

# **Technologies for Mental Health and Wellness – EC.744/794**

## **Assignment #8 : Emerging Mental Health Therapies (Due end of Nov 17)**

This week's topic is about emerging technologies that can be used for detecting of treating mental illness.

### **1) Electromagnetic Fields and the Brain**

Although psychotherapy and psychopharmacology – and even medication – are probably as old as human culture, the use of electromagnetic fields is relatively new.

The interaction between electromagnetic fields and the brain is still an active area of research. One of the most active areas of research is trying to understand how the brains or animals as well as humans can detect electromagnetic fields.

A practical use of magnetic field detection is navigation.

Please see a sample youTube video here:

[https://www.youtube.com/watch?v=tdXb\\_4EkYtU](https://www.youtube.com/watch?v=tdXb_4EkYtU)

Other animals, such as fish that live in muddy water, have developed the ability to sense electric fields and to use that sense as a way to detect objects that are nearby.

In the late 1800s, just as human science was starting to discover the nature of electricity, researchers also began exploring how the application of electric or magnetic fields could have some effect on the brain. This became known as *electrotherapy*. For roughly a century, electromagnetism was viewed as an amazing new technology that could be applied to a wide variety of health conditions, including mental health. At the turn of the century, institutions, such as Massachusetts General Hospital, were applying electromagnetic fields for the treatment of mental health. Electromagnetism was trendy, and even famous people like the writer Mark Twain invested in Nicola Tesla's high voltage technology (until one of his electric field therapy sessions gave him diarrhea).

By the 1930s, various forms of electrotherapy faded away, as scientists had a better understanding of the technology and the technology mainly produced mixed results. However, the interest in electromagnetic fields once again gained resurgence in the late 20<sup>th</sup> century.

Transcranial magnetic stimulation (TMS), which uses magnetic fields gained popularity at the turn of the century (2000); and transcranial direct current stimulation (tDCS), which uses electric field potentials, gained popularity shortly afterwards.

Now, just in the past few years alone, there are 10's of thousands of publications on these methods applied to a variety of mental health conditions.

Please read the following review papers (found on Stellar):

- Gilman, S.L., 2008. Electrotherapy and mental illness: then and now. *History of Psychiatry*, 19(3), pp.339-357.
- Filmer, H.L., Dux, P.E. and Mattingley, J.B., 2014. Applications of transcranial direct current stimulation for understanding brain function. *Trends in neurosciences*, 37(12), pp.742-753.
- Rossini, P.M., Rossini, L. and Ferreri, F., 2010. Brain-behavior relations: transcranial magnetic stimulation: a review. *IEEE Engineering in Medicine and Biology Magazine*, 29(1), pp.84-96.

### **Assignment:**

Answer the following questions:

- Part #1: Describe some of the differences between TMS and tDCS.
- Part #2: Are there any differences between the mental health conditions that can be treated by TMS and tDCS?
- Part #3: If TMS and tDCS are considered beneficial tools, then why is cell phone radiation considered harmful?

### **2) Biofeedback**

Another health treatment which has made a resurgence is biofeedback, which is a method of training a person to control particular physiological signals by providing some type of real-time feedback. This general approach became popular in the 1970's and became associated with the "new age" movement, but lost favor within the medical community due to lack of rigor and lack of clinical research evidence.

Perhaps one of the oldest and most well-known companies working in biofeedback is HeartMath, who have been in business for over 25 years and primarily worked to develop relaxation techniques that use biofeedback from heart rate and respiration. A demonstration and review of one of their recent iPhone apps is shown in the video here:

<https://www.youtube.com/watch?v=h-9nec3vmQI>

Next generation technologies, including machine learning and AI are now enabled new opportunities for biofeedback. In brain research, most biofeedback projects use the simple single-channel EEG as the input.

An introductory TED talk video is here:

<https://www.youtube.com/watch?v=m8pMbiyWPxc>

With machine learning, biofeedback can now be used to adapt to individual users, and also enables the possibility of identifying complex patterns of brain signals that correspond to specific brain states.

Please read the following sample papers (on Stellar):

- Karydis, T., Aguiar, F., Foster, S.L. and Mershin, A., 2015, July. Self-calibrating protocols enhance wearable EEG diagnostics and consumer applications. In *Proceedings of the 8th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (p. 96). ACM.
- Karydis, T., Langer, S., Foster, S.L. and Mershin, A., 2018, June. Identification of post-meditation perceptual states using wearable EEG and Self-Calibrating Protocols. In *Proceedings of the 11th Pervasive Technologies Related to Assistive Environments Conference* (pp. 566-569). ACM.
- Karydis, T., Foster, S.L. and Mershin, A., 2016, June. Self-Calibrating Protocols as diagnostic aids for personal medicine, neurological conditions and pain assessment. In *Proceedings of the 9th ACM International Conference on Pervasive Technologies Related to Assistive Environments* (p. 61). ACM.

### **Assignment:**

Write 1-2 paragraphs answering this question:

- If you could create a biofeedback technology to train your brain to enter a specific state or perform a specific task, what would it be? Can you provide an example?

### 3) Olfaction and Aroma therapy

*Olfaction* is the field of smell, detecting and analyzing odors. We know that in the animal kingdom, smell is extremely important. Some famous examples are flying insects or dogs. Insects and dogs have both been trained to detect explosives or specific organic compounds. In the medical field, dogs have been trained to detect glucose levels, epileptic seizures, and detect different types of cancer. In the future, certain types of mental illness may be detectable by smell.

Please watch MIT scientist Andreas Mershin discuss his work on creating machines for olfaction:

<https://www.youtube.com/watch?v=0-Ggro4WPCI>

In the area of mental health, the ability to smell has been associated with certain parts of the brain and also with certain types of mental illness. One example is in degenerative disorders of the brain, people developing Alzheimer's disease (dementia) have difficulty smelling peppermint, orange, rose, fish, and leather, for example.

Finally, the third way that odor and smell are related to mental health is in the treatment of mental health disorders. As an example, please read the following short review paper:

- Perry, N. and Perry, E., 2006. Aromatherapy in the management of psychiatric disorders. *CNS drugs*, 20(4), pp.257-280.

The use of aromas is now being extended to other brain functions, such as learning and memory.

#### **Assignment:**

Write 1-2 paragraphs, answering these questions:

- If we had technology that could use olfaction to automatically detect specific mental health conditions, or treat mental illness, what are some systems that this technology would enable? Give an example.

## 4) Optogenetics

Neuroscience researchers have long dreamed of having some electronic device implanted in the brain to assist with specific mental illness, such as turning off tremors in Parkinson's disease, or suppressing an epileptic seizure. On a crude level, brain implants have existed for at least 20 years; however, brain implants have many practical challenges.

Rather than creating a device that would apply electric shocks or release a certain drug inside the brain, researchers recently created ways to activate and de-activate specific circuits in the brain using pulses of light. The advantage is more precise brain stimulation. This technology is known as *optogenetics*.

One of the co-inventors of this technology is Ed Boyden, who was an MIT Undergrad and UROP student at the Media Lab, then helped invent this technology at Stanford before returning to become a professor at the Media Lab and Brain and Cog. Sciences.

Please watch a short TED talk by Ed Boyden here:

<https://www.youtube.com/watch?v=hupHAPF1fHY>

Although optogenetics has enabled a new paradigm for controlling circuits in the brain, it still requires having either a device or an optic fiber going into the brain, in order to produce light.

For more details on what the components of an optogenetic system look like, please skim through the following article (on Stellar):

- Yang, W., Khan, W., Wu, J. and Li, W., 2019. Single-channel opto-neurostimulators: a review. *Journal of Micromechanics and Microengineering*, 29(4), p.043001.

Please read through the introduction and conclusion sections of the following paper that describes some practical issues with optogenetics:

- Goncalves, S.B., Ribeiro, J.F., Silva, A.F., Costa, R.M. and Correia, J.H., 2017. Design and manufacturing challenges of optogenetic neural interfaces: a review. *Journal of neural engineering*, 14(4), p.041001.

Interestingly, the research community has been developing clever ways to create even more practical optogenetic devices. Although the higher frequencies of light that are often used for optogenetics cannot penetrate the skull, longer wavelength of light does have the ability to penetrate the skull and reach various parts of the brain. By making use of non-linear optical materials that can up-convert the frequency of the incident light, it is now possible, in theory, to have a long-wavelength light source that can be worn on the head, and this light can be used to excite special optical material implants inside the brain.

Please read the following paper:

- [Chen, S., 2019. Optical modulation goes deep in the brain. \*Science\*, 365\(6452\), pp.456-457.](#)

**Assignment:**

Write 1 paragraph to answer each of these questions:

- Part 1: Besides safety and research evidence, what are some practical considerations that are currently preventing optogenetic systems from becoming commercial products?
- Part 2: Give one example of how optogenetics can be used for a specific mental illness.

## 5) Photo-neuromodulation

Another type of electromagnetic stimulation of the brain is the use of *visible light*. We know from previous lectures in our class that the human eyes (and even skin) contain a variety of photoreceptors, and these photoreceptors control different neurobiological pathways. (e.g. melatonin levels).

Over the past decade, a wide variety of treatments have emerged that make use of light for modulating neurological processes as part of treatment for specific mental illnesses. A couple of the leading researchers in this field are based at Mass General Hospital in Boston.

Please read the following paper that reviews and introduces photobiomodulation:

- [Hamblin, M.R., 2016. Shining light on the head: photobiomodulation for brain disorders. \*BBA clinical\*, 6, pp.113-124.](#)

**Assignment:**

Write 1-2 paragraphs answer this question:

- Describe which diseases are best suited for treatment with photoneuromodulation.

## 6) Photobiomodulation of our gut brain

We know that the gut microbiome and all the organisms living inside our body are strongly connected to our physical health.

This gut microbiome is also strongly connected to certain mental health disorders.

A list of diseases is described in the following paper:

- Tremlett, H., Bauer, K.C., Appel-Cresswell, S., Finlay, B.B. and Waubant, E., 2017. The gut microbiome in human neurological disease: a review. *Annals of neurology*, 81(3), pp.369-382.

Photoneuromodulation has also been explored for use with our microbiome and gut brain. This provides a new modality for treatment by applying near-infrared light to our abdomen.

Please read the following paper:

- Liebert, A., Bicknell, B., Johnstone, D.M., Gordon, L.C., Kiat, H. and Hamblin, M.R., 2019. "Photobiomics": Can Light, Including Photobiomodulation, Alter the Microbiome?. *Photobiomodulation, photomedicine, and laser surgery*.

### Assignment:

Write a 1 paragraph answer to this question:

- Describe specific illnesses for which this technology could be employed.

## 7) For students taking the grad version (EC.794):

### Assignment:

Choose one or more of the technologies described in the homework and write a 1-page description of a future commercial system that could be used for addressing mental health and wellness.