Technology Roadmap

Introduction

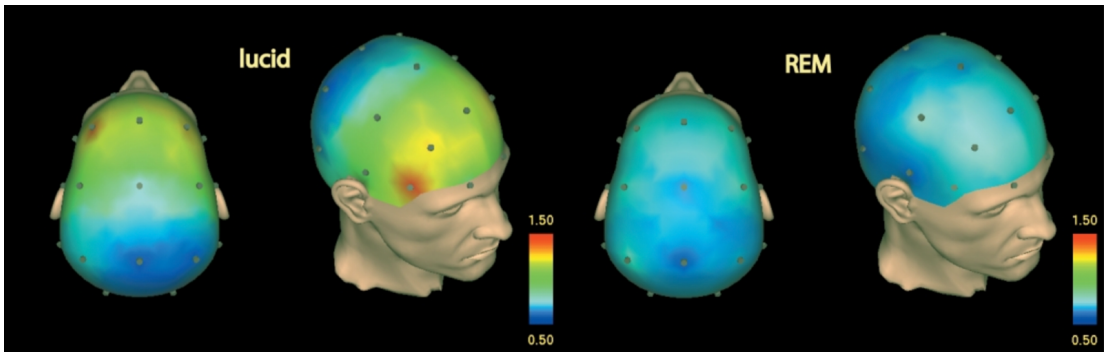
Prophetic is a neurotechnology company inventing a wearable device that *stabilizes lucid dreams*. Prophetic's mission is deeply ambitious with the potential to radically transform human consciousness.

What is a lucid dream?

Lucid dreaming is a state of sleep where a person becomes aware that they are dreaming. Lucid dreamers are able to exert control over their dream, changing the narrative, characters, and/or environment.

Frontal Activation

One of the defining characteristics of a lucid dream is increased activity of frontal brain regions.[1, 2, 12, 13, 15, 16] Regions like the prefrontal cortex are associated with self-awareness and decision making. These regions are less active during regular dreaming, which could explain why we accept bizarre dream scenarios without question. However, when we become lucid, the prefrontal cortex "wakes up," allowing us to realize that we are dreaming.



This image depicts heightened neural activity in the prefrontal cortex during a lucid dream compared to REM sleep. (Voss 2009)[3]

Emerging Neurostimulation Research

A growing body of research has explored the potential of using non-invasive stimulation to artificially create this frontal activity to stabilize lucid dreaming.

Direct Current

In 2013, without the use of any machine learning, Stumbrys experimented with transcranial direct current stimulation. Stumbrys applied a consistent 1 mA of direct current for 10 minutes via two electrodes placed on the frontal scalps of 19 participants during REM sleep. Comparing this stimulation to sham stimulation over 3 nights, participants, with a history of lucid dreaming, reported a small but statistically significant increase in dream lucidity. [5]

Alternating Current

In 2014, Voss conducted a study on 27 participants over four nights in a sleep laboratory to investigate the impact of transcranial alternating current stimulation on lucid dreaming. They applied alternating current in different frequencies to the frontolateral scalp regions during REM sleep. Using the Lucidity and Consciousness in Dreams (LuCiD) scale, they found that 40 Hz stimulations significantly increased 2 out of 8 factors of LuCiD scale (insight and dissociation) by an average of two standard errors compared to sham.[6]

Modulating Dream Contents

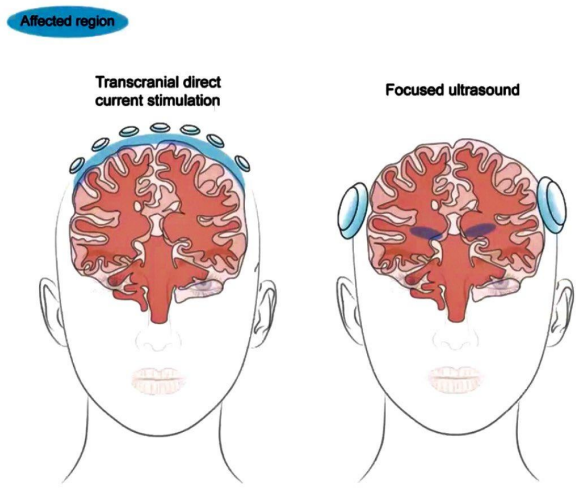
In 2020, Noreika was able to modulate dream experience by utilizing direct current stimulation to stimulate the sensorimotor cortex. This resulted in a reduction of dream movement reported by the participants in comparison to sham stimulation.[7]

These results suggest that there is a deep link between our brain's motor process and the movement sensations of the dreamer, a finding that Noreika noted has "broader implications for understanding the neural basis of self-experience in dreams."

This will be further discussed below (Safety, Privacy, and Ethics).

Focused Ultrasound

Both transcranial direct current stimulation and transcranial alternating current have been around for many decades. Transcranial focused ultrasound stimulation is an emerging non-invasive brain stimulation technique that uses ultrasound waves to modulate neural activity.

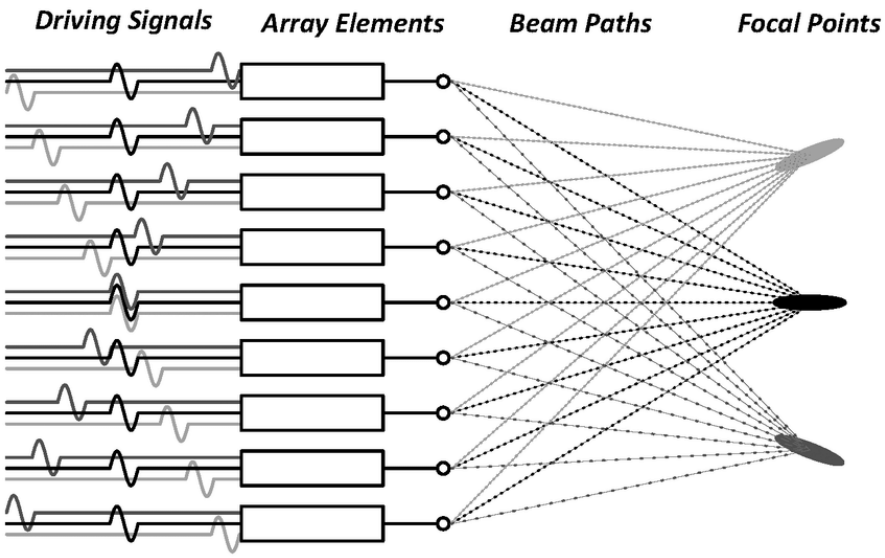


Direct Current vs Focused ultrasound [17]

In terms of spatial precision, focused ultrasound has many advantages over some other non-invasive neuromodulation techniques like electric stimulation. Here's why:

1. **Millimeter Precision**: Similar to a magnifying glass, the ultrasonic transducer is curved, which aims the sound waves to a specific focal point. In terms of spatial resolution, this results in an improvement of multiple orders of magnitude compared to electric stimulation.
2. **Steering:** Multielement ultrasonic transducers can be activated in sequences that allow the ultrasonic beam to be steered without moving the transducer, which allows neuromodulation pulses to occur in sequential spatial patterns rather than fixed to a single location.
3. **Depth of Penetration**: Unlike electrical stimulation, which primarily affects the cortical surface regions close to the electrodes, focused ultrasound can penetrate and modulate deeper brain structures. This ability to noninvasively modulate both superficial and deep brain regions is groundbreaking.
4. **Reduced Spread**: Electrical currents can spread across the scalp and underlying tissues, leading to less localized effects. In contrast, focused ultrasound can be more tightly focused on the desired brain region, minimizing potential off-target effects.

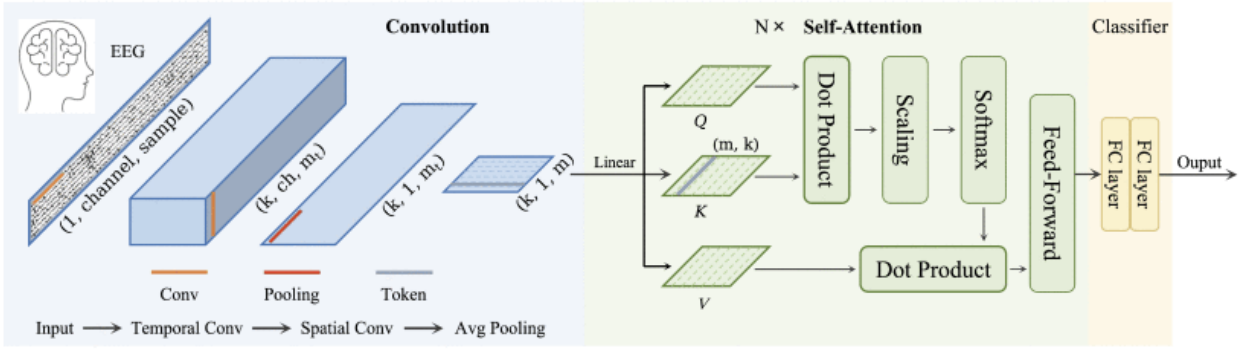
Transcranial focused ultrasound stimulation has been shown many times to be safe and beneficial. It has been shown that it can significantly improve working memory.[10] This is important because during a regular dream, working memory is strongly impaired.[11]



Example of Steering Capabilities of Multi Element Transducer

Generative Ultrasonic Transformer

The transformer architecture, which is the technology underpinning powerful LLMs like ChatGPT, has established itself as the holy grail of sequential pattern recognition and generative artificial intelligence. Modified versions have been developed to process EEG neural activity and has established itself as the new state-of-the-art of neural decoding.[14]



EEG Convolutional Transformer Encoder Architecture [14]

This year we are partnering with the Donders Institute on a study to collect the largest dataset of fMRI imaging data of lucid dreamers. With this data, we are standardizing a dataset of neural activation patterns of lucid dreams and modifying a generative decoder block to output steering controls for the ultrasonic stimulation pulses. This will allow the system to artificially mimic the neural activity observed in naturally occurring lucid dreams.

What this means

Given the distinction between regular and lucid dreaming is largely the activation of the frontal brain regions and given the growing body of research into non-invasive neural stimulation techniques, it is becoming increasingly inevitable that we will develop a technology capable of reliably stimulating these areas. Such targeted activation would transition a standard dream into a lucid one, ushering in a new era where the boundaries of dream states are more within our conscious control. As technology and neuroscience continue their evolution, dreams will soon become a more tangible and manipulable dimension of human experience.

Safety, Privacy, and Ethics

While the potential for inducing lucid dreams through transcranial ultrasound stimulation is an exciting prospect, it's necessary that considerations for safety and privacy are at the forefront of this technology's development and application. From a safety perspective, the technology must undergo rigorous testing to ensure it doesn't negatively impact brain function or cause any physical harm.

Specifically, we are developing an ultrasonic stimulation system with spatial-peak temporal average (ISPTA) and spatial-peak pulse average (ISPPA) below the FDA’s regulations for diagnostic ultrasound. Furthermore, we are developing fail-safe mechanisms to ensure these values cannot be exceeded under any circumstance.

Privacy concerns also come into play with this technology. The ability to modulate dreams, as mentioned in the 3rd study above, could conceivably open the door to manipulative practices, where dreams are directed for advertising, propaganda, or more nefarious purposes. As such, it is essential to establish robust regulations and safeguards to prevent misuse. This technology should be strictly used to facilitate the lucidity to give dreamers control over their dreams.

Strong ethical guidelines should be implemented to ensure that users retain control over their dream experiences and that their personal and subconscious are not intruded upon. It is our responsibility to ensure that as we pioneer this technology, we do so in a manner that is safe, secure, and respectful of the individual's cognitive and noetic autonomy.

Our First Research Studies

We are launching multiple studies in partnership with the Donders Centre for Cognitive Neuroimaging at Radboud University in the Netherlands. Led by Dr. Martin Dresler, who is one of the world's leading neuroscience researchers, these studies focus on the neural correlates of lucid dreaming and development and validation of strategies to stabilize lucid dreaming.

1. **Neuroimaging of Lucid Dreaming**: The aim of this study is to have 100 lucid dreamers to be scanned with the following neuroimaging: a 3 Tesla structural and functional MRI, 32 channel polysomnography (EEG, EOG, EMG), and Functional near-infrared spectroscopy (fNIRS).
2. **Electrophysiology of Lucid Dreaming**: The aim of this study is to have 80 participants validate the use of different wearable sleep sensing systems under natural conditions.
3. **Transcranial Focused Ultrasound of Lucid Dreaming**: The aim of this study is to have 30 participants recorded with multi-channel polysomnography while undergoing transcranial focused ultrasound during sleep. Participants will be imaged via fMRI pre- and post-sleep. Our stimulation targets will primarily encompass areas such as the Anterior Cingulate Cortex, Frontal Forebrain, and Frontopolar Cortex.

fMRI machine

Through this combination of advanced neuroimaging, electrophysiological measurements, and innovative brain stimulation techniques, these studies seek to uncover the mysteries of lucid dreaming and open doors to exciting possibilities for exploring human consciousness and cognition.

Introducing: The Halo

The Halo is a tool for humans to explore their subconscious. The Halo is a closed-loop neurostimulation device that combines EEG and transcranial ultrasound stimulation to stabilize lucid dreams.

The Halo

Using a transformer architecture and other advanced artificial intelligence methods, the Halo is able to use EEG feedback to intelligently spatially generate ultrasonic pulses to mimic naturally occurring neural activation patterns from a training set of fMRI data of lucid dreamers.

Design Direction

We are thrilled to be working with Afshin Mehin to design the Halo. Afshin and his team are incredibly talented and have an impressive portfolio. Notably, they designed the Neuralink N1, which Elon Musk presented to the world in 2019.

Neuralink N1 wearable

When we first met Afshin, we expressed our desire to seek a design language that departs from the status quo of simplistic minimalism that grips much of technology today. We wanted something that extends to a deeper understanding of humanity and our relationship to the universe. Afshin understood this vision, and together, we aim to push the boundaries of neurotechnology and human consciousness.

Prototyping

We are also excited to be advised by Sterling Crispin, who worked at Apple for 3 years on the VisionPro team as a Neurotechnology Prototyping Researcher. As an advisor for Prophetic, Sterling brings valuable insight into the process of inventing transformative hardware. By bringing Apple's practices to Prophetic, we aim to emulate Apple's creative technology prototyping process.

Apple VisionPro

Fundraising

None of this would be possible without the support of our investors. We recently closed a $1.1 million pre-seed. A special thanks to The Box Group, Space Cadet Ventures, O'Shaughnessy Ventures, and many others. It feels great to be aligned with this incredible group of investors to aggressively pursue this technology.

Final Thoughts

To invent is to create something new - something that hasn't existed before. Transformative engineering never happens in a straight line. We will experiment, fail, learn, and iterate. The product will evolve. The design will change. But we have a clear goal in mind: to give humanity the tools to explore and expand consciousness.

I'm grateful to be on this exciting journey with my co-founder, Eric. Eric has an incredible vision for the future coupled with a hunger to execute. Eric is among a tiny minority of people with the guts to take extremely big swings. Swings that if successful would transform the world.

There's a Steve Jobs quote that I love:

There is something going on here in life beyond just a job and a family and two cars in the garage and a career. There is something more going on. There is another side of the coin, that we don't talk about much. We experience it when there are gaps. When everything is not ordered and perfect, when there's a gap, you experience this inrush of something. And a lot of people have set off throughout history to find out what that was. Whether it's Thoreau, whether it's some Indian mystics, or whatever it might be.

-Steve Jobs

There's something much deeper going on in the universe and reality that humans have continually sought to uncover. Through the centuries, we've chipped away at the unknown and slowly gained a better understanding of our own existence but there is much more to discover.

What is reality? How does consciousness work? Where did this all come from? What is life all about?

When we were kids we thought when we got out of school there would be answers to these questions waiting for us out there in the real world. Now we are at a technological inflection point to create the tools to explore these questions and find the answers ourselves.

- Wesley Louis Berry III, Chief Technology Officer, October 2023

Citations

1. Benjamin Baird, Sergio A. Mota-Rolim, Martin Dresler, The cognitive neuroscience of lucid dreaming, Neuroscience & Biobehavioral Reviews, Volume 100, 2019, Pages 305-323, ISSN 0149-7634, https://doi.org/10.1016/j.neubiorev.2019.03.008.
2. Mota-Rolim, Sergio & Erlacher, Daniel & Tort, Adriano & Araujo, John & Ribeiro, Sidarta. (2010). Different kinds of subjective experience during lucid dreaming may have different neural substrates. International Journal of Dream Research. 3. 33-35. 10.11588/ijodr.2010.1.596.
3. Voss U, Hobson JA, Holzmann R, Tuin I. Lucid dreaming: a state of consciousness with features of both waking and non-lucid dreaming. Sleep. 2009 Sep;32(9):1191-200. doi: 10.1093/sleep/32.9.1191. PMID: 19750924; PMCID: PMC2737577.
4. Priyanka A. Abhang, Bharti W. Gawali, Suresh C. Mehrotra, Chapter 2 - Technological Basics of EEG Recording and Operation of Apparatus, Editor(s): Priyanka A. Abhang, Bharti W. Gawali, Suresh C. Mehrotra, Introduction to EEG- and Speech-Based Emotion Recognition, Academic Press, 2016, Pages 19-50, ISBN 9780128044902, https://doi.org/10.1016/B978-0-12-804490-2.00002-6.
5. Stumbrys T, Erlacher D, Schredl M. Testing the involvement of the prefrontal cortex in lucid dreaming: a tDCS study. Conscious Cogn. 2013 Dec;22(4):1214-22. doi: 10.1016/j.concog.2013.08.005. Epub 2013 Sep 8. PMID: 24021850. https://pubmed.ncbi.nlm.nih.gov/24021850/
6. Voss, U., Holzmann, R., Hobson, A. et al. Induction of self awareness in dreams through frontal low current stimulation of gamma activity. Nat Neurosci 17, 810–812 (2014). https://doi.org/10.1038/nn.3719
7. Noreika, V., Windt, J.M., Kern, M. et al. Modulating dream experience: Noninvasive brain stimulation over the sensorimotor cortex reduces dream movement. Sci Rep 10, 6735 (2020). https://doi.org/10.1038/s41598-020-63479-6
8. https://brainbox-neuro.com/techniques/tus
9. Sanguinetti Joseph L., Hameroff Stuart, Smith Ezra E., Sato Tomokazu, Daft Chris M. W., Tyler William J., Allen John J. B. Transcranial Focused Ultrasound to the Right Prefrontal Cortex Improves Mood and Alters Functional Connectivity in Humans. Frontiers in Human Neuroscience v.14 2020 https://www.frontiersin.org/articles/10.3389/fnhum.2020.00052
10. Wang F, Wang Q, Wang L, Ren J, Song X, Tian Y, Zheng C, Yang J, Ming D. Low-Intensity Focused Ultrasound Stimulation Ameliorates Working Memory Dysfunctions in Vascular Dementia Rats via Improving Neuronal Environment. Front

Aging Neurosci. 2022 Feb 21;14:814560. doi: 10.3389/fnagi.2022.814560. PMID: 35264943; PMCID: PMC8899543.

11. Hobson, J., Pace-Schott, E. The cognitive neuroscience of sleep: neuronal systems, consciousness and learning. Nat Rev Neurosci 3, 679–693 (2002). https://doi.org/10.1038/nrn915
12. Neider M, Pace-Schott EF, Forselius E, Pittman B, Morgan PT. Lucid dreaming and ventromedial versus dorsolateral prefrontal task performance. Conscious Cogn. 2011 Jun;20(2):234-44. doi: 10.1016/j.concog.2010.08.001. Epub 2010 Sep 9. PMID: 20829072; PMCID: PMC3026881.
13. Dresler M, Wehrle R, Spoormaker VI, Koch SP, Holsboer F, Steiger A, Obrig H, Sämann PG, Czisch M. Neural correlates of dream lucidity obtained from contrasting lucid versus non-lucid REM sleep: a combined EEG/fMRI case study. Sleep. 2012 Jul 1;35(7):1017-20. doi: 10.5665/sleep.1974. PMID: 22754049; PMCID: PMC3369221.
14. Y. Song, Q. Zheng, B. Liu and X. Gao, "EEG Conformer: Convolutional Transformer for EEG Decoding and Visualization," in IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 31, pp. 710-719, 2023, doi: 10.1109/TNSRE.2022.3230250.
15. Baird B, Castelnovo A, Gosseries O, Tononi G. Frequent lucid dreaming associated with increased functional connectivity between frontopolar cortex and temporoparietal association areas. Sci Rep. 2018 Dec 12;8(1):17798. doi: 10.1038/s41598-018-36190-w. PMID: 30542052; PMCID: PMC6290891.
16. Filevich E, Dresler M, Brick TR, Kühn S. Metacognitive mechanisms underlying lucid dreaming. J Neurosci. 2015 Jan 21;35(3):1082-8. doi: 10.1523/JNEUROSCI.3342-14.2015. PMID: 25609624; PMCID: PMC6605529.
17. Kim Butts Pauly and Keith Murphy / Stanford University. BIOE 225.