Chapter 81

Differential Within and Between Effects on Prefrontal Hemodynamics of fNIRS Guided HD-tDCS

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Noninvasive brain stimulation via transcranial direct current stimulation (tDCS) has seen a surge in research popularity. This technology has shown promise in terms of enhancing cognition, knowledge acquisition, and psychomotor abilities in both clinical and nonclinical populations. However, only a handful of studies have attempted to measure the effects that tDCS have on brain activity during said enhancement. To add to this growing literature, we monitored the effects of high-density transcranial direct current stimulation (hd-tDCS) while individuals performed a spatial working-memory task. Prior to stimulation, a montage was selected based on brain activity related to increased spatial working-memory performance as observed via functional near-infrared spectroscopy (fNIRS) of the prefrontal cortex and a finite-element analysis of current flow to this brain region. Stimulation was implemented as both within and between subjects. The control group received two 15 min sessions of sham stimulation (ie, ramp up to 1 mA and immediate ramp down to 0 mA), whereas the experimental group received an initial session of the same sham stimulation followed by a 15 min session of actual stimulation at 1 mA. After the second session, both groups continued to perform the task for an additional 15 min. Both groups' prefrontal cortexes were continuously monitored with fNIRS from the start to the end of the testing session. The experimental group that received stimulation showed an increase in performance across the testing session. Interestingly, different between and within effects of stimulation were observed for changes in oxygenation (oxygenated—deoxygenated hemoglobin). Within subjects receiving stimulation, the level of cerebral oxygenation increased over the test session prior to the onset of the hemodynamic response; this was observed throughout the right prefrontal cortex. Between subjects the rate of oxygenation change during the hemodynamic response in the second testing session (active stimulation) was significantly reduced in the stimulation group. However, this was due to the rate of oxygenation change in the sham group during this session being significantly positive and the rate being flat in the stimulation group. Overall, the tDCS to a region of the right prefrontal cortex enhanced spatial working-memory performance, and this was related to an increase in overall cerebral oxygenation along with a relative decrease magnitude of the hemodynamic response. Noninvasive brain stimulation may have multiple effects on cerebral metabolism, and going forward these differential effects need to be considered as more mature models of the physiological effects of noninvasive stimulation are developed.

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