# PSYC 892-006 – Human Brain Stimulation

Mondays, 10:30am – 1:10pm. Robinson B442


**Instructor**

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David King Hall, Room 2055


**Office Hours**

Wednesdays, 10:00am-11:50am,

**Grade Criteria**

| Grade | Percent |
|---|---|
| A | 90-100% |
| B | 80-89.9% |
| C | 70-79.9% |
| D | 60-69.9% |
| F | Below 60% |

**Course Overview**

For almost as long as modern science has been around, humans have been trying to devise methods to stimulate their brains, beyond the senses that nature provides. This course will be focused on an overview of these methods, their strengths, and shortcomings. We will focus here specifically on non-invasive methods, eschewing the ones that require opening of the skull (deep brain stimulation, microstimulation, etc.). By the time this course is over, you will understand and have some experience with various methods used by neuroscientists, and further be able to critically evaluate if a study's claims are correct.

**Evaluation Criteria**

Paper Reviews (25%): The content of this course will primarily focus on discussion. The initial run of classes will consist of plenary lectures on various stimulation methods. Once these lectures are over, we will switch to a seminar style, in which we will review brain stimulation papers every week. Two papers will be assigned each week, available on Blackboard. You are required to read both papers, pick one, and write a review/critique of that paper on Blackboard. **Reviews must be posted by 7pm on Sunday evening**. These reviews will contribute to your grade for the course.

Paper Presentations (25%): Once the paper reviews begin, one of you will give a presentation each week on one of the papers* (two presentations per class). The presentation should take the form of a powerpoint lecture, in which you discuss the background of the paper, the methods, results, and conclusions, along with your commentary. You will be able to sign up for your **two papers** on the first day of class or any day thereafter. The format of the discussion will take the place of a journal club, and so all students are expected to participate in the discussion. In-class participation is part of your grade (10%).

*If you do not see any papers that are of interest to you, you are free to suggest an alternate paper if you have one in mind. You must speak with me to propose your alternate paper.

Proposal Paper (30%): There is no final exam for this course. Instead, you will be required to write a paper to be turned in by December 19th. The paper will take the form of an experiment proposal, in which you will propose to run a brain stimulation study, using any of the methods discussed in class. The topic of the paper is entirely up to you, but you will be required to write an introduction, methods, expected results, and brief discussion section, with a bibliography. The page limit is 10 pages (not including bibliography).

TMS Practicum (10%): Another feature of this course is a hands-on demonstration of Transcranial Magnetic Stimulation (TMS), one of the methods we will primarily focus on. GMU has a TMS setup on the first floor of DKH. I will provide a technical demonstration one day of how TMS works. A hallmark of the TMS method is called the "Motor Evoked Potential", or MEP, in which TMS is used to elicit a muscle movement in the hand by stimulating the contralateral primary motor cortex (M1). You will each choose a partner

in the class, and at one point during this semester you will each practice eliciting a MEP from each other. You will all be required to arrange with me for a time to try out the TMS demonstration. If, for whatever reason, you cannot receive TMS, an alternative for receiving credit will be determined, on a case-by-case basis.

**General Policy**

Honor Code: George Mason University has an Honor Code, which requires all members of this community to maintain the highest standards of academic honesty and integrity. Cheating, plagiarism, lying, and stealing are all prohibited. All violations of the Honor Code will be reported to the Honor Committee. See honorcode.gmu.edu for detailed information.

Plagiarism is the unacknowledged use of another person's labor, another person's ideas, another person's words, or another person's assistance. Unless otherwise stated in class, all work done for courses -- papers, examinations, homework exercises, laboratory reports, oral presentations -- is expected to be the individual effort of the student presenting the work. Any assistance must be reported to the instructor. If the work has entailed consulting other resources -- journals, books, or other media -- these resources must be cited in a manner appropriate to the course. Everything used from other sources -- suggestions for organization of ideas, ideas themselves, or actual language -- must be cited. Failure to cite borrowed material constitutes plagiarism. Undocumented use of materials from the World Wide Web is plagiarism. If you are caught plagiarizing or cheating, you will be referred to the honor committee and, if found guilty, will fail the assignment, and, depending upon the severity of the violation, you may fail the class.

Disability Statement: If you are a student with a disability and you need academic accommodations, please see me and contact the Disability Resource Services (DRS) at 703-993-2474. All academic accommodations must be arranged through that office. Please see me as soon as possible about this, as I will not adjust grades for exams after they have been given.

Make-up policy: Make-up exams will only be given if exceptional circumstances are claimed AND substantiated. I must see proof of what you are claiming to verify that it is true.

Add/Drop Deadlines: Please note that the *last day to add classes* is **September 6th**. The last day to drop a course *with no tuition penalty* is also **September 6th**. The last day to drop *with a 33% tuition penalty* is **September 20th**. The final day to *drop with a 67% tuition penalty* is **September 30th**. After September 30th, withdrawal from the class requires approval of the dean and is only allowed for nonacademic reasons.

Official Communications via GMU E-mail: Mason uses electronic mail to provide official information to students. Examples include communications from course instructors, notices from the library, notices about academic standing, financial aid information, class materials, assignments, questions, and instructor feedback. Students are responsible for the content of university communication sent to their Mason e-mail account and are required to activate that account and check it regularly. If class has to be canceled, you will be informed via e-mail. Information will be provided in the e-mail about making up the missed class.

Technology: For this class, you will be asked to give presentations. This will require that you have access to a computer with some type of presentation software (PowerPoint, Keynote, etc.). If you do not have access to a laptop, one will be provided for you to give your presentation on.

## Course Schedule:

| Date | Lecture topics/Activities |
|---|---|
| 8/29 | Introduction to Course and Brain Stimulation Methods |
| 9/5 | No Class |

| | |
|---|---|
| 9/12 | Transcranial Magnetic Stimulation |
| 9/19 | Transcranial Electrical Stimulation |
| 9/26 | Seminar Begins |
| 10/10 | No Class |
| 12/19 | Papers Due |

**Course Readings**

Introduction to Course (8/29)

Parkin, B. L., Ekhtiari, H., & Walsh, V. F. (2015). Non-invasive human brain stimulation in cognitive neuroscience: a primer. *Neuron*, *87*(5), 932-945.

Dayan, E., Censor, N., Buch, E. R., Sandrini, M., & Cohen, L. G. (2013). Noninvasive brain stimulation: from physiology to network dynamics and back. *Nature neuroscience*, *16*(7), 838-844.

Lewis, P. M., Thomson, R. H., Rosenfeld, J. V., & Fitzgerald, P. B. (2016). Brain Neuromodulation Techniques A Review. *The Neuroscientist*, 1073858416646707.

Transcranial Magnetic Stimulation (9/12)

Walsh, V., & Cowey, A. (2000). Transcranial magnetic stimulation and cognitive neuroscience. *Nature Reviews Neuroscience*, *1*(1), 73-80.

De Graaf, T. A., & Sack, A. T. (2011). Null results in TMS: from absence of evidence to evidence of absence. *Neuroscience & Biobehavioral Reviews*, *35*(3), 871-877.

Silvanto, J., Muggleton, N., & Walsh, V. (2008). State-dependency in brain stimulation studies of perception and cognition. *Trends in cognitive sciences*, *12*(12), 447-454.

Fox, M. D., Halko, M. A., Eldaief, M. C., & Pascual-Leone, A. (2012). Measuring and manipulating brain connectivity with resting state functional connectivity magnetic resonance imaging (fcMRI) and transcranial magnetic stimulation (TMS). *Neuroimage*, *62*(4), 2232-2243.

Transcranial Electrical Stimulation (9/19)

Nitsche, M. A., Cohen, L. G., Wassermann, E. M., Priori, A., Lang, N., Antal, A., ... & Pascual-Leone, A. (2008). Transcranial direct current stimulation: state of the art 2008. *Brain stimulation*, *1*(3), 206-223.

Herrmann, C. S., Rach, S., Neuling, T., & Strüber, D. (2013). Transcranial alternating current stimulation: a review of the underlying mechanisms and modulation of cognitive processes. *Frontiers in human neuroscience*, *7*.

Horvath, J. C., Carter, O., & Forte, J. D. (2014). Transcranial direct current stimulation: five important issues we aren't discussing (but probably should be). *Frontiers in systems neuroscience*, *8*, 2.

Horvath, J. C., Forte, J. D., & Carter, O. (2015). Quantitative review finds no evidence of cognitive effects in healthy populations from single-session transcranial direct current stimulation (tDCS). *Brain stimulation*, *8*(3), 535-550.

9/26 Readings – "Classic" TMS Effects

Pascual-Leone, A., & Walsh, V. (2001). Fast backprojections from the motion to the primary visual area necessary for visual awareness. *Science*, *292*(5516), 510-512.

Huang, Y. Z., Edwards, M. J., Rounis, E., Bhatia, K. P., & Rothwell, J. C. (2005). Theta burst stimulation of the human motor cortex. *Neuron*, *45*(2), 201-206.

10/3 Readings – "Classic" tES Effects

Nitsche, M. A., Schauenburg, A., Lang, N., Liebetanz, D., Exner, C., Paulus, W., & Tergau, F. (2003). Facilitation of implicit motor learning by weak transcranial direct current stimulation of the primary motor cortex in the human. *Journal of cognitive neuroscience*, *15*(4), 619-626.

Kanai, R., Chaieb, L., Antal, A., Walsh, V., & Paulus, W. (2008). Frequency-dependent electrical stimulation of the visual cortex. *Current Biology*, *18*(23), 1839-1843.

*Kar, K., & Krekelberg, B. (2012). Transcranial electrical stimulation over visual cortex evokes phosphenes with a retinal origin. *Journal of neurophysiology*, *108*(8), 2173-2178.

10/11 Readings – TMS/tES Mechanisms

Allen, E. A., Pasley, B. N., Duong, T., & Freeman, R. D. (2007). Transcranial magnetic stimulation elicits coupled neural and hemodynamic consequences. *Science*, *317*(5846), 1918-1921.

Bikson, M., Inoue, M., Akiyama, H., Deans, J. K., Fox, J. E., Miyakawa, H., & Jefferys, J. G. (2004). Effects of uniform extracellular DC electric fields on excitability in rat hippocampal slices in vitro. *The Journal of physiology*, *557*(1), 175-190.

10/17 Readings – "Newer" tES Effects

Fertonani, A., Pirulli, C., & Miniussi, C. (2011). Random noise stimulation improves neuroplasticity in perceptual learning. *The Journal of Neuroscience*, *31*(43), 15416-15423.

Cappelletti, M., Gessaroli, E., Hithersay, R., Mitolo, M., Didino, D., Kanai, R., ... & Walsh, V. (2013). Transfer of cognitive training across magnitude dimensions achieved with concurrent brain stimulation of the parietal lobe. *The Journal of neuroscience*, *33*(37), 14899-14907.

10/24 Readings – fMRI-Guided Stimulation

Feredoes, E., Tononi, G., & Postle, B. R. (2007). The neural bases of the short-term storage of verbal information are anatomically variable across individuals. *The Journal of Neuroscience*, *27*(41), 11003-11008.

Sack, A. T., Kadosh, R. C., Schuhmann, T., Moerel, M., Walsh, V., & Goebel, R. (2009). Optimizing functional accuracy of TMS in cognitive studies: a comparison of methods. *Journal of Cognitive Neuroscience*, *21*(2), 207-221.

10/31 Readings – "Weird" Techniques

Legon, W., Sato, T. F., Opitz, A., Mueller, J., Barbour, A., Williams, A., & Tyler, W. J. (2014). Transcranial focused ultrasound modulates the activity of primary somatosensory cortex in humans. *Nature neuroscience*, *17*(2), 322-329.

Gonzalez-Rosa, J. J., Soto-Leon, V., Real, P., Carrasco-Lopez, C., Foffani, G., Strange, B. A., & Oliviero, A. (2015). Static magnetic field stimulation over the visual cortex increases alpha oscillations and slows visual search in humans. *The Journal of Neuroscience*, *35*(24), 9182-9193.

*Rohan, M., Parow, A., Stoll, A. L., Demopulos, C., Friedman, S., Dager, S., ... & Renshaw, P. F. (2004). Low-field magnetic stimulation in bipolar depression using an MRI-based stimulator. *American Journal of Psychiatry*, *161*(1), 93-98.

11/7 Readings – Rhythmic TMS

Chanes, L., Quentin, R., Tallon-Baudry, C., & Valero-Cabré, A. (2013). Causal frequency-specific contributions of frontal spatiotemporal patterns induced by non-invasive neurostimulation to human visual performance. *The Journal of Neuroscience*, *33*(11), 5000-5005.

Thut, G., Veniero, D., Romei, V., Miniussi, C., Schyns, P., & Gross, J. (2011). Rhythmic TMS causes local entrainment of natural oscillatory signatures. *Current biology*, *21*(14), 1176-1185.

11/14 Readings – State Dependent TMS

Perini, F., Cattaneo, L., Carrasco, M., & Schwarzbach, J. V. (2012). Occipital transcranial magnetic stimulation has an activity-dependent suppressive effect. *The Journal of Neuroscience*, *32*(36), 12361-12365.

Schwarzkopf, D. S., Silvanto, J., & Rees, G. (2011). Stochastic resonance effects reveal the neural mechanisms of transcranial magnetic stimulation. *The Journal of neuroscience*, *31*(9), 3143-3147.

11/21 Readings - TMS-EEG

Morishima, Y., Akaishi, R., Yamada, Y., Okuda, J., Toma, K., & Sakai, K. (2009). Task-specific signal transmission from prefrontal cortex in visual selective attention. *Nature neuroscience*, *12*(1), 85-91.

Taylor, P. C., Nobre, A. C., & Rushworth, M. F. (2007). FEF TMS affects visual cortical activity. *Cerebral Cortex*, *17*(2), 391-399.

11/28 Readings - TMS-Connectivity

Wang, J. X., Rogers, L. M., Gross, E. Z., Ryals, A. J., Dokucu, M. E., Brandstatt, K. L., ... & Voss, J. L. (2014). Targeted enhancement of cortical-hippocampal brain networks and associative memory. *Science*, *345*(6200), 1054-1057.

Koch, G., Cercignani, M., Bonnì, S., Giacobbe, V., Bucchi, G., Versace, V., ... & Bozzali, M. (2011). Asymmetry of parietal interhemispheric connections in humans. *The Journal of Neuroscience*, *31*(24), 8967-8975.

12/5 Readings – "New Tricks"

Brittain, J. S., Probert-Smith, P., Aziz, T. Z., & Brown, P. (2013). Tremor suppression by rhythmic transcranial current stimulation. *Current Biology*, *23*(5), 436-440.

Klein-Flügge, M. C., Nobbs, D., Pitcher, J. B., & Bestmann, S. (2013). Variability of human corticospinal excitability tracks the state of action preparation. *The Journal of Neuroscience*, *33*(13), 5564-5572.