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Repeated anodal HD-tDCS stimulation might render silver chloride electrodes unreliable

Dear Editor,

We would like to report a technical problem that can arise from the use of silver chloride (Ag/AgCl) disc electrodes with 4 × 1 high-definition transcranial direct current stimulation (HD-tDCS). This problem might affect the produced electric field and thus the effectiveness of anodal HD-tDCS. Specifically, we are concerned that repeated use of one anode and four cathodes (anodal HD-tDCS) might result in elevated levels of oxidation of the electrodes, which in turn renders the electrodes useless or unreliable. We elaborate on our observations below.

We recently tested 89 participants (eight at a time) using anodal HD-tDCS with an intensity of 2mA for a maximum stimulation duration of 20 minutes (shorter if participants had already finished the experimental task). According to the 10–20 EEG system, the anode was placed on position P6 or Cz, and the cathodes on positions C6, CP8, PO8, P2 or C1, C2, FCz, CPz, respectively. We used new Ag/AgCl disc electrodes and within each of our eight sets of five electrodes, we always used the same electrode as anode. We ensured that the impedance for all participants was below 8kΩ. We obtained this impedance by applying pressure on the electrodes and filling the space between the electrodes' surfaces and the scalp with saline base gel. We have used this setup successfully in the past, albeit in experiments that switched between anodal and cathodal stimulation.

In this case, however, after approximately 8 uses, we observed a sudden and significant increase in impedances, which led to an automatic stop of the stimulation for safety reasons. Upon inspection of the electrodes, the anode appeared significantly more oxidised than usual, apparent from a black layer that had developed on the surface of the electrode [see also [1] for an experimental investigation on electrode types and conductive gels used in HD-tDCS research]. As a consequence of this oxidation, the conductivity of the anode was not as desired. We assume that this problem occurred in this specific setup and not in others, because the oxidation happens only at the anode, while a reduction takes place at the cathode (potentially reducing the decaying effect of the oxidation). Thus, by repeatedly using anodal stimulation and by repeatedly using the same electrode as anode, the decay of the electrodes proceeds at a much faster rate than desired. Indeed, already during the first 20 minutes of use the anode visibly oxidised (for a time-looped visualisation see supplementary video, the electrode with the white cable is the anode and increasingly darkens).

One solution to this problem might be to rotate the electrodes. I.e., rather than using the same electrode repeatedly as central anode, each electrode is used four times as (cathodal) return electrode before being used as central anode again. This way, not only will the oxidation happen more slowly (as it takes place only on every fifth stimulation), but we also assume that the corresponding reduction at the cathode will contribute to ensuring the longevity of the electrode. However, we encourage researchers with a stronger focus on the technical aspects of tDCS to investigate these mechanisms in more detail. Note that some authors before us have suggested a maximum use per electrode and a similar rotation system [2]. However, researchers do not routinely describe how often they used their electrodes, which indicates that this is not a commonly known issue in the brain stimulation community. Additionally, our observation suggest that stimulation can stop prematurely even when the initial impedance check raises no concerns.

Importantly, even with rotating the electrodes, one potential source of confound might remain. After as little as one 20-min stimulation, the anode was visibly oxidised. If, as proposed by us, the central electrode is now used as one of the return electrodes, there will be one oxidised return electrode and three unoxidised ones. Potentially, this could result in inhomogeneous electric fields, even if the overall impedance between the return electrodes and the central electrode is satisfactory. Without a setup that allows measurement of the impedances per channel, this problem seems hard to solve, and has not been sufficiently addressed by the literature thus far. Besides its relevance for basic science, this issue might be especially important for applied clinical uses, where the repeated use of electrodes for economical and logistical reasons is likely.

Of course, our observations do not devalue previous HD-tDCS studies. However, they do demonstrate a need to more systematically investigate the effects of repeated 4×1 HD-tDCS sessions on the electrodes' oxidation and, in turn, on the resulting electric fields. In our view, the brain stimulation community could profit if authors routinely report how often they used their silver chloride electrodes and take the potential decay into consideration when planning their studies.

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