Targeted multielectrode tDCS increases functional connectivity within the arcuate fasciculus network: An exploratory study and analysis

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**Introduction.** tDCS is an important tool in stroke recovery and other types of patient care. Stroke and other impairments can lead to dysfunction of the arcuate fasciculus network (AF-network). A gray matter tract in both hemispheres that connects STG, SMG, and IFG regions. Stimulation of those network nodes can lead to increased functional connectivity and behavioral outcomes, but a single electrode is typically used. Stimulation of multiple nodes of the network simultaneously may harness behavioral outcomes, particularly in aphasic stroke recovery in the hemisphere contralateral to the lesion. Here we test two multielectrode montages for the effects on functional connectivity between SMG and IFG, and contrast that with single-electrode montages. We find that a triangular multielectrode montage significantly increases functional connectivity compared to single-electrode montages, and that finite element modeling confirms that functional connectivity should be increased, particularly with the doses we selected for each anode electrode.

**Methods.** 27 subjects were recruited to undergo simultaneous tDCS and resting state fMRI (rs-fMRI) to record the BOLD signal and analyze functional connectivity using SPM and CONN tools. 4 sessions of each of 3 single-electrode montages were run (Fig. 1), and 3 sessions for each of 2 multielectrode montages were run. For comparison, 6 sessions without any IDCS stimulation were also run (no-stim). If any montage led to an increase in functional connectivity compared to a threshold established with the no-stim sessions, 3 more sessions were run. The triangular multielectrode montage did pass this threshold, so a total of 6 were run for that montage (Fig. 2b). The multielectrode montage that had an effect, triangular, also targeted both anterior and posterior/inferior nodes of the AF network, while a different multielectrode montage that targeted cortical regions in a more linear fashion showed a trend of a functional connectivity increase, but only on the order of single-electrode montages. The multielectrode montage that had an effect, triangular, also targeted both anterior and posterior/inferior nodes of the AF-network, which could be a reason for its ability to drive functional connectivity. Single-electrode montages, either separately or in combination, did not have a significant positive correlation with single-electrode montages. We find that a triangular multielectrode montage (Fig. 2b) significantly increased SMG and IFG functional connectivity. All single-electrode montages are in green, triangular in translucent circles. It is evident that current density is more homogeneous for the latter of the three montages.

**Results.** No single-electrode montage significantly changed functional connectivity (Fig. 3a), and neither did the linear multielectrode montage. However, the triangular multielectrode montage (Fig. 3b) showed a trend of a functional connectivity increase, but only on the order of single-electrode montages. We also modeled 6 current ratio setups in addition to the one we actually used (Fig. 3f). In addition to 2:1-1, we modeled 1:2-1, 1:2-2, 5:3-0:5, 5:3-0:5, 0:5-5:3, and 1:3-1:3-1:4, to test whether there is a better current ratio setup that could be used with tDCS to increase functional connectivity. The electric field in the brain induced by the DCS was also modeled with SimNIBS. The current density tangential to the cortical surface (J tangent) was analyzed for homogeneity between SMG and IFG to correlate with functional connectivity.

**Discussion.** A novel design was derived to determine whether a multielectrode DCS montage targeting nodal cortical regions of an established network, the right AF-network, could differentially increase functional connectivity between nodes of this network. One particular montage that was designed to target these nodes was found to significantly increase functional connectivity between two prominent cortical nodes, the right SMG and IFG, compared to single-electrode stimulation. No increases in functional connectivity was found with single-electrode stimulation targeted to single regions of the network, while a different multielectrode montage that targeted cortical regions in a more linear fashion showed a trend of a functional connectivity increase, but only on the order of single-electrode montages. The multielectrode montage that had an effect, triangular, also targeted both anterior and posterior/inferior nodes of the AF network, which could be a reason for its ability to drive functional connectivity. Single-electrode montages, either separately or in combination, did not have a significant effect on functional connectivity between nodes of the AF network in the targeted right hemisphere. A clear path toward answering the interesting questions on this topic more directly has thus been laid through the comparisons explored in this study.