**Blinding of transcranial direct current stimulation is compromised in typically-developing children compared to young adults**

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**Blinding of transcranial direct current stimulation is compromised in typically-developing children compared to young adults**

Achieving successful blinding is a persistent challenge for clinical trials involving transcranial direct current stimulation. Studies involving populations with increased sensory sensitivity, such as children, could be at risk for increased bias from inadequate blinding due to unique sensation of stimulation relative to adults. The objectives of this study were 1) To examine differences in transcranial stimulation blinding between children and young adults and its relationship to sensory sensitivity. 2) To test the efficacy of an ActiSham protocol for participant blinding, compared to a traditional sham protocol. Typically developing right-handed children (N=11, 5-14 yr) and young adults (N=14, 15-25 yr) completed a single-session study to test transcranial stimulation blinding after three conditions counterbalanced across participants: Active, Sham, and ActiSham. Stimulation was paired with a motor learning task to simulate a combinatory neurorehabilitation intervention. After each condition, participants reported if they received real or fake stimulation and their response confidence. To quantify sensory sensitivity, participants completed the Sensory Profile (2nd edition). Compared to a chance level, 1) children and young adults correctly identified Active stimulation, 2) children incorrectly identified Sham and ActiSham stimulation, 3) young adults identified Sham and ActiSham stimulation at chance-level. Blinding accuracy was not related to sensory sensitivity. Children report stimulation as real stimulation with higher confidence for almost all conditions, indicating unsuccessful blinding compared to young adults. Future studies should consider alternative sham protocols or methods to improve blinding in child participants.

**Keywords**: blinding, tDCS, children, sensation, sham, rehabilitation

**Introduction**

Transcranial direct current stimulation (tDCS) is a potential therapeutic intervention for individuals with neurological and psychiatric conditions across the lifespan. A persistent challenge for experimental studies testing the efficacy of tDCS is developing appropriate control or sham conditions to ensure blinding is maintained and to mitigate expectancy effects (Fonteneau et al., 2019; Rabipour, Vidjen, et al., 2018; Rabipour, Wu, et al., 2018). Traditional sham tDCS involves the “fade-in, fade-out” approach wherein electrical current is introduced and extinguished gradually at the beginning and end of the stimulation protocol. Such ramping protocols mimic the sensations (e.g. tingling, itchiness, warmth) of stimulation but may not be effective for blinding, especially for participants not naïve to tDCS (Ambrus et al., 2010; Turi et al., 2019). As an alternative to traditional sham, an active-sham (“ActiSham”) stimulation protocol has been proposed to closely mimic the sensations felt during active tDCS (Neri et al., 2020). Using high-definition tDCS (HD-tDCS) montages, the polarity and intensity of the electrodes are optimized to yield a very low net electrical field across the targeted cortical region. Although promising, testing of ActiSham protocols was limited to scalp sensations and symptoms relative to active stimulation (Neri et al., 2020). Specifically, it is not known if ActiSham outperforms traditional sham for participant blinding.

In addition to sham protocols, other participant-specific factors such as individual sensory threshold, may influence blinding. Prior research has shown differences in sensory sensitivity and related report of symptoms in young vs. older adults (Wallace et al., 2016) and in men vs. women (Workman et al., 2021). Thus, individuals with greater sensitivity to electrical and mechanical stimuli may be more likely to report symptoms and potentially to perceive tDCS as “real”. Still, how differences in sensory sensitivity may impact blinding, particularly for populations with substantially different sensory thresholds such as children, has not been directly examined. Children are less sensitive to mechanical stimuli (i.e. tactile sensation) but more sensitive to painful stimuli, likely related to the incomplete development of the nervous system (Hirschfeld et al., 2012). Altogether, children may have a unique perception of tDCS relative to adults that could affect resultant tDCS blinding. Given the increasing volume of published tDCS studies in pediatric populations (Buchanan et al., 2021), investigating differences in blinding and overall tDCS perception between children and adults is critical for enhancing the rigor of clinical trial design in pediatric tDCS studies.

Therefore, there were two objectives for this study. The first was to examine age-related differences in the perception and overall experience of tDCS in a child and young adult cohort and if blinding was related to sensory sensitivity. We hypothesized that young children will be more likely to report stimulation as “real” compared to young adults and that this would be associated with heightened in sensory sensitivity. The second objective was to test the efficacy of an ActiSham protocol for participant blinding, compared to a traditional sham protocol. We hypothesized that ActiSham would be more effective in blinding participants compared to traditional sham.

**Materials & Methods**

***Study Design and Setting***

The experimental design was a within-subjects, one-day, 2.5-hour session consisting of three 20-minute conditions of tDCS paired with motor training modeled from prior pediatric neurorehabilitation studies (Ciechanski & Kirton, 2017; Kirton et al., 2017). The three tDCS conditions were active/verum, (ACTIVE), traditional sham (SHAM), and ActiSham, (ACTISHAM) and the order was counterbalanced across participants. At three intervals (5 min, 10 min, and 15 min) within each 20-minute tDCS condition, participants practiced a fine motor dexterity task. Assessments were administered before the first (Baseline) and immediately after each tDCS condition (Post1, Post2, Post3). Participants were allowed a short break in between each condition after completing the post-condition assessment (Figure 1). Marquette University's institutional review board approved all procedures. For minors (younger than 18), written consent was obtained by two parents/caregivers and verbal assent was obtained by the child participant; participants older than 18 provided written consent to participate. All personnel were trained in safety protocols for using tDCS and have practiced implementing the intervention and assessments prior to involvement with participants.

***Participants***

Potential participants were recruited through advertisements to Marquette University students and faculty, local schools, lab database of families interested in research (obtained from the PI's prior studies) and personal contacts. Individuals needed to be right-handed, age 5-25, and have typically-developing cognitive and motor skills (according to the parent report or self-report for those over 18 years old during screening). Participants were excluded based on these criteria: (1) a history of seizures, epilepsy, or other neurological conditions, (2) any neuropsychological or developmental diagnoses, (3) taking centrally-acting medications including those for attention disorders, (4) injury to muscle or bone in non-dominant upper extremity, (5) loss of sensation in scalp or non-dominant upper extremity, (6) pregnant, (7) difficulty communicating, (8) surgeries, metal, or implants in the head, and (9) unexplained headaches. Sixty-four individuals were screened for eligibility and 27 were enrolled (12 children aged 5-14 years and 15 young adults aged 15-25, Table 1). Given the lack of precise estimates of effect size, we performed a sensitivity power analysis using GPower (v.3.1.9.6) with the obtained convenience sample size rather than an *a priori* power analysis. With 27 participants and a within-subject factor with 3 levels, we could detect a minimum standardized effect size of 0.45 between groups at 80% power.

***tDCS protocol and administration***

tDCS was administered using the Neuroelectrics Starstim tDCS-EEG system (Neuroelectrics Inc., Barcelona, Spain) with a high-density multielectrode montage. The anode was the C4 EEG location corresponding to the right primary motor area (Figure 1, Appendix A). Four cathodes were configured around the anode at FC6, FC2, CP2, and CP6. ACTIVE tDCS consisted of a consistent 19 minutes of 2 mA stimulation preceded by and ending with a 30 second ramp-up/ramp-down period, resulting in a predicted net electric field of 0.1106 V/m. SHAM tDCS consisted of 0 mA for 20 minutes preceded by and ending with a 30 second ramp-up/ramp-down to 2 mA. ACTISHAM tDCS protocol was developed by the device manufacturer (Neuroelectrics, Inc.) and consisted of continuous stimulation for 20 min with the electrodes to provide a near-zero electric field, which theoretically would not impact the electrical field of the brain however still provide the tactile sensation of stimulation. The electrodes for this condition were FC2, FC6, and CP6, resulting in a predicted net electric field of −0.0004 V/m. Additional details and modeling output are shown in Appendix A.

During each 20 minute stimulation condition, participants practiced the nine hole peg test (see below) at 5 minute intervals with feedback and encouragement provided by the experimenter. The non-dominant hand (and associated stimulation target of the right motor cortex) was chosen to minimize ceiling effects of training the dominant hand (Ciechanski & Kirton, 2017).

**Assessments**

*Blinding*

To assess blinding, after each tDCS condition, the participant and experimenter (who was the same for all participants and blinded to tDCS condition) reported if they believed they received "real" or "fake" stimulation (Palm et al., 2013; Wallace et al., 2016).  After this binary estimation, a follow-up confidence question of “On a scale of 1 to 10, how confident are you about that answer?” was asked, with 1 being low confidence and 10 being high confidence (Turner et al., 2021). Participants were educated on the concept of “real” and “fake” using pictures of play-based analogies (i.e. a sanctioned astronaut representing “real” and a child playing pretend in an astronaut costume representing “fake”, See Appendix B ).

*Sensory sensitivity*

The Sensory Profile, 2nd edition (SP) is a standardized questionnaire that evaluates how a participant’s sensory processing affects them in their school, home, and community (Brown et al., 2001; Dunn, 1994; Dunn & Brown, 1997). There are separate questionnaires for children (completed by a parent proxy) and adults. We used this global assessment because it examines multiple sensory systems (e.g. touch, auditory, olfactory) that are related to everyday function (Dunn, 1994). The profile quantifies four quadrants of sensory processing: low registration (how much someone “attends to sensory input”), sensation seeking (how much someone “obtains sensory input”), sensation sensitivity (how much someone “detects sensory input”), and sensation avoidance (how much someone “is bothered by sensory input”). Developmentally, sensory processing skills play an important role in learning, play, gaining independence in self-care skills, and overall self-regulation, as shown in prior work establishing a link between SP and childhood-onset neurodevelopmental disorders such as cerebral palsy (Pavao et al., 2021), developmental coordination disorder (Delgado-Lobete et al., 2020), and Down Syndrome (Will et al., 2019).

*Motor Performance*

The Nine Hole Peg Test (NHPT) and the Box and Blocks Test (BBT) were used to monitor the possible positive or negative effects of tDCS motor function and are commonly used in prior pediatric studies investigating the effects of tDCS on motor learning (Inguaggiato et al., 2019; Kirton et al., 2017; Rich et al., 2018). The NHPT is a standardized assessment that quantitatively measures finger dexterity by measuring the time needed to place and remove 9 pegs in a pegboard (Oxford Grice et al., 2003). The BBT is a standardized assessment that quantitatively measures manual dexterity by measuring the number of wooden cubes a participant can transfer from one compartment to another in one minute (Mathiowetz, 1985; Mathiowetz et al., 1985).  Participants completed each task using their dominant and non-dominant hands. Three trials of each test were completed and the median score was used for analysis.

**Safety**

Participants and caregivers were screened before beginning the study to confirm there were no contraindications to tDCS (Antal et al., 2017; B. T. Gillick et al., 2018). In addition, during the study, participants were asked a battery of questions related to potential minor side effects or adverse events before, during, and after stimulation sessions to track the frequency and severity of symptoms (B. T. Gillick et al., 2018). The number of reported tDCS symptoms is shown in Table 1 and Appendix C. The study team personnel demonstrated and explained the procedures as they applied the tDCS electrodes. The study team personnel used distraction techniques to minimize discomfort in participants, particularly children, who reported mild discomfort or pain during each condition.

**Data Analysis**

*Blinding and sensory sensitivity*

Blinding accuracy was determined by a weighted estimation from participants’ and experimenter’s self-reported answers to the blinding question methods similar to Turner et al. (Turner et al., 2021). Correct and incorrect estimations were scored +1 and -1 respectively. These scores were then multiplied by the participant’s confidence rating to give a scaled pseudo-continuous estimation of blinding ranging from -10 to 10. Statistical tests were performed with IBM Statistical Package for the Social Sciences, v.28 (IBM SPSS) and Matlab (v2020a, The Mathworks, Inc.) with the following analytical plan including null hypothesis significance testing, effect size estimates, and confidence intervals. Since the primary outcome of blinding accuracy was not normally distributed, we used non-parametric tests to evaluate the effects of AGE (child or young adult, Mann-Whitney U test) and tDCS-TYPE (ACTIVE/SHAM/ACTISHAM, Friedman’s test) on blinding accuracy; post-hoc paired tests (Wilcoxon signed ranks test) were used if a significant main effect of tDCS-TYPE was found. Since naivete to tDCS may affect blinding (Ambrus et al., 2012), secondary non-parametric tests were performed to examine changes in blinding accuracy based upon the order (main effect ORDER) of tDCS conditions each participant received. Specifically, we tested whether participants were more accurate in their estimations after successive exposure to tDCS, regardless of the type of stimulation (sham or real). We hypothesized participants would have the poorest accuracy on the first experimental condition. To correct for multiple comparisons (6 total statistical tests for blinding accuracy), the level of statistical significance was adjusted to .

In the secondary analytical plan, 95% confidence intervals (CI) around the median values were calculated separately for young adult and child subgroups using a bootstrapping procedure with 5000 permutations. The CIs were used to determine if blinding accuracy was greater (or less) than a theoretical chance threshold. We used the interval [−1 1], which corresponded to a low confidence incorrect and correct estimation of blinding, as the chance threshold. Thus, if the bootstrapped confidence interval overlapped this threshold, we concluded that there was uncertainty in the participants’ estimation and that they were adequately blinded for that condition.

*Sensory Sensitivity*

The sensory profile was scored based on its published guidelines (Ermer & Dunn, 1998). Raw quadrant scores were converted to z-scores because of different scoring scales used for the adult and child versions. To test the hypothesis that sensory processing was associated with blinding accuracy (i.e. reporting stimulation to be “real”), we used a multivariate ANOVA. The dependent variables were blinding accuracy for the three tDCS conditions, the independent variable was AGE, and the covariates were the SP z-scores (all 4 quadrants).

*Motor Performance*

Although not hypothesized to be related to tDCS, we analyzed the changes in motor performance during the experiment as follows. The change in motor performance on the NHPT and BBT after each tDCS condition was determined by the difference between two consecutive scores: Δ1=Post1-Baseline; Δ2=Post2-Post1; Δ3=Post3-Post2. Outlier values that were 2 SDs away from the mean were considered (3 children and 1 young adult for NHPT, 2 children for BBT), however sensitivity analyses showed the main conclusions were not affected by the presence of these outliers, thus all participants were included in the analysis. The outcomes followed normal distributions, as confirmed by Shapiro-Wilk tests, thus an ANOVA was used with main effects of AGE, tDCS-TYPE, and an additional within-subjects variable of HAND (trained/untrained) to evaluate motor performance changes. Post-hoc analysis (independent t-tests) comparing the dependent measures among child and young adult participants within each tDCS condition were performed if main effects were present. To examine general practice effects of the training independent of tDCS, we used a secondary ANOVA with main effects AGE, ORDER, and HAND.

**Results**

*Participant and Experimenter Blinding*

Participant and experimenter blinding accuracy are shown in Figure 2A and 2B. Overall, children reported receiving real stimulation on 32/36 (89%) occasions and had higher confidence ratings (median = 8) compared to young adults (22/45 [49%], median confidence = 6). These observations were supported by the non-parametric tests that showed statistically significant effects of AGE for each tDCS condition (Mann-Whitney U tests; SHAM: Z = −3.07, p = 0.001; ACTIVE Z = −2.60, p = 0.009; ACTISHAM: Z = −2.73, p = 0.006).) and tDCS-TYPE (Friedman’s test: χ2 = 15.8, p < 0.001). Post-hoc testing (Wilcoxon) within the child subgroup indicated significant differences in blinding accuracy between SHAM and ACTIVE (Z = −3.42, p < 0.001), between ACTISHAM and ACTIVE (Z = −2.75, p = 0.006), but not between SHAM and ACTISHAM (z = −1.20, p = 0.23).

Examination of the bootstrapped 95% CI showed that children’s estimates did not overlap with the chance-level threshold of [−1 1] for any of the tDCS conditions, meaning children were overall more certain in their estimations, even though they guessed incorrectly for SHAM and ACTISHAM (Figure 2A). Young adults’ estimates overlapped the chance-level threshold for SHAM and ACTISHAM but not for REAL, indicating there was more uncertainty for young adults’ estimations in the two sham conditions.

There were no statistically significant differences in the experimenter’s blinding accuracy for AGE or tDCS-TYPE (Figure 2B). The 95% CI of the experimenter’s accuracy for the child subgroup overlapped with the chance-level threshold for ACTISHAM only. The 95% CI of the experimenter’s accuracy for young adults overlapped with the chance-threshold for ACTIVE only.

Figures 2C and 2D show blinding accuracy based on the order of tDCS conditions. Young adults’ median accuracy increased from condition 1 to 2 and condition 1 to 3, however, there were no significant effects of AGE (Z ≤ −1.28, p ≥ 0.22) or ORDER (χ2 = 1.34, p = 0.51) on participant’s accuracy. However, the 95% CI for young adults did not overlap with the chance-threshold on any condition, with the young adults guessing incorrectly on condition 1 and correctly on conditions 2 and 3. The experimenter’s median accuracy for young adults increased across conditions, however, there were no significant effects of AGE (Z ≤ −1.51, p ≥ 0.14) or ORDER (χ2 = 3.90, p = 0.14). Similar to the participant’s accuracy, the 95% CI for the experimenter’s accuracy for young adults did not overlap the chance-level threshold at any condition and the experimenter guessed correctly for all three conditions.

*Sensory Sensitivity*

According to the instrument’s published criteria, one young adult scored above normal and one child scored below normal in three of the four quadrants of sensory processing. All other participants scored in the normal range for at least two of the four quadrants. The relationship between sensory profile and blinding accuracy is displayed in Figure 3. The SP was not a significant factor in explaining blinding accuracy after accounting for any group differences (all ηp2 ≤ 0.11, p ≥ 0.120).

*Motor Performance*

Changes in motor performance on the NHPT and BBT for each tDCS condition and for each hand (trained/untrained) are shown in Appendix D. There were no statistically significant changes in motor performance on the NHPT or BBT for any tDCS condition, between the age groups, or between trained and untrained hands (all p > 0.12). There was an overall effect of ORDER for NHPT (F2,50 = 7.19, p = 0.002) and for BBT (F2,50 = 3.56, p = 0.04) indicative of practice effects.

**Discussion**

In this study of three distinct tDCS conditions, we examined the accuracy of participant and experimenter blinding in child and young adult participants and whether differences in sensory sensitivities was related to blinding. Our main findings were: 1) children perceived most all tDCS as “real” and were thus not successfully blinded; 2) blinding success for ActiSham was comparable to traditional Sham but different than Active, and 3) sensory sensitivity was unrelated to blinding accuracy.

*Blinding accuracy in children differed from young adults*

After each tDCS condition, almost all (89%) of child participants reported, with a high level of confidence, that tDCS was real compared to the total proportion of young adult participants (49%) who reported they received real stimulation. Previous studies using tDCS in pediatric populations typically have not reported blinding outcomes (Andrade et al., 2014; Auvichayapat et al., 2013; Duarte et al., 2014; B. Gillick et al., 2018; Gillick et al., 2015; Grecco et al., 2014; Gómez et al., 2017; Rich et al., 2018; Young et al., 2013). However, two studies found children could not accurately predict the real or sham tDCS at the group level, although the proportions within the real and sham treatment groups were not provided (Ciechanski & Kirton, 2017; Kirton et al., 2017). Thus, it is possible that, similar to our results, children receiving Sham or Active tDCS reported stimulation as “real”. More detailed measures of blinding success consider each treatment group, rather than across the entire sample (Bang et al., 2010). With this approach, it is clear that during Active tDCS, blinding was not achieved as almost all participants identified this as real stimulation. Blinding was also not achieved for Sham or ActiSham in the child group, as most children also incorrectly identified this as real stimulation above chance level.

Importantly, our results suggest that children had a unique perception and experience of tDCS possibly related to a fundamentally different expectation for what “fake” stimulation is or what it should feel like. First, children may not have understood experimental concepts of “real” and “sham”. We explained these concepts using age-appropriate play-based analogies with visual graphics (fake is pretending to be an astronaut, real is a real astronaut, Appendix B). Older participants likely had a more complete understanding of these experimental design concepts, leading to *a priori* estimation that at least one of the experimental conditions would be sham. This could explain the lower confidence and better blinding for young adults. Second, if children expected to not feel anything during sham, any scalp sensation may have been considered “real” stimulation, thus explaining the higher proportion and confidence of receiving real tDCS. One limitation is that we did not perform de-briefing interviews to gather information about participant’s perceptions during stimulation; such interviews would provide insight on differences between children and young adults related to expectation and knowledge of experimental conditions. In sum, the observation that children were more likely to identify tDCS as real suggests that future pediatric tDCS trials should consider including age-appropriate communication and explanations for study materials and experimental procedures.

*ActiSham was more similar to Sham than Active stimulation*

Participants’ estimations were less accurate overall during Sham and ActiSham tDCS but more accurate for Active tDCS. There have been conflicting reports about the effectiveness of traditional sham for blinding (Ambrus et al., 2012; Brunye et al., 2014; Fonteneau et al., 2019; O’Connell et al., 2012), leading to the advent of ActiSham. ActiSham provides a constant low-level but perceptible electrical current to better match sensations of active stimulation. Since participants demonstrated low accuracy and confidence (indicated by the large 95% CI) during ActiSham and Sham, these results suggest ActiSham may be a suitable alternative to traditional sham in experimental trials. In contrast, most participants could correctly identify Active tDCS, suggesting there remains a strong association between scalp sensation and blinding accuracy. Additional direct comparisons of ActiSham and Active tDCS should be tested to support ActiSham as a more favorable sham protocol. While definitions for blinding success vary (Bang et al., 2010), altogether these results highlight the persistent challenge for blinding in tDCS studies.

Another key variable for interpreting these results might be prior experience with tDCS. In the present study, all participants were tDCS-naive, but the within-subjects design meant participants based their blinding estimations upon previous tDCS conditions. Still, we did not find a significant effect of condition order, meaning participants were not statistically better able to identify real or sham with each subsequent exposure to tDCS. Together, these results indicate prior tDCS experience may not alter participants’ blinding accuracy. This is important in cross-over studies where participants receive both real and sham tDCS.

*Sensory sensitivity was not linked to blinding*

Contrary to our hypothesis that individuals with greater sensory sensitivity will more often report receiving real stimulation, we did not observe any association between sensory sensitivity and blinding accuracy. Because we included neurotypical children and young adults, the scores on the SP reflected normal ranges of sensory sensitivity. Furthermore, the SP reflects multiple sensory systems and may not directly be related to tactile or thermal sensitivity of the scalp related to a participant’s experience of tDCS. Studies that include children or adults with known atypical sensory processing might reveal different patterns, leaving another avenue for future studies to probe atypical sensory sensitivity and its relationship to blinding.

*Marginal changes in motor performance after tDCS*

We did not observe any effect of tDCS on motor improvements on the NHPT for either group. We made no *a priori* hypotheses about motor changes given the heterogenous reports on the impact of tDCS for motor learning (Halakoo et al., 2020; Zhang et al., 2024), the probable practice and carry-over effects associated with repeated performance of the same task (Biabani et al., 2018), and that motor learning could not be inferred from our single day session. Still, even without substantial practice effects, we also did not observe any changes on the untrained task (BBT), suggesting there were no significant changes in motor performance associated with tDCS. The use of NHPT as an assessment, while simplistic, was a primary limitation in detecting motor changes due to ceiling effects in performance. Thus, our motor performance data can serve as a caution for future investigations aiming to detect motor learning effects and suggest they employ tasks with greater sensitivity and minimal ceiling effects.

*Potential connection to tDCS expectancy effects*

Perhaps a more important factor than blinding accuracy is prior expectations or beliefs about treatment effects. For tDCS, the expectation of benefit may outweigh the actual physiological effects of tDCS, as revealed in adult studies (Haikalis et al., 2023; Rabipour, Wu, et al., 2018). Before commencing with tDCS, we asked participants a yes/no expectancy question (“Do you think this type of stimulation will improve how you move your hand?”); most answered “yes” (19/27, 70%) and thought that it would help. It is reasonable to expect that children, particularly those with motor or cognitive impairment, have a different expectation than adults about the benefit of medical interventions. This might further confound the relationship between expectancy and outcomes after tDCS. Thus, future clinical trials involving tDCS in clinical population should strongly consider tDCS expectancy effects and perhaps include qualitative measures for in-depth insight into participants’ conceptions that would impact on blinding and task performance.

In conclusion, we found that typically-developing children are more likely than young adults to indicate that tDCS is real stimulation, regardless of what sham tDCS protocol is used. Differences in blinding accuracy were not related to an individual’s global sensory sensitivity. These results highlight the importance of comprehensive blinding assessments in clinical trials with pediatric and adult participants to account for placebo and expectancy effects that confound tDCS studies. A more complete understanding of the behavioral and possible neurophysiological underpinnings of blinding accuracy remain to be discovered in future work.

**Conflicts of interest**: None of the authors have potential conflicts of interest to be disclosed.

**Data availability statement:** The data that support the findings of this study are openly available in the Open Science Framework at http://doi.org//10.17605/OSF.IO/X65WF

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| --- | --- | --- |
| **Table 1. Sample Characteristics** |  |  |
|  | **Child**  **(N=12)** | **Young adult (N=15)** |
| Age (mean ± SD, yrs) | 9.33 ± 2.77 | 22 ± 2.75 |
| Sex N (%) |  |  |
| Female | 7 (58) | 12 (80) |
| Mother’s education (N) |  |  |
| High School Diploma | 0 | 2 |
| Associate’s Degree | 0 | 0 |
| Bachelor’s Degree | 7 | 9 |
| Master’s Degree | 2 | 1 |
| Doctoral/professional Degree | 3 | 1 |
| Ethnicity N (%) |  |  |
| Hispanic or Latino | 1 (8) | 0 (0) |
| Race N (%) |  |  |
| White | 11 (92) | 13 (87) |
| Asian | 0 (0) | 2 (13) |
| More than one race | 1 (8) | 0 (0) |
| tDCS Symptoms N (%)a |  |  |
| Sham | 31 (7) | 35 (6) |
| ActiSham | 39 (8) | 25 (4) |
| Active | 31 (7) | 29 (5) |
| Sensory Profile N (%)b |  |  |
| Seeking | 10 (83.3) | 12 (80.0) |
| Avoiding | 10 (83.3) | 13 (86.7) |
| Sensitivity | 12 (100) | 10 (66.7) |
| Registration | 11 (91.7) | 8 (53.3) |
| *Note.* aN is total number of symptoms reported during that condition for all participants; % is mean # of symptoms felt per participant,b% who scored within the normative range | | |

**Figure Legends**

**Figure 1.** Experimental design and tDCS setup. Baseline outcome measures were obtained including NHPT, BBT, and SP. Then, participants completed three 20-minute conditions of tDCS+motor training in a one-day session. The order of tDCS conditions was counterbalanced across participants. Participants completed three 5-minute training sessions (Train 1.1, 1.2, …) using the NHPT during each tDCS condition. Outcome measures of Blinding, NHPT, BBT, and Sx were repeated after each session (Post1, Post2, Post3). Each tDCS condition consisted of a 4x1 electrode montage with EEG coordinates CP6, CP2, C4, FC6, FC2. Electrodes shaded red and blue were positive current and negative currents respectively. The schematic below each montage reflects the time-course of duration and intensity of stimulation. NHPT = Nine Hole Peg Test; BBT = Box and Blocks Test; SP = Sensory Profile; tDCS = transcranial direct current stimulation; Blinding = end of condition questions “Do you think you received real or pretend stimulation during this condition?” and “On a scale of 1-10 with 1 being that you feel unsure and are making a guess and 10 being very confident, how confident are you in your answer?;” Sx = symptom tracker.

**Figure 2.** Blinding accuracy weighted by response confidence in children and young adults reported by participants (A and C) and the experimenter (B and D). Figures A and B show blinding based on the tDCS condition (Sham, Actisham, and Active) received and Figures C and D show blinding based on the order of the tDCS condition. The yellow (correct) and gray (incorrect) shaded regions accuracy of estimations above a chance level. Error bars are 95% CI from bootstrapping procedure.

**Figure 3.** Relationship between the Sensory Profile and blinding estimation. Subplots show the four quadrants of the Sensory Profile (1st column: Low Registration, 2nd column: Sensation Avoiding, 3rd column: Sensory Sensitivity, 4th column: Sensation Seeking) stratified by tDCS condition (1st row: Sham, 2nd row: ActiSham, 3rd row: Active). There were no significant correlations between a participant’s Sensory Profile scores and their report of whether stimulation was real or fake.

**Figure 1**

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**Figure 2**

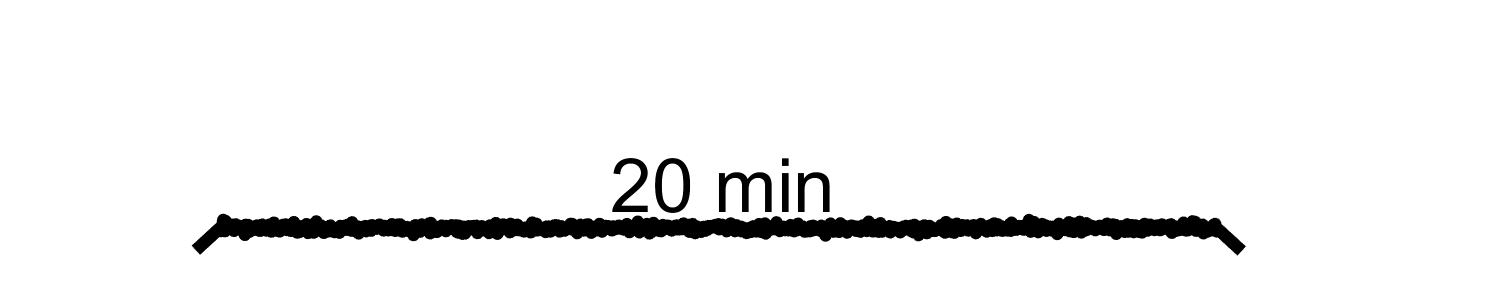
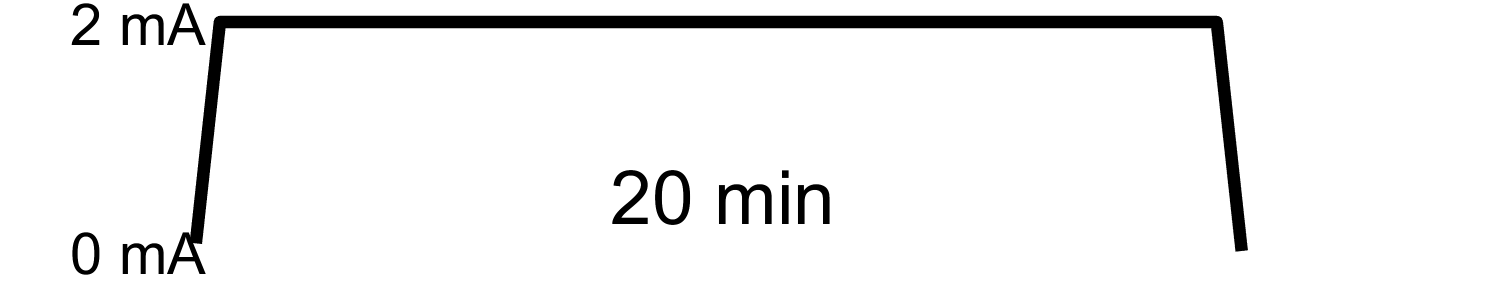
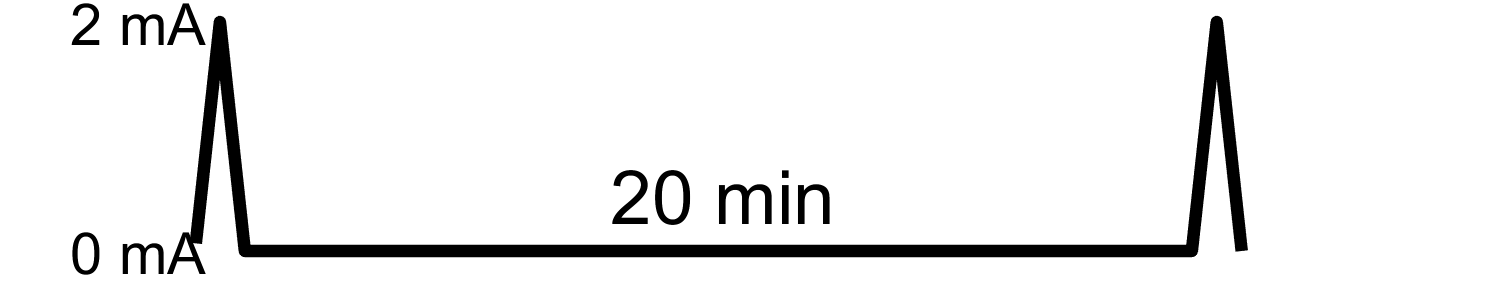
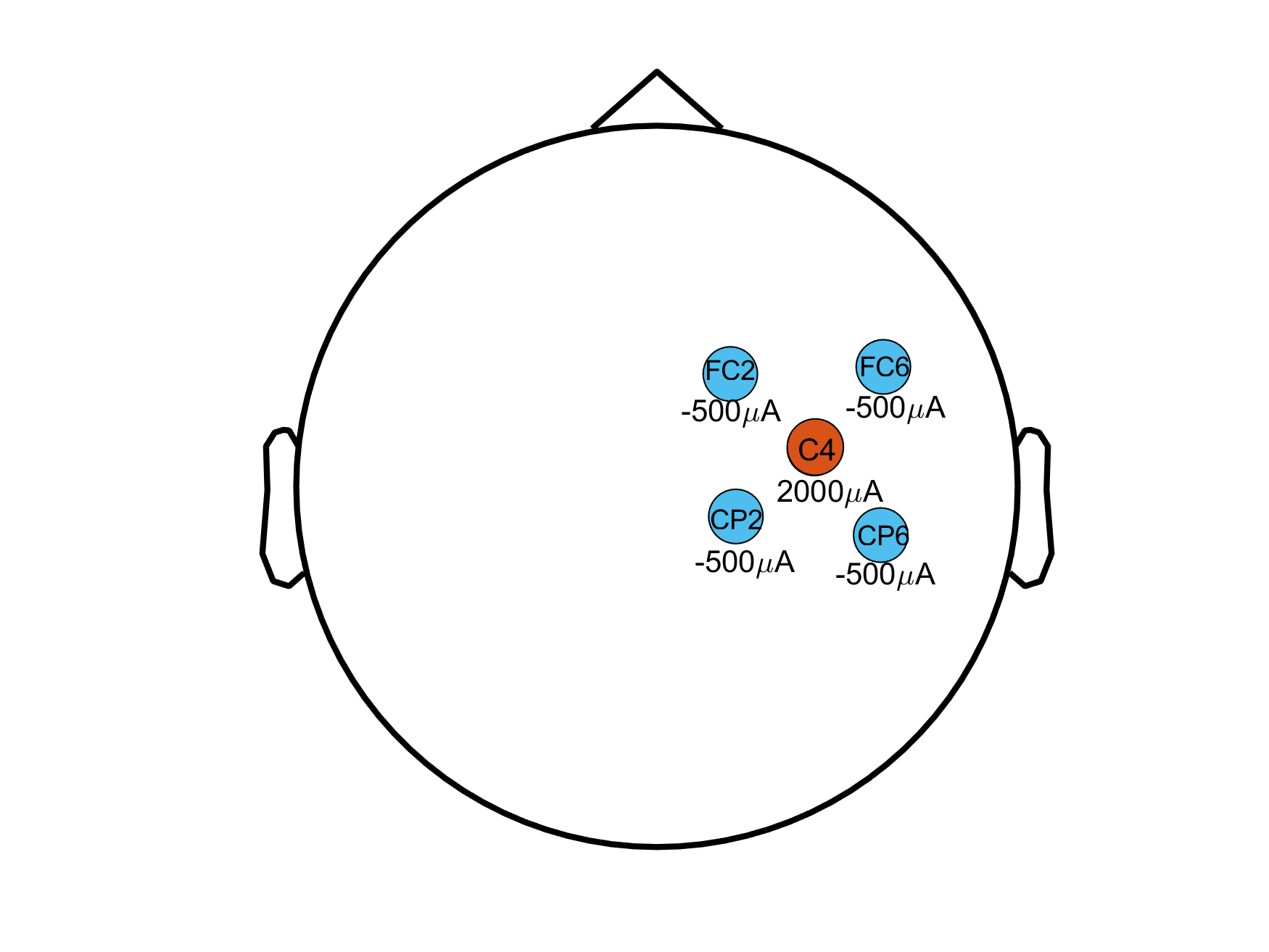
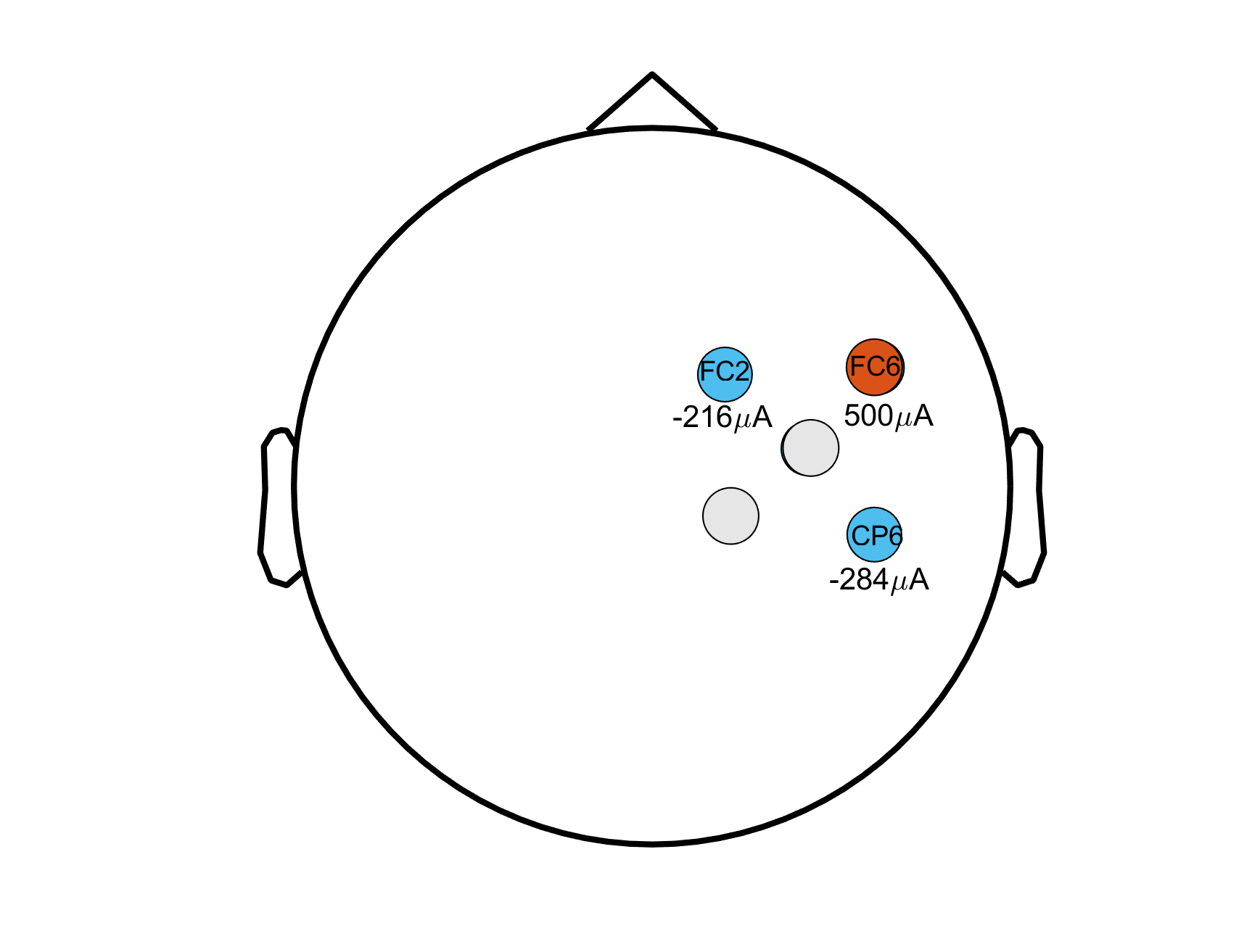
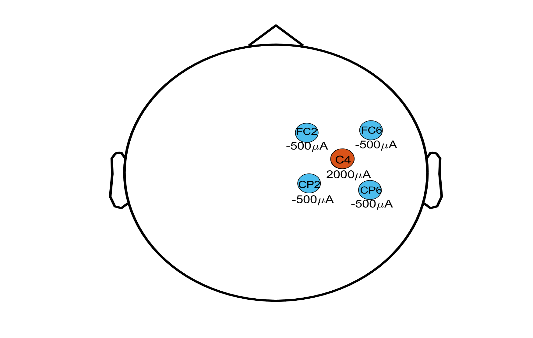
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**Figure 3**

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**Graphical Abstract**



**Active**

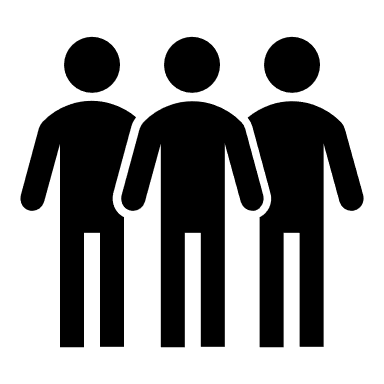
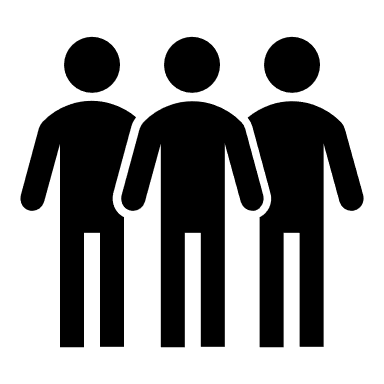
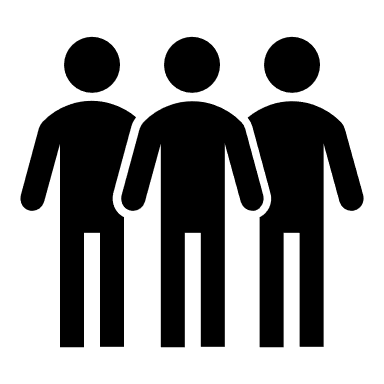
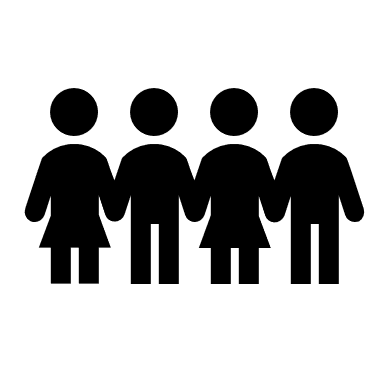
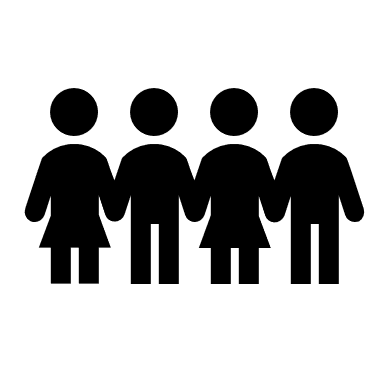
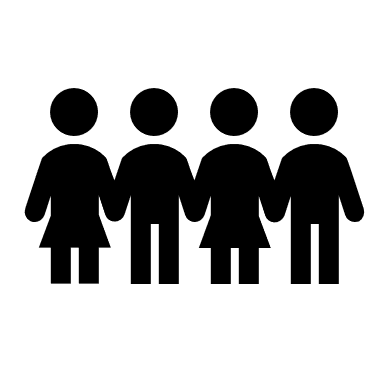
**Sham**

**Actisham**

tDCS Conditions and Montages

**The stimulation was “real”**

**The stimulation was “fake”**



Blinded

Not Blinded

Not Blinded

In this study, we compared children and young adults’ blinding to transcranial direct current stimulation. Using three distinct modes of tDCS, we found that children responded that tDCS was almost always “real” whereas adults were more balanced between responses of “fake” and “real” stimulation. Blinding was only confirmed for the sham conditions but not the real/active tDCS condition, given that most participants reported this as “real” stimulation. These findings are important for ensuring proper control/sham tDCS protocols and to test for blinding efficacy in studies including both children and electrical brain stimulation.