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Letter to the Editor

A Double-Blind Study Exploring the Use of Transcranial Direct Current Stimulation (tDCS) to Potentially Enhance Mindfulness Meditation (E-Meditation)

Dear Editor:

In the past decade, Western medicine has seen increased interest in mindfulness-based interventions (MBIs) for the treatment of neuropsychiatric disorders [1]. MBIs are associated with improvements in physical, mental, and social well-being, along with decreased feelings of stress, anxiety, depressive symptoms, rumination, and cognitive reactivity. MBIs also improve pleasant affect, life satisfaction, empathy, and task performance [2]. Although still considered in their infancy, MBIs are a promising complement to standard neuropsychiatric interventions.

Meditators have demonstrated anatomical and functional connectivity changes compared to non-meditators [3]. Long-term meditation practice induces changes in cerebral macro-structure and function, including increased hippocampal and frontal cortex grey matter volume. These findings suggest there is a neurological foundation for the benefits of meditation, however the neural mechanisms are relatively unknown. A leading hypothesis suggests that the altered state of consciousness induced by meditation is due to transient hypofrontality via prefrontal cortex deregulation [4].

The practice of meditation is inherently difficult, requiring dozens of hours of dedicated training. Many people attempt to meditate for its health benefits, but they often quit after the initial training or primary sessions due to the steep learning curve. Meditation-naïve individuals often listen to an audio recording which helps guide the initial training period and instructs them how to properly meditate [5]. Behavioral outcomes are generally subjective and reflective of the individual's perception of their session. In the research setting, the Five Facet Mindfulness Questionnaire (FFMQ) and Toronto Mindfulness Scale (TMS) quantify these outcomes. These validated scales measure an individual's mindfulness, with overall increases in the FFMQ and TMS being reported after MBIs [6,7]. Visual analog scales (VAS) are also used to measure subjective changes in positive and negative effects.

Transcranial direct current stimulation (tDCS) is a noninvasive form of brain stimulation that induces changes in excitability of desired target cortical regions. Generally, the anode selectively and transiently excites the underlying cortex, whereas the cathode decreases excitability. [8] tDCS is most effective when simultaneously paired with a task, synergistically enhancing behavioral results of the task. For example, tDCS paired with speech therapy enhances speech motor recovery [9]. Several ongoing studies are exploring its ability to enhance learning, post-stroke recovery, and cognitive behavioral therapy.

More people might practice and benefit from meditation if it were more accessible and less difficult. We performed a small pilot study using tDCS paired with a guided mindfulness meditation recording to potentially reduce the learning curve of meditative sessions while simultaneously enhancing mindfulness. This novel method, which we call E-meditation, was tested in healthy individuals with no prior MBI experience. We hypothesized that E-meditation (active tDCS + guided audio) would enhance positive affect and mindfulness as measured by mood VAS, TMS, and FFMQ when compared to audio-guided meditation alone (sham tDCS). Cathodal stimulation of the supraorbital region was selected based on the hypothesis that electrically inducing transient hypofrontality [8] would synergistically enhance the effect of guided audio meditation [4]. Anodal F8 stimulation was selected based on prior tDCS findings suggesting this area to be associated with task specific learning [10].

Fifteen healthy individuals (7 female, mean age = 28.2 y/o SD 6.8) were recruited for this double-blind, sham-controlled, crossover study. This study was approved by the MUSC IRB and its clinicaltrials.gov registration number is NCT02790619 and each participant signed an informed consent before enrollment.

All participants attended an initial screening visit where a Structured Clinical Interview for DSM-IV (SCID) was conducted, as well as tDCS safety screening and a baseline FFMQ. Following the screening visit, participants returned for 3 weekly meditation visits as demonstrated in Fig. 1a. Each 20 min E-meditation visit consisted of one of three randomized stimulation conditions (sham, active 1 mA, or 2 mA; anode – EEG F8, cathode – left supraorbital) delivered via a Chatanooga Ionto™ stimulator and 2 in. × 2 in. sponge electrodes. Stimulation was synchronized with a guided mindfulness recording (recorded by ELG) lasting 20 min. Meditators were monitored remotely via webcam. Visits were conducted 1-week apart to avoid carryover effects. Custom tDCS double-blinding software and hardware were used [9]. See Supplemental Video for E-meditation method demonstration.

The following scales were administered before each E-meditation visit: Mood VAS (12 questions; e.g. "I feel calm") rated from 0(not at all) – 100(completely) and the TMS. Following pre-scales, subjects conducted their E-meditation session. Immediately following E-meditation, subjects filled out post-scales: FFMQ, TMS, and Mood Statements VAS. There were no side effects or adverse events reported and any skin irritation due to tDCS was resolved using vitamin-E skin cream.

There were mathematical but non-significant changes between stimulation conditions in mood VAS. The four mood states closest to trending toward significance were "I feel sad," "I feel excited," "I feel restless," and "I feel calm" Fig 1b. Mean ratings of calmness

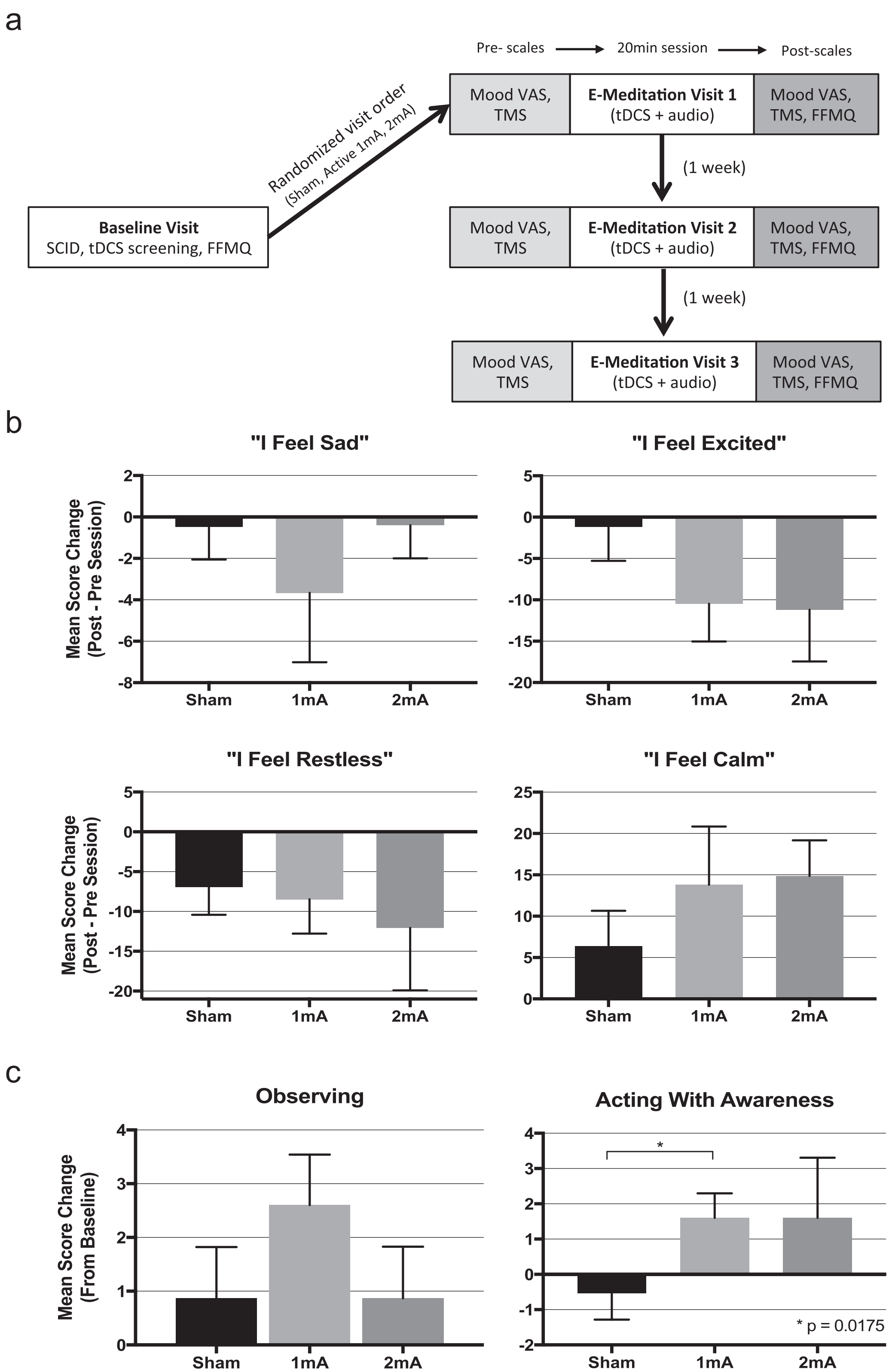

Figure 1. a) Flow diagram summarizing the trial order of events. b) Mean mood VAS rating change after each E-meditation session for all subjects (n = 15) by condition. Error bars = S.E.M. c) Mean change from baseline in the Observing and Acting with Awareness facets of the FFMQ for all subjects (n = 15) by condition. Error bars = S.E.M, * = P < 0.05.

increased 2.5 fold in stimulation conditions compared to audio guidance alone. Mean ratings of excitement and restlessness decreased in the stimulation conditions, however only 1 mA E-meditation reduced ratings of sadness. There was no discernible dose response in the majority of stimulation conditions with the exception of 1 mA optimally decreasing sadness rating.

Of the five facets of the FFMQ, E-meditation only influenced Acting with Awareness and Observing facets Fig 1c. 1 mA

E-meditation showed a significant mean difference from baseline change in the Acting with Awareness facet as compared to sham (paired t-test, $p = 0.0175$). 1 mA E-meditation also proved to be the most effective in increasing the Observing facet. TMS scales remained unchanged between pre- and post-sessions.

E-meditation is a novel approach to a centuries old tradition of meditation for psychological well-being. This is the first report of tDCS used to enhance meditation and our pilot demonstrates the feasibility, safety, and effect size of remotely supervised tDCS-enhanced meditation sessions. Given, relevant mathematical increases and decreases quantified in various measures (e.g. mood and dispositional mindfulness scales), additional longer-term (e.g. 8-weeks) trials of the effectiveness of E-Meditation are warranted. Furthermore, these preliminary findings suggest that E meditation be further examined as an adjunctive treatment for neuropsychiatric disorders.

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Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.brs.2016.09.009.

Video S1. This supplemental video demonstrates the E-meditation setup, including necessary equipment and electrode placement

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