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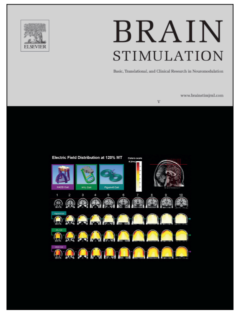

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PII: S1935-861X(22)00005-5

DOI: https://doi.org/10.1016/j.brs.2022.01.004

Reference: BRS 2112

To appear in: *Brain Stimulation*

Received Date: 13 December 2021

Revised Date: 28 December 2021

Accepted Date: 5 January 2022

TDCS in a Patient with Dreadlocks: Improvements in COVID-19 Related Verbal Fluency Dysfunction

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To the Editor

The enduring neuropsychological impacts of COVID-19, termed PASC (post-acute sequelae SARS-CoV-2 infection), remain poorly understood. Transcranial direct current stimulation (tDCS) is an appealing treatment for PASC because of the tolerability and feasibility of home use and emerging evidence for efficacy [1]. Here we describe a person with PASC presenting with speech and language dysfluency, a symptom responsive to frontal tDCS treatment [2]. To the best of our knowledge, this is the first demonstration that tDCS remediates acquired dysfluency following severe SARS-CoV-2 infection.

The patient was a 63 year-old Veteran of African and Native American descent who recovered from severe COVID-19, presented with markedly dysfluent speech, and wore dreadlocks. He reported a developmental history of "stuttering" that resolved by high school. He graduated from an elite college with a degree in electrical engineering and worked as a network operations manager. In January 2021, he was hospitalized with severe COVID-19. Seven months later, speech pathology assessment (see Supplement Table 1 for detailed language testing results) revealed marked dysfluency in spontaneous speech. Given his education, verbal fluency should have been in the high average range but was instead low average on a word list generation measure [3]. He was referred to our larger study of COVID-related stress that provided combined psychotherapy and tDCS of the frontal lobes during guided relaxation (Supplement to NCT03851380). African Americans with dreadlocks or cornrows are commonly excluded from tDCS studies due to concerns that consistent electrode contact with the scalp may not be reliable and that hair oil treatments or the thick, braided, hair may cause excessive electrode movement that may change current delivered by tDCS to the brain [4]. However, we knew of no empirical evidence that such hairstyles necessarily interfere with tDCS outcomes and enrolled him after obtaining informed consent. A clinical MRI from immediately before therapy revealed only a small lesion on diffusion weighted imaging in the anterior insula.

He self-administered a total of 30 tDCS sessions from home with a battery driven, constant current stimulator (REMOTE Mini-CT, Soterix Medical, NY), and disposable, premoistened, saline-soaked sponge electrodes (5x5 cm). Stimulation occurred twice daily over 3 weeks (2 mA, 30 minutes duration with 30 seconds ramp-up/ramp-down) with a bifrontal montage positioned with a SNAPstrap (Soterix Medical). The anode targeted the left dorsolateral prefrontal cortex (DLPFC) and the cathode the right DLPFC (F3 and F4 according to the 10-20 EEG system), slightly adapted to accommodate the patient's dreadlocks (see Figure 1a). For the first two weeks the patient received stimulation with electrodes at the hairline, half on the forehead and half on the scalp over the dreadlocks (but close to F3/F4), during which time the patient cleaned the underlying scalp area with saline prior to sessions to improve contact and reduce the potential interference of oil-based hair products (montage 1). Continuous monitoring of electrode contact quality using montage 1 revealed adequate contact for 99.7% of treatment and poor contact for only one session for a total of 5 seconds. For the third (final) week he moved the montage just anterior to the hairline so the entire electrode made skin contact; the electrodes were thus farther from F3/F4 but the stimulation was unaffected by the dreadlocks, and no instances of poor contact quality were recorded (montage 2). Figure 1a displays the electric field maps for montage 1 and montage 2 [5]. Beginning after the second to last treatment, the patient developed skin irritation and swelling under the anode near the eye (no lesions), which resolved after the last treatment, about a day later. Skin irritation has been previously reported in about 3.3% of subjects undergoing tDCS, typically developing after 4-5 sessions [6]. We doubt that our patient's skin irritation was related to the dreadlocks, because no irritation occurred during the first two weeks of treatment when stimulation was delivered over the dreadlocks, but only occurred after a week after delivery exclusively on the forehead. Therapy course was otherwise uncomplicated, with the patient reporting occasional sleepiness post-stimulation, but no other unexpected side effects (See Supplement: Observation and Reporting of Side Effects).

The electric field map of Figure 1b reveals maximal modulation in inferior frontal areas 44, 45, 47, IFJa, and IFSp [7, p.73], which partially overlaps with the language network white matter tracts derived using O8t (Omniscient Neurotechnologies). Verbal fluency markedly improved after tDCS. To reduce practice effects, validated parallel test forms were used. Whereas a healthy cohort produces on average fewer than one more word on second testing [3], our patient produced nine more words for phonemic (letter) cues, ten more for semantic (category) cues, and two more in the switching condition (switching between two categories). Figure 1c displays the magnitude of this improvement in terms of the patient's age-corrected scaled scores relative to a normative cohort (mean=10, standard deviation=3), illustrating increases of about one standard deviation from pre to post stimulation for all subtests and final performance in the average to high average range. Our improvements are consistent with a prior study of anodal left DLPFC stimulation in healthy participants [8] who showed improvements in both phonemic and semantic fluency, using a cathode positioned over the right shoulder. Modeling of semantic and phonemic similarity of the patient's wordlists suggest search strategy changes with therapy. Semantic similarity was assessed using GloVe [9] and phonemic similarity was based on edit distance. Results indicated reliance on phonemic similarity increased during the letter cues (Figure 1d, p=0.037 and decreased during fluency to category fluency cues (Figure 1d, p=0.028).

In summary, we believe this is the first reported case of tDCS therapy improving COVID-related speech/language dysfunction. Modeling of fluency items suggested that frontal stimulation enabled more flexible use of phonemic search to promote lexical access. Further studies that monitor electrode contact quality and outcomes are needed to evaluate whether the electrode positioning adjustments we made impact treatment success in patients with dreadlocks. Provided proper equipment is used, tDCS can be successfully applied in individuals with dreadlocks without requiring hairstyle changes. This removes a barrier to tDCS treatment acceptance in the African American population that has been disproportionately affected by COVID-19 [10], and supports using tDCS to support recovery from PASC.

Conflicts of interest

Dr. Rosen, Mr. Lavacot, Mr. Porter, Dr. Chao, Dr. Kumar, and Dr. Cardenas have no conflict to disclose. The City University of New York holds patents on brain stimulation with Dr. Bikson as inventor. Dr. Bikson has equity in Soterix Medical Inc. Dr. Bikson consults, received grants, assigned inventions, and/or serves on the Scientific Advisory Boards of SafeToddles, Boston Scientific, GlaxoSmithKline, Biovisics, Mecta, Lumenis, Halo Neuroscience, Google-X, i-Lumen, Humm, Allergan (Abbvie), Apple.

Acknowledgements

This work was supported by a Merit Award #RX003152 and supplement to support research on COVID-19 from the United States (U.S.) Department of Veterans Affairs, Office of Research and Development.

Figure Caption

Figure 1: a) The norm of the electric field generated by the electrode montages on the subject's brain surface, with the electrode (gray square) positions shown. Electric fields were generated using SimNIBS 3.2. b) The norm of the electric field throughout the brain volume is shown, with the white matter tracts of the language network (derived using O8t, Omniscient Neurotechnologies) overlaid in white. c) D-KEFS scores before (PRE) and after (POST) tDCS treatment; d) Semantic and phonemic similarity scores in the letter cue and category cue conditions, PRE and POST treatment. Error bars denote standard errors of the similarity score model estimates derived from the patient's consecutive responses.

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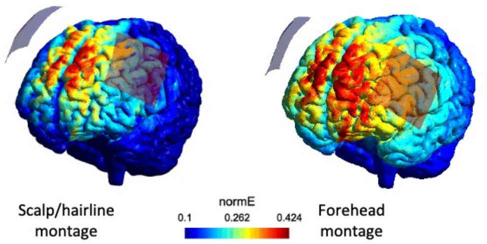
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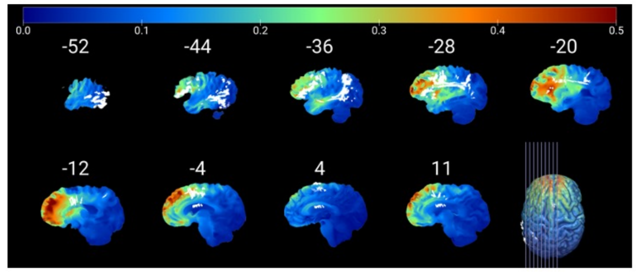
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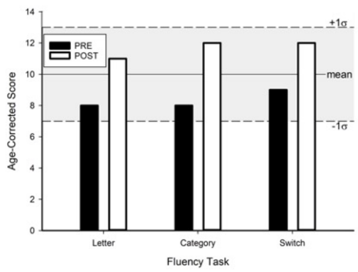
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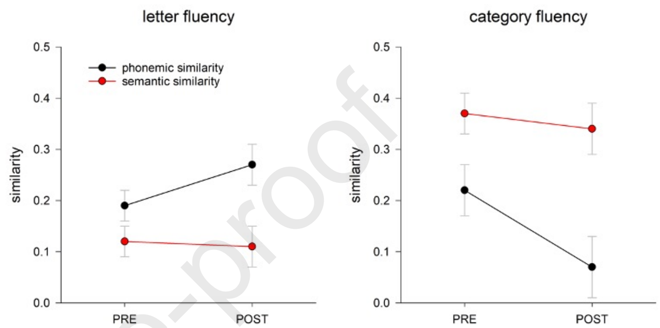
Switch
Fluency Task

c)


letter fluency
category fluency
phonemic similarity
semantic similarity
similarity
PRE
POST

d)

Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

The City University of New York holds patents on brain stimulation with MB as inventor. MB has equity in Soterix Medical Inc. MB consults, received grants, assigned inventions, and/or serves on the SAB of SafeToddles, Boston Scientific, GlaxoSmithKline, Biovisics, Mecta, Lumenis, Halo Neuroscience, Google-X, i-Lumen, Humm, Allergan (Abbvie), Apple.

MB is supported by grants from Harold Shames and the National Institutes of Health: NIH-NIDA UG3DA048502, NIH-NIGMS T34GM137858, NIH-NINDS 1R01NS112996, NIH-NINDS 1R01NS101362, NIH-NIMH 1R01MH111896, and NIH-NINDS 1R01NS095123

No other authors declare any competing interests.