation, tACS). Neurons respond to tDCS by altering their firing rates. Several studies using animal models (Bindman et al., 1964; Creutzfeldt et al., 1962) suggest that cathodal tDCS reduces spontaneous neuronal firing rates, while anodal tDCS has the opposite effect. Firing increases when the positive pole (anode) is located near the cell body or dendrites and decreases when the field is reversed. Accordingly, similar neurophysiological effects have been observed (e.g., Nitsche et al., 2008). Cathodal polarisation over the motor cortex can induce robust motor cortex excitability reductions, while anodal polarisation increases motor cortex excitability (Nitsche & Paulus, 2000). tRNS has been used in only one study (Terney et al., 2008). In contrast to tDCS, it has no constraints of current flow direction sensitivity. Terney et al. (2008) reported that tRNS improved performance in implicit motor learning tasks and increased motor cortex excitability for many minutes post-stimulation. Therefore, tRNS, like tDCS, can change cortex excitability by inducing depolarisation. Finally it is possible to deliver an oscillatory current to the cortex in a frequency-specific fashion to induce entrainment using tACS (Kanai et al., 2008). In this respect, tACS may serve as an instrument for interacting with ongoing cortical oscillations and induce entrainment (Thut & Miniussi, 2009) and thereby contribute to a better understanding of cortical rhythms.

Importantly, tES effects have been shown to outlast the stimulation period itself, and mechanisms of synaptic long term potentiation/depression (LTP/LTD) have been suggested to account for these modifications. Using tDCS behavioural facilitatory effects have been highlighted in healthy subjects with regard to implicit motor learning (Nitsche et al., 2003), working memory (Fregni et al., 2005; Ohn et al., 2008), perception (Antal et al., 2004) and language (Fertonani et al., 2009; Iyer et al., 2005; Sparing et al., 2008). Recently it has also been shown that a single tDCS session can ameliorate visuospatial attention deficits in stroke patients suffering from neglect (Sparing et al., 2009), naming abilities in vascular aphasia (Monti et al., 2008), and recognition memory in Alzheimer's disease (Ferrucci et al., 2008), motor functions (Williams et al., 2009), in depression (Fregni et al., 2006; Boggio et al., 2008a; Rigonatti et al., 2008), alcohol craving (Boggio et al., 2008b) and many others pathologies (Nitsche et al., 2008).

The facilitatory function highlighted in healthy subjects and patients may be very important for the use of tDCS in cognitive neuroscience, not

only in establishing the role of the stimulated area, but also to enhance reduced function in cognitive neurorehabilitation. Given these premises, there is currently a growing interest in applying tES not only to study the basic aspects of the central nervous system but also as an alternative therapeutic approach of different pathologies to ameliorate psychiatric, motor, perceptual, behavioral and cognitive deficits in many type of patients.

Moreover the combination of brain stimulation with other approach of brain imaging, tDCS-electroencephalography or tDCS and functional Magnetic Resonance co-registration, has potential to be of great value for understanding human brain function. It provides real time information about the state of the cortex activity, its functional connectivity, and how brain stimulation modifies such activity and connectivity. Moreover study on animals and humans, about neurophysiological, biochemical and genomic aspects might be very useful to understand influences of brain stimulation on the central nervous system. Work in this area might provide new insights into the neurobiological mechanism underlying neuroplasticity (Fritsch et al., 2010) and lead to the identification of molecular profiles useful for the personalisation of future clinical applications.

The use of tES provides an important opportunity to gain insight into the mechanisms underling the central nervous system and the possibility of non-invasively interacting with brain functions and its plasticity mechanisms. The aim of this workshop is to cover the basic topics that could be useful when using tES in the basic but also clinical neuroscience fields.

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