Cutaneous perception during tDCS: Role of electrode shape and sponge salinity

Transcranial direct current stimulation (tDCS) is a noninvasive method of brain modulation that is increasingly tested for the treatment of neuropsychiatric disorders (Murphy et al., 2009) and cognitive enhancement (Paulus, 2004; Talelli and Rothwell, 2006). Conventional tDCS protocols apply 1–2 mA of current, for several minutes, through conductive-rubber electrodes inserted in sponge wrappers, which are typically soaked in saline, before being placed on the scalp. tDCS has many useful characteristics including low cost, ease of use, portability, and absence of significant side-effects. Indeed, during tDCS, mild tingling or itching sensation are the most common adverse effects (Poreisz et al., 2007), and though isolated cases of skin burns have been reported (Lagopoulos and Degabriele, 2008; Palm et al., 2008), relatively large scale experiences from several active centers, including at Gottingen, suggest that under proper protocols, significant adverse events can be avoided (Dundas et al., 2007; Loo et al., 2010; Poreisz et al., 2007).

Acute sensation under electrodes during DC stimulation is well established (Leeming et al., 1970; Mason and Mackay, 1976) and is highly dependent on both stimulation intensity and electrode design (Dundas et al., 2007; Forrester and Petrosky, 2004; Martinsen et al., 2004; Minhas et al., 2010). Sensation does not simply correlate with either skin damage or brain modulation (Bikson et al., 2009) because of the importance of electrode design and montage (for example, decreasing the distance between electrodes decreases total brain but not skin current). None-the-less, sensation is clinically significant in itself for several reasons including tolerability (especially in vulnerable populations), confounding of experimental and clinical results, and blinding. The report in this issue by Ambrus and colleagues in Gottingen evaluated sensation at electrode edges, at different stimulation sites; (2) potential difference in skin properties (skin micro-architecture). Indeed, Ambrus and colleagues report significant differences in sensitivity across stimulation sites.

The simplest explanation for sensation and discomfort during transcutaneous electrical stimulation is the excitation of peripheral nerves; electrochemical processes (Minhas et al., 2010), but not heating, (Nitsche et al., 2003; Datta et al., 2009b) may also contribute during tDCS. Regardless of the mechanism(s), hot spots of current density around the electrode edges, and perhaps around skin inhomogeneities (e.g. sweat glands), are considered to increase sensitivity, and thus approaches to increase uniformity of current density at the electrode–skin interface are rational.
In conclusion, it is important to emphasize that current technologies and protocols in transcranial stimulation, which have been largely incrementally and empirically derived, can likely be further optimized and refined. For example, electrolyte fluids and gels optimized specifically for tDCS have only recently been explored (Dundas et al., 2007; Minhas et al., 2010). The ultimate goal of such design efforts would be electrodes that minimize (if not eliminate) all sensation and prevent skin irritation, even under non-optimal conditions, while maintaining the simplicity and cost-effectiveness of existing designs. The report in this issue by Ambrus and colleagues is a valuable step toward this goal.

References


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