Effects of Transcranial Alternating Current Stimulation (tACS) on Memory Recall in Elderly Participants

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Electroencephalogram (EEG)

Figure 1. Participant with EEG cap

- Non-invasive neuroimaging technique that measures electrical activity in the brain
- Neural oscillation patterns move at **different speeds** (alpha, gamma, etc.)
- Gel is placed under each electrode to maximize contact and ensure quality signaling

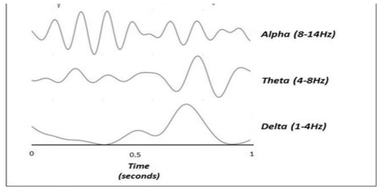


Figure 2. Neural oscillation patterns for alpha, theta, and delta frequencies

Transcranial Alternating Current Stimulation (tACS)

- Non-invasive brain stimulation that has been used to alter neural oscillatory patterns
- Neural entrainment, the phase synchronization of a population of neurons to an external rhythmic stimulus, is a fundamental mechanism
  → Computational modeling and human studies suggest that tACS modulates oscillations by entrainment
- Stimulation targeted **bilateral temporal lobes** due to functions in visual processing and memory formation
- Administers a **sinusoidal alternating current** to the scalp, influencing the synchronization and functional connectivity of cortical neurons

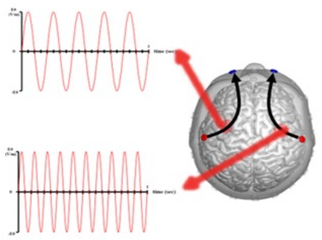


Figure 3. Depiction of tACS neural entrainment

Devices

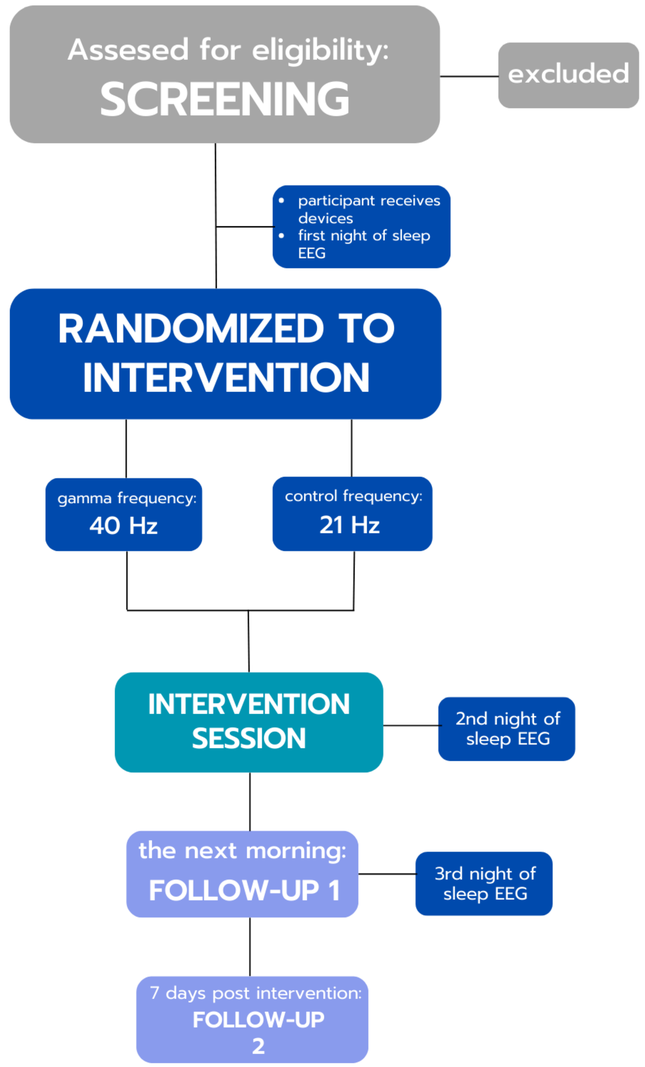
Actiwatch
The Actiwatch is a small, wrist-worn device used to monitor activity levels and sleep patterns.
- Provided insights into into participants' activity patterns and sleep-wake cycles
- Helps correlate self-reported sleep and wake times and the ULTEEMNite recordings

ULTEEMNite
The ULTEEMNite is a device worn by participants while they slept.
- Dry electrodes measure electrical brain activity between the temples
- Spectrogram displays sleep spindles and slow wave activity without interference from the power line frequency (50 Hz)

Introduction

- Cognitive decline is a prevalent concern in **aging populations**
- Alterations in gamma activity during sleep may contribute to deficits in declarative memory
- Large-scale synchronization of gamma activity is essential for memory and perception processes during wakefulness.
- Investigated the impact of transcranial alternating current stimulation (tACS) at gamma frequency (40 Hz) and control frequency (21 Hz) on bilateral temporal cortices
- Hypothesized that **gamma frequency tACS would improve memory consolidation**, leading to improved memory recall the morning after stimulation

Methods and Data Collection



This sequence is repeated the following week for the respective other stimulation condition.

Discussion

- Gamma oscillations facilitate the transmission of sensory information to the hippocampus during memory encoding; crucial for the formation and retrieval of episodic memories
- Episodic memory formation relies on long-term potentiation (LTP), with gamma oscillations involved in spike timing-dependent plasticity (STDP)
- We expect memory consolidation to improve due to the findings of 'Long-lasting, dissociable improvements in working memory and long-term memory in older adults with repetitive neuromodulation,' (Grover et al., 2022) whose results suggested that memory function can be improved in older adults through modulation of gamma rhythms.
- Results of this paper demonstrated that selective improvements in working memory (WM) and long-term memory (LTM) were observed in older adults through entrainment of gamma rhythms in the dorsolateral prefrontal cortex (DLPFC).
- Targeting the temporal cortices is motivated by their critical role in memory and sleep processes, including regulation of sleep—wake cycles

Future Directions

- Future investigations should employ larger and more diverse participant samples
  → Pilot study (n=12)
- Longitudinal studies with extended follow-up periods could provide insights into the sustainability of cognitive improvements and potential implications for real-world functioning
- The integration of tACS with cognitive testing demonstrated feasibility and safety in an older population.
  → Post-stimulation, participants completed a Stimulation Side Effect form to assess side effects, and notably, no adverse effects or major discomfort were reported during or after the stimulation sessions.

References

1. Ferrara, M., Moroni, F., Gennaro, L. D., & Nobili, L. (2012). Hippocampal Sleep Features: Relations to Human Memory Function. *Frontiers in Neurology*, *3*. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3327976/#:~:text=For%20instance%2C%20large%2Dscale%20synchrony,related%20deficits%20of%20declarative%20memory.
2. Griffiths, B. J. (2023). Gamma oscillations and episodic memory. *Trends in Neuroscience*, *46*(10), 832–846. https://doi.org/10.1016/j.tins.2023.07.003
3. Grover, S., Wen, W., Viswanathan, V., Gill, C. T., & Reinhart, R. M. G. (2022). Long-lasting, dissociable improvements in working memory and long-term memory in older adults with repetitive neuromodulation. *Nature Neuroscience*, *25*, 1237–1246.
4. Kropotov, J. D. (2016). Chapter 2.3—Beta and Gamma Rhythms. In J. D. Kropotov (Ed.), *Functional Neuromarkers for Psychiatry* (pp. 107–119). Academic Press. https://doi.org/10.1016/B978-0-12-410513-3.00009-7
5. McLaughlin, M., Khatoun, A., & Asamoah, B. (2022). Detection of tACS Entrainment Critically Depends on Epoch Length. *Frontiers in Cellular Neuroscience*, *16*. https://www.frontiersin.org/articles/10.3389/fncel.2022.806556/full
6. Nissim, N. R., Pham, D. V. H., Poddar, T., Blutt, E., & Hamilton, R. H. (2023). The impact of gamma transcranial alternating current stimulation (tACS) on cognitive and memory processes in patients with mild cognitive impairment or Alzheimer's disease: A literature review. *Brain Stimulation*, *16*(3), 748–755.
7. Rodriguez Larios, J. (2021). EEG alpha-theta (cross-frequency) dynamics during arithmetic performance, mind wandering and meditative states. *Lirias*. https://kuleuven.limo.libis.be/discovery/search?query=any,contains,LIRIAS3423055&tab=LIRIAS&search_scope=lirias_profile&vid=32KUL_KUL:Lirias&offset=0
8. Santarnecchi, E., & Sprugnoli, G. (2019). Gamma tACS over the temporal lobe increases the occurrence of Eureka! Moments. *Scientific Reports*, *9*.

Takeuchi, S., Mima, T., Murai, R., Shimazu, H., Isomura, Y., & Tsujimoto, T. (2015). Gamma Oscillations and Their Cross-frequency Coupling in the Primate Hippocampus during Sleep. *Sleep*, *38*(7), 1085–1091. https://doi.org/10.5665/sleep.4818