Brain Stimulation 15 (2022) 1351–1353

Contents lists available at ScienceDirect

Brain Stimulation

journal homepage: http://www.journals.elsevier.com/brain-stimulation

Complementary practical considerations to home-based, remotely-controlled and independently self-applied tES combined with cognitive training

Dear Editor,

Over the last three decades, substantial evidence has been accumulated that transcranial electrical stimulation (tES) can have beneficial effects on cognitive and motor functions or ameliorate their decline. Recently, this generated increasing interest in potential home-based clinical tES applications [1]. In this context, remotely-controlled and independently self-applied tES approaches in combination with repeated behavioral interventions can enhance accessibility and training intensity for participants, while reducing burdens on clinical resources (e.g., personnel, space), with the ultimate goal to incorporate home-based treatment approaches into routine clinical care.

Implementation of home-based tES applications require decisions about several essential aspects such as selection of suitable tES parameters, training of clinical staff, assessment of end-user capability, consideration of ethics and safety, development of telehealth solutions (including remote control and monitoring of tES), and implementation of procedures pertaining to data transfer and safety [2,3]. This has been addressed in recent comprehensive guidelines for remotely-supervised tES in clinical and research contexts [4,5]. In addition, brief video publications have evaluated the feasibility of portable devices for home-use, concurrent administration of computer-based activity, and real-time monitoring of remotely-supervised tDCS [6–8]. However, home-based approaches using *remotely-supervised* tES require supervision via video-monitoring (for at least some parts of the intervention) by research or clinical staff (i.e., "real-time" supervision) [4,7,8], thus reducing demands on space but not necessarily personnel. Therefore, health economic benefits are limited. Here, *remotely-controlled, yet independently self-applied* approaches enable trained staff to monitor the device from a distance (e.g., tracking the quality, duration, and completeness of sessions or logged problems) while the stimulation is self-applied by participants without "real-time" supervision [9]. Fig. S1 provides an overview of the different parameters that describe operator and device control in home-based settings and the degree of supervision provided.

Feasibility studies of home-based, remotely-controlled and independently self-applied tES are still scarce [see 10 for one of the first pilot studies] and there are currently no guidelines. Indeed, most studies and guidelines describe "offline" tES applications (i.e., tDCS without concurrent training or therapy) and its implementation [4–6], without explicitly addressing the challenge of operating several technical devices at the same time. "Online" approaches, however, are important when using tES like transcranial direct current stimulation (tDCS), because these techniques rely on interactions of the applied current with ongoing brain activity to enhance neural plasticity [11]. Simultaneous application of training and tES, especially in a remotely-controlled approach without "real-time" supervision, poses additional challenges compared to remotely-supervised and "offline" tES.

Here, we address this knowledge gap by providing additional practical suggestions for remotely-controlled, independently self-applied tES plus training. This complements previous guidelines with regard to important clinical and health economical aspects by providing a detailed manual, instruction videos and a checklist for participants (see supplement) that can be used as templates for future research (Table 1). Importantly, these materials can be customized to individual study requirements, including the investigated populations and tES equipment.

This approach has been developed in the context of an ongoing clinical study where healthy older adults self-apply tDCS during a memory training-task over two weeks (six sessions total; ClinicalTrials.gov identifier: NCT04817124, [12]). As also described by Maceira-Elvira et al. [10], participants received extensive training on how to administer the combined tES plus training prior to trial commencement in our laboratory. In addition, we scheduled one visit in participants' homes at the beginning of the intervention to address potential technical problems associated with use of the equipment, and to validate participants' internet connection and training setting. All equipment was customized for home-use (e.g., caps have colored rivets to show the position of each electrode, saline solution is provided in 10 ml-NaCl-filled phials for each session; equipment is provided in specifically labeled bags).

Home-based tES applications during administration of training or therapy. To avoid introduction of another technical device for task administration that needs to be operated by the participants, we developed a solution that allows controlling several components (i.e., training task and stimulator) via a single device and software package. This facilitates concurrent administration of training-and-tES components, monitoring of adherence (i.e., logging of schedules and duration of stimulation sessions in a cloud-based system) and importantly, allows controlling for simultaneous timing of concurrent training and tES (including termination of the other modality when one is aborted, e.g., the task ends when stimulation stops due to high impedance).

In our study, we used the Starstim®-Home system (Neuroelectrics, Barcelona, Spain). Using this device, the investigator creates

https://doi.org/10.1016/j.brs.2022.09.010

Table 1
Overview of challenges considered by previously published guidelines for home-based tDCS (top) followed by our complementary practical considerations and materials.

	Practical guides	Instructional videos
	[4,5]	[6–8]
Previously published guidelines for *home-based tDCS* cover …	•tES parameter selection (i.e. intensity, duration, electrode locations, sham procedures, impedance checks, etc.) •Training of clinical staff (tES supervisors) and tES users •User selection (i.e. inclusion/exclusion criteria, incl. assessment of capability) •Device and electrode preparation (e.g., component labeling, prefilling saline syringes) •Proper use of devices by participants •Proper treatment environment (i.e. distraction-free setting) •Telehealth solutions (i.e. use of videoconferencing) •Ethical considerations, safety precautions (incl. monitoring of adverse events), monitoring (incl. criteria for discontinuation), and data transfer (i.e. cloud-based solutions) •*Remotely-supervised*[a] tES: Ongoing supervision in "real-time" via video monitoring	•Videos *for investigators*
Additional considerations on …	•Technical challenges for combining tES with concurrent training and administration of tDCS over multiple consecutive sessions •Suggestions for *remotely-controlled and independently self-applied*** tDCS, including a step-by-step manual and checklist for participants, which can be used as a template for development of study-specific manuals	•Videos *for participants*

[a] In line with previous recommended definitions [9], "*remotely-supervised*" tDCS refers to home-based application with real-time supervision by clinical staff via video-monitoring for at least some parts of the intervention (see also Fig. S1 for an illustration of relevant parameters to describe different approaches). ** "*Remotely-controlled and independently self-applied*" specifically refers to home-based tDCS studies where staff monitors the intervention from a distance, e.g. by tracking the quality, duration and completeness of sessions or logged problems.

stimulation protocols, uploads them into the cloud, and plans the stimulation sessions for a specific date and time. Importantly, the investigator can be assigned an account for controlling the necessary parameters without unblinding (important for double-blind clinical studies). The device is delivered with a tablet, allowing the participant to connect it via WiFi with the internet and to start the stimulation after electrodes have been attached. To facilitate feasibility for participants, we integrated the training task and the stimulation into a unified set-up. Specifically, an app-based solution allows stimulation and training task to commence simultaneously following a button press by the participants, confirming that they are fully prepared. At the end of each session, information about adverse events is requested and instructions for electrode cap removal and storage of equipment are provided. With this procedure, the participants are required to operate only one technical device after attaching the stimulation electrodes, rendering the application as comfortable, user-friendly and simple as possible [6,10]. Simplicity of the set-up in technically challenging combined approaches, including study populations-specific adaptations of instructions, will be particularly relevant to assure low drop-out rates and increase efficacy [4].

Home-based, remotely-controlled, independently self-applied tES. In their first visit to our lab, participants are trained using videos, practical demonstrations and standardized instructions. They are provided with the opportunity to practice the combined application. Training materials, including checklists, manuals and video instructions are also handed out for home-use (see supplement for materials). Importantly, frequently arising problems (such as excess impedance, low battery of the DC stimulator, etc.), are discussed and further appointments are scheduled, including sessions with supervised tES self-application in the lab. In our study, an investigator additionally visits each participant at home prior to study commencement to ensure a quiet, comfortable environment, and that technical requirements such as a stable WiFi connection are met (internet connection is only needed at the beginning of each session to synchronize information with the cloud). Additionally, remote access software is installed and configured on the tablet in case troubleshooting is required. Importantly, because sessions are not monitored, researchers and participants have to agree on the frequency of investigator-initiated contacts. In our study, we scheduled a call for all participants after one week. In case log files are not uploaded into the cloud (note that no personal data is saved in the cloud, thus adhering to the standard for quality of data security and transfer), or if sessions are aborted, investigators are automatically notified by the system via email or short message, and subsequently contact participants.

So far, ten participants have completed nine training sessions each with tDCS in our ongoing trial [12] without any major problems. These preliminary findings suggest feasibility of implementing home-based, remotely-controlled and independently self-applied tES plus training with our chosen approach, which was also well tolerated by all participants. In sum, home-based, remotely-controlled, independently self-applied tES combined with training or therapy may help to incorporate this approach into routine clinical care, but several practical challenges have to be addressed, and appropriate materials have to be made available to participants [4]. Complementing previously published guidelines, we provide additional recommendations on setting up a home-based intervention, including an adaptable instructional manual and videos. Although previously published guidelines emphasize the importance of creating a manual and a video, with photographs and screenshots [4,7], no exemplary material for participants has been made available to researchers so far. Our materials may be used as a template for designing home-based tES protocols.

Authorship statement

The authors confirm that they meet the requirements for authorship.

Funding

This work was supported by the Bundesministerium für Bildung und Forschung (Grant 01GQ1424A to AF) and by the Defitech Foundation, Morges (StS project to FCH).

Declaration of competing interest

None.

Acknowledgements

The authors would like to thank Robert Malinowski for technical support and assistance with software development, Rafal Nowak

for assistance during the planning phase of the project, Anne-Christine Schmid for consultation during manual development, and Malte Backhaus for manual translation.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brs.2022.09.010.

References

[1] Sandran N, Hillier S, Hordacre B. Strategies to implement and monitor in-home transcranial electrical stimulation in neurological and psychiatric patient populations: a systematic review. J Neuro Eng Rehabil 2019;16(1):58.
[2] Hordacre B. The role of telehealth to assist in-home tDCS: opportunities, promising results and acceptability. Brain Sci 2018;8(6).
[3] Riggs A, Patel V, Paneri B, Portenoy RK, Bikson M, Knotkova H. At-home transcranial direct current stimulation (tDCS) with telehealth support for symptom control in chronically-Ill patients with multiple symptoms. Front Behav Neurosci 2018;12:93.
[4] Charvet LE, Kasschau M, Datta A, Knotkova H, Stevens MC, Alonzo A, et al. Remotely-supervised transcranial direct current stimulation (tDCS) for clinical trials: guidelines for technology and protocols. Front Syst Neurosci 2015;9:26.
[5] Charvet LE, Shaw MT, Bikson M, Woods AJ, Knotkova H. Supervised transcranial direct current stimulation (tDCS) at home: a guide for clinical research and practice. Brain Stimul 2020;13(3):686–93.
[6] Carvalho F, Brietzke AP, Gasparin A, Dos Santos FP, Vercelino R, Ballester RF, et al. Home-based transcranial direct current stimulation device development: an updated protocol used at home in healthy subjects and fibromyalgia patients. J Vis Exp: JoVE 2018;(137).
[7] Kasschau M, Sherman K, Haider L, Frontario A, Shaw M, Datta A, et al. A protocol for the use of remotely-supervised transcranial direct current stimulation (tDCS) in multiple sclerosis (MS). J Vis Exp: JoVE 2015;(106):e53542.
[8] Shaw MT, Kasschau M, Dobbs B, Pawlak N, Pau W, Sherman K, et al. Remotely supervised transcranial direct current stimulation: an update on safety and tolerability. Journal of visualized experiments : JoVE 2017(128).
[9] Palm U, Kumpf U, Behler N, Wulf L, Kirsch B, Wörsching J, et al. Home use, remotely supervised, and remotely controlled transcranial direct current stimulation: a systematic review of the available evidence. Neuromodulation: J Int Neuromodulation Soc 2018;21(4):323–33.
[10] Maceira-Elvira P, Popa T, Schmid AC, Hummel FC. Feasibility of home-based, self-applied transcranial direct current stimulation to enhance motor learning in middle-aged and older adults. Brain Stimul 2020;13(1):247–9.
[11] Bergmann TO, Hartwigsen G. Inferring causality from noninvasive brain stimulation in cognitive neuroscience. J Cogn Neurosci 2021;33(2):195–225.
[12] Thams F, Rocke M, Malinowski R, Nowak R, Grittner U, Antonenko D, et al. Feasibility of cognitive training in combination with transcranial direct current stimulation in a home-based context (TrainStim-Home): study protocol for a randomised controlled trial. BMJ Open 2022;12(6):e059943.

Daria Antonenko*, Merle Rocke, Friederike Thams
University Medicine Greifswald, Department of Neurology, 17475, Greifswald, Germany

Friedhelm C. Hummel, Pablo Maceira-Elvira
Defitech Chair of Clinical Neuroengineering, Center for Neuroprosthetics (CNP) and Brain Mind Institute (BMI), Swiss Federal Institute of Technology (EPFL), 1202, Geneva, Switzerland

Defitech Chair of Clinical Neuroengineering, Neuro-X Institute (INX) and Brain Mind Institute (BMI), Swiss Federal Institute of Technology (EPFL Valais), Clinique Romande de Réadaptation, 1951, Sion, Switzerland

Clinical Neuroscience, University of Geneva Medical School, 1202, Geneva, Switzerland

Marcus Meinzer, Agnes Flöel
University Medicine Greifswald, Department of Neurology, 17475, Greifswald, Germany

* Corresponding author. University Medicine of Greifswald, Department of Neurology, Ferdinand-Sauerbruch-Straße, 17475, Greifswald, Germany.
E-mail address: daria.antonenko@med.uni-greifswald.de (D. Antonenko).

28 June 2022
Available online 30 September 2022