NeuroStim

by
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Envisioning the Future of Computing Prize
Social and Ethical Responsibilities of Computing
Massachusetts Institute of Technology

Hospital for
Neurotherapeutics and Rehabilitation

HNR

Attending Doctor: Dr. Boris Whitehead
Patient Information:

Name: John Dearborn	Medical Record Number: 1784362	Date: 1/27/42
Gender Identity: Male	DOB: 3/14/02	Age: 39
Sex Assigned at Birth: Male	Sexual Orientation: Heterosexual	Phone number: 215-392-4925
Email: dearbornj@gmail.com	Address: 1901 Dudley St.	City: Philadelphia
State: PA	Zip: 19145-2814	Country: USA

Primary Issue: comatose state

History of Present Illness: in a comatose state as a result of a vehicular accident on 1/26/42. Located in the passenger's seat at time of collision, the patient has lacerations on both arms, a fragmented left tibia, and bruising across the abdomen. Patient was intubated for several hours but has since been pronounced stable and moved from the ICU. Most pressing current concern remains the persistent lack of consciousness. Patient responsive to painful stimuli but remains unresponsive to visual or auditory stimuli.

Medical History: patient has no prior medical history of significance aside from an elective kidney surgery and allergies, none of which would interfere with potential medications

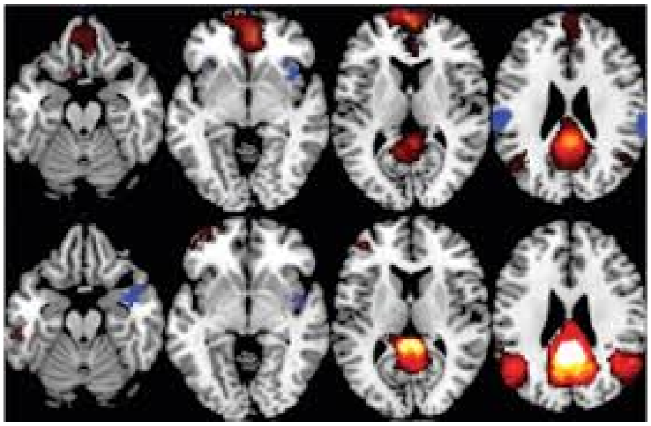
Surgical History: kidney donation surgery (2026)

Family History: alcoholism, anemia, schizophrenia, and depression

Allergies: peanuts (anaphylactic), pollen (mild itching), apples (mild itching)

Physical Examination: Height 5”9 Weight 167 lb BMI 24.66

Radiographic Examination/Diagnostic Studies:



Note: see decreased neural activity in key cortical regions as well as abnormal activity in the thalamus. Minor blunt force trauma to the left occipital lobe noted.

Glasgow Coma Scale (GCS) Score: 7

- **Eye Response:** 2
- **Motor Response:** 3
- **Verbal Response:** 2

Assessment:
Mr. Dearborn suffers from blunt force trauma which has propelled him to a state of prolonged unconsciousness. As time progresses, the statistical risk of Mr. Dearborn remaining in a prolonged vegetative state indefinitely increases exponentially. Attempts to engage with the patient using auditory and visual stimuli have thus far been unsuccessful. Given Mr. Dearborn’s relatively uncomplicated medical history and lack of pre-existing neurological conditions, he may be a candidate for NeuroStim’s selective neural stimulator approach to increase consciousness and improve motor and verbal function.

Plan:
Patient to explore NeuroStim testing using continuous low range voltage electrostimulation in the thalamus for a week followed by increases in voltage levels contingent on positive response. Under the scrutiny of Dr. Whitehead, Mr. Dearborn’s progress will be monitored and used to inform relative temporal or duration adjustments for the electrostimulation of target thalamic pathways.

NeuroStim: Revolutionizing the Scope of Modern Neurological Intervention

NeuroStim is the latest in therapeutic neurotechnology. Patented in 2035, NeuroStim is a non-invasive intervention through which external electromagnetic coils are able to target individual neurons and stimulate their action potentials. What truly makes NeuroStim revolutionary, however, is the operator's ability to choose which neurons the action potential propagates to. By depolarizing one neuron after another in series, the stimulator can strengthen or even create a new pathway that didn't exist previously. Use of this technology is mainstream and has been known to help combat a myriad of neurological disorders.

History of NeuroStim

NeuroStim was originally inspired by optogenetics, which, first conceived in 1979[1], combines the use of chemical and light signals to stimulate specific neurons in animals. Optogenetic methods were heavily relied upon in early neurophysiological studies to allow scientists– via the stimulation or suppression of specific neurons– to determine both the purpose and necessity of neurons in various functions.

In the late 20th century, the development of methods like Transcranial Magnetic Stimulation (TMS) and Deep Brain Stimulation (DBS) proved that, while controlling the function of specific cortical regions within the human brain is difficult, it is far from impossible. First FDA approved in 2008,[2] TMS is a non-invasive electromagnetic intervention whereby coils are placed on a patient's forehead and used to stimulate various neural regions as an alternate means of combating neurological illnesses– namely Obsessive Compulsive Disorder (OCD), depression, migraines, and nicotine addictions. rTMS methods– or repetitive TMS– allows for a weaker electromagnetic coil to target more peripheral areas of the brain, while dTMS methods– or deep TMS– enables a stronger electromagnetic coil to penetrate a wider array of neural regions.[3]

In contrast to TMS, DBS is an invasive form of therapeutic treatment commonly used for diseases like epilepsy, Parkinson's, dystonia, depression, and OCD. A DBS electrode is surgically implanted on the surface of the brain to provide electrical stimulation to targeted neural areas. This includes regions like the lower frontal cortex to decrease the incidence of seizures in epileptics,[4] the subthalamic nucleus to limit tremors in Parkinson's patients[5], and the ventral capsule/ventral striatum (VC/VS) to help OCD patients that are deemed

1 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7000355/#:~:text=Historically%2C%20the%20concept%20of%20optogenetics,methods%20to%20apply%20such%20photosensitive

2 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8864803/#:~:text=a%20separate%20window-,Fig.,(k)%20pathway%20in%202009.

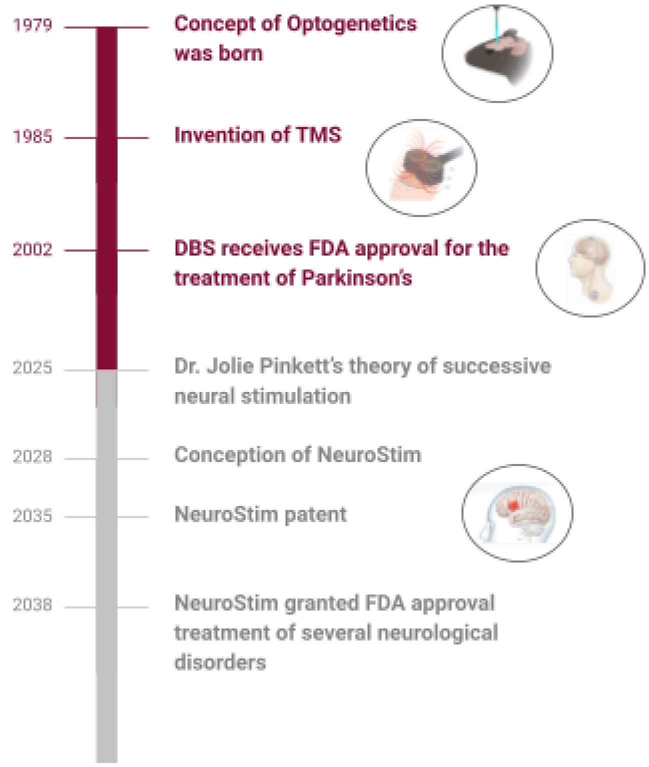
3 https://lifequalitytms.com/blog/what-are-rtms-and-dtms-understanding-the-key-differences/#:~:text=While%20rTMS%20is%20advisable%20for,treatment%20is%20right%20for%20you.

4 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4815479/

5 https://www.michaeljfox.org/deep-brain-stimulation#:~:text=In%20DBS%20surgery%2C%20the%20surgeon,pallidus%20interna)%20that%20control%20movement.

treatment-resistant.[6] Other similarly general neurostimulation methods that were developed either in parallel or in subsequent years to TMS and DBS were variations of the same. For instance, the Vagus Nerve Stimulation (VNS) was used commonly to treat epilepsy,[7] Electroconvulsive Therapy (ECT) was relied upon primarily for schizophrenia and depression,[8] and Magnetic Seizure Therapy (MST) helped individuals mitigate mental health issues.[9]

With the development of these methods the landscape of neurological treatment began to change. However, limited public access to the intervention, inability to target exact neurons, high incidence of side effects, and inaccessibly high required commitment,[10] prevented them from being able to accurately tackle a wide breadth of diseases with few risks.



Computationally, the leap from DBS, TMS, and other localized neurostimulation therapies to NeuroStim was difficult on many fronts. Firstly, a certain degree of accuracy is required in order to deliver electrical stimulation to a specific neuron. While the layout of the brain is conserved from one person to another, the relative size of each brain varies among people, leaving, for instance, the Central Amygdala in a slightly different location in Patient A as compared to Patient B. Therefore, the product– which is essentially a wearable hat embedded with electromagnetic coils, sensors, and microchips– needed to correctly identify not only the area, but also the coordinates of the specific desired neuron in order to send an electromagnetic signal.

To further increase the accuracy of the electromagnetic stimulation, the microchip needed to combine this fine-tuned scanning method with the knowledge of the brain's genetic markers. Once the wearable could identify in real-time which neurons have which specific combination of genetic markers, the machine learning algorithm could integrate the two pieces of information, weight them according to confidence level, and stimulate the target neuron. The creation of

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[6] https://iocdf.org/expert-opinions/expert-opinion-dbs/

[7] https://kidshealth.org/en/parents/vagus-nerve-stimulator.html#:~:text=Vagus%20nerve%20stimulator%20(VNS)%20therapy,shorten%20the%20length%20of%20seizures.

[8] https://kidshealth.org/en/parents/vagus-nerve-stimulator.html#:~:text=Vagus%20nerve%20stimulator%20(VNS)%20therapy,shorten%20the%20length%20of%20seizures.

[9] https://med.uth.edu/psychiatry/magnetic-seizure-therapy-mst/

[10] https://mindfulhealthsolutions.com/the-pros-and-cons-of-transcranial-magnetic-stimulation-tms-for-depression/#:~:text=While%20TMS%20has%20many%20benefits,is%20the%20commitment%20it%20takes.

these locating and decision making algorithms, combined with the fact that the signal must be sent from an external source to enable NeuroStim to be a non-invasive therapeutic option, proved difficult.

The second primary challenge in the development of NeuroStim related to the area in which the intervention is truly novel: the ability to choose an exact neural pathway to stimulate. The technology relies upon a theory that had been postulated by neuroscientist Dr. Jolie Pinkett in 2025 but remained untested for many years. The theory was as follows:

> *If one artificially activated neighboring neurons in a sequence that mirrored the temporal spacing of naturally generated action potentials and resembled a pathway, would the brain believe that the path was actually activated? More poignantly, would the principles of neuroplasticity apply in this case?*

After many years and a series of animal studies confirmed this to be true, NeuroStim took off, launching its human interventions branch, wearables branch, and research team.

Overcoming these technical challenges and building on the fundamental ideas of the pre-existing technology, NeuroStim was granted a patent in 2035. After several rounds of clinical trials, NeuroStim has since received FDA approval to treat several prevalent diseases and assist in addiction therapy. Research into the ethical limitations and risks of such an intervention are ongoing.

Benefits and Common Uses of NeuroStim

Treating Neurological Disorders

Although the possibilities for the future are endless, currently NeuroStim primarily treats three specific conditions: epilepsy, phantom limb pain, and comas.

With epilepsy, the primary issue is the erratic electrical stimulation in the brain. Similar to a DBS approach, NeuroStim modulates the circuitry primarily hijacked by seizures through regular stimulation of the thalamus.[11] As a non-invasive treatment, NeuroStim provides consistent interruption of the aberrant neuronal signals as DBS without the dangers of surgery. Therefore, instead of being a backup option in the event that the individual is medication resistant, NeuroStim allows neurological intervention to act as a primary form of care. Patients can purchase one of the portable wearable options, try it out under the watch of their medical professional, and decide whether or not the results are more effective than medication for them.

Another use of NeuroStim is in the treatment of phantom limb pain. For many years, scientists were unsure of the reason for the phenomena. Many theories were proposed, some related to the maintained body schema from prior to amputation, others related to peripheral nerve misfirings,[12] and the last, which was proven to be the primary reason in 2027, is cortical reorganization. Within cortical reorganization, neurons in the somatosensory cortex that

[11] https://www.youtube.com/watch?v=mkRfISFBku0
[12] https://www.youtube.com/watch?v=GYxksqaLBxc

previously were responsible for computing sensory information related to the missing limb[13] are now responding to neighboring neurons. This creates the feeling as though that missing body part is being stimulated in some way. To mitigate these effects NeuroStim modulates the activity of the somatosensory neurons that are typically responsible for the missing limb. If a neighboring neuron attempts to stimulate one such neuron, NeuroStim will immediately activate the corresponding neighboring inhibitory neuron to neutralize the excitation, thereby preventing phantom limb sensation.

NeuroStim has also proven useful in awakening comatose patients. In 2021, preliminary results from the study “Ultrasonic thalamic stimulation in chronic disorders of consciousness,” by Joshua Cain et. al indicated that non-invasive stimulation of the thalamus, an area associated with consciousness disorders, may help comatose patients.[14] While Cain’s work tested few subjects and showed smaller improvements, such as mildly better responsiveness and mobility, research in the later half of the decade catalyzed vast improvements in the area of electrostimulatulation in comatose patients. Now, NeuroStim is used to stimulate the thalamus to help wake up comatose patients, decreasing the 12% that statistically remain in a vegetative state[15] to 3%.

Other common uses of NeuroStim include the mitigation of tremors in Parkinson’s patients via the modulation of neurons in the subthalamic nucleus,[16] memory improvement in Alzheimer’s patients via the stimulation of the hippocampus,[17] and reduction in involuntary movements for dystonia patients via the regulation of neural activity in the internal globus pallidus.[18]

Addiction Treatment

Generally, addictions stem from the repeated use of a substance that contains a chemical– such as caffeine, sugar, nicotine, or cocaine– that immediately produces higher levels of dopamine for the nucleus accumbens (NAcc), the reward center of the brain[19]. When the chemical is consumed or ingested, the nerve cells release dopamine,[20] which triggers a sense of joy and

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13 https://study.com/academy/lesson/somatosensory-cortex-definition-location-function.html#:~:text=Its%20primary%20function%20is%20to.contralateral%20side%20of%20the%20body.

14 https://www.sciencedirect.com/science/article/pii/S1935861X21000097?via%3Dihub

15 https://www.sciencedirect.com/topics/medicine-and-dentistry/coma#:~:text=Overall%2C%20only%2015%25%20of%20patients.the%20cause%20of%20medical%20coma.

16 https://www.michaeljfox.org/deep-brain-stimulation#:~:text=In%20DBS%20surgery%2C%20the%20surgeon.pallidus%20interna)%20that%20control%20movement.

17 https://www.google.com/search?q=area+for+memory+in+brain&rlz=1C5CHFA_enUS959US959&oq=area+for+memor&gs_lcrp=EgZjaHJvbWUqBwgAEAAYgAQyBwgAEAAYgAQyBggBEEUYOTIICAIQABgWGB4yCAgDEAAYFhgeMggIBBAAGBYYHjINCAUQABiGAxiABBiKBTINCAYQABiGAxiABBiKBTINCAcQABiGAxiABBiKBTINCAgQABiGAxiABBiKBdIBCDM4MjdqMGo5qAIAsAIA&sourceid=chrome&ie=UTF-8

18 https://journals.sagepub.com/doi/10.1177/2398212818816017

19 https://rewardfoundation.org/brain-basics/reward-system/#:~:text=The%20main%20source%20of%20dopamine.the%20trigger%20ready%20for%20action.

20 https://www.healthdirect.gov.au/dopamine

gives someone the "hit" that they were craving. While occasionally consuming or absorbing a substance predominantly classified as addictive is not inherently problematic, the continued use of it will inevitably trigger some sort of addictive behavior.

This addiction manifests itself neurologically in a variety of ways. Firstly, the continued use of a particular addictive substance will cause the minimum amount of that substance required to elicit a dopaminergic response to increase over time. Simply put, if 5 mg of cocaine was sufficient to get an individual high earlier in their drug career, later on they may require 10 or 15 mg to attain that same feeling.

Secondly, when a neural pathway is continuously used– for instance, nicotine causes dopamine release which creates a sense of happiness– that relationship gets strengthened via a process known as neuroplasticity. A byproduct of neuroplasticity is that later instances in which the pathway gets triggered, the action potential will have an easier time reaching its ultimate goal. While in cases such as memorizing multiplication tables this streamlining of the process is beneficial, for developing addictions, neuroplasticity only serves to help the state of the addict devolve faster.

In addiction cases, NeuroStim has been proven beneficial 94% of the time. Unlike typical addiction treatments such as nicotine patches or group therapy, which relies on human willpower to overcome biological instinct, NeuroStim rewires the connectivity of the brain to avoid that problem. For instance, NeuroStim may have nicotine intake propagate an action potential to the insular cortex, putamen, and left superior frontal gyrus (the areas associated with hatred),[21] causing the substance to be abhorred rather than craved.

Harnessing the principles of neuroplasticity, NeuroStim treatment for addiction involves repeated stimulation of that manufactured pathway, strengthening it to the point where feelings of disdain towards the substance becomes more easily accessible than that of the craving. Without the biological reward competing against logic, it becomes infinitely easier for patients to abstain from the addictive substance and overcome withdrawal symptoms.

Ethical Limitations

Talent Acquisition

As previously outlined, neuroplasticity is an extremely powerful phenomenon within the human brain. Although it can be harnessed for the improvement of an individual's life and overall betterment of society, NeuroStim– which heavily relies upon the principles of neuroplasticity– also has the potential to be abused.

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21 https://www.psychologytoday.com/us/blog/your-brain-food/202208/what-is-hate-and-where-does-it-live-in-the-brain#:~:text=The%20insular%20cortex%2C%20putamen%2C%20and%20left%20superior%20frontal%20gyrus%20are,of%20people%20who%20they%20hate.

In 2012, CRISPR-Cas9 was first developed as a gene editing tool[22] and was used to prenatally correct mutations, prevent illnesses, assist with diagnostics, and revolutionize agriculture.[23] However, along with the excitement generated within the scientific community, CRISPR also caused a great deal of panic and hesitation due to the inevitability of designer babies. Evocative of a dystopian future in which parents choose to edit non-essential features of their children– such as eye or hair color, the idea of a "designer baby" gave rise to much controversy.

With the development of NeuroStim also came the rise of a parallel concern– "designer adults." Coined by neuroscientist Dr. Paul Lazarus in 2039, "designer adults" is a term designated to someone who elects to artificially improve their skills in a certain realm by using NeuroStim to strengthen the neural pathways required for that activity. This circumvents the typical trajectory wherein people must continuously practice in order to gain proficiency in that particular skill. The act of practicing reinforces the neural pathway and allows the individual to have greater recall or quicker instinct in the subsequent instances.

When someone can skip the effort required to become an expert speller or a skilled soccer player, for instance, then the value placed on being at the forefront of such a field vastly decreases. In order to mitigate the potential for "designer adults," NeuroStim only grants medical professionals access to the tool and regulates usage so that it only be harnessed for medical-adjacent concerns, each of which have been approved by the FDA on a case by case basis.

Mind Control

Another ethical concern raised by the creation of NeuroStim is the potential for mind control. By stimulating a specific sequence of neurons, NeuroStim could, theoretically, elicit certain thoughts, surface specific feelings, or even generate desired movements. For instance, triggering the amygdala could cause fear,[24] stimulating the hypothalamus could make someone insatiably hungry,[25] and propagating action potential in the cerebellum could disrupt muscle control.[26] Especially given the non-invasive nature of the intervention, which would make it easier for individuals to use the technology, people have become concerned that NeuroStim is a government-arranged front for developing mind control technology.

Reddit threads, youtube conspiracy videos, Elon Musk's twitter page, and fringe members of the Libertarianism movement have been supporting these theories since the patent was cleared in 2035. While the aforementioned accusations are very false and extremely detrimental to the company's work, there is merit to the idea that the technology has the potential to be abused and should therefore be heavily regulated. To that end, NeuroStim has worked closely with

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[22] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9377665/#:~:text=CRISPR%20%E2%80%93%20clustered%20regularly%20interspaced%20short,1987%20by%20Ishino%20et%20al.

[23] ibid

[24] https://my.clevelandclinic.org/health/body/24894-amygdala

[25] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2777281/#:~:text=The%20hypothalamus%20acts%20as%20the,directly%20interact%20with%20its%20neurons.

[26] https://nida.nih.gov/videos/human-brain-major-structures-functions

regulatory bodies to ensure that only authorized professionals are cleared to own and operate the machinery and that they may only use it for a FDA-approved medical reason. NeuroStim has also internally established an interdisciplinary subcommittee on ethics, which comprises doctors, medical ethicists, hardware engineers, philosophers, and politicians, to help inform checks and balances placed on the future development of the intervention.

Conclusion

Ultimately, although there is some potential for negative repercussions, the overall benefit of NeuroStim and its ability to treat neurological diseases in an unprecedented fashion outweighs the risks. Especially in a world where we can regulate use and mitigate such concerns, it is vital to prioritize human health. With NeuroStim, humanity can continue to make great strides in not only passively understanding the brain, but becoming partners in determining its function.

Page Overview

Written as a medical record and a product information pamphlet, the essay details a futuristic therapeutic intervention called NeuroStim, which acts as a targeted neural pathway stimulator. Unlike some of its predecessors such as DBS and TMS, NeuroStim is both non-invasive by nature and allows the operator to target or create a specific neural pathway. Computationally, the leap to NeuroStim was difficult, as it entailed the ability to externally triangulate the location of specific neurons, scan the brain in real-time for the co-location of specific subsets of genetic markers, design a decision making algorithm that would best determine where to electrically stimulate, and keep precise temporal spacing between the stimulations such that it mimics the propagation of the action potential.

With the development of NeuroStim would come great progress in the realm of treating neurological disorders. Some of these disorders were treatable through previous localized brain stimulation interventions but now would have an increase in safety and accuracy, while others are novel in their ability to be treated via non-medication methods. Additionally, NeuroStim has the ability to help fast-track addiction recovery. Although the potential for benefit from NeuroStim is exponential, there are several ethical limitations to be aware of, namely, the potential for “designer adults” and mind control. With sufficient legal, ethical, and technological regulation, however, such concerns can be mitigated. Ultimately, the benefits of the intervention would outweigh potential negative outgrowths and revolutionize the scope of the human capability to cope with neurological dysfunction.

Disclaimer: I attempted to delineate between fact and fiction by indicating a futuristic date for people, ideas, or studies that have not actually occurred.