4-5-2018

The Impact of Task-Specific Transcranial Direct Current Stimulation (tDCS) on Sustained Attention in a Healthy Population

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THE IMPACT OF TASK-SPECIFIC TRANSCRANIAL DIRECT CURRENT STIMULATION (tDCS) ON SUSTAINED ATTENTION IN A HEALTHY POPULATION

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Arts

in

The Department of Communication Sciences and Disorders

by
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B.A., Louisiana Tech University, 2013
May 2018

This manuscript is dedicated to the educators, family, and friends who have supported me throughout my academic journey.

ACKNOWLEDGEMENTS

This thesis was made possible by the unwavering and thoughtful support of my advisor, Dr. E. Susan Duncan. To Dr. Duncan, thank you for your endless patience, knowledge, and guidance throughout the entire thesis process. The insight you have so generously provided me has informed my development as a researcher, a clinician, and an individual. I am honored and indescribably grateful for the opportunity to work with and learn from you.

To my committee members, Dr. Neila Donovan and Dr. Melissa Beck, thank you for your time, advice, and professional expertise throughout the duration of this project. Additionally, the opportunity to utilize equipment and data analysis software afforded to me by the LSU COMD Language Imaging & Brain Research Laboratory proved an indispensable asset in completing this project.

Finally, I'd like to thank my spouse, Aimee Janelle Hinkley, and my friends. Aimee, thank you for your patience, understanding, consolation, and doing pretty much all of the laundry throughout this entire process. You are a source of constant support and I couldn't have done this without you. To my friends, thanks for your patience, comforting words, and dragging me out of the house when necessary. I'm so grateful to all of you.

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ABSTRACT

Objective: To examine the impact of task-specific anodal transcranial direct current stimulation (tDCS) administered over the left dorsolateral prefrontal cortex (L-DLPFC) on sustained attention in healthy participants.

Methods: This study examined the effects of task-training and tDCS over the left dorsolateral prefrontal cortex on sustained attention. Participants (n=13) completed four sessions consisting of either true-stimulation (2 mA for 10 minutes) or sham-stimulation (2 mA for 30 sec) in counterbalanced order. Participants completed one session every 7 to 10 days and were randomly assigned to one of two task-specific conditions in counterbalanced order. All sessions consisted of a 10-minute Go/No-Go Task (GNGT) immediately prior to and after stimulation. Between pre- GNGT and post-GNGT, participants completed either another 10-minute GNGT or a passive cartoon viewing task. Changes in reaction times and response accuracy on post-GNGT were compared across conditions using repeated measures ANOVA.

Results: 2x2 repeated measures ANOVA revealed no significant main effects of task (practice vs. passive) or stimulation type (true vs. sham) for reaction times or response accuracy; interaction was also nonsignificant. Unplanned post-hoc analyses using 2x2 repeated measure ANOVA to assess fatigue were conducted on the first half of Go/No-Go performances and revealed an interaction effect for task and stimulation on accuracy. To assess isolated sustained attention, performances during Go trials were assessed at full length, midway, and a quarter through sessions. Analyses revealed a significant main effect of stimulation (diminished performance with true stimulation) and a significant interaction between task and stimulation for total Go trials (i.e., true hits) accuracy performance.

Conclusion: This study revealed no significant effect of task type or stimulation type on accuracy performance or reaction time. Post-hoc analyses reveal diminished accuracy performance during Go trials/sustained attention with true stimulation that may be related to interhemispheric inhibition, but ceiling effects may skew data. Interaction effects during Go-Trial intervals will be explained in the discussion portion of this paper.

CHAPTER 1. INTRODUCTION

Attention deficits are a common symptom associated with neurological disorders, including stroke. The Center for Disease Control (2017) reports that 795,000 people in the United States experience a stroke every year. During the acute recovery phase of stroke, attention is the most frequently affected cognitive ability and remains the greatest deficit after a year of recovery (Xu, Ren, Prakash, Vijayadas, & Kumar, 2013). Performance in sustained attention is of particular interest due to the intrinsic role of this cognitive function in alerting and maintaining focus (Fortenbaugh, DeGutis, & Esterman, 2017). The prevalence of attention deficits in post-stroke populations warrants examination of potentially more efficient and effective supplementary treatment methods, such as transcranial direct current stimulation (tDCS).

tDCS is a form of noninvasive brain stimulation that alters neuronal resting membrane potential through transmission of positively and negatively charged electrical currents (Brunoni et al., 2012). Previous tDCS studies have examined an extensive number of cortical areas involved in sustained attention. The left dorsolateral prefrontal cortex (L-DLPFC) is a prevailing area of interest within the tDCS literature; however, there are inconsistencies regarding current duration, current intensity, and online vs. offline performance measurements (Kang, Baek, Kim, & Paik, 2009; Nelson, McKinely, Golob, Warm, & Parasuraman, 2013). This study seeks to explore the impact of concurrent task with tDCS applied to the L-DLPFC at 2 mA for a period of 10 minutes on sustained attention in a healthy population using a Go/No-Go task.

CHAPTER 2. LITERATURE REVIEW

The following literature review addresses three critical components of this study. Those components include: attention deficits and stroke, traditional treatment methods for attention deficits, and tDCS treatment for attention deficits.

2.1 Attention Deficits and Stroke

A primary concern regarding attention deficits in communication-disordered populations is the potential threat to individuals' safety and well-being. According to research by Pearce, Stolwyk, New, and Anderson (2016), individuals who have experienced a stroke often exhibit sustained attention deficits manifested by slower and more variable reaction times. A reduced ability to detect and attend to stimuli increases the risk of accidental injury in this population. In a study examining the prevalence of balance deficit and fall history in stroke patients, Hyndman and Ashburn (2003) found that deficits in both sustained and divided attention were correlated with an increased occurrence of falls. Increased risk of physical injury is only one of many repercussions related to sustained attention deficits.

Deficits in sustained attention also jeopardize the efficiency and effectiveness of rehabilitation methods. The severity of cognitive impairment in the acute recovery phase of stroke is highly predictive of functional outcomes (Hachioui et al., 2014; Zinn et al., 2004). The prognostic value of sustained attention deficits is supported by resource-control theory, which suggests that sustained attention consists of two components: a default, introspective, cognitive state (mind-wandering) and an executive-controlled, goal-oriented, intrinsically-motivated mindset (Thomson, Besner, & Smilek, 2015). After neurological insult, diminishment in the executive control required to maintain a goal-oriented mindset during rehabilitative tasks may result in reduced intrinsic motivation.

Remediation of cognitive communicative and linguistic deficits associated with stroke are particularly susceptible to sustained attention deficits. Efficacy of remediation methods for aphasia, or impaired language expression or comprehension often secondary to stroke, have proven less effective in individuals with concomitant attention deficits (Goldenberg, Dettmers, Grothe, & Spatt, 1994). The detrimental effect of attention deficits is evident in studies examining the relationship between stroke and vocational outcomes. Dysfunction in attention has been identified as having a significant impact on returning to work after experiencing a stroke (Tanaka, Toyonaga, & Hashimoto, 2013). The prevalence of attention deficits within stroke populations and other populations often treated for communication disorders has led to the development of readily used treatment methods.

2.2 Traditional Treatment Methods for Attention Deficits

Traditionally implemented treatment methods for attention deficits include direct attention training and metacognitive strategy training, though research suggests that the long-term efficacy of these approaches is uncertain (Loetscher & Lincoln, 2013). Direct attention training is defined as a repetitive stimulation of attention through graded exercises that target underlying neurocognitive and attention functioning (Cicerone, Langenbahn, Braden, & Ashman, 2011). A common direct attention training technique uses Attention Process Training (APT). This computer program directly targets various components of attention through the completion of increasingly difficult auditory and visual tasks (Sohlberg, Johnson, Paule, Raskin, & Mateer, 2001). Tasks on the APT often resemble common cognitive tasks, such as Go/No-Go tasks and Continuous Performance tasks.

Contrarily, metacognitive training utilizes a more generalized, skill-based approach. Metacognitive strategy training treats deficits through emphasis of skills used in the completion

of activities of daily living, such as self-regulation and self-monitoring (Ponsford et al., 2014). Generalization of skills through metacognitive training is achieved through segmenting complex tasks into smaller components with a strategic mindset (Kennedy et al., 2008).

Results of both direct attention training and metacognitive strategy training are mixed. A meta-analysis by Loetscher and Lincoln (2013) found that within six studies of 223 participants there was no evidence of cognitive rehabilitation benefits persisting beyond an acute treatment period. Given the uncertainty surrounding the long-term efficacy of current cognitive rehabilitation methods, supplementary approaches, such as tDCS, are desirable.

2.3 tDCS Treatment for Attention Deficits

tDCS is a relatively novel approach to the remediation of sustained attention deficits. This technology involves administration of minute electrical stimuli via anodal and cathodal electrodes applied to the scalp in an attempt to stimulate underlying cortex (Izzidien, Sriharasha, Roula, & McCarthy, 2016). Application of charged electrical currents allows researchers to modulate the excitability of targeted populations of neurons. The tDCS literature reveals a number of variables that are manipulated in an attempt to alter the efficacy of stimulation. These variables include: electrode montage (electrode placement), current intensity and duration, and online vs. offline performance measurement.

The most common area stimulated in an attempt to remediate sustained attention deficits is the L-DLPFC (Nelson et al., 2013; Kang et al., 2009). Given the intention to ultimately implement tDCS for the remediation of sustained attention deficits in a therapeutic environment, it is also important to consider the role of the L-DLPFC in joint attention. Qiu, Zhang, and Li (2015) found that when exposed to joint attention vs. non-joint attention stimuli, the greatest contrast in blood supply, as indicated by functional near-infrared spectroscopy (fNIRS), was

present in the L-DLPFC. The importance of joint attention in the implementation of cognitive rehabilitation therapy techniques further substantiates this region as a viable target for stimulation.

The attentional effects of application of anodal tDCS to the L-DLPFC have been explored within two major studies. Kang et al. (2009) first examined the efficacy of tDCS stimulation on this area in reducing post-stroke attention decline. Results of this study were promising. Improvements in accuracy and speed, as indicated by results on a Go/No-Go task, were found exclusively in post-stroke populations and were absent in healthy populations (Kang et al., 2009). Though results in healthy populations may have been confounded by ceiling performance in this study, the ability to evoke change in a healthy control group could prove informative in future research. We address these concerns in this study through use of a more challenging task.

A second major study to address the impact of anodal tDCS application to the L-DLPFC focused explicitly on its potential for enhancing vigilance, or sustained attention, in a healthy population. In a transcranial Doppler study, Nelson et al. (2013) examined changes in vigilance decrement, the phenomenon in which the ability to detect targets is reduced and reaction time lengthens as duration of a task increases, over a period of 40 minutes. However, given the intended therapeutic use of this research and negative performance effects of increased time on task, our study implemented a smaller number of stimuli (Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2011). A number of physiological and operational parameters, as indicated by signal detection analysis and Doppler ultrasonography, were examined within Nelson's study. Increased hit rate (accuracy), hemispheric blood flow velocity, and regional blood oxygenation during stimulation were found to be significantly greater during true stimulation compared to

sham-stimulation (Nelson et al., 2013). Both of these studies strongly suggest that stimulation of the L-DLPFC is effective in improving performance in sustained attention; however, there is some variation in the literature regarding cathode placement, current intensity and duration, and use of online vs. offline performance measurements.

Though research strongly suggests anodal placement as the L-DLPFC to improve attention, there are variations in the placement of the cathode. Careful consideration should be given to cathodal placement due to potential inhibitory effects (Stone & Tesche, 2009). Electrical current flows from the anode to the cathode along a path of least resistance. If electrodes are placed too closely together, there is an increased risk that shunting will occur, and the electrical current will be transferred along the scalp or skin, rather than through the brain. Kang et al. (2009) selected the right supraorbital region as the site for cathode placement, whereas Nelson et al. (2013) selected the R-DLPFC. Based on previous research and computational models (Datta, Baker, Bikson, & Fridriksson, 2011; Kang, 2009), cathode placement for this study will be on the right supraorbital region; we seek to replicate Kang's positive findings for a clinical population in healthy participants by manipulating task difficulty to eliminate potential ceiling effects.

Besides cathode placement, current intensity and duration are two important variables. Parameters of current intensity differed between the two studies that motivate the present work (Kang et al., 2009, Nelson et al., 2013). tDCS studies generally apply a small 0.5-2.0 mA current through the scalp and skull (Coffman, Clark, & Parasuraman, 2014). The intensity of the current, in combination with the size of the electrodes, determines the amount of electrical stimulation being applied to the target area. Kang et al. (2009) implemented a current intensity of 2 mA and, as previously mentioned, found significant improvements only in the post-stroke group. Nelson

et al. (2013) implemented a weaker 1 mA current, but, as previously mentioned, found hit rate, hemispheric blood flow velocity, and regional blood oxygenation were significantly greater in those who received active stimulation, perhaps due to differences in electrical montage or nonlinear effects of current intensity (Batsikadze, Moliadze, Paulus, Kuo, & Nitsche, 2013). In addition to variations in current intensity, the duration of stimulation can also alter the efficacy of tDCS.

The two referenced studies also differed in duration of stimulation. Research indicates that duration of 9 to 13 minutes can result in up to 1.5 hours of after-effects (Nitsche & Paulus, 2001). Studies regarding treatment of attention components generally utilize durations that fall within this range. Kang et al. (2009) implemented a duration of 20 minutes for active stimulation and 60 seconds for sham stimulation. Again, results of this study indicated improvements only in post-stroke participants. Nelson et al. (2013) implemented a briefer duration time of 10 minutes for active stimulation and 30 seconds for sham stimulation, yet still achieved significant results in healthy individuals. Differences in findings within these studies may be attributable to the nonlinear relationship between duration and tDCS effects. Monte-Silva, Kuo, Liebetanz, Paulus, and Nitsche (2010) found that longer stimulation times can actually reverse expected effects of tDCS.

The final variable that is often manipulated to alter the efficacy of tDCS is task. Within the tDCS literature, the term task-specificity is used to refer to the hypothesis that stimulation will be more efficient in modulating neuron populations that are already activated through task-dependent conditions (Bikson & Rahman, 2013). Additionally, task performance may also be measured online (i.e., during stimulation) or offline (i.e., after stimulation) (Bruckner & Kammer, 2017; Kang, 2009; Nelson et al., 2013). Task training can also occur online or offline.

While neither of the cited studies included a specific training component, differences in performance on a Go/No-Go task in healthy populations between these two studies could be attributed to the variation in online vs. offline performance measurement. Kang (2009) compared post-stimulation (offline) performance on a Go/No-Go task to pre-stimulation (baseline) condition, whereas Nelson (2013) compared performance during stimulation (online) to baseline. The present study seeks to primarily investigate offline effects of tDCS, as this is the measure best suited to a clinical rehabilitation program (as opposed to use of tDCS as a neural prosthetic device). However, we include an online training component to potentially enhance the offline effects of tDCS measured following stimulation.

The variations, as well as the similarities, between these two studies should be carefully considered. As evidenced by Kang et al. (2009) and Nelson et al. (2013), performance on Go/No-Go tasks has been effectively used to assess the impact of tDCS on sustained attention. Unfortunately, there are a number of variables, including electrode montage, stimulation intensity and duration, and online vs. offline performance measurement, that have not yet been optimized and warrant further investigation. Ideally, implementing an exceptionally efficient supplemental method in cognitive rehabilitation could reduce healthcare costs. Costs for outpatient stroke rehabilitation services and medications average around $17,081 for the first year after inpatient rehabilitation discharge (Godwin, Wasserman, & Ostwald, 2011). A better understanding of the implications for combining tDCS with task-specific, therapeutic methods could increase the efficacy and efficiency of current cognitive rehabilitative approaches.

CHAPTER 3. METHODS

3.1 Participants

This study enrolled a total of 13 healthy participants who were recruited through a southern university and from the surrounding region. Inclusion criteria required that participants be between the ages 18 to 40 and be available for a weekly session over the course of four consecutive 7 to 10 day periods. Participants with neurological, psychiatric, cognitive, or motor disorders were excluded from this study. Participants currently receiving treatment for attention deficits were also excluded. Finally, customary exclusionary criteria for tDCS studies, including history of epilepsy or seizures, cerebral disease, implants, or pregnancy, were applied All 13 participants met both inclusion and exclusion criteria. Participant sex, age, occupation, and years of education are summarized in Table 1. All participants underwent the four conditions depicted in Figure 1 (order counterbalanced across subjects).

Study protocol was approved by the Institutional Review Board of Louisiana State University (Appendix B). Prior to beginning the study, participants were provided with a consent form, given a verbal explanation of the study, encouraged to ask questions, and provided with a signed copy of their consent form.

Table 1. Participant Characteristics					
Participant	Sex	Age	Occupation	Years of Education	Handedness
1	M	29	Chef	12	Ambidextrous
2	F	34	Student	18	Right Handed
3	F	25	Student	18	Right Handed
4	F	26	Business Owner	16	Ambidextrous
5	M	28	Cashier	12	Right Handed
6	F	30	Manager	14	Ambidextrous
7	M	27	Manager	16	Right Handed
8	M	32	Office Worker	16	Ambidextrous
9	M	29	Chef	12	Right Handed
10	F	24	Student	18	Right Handed
11	F	29	Chef	14	Ambidextrous
12	M	28	Waiter	13	Right Handed
13	F	28	Waiter	14	Ambidextrous

3.2 Setting

The study took place in a controlled laboratory setting in a university speech, language, hearing department.

3.3 Experimental Design

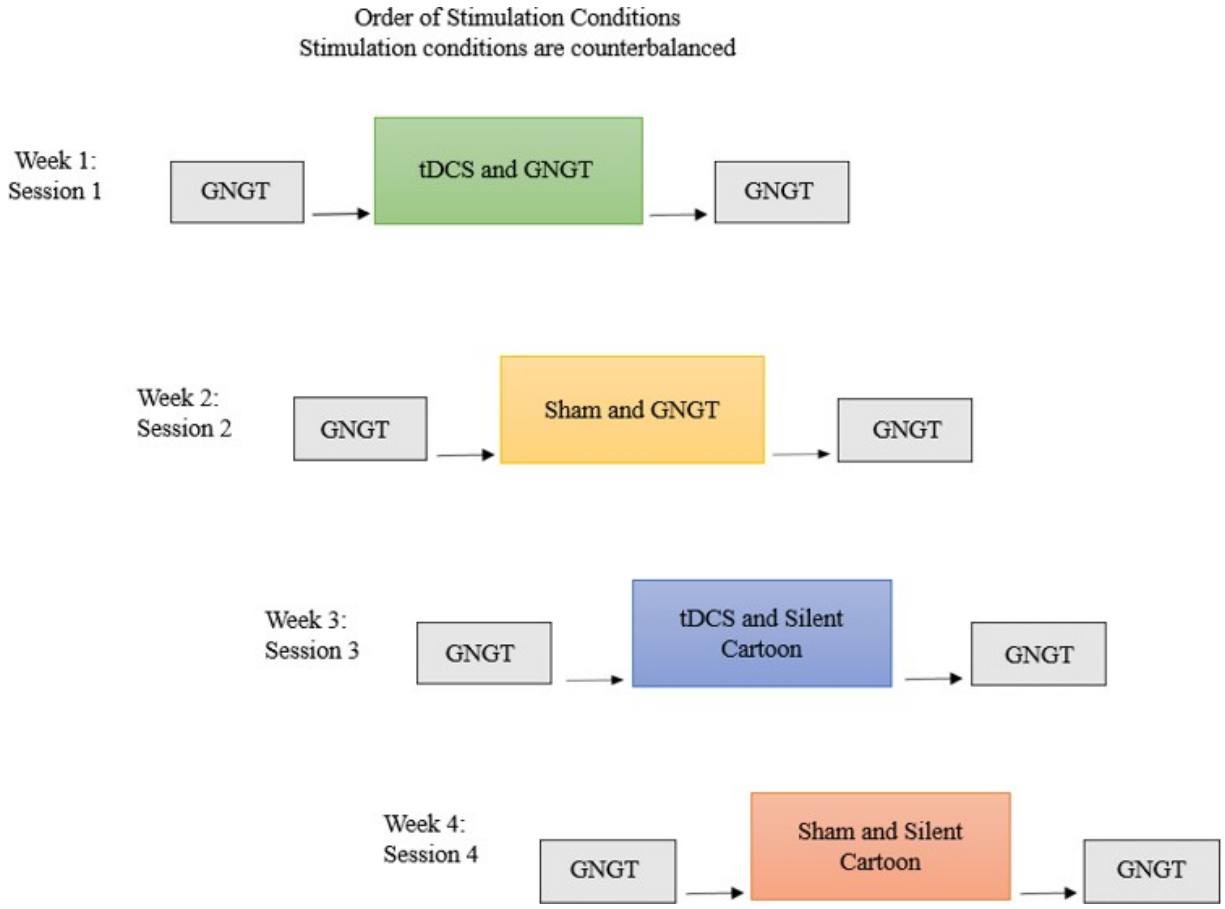

Figure 1. Experimental Design. GNGT in this figure is representative of a Go/No-Go Task. tDCS in this figure is representative of Transcranial Direct Current Stimulation.

Participants (n=13) completed four total sessions: two sessions of active stimulation (2 mA for 10 minutes) and two sessions of sham stimulation (2 mA for 30 sec) in counterbalanced order. Participants completed one session every 7 to 10 days for four consecutive periods. Order of sessions (concurrent task and stimulation type) was partially counterbalanced; Figure 1 shows one possible sequence. During all sessions, anodal placement was the L-DLPFC and cathodal placement was the right supraorbital region. Sessions were separated by ≥ 1 week (7-10 days) to permit washout of residual tDCS effects between sessions. During the practice treatment

condition, participants completed a 10-minute Go/No-Go Task (GNGT) immediately prior to, during, and immediately after stimulation during each session. During the passive treatment condition, participants completed a 10-minute GNGT prior to stimulation, watched a 10-minute silent cartoon during stimulation, and completed a 10-minute GNGT after stimulation. Tasks were separated by a period of 1 minute. Changes in reaction time and response accuracy (the number of true hits and true misses) between pre- and post- stimulation GNGT served as the performance measures in this study.

3.4 Pre-/Post-Assessment Measures

Participants completed a medical history intake form, Edinburgh Handedness Inventory, and Screening Questionnaire for Transcranial Direct Current Stimulation prior to the initial session. Before each session, participants were asked, via informal interview, to rank their sleep quality and fatigue levels on a scale of 1-10; these data were recorded to account for individual differences if needed. Following each session, participants completed the Survey of Sensations Related to Transcranial Direct Current Stimulation to determine the effectiveness of participant blinding to active/sham stimulation. These measures are provided in Appendix A and briefly described in the following paragraphs.

The Edinburgh Handedness Inventory is a quantitative assessment of individual hand preference during a variety of activities that was administered prior to the first session only. The scale utilizes an inventory of 10 items and analyzes individual preference regarding varying or dominant hand usage (Oldfield, 1971). The Screening Questionnaire for Transcranial Direct Current stimulation is a questionnaire that screens participants for potential contraindications regarding use of tDCS (adapted from: Miniussi, 2017); this was also administered prior to the first session only.

The Survey of Sensations Related to Transcranial Direct Current Stimulation is a survey that assesses discomfort or annoyance experienced during tDCS. The survey allows participants to rate common experiences, such as itching, pain, burning, and fatigue, from a range of "None (0)" to "Strong (4)" and assesses the onset, length, and perceived effects of tDCS experienced by individual participants (adapted from: Fertonani, Ferrari, & Miniussi, 2015). This survey permits evaluation of effectiveness of participant blinding to active/sham stimulation and was administered upon completion of each session.

Finally, the Go/No-Go task (GNGT) consisted of presentation of the figures "O" or "X" appearing randomly at the center of the screen over the course of 10 minutes. This task was implemented before and after stimulation to assess behavioral effects, and also as a task-training component in this study. Prior to the initial session, participants were allotted a 10 second (9-13 trials) training interval to introduce the task. During GNGT, participants were instructed to press the spacebar when an "X" appeared and to do nothing when an "O" appeared. In order to reduce potential ceiling effects, the opacity of the provided stimulus lightened in response to correct responses and darkened in response to incorrect responses (adapted from: Kang et al., 2009). Additional information on the GNGT parameters can be found below.

3.5 tDCS Parameters

Participants were measured and fitted with the tDCS equipment according to the 10-20 EEG system. Using a tape measure and a surgical marker, the left dorsolateral prefrontal cortex (F3 in the 10-20 EEG system) was identified and marked for anodal placement. The right supraorbital region (Fp2) was similarly identified for cathodal placement. Rubber straps were applied around the circumference of the head to accommodate electrode placement. Two electrodes, each measuring 5x7 cm, were inserted into two sponge coverings dampened with

0.9% saline solution. The anode was applied between the scalp and the rubber strap over the left dorsolateral prefrontal cortex, and the cathode was placed on the forehead between the right supraorbital region and rubber strap. Stimulation condition, either the sham or active 2 mA stimulation condition, was determined via randomized codes that were entered into the NeuroConn DC-Stimulator prior to stimulation for operator blinding.

3.6 Go/No-Go task Parameters

The Go/No-Go task (GNGT) consisted of presentation of the figures "O" or "X" at random intervals at the center of the screen of a Dell Precision 5510 laptop. This task was programmed using PsychoPy software. Participants were instructed to press the spacebar when presented with "X" (a go trial) and to do nothing when presented with "O" (a no-go trial). Each GNGT consisted of 300 trials (150 go trials and 150 no go trials). In order to reduce ceiling effects and increase task difficulty, interstimulus interval (ISI) jitter and stimulus opacity were modified. Interstimulus interval (ISI) jitter was set at 50% (500, 750, 1000, 1250, and 1500 ms). This jitter percentage has been linked with longer reaction times (Wodka, Simmonds, Mahone, & Mostofsky, 2009). Opacity of the provided stimulus lightened in response to correct responses and darkened in response to incorrect responses. Potential opacity variables ranged from a minimum of .02 to 1. The variable was first presented at a solid opacity variable of 1. Correct responses resulted in an opacity reduction of .5, whereas incorrect responses resulted in an opacity increase of .05, up to the maximum opacity value of 1.

3.7 Data Reliability

The primary investigator and co-investigator transferred all reaction times, false response scores, and opacity measures reported in PsychoPy. One hundred percent inter-rater reliability was required. Scores with less than one hundred percent inter-rater agreement were re-examined

by the primary investigator. The score was accepted when two reliability checks revealed identical scores. Data was entered into the Statistical Package for the Social Sciences (SPSS) by the Investigator and rechecked for accuracy by the co-investigator. Both investigators were blinded to whether the stimulation was active or sham through use of pre-programmed codes.

3.8 Data Analysis

SPSS was used to analyze data. The double-blind, sham-controlled, 2 x 2 within-subjects study used 2x2 repeated measures ANOVA (Factors: stimulation and task; Levels: active or sham stimulation; practice or passive task) to address questions about two dependent variables (reaction time and response accuracy). The questions are as follows:

The first question was, “Will active tDCS paired with an active Go/No-Go practice task lead to greater decreases in reaction time on the Go/No-Go Task compared to active tDCS paired with a passive cartoon viewing task or sham tDCS?”. It was hypothesized that active stimulation paired with the Go/No-Go practice task would result in significantly decreased reaction times compared to either the passive cartoon viewing task or sham stimulation.

The second questions was, “Will active tDCS paired with an active Go/No-Go practice task lead to more correct responses (true hits and true misses) on the Go/No-Go Task compared to active tDCS paired with a passive cartoon viewing task or sham tDCS?”. It was hypothesized that active stimulation paired with the Go/No-Go practice task would result in significantly increased correct responses compared to either the passive cartoon viewing task or sham stimulation.

Performance scores from 12 participants were included in the analysis. Data from a single participant were excluded due to reported visual acuity deficits, eye strain, and subsequent outlying scores.

CHAPTER 4. RESULTS

4.1 Primary Results

To answer the first question, we assessed reaction time performance during each session by determining the difference in average reaction times on pre- and post-task trials. A 2x2 repeated measures ANOVA assessing the effects of our independent variables on reaction time found no significant main effect for type of stimulation ($F(1,11) = 0.501$, $p = 0.494$, partial $\eta^2 = .044$) or type of task ($F(1,11) = 0.743$, $p=0.407$, partial $\eta^2 = .063$) and no significant interaction ($F(1, 11) = 0.820$, $p=0.385$, partial $\eta^2 = .069$). Though not significant, descriptive statistics indicate that average reaction times scores were diminished for Cartoon/Sham Stimulation, GNGT/True Stimulation, and GNGT/Sham Stimulation, while reaction time improved for Cartoon/True Stimulation. Changes in average reaction times from pre- to post-GNGT performance for all participants are depicted below in Figure 2 and listed in Table 2. Raw scores for reaction times are depicted in Table 3.

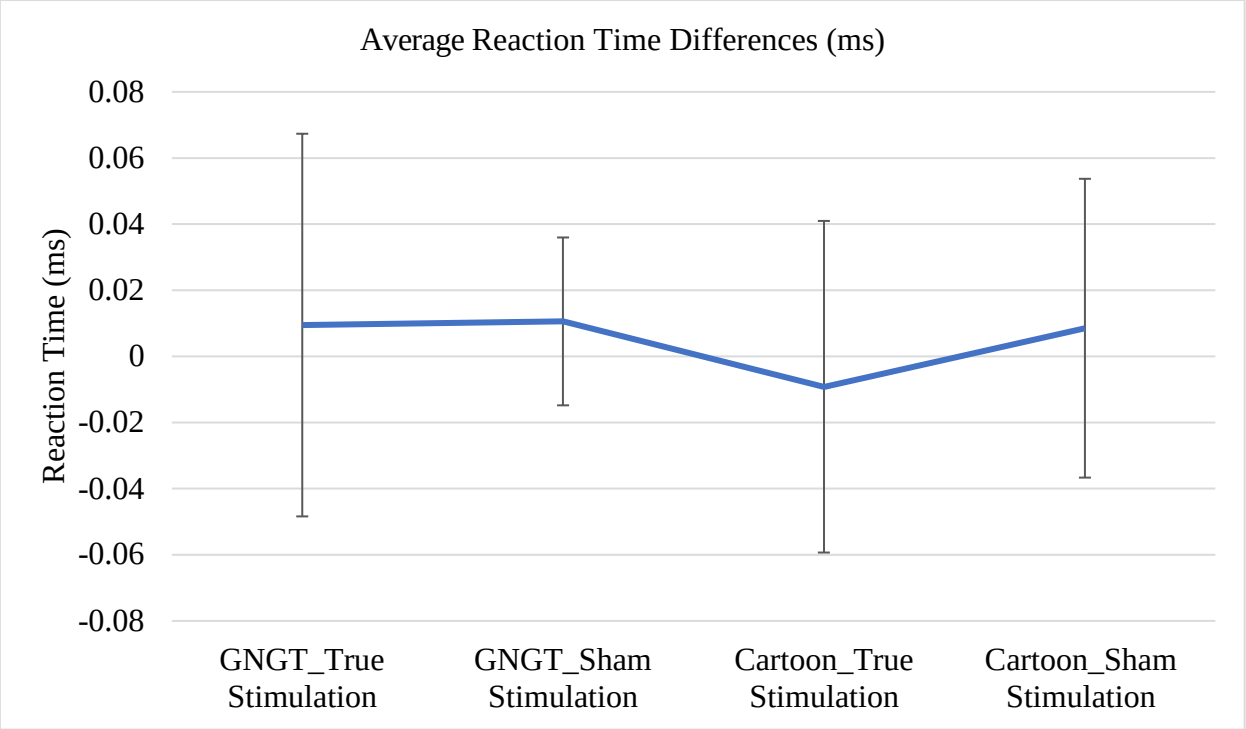

Figure 2. Difference in Pre- and Post-Reaction Time Performance Scores. Error bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

Table 2. Go/No-Go Trials (GNGT): Average Reaction Times				
	GNGT_True Stimulation	GNGT_Sham Stimulation	Cartoon_True Stimulation	Cartoon_Sham Stimulation
Reaction Times (ms)	.0095	.0106	-.0092	.0085

Table 3. Raw Go/No-Go (GNGT) Reaction Time Scores					
Participant	Session	Task/ Stimulation Combination	Pre-GNGT Reaction Times	Training Task Reaction Times	Post-GNGT Reaction Times
A	1	GNGT/Sham	0.54877	0.55238	0.56629
	2	Video/Sham	0.59	N/A	0.629
	3	GNGT/True	0.533889	0.570493	0.563055
	4	Video/True	0.535876	N/A	0.58771
B	1	Video/Sham	0.538897	N/A	0.516671
	2	GNGT/Sham	0.533546	0.5285282	0.506876
	3	Video/True	0.508772	N/A	0.45622
	4	GNGT/True	0.516066	0.5231548	0.512819
C	1	Video/Sham	0.516248	N/A	0.49524
	2	GNGT/True	0.520096	0.54102	0.5911
	3	Video/True	0.503819	N/A	0.481682
	4	GNGT/Sham	0.487709	0.49359	0.49158
D	1	GNGT/Sham	0.553359	0.564762	0.570064
	2	Video/True	0.530973	N/A	0.54341
	3	GNGT/True	0.50779	0.554474	0.538284
	4	Video/Sham	0.508947	N/A	0.543421
E	1	Video/True	0.50756	N/A	0.47617
	2	GNGT/Sham	0.520632	0.519717	0.524426
	3	Video/Sham	0.50977	N/A	0.63678
	4	GNGT/True	0.489669	0.495472	0.467261
F	1	GNGT/Sham	0.478535	0.509369	0.49869
	2	Video/Sham	0.502942	N/A	0.489786
	3	GNGT/True	0.49131	0.49874	0.505045
	4	Video/True	0.485995	N/A	0.56326
G	1	Video/True	0.507537	N/A	0.506941
	2	GNGT/True	0.498695	0.529347	0.559231
	3	Video/Sham	0.533528	N/A	0.520042
	4	GNGT/Sham	0.5144	0.53926	0.57828
H	1	GNGT/True	0.645253	0.583123	0.531919
	2	Video/True	0.597129	N/A	0.551201
	3	GNGT/Sham	0.548693	0.55922	0.53671
	4	Video/Sham	0.562152	N/A	0.54755

(Table cont'd.)

Participant	Session	Task/ Stimulation Combination	Pre-GNGT Reaction Times	Training Task Reaction Times	Post-GNGT Reaction Times
I	1	Video/Sham	0.536651	N/A	0.542377
	2	GNGT/True	0.0528474	0.54529	0.54769
	3	Video/True	0.530785	N/A	0.52717
	4	GNGT/Sham	0.542961	0.587618	0.58392
J	1	GNGT/True	0.53	0.487	0.458
	2	Video/Sham	0.453754	N/A	0.422486
	3	GNGT/Sham	0.462635	0.4747	0.48002
	4	Video/True	0.52277	N/A	0.41263
K	1	Video/True	0.44587	N/A	0.42915
	2	GNGT/Sham	0.45693	0.46296	0.45671
	3	Video/Sham	0.448541	N/A	0.419032
	4	GNGT/True	0.44788	0.45192	0.44405
L	1	GNGT/Sham	0.56768	0.54068	0.54712
	2	Video/Sham	0.525486	N/A	0.560063
	3	GNGT/True	0.524967	0.524775	0.5726
	4	Video/True	0.563131	N/A	0.591987

To answer the second question, response accuracy during each session was assessed by determining the difference between the cumulative correct go/no-go trials during pre- and post-GNGT trials (i.e., true hits + true misses within a session). A second 2x2 repeated measures ANOVA assessing the effects of task and stimulation on response accuracy found no significant main effect of stimulation ($F(1, 11) = 0.836$, $p = 0.380$, partial $\eta^2 = .071$) or task ($F(1, 11) = 0.033$, $p = 0.859$, partial $\eta^2 = .003$), and no significant interaction ($F(1, 11) = 0.886$, $p = 0.367$, partial $\eta^2 = .075$). A mean performance of 295.73 ($M = 295.73$), out of 300 possible items, indicates that attempts to reduce ceiling effects were not successful and that differences in performance may be minute. Though not significant, descriptive statistics indicate average response accuracy scores were diminished for Cartoon/True Stimulation, Cartoon/Sham Stimulation, and GNGT/Sham Stimulation, while no changes were observed during GNGT/True

Stimulation. Changes in average accuracy scores from pre- to post-GNGT performance for all participants are depicted below in Figure 3 and listed in Table 5. Raw scores for Go/No-Go trial accuracy scores are depicted in Table 4.

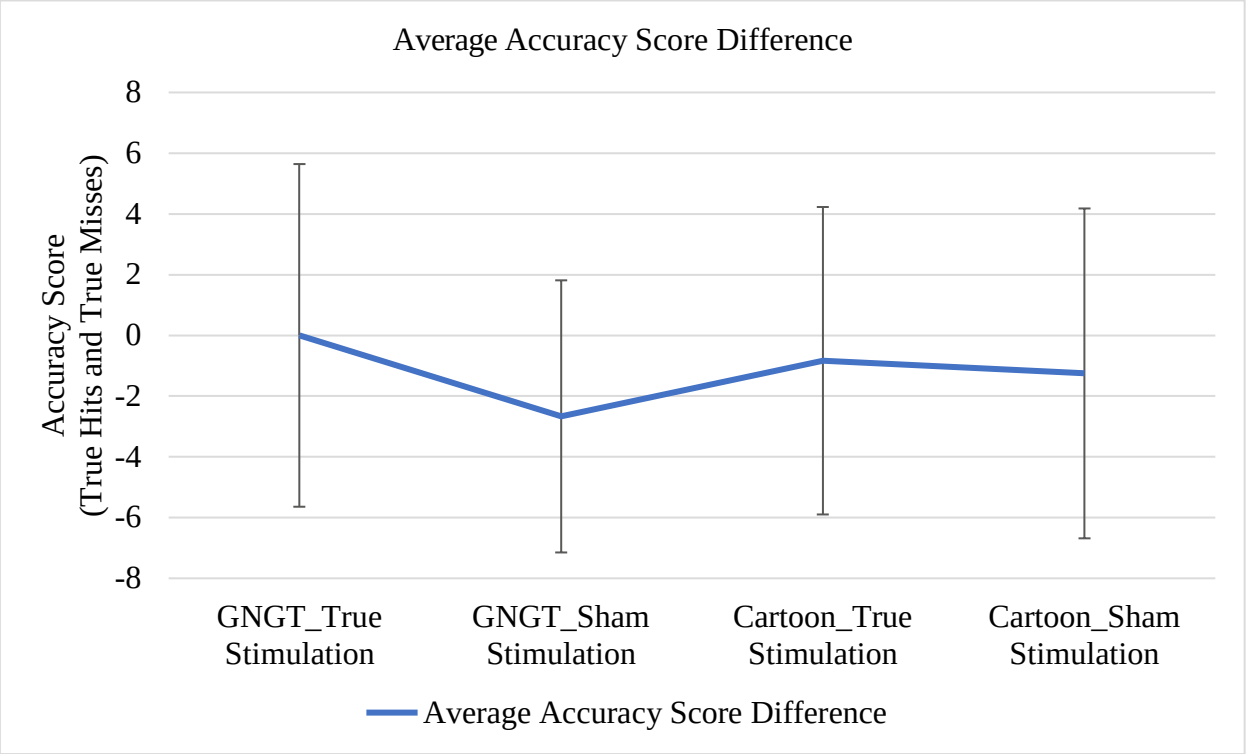

Figure 3. Difference in Pre- and Post-Accuracy Performance Scores. Error bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

Table 4. Raw Go/No-Go (GNGT) Accuracy Performance Scores					
Participant	Session	Combination	Pre-GNGT Accuracy Performance Score	Training Task Accuracy Performance Score	Post-GNGT Accuracy Performance Score
A	1	GNGT/Sham	297	298	296
	2	Video/Sham	294	N/A	296
	3	GNGT/True	287	287	291
	4	Video/True	299	N/A	290
B	1	Video/Sham	300	N/A	296
	2	GNGT/Sham	299	295	295
	3	Video/True	298	N/A	299
	4	GNGT/True	297	294	295
C	1	Video/Sham	293	N/A	299
	2	GNGT/True	297	295	292
	3	Video/True	300	N/A	299
	4	GNGT/Sham	296	294	297
D	1	GNGT/Sham	300	298	297
	2	Video/True	298	N/A	299
	3	GNGT/True	300	300	299
	4	Video/Sham	300	N/A	300
E	1	Video/True	300	N/A	294
	2	GNGT/Sham	294	292	294
	3	Video/Sham	297	N/A	284
	4	GNGT/True	300	293	296
F	1	GNGT/Sham	299	299	299
	2	Video/Sham	298	N/A	290
	3	GNGT/True	299	294	294
	4	Video/True	294	N/A	288
G	1	Video/True	286	N/A	293
	2	GNGT/True	290	292	286
	3	Video/Sham	286	N/A	288
	4	GNGT/Sham	292	282	279
H	1	GNGT/True	287	299	298
	2	Video/True	298	N/A	296
	3	GNGT/Sham	297	299	298
	4	Video/Sham	294	N/A	300

(Table cont'd.)

Participant	Session	Combination	Pre-GNGT Accuracy Performance Score	Training Task Accuracy Performance Score	Post-GNGT Accuracy Performance Score
I	1	Video/Sham	300	N/A	296
	2	GNGT/True	289	300	299
	3	Video/True	290	N/A	298
	4	GNGT/Sham	291	280	281
J	1	GNGT/True	300	298	300
	2	Video/Sham	299	N/A	296
	3	GNGT/Sham	300	299	300
	4	Video/True	298	N/A	299
K	1	Video/True	299	N/A	299
	2	GNGT/Sham	299	299	299
	3	Video/Sham	300	N/A	300
	4	GNGT/True	298	299	299
L	1	GNGT/Sham	300	294	297
	2	Video/Sham	296	N/A	299
	3	GNGT/True	299	298	294
	4	Video/True	299	N/A	295

4.2 Post-Hoc Analysis

Due to the fatiguing nature of trials, which could have potentially obscured behavioral effects over the extended period of our task, differences in reaction time and response accuracy were analyzed during the first half and first fourth of responses using 2x2 repeated measures ANOVA analyses identical to those described above. We examined these data to explore the impact of possible vigilance decrement, or the tendency for accuracy to decrease and reaction time to lengthen as duration of a task increases, and fatigue. Similar analyses of isolated hit performance at varying intervals were also conducted to further examine sustained attention performance. Additionally, pre-task reaction time and accuracy performance data from the first two sessions were compared to performance during the last two sessions using a paired t-test to

examine potential carryover effects and the possible impact of fatigue throughout the experiment. Finally, the relationship between online and offline stimulation parameters and accuracy performance were also analyzed using a paired t-test to determine the performance effects of stimulation during a task as opposed to preceding the task. To summarize, additional post hoc analyses were conducted to examine performance regarding hits and misses at varying intervals, hits at varying intervals, session order, and online vs. offline parameters.

4.3 Intra-Session Analysis: Reaction Time and Accuracy Performance

To examine potential effects of fatigue and vigilance decrement, performance during each session was assessed by determining the difference in reaction times and accuracy scores on pre- and post- task trials for the first half, or 150 responses, of GNGT performance. Analysis revealed no significant effects on reaction time, but did identify trends in accuracy performance. Though type of task and type of stimulation had no statistically significant effect, a trend towards a significant interaction was observed ($F(1, 11) = 3.634$, $p = 0.083$, partial $\eta^2 = .248$). Analysis of differences in response accuracy during the first half of trials revealed improved performance for GNGT/True Stimulation and diminished performance for Cartoon/Sham Stimulation, Cartoon/True Stimulation, and GNGT/Sham Stimulation. Though a trend was observed, GNGT accuracy performance scores generally neared ceiling performance and average differences ranged from +0.25 to -2 items. The trend was explored further through analysis of the first fourth, or 75 responses, of GNGT performance using another 2x2 repeated measures ANOVA; however, there was no significant effect of task type, stimulation type, or task and stimulation interaction on reaction time or accuracy performances. Changes in average accuracy scores for the first half of Go/No-Go Trials from pre- to post-GNGT performance for all participants are depicted in Figure 4 and in Table 5.

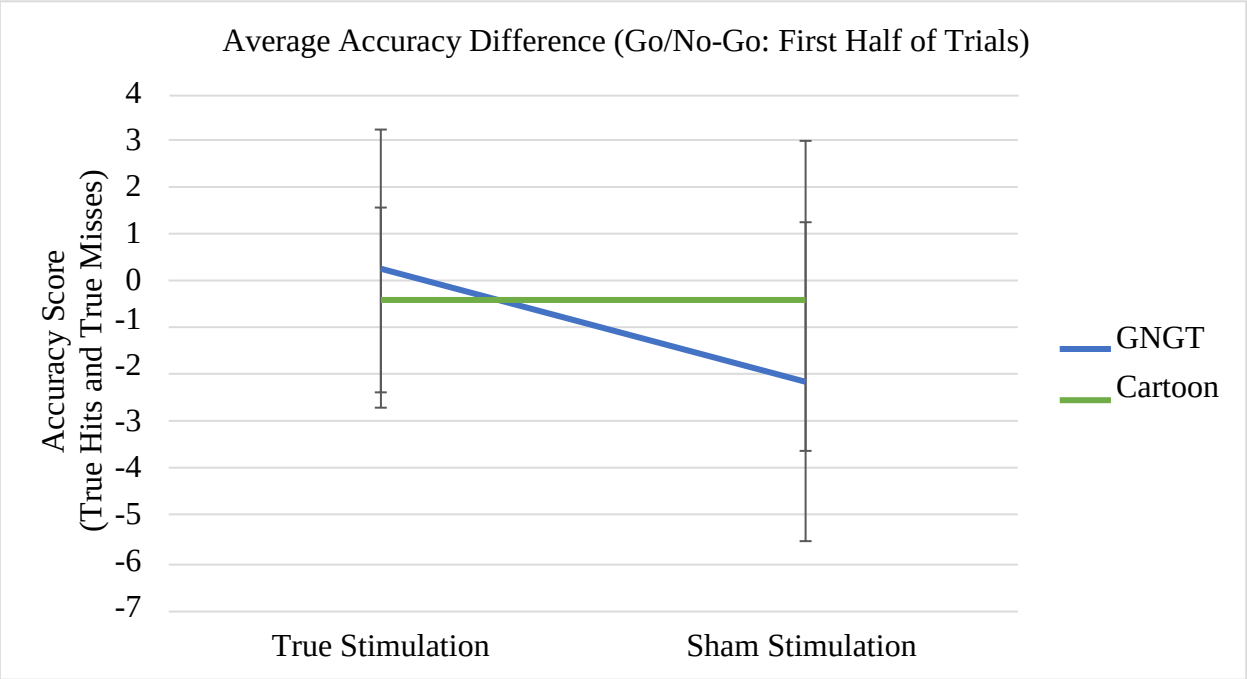

Figure 4. Difference in Pre- and Post-Task Accuracy Performance Scores for First Half of Go/No-Go Trials. Error bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

4.4 Intra-session Analysis of Go Trials: Reaction Time and Accuracy Performances

Given the inhibitory nature of No-Go trials, Go trials were examined in isolation to further assess effects on sustained attention. Performance on Go trials was assessed by determining the difference in reaction time and accuracy scores on pre- and post-task trials for the full amount of possible hits/Go trials (150) using a 2x2 repeated measures ANOVA and revealed accuracy trends toward a significant interaction ($F(1, 11) = 3.957$, $p = .072$, partial $\eta^2 = .265$). These trends are depicted in Figure 5. The trend was further explored by analyzing the first half of hits/Go trials (75) using another 2x2 repeated measures ANOVA and revealed a significant main effect of stimulation type ($F(1,11) = 6.061$, $p = .032$, partial $\eta^2 = .355$) indicative of diminished performance with true stimulation. Accuracy performance trends on the first half of Go trials are depicted in Figure 6. Finally, this significance was again explored by analyzing the first fourth of hits/Go trials (38) using another 2x2 repeated measures ANOVA and

revealed trends toward a main effect of stimulation type ($F(1,11) = 4.000$, $p = .071$, partial $\eta^2 = .267$), again, indictive of diminished performance with true stimulation. Go trial accuracy performance often neared maximum performance and average differences were very small ranging from less than +0.5 to approximately 1 point. These trends are depicted in Figure 7.

Analysis of differences in response accuracy in a full run of Go trials revealed that, on average, scores improved for Cartoon/Sham Stimulation, but diminished for GNGT/True Stimulation, Cartoon/True Stimulation, and GNGT/Sham Stimulation. Analysis of differences in response accuracy during the first half of each run revealed improvements for Cartoon/Sham Stimulation, no changes for GNGT/Sham Stimulation, and diminished scores for GNGT/True Stimulation and Cartoon/True Stimulation. Finally, analysis of differences in response accuracy during the first quarter of Go trials performance revealed improvements for GNGT/Sham Stimulation, no changes for Cartoon/Sham Stimulation, and diminished scores for GNGT/True Stimulation and Cartoon/True Stimulation. These scores suggest that overall task/stimulation variables effected performance negatively compared to sham stimulation and the passive task condition. However, given the presence of ceiling effects, small differences in average accuracy may indicate significant effects for minimal change in performance. Changes in average accuracy scores from pre- to post-GNGT performance for full Go trial runs, the first half of Go trials, and first quarter of Go trials are depicted in Figure 8 and Table 5. Raw scores for Go trials are depicted in Table 6.

Figure 5. Difference in Pre- and Post-Task Accuracy Performance Scores for Full Go Trial Run. Error bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

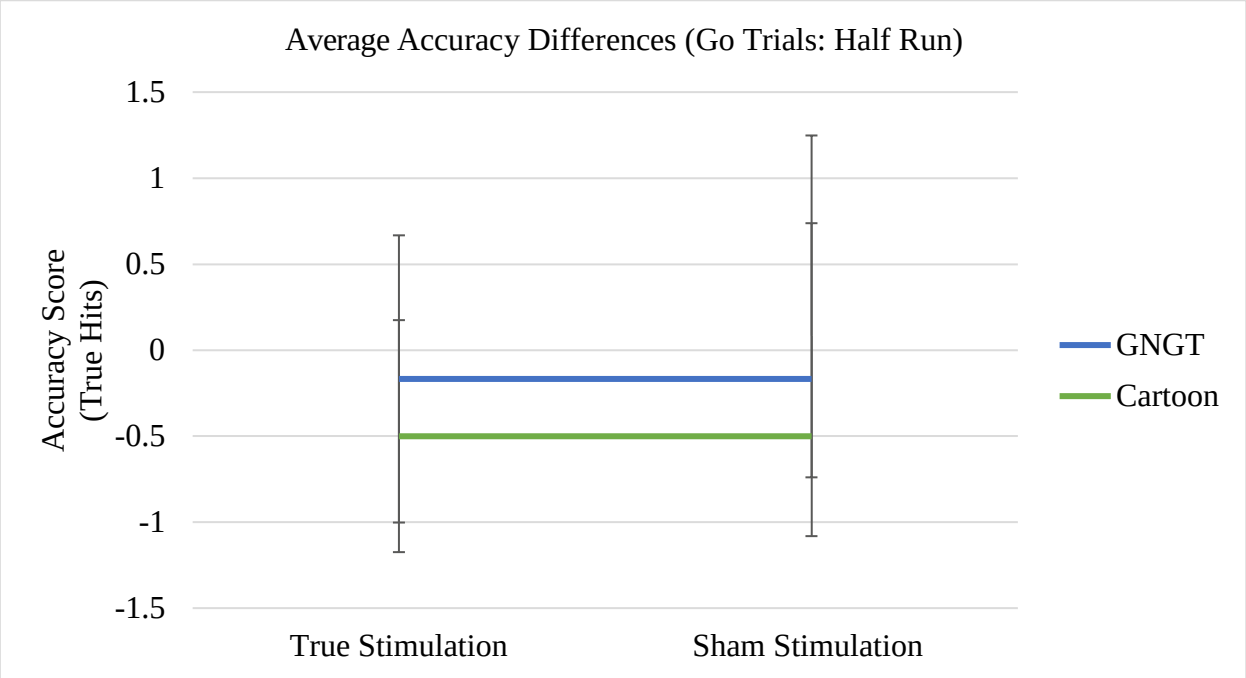

Figure 6. Difference in Pre- and Post-Task Accuracy Performance Scores for Half of Go Trial Run. Error Bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

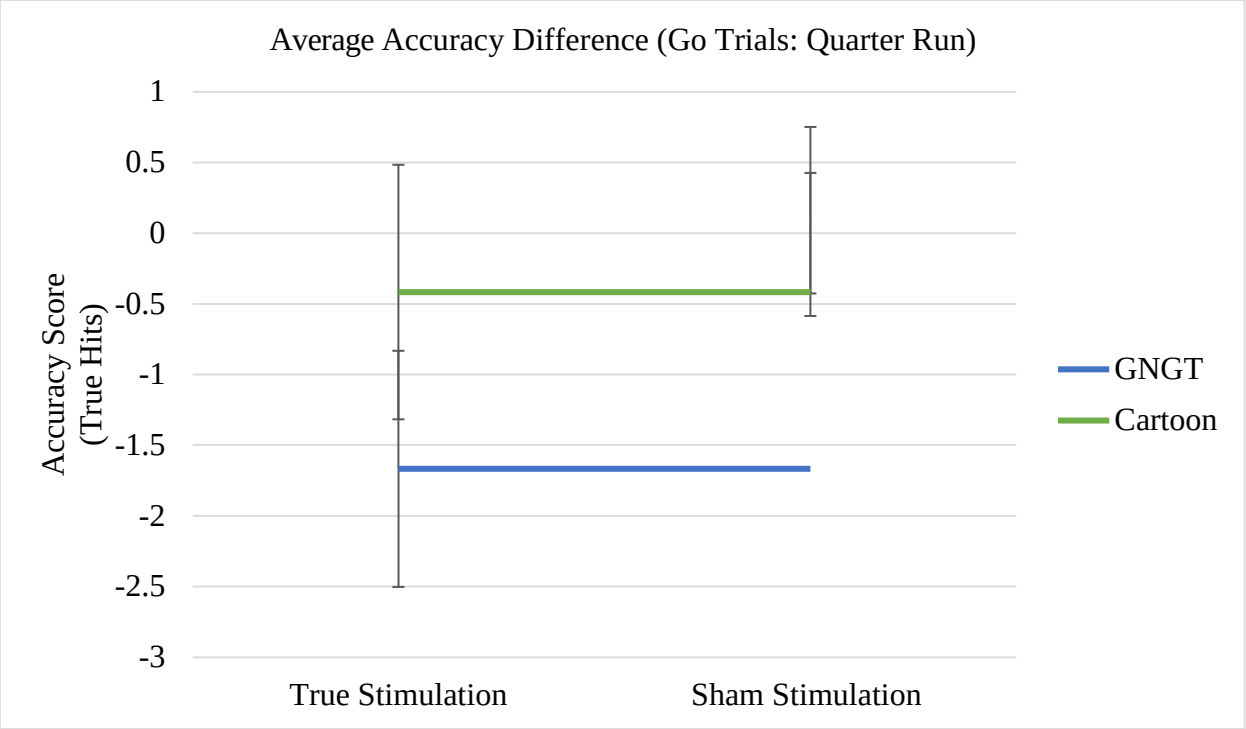

Figure 7. Difference in Pre- and Post-Task Accuracy Performance Scores for Quarter of Go Trial Run. Error Bars are indicative of standard deviation. GNGT is indicative of Go/No-Go Task.

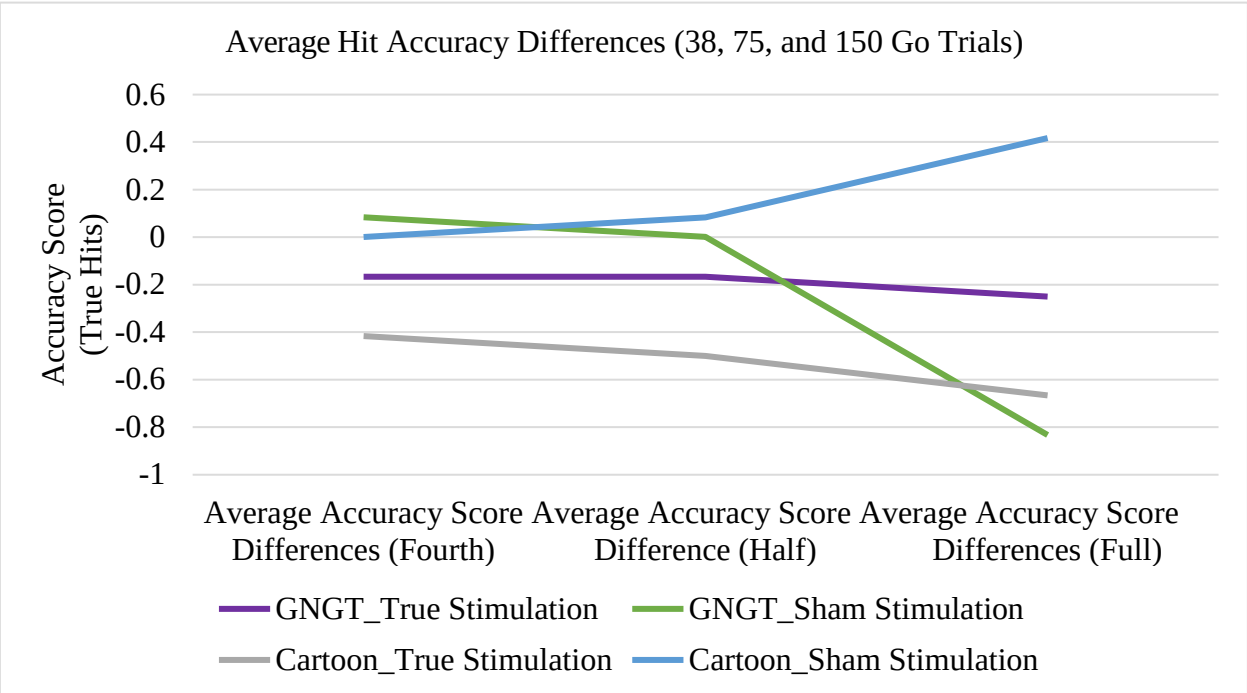

Figure 8. Difference in Pre- and Post-Task Accuracy Performance Scores for 38/75/150 Go Trials. GNGT is indicative of Go/No-Go Task.

Table 5. Average Accuracy for Go/No-Go Trials and Go Trials at Varying Intervals				
	GNGT_True Stimulation	GNGT_Sham Stimulation	Cartoon_True Stimulation	Cartoon_Sham Stimulation
Go/No-Go Trials (GNGT): Full Run	0.0000	-2.6667	-.8333	-1.2500
Go/No-Go Trials (GNGT): First Half	.2500	-2.1667	-0.4167	-.3333
Go Trials: Full Run	-.2500	-.8333	-.6667	.4167
Go Trials: First Half	-.1667	.0000	-.5000	.0833
Go Trials: First Quarter	-.1667	.0833	-.4167	.0000
Note: GNGT is indicative of Go/No-Go Task.				

Table 6. Raw Go Trial Accuracy Performance Scores					
Participant	Session	Combination	Pre-GNGT Go Trial Accuracy Score	Training Task Go Trial Accuracy Score	Post-GNGT Go Trial Accuracy Score
A	1	GNGT/Sham	149	150	149
	2	Video/Sham	147	N/A	150
	3	GNGT/True	148	144	145
	4	Video/True	150	N/A	143
B	1	Video/Sham	150	N/A	148
	2	GNGT/Sham	150	147	148
	3	Video/True	149	N/A	149
	4	GNGT/True	149	146	146
C	1	Video/Sham	145	N/A	149
	2	GNGT/True	149	148	145
	3	Video/True	150	N/A	149
	4	GNGT/Sham	148	146	148
D	1	GNGT/Sham	150	150	148
	2	Video/True	149	N/A	149
	3	GNGT/True	150	150	149
	4	Video/Sham	150	N/A	150
E	1	Video/True	150	N/A	147
	2	GNGT/Sham	146	144	145
	3	Video/Sham	149	N/A	139
	4	GNGT/True	150	146	147
F	1	GNGT/Sham	150	150	150
	2	Video/Sham	149	N/A	145
	3	GNGT/True	150	148	147
	4	Video/True	147	N/A	143
G	1	Video/True	145	N/A	147
	2	GNGT/True	149	147	141
	3	Video/Sham	145	N/A	150
	4	GNGT/Sham	146	144	137
H	1	GNGT/True	138	149	149
	2	Video/True	149	N/A	147
	3	GNGT/Sham	149	149	150
	4	Video/Sham	146	N/A	150

(Table cont'd.)

Participant	Session	Combination	Pre-GNGT Go Trial Accuracy Score	Training Task Go Trial Accuracy Score	Post-GNGT Go Trial Accuracy Score
I	1	Video/Sham	150	N/A	150
	2	GNGT/True	147	150	149
	3	Video/True	149	N/A	150
	4	GNGT/Sham	149	140	148
J	1	GNGT/True	150	150	150
	2	Video/Sham	150	N/A	150
	3	GNGT/Sham	150	149	150
	4	Video/True	149	N/A	150
K	1	Video/True	150	N/A	150
	2	GNGT/Sham	149	150	150
	3	Video/Sham	150	N/A	150
	4	GNGT/True	150	150	149
L	1	GNGT/Sham	150	146	148
	2	Video/Sham	149	N/A	150
	3	GNGT/True	150	150	149
	4	Video/True	150	N/A	146

4.5 First Sessions vs. Last Sessions: Reaction Time and Accuracy Performance

A paired t-test was conducted on pre-GNGT performance to determine if there was any significant effect of session order on reaction time or response accuracy. Results of the analysis revealed no significant effects.

4.6 Online vs. Offline Stimulation

Paired t-tests were used to determine if there was any significant effect of online or offline stimulation on reaction time performance scores or accuracy performance scores throughout various intervals of post-task trials. No significant effects were indicated by the analyses.

CHAPTER 5: DISCUSSION

Overall, inferential statistics indicate that neither tDCS nor type of task had a significant effect on sustained attention. While descriptive statistics suggest the development of certain patterns during performance, ceiling effects indicate that these patterns are minute and insignificant. Post-hoc analysis revealed a significant interaction of task and stimulation on response accuracy when only the first half of Go/No-Go trials were analyzed in view of the fatiguing nature of the task. Additional post-hoc analyses revealed a trend towards a significant interaction of task and stimulation for response accuracy when only Go trials were considered (i.e., sustained attention without inhibition), as well as a significant main effect of stimulation (sham>active) during further analysis of the first half of Go trials. Despite significant effects and trends throughout analysis of Go trials, results are minimal given ceiling effects and minimal ranges of error. Small margins of error decrease the amount of difference necessary for results to qualify as significant.

5.1 Go/No-Go Trials: Reaction Time Performance

Reaction time data suggest that the initial hypothesis – that active stimulation paired with the Go/No-Go practice task would result in significantly decreased reaction times compared to either sham stimulation or the passive cartoon viewing task – was not entirely accurate. Although there was no significant effect associated with stimulation or task type, on average, reaction times only decreased for the combination of active stimulation and the passive cartoon viewing task, and not for the other three conditions. This may suggest that, contrary to the original hypothesis, the cartoon viewing task resulted in greater improvements in reaction time than the GNGT practice task.

While we failed to reject the null hypothesis for reaction time, the direction of this relationship with regards to stimulation was consistent with our expectations for the effects of tDCS based on the published literature. However, the direction of task-training effects, if supported in future studies with greater power, would be more difficult to explain. Performance during both cartoon tasks as compared to GNGT practice tasks could be suggestive of negative performance effects secondary to an intensive task-training component in combination with tDCS though no significance is indicated. If upheld by future investigation, this phenomenon could be explained by excessive taxation on sustained attention by the GNGT task, which was deliberately engineered to reduce ceiling effects. Efficacy of this prevention is evident when comparing the average accuracy score across all sessions (-1.1875) to the maximum accuracy score improvement achieved across all sessions (8). Sarter, Givens, and Bruno (2001) found that factors that tax sustained attention include: successive presentation of signal and non-signal features, high event rate (frequency of signal events), asynchrony (unpredictability of the time of the presentation of the event), event type (signal vs non-signal), and use of dynamic stimuli (opacity). Each of the previously mentioned factors was manipulated to the greatest extent that would still allow for completion of the task. Again, interstimulus interval (ISI) jitter was set at 50% (500, 750, 1000, 1250, and 1500 ms) and potential opacity variables ranged from a minimum of .02 to 1.

Additionally, it should be noted that the individual who achieved the maximum accuracy score improvement is the only participant with a previous diagnosis of Attention Deficit Hyperactivity Disorder. These improvements may mirror findings in Kang's study where improvements were only observed in "patient" samples. While not significant, it is of interest that in three out of four task/stimulation combinations, reaction times increased (i.e., got worse)

from pre-task to post-task performance. Increased reaction time from pre- to post-task GNGT trials is likely related to the capacity theory of attention that postulates that attention is a limited resource (Kahneman, D., 1973). The conceptualization of sustained attention as a process that consistently consumes processing resources due to requirements of an attentional supervisory system that maintains the concept of a target while simultaneously attempting to detect the stimuli would readily tax a limited attentional resource. (Stuss, D. T., Shallice, T., Alexander, M. P., & Picton, T. W., 1995). The combination of GNGT and true stimulation induced performances that appeared superior to GNGT with sham stimulation and inferior to performances observed with the cartoon task, regardless of stimulation condition may suggest that true stimulation served as a buffer to the performance decrements that occurred naturally over the course of an activity that taxes sustained attention.

5.2 Go/No-Go Trials: Accuracy Performance

Response accuracy data suggest that the initial hypothesis – that active stimulation paired with the Go/No-Go practice task would result in significantly increased correct responses compared to either sham stimulation or the passive cartoon viewing task – may in fact be correct, even if the current study was underpowered to reliably detect such differences. While there were no significant effects, the findings suggest that true stimulation paired with the GNGT practice task did not diminish accuracy scores. Response accuracy decreased across all conditions with the exception of the GNGT combined with active stimulation.

Though insignificant, observed effects of task and true stimulation interaction on accuracy are consistent with the original hypothesis; however, performance during sham stimulation sessions are contrary to our original expectations. Possible improvements in response accuracy would be consistent with those found in Nelson's study despite differences in current

intensity and cathodal placement (Nelson et al., 2013). With greater power in future research, task training with true stimulation could improve accuracy performance as opposed to a passive viewing task paired with true stimulation. Similar training effects were observed in a study on more advanced forms of attention, such as selective attention and divided attention (Sacco et al. 2016). However, without the theoretical protective buffer of true stimulation, as described above, the fatigue caused by the repeated GNGT practice task seems to outweigh potentially beneficial training effects. The substantial contrasts between reaction time and response accuracy during the GNGT with true stimulation sessions may correspond with the previous report that as reaction times increase, accuracy decreases (Sarter, Givens, & Bruno, 2001).

5.3 Post-Hoc Discussion

Findings from the post-hoc analyses indicate that true stimulation actually diminished response accuracy in isolated Go trials during earlier trials; additionally, task and stimulation interaction effects were found to effect accuracy performance during both later isolated Go trial responses and later Go/No-Go trial responses. Despite these findings, scores often approached ceiling performance and minute differences in scores could become statistically significant.

5.4 Intra-Session Analysis of Go and Go/No-Go Trials: Reaction time and Accuracy Performances

Negative effects of true stimulation on hit accuracy (i.e. true hits/total hits) may be related to interhemispheric inhibition, a neural mechanism that causes the inhibition of one hemisphere due to activation of the other (Iwata, Jono, Mizusawa, Kinoshita, & Hiraoka, 2016). Though the L-DLPFC was targeted in this study due to its involvement in joint attention and previous successful implementation in studies, this choice for anodal placement may have been counterproductive to pure sustained attention performance. Research has previously indicated

that there is substantial activation of the prefrontal right hemisphere and parietal regions during sustained attention tasks (Sarter, Givens, & Bruno, 2001). Activation of the left hemisphere may have inhibited areas within the right hemisphere that are responsible for completing sustained attention tasks, though this would be contradictory to positive findings found with Nelson's bilateral montage.

Accuracy performance during full go trial runs and midway through go/no-go trial runs revealed significant trends related to task and stimulation interaction effects. Interaction effects are likely related to two phenomena: improved no-go trial performance during GNGT secondary to stimulation dependent interhemispheric inhibition of the right hemisphere and improved early go trial performance secondary to task training. However, it should be noted that performance decrements associated with vigilance decrement during a monotonous task, such the GNGT, may diminish later go trial performance. Superior performance in isolated go trials during cartoon and sham stimulation sessions further substantiates the idea of interhemispheric inhibition as an interference in accuracy performance given the lack of interhemispheric inhibitory effects potentially related to true stimulation.

CHAPTER 6. LIMITATIONS

The small sample size within this study is a limitation. It is unknown whether potentially developing patterns observed within descriptive statistics would become more apparent in a larger sample. Additionally, the age range within the sample was relatively limited, ranging from 24 years to 34 years of age. An older sample size may have yielded significantly different results due to greater differences in baseline sustained attention performance. Also, participants were not screened for visual acuity deficits prior to enrollment in the study. Inconsistent sensitivities to light, opacity variations, and eye strain across participants were also limitations. Finally, design of the Go/No-Go Task was flawed. The fatiguing and monotonous nature of the Go/No-Go Task combined with implemented opacity and jitter variables may have exhausted sustained attention resources over the extensive duration of the task. Additionally, performances on the Go/No-Go Task often neared ceiling performance. Minimal error on the task means that small differences may appear more significant than they truly are.

CHAPTER 7. IMPLICATIONS FOR FUTURE RESEARCH

First, a larger sample size is suggested for future implementation of this study. Additionally, participants should be screened for sensitivities to lighting, opacity variations, and predisposition to eye strain. Ideally, in future research, performance with anodal stimulation of the left dorsolateral prefrontal cortex could be compared to anodal stimulation of the right dorsolateral prefrontal cortex or bihemispheric montage to determine the potential effects of interhemispheric inhibition. Regarding experimental design, it may be beneficial to extend the period of time between pre-assessment, training tasks, and post-assessment to reduce the effects of fatigue. The Go/No-Go task design could benefit from increased complexity to reduce the presence of ceiling effects. Finally, more extensive pretesting could inform individual variability in performance and susceptibility to performance decrements related to monotony.

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APPENDIX A: PRE-ASSESSMENT MEASURES

History Intake Form

Name: _____

Date of Birth: _____ Age: _____

Have you ever been diagnosed with or experienced any of the following?

YES	NO	Anxiety	YES	NO	Loss of Consciousness
YES	NO	Bipolar Disorder	YES	NO	Mental Illness
YES	NO	Blood Clots	YES	NO	Migraine
YES	NO	Brain Tumor	YES	NO	Multiple Sclerosis
YES	NO	Cancer	YES	NO	Panic Attacks
YES	NO	Cardiac Problems	YES	NO	Parkinson's Disease
YES	NO	Depression	YES	NO	Schizophrenia
YES	NO	Diabetes	YES	NO	Seizure
YES	NO	Eating Disorder	YES	NO	Stroke
YES	NO	Epilepsy	YES	NO	Transient Ischemic Attack
YES	NO	Head Trauma			
YES	NO	Heart Disease			

If YES to any of the above, please describe: _____
_____
_____

FOR WOMEN: Are you currently pregnant or think you might be pregnant? YES NO

Do you use tobacco? YES NO
If so, how much/frequently? _____
Last use: _____

Do you use alcohol? YES NO
If so, how much/frequently? _____
Last use: _____

Do you take or are you prescribed any medication? YES NO
If so, what kinds? _____
_____

List any past surgeries and dates: _____
_____
_____

List hospitalizations, including dates and reasons: _____
_____
_____

Do you have any medical or surgical implants? YES NO
Describe: _____
_____

Please list any allergies to materials (e.g., latex): _____

Is there anything else about your physical or mental health you believe we should be aware of? _____
_____
_____
_____

Edinburgh Handedness Inventory[1]

Your participant ID:_____

Please indicate with a one (1) your preference in using your left or right hand in the following tasks.

Where the preference is so strong you would never use the other hand, unless absolutely forced to, put a two (2).

If you are indifferent, put a one in each column (1 | 1).

Some of the activities require both hands. In these cases, the part of the task or object for which hand preference is wanted is indicated in parentheses.

Task / Object	Left Hand	Right Hand
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking a Match (match)		
10. Opening a Box (lid)		
Total checks:	LH =	RH =
Cumulative Total	CT = LH + RH =	
Difference	D = RH – LH =	
Result	R = (D / CT) × 100 =	
Interpretation: (Left Handed: R < -40) (Ambidextrous: -40 ≤ R ≤ +40) (Right Handed: R > +40)		

Please stop

[1] Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh inventory. *Neuropsychologia*, *9*, 97-113.

SCREENING QUESTIONNAIRE FOR TRANSCRANIAL DIRECT CURRENT STIMULATION (tDCS)

Before tDCS please answer the following questions:

		YES	NO
1	Do you have epilepsy or have you ever had a convulsion or a seizure?		
2	Have you ever had a fainting spell or syncope? If yes, please describe the occasion(s) _____		
3	Have you ever had severe (i.e., followed by loss of consciousness) head trauma?		
4	Do you have skin problems, such as dermatitis, psoriasis or eczema?		
5	Do you have electronic implants (like cochlear implantation) or bio-stimulators in general?		
6	Are you pregnant or is there any chance that you might be?		
7	Do you have metal in the brain/skull (other than titanium)? (e.g., splinters, fragments, clips, etc.). If yes, specify the type of metal. _____		
8	Do you have an implanted neurostimulator? (e.g., DBS, epidural/subdural, VNS)		
9	Do you have a cardiac pacemaker or intracardiac lines or metal in your body?		
10	Do you have a medication infusion device?		
11	Are you taking any medications? (please list) _____		
12	Do you have a spinal or ventricular shunt or derivation?		
13	Did you ever undergo tDCS, tES (transcranial electrical stimulation), or TMS (transcranial magnetic stimulation) in the past? If yes, did you have any problems? _____		
14	Did you ever undergo MRI in the past? If yes, did you have any problems? _____		
15	Do you have any cerebral problems (eg., stroke) or cerebral disease in general?		
16	May we keep your information to contact you for participation in future studies?		

Positive answers to one or more questions do not represent an absolute contraindication. In case of positive answers, it is recommended to have a closer examination of the problem, and evaluate the risk\benefit ratio before performing any stimulation. In neurorehabilitation protocols, please explain known risks to the patient and record the drugs in the patient's documentation if answers to questions 1, 3, 11, 15 are positive.

SIGNATURE ---------- DATE ----------

Survey of sensations related to transcranial direct current stimulation (tDCS)

Subject/Session code: _____ **Date:** ____/____/____

Experiment: Transcranial Direct Current Stimulation and Language

Did you experience any discomfort or annoyance during the electrical stimulation? Please answer the following questions regarding the different sensations and indicate the degree of intensity of your discomfort according to the following scale:

- ***None*** **= I did not feel the described sensation (0)**
- ***Mild*** **= I mildly felt the described sensation (1)**
- ***Moderate*** **= I felt the described sensation (2)**
- ***Considerable*** **= I felt the described sensation to a considerable degree (3)**
- ***Strong*** **= I strongly felt the described sensation (4)**

Itching:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Pain:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Burning:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Warmth/Heat:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Pinching:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Metallic/Iron taste:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Fatigue:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong
Other_____:	◻ None	◻ Mild	◻ Moderate	◻ Considerable	◻ Strong

When did the discomfort begin?

◻ At the beginning ◻ At approximately the middle ◻ Towards the end

How long did it last?

◻ It stopped quickly ◻ It stopped in the middle ◻ It stopped at the end

How much did these sensations affect your performance or focus?

◻ Not at all ◻ Slightly ◻ Considerably ◻ Much ◻ Very much

Identify whether these sensations were located on the head or in a different location

◻ On the head _____ ◻ Other _____

If you would like to provide more details, please briefly describe the experimented sensations in relation to the "Other" or "Fatigue" response:

Do you believe that you received a real or placebo stimulation?

◻ real ◻ placebo ◻ I don't know

Adapted from: Fertonani A., Ferrari C. and Miniussi C. What do you feel if I apply transcranial electric stimulation? Safety, sensations and secondary induced effects. Clinical Neurophysiology, 2015

For the researcher/clinician:
Please report any adverse event/problem (e.g., skin irritation, headache, scalp pain, dizziness, or others, please specify) that occurred and rate the event/problem on a scale from 1 to 4 as previously described.

_____
_____
_____
_____

More comments:

_____
_____
_____
_____

APPENDIX B: IRB APPROVAL

ACTION ON PROTOCOL APPROVAL REQUEST

Institutional Review Board
Dr. Dennis Landin, Chair
130 David Boyd Hall
Baton Rouge, LA 70803
P: 225.578.8692
F: 225.578.5983
irb@lsu.edu
lsu.edu/research

TO: E. Susan Duncan
Communication Sciences and Disorders

FROM: Dennis Landin
Chair, Institutional Review Board

DATE: November 15, 2017

RE: **IRB#** 3973

TITLE: The Impact of Task-Specific Transcranial Direct Current Stimulation (tDCS) on Sustained Attention in a Healthy Population

New Protocol/Modification/Continuation: New Protocol

Review type: Full____Expedited X **Review date:** 11/10/2017

Risk Factor: Minimal___X___Uncertain_____Greater Than Minimal_____

Approved_____X_____**Disapproved**_____

Approval Date: 11/15/2017 **Approval Expiration Date:** 11/14/2018

Re-review frequency: (annual unless otherwise stated)

Number of subjects approved: 20

LSU Proposal Number (if applicable)**:**

Protocol Matches Scope of Work in Grant proposal: (if applicable)

By: Dennis Landin, Chairman _____

PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –
Continuing approval is CONDITIONAL on:

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. **SPECIAL NOTE: When emailing more than one recipient, make sure you use bcc.**

**All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at http://www.lsu.edu/irb*

VITA

Kasi Dawn Steele is originally from southeastern Ohio. She received her bachelor's degree in Psychology in 2013 from Louisiana Tech University, Ruston. In 2015, she was accepted into the Louisiana State University Fast Tracker program in Communication Sciences and Disorders. She is currently employed in Dr. E. Susan Duncan's Language Imaging & Brain Research Laboratory. She expects to graduate with her Master of Arts degree in May 2018.