AUTOMATED REASONING AND DECISION MAKING

Presentation On

Studying and modifying brain function with non-invasive brain stimulation

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Executive Summary

- Non-invasive brain stimulation (NIBS) is a method of changing how the brain works without surgery. It involves applying mild electric currents or magnetic fields to the scalp to influence brain activity. This technique is used in research to understand the brain better and in medicine to treat certain brain-related conditions like depression.

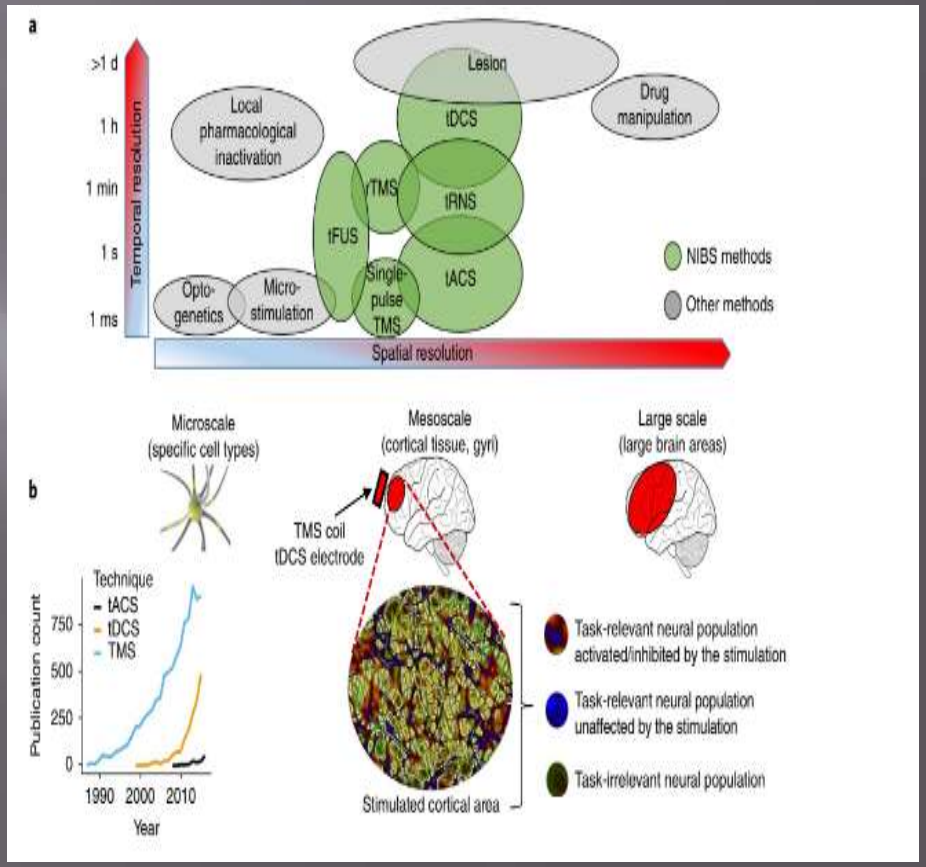
- In the past, researchers could only directly mess with brain activity in animals using invasive methods. But these methods aren't suitable for humans because they're too invasive and risky. So, scientists figured out ways to gently stimulate the human brain from the outside.

- One method involves using magnetic fields to activate parts of the brain. Another method uses weak electrical currents applied to the scalp. These methods are painless and safe. They help researchers see how certain brain areas affect behavior without opening up the skull.

- Despite their growing popularity, there's still a lot we don't understand about how these techniques work and their limitations. Scientists are debating how best to use them and whether they're reliable for medical treatments.

a) NIBS methods like TMS and tDCS change how the brain works. They do this at the mesoscale level, affecting large areas of the brain. The speed at which these methods work varies depending on the specific technique used. While NIBS seems to be very precise in its effects, it actually activates many neurons at once, which might not be very specific to certain brain functions. It might disrupt normal brain activities that involve small groups of cells within larger brain areas.

b) This graph shows how the number of scientific papers mentioning TMS, tDCS, and tACS has grown over the years. This indicates a growing interest in these non-invasive brain stimulation techniques among researchers.



Background

- Neuroscientists want to understand how the brain affects our thoughts, feelings, and actions. They use techniques like brain imaging to see which brain areas are active during different tasks. However, just seeing activity isn't enough to understand how the brain works. We need to be able to change brain activity to see how it affects behavior.

- That's where non-invasive brain stimulation (NIBS) comes in. It's a way to safely change how the brain works without surgery. NIBS methods, like transcranial magnetic stimulation (TMS) and transcranial electrical stimulation (tES), have been around for a while. They've helped researchers learn a lot about the brain.

Experiments and Results

Making Memory Better with Brain Zaps

- Experiment: Scientists tested if a type of brain zap called tDCS could improve memory. They gave some people the real zap and others a fake one (like a placebo). Then, everyone did memory tasks while getting zapped.

- Results: People who got the real zap did better on the memory tasks compared to those who got the fake zap. Brain scans also showed changes that matched better memory.

Cheering Up with Magnetic Brain Waves

- Experiment: Researchers tried using a magnetic method called rTMS to cheer up people with depression. They aimed the magnetic waves at a specific part of the brain related to emotions.

- Results: After the treatment, people felt happier and less depressed. Brain scans showed that the targeted brain area started working more normally.

Methodology

1. **Study Design and Hypotheses:**

- The study design aims to investigate the variability of NIBS effects and their impact on behavior and neural processes.
- Hypotheses are formulated based on previous literature and aim to test relationships between NIBS-induced modulations and behavioral outcomes.

2. Participant Selection:

- Participants are recruited based on predetermined inclusion and exclusion criteria to ensure a representative sample.
- Sample size determination is based on power analyses to achieve statistical power.

3. Experimental Procedures:

- Neuronavigation techniques are employed to precisely locate the target regions of interest in each participant using functional or structural neuroimaging data

- Control tasks or behavioral measures are included to ascertain the specificity of NIBS effects on the behavior under study.

- Neuroimaging techniques, such as functional magnetic resonance imaging (fMRI), are combined with NIBS to quantify the strength of stimulation effects on local neural activity and connected brain networks

4. Data Collection:

- Physiological and behavioral data are collected before, during, and after NIBS interventions to capture immediate and potential long-term effects
- Care is taken to blind the NIBS intervention, and placebo effects are controlled for in the experimental design

5. Data Analysis:

- Statistical analyses are performed to evaluate whether the targeted cognitive processes are specifically affected by the NIBS intervention
- Statistical comparisons with control tasks, brain regions, and neuro computational latent variables are conducted to identify the specificity of the NIBS-induced effects on behavior and neural function

Key Findings

- NIBS effects exhibit variability influenced by brain-intrinsic factors, task demands, and methodological variations
- Individual differences and stimulation parameters contribute to the variability in outcomes.
- NIBS effects are task-specific and can be influenced by participant behavior during stimulation.
- Methodological variations such as stimulation intensity and electrode positioning significantly affect outcomes
- Precise targeting of brain regions using neuronavigation enhances the reliability of NIBS outcomes.

- Caution is warranted in the use of NIBS for neuro-enhancement due to variability in effects and ethical concerns.
- Clinical applications of NIBS require optimization of protocols for efficacy and safety through rigorous research.
- Coordinated efforts are necessary to ensure methodological rigor in NIBS research, enhancing its translational potential

Key Discussion Points

- **Variability in NIBS Effects:** NIBS outcomes can vary due to differences in individuals, tasks, and how the stimulation is done.
- **Individual Differences Matter:** Age, genetics, and attention can affect how someone responds to NIBS.
- **Task-Specific Effects**: What a person is doing during stimulation can change how effective NIBS is.
- **Method Matters:** Small changes in how NIBS is applied, like where electrodes are placed, can change the results.
- **Better Targeting Helps:** Using tools to precisely aim the stimulation at specific brain areas makes the outcomes more reliable.

- **Need for Control Measures:** Comparing NIBS effects to control conditions helps understand if the changes are really due to the stimulation.
- **Combining Techniques Gives Better Insight:** Using NIBS alongside brain imaging techniques helps understand how the brain responds to stimulation.
- **Ethical Concerns in Neuro-Enhancement:** Using NIBS to enhance brain function raises questions about safety, fairness, and potential side effects.
- **Improving Clinical Use:** To use NIBS as a treatment, we need to refine the techniques, understand how they work, and test them in larger studies.
- **Call for Better Research Practices:** We need clear guidelines and standards to ensure that NIBS research is reliable and can be used to benefit people.

Limitations

- NIBS effects can vary widely due to factors like individual differences and how the stimulation is applied.
- Current understanding of NIBS effects is limited, especially regarding long-term effects and potential side effects.
- Ethical concerns surround the use of NIBS for cognitive enhancement, particularly regarding safety and fairness.

Open Questions

- How can we optimize NIBS protocols to ensure consistent and effective outcomes?
- Optimizing NIBS protocols involves refining stimulation parameters and targeting specific brain regions to enhance reliability and efficacy
- What are the long-term effects of NIBS, and how do they impact cognitive function?
- The long-term effects of NIBS on cognitive function remain uncertain, warranting further research to understand their implications

- What ethical considerations should be addressed before widespread use of NIBS for cognitive enhancement?
- Before widespread use of NIBS for cognitive enhancement, ethical considerations should address issues of safety, informed consent, potential and equitable access.

Thanks