The ethics of noninvasive brain stimulation for cognitive enhancement

Roy H. Hamilton, MD, MS; Samuel B. Messing, BA; Anjan Chaterjee, MD

Presenter

University of Pennsylvania

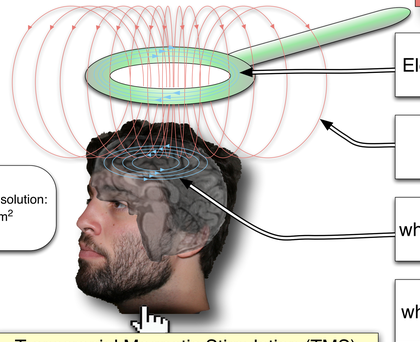
Laboratory for Cognition and Neural Stimulation

Introduction

- **Cognitive enhancement:** enhancing the cognition of healthy individuals using methodologies originally developed for helping patients.
- Increasingly widespread use of cognitive enhancement has led to the emergence of a new and controversial field, Cosmetic Neurology.[4,5,6]
- Below, we consider the ethical dilemmas surrounding noninvasive brain stimulation (NIBS), a set of methodologies that have shown promise for cognitive enhancement.

NIBS Methodologies

Transcranial Magnetic Stimulation (TMS)



Spatial Resolution: ~1cm²

Electricity passes through a copper coil,

generates a magnetic field,

which induces electric currents in cortex,

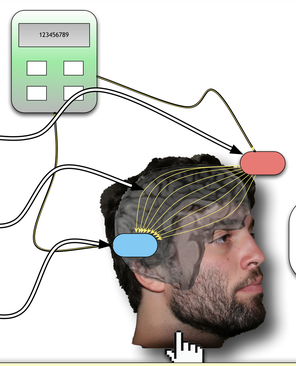
which in turn leads to action potentials.[13]

Transcranial Magnetic Stimulation (TMS)
Blue lines, Electrical current lines; Red lines, Magnetic Field Lines

Variations:

Repetitive TMS (rTMS): repeated administration of magnetic pulses (usually >0.3Hz), capable of inducing lasting changes in cognitive and behavioral function.[13]
Single Pulse TMS: administration of a single pulse, causing interruption of function lasting only 40-60 ms.

Transcranial Direct Current Stimulation (tDCS)



Small electric currents (1-2mV) pass through an electrode (anode),

about one half this current reaches cortex, modulating the resting membrane potentials of neurons,

and passes out through a different electrode (cathode).[15]

Spatial Resolution: ~25cm²

Transcranial Direct Current Stimulation (tDCS)
Blue electrode, Cathode; Red electrode, anode; Yellow lines, direction of electric current.

Variations:

Cathodal stimulation: associated with hyperpolarization (less activity)
Anodal stimulation: associated with sub-threshold depolarization (more activity)[15]
Unilateral Stimulation: only one electrode on cortex
Bilateral Stimulation: both electrodes over cortex

Examples of Cognitive Enhancement

Enhancing Processing Abilities: improving memory, linguistic processing, learning abilities, information processing, etc.

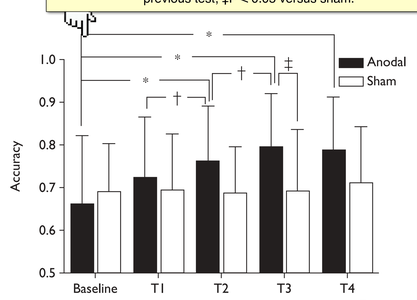
Ohn et al, 2008: **tDCS**

- 3-back verbal working-memory task (Korean)
- Stimulation over L DLPFC (Anodal, Sham)
- Reference electrode: right supraorbital sinus
- 1mA for 30 minutes

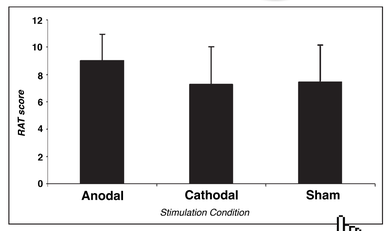
Results: significant improvement in accuracy for anodal vs. sham condition after 30 minutes of stimulation.

Suggests: NIBS can be used to increase WM accuracy.

Figure from Ohn et al., 2008.[16]
Changes in accuracy induced by anodal tDCS. T1, after 10 min of tDCS; T2, after 20 min of tDCS; T3, after 30 min of tDCS; T4, 30 min after completing tDCS. *P < 0.05 versus baseline; †P < 0.05 versus previous test; ‡P < 0.05 versus sham.



Cerruti et al, 2009: **tDCS**



- RAT (Remote Association Task)
- Stimulation over L DLPFC (F3)
- Reference electrode: right supraorbital sinus
- 1mA for 20 minutes

Results: Significant increase in performance due to anodal tDCS stimulation compared to cathodal and sham.

Suggests: NIBS can be used to enhance connections in semantic networks.

Figure adapted from Cerruti et al., 2009.[3]
Mean number and standard deviation of RAT problems solved in the three stimulation conditions.

Enhancing Social Cognition: Modulate an individual's understanding and relationship to others, especially related to concepts of social norms and rules.

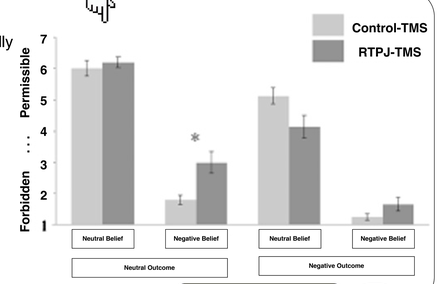
Young et al, 2010: **TMS**

- Moral judgement task (is this action morally permissible?)
- Stimulation site: Right TPJ
- Control site: Right parietal cortex
- Offline rTMS, 1Hz (inhibitory) for 25 min

Results: When stimulated over RTPJ, subjects were less likely to consider the intention of the agent in determining the moral permissibility of his or her action.

Suggests: NIBS can modulate how individuals make moral judgments.

Figure adapted from Young et al. 2010.[20]
Changes in moral permissibility ratings of actions due to TMS. **P < 0.05.*



Enhancing Mood: Broadly affect an individual's subjective evaluation of personal experience

- Evidence largely from use of NIBS to treat patients with depression[2,7,8,9]
- NIBS also a possible treatment for OCD,[1] PTSD,[14] and Schizophrenia[12]
- Preliminary studies show efficacy in normals.[10]
- Stimulation paradigms differ between normals and clinical populations.

Ethical Concerns

Safety

Main Question: How does one accurately calculate risk/benefit ratio when the alternative is normalcy?

- Although TMS and tDCS are thought to be minimal risk,[18] not much is known about the long term effects of NIBS.
- Possible that stimulation parameters for enhancement of a particular ability will be deleterious to others.

Character

Main Question: What hardships are important for forming a human identity?

- Are there human qualities so fundamental that modulating them would change identity?
- Would long term mood modulation with NIBS be beneficial or detrimental to character? Are there certain hardships that humans *need* to face?

Autonomy

Main Question: Could soomeone be implicitly or explicitly coerced to undergo brain stimulation?

- Explicit coercion: punitive (criminals), investigative (lie detection)
- Implicit coercion: to remain competitive (workforce, education, etc.). Evidence suggests individuals already do this with pharmacalogic enhancements.[17]

Justice

Main Question: How do we ensure equitable distribution of cognitive enhancements?

- Cognitive enhancements are not likely to be covered by insurance.
- Could this lead to the creation of a cognitive underclass?

References

1. Alonso P, et al. 2001; *Am J Psychiatry.*
2. Boggio PS, et al. 2008; *Int J Neuropsychopharmacol.*
3. Cerruti, C. et al. 2009; *J Cogn Neurosci.*
4. Chatterjee, A. 2004; *Neurology.*
5. Chatterjee, A. 2006; *J Med Ethics.*
6. Chatterjee, A. 2007; *Cambridge Quart Healthcare Ethics.*
7. Fregni F, et al. 2006; *Bipolar Disord.*
8. George MS, et al. 2010; *Neuropsychopharmacology.*
9. George MS, et al. 2000; *Biol Psychiatry.*
10. George MS et al. 1996; J *Neuropsychiatry Clin Neurosci.*
11. Kim DR, et al. 2009; *Curr Psychiatry Rep.*
12. Lee SH, et al. 2005; *Neurosci Lett.*
13. Maeda F, et al. 2003; *Psychopharmacology.*
14. McCann UD, et al. 1998; *Arch Gen Psychiatry.*
15. Priori, A. 2003; *Clin Neurophysiol.*
16. Ohn, S., et al. 2008; *Neuroreport.*
17. Priori A. 2003; *Clin Neurophysiol.*
18. Sahakian B, et al. 2007; *Nature.*
19. Wassermann EM. 1998; *Electroencephalogr Clin Neurophysiol.*
20. Young, L, et al. 2010; *Proc Natl Acad Sci U S A.*