Spring 2018

Establishing effective amplitude criterion for transcranial direct current stimulation

Lindsey Michele Schwenger
James Madison University

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An Honors College Project Presented to

the Faculty of the Undergraduate

College of Health and Behavioral Studies

James Madison University

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by Lindsey Michele Schwenger

May 2018

Accepted by the faculty of the Department of Communication Sciences and Disorders, James Madison University, in partial fulfilment of the requirements for the Honors College.

FACULTY COMMITTEE:

____

Project Advisor: Kamarunas, Erin
Assistant Professor, Ph.D., CCC-SLP

____

Reader: Griffin, Lindsay
Doctoral Student, MS, CCC-SLP

____

Reader: Clinard, Erin
Instructor & Clinical Educator, MA, CCC-SLP

HONORS COLLEGE APPROVAL:

____

Bradley R. Newcomer, Ph.D.,
Dean, Honors College

PUBLIC PRESENTATION

This work is accepted for presentation, in park or in full, at the Honors Symposium on April 18th, 2018.

Establishing Effective Amplitude Criterion for Transcranial Direct Current Stimulation

Lindsey M. Schwenger

James Madison University

Abstract

My honors project will document and reflect on my experiences as a member of a research team that is studying transcranial direct current stimulation (tDCS) as a treatment for dysphagia, or difficulty swallowing, which affects a vast, diverse group of individuals. There is substantial need for more efficient and effective rehabilitation strategies used to restore abilities and reduce the risks associated with dysphagia. Recent studies have addressed these risks by exploring tDCS as a treatment for central nervous system damage caused by stroke, traumatic brain injury, and Parkinson's disease. Research has recently been conducted to test its effectiveness, but has proven variable, as a range of methods have been utilized when administering the stimulation. The research team's specific aim was to first establish an effective amplitude criterion for tDCS by documenting its effect on cortical blood flow, muscle contraction during an effortful swallow, and a participant's perception of discomfort. This goal is useful to the field because an optimal tDCS paradigm would allow professionals to be one step closer to being able to use this tool to help individuals with dysphagia achieve a healthier swallow. My honors project is a reflection piece based on my experience and acquired knowledge from the larger study. An observation protocol was employed to facilitate reflections and observations about empirical research in the field of communication sciences and disorders for assist with this reflection.

Establishing Effective Amplitude Criterion for Transcranial Direct Current Stimulation

The issue of swallowing is complex and affects the health and quality of life of individuals across the globe. Dysphagia, or disordered swallowing, can result from etiologies such as a stroke, traumatic brain injury, multiple sclerosis, or head and neck cancer, which affect the muscles, nerves, and/or neural pathways responsible for swallowing. A disordered swallow can potentially be a significant risk to a patient’s health as they recover from a traumatic event or condition as misdirected food that enters the airway can lead to lung infection and worsen a patient’s condition.

Individuals who have dysphagia comorbid with other medical problems require a great deal of resources, as they usually spend more time in the hospital, require extensive rehabilitation, and are at risk for severe complications that debilitate the person’s overall health (Pisegna, Kaneoka, Pearson, Kumar, & Langmore, 2016; Martino, Foley, Bhogal, Diamant, Speechley, & Teasell, 2005). Although the exact incidence of dysphagia is unknown, some studies have estimated that around 22% of people over the age of 50 will experience this issue at some point in their lives (National Foundation of Swallowing Disorders, 2018). Therefore, dysphagia is more common in the older population and can be considered a significant health complication where resources, prognosis, and health are concerned (Altman, Yu, & Schaefer, 2010).

When a patient presents with dysphagia, it is common for them to work with a speech-language pathologist (SLP) to determine the safest way to swallow and if rehabilitation is an appropriate treatment course. Although dysphagia is a critical issue, treatment options are somewhat limited. Currently, there are only a few rehabilitation techniques that are used clinically. A clinician may use postural adjustments, such as asking the patient to sit in a specific position and adjust their head or neck to help make it safer and easier for food or drink to pass through to their esophagus. It is also common for SLPs to adjust the consistency and texture of the food or drink so it is easier and safer to swallow (American Speech Language and Hearing Association). Although these management strategies assist the patient in limiting the negative effects of a disordered swallow, they fail to provide long term improvement in a patient's actual swallow physiology and can have a negative impact on quality of life (Pisegna et al., 2016).

Transcranial direct current stimulation (tDCS) for rehabilitation is relatively new in the literature and is not yet FDA approved to be used in dysphagia rehabilitation in clinical settings. tDCS is a low-level electrical current applied to the cortex via the scalp with large, flat electrodes for the purpose of neuromodification of cortical excitability. This technique has been examined for efficacy in the dysphagic stroke population (Pisegna et al., 2016). Although more research studies on tDCS and dysphagia have been published in the past few years (Pisegna et al., 2016), studies have proven to be highly variable, as a wide range of methods have been utilized when administering the electrical stimulation. This makes it more difficult to establish potential tDCS guidelines for clinicians in the treatment of dysphagia. This study investigated the effect of tDCS on cortical blood flow in healthy adults, with the aim of determining the optimal settings of tDCS application. The research team's specific aim was to establish the optimal amplitude criterion for tDCS.

I served as the primary research assistant for this study. I was present for as many participant's session in the lab as my schedule allowed and assisted with set-up, data collection, and data analysis.

tDCS Background

The study and rehabilitation of swallowing is still relatively new to the field of communication sciences and disorders (CSD) and evidence-based research is still ongoing. The literature shows that the use of non-invasive brain stimulation can promote interhemispheric interactions and cortical reorganization (Harris-Love & Cohen, 2006), which can help restructure damaged areas in the brain. This reorganization can aid in motor recovery, as bilateral cortical pathways project to brainstem swallowing regions (Harris-Love & Cohen, 2006; Kumar, Wagner, Frayne, Zhu, Selim, Feng, & Schlaug, 2011; Pisegna et al., 2016). This means that both the left and right sides of the brain are involved in swallowing and communicate with one another via interhemispheric interneurons. Therefore, if activation and connectivity improvements occur in one or both hemispheres, a person's swallowing physiology may also improve (Zhao, Dou, Wei, Li, Dai, Wang, & He, 2015). The literature to date demonstrates that tDCS affects brain activity at the neural level. When the electrodes are placed on the scalp, the stimulus reduces the neural action potential, enhancing neural excitability, which promotes reorganization and interhemispheric interaction (Harris-Love & Cohen, 2006).

In recent years, tDCS has been proven to successfully facilitate recovery in individuals with dysphagia and is a possible support strategy during swallowing training (Shigematsu, Fujishima, & Ohno, 2013; Yang, Back, Shin, Lim, Jang, Kim, & Paik, 2012; Adeyemo, Simis, Macea, & Fregni, 2012; Pisegna et al., 2016; Ahn, Sohn, Park, Ahn, Shin, Park, Ko, & Shin, 2016). The available literature asserts tDCS has been found to be well-tolerated and free of serious adverse effects (Kessler, Turkeltaub, Benson, & Hamiliton, 2012; Adeyemo et al., 2012; Bikson, Grossman, Thomas, Zannou, Jiang, Adnan, & Woods, 2016). Individuals have reported minor discomfort, such as itching, burning, and tingling while stimulation was occurring, but this has easily been resolved by reducing the intensity of the stimulation (Kessler, Turkeltaub, Benson & Hamilton, 2012).

Clinical trials conducted thus far have not been exclusive to one group. Many clinical trials have focused on participants with stroke and dysphagia, as swallowing impairment tends to be extensive in this specific population and the nature of their injury fits the theoretical underpinnings of how tDCS likely augments rehabilitation strategies. Trials have also explored the use of tDCS for individuals with traumatic brain injuries and head and neck cancer (Lee, Kim, & Park, 2015; Langmore, McCulloch, Krisciunas, Lazarus, Daele, Pauloski, & Doros, 2015; Lee, Yeom, Lee, Seo, Oh, & Han, 2016). Researchers are finding that the use of brain stimulation may not be as limited as it once seemed, and larger clinical trials could potentially be generalized to various populations.

Although the effectiveness of tDCS has been revealed by the research thus far, developing considerations regarding methodology emphasize the requirement for further investigation. The current literature demonstrates wide variability in tDCS stimulus administration. Factors that lack a set protocol in the literature include target hemisphere, stimulation duration, and stimulation amplitude. This project targets stimulation amplitude as it is an essential component of tDCS where dysphagia recovery is concerned (Yang, Back, Shin, Lim, Jang, Kim, & Paik, 2012).

In a study that was conducted in 2012, Yang and colleagues compared the effects of different amplitude criterions of tDCS. The first group of participants received stimulation of 1milliamps (mA) of anodal tDCS for 20 minutes for 10 days, while another group was received 2 mA of tDCS over a five-day period for 30 minutes each day; both groups were compared to a control group who received no stimulation. Functional Dysphagia Scale (FDS) scores based on videofluorosopic study (VFSS) were measured at baseline and three months after the intervention. FDS scores represented the status of 11 oral and pharyngeal swallowing functions, such as lip closure, oral transit time, and residue in valleculae. Results indicated that the first treatment group displayed no difference when compared to the control group, while the second treatment group produced more positive results (Yang et al., 2012). As this study varied stimulation amplitude, stimulation duration, and treatment duration, it is difficult to determine which of these factors played the greatest role or if it was a combination of factors. It is clear that tDCS amplitude requires more extensive and controlled study.

As such, the specific aim of the current study was to establish an effective amplitude criterion for tDCS by establishing how different tDCS amplitudes (in milliamps, mA) affect cortical activation and submental muscle contraction during swallowing, as well as the participants' perception of discomfort during stimulation. Three groups of participants receiving different tDCS amplitudes (0 mA [control], 1 mA, or 2 mA) were compared to each other. The initial hypothesis was that both 1 mA and 2 mA tDCS groups will have greater cortical activation change and submental muscle contraction change post-treatment compared to the control group with the 2 mA group experiencing the greatest significance.

Design and Methods

A between and within subjects randomized controlled trial was employed to answer the research questions. The experiment was a double-blind ABA design in which the dependent variables were measured at baseline and again after tDCS application. Both the principle investigator, Lindsay Griffin, and the participants were unaware of group assignment (e.g., 0 mA, 1 mA, 2 mA). This study was funded through a James Madison University (JMU) research grant and approved by the JMU Institutional Review Board (17-0284). Each session was approximately 2-2.5 hours in duration.

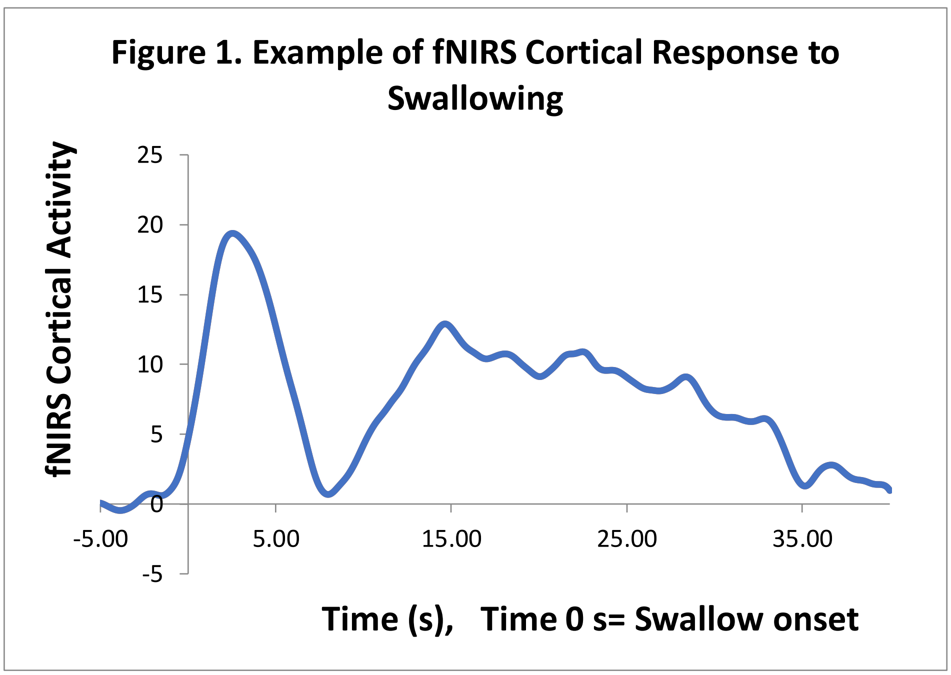
Participants

This project began with a pilot study to determine feasibility and to inform a power analysis, which is the portion of the study that I participated in and reflected upon. The pilot study collected data from 18 healthy participants, age 30 and above. Participants volunteered their time in response to both email requests and flyers that were distributed within the university setting as well as the Harrisonburg communities. Participants received a monetary payment of $40.00 for their time.

All participants completed a preliminary survey online that gave the researchers notice of any exclusionary criteria that might apply to that individual. Exclusionary criterion included, but was not limited to: history of swallow problems, history of epileptic seizures, and allergy to medical tape. Participants also completed both the Mini-Mental State Evaluation as a cognitive screener and the Reflux Symptom Index screener. All participants gave informed consent. Participants were randomly assigned to one of three groups, the 0 mA group (control), 1 mA group, or 2 mA group (between-subjects factor). The pilot study had six participants in each group, with the potential of eventually having 15 participants in each group should the pilot study expand.

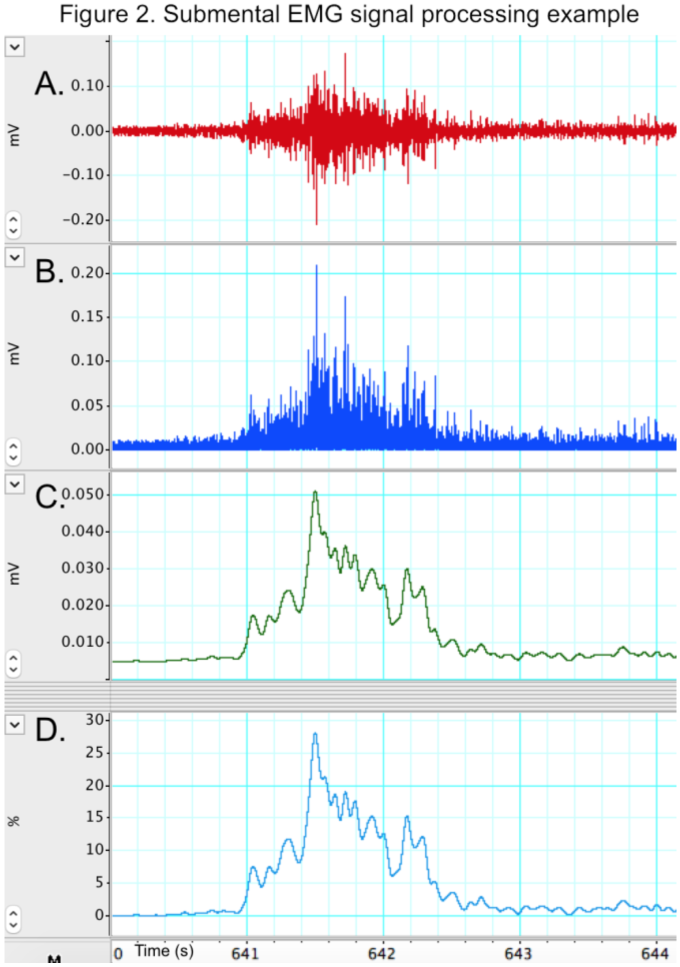
Instruments

Two of the dependent variables in this experiment included changes in cortical activation and submental muscle contraction. These signals were digitized and recorded using functional near-infrared spectrometry (fNIRS) and surface electromyography (sEMG) respectively. fNIRS allows for monitoring cortical neural activity using light emitters and detectors placed on the participant's scalp over cortical regions known to be active during swallowing (Lowell, Poletto, Knorr-Chung, Reynold, Simonva & Ludlow, 2008). fNIRS is an effective tool to measure changes in cortical blood flow, a correlate of neural activity, when used in tandem with tDCS (Mckendrick, Parasuraman, & Ayaz, 2015). fNIRS was digitized at a 50 Hz sampling rate. The fNIRS channel signals were high- and low-pass filtered at 0.01 Hz and 0.5 Hz respectively to remove physiological signals (e.g. Mayer's waves, respiratory, and cardiac). A CBSI Motion Correction filter performed a correlation-based signal improvement to correct for motion artifact (Cui, Bray, & Reiss, 2010). Swallow onset was defined as time 0 s. For each participant, event-related averages for each of the cortical region of interest were computed from 5 s before swallow onset to 35 s after swallow onset (Figure 1) and analyzed for peak (highest value of the signal) and area under the curve (AUC).



Electromyography electrodes (EMG) were used to measure the submental muscle contraction during swallowing pre-tDCS, during tDCS, and post-tDCS (John Hopkins). EMG was digitized at a 10 kHz sampling rate. The EMG data was high- and low-pass filtered at 500 Hz and 75 Hz respectively to extract noise and participant movement from the signal (Figure 2A). The signal was then rectified and smoothed using a 10 Hz low-pass filter (Figure 2B & C). The smoothed signal was normalized into percentage by referencing the maximum value recorded for each participant during a swallow as 100% and referencing periods of no movement as 0% (Figure 2D). The EMG data was marked for swallow onset, defined as when the EMG signal reached 10% above baseline during a swallow, and swallow offset, which was defined as then the EMG signal returned to 10% above baseline after a swallow. The root mean square value for each swallow from onset to offset was determined. Both fNIRS and EMG were analyzed offline.

Figure 2. Submental EMG signal processing example



Other digitized physiological signals included laryngeal accelerometry (Kistler Instrument Corporation), which measures laryngeal movement during a swallow using a small sensor, which was placed directly over or just above the thyroid notch (Adam's apple). Additionally, Respitrace bands (Ambulatory Monitoring Inc.) were placed around the participant's rib cage and abdomen to monitor the participant's respiratory movements, including apneic periods that occur during swallowing. Although the data taken from laryngeal accelerometry or respiratory signals were not analyzed, they were used to help confirm the occurrence of swallows in off-line analyses. All physiological signals were digitized and synchronized using PowerLab 16/30 (AD Instruments) and Labchart 8 software (AD Instruments).

The within-subjects factor was time, as measurements were taken before, during, and after tDCS application. This is described below.

Baseline Measures

One mL of room temperature distilled water was delivered to the participant every 40 seconds using a water pump (Masterflex L/S) and a tube held between the participant's teeth. The participant was instructed to swallow each water bolus with effort. One mL is a small amount and replicated a typical saliva swallow. A total of 30, 1-mL boluses were delivered over the 20-minute baseline condition with continuous recording of cortical activity (fNIRS) and swallowing muscle contraction (sEMG).

tDCS Application

Upon completion of baseline measures, the participant received 30 minutes of tDCS according to group assignment (0 mA [control], 1 mA, 2 mA) over the left lateral posterior frontal/anterior parietal region of the brain. At the beginning of the stimulation period, the participant received a 1 mL bolus of water every 40 seconds for a total of 5 minutes. This was followed by a 20-minute rest period (no water delivered) with continuous tDCS stimulation. During the last five minutes of stimulation, the participant was again instructed to swallow 1 mL of water every 40 seconds. During this time, continuous EMG and fNIRS from the right hemisphere were digitized. After this 30-minute block of tDCS stimulation, the tDCS electrodes were removed and post-testing took place.

Post-Testing

Baseline measures as described above were repeated post-tDCS. The participant was administered 1 mL of water every 40 seconds for 20-minutes and instructed to swallow hard for each swallow while fNIRS and sEMG were continuously digitized.

Comfort during stimulation

Upon completion of post-testing procedures, all devices were removed from the participant, and they completed a questionnaire that assessed the level of discomfort they experienced during the session. The participants rated their comfort on a 100 mm general magnitude scale with the left end labeled as “No discomfort throughout the 30 minutes” and the right end labeled as “Discomfort that was difficult to tolerate for 30 minutes.” Ratings were later converted into a 0-100 comfort score.

Data Analysis and Confidentially

All digitized data was coded for blinding purposes. To ensure participant confidentiality, each participant was randomly assigned an ID code and their individual data was stored using only this code. In addition, video recordings of the participant were recorded only from the bottom of the nose and down to protect their identity. These video recordings were saved in a de-identified manner. All physiological signals, such as sEMG and fNIRS, were saved on the Neural Bases of Communication and Swallowing Laboratory's secure server.

Observation Protocol

After running approximately 10 participants, a set of questions that addressed topics regarding my future career and the way in which inquiries are investigated through empirical research in the CSD field were answered (Appendix B). An observation protocol was employed at the completion of each individual session (Appendix A). This document includes general observations that also informed my overall reflection.

Results

Two-way analysis of variance (ANOVAs) (3x3) were performed to determine the effect of group (control, 1 mA, 2 mA) and condition (baseline, tDCS, post) effect on fNIRS peak and area under the curve and on EMG root mean square (RMS). Alpha levels were set to .05. Results are provided in Figures 3-6.

For fNIRS peak, which represents the maximum blood flow response in cortical regions of interest during swallowing, there was no effect of condition ($F=1.1$, $p=.34$) or interaction of group and condition ($F=2.1$, $p=.11$) (Figure 3). For fNIRS area under the curve, which represents the total blood flow response during swallowing in cortical regions of interest, there was also no effect of condition ($F=1.2$, $p=.33$) or interaction of group and condition ($F=1.7$, $p=.18$) (Figure 4). For EMG root mean square, which represents submental muscle contraction during swallowing, there was no effect of condition ($F=0.94$, $p=.40$) or interaction of group and condition ($F=0.36$, $p=.83$) (Figure 5).

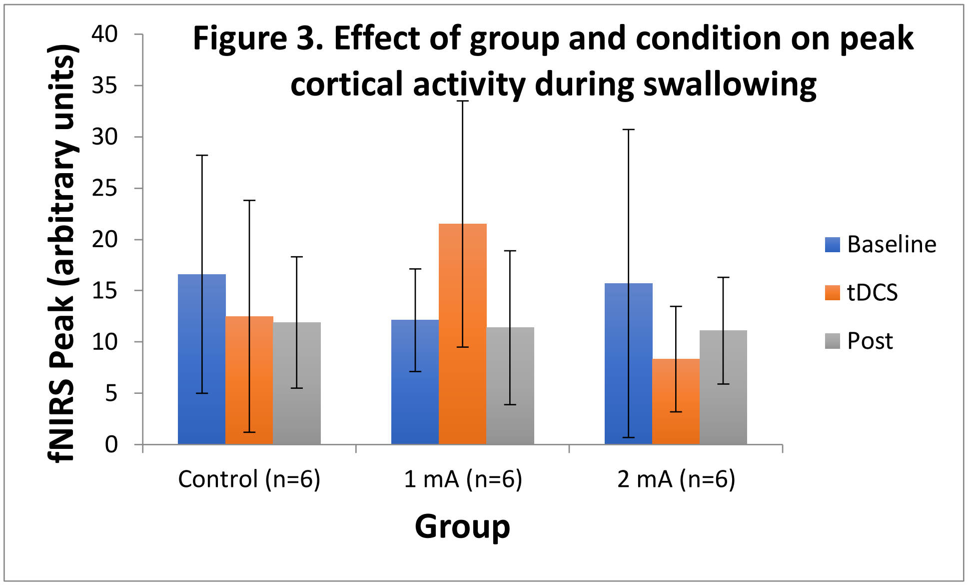


Figure 3. Effect of group and condition on peak cortical activity during swallowing

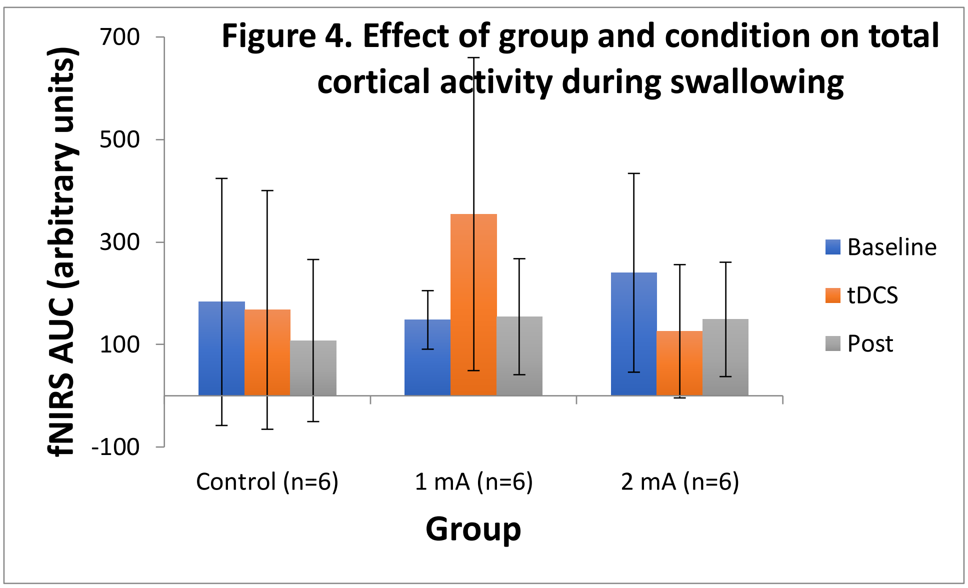


Figure 4. Effect of group and condition on total cortical activity during swallowing

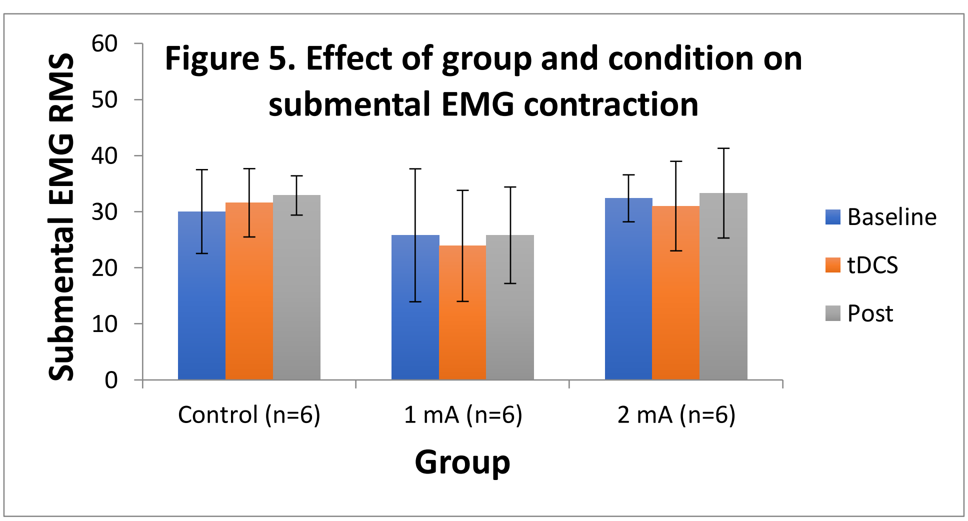
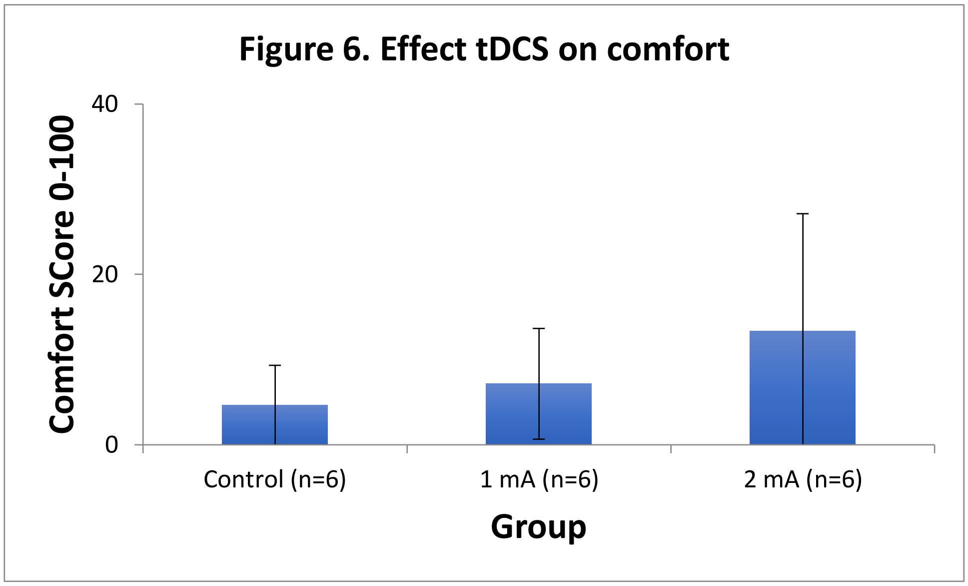


Figure 5. Effect of group and condition on submental EMG contraction

Although participants' level of discomfort increased with tDCS amplitude, the increase was not statistically significant (F=1.4, p=.28) (Figure 6).



Conclusion

This pilot study did not establish an optimal amplitude criterion for tDCS as there were no significant statistical outcomes. No outliers were identified for this study. The initial hypothesis was that both 1 mA and 2 mA tDCS groups would have greater cortical activation change and submental muscle contraction change post-treatment compared to the control group, but the 2 mA group will have greater significance compared to the 1 mA group was not proven by this study, although the group sizes are too small to draw a general conclusion.

Future Modifications

Continuing this study will be dependent upon funding. If research continues, the study design will be adjusted to increase the likelihood of achieving statistically significantly results. A power analysis based on the current data indicates proper power (.95) could be achieved with

8-11 participants in each group. The protocol of this study would be adjusted so the pretesting, tDCS application, and post-testing would each be 30 minutes in duration. Doing this would result in the researchers being able to compare the same amount of time and swallows for each section, rather than comparing 20 minutes of data in the pretesting and post-testing sections to the 30-minute tDCS application.

The swallows would also occur in blocks of five minute durations for all sections of the study, rather than being delivered to the participant every 40 seconds, which would result in approximately one swallow per minute. This standardization of the protocol would also allow the researchers to more accurately compare the pretesting, tDCS application, and post-testing sections.

Reflection

Question 1

What have you learned about the dynamics of collaboration? How does collaboration encourage and assist in the success of empirical research?

The concept of collaboration is one that is complex and takes experience to truly understand in the empirical research realm. Whether the research team was running a participant, analyzing data, working on equipment, emailing back and forth, or doing something else, I noticed that I was gaining knowledge about collaboration and the dynamic of the members of the research team every step of the way. One of the most crucial things I learned about this topic is that communication and teamwork are key to succeeding in this type of work. Because several things were being completed at once most of the time, all the members of the team needed to communicate about who was doing what task and when. Responsibilities were constantly being delegated so that we could make efficient progress toward our overall goal. In addition, because running participants was such a lengthy process, there were instances when one team member could not stay the entire time of the process or could not attend at all. Therefore, other team members had to perform jobs they did not typically do. This taught me a great deal about how teamwork, cooperation, and overall competency is necessary in the empirical research process. When people are understanding and flexible, the entire study benefits.

Through this process, I also learned about how collaboration can facilitate the transfer of knowledge from one person to another. For example, my advisor, Dr. Kamarunas, has a plethora of knowledge and experience that she is constantly transferring to the people around her. Being the recipient of her expertise has taught me the value of surrounding oneself around more accomplished and knowledgeable people.

In addition, I have come to realize that each person, no matter their skill level or background, has something to bring to the table that can benefit research in some way. For example, there was a specific task during the set-up process that needed to be completed for each participant that involved using a pointer to find specific locations on the scalp for the continuous recording of cortical activity (fNIRS). Even though I am the least educated and experienced team member of the group, I seemed to have a natural ease completing this specific task. This was beneficial because it cut down the time it took to set up each participant in the beginning of the study. Overall, I have gained knowledge about collaboration and am better at working with others in a professional manner as a result of being a research assistant in this study.

Question 2

In what ways has participating in this research affected my attitudes about becoming an SLP?

Participating in this research has made me more motivated and enthusiastic about becoming an SLP. I can say with certainty that how I operate in the future as a clinician will be affected by receiving research exposure during my undergraduate experience at James Madison University. I now have a deeper understanding of how knowledge is systematically obtained in not just the field of Communication Sciences and Disorders, but in virtually every field. The empirical process of uncovering information is extensive and meticulous. There have been several times throughout this process that I have found myself in awe of the fact that as a society, we know as much as we do.

As a future clinician, I plan to make it a point to refer to the most up-to-date research available to inform my practice. As a result of being a part of this study, I have gained an understanding of the importance of research and the way in which it shapes what we do as SLPs. Intensively researching the topic of Transcranial Direct Current Stimulation throughout this process has helped me develop the skills I will need to be an informed SLP. For instance, I now understand how to find, decipher, and utilize peer reviewed journal articles. This is a crucial skill that in my opinion, takes time to develop, as these articles can sometimes be confusing to an unexperienced reader like myself at the beginning of this process. This skill will enable me to efficiency and accurately obtain evidence-based information throughout my career.

This experience has also made me more excited about interacting with people in my future career. I have really enjoyed talking with participants in this type of setting. By observing Dr. Kamarunas' and Lindsay Griffin's interactions with the participants, I have learned about how to act in a professional manner and develop rapport with a client. Because I have not yet been in a professional situation with a client before in which I am a trained clinician, watching this has made me excited for the future.

Question 3

What have I learned about the scientific process? How does this relate and contribute to the CSD field?

As briefly mentioned above, I have been fascinated and surprised while learning more about the scientific process in the CSD field. There are various aspects of this topic to which I have been exposed. One of the first steps of this process that I was exposed to was deciding on a research topic. Lindsay Griffin was the individual who chose to research the topic of establishing an effective amplitude criterion for tDCS. I now understand the importance of being passionate and highly interested in a topic when conducting an empirical study. When one is highly motivated to uncover the answer to a research question like Lindsay Griffin, the researchers are more likely to stay motivated and focused, as this process can be lengthy, and in my opinion, monotonous at times.

The next aspect of the scientific process that I learned about was the Institutional Review Board (IRB) process. Prior to this study, I knew nothing about the IRB. I now know more about its purpose, importance, and the process involved in getting a study approved. I was able to see what the IRB document for this study looked like and read through all of it. This study's IRB submission was accepted on the first try, but I talked to other honors students who had to submit their IRB several times before it was accepted. Therefore, I know that this can sometimes be a challenging, but necessary process to ensure the safety of human participants.

I also learned about the issue of funding in the scientific process. To my surprise, research is highly dependent on being funded. Therefore, even if a researcher wanted to complete a specific project, they may not be able to do so if they do not receive the necessary funds. For this study, we received a grant that enabled us to conduct the pilot study. In order to receive money for a study, researchers must apply for specific grants and are not guaranteed to get them. In addition, I was surprised to learn that the money received by grants must be spent within a certain time frame. Therefore, I learned that receiving and utilizing grants is a highly systematic and interesting process that is crucial to scientific research.

Another significant aspect I learned about regarding the scientific process is the use of technology and equipment. Through this experience, I had the opportunity to learn how to use various instruments, such as functional near-infrared spectrometry (fNIRS), surface electromyography (sEMG), laryngeal accelerometry (Kistler Instrument Corporation), Respitrace bands (Ambulatory Monitoring Inc.), and PowerLab 16/30 (AD Instruments). Troubleshooting was a common occurrence when running participants. Because we were working with so many pieces of sophisticated technology, it was difficult making sure that everything was running properly. Although technology is a crucial aspect of the scientific process, it can also be a challenge.

While interacting with various members of the community who volunteered to be participants, I gained crucial knowledge about privacy and confidentiality. To ensure participant confidentiality in our study, each participant was randomly assigned an ID code and their individual data was stored using only this code. In addition, video recordings of the participant were recorded only from the bottom of the nose and down to protect their identity and were saved in a de-identified manner. Prior to being a part of this study, I did not give a great deal of thought about why it is important to keep a person's private information secure and protected. This study, in addition to learning about the Health Insurance Portability and Accountability Act (HIPAA) in one of my classes this semester, I have a new understanding and appreciation for confidentiality. This topic applies to every specialty within the field of CSD. I believe that this will inform my practice as a future clinician.

I have also learned a great deal about the process of data collection and analysis in the scientific process. As mentioned previously, I mostly used Labchart 8 software (AD Instruments) to analyze participant data. Analyzing data for this study required a great deal of time and effort. Because of experiencing this fact, I now have a deeper appreciation for the research that influences and informs the evidence-based practices in the field of CSD. I now feel proficient in using Labchart 8 software (AD Instruments), which will most likely prove useful in the future, as it is an extremely useful tool.

One aspect of data analysis that I did not anticipate is the subjective nature that exists in the decision-making process. It quickly became apparent to me that although two researchers could be given the same instructions when analyzing data, they may analyze data differently than one another. In the case of this study, when analyzing sEMG data, for example, it was up to the discretion of the person analyzing the data to determine at which exact peak the swallow occurred. This was at times, in my opinion, highly subjective, and this subjectivity most likely affected the sEMG outcomes in some way. Obviously, decisions made throughout the scientific process should be as objective as possible. Overall, I have learned that this is a goal that researchers must constantly work toward when conducting a study, and it is not something that simply comes from the research design alone. When I am an active member in the CSD field, I will keep this in mind when referencing any research.

The final and arguably most important aspect I have learned about the scientific process is that things do not always go as planned. This can apply to almost every aspect of a study, including all the factors involved in running a participant, receiving a grant, the timeline of a study, and the overall results and outcomes. These aspects of the scientific process are exceedingly difficult to predict, and often do not occur as a researcher would like. Because the overall results of this study were not what was initially hypothesized, I have had the opportunity to witness this aspect of the scientific process first-hand, which I have found to be extremely valuable. This relates to not only research, but to the CSD field as a whole. Therefore, this will inform my practice as an SLP because I will be aware that not every treatment or lesson plan will result in improvement, and therefore I will need to constantly adjust what I am doing. This will make me a better clinician because instead of being surprised and discouraged when this occurs, I will know that unintended results are a plausible outcome from the beginning, and I will always be ready to introduce another idea when the initial one does not work.

Question 4

Is research something I will want to pursue in graduate school? Is this aspect of the field something I will aspire to pursue later in my career as an SLP? If it is something I would like to pursue, do I want to research swallowing?

After this experience, I have come to realize that I do not feel particularly passionate about research at this point. However, because I feel that I have gained so much knowledge and experience from being a part of this study, I would not be opposed to contributing to a different research project during graduate school. In the past, I have volunteered to be a participant in other professors' studies and based on those experiences, it appears every study is vastly different. For this reason, I am hesitant to make statements that would be all encompassing about my future involvement in research. I can say, however, that at this point I view research as a rich learning opportunity and therefore, am open to future research experiences in graduate school. As a passionate and invested student, I am open to virtually any opportunity that would allow me to gain more knowledge and experience at this point in my education.

As for my future career as an SLP, I predict that I will not pursue a Doctor of Philosophy degree, as I am not interested in teaching or in conducting research in my career. At this point, I am predominantly interested in working hands-on with children. However, it is possible that I will generate questions that I would like to research while I am doing this. If this occurs, perhaps I will change my mind about pursuing research in the future. Because this is an unlikely occurrence that I do not feel avid about right now, I am not sure what the topic of this future research would be and therefore, swallowing could potentially be the subject of my studies.

Question 5

After graduate school, do I want to work in a hospital and with swallowing?

5a: If not, what area do I want to explore next?

At this point in my education, I am open to exploring various work environments. I feel confident that I will gain a better idea of where I would like to start working once I gain clinical experience in graduate school. Working in a children's hospital with feeding and swallowing is an area that I would like to explore. I like the idea of doing this because it combines my interests of working with children and the medical side of the field. I know that in most graduate programs, students are required to have an externship experience that is in a medical environment, and one that is in a non-medical environment, such as a school. Hopefully, I will have the opportunity to be placed in a medical setting where I can gain knowledge about pediatric feeding and swallowing. If I find that I enjoy working with this population in this type of setting, I would seek employment in this environment after graduate school. Through my participation in this study, my interest in swallowing has become stronger. This is an aspect of the field that I will be sure to seek more opportunities to learn about during graduate school and afterward.

If I find that I do not want to work in a hospital with swallowing after graduate school, I am also interested in the idea of working in a private practice or doing at-home therapy. After observing in both environments, I have discovered aspects that I enjoy about each one. Like the hospital environment, I hope to learn more about these during graduate school.

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Appendix

Appendix A

Question 1: What things were working well in the lab today (collaboration, interactions with participants, rapport, communication)?

Question 2: What challenges did I notice in the lab today (technical, social, procedural)?

Question 3: What did you learn today?

Question 4: What did you notice about participant-clinician interactions?

Question 5: Was there anything you would have done differently today, looking back on your experience?

Question 6: What connections did you see between what happened today and broader topics in your discipline or profession?

Question 7: Are there any other miscellaneous observations that I want to record?

Appendix B

Question 1: What have you learned about the dynamics of collaboration? How does collaboration encourage and assist in the success of empirical research?

Question 2: In what ways has participating in this research affected my attitudes about becoming an SLP?

Question 3: What have I learned about the scientific process? How does this relate and contribute to the CSD field?

Question 4: Is research something I will want to pursue in graduate school? Is this aspect of the field something I will aspire to pursue later in my career as an SLP? If it is something I would like to pursue, do I want to research swallowing?

Question 5: After graduate school, do I want to work in a hospital and with swallowing?

5a: If not, what area do I want to explore next?