The electric buzz behind better movement

A systematic Review and Meta-Analysis on the effect of transcranial random noise stimulation on motor learning (2011-2024)

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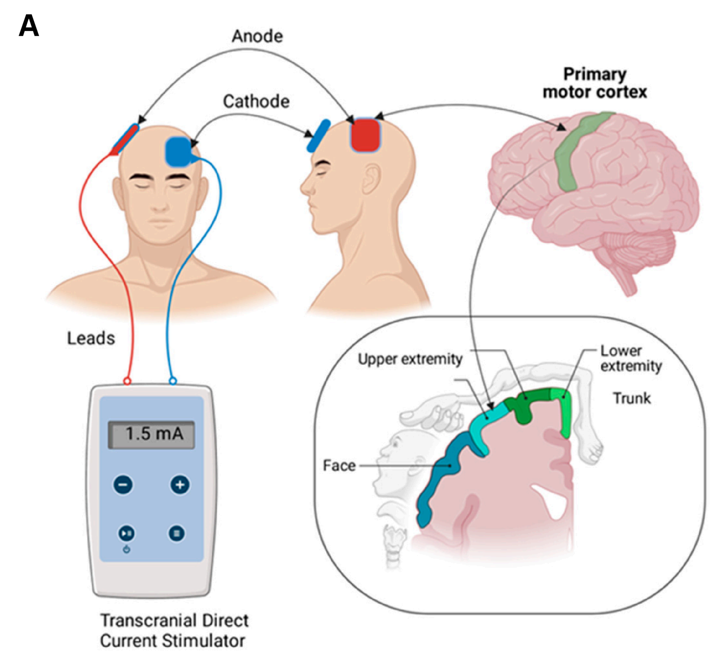
*Equal contribution, ordered in alphabetical order

1. Introduction

- Transcranial random noise stimulation (tRNS) is a promising, yet relatively less understood non-invasive brain stimulation technique [1]
- tRNS introduces electrical noise to cortical circuits to modulate physiology & behavior [2]
- tRNS can enhance motor learning processes [1] ,[2]

A



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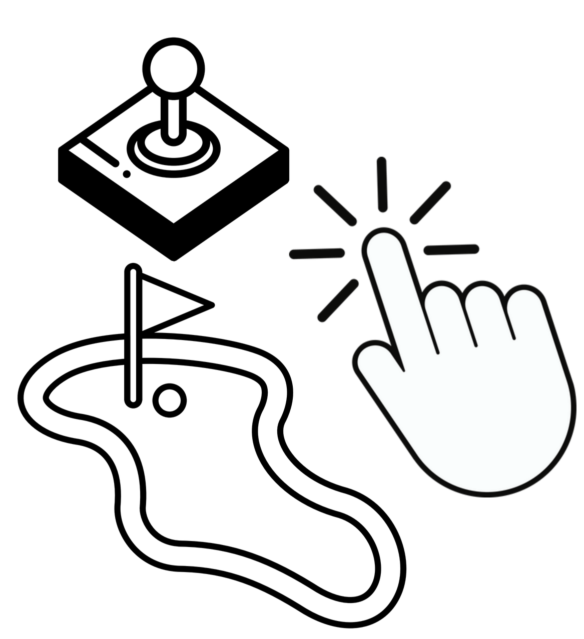

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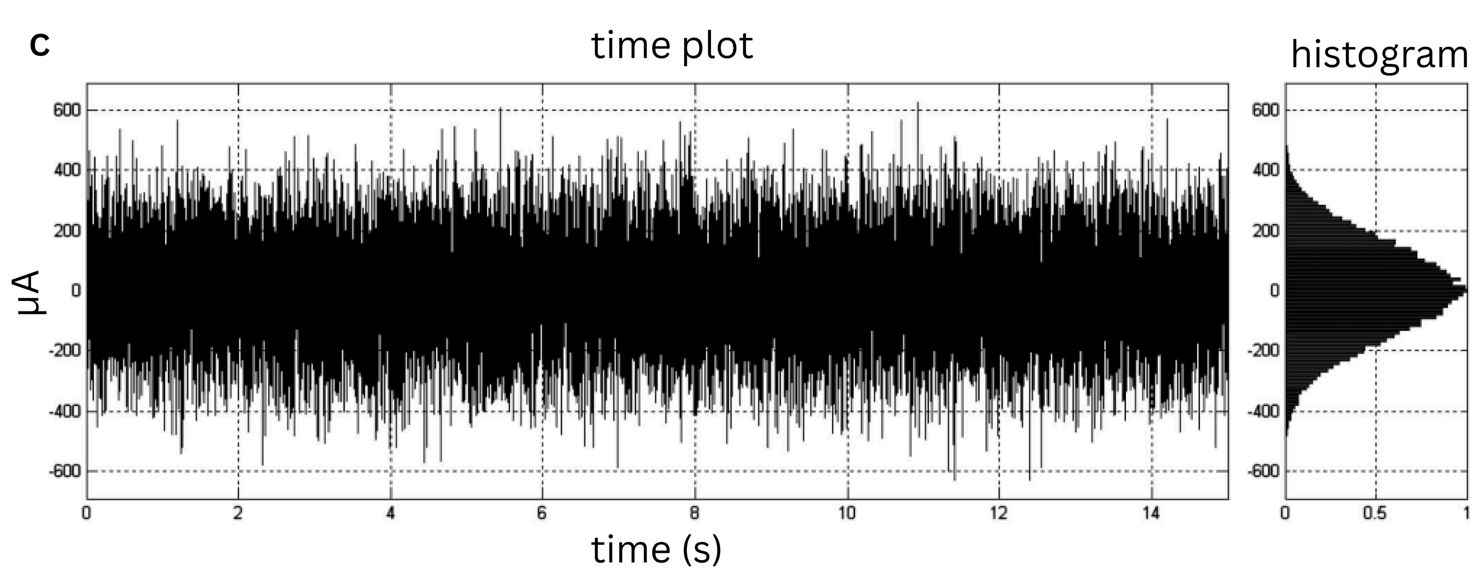


Figures:
(A) Illustration adapted to represent typical electrode placement and target region (M1) in tRNS protocols aiming to enhance motor learning.
(B) Motor learning assessed via tasks completed throughout tRNS stimulation.
Selected examples of motor tasks commonly used in tRNS studies to assess motor learning
(C) The left panel shows the random fluctuations of the tRNS current over time. The right panel displays a Gaussian distribution of current amplitudes centered around zero, characteristic of white noise [1]

2. Objective

- Curate & organize information for a Meta-analysis on tRNS effect on motor learning
- Experimental studies from 2011 to 2024, with an active manipulation
- Healthy adult human participants
- Only studies using tRNS, excluding other neuromodulation methods (e.g., tDCS, tACS, TMS)
- Analyze outcomes related to motor performance, neural activity, and cognitive-behavioral measures
- Quantify the effect of tRNS on motor learning

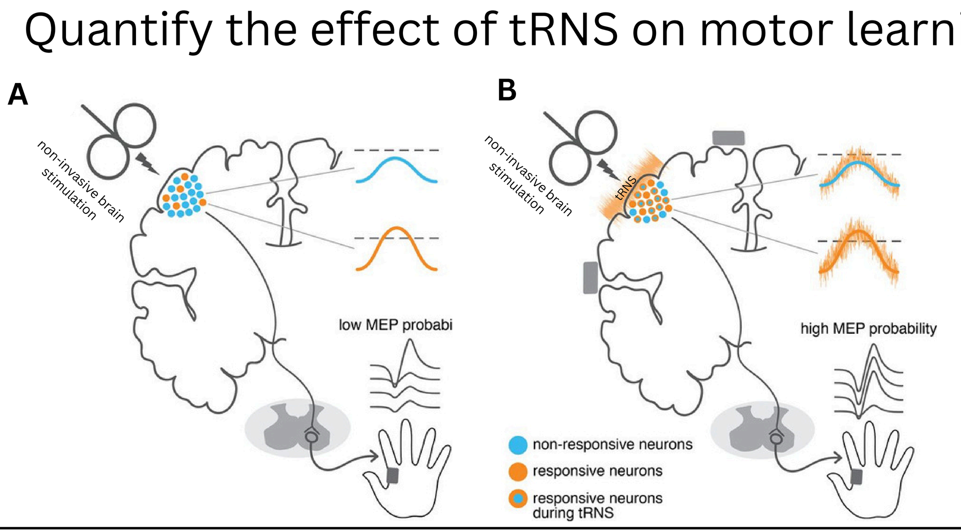
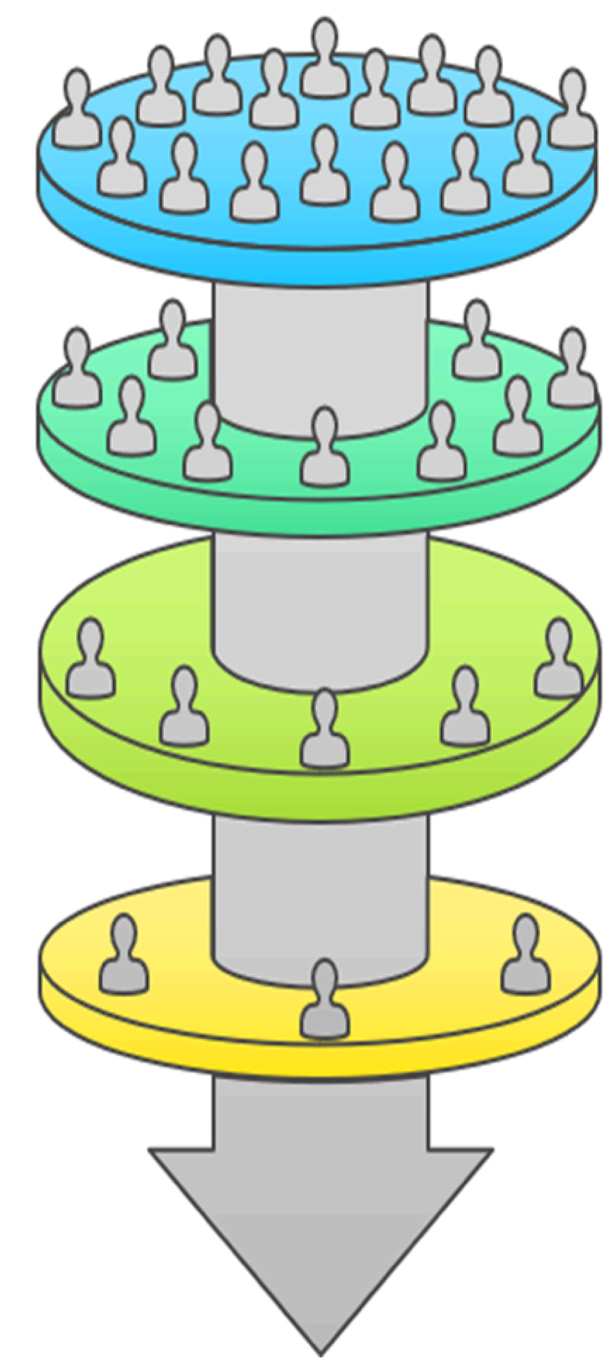


figure: Illustration showing how tRNS applied to M1 lowers the activation threshold and increases MEP probability [3].

3. Methodology

- Step 1: Building an initial database using the query: “Transcranial random noise stimulation” across seven academic sources (Semantic Scholar, PubMed, Google Scholar, Crossref)
- Step 2: Defining a semantic field with specific terms/ keywords, based on literature, dictionaries, and AI tools (e.g., Motor, Reach ,Muscle, M1, etc.)
- Step 3: Identifying relevant studies by searching for the keywords in the abstracts & titles, and applying inclusion criteria outlined in the objective
- Step 4: Extracting descriptive statistics to calculate effect size for each study



Database construction & Web Scraping

Records identified through database search 2008-2024 (n = 22,067)

Exclusion:
- duplicates (n = 7,651)
- non experimental (n = 1,710)
- non-english (n = 0)

Remaining records after exclusion of irrelevant articles (n = 12,706)

Keyword Identification & Database Narrowing

screening by title & abstract using keywords
- Remaining records after keyword search (n = 1951)
- retrieved by keyword match but containing non-relevant terms (n = 86)

Remaining records after screening by keywords (n = 1,865)

Title and Abstract Filtering

Screening by Title and Abstract, applying inclusion and exclusion criteria.
* At this stage, the years 2008–2010 were excluded (n = 228) ; therefore, data is presented only for 2011–2024.

Exclusion:
- non experimental (n = 255)
- non humans (n = 41)
- not transcranial electrical stimulation (n = 692)
- not tRNS (n = 501)
- clinical (n = 33)
- not adults (n = 5)
- not motor-related (n = 10)

Remaining records after screening by title & abstract (n = 100)

Full Article Verification & Statistical Data Extraction

Full-text screening, applying inclusion and exclusion criteria

Exclusion:
- non experimental (n = 37)
- non humans (n = 2)
- not transcranial electrical stimulation (n = 10)
- not tRNS (n = 8)
- clinical (n = 4)
- not adults (n = 0)
- not motor-related (n = 7)
- duplicates (n=11)

Remaining records after full-text assessment, from which statistical data were extracted (n = 21)

Article selection according to PRISMA protocol [1] ,[4]

4. Preliminary Results

1. Task types and behavioral measures are heterogeneous and not always clearly defined
2. Terminology inconsistencies
3. Pairwise comparisons (e.g., tRNS vs. sham) are often missing or poorly reported
4. Numerous studies focused solely on neural responses, with no behavioral measures
5. Stimulation parameters are often reported vaguely

5. Discussion

- The primary finding so far is a high degree of heterogeneity across the literature
- **future**: calculating the effect size of tRNS on motor learning, while accounting for :
  - **A.** moderators (Stimulation frequency, Current intensity, Stimulation timing, electrode distance (stimulation density)
  - **B.** publication bias
- **Recomendations:** Standardize experimental protocols, clarify experimental designs, use precise and consistent terminology and outcome measures, ensure transparent and complete statistical reporting, prioritizing behavioral over neural indices

6. References

1. Potok, W., van der Groen, O., Bächinger, M., Edwards, D., & Wenderoth, N. (2022). Transcranial Random Noise Stimulation Modulates Neural Processing of Sensory and Motor Circuits, from Potential Cellular Mechanisms to Behavior: A Scoping Review. *eNeuro, 9*(1), ENEURO.0248-21.2021. https://doi.org/10.1523/ENEURO.0248-21.2021
2. Terney, D., Chaieb, L., Moliadze, V., Antal, A., & Paulus, W. (2008). Increasing Human Brain Excitability by Transcranial High-Frequency Random Noise Stimulation. *The Journal of Neuroscience, 28*(52), 14147–14155. https://doi.org/10.1523/JNEUROSCI.4248-08.2008
3. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* (Online), 372, n71. https://doi.org/10.1136/bmj.n71
4.Potok, W., Bächinger, M., Van der Groen, O., Cretu, A. L., & Wenderoth, N. (2021). Transcranial random noise stimulation acutely lowers the response threshold of human motor circuits. *Journal of Neuroscience, 41*(17), 3842-3853.