Transcranial Direct Current Brain Stimulation During Sleep Deprivation Reduces Performance and Recovery

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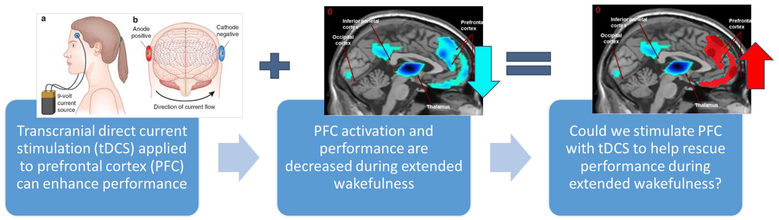
Background

- Multi-Domain Operations (MDO) require around the clock operations where sometimes adequate sleep is not possible
- THEREFORE quick and efficacious short-term solutions are needed to help sustain performance in the face of operationally necessary extended wakefulness
- Could transcranial direct current stimulation (tDCS) be a fieldable solution to this problem?

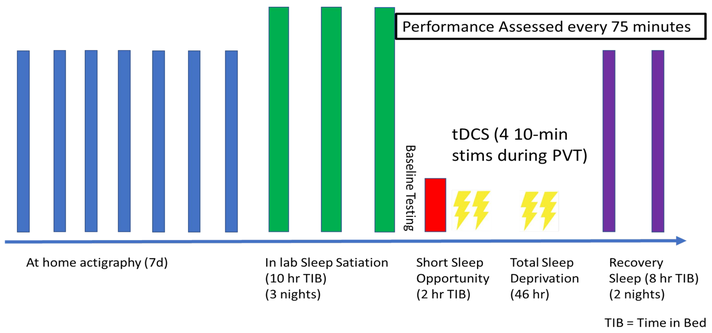


Methods: Study Design

Seventeen healthy participants were randomly assigned either to the stimulation (N=9) or sham group (N=8) but remained blinded to their assignment. The two groups were not statistically different from each other on any demographic.

	ALL	STIM	SHAM	Difference P Value
N	17	9	8	
Age	29.53 ± 5.87	27.22 ± 5.26	32.13 ± 5.72	0.09
Beck Depression Inventory	1.18 ± 2.26	0.33 ± 1.00	2.00 ± 2.98	0.13
Spielberger Trait Anxiety	25.94 ± 4.19	25.22 ± 4.12	26.75 ± 4.40	0.47
Morningness – Eveningness Questionnaire	58.88 ± 6.00	56.56 ± 3.13	61.50 ± 4.54	0.09
Caffeine Consumption Questionnaire	72.71 ± 122.73	74.56 ± 117.60	70.63 ± 136.45	0.95

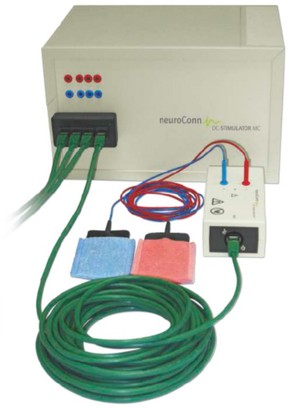
- Study Design is outlined below – note that testing every 75 minutes began following the in-lab sleep satiation phase and lasted through the recovery phase – but only the change from baseline for testing blocks between 0730 and 1915 during the sleep deprivation and recovery phases were used in this analysis.
- Performance testing included a 10-minute Psychomotor Vigilance Test (PVT), Mood Assessments, and a Math Processing Task (results not shown here).
- All sleep periods were investigated using a 13-lead Polysomnogram.

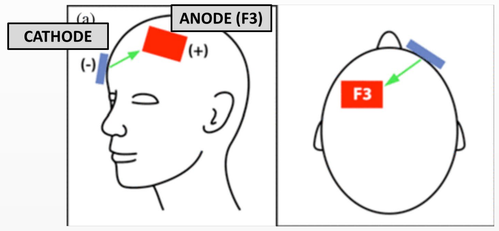


Methods: tDCS Parameters and Administration, Statistical Analysis

tDCS Parameters and Administration Methods

- tDCS stimulation was applied using a research grade stimulator – the Neuroconn DC-Stimulator MC
- Dosage: 2mA (milliamps) tDCS applied for 10 minutes during four stimulation periods while the PVT was performed
  - 4 Stimulation Periods:
    - 1) First morning of sleep deprivation – 0230 (1.5 hrs into Sleep Deprivation, SD)
    - 2) First morning of sleep deprivation – 0345 (2.75 hrs into SD)
    - 3) Second morning of sleep deprivation – 0215 (25.25 hrs into SD)
    - 4) Second morning of sleep deprivation – 0330 (26.5 hrs into SD)
- Stimulation Sequence: 30 second ramp up, 9 minutes of constant current, 30 second ramp down
- Sham Sequence: 30 second ramp up and ramp down at the beginning and end of the 10 minute period
- Mode and location of administration:
  - Anode = left dorsolateral prefrontal cortex (DLPFC) and electrode location F3
  - Cathode = right supraorbital area
  - 5x7 sponges soaked in saline

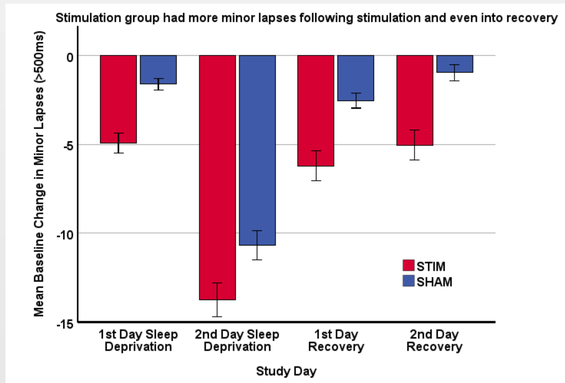




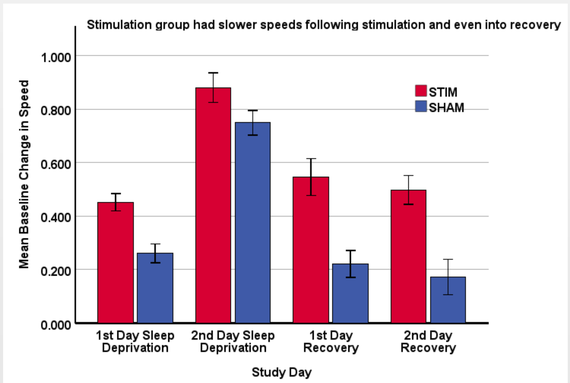
Statistical Analysis Methods

- PVT Minor Lapses (> 500 ms) and PVT Speed change from baseline were analyzed using a 4 (Study Day) x 2 (Group) Mixed Linear Model. Change from baseline measures were collapsed across each day.
- N3 sleep duration was analyzed for the two recovery nights in a 2 (Study Night) x 2 (Group) Mixed Linear Model.
- All error bars represent 1 Standard Error.

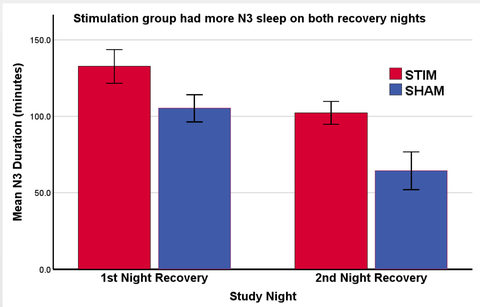
Results



Main Effect of Study Day: F(4,1061) = 24.71, p < 0.001
Main Effect of Group: F(1,1061) = 18.76, p <0.001
Interaction of Group and Day: F(4,1061) = 3.24, p = 0.012



Main Effect of Study Day: F(4,1061) = 29.41, p < 0.001
Main Effect of Group: F(1,1061) = 11.45, p <0.001
Interaction of Group and Day: F(4,1061) = 3.86, p = 0.004



Main Effect of Study Night: F(1,30) = 12.53, p = 0.001
Main Effect of Group: F(1,30) = 10.50, p = 0.003
Interaction of Group and Night: F(1,30) = 0.27, p = 0.606

Conclusion

- Prefrontal tDCS given during extended sleep loss causes more lapses and slower speeds compared to sham stimulation
- This negative impact of tDCS was seen even after two nights of recovery sleep and the stimulation group needed more N3 sleep in recovery
- It may be that tDCS accelerates the accrual of homeostatic sleep drive
- **Therefore, tDCS is not recommended during extended wakefulness as an intervention to boost performance**
  - However, we have shown that Slow Oscillatory Transcranial Electrical Stimulation (SO-TES) given during sleep does boost PVT performance during subsequent sleep loss (Hughes et al., 2021)

Reference
Hughes, J., Doty, T. J., Ratcliffe, R., & Balkin, T. (2021). 044 Slow oscillatory transcranial direct current stimulation enhances cognitive performance during subsequent sleep deprivation. Sleep, 44, A19.