**Supplementary Materials**

# Methods

We have reported Linear mixed model (LMM) analysis in the manuscript. Commonly available statistical packages do not provide a way to calculate effect sizes with LMM analysis. Thus, we performed supplementary analysis using repeated measures ANOVA to estimate the effect sizes. Moreover, to confirm whether our data provides the evidence of null or alternate hypothesis, we also performed Bayesian repeated measures ANOVA.

## Statistics

Two-way repeated measures ANOVA was performed with factors Stimulation (Active and Sham) and Sessions (Baseline, Online tDCS, post tDCS). Bayesian repeated measures ANOVA was also performed with the same factors. For post-hoc results of the factor “Session”, we replaced “Baseline”, “Online tDCS”, and “Post tDCS” with “Session 1”, “Session 2”, and “Session 3” respectively, to evaluate learning over time irrespective of active or sham stimulation. Both factors were specified as within-subject factors. Results were considered statistically significant for p < 0.05. The data are reported as mean ± SD unless otherwise indicated.

# Results

## Repeated Measures ANOVA

Homogeneity of variance assumption was met as Mauchly’s test of sphericity was not significant for the factor Sessions (*W* = 0.94, p > 0.05) and for the interaction between Stimulation and Sessions (*W* = 0.88, p > 0.05). Overall, the results of repeated measures ANOVA (Table S1) are not different from the LMM analysis with only significant difference for the factor Session (F(2, 28) = 10.80, p < 0.001; ηp2 = 0.44) whereas no significant differences were observed for the factor Stimulation (F(1, 14) = 0.02, p>0.05; ηp2 = 0.001), and interaction of Stimulation and Session (F(2, 28) = 0.03, p>0.05; ηp2 = 0.03).

**Table S1. Within Subjects Effects**

| Source | Sum of Squares | df | Mean Square | F | p | η² | η² p | ω² |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Stimulation | 359.32 | 1 | 359.32 | 0.02 | 0.89 | 7.34e-4 | 1.45e-3 | 0.00 |
| Residuals | 247417.82 | 14 | 17672.70 |  |  |  |  |  |
| Sessions | 72907.74 | 2 | 36453.87 | 10.80 | **<0.001** | 0.15 | 0.44 | 0.08 |
| Residuals | 94484.64 | 28 | 3374.45 |  |  |  |  |  |
| Stimulation\*Sessions | 2256.35 | 2 | 1128.18 | 0.44 | 0.65 | 4.61e-3 | 0.03 | 0.00 |
| Residuals | 72263.81 | 28 | 2580.85 |  |  |  |  |  |

The post hoc analysis of the factor “Session” (Table S2) revealed significant improvement of scores from Session 1 to Session 2, and from Session 1 to Session 3 but the improvement in scores was not significant from Session 2 to Session 3.

**Table S2. Post Hoc Comparisons for factor ‘Sessions’**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Comparison | | Mean Difference | SE | t | Cohen’s d | pbonf |
| Session 1 | Session 2 | -57.33 | 15.00 | -3.82 | -0.99 | 2.03e-3\*\* |
| Session 1 | Session 3 | -63.02 | 15.00 | -4.20 | -1.08 | <.001\*\*\* |
| Session 2 | Session 3 | -5.69 | 15.00 | -0.38 | -0.10 | 1.00 |

\*\*: p < 0.01, \*\*\*: p < 0.001

## Bayesian Repeated Measures ANOVA

Results from Bayesian repeated measures ANOVA are presented in Table S3. Model including the factor “Stimulation” had BF10 = 0.22; model including the factors “Stimulation + Session” had BF10 = 2.96; and the model including the factors “Stimulation + Sessions + Stimulation \* Sessions” had BF10 = 0.54. Similarly, model evidence for the factor “Session” alone was BF10 = 13.25. Bayes Factor of 0.33 ≤ BF10 ≤ 1 is considered weak or inconclusive evidence in favour of null hypothesis, and 0.1 ≤ BF10 ≤ 0.33 is considered moderate evidence in favour of null hypothesis (van Doorn et al., 2020). Since the model with “Stimulation” resulted in BF10 = 0.22 (0.1 ≤ BF10 ≤ 0.33), thus our findings suggest a moderate evidence for null hypothesis. However, the model with interaction term (Stimulation + Sessions + Stimulation \* Sessions) suggests inconclusive evidence for null hypothesis as BF10 = 0.54.

Based on above, we can suggest that our data is 4.54 times (BF01 = 1/0.22) likely to be under null hypothesis than alternative hypothesis for the factor “Stimulation”.

**Table S3. Model Comparison**

| Model | P(M) | P(M|data) | BF M | BF 10 | error % |
| --- | --- | --- | --- | --- | --- |
| Null model (incl. subject) | 0.20 | 0.06 | 0.24 | 1.00 |  |
| Stimulation | 0.20 | 0.01 | 0.05 | 0.22 | 1.14 |
| Sessions | 0.20 | 0.74 | 11.21 | 13.25 | 0.69 |
| Stimulation + Sessions | 0.20 | 0.16 | 0.79 | 2.96 | 1.27 |
| Stimulation + Sessions + Stimulation  ✻  Sessions | 0.20 | 0.03 | 0.12 | 0.54 | 1.38 |

*Note*. All models include subject

The post hoc analysis of the factor “Session” is shown in Table S4 showing strong model evidence of difference in scores from Session 1 to Session 2, and from Session 1 to Session 3 but there was close to no evidence of difference in scores from Session 2 to Session 3.

**Table S4. Post Hoc Comparisons for Factor Sessions**

| Comparison | | Prior Odds | Posterior Odds | BF 10, U | error % |
| --- | --- | --- | --- | --- | --- |
| Session 1 | Session 2 | 0.59 | 37.66 | 64.12 | 9.90e -5 |
| Session 1 | Session 3 | 0.59 | 71.10 | 121.04 | 2.54e -5 |
| Session 2 | Session 3 | 0.59 | 0.13 | 0.22 | 7.62e -3 |

Note. The posterior odds have been corrected for multiple testing by fixing to 0.5 the prior probability that the null hypothesis holds across all comparisons (Westfall et al., 1997). Individual comparisons are based on the default t-test with a Cauchy (0, r = 1/sqrt(2)) prior. The "U" in the Bayes factor denotes that it is uncorrected.

# Correlations between Repeated Measures

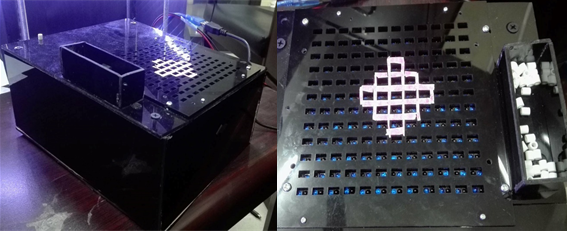
**Table S5. Correlations (Pearson’s r) in Anodal Session**

| Variable | Baseline | Online tDCS | Post tDCS |
| --- | --- | --- | --- |
| Baseline | — |  |  |
| Online tDCS | 0.77 | — |  |
| Post tDCS | 0.86 | 0.82 | — |

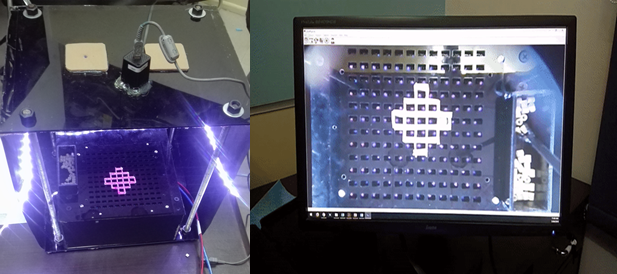
**Table S6. Correlations (Pearson’s r) in Sham Session**

| Variable | Baseline | Online tDCS | Post tDCS |
| --- | --- | --- | --- |
| Baseline | — |  |  |
| Online tDCS | 0.70 | — |  |
| Post tDCS | 0.61 | 0.77 | — |

# Supplementary Figures

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**Figure S1. Digital Laparoscopic Trainer.** 3D view on left and top view on right.



**Figure S2. Experimental Setup.** *Left:*Digital laparoscopic trainer placed inside a stage with holes for inserting laparoscopes and a camera for live video feed and recording. Subjects stood at the opposite side of stage with that side of stage completely covered. *Right:*Screen with live video feed from camera.

# Effect Size Equations

## Ciechanski et al., 2018

The study performed independent t-test on post-test scores. We thus estimated effect size based on post-test differences during sample size estimation. Following equations were used from (Borenstein et al., 2021).

|  |  |  |
| --- | --- | --- |
|  |  | () |

where

|  |  |  |
| --- | --- | --- |
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|  |  |  |
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|  |  | () |

where

|  |  |  |
| --- | --- | --- |
|  |  | () |

## Ciechanski et al., 2019

Same equations were used for effect size calculation of this study as listed above.

## Cox et al., 2020

We used the equation from (Morris & DeShon, 2002).

|  |  |  |
| --- | --- | --- |
|  |  | (5) |

# References

Borenstein, M., Hedges, L. V, Higgins, J. P. T., & Rothstein, H. R. (2021). *Introduction to meta-analysis*. John Wiley & Sons.

Ciechanski, P., Cheng, A., Damji, O., Lopushinsky, S., Hecker, K., Jadavji, Z., & Kirton, A. (2018). Effects of transcranial direct-current stimulation on laparoscopic surgical skill acquisition. *BJS Open*, *2*(2), 70–78. https://doi.org/10.1002/bjs5.43

Ciechanski, P., Kirton, A., Wilson, B., Williams, C. C., Anderson, S. J., Cheng, A., Lopushinsky, S., & Hecker, K. G. (2019). Electroencephalography correlates of transcranial direct-current stimulation enhanced surgical skill learning: A replication and extension study. *Brain Research*, *1725*, 146445. https://doi.org/10.1016/j.brainres.2019.146445

Cox, M. L., Deng, Z. De, Palmer, H., Watts, A., Beynel, L., Young, J. R., Lisanby, S. H., Migaly, J., & Appelbaum, L. G. (2020). Utilizing transcranial direct current stimulation to enhance laparoscopic technical skills training: A randomized controlled trial. *Brain Stimulation*, *13*(3), 863–872. https://doi.org/10.1016/j.brs.2020.03.009

Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological Methods*, *7*(1), 105–125. https://doi.org/10.1037/1082-989X.7.1.105

van Doorn, J., van den Bergh, D., Böhm, U., Dablander, F., Derks, K., Draws, T., Etz, A., Evans, N. J., Gronau, Q. F., Haaf, J. M., Hinne, M., Kucharský, Š., Ly, A., Marsman, M., Matzke, D., Gupta, A. R. K. N., Sarafoglou, A., Stefan, A., Voelkel, J. G., & Wagenmakers, E. J. (2020). The JASP guidelines for conducting and reporting a Bayesian analysis. In *Psychonomic Bulletin and Review* (Vol. 28, Issue 3, pp. 813–826). Springer. https://doi.org/10.3758/s13423-020-01798-5

Westfall, P. H., Johnson, W. O., & Utts, J. M. (1997). A Bayesian perspective on the Bonferroni adjustment. *Biometrika*, *84*(2), 419–427. https://doi.org/10.1093/BIOMET/84.2.419