

Modulation of Motor Learning via tDCS in a Dexterous Video Game Task

NCT: 26243

Initial Approval Date 2/17/2026

Modulation of Motor Learning via tDCS in a Dexterous Video Game Task

Zachary Riley, M.S., Ph.D.: Primary Investigator
Associate Professor, Director of Graduate Studies
Kinesiology Department
School of Health and Human Science
Indiana University Indianapolis
901 W. New York Street
Indianapolis, Indiana 46202

Emelia Duchow: Co-Primary Investigator
Undergraduate Student, Research Assistant
Kinesiology Department
School of Health and Human Science
Indiana University Indianapolis
901 W. New York Street
Indianapolis, Indiana 46202

Table of Contents:

Study Schema

- 1.0 Background & Rationale**
- 2.0 Objectives**
 - 2.1 Primary Objective**
 - 2.2 Secondary Objective**
- 3.0 Outcome Measures**
 - 3.1 Primary Outcome Measures**
 - 3.2 Secondary Outcome Measures**
- 4.0 Eligibility Criteria**
 - 4.1 Inclusion Criteria**
 - 4.2 Exclusion Criteria**
- 5.0 Study Design**
- 6.0 Enrollment/Recruitment**
- 7.0 Study Procedures**
- 8.0 Study Calendar**
- 9.0 Reportable Events**
- 10.0 Data Safety Monitoring**
- 11.0 Study Withdrawal/Discontinuation**
- 12.0 Statistical Considerations**
- 13.0 Data Management**
- 14.0 Privacy/Confidentiality Issues**
- 15.0 Follow-up and Record Retention**
- 16.0 References**

1. Background & Rationale

Skill acquisition is a complex process that generally occurs through the practice and repetition of a task. Any voluntary motor activity is predicated by the engagement of specific motoneuronal circuits that coordinate the intricate firing patterns required to produce the desired movement (Krakauer and Mazzoni 2011). As these circuits are repeatedly called into action, they undergo plastic changes which allow for a consolidation and refinement of the movement associated with skill acquisition. This process of motor refinement and skill consolidation is referred to as, “motor learning” (Krakauer et al. 2019). Motor learning plays an important role in the acquisition of new skills, improvement of old skills, or even the relearning of lost skills after injury. There is considerable interest in strategies to enhance the rate of motor learning exist.

Transcranial direct current stimulation (tDCS) is a non-invasive brain stimulation technique that can be used to modulate the excitability of cortical circuits. This is performed by passing a weak electrical current between two electrodes placed on specific regions of the scalp (Stagg *et al.*, 2018). By using a sub-threshold stimulus, tDCS can directly influence the resting membrane potentials of the cortical neurons without causing them to discharge. Instead, a polarity dependent facilitatory (anodal) or inhibitory (cathodal) function is served (Antal et al. 2011). The tolerability and safety of tDCS has been well established for most applications (Bikson et al. 2016; Buchanan et al. 2021; Turski et al. 2017). However, contraindications for tDCS do exist and need to be taken into consideration. Special consideration should also be given when performing untested protocols, especially in more vulnerable populations (Salehinejad et al. 2021).

A modest body of literature exists to support the efficacy of tDCS as means to enhance motor learning (Halakoo et al. 2020; Patel et al. 2019; Wang et al. 2021). A 2019 meta-analysis including 37 studies in upper limb motor task performance found that tDCS significantly improves performance in tasks of reaction time, execution time, and force production when compared to sham stimulation conditions (Patel et al. 2019). Additionally, the 2021 review paper by Wang and colleagues investigated the effects of tDCS on physical performance and cortical excitability. After analysis of 24 studies, they concluded that anodal tDCS (a-tDCS) combined with physical training significantly enhances cortical excitability, physical performance, and motor learning when compared to sham conditions (Wang et al. 2021).

The use of tDCS significantly enhances motor learning and motor task performance (Ammann et al. 2016). These effects appear to hold true for both the early and late stages of motor learning/task consolidation (Kim et al. 2021; Meek et al. 2021). The early and late phases of motor learning are distinct from one another and likely involve differing mechanisms and brain regions (Rosenkranz et al. 2007). During tDCS, acute changes in skill performance may be tied to changes in cortical excitability and long-term consolidation of skill may be more associated with plastic reorganization of the cortex and/or a functional change in synaptic transmission (Stagg et al. 2018). Our study seeks to investigate these mechanisms by assessing the changes in performance of a relatively novel, dexterous videogame motor task (Guitar Hero). We seek to determine if there are changes between groups (tDCS versus SHAM), and within groups (day 1 test and day 2 retention). The goal of this work is to find tasks that are difficult enough to stimulate plasticity in the motor cortex, while still being enjoyable enough that they could translate to rehabilitation settings and be routinely performed by individuals suffering from Stroke, Parkinson’s Disease, etc.

2.0 Objectives

2.1 Primary Objective

To determine whether a-tDCS influences motor skill acquisition of a dexterous video game task.

2.2 Secondary Objective

To investigate the effects of skill consolidation by examining video game performance in a follow-up testing session.

3.0 Outcome Measures

3.1 Primary Outcome Measures

Learning will be measured between groups (a-tDCS and SHAM) by examining the performance improvements during the video game task in the first and second sessions. Performance in Guitar Hero is measured by the total number of correct notes hit, and the total score. Total score is dependent on the number of consecutive notes hit, as 10 consecutive notes introduces a score multiplier.

3.2 Secondary Outcome Measures

Learning will be measured within-groups by examining retention, or the performance changes between the first and second sessions. The same scoring metrics will be used in the retention analysis.

4.0 Eligibility Criteria

4.1 Inclusion Criteria

- Between ages 18 and 45 years old (to avoid any changes in the developing brain, or with aging).
- Answer 'no' to questions 2 through 16 on the tDCS checklist as these factors can increase likelihood of adverse events with tDCS
- No neurological damage, disease, or dysfunction (nerve damage, chronic pain disorders, diabetic neuropathy) that affect the upper limbs.
- No significant acute or chronic medical, neurologic, or illness in the patient that, in the judgment of the Principal Investigator, could compromise subject safety, limit the ability to complete the study, and/or compromise the objectives of the study

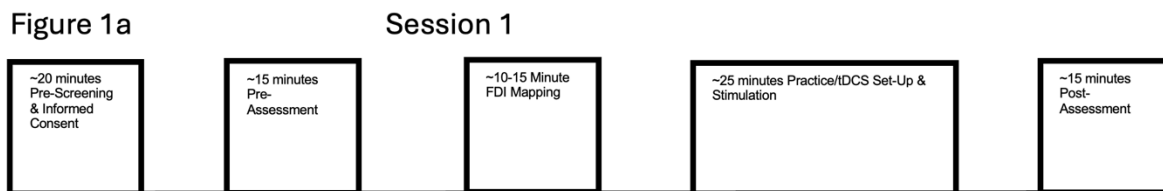
4.2 Exclusion Criteria

- Currently prescribed and taking stimulant medication (Adderall, Ritalin, Vyvanse, etc.)
- Consumption of over-the-counter stimulants such as caffeine or nicotine (coffee, soda, supplements, energy drinks, tobacco products, or other nicotine containing products such as gum, vape pens, etc...) 12 hours prior to entering the lab on the day of testing as this can directly affect cortical excitability. If a subject takes any of these substances 12 hours prior to session 1 they will be asked to reschedule for a later date.
- Have played a real stringed instrument in the last 12 months (e.g. guitar, bass, violin)

- Have played the videogame “Guitar Hero” on a traditional guitar controller in the last 12 months.

5.0 Study Design

The study will utilize a between-subjects, SHAM controlled design. Subjects will be randomly selected to receive either SHAM (n=26) or a-tDCS (n=26) stimulation and will be blinded to their condition throughout testing. Subjects will complete a total of two testing sessions, separated by ~24 hours. Both sessions will have the subject play the videogame “Guitar Hero”, with a single song done for several trials as pre- and post-assessments. The first session will contain a 20-minute practice/stimulation block where subjects practice the guitar task while receiving either “active” or “inactive” stimulation of the motor cortex. The first session will last approximately 75 to 90 minutes whereas the second session will last approximately 15 to 20 minutes. See *Figures 1a & 1b* below for an ordered list of events to be completed in each session. The times listed for each event are approximate. The pre-and post assessments are standard. After the pre-assessment, there will be a period where we will need to measure the skull and follow standard procedures for determining the correct stimulation spot for the index finger muscle, the first dorsal interosseus (FDI), which is a common muscle used in tDCS due to the large cortical representation. Following that, we will place the electrodes on for stimulation and begin the 20 minute practice period. Figure 1b shows the retention testing session ~24 hours after the first session. The subject will be asked to avoid the consumption of over-the-counter stimulants for 12 hours prior to the retention testing session, same as the first session. If the subject forgets and consumes a stimulant, we can reschedule them for up to another 24 hours, after which time they will be withdrawn from the study by the investigators.



Session 1 Only

When subjects arrive in the lab, they will have the informed consent explained to them and be given time to read and decide whether they would like to participate. If they decide to participate then the consent will be signed and filed away by the researchers. The subjects will be given a blank copy of the informed consent to keep for themselves. After this, the subject will complete the Edinburgh Handedness Inventory (EHI) and subject “previous gaming experience” questionnaire. The gaming experience questionnaire will ask about frequency and duration of different videogame play and there will be a specific question related to the game “Guitar Hero”. The subject will then be randomly assigned to the a-tDCS or SHAM group.

Subjects will be given basic instructions by the researchers on how to use the guitar controller. Subjects will then be allowed to play the test song one time on the video game as a familiarization trial. The test song is approximately 3 minutes in length. Upon completing the familiarization trial, the subjects will then perform 3 more test song trials with 2-minute rest between each. The performance of these three trials will be averaged and that will serve as the pre-assessment measure. The subject will then be outfitted with the tDCS device, and the practice phase will ensue.

The practice phase will consist of performing 4 practice test song trials while concurrently receiving a-tDCS or SHAM. To ensure that the practice is standardized, they will start the practice trials at Minute 0, 5, 10, and 15. A Soterix 1x1 tDCS unit will be used to deliver anodal current through M1, of the opposite hemisphere to the fret hand, with a 30-second ramp up to 1 mA followed by 20 minutes of continuous stimulation will be delivered in the a-tDCS condition. The SHAM condition will simulate stimulation by administering a 30 second ramp up to 1 mA followed by an immediate shut off. When the 20-minute practice session concludes, the tDCS electrodes will be removed and the subject will repeat the same procedures (3 trials) as the pre-assessment, and this will be considered the post-assessment.

Session 2

The subject will visit the lab for a brief follow-up by completing 3 song trials, the exact same as the pre- and post-assessment.

6.0 Enrollment/Recruitment

Participation in the study will be self-selected by the individual's response to flyers posted in buildings across campus and by IU Indianapolis wide listserv announcements that go out to all current IU Indianapolis students. The flyer and list-serv announcement both include a brief description of the study as well as the contact information for Miss Duchow (Co-PI).

Subjects will be able to contact Miss Duchow in-person at her office (NIFS Rm. 116), via email (eeduchow@iu.edu) if they are interested in participating.

Prior to scheduling their first visit, potential subjects will complete a tDCS screening questionnaire to ensure that they meet the inclusion/exclusion criteria as outlined above.

7.0 Study Procedures

METHODS

• Participants

52 healthy adults (males and females, ages 18-45) with no history of significant neurological disorder will be recruited for this study. All of those recruited will receive a copy of the informed consent form and it will be explained to them by the researchers. Subjects will also be asked to read the informed consent, and researchers will answer any questions that potential subjects may have prior to their signing. Subjects will then complete a brief gaming history questionnaire. After completing these steps, subjects will fill out an Edinburgh Handedness Inventory Assessment and hand dominance will be determined before beginning the task.

• tDCS Stimulation Parameters

A transcranial direct current stimulator (tDCS) will be used for both conditions. The anodal electrode (5x5cm in size) will be placed inside of a saline soaked sponge that will be fixed directly over a previously marked point of the scalp that corresponds with the index finger muscle, the first dorsal interosseus (FDI), which is a common muscle used in tDCS due to the large cortical representation. Specifically, the electrode will be placed on the brain hemisphere opposite (contralateral) to the fret hand of the guitar (non-strumming hand). A cathodal electrode will be placed above the eyes on the forehead to direct the current. Stimulation will last for 20 mins with a 30 second ramp up to a current of 1 mA at the beginning and a 30 second ramp down at the end. The SHAM condition will simulate stimulation by incorporating a 30 second ramp up to 1mA followed by an immediate shut off. This will assist with blinding subjects to the stimulation condition by providing the sensation of receiving stimulation.

• **Guitar Hero Song Task**

Subjects will perform a rhythm-based music task (Guitar Hero) using the standard guitar controller. The fret buttons will be used to select notes, colors that appear on the board, and the strum bar will be used to play the notes. The goal will be for subjects to complete a song with the highest possible accuracy. The pre- and post- assessments will be identical. There will be no penalties or Power ups that will affect the accuracy score. The accuracy score will only be calculated based on total number of beats and number of hit beats.

The practice phase will consist of 20 minutes of continuous playing. This will be performed on the same song with the same level of difficulty in the pre- and post-assessments. During practice, subjects will be instructed to focus on improving their accuracy with each song. Stimulation or SHAM will begin immediately upon starting the practice song and practice will end at the end of 20 minutes. Four total song trials will be performed during the practice period.

To maintain consistency between subjects, the same song and difficulty will be used for each subject. The ability to activate Star Power (a power up that temporarily multiplies the scores by tilting the guitar) will be disabled. Aside from a “restart button,” subjects will only have access to the fret buttons and strum bar. Finally, each subject will complete a single “practice song” to familiarize themselves with the controls and the song before beginning the pre-assessment.

8.0 Study Calendar

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I												
R												
T												
D												
S												
	1 st Quarter			2 nd Quarter			3 rd Quarter			4 th Quarter		

- **I = IRB**
- **R = Recruiting/Follow Up**
- **T = Testing/Data Collection**
- **D = Data Analysis/Manuscript Prep**
- **S = Submission for Publication**

The IRB will be initiated prior to subject recruitment in the first quarter. Subject recruitment will begin around halfway through the first quarter and continue on through the second and into the early third quarter. Testing will begin shortly after recruitment starts and conclude by the end of the third quarter. Analysis will begin as soon as possible near the beginning of the third quarter. At this time, we will begin manuscript preparation and will apply for journal submission by the middle of the fourth quarter. We are expected to bring the project to a close by the end of the fourth quarter.

9.0 Reportable Events

Any event that requires prompt reporting to the IU IRB per the IU HRPP Policy on Reportable Events will be reported within five business days in compliance the IU HRPP Policy. Minor noncompliance and minor protocol deviations not meeting the requirements for prompt reporting will be reported at time of protocol renewal.

The common *side effects* of tDCS include itching/tingling/burning sensation, reddening of the skin, mild headache. Since the term ‘adverse event’ implies that an event is unexpected, potentially harmful, and that an intervention is often needed to alleviate the adverse outcomes, the tDCS side effects do not constitute adverse events since they are well-known, benign, mild, transient, self-resolving, and expected by the researchers. It is important to note that the rates of these common side effects are similar between active and sham (inert placebo) stimulation conditions (Fregni et al. 2015; Tadini et al. 2011). We will, however, gather information about any side effects that subjects experience. At the conclusion of the retention session, we will ask participants if they think that they received active or sham stimulation, and we will ask if they experienced any side effects from the stimulation. We will also document any freely offered claims of side effects during the sessions, but we will not ask the subjects about side effects until the end of the study to prevent biasing subjects in any way.

10. Data Safety Monitoring

The principal (Dr. Riley) and co-investigator (Miss Duchow) will be responsible for data and safety monitoring. Dr. Jefferson Streepey will also serve as a data safety monitor. He has no role in the study and is independent from the PI.

The total number of subjects enrolled, withdrawn, or screened out prior to enrollment will all be monitored monthly by the PI. Any adverse events will be reported. If any subjects withdraw from the study the reason for withdrawal will also be reported.

11. Study Withdrawal/Consideration

Taking part in this study is voluntary. A subject may choose not to take part or may leave the study at any time. Leaving the study will not result in any penalty or loss of benefits to which the participant is entitled. The decision whether or not to participate in this study will not affect the participants current or future relations with IU Indianapolis.

In the event that a subject withdraws from the study voluntarily, the test data will be discarded. If the subject is withdrawn for reasons of non-compliance or due to safety concerns, their data will be discarded and they will not be eligible for a reschedule.

If an individual decides to participate, but later changes his or her mind, permission to use personal data may be withdrawn at any time by contacting the principal investigator, Emelia Duchow, at the number listed above.

12. Statistical Considerations

Based on previous work from our laboratory using dart throwing, a similar whole arm movement, we expect that we will observe a 10% improvement with a-tDCS over Sham stimulation. We also expect that we will have ~10-15% variability within groups (use 12.5% for accuracy). Based on this, we can expect a Cohen's *d* of 0.80. To obtain statistical power of 80%, we will need 26 subjects in each group (*n* = 52 total).

Performance data from the Guitar Hero game will be compared with mixed model ANOVAs with repeated measures on the different time points.

13.0 Data Management

Primary data will be collected from the game and stored on a Microsoft Excel file on Miss Duchow's password protected computer. Data will be backed up daily onto a password protected external hard drive and kept in a locked cabinet within the Neural Control Lab (NIFS 116). Data sheets from the Edinburgh Handedness Inventory and the Gaming Experience Questionnaire will also be kept in a locked cabinet within the Neural Control Lab. Monthly review of the spreadsheet by the primary investigator will be performed for quality assurance to ensure accurate data entry is taking place.

14.0 Privacy/Confidentiality Issues

The data collected will be assimilated and stored anonymously to ensure confidentiality is upheld. Subjects will be randomly assigned a number to which their data will be tied in order to organize and match the data collected from different sources. The subject's number will not be known to the subject and will be used solely for the purposes of synthesizing data. Any records and questionnaires will be stored in a password protected box within the Neuro Control Lab (NIFS 116) and will be accessible only to the researchers involved with the study.

15.0 Follow-up and Record Retention

The study could last up to a year. The records will be stored for up to 5 years after the study in which the data will then be destroyed by erasing the data from the hard drive and having the informed consents shredded by a confidential paper shredding company.

16.0 References

- Ammann C, Spampinato D, and Márquez-Ruiz J.** Modulating Motor Learning through Transcranial Direct-Current Stimulation: An Integrative View. *Frontiers in Psychology* 7: 1981, 2016.
- Antal A, Polania R, Schmidt-Samoa C, Dechent P, and Paulus W.** Transcranial direct current stimulation over the primary motor cortex during fMRI. *Neuroimage* 55: 590-596, 2011.
- Bikson M, et al.** Safety of Transcranial Direct Current Stimulation: Evidence Based Update 2016. *Brain Stimul* 9: 641-661, 2016.
- Buchanan DM, et al.** Systematic Review on the Safety and Tolerability of Transcranial Direct Current Stimulation in Children and Adolescents. *Brain Sci* 11: 2021.
- Fregni F, et al.** Regulatory considerations for the clinical and research use of transcranial direct current stimulation (tDCS): Review and recommendations from an expert panel. *Clin Res Regul Aff* 32: 22-35, 2015.
- Halakoo S, Ehsani F, Hosnian M, Zoghi M, and Jaberzadeh S.** The comparative effects of unilateral and bilateral transcranial direct current stimulation on motor learning and motor performance: A systematic review of literature and meta-analysis. *J Clin Neurosci* 72: 8-14, 2020.

Kim T, Kim H, and Wright DL. Improving consolidation by applying anodal transcranial direct current stimulation at primary motor cortex during repetitive practice. *Neurobiology of Learning and Memory* 178: 107365, 2021.

Krakauer JW, Hadjiosif AM, Xu J, Wong AL, and Haith AM. Motor Learning. *Compr Physiol* 9: 613-663, 2019.

Krakauer JW, and Mazzoni P. Human sensorimotor learning: adaptation, skill, and beyond. *Curr Opin Neurobiol* 21: 636-644, 2011.

Meek AW, Greenwell D, Poston B, and Riley ZA. Anodal tDCS accelerates on-line learning of dart throwing. *Neuroscience Letters* 764: 136211, 2021.

Patel R, et al. The Impact of Transcranial Direct Current Stimulation on Upper-Limb Motor Performance in Healthy Adults: A Systematic Review and Meta-Analysis. *Front Neurosci* 13: 1213, 2019.

Rosenkranz K, Kacar A, and Rothwell JC. Differential modulation of motor cortical plasticity and excitability in early and late phases of human motor learning. *J Neurosci* 27: 12058-12066, 2007.

Salehinejad MA, et al. Safety and Tolerability. In: *Transcranial Direct Current Stimulation in Neuropsychiatric Disorders* Springer, 2021, p. 667-676.

Stagg CJ, Antal A, and Nitsche MA. Physiology of Transcranial Direct Current Stimulation. *J ECT* 34: 144-152, 2018.

Tadini L, et al. Cognitive, mood, and electroencephalographic effects of noninvasive cortical stimulation with weak electrical currents. *J ECT* 27: 134-140, 2011.

Turski CA, et al. Feasibility and dose tolerability of high definition transcranial direct current stimulation in healthy adults. *Brain Stimulation: Basic, Translational, and Clinical Research in Neuromodulation* 10: e23, 2017.

Wang B, Xiao S, Yu C, Zhou J, and Fu W. Effects of Transcranial Direct Current Stimulation Combined With Physical Training on the Excitability of the Motor Cortex, Physical Performance, and Motor Learning: A Systematic Review. *Front Neurosci* 15: 648354, 2021.