Brain Activity Decoder Can Reveal Stories in People's Minds

MAY 1, 2023 • BY MARC AIRHART

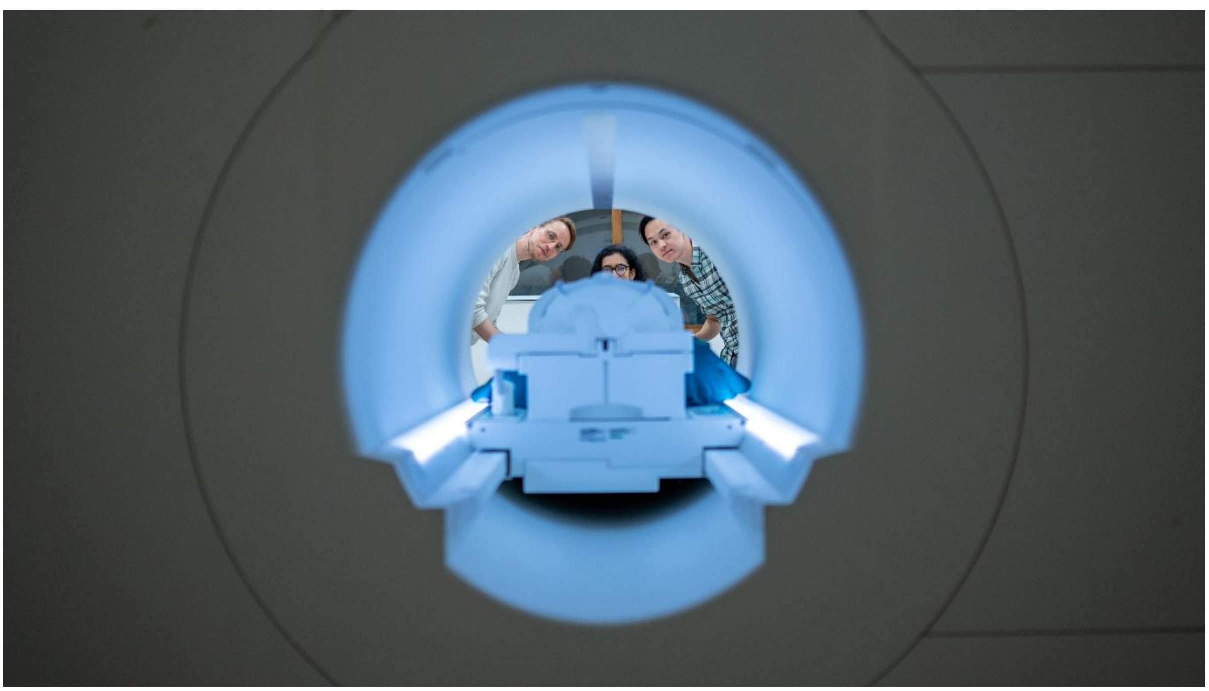
The work relies in part on a transformer model, similar to the ones that power ChatGPT.

Alex Huth (left), Shailee Jain (center) and Jerry Tang (right) prepare to collect brain activity data in the Biomedical Imaging Center at The University of Texas at Austin. The researchers trained their semantic decoder on dozens of hours of brain activity data from participants, collected in an fMRI scanner. Photo Credit: Nolan Zunk/University of Texas at Austin.

A new artificial intelligence system called a semantic decoder can translate a person's brain activity — while listening to a story or silently imagining telling a story — into a continuous stream of text. The system developed by researchers at The University of Texas at Austin might help people who are mentally conscious yet unable to physically speak, such as those debilitated by strokes, to communicate intelligibly again.

The study, published in the journal *Nature Neuroscience*, was led by Jerry Tang, a doctoral student in computer science, and Alex Huth, an assistant professor of neuroscience and computer science at UT Austin. The work relies in part on a transformer model, similar to the ones that power Open AI's ChatGPT and Google's Bard.

Unlike other language decoding systems in development, this system does not require subjects to have surgical implants, making the process noninvasive. Participants also do not need to use only words from a prescribed list. Brain activity is measured using an fMRI scanner after extensive training of the decoder, in which the individual listens to hours of podcasts in the scanner. Later, provided that the participant is open to having their thoughts decoded, their listening to a new story or imagining telling a story allows the machine to generate corresponding text from brain activity alone.



"For a noninvasive method, this is a real leap forward compared to what's been done before, which is typically single words or short sentences," Huth said. "We're getting the model to decode continuous language for extended periods of time with complicated ideas."

The result is not a word-for-word transcript. Instead, researchers designed it to capture the gist of what is being said or thought, albeit imperfectly. About half the time, when the decoder has been trained to monitor a participant's brain activity, the machine produces text that closely (and sometimes precisely) matches the intended meanings of the original words.

For example, in experiments, a participant listening to a speaker say, "I don't have my driver's license yet" had their thoughts translated as, "She has not even started to learn to drive yet." Listening to the words, "I didn't know whether to scream, cry or run away. Instead, I said, 'Leave me alone!'" was decoded as, "Started to scream and cry, and then she just said, 'I told you to leave me alone.'"

THIS IMAGE SHOWS DECODER PREDICTIONS FROM BRAIN RECORDINGS COLLECTED WHILE A USER LISTENED TO FOUR STORIES. EXAMPLE SEGMENTS WERE MANUALLY SELECTED AND ANNOTATED TO DEMONSTRATE TYPICAL DECODER BEHAVIORS. THE DECODER EXACTLY REPRODUCES SOME WORDS AND PHRASES AND CAPTURES THE GIST OF MANY MORE. CREDIT: UNIVERSITY OF TEXAS AT AUSTIN.

Beginning with an earlier version of the paper that appeared as a preprint online, the researchers addressed questions about potential misuse of the technology. The paper describes how decoding worked only with cooperative participants who had participated willingly in training the decoder. Results for individuals on whom the decoder had not been trained were unintelligible, and if participants on whom the decoder had been trained later put up resistance — for example, by thinking other thoughts — results were similarly unusable.

"We take very seriously the concerns that it could be used for bad purposes and have worked to avoid that," Tang said. "We want to make sure people only use these types of technologies when they want to and that it helps them."

In addition to having participants listen or think about stories, the researchers asked subjects to watch four short, silent videos while in the scanner. The semantic decoder was able to use their brain activity to accurately describe certain events from the videos.

The system currently is not practical for use outside of the laboratory because of its reliance on the time need on an fMRI machine. But the researchers think this work could transfer to other, more portable brain-imaging systems, such as functional near-infrared spectroscopy (fNIRS).

"fNIRS measures where there's more or less blood flow in the brain at different points in time, which, it turns out, is exactly the same kind of signal that fMRI is measuring," Huth said. "So, our exact kind of approach should translate to fNIRS," although, he noted, the resolution with fNIRS would be lower.

This work was supported by the Whitehall Foundation, the Alfred P. Sloan Foundation and the Burroughs Wellcome Fund.

The study's other co-authors are Amanda LeBel, a former research assistant in the Huth lab, and Shailee Jain, a computer science graduate student at UT Austin.

Alexander Huth and Jerry Tang have filed a PCT patent application related to this work.

Once the paper has been published online, it will be available at the following URL: https://www.nature.com/articles/s41593-023-01304-9

Full resolution images, videos and audio quotes for this story can be downloaded here: https://utexas.box.com/s/7kluiwmtlan5jw00s8nsiynlxl412132

PH.D. STUDENT JERRY TANG PREPARES TO COLLECT BRAIN ACTIVITY DATA IN THE BIOMEDICAL IMAGING CENTER AT THE UNIVERSITY OF TEXAS AT AUSTIN. THE RESEARCHERS TRAINED THEIR SEMANTIC DECODER ON DOZENS OF HOURS OF BRAIN ACTIVITY DATA FROM PARTICIPANTS, COLLECTED IN AN FMRI SCANNER. PHOTO CREDIT: NOLAN ZUNK/UNIVERSITY OF TEXAS AT AUSTIN.

Frequently Asked Questions

Could this technology be used on someone without them knowing, say by an authoritarian regime interrogating political prisoners or an employer spying on employees?

No. The system has to be extensively trained on a willing subject in a facility with large, expensive equipment. "A person needs to spend up to 15 hours lying in an MRI scanner, being perfectly still, and paying good attention to stories that they're listening to before this really works well on them," said Huth.

Could training be skipped altogether?

No. The researchers tested the system on people whom it hadn't been trained on and found that the results were unintelligible.

Are there ways someone can defend against having their thoughts decoded?

Yes. The researchers tested whether a person who had previously participated in training could actively resist subsequent attempts at brain decoding. Tactics like thinking of animals or quietly imagining telling their own story let participants easily and completely thwart the system from recovering the speech the person was exposed to.

What if technology and related research evolved to one day overcome these obstacles or defenses?

"I think right now, while the technology is in such an early state, it's important to be proactive by enacting policies that protect people and their privacy," Tang said. "Regulating what these devices can be used for is also very important."

ALEX HUTH (LEFT), DISCUSSES THE SEMANTIC DECODER PROJECT WITH JERRY TANG (CENTER) AND SHAILEE JAIN (RIGHT) IN THE BIOMEDICAL IMAGING CENTER AT THE UNIVERSITY OF TEXAS AT AUSTIN. THE RESEARCHERS TRAINED THEIR SEMANTIC DECODER ON DOZENS OF HOURS OF BRAIN ACTIVITY DATA FROM PARTICIPANTS, COLLECTED IN AN FMRI SCANNER. PHOTO CREDIT: NOLAN ZUNK/UNIVERSITY OF TEXAS AT AUSTIN.

About Point of Discovery

From Thought to Text: AI Converts Silent Speech into Written Words

FeaturedNeuroscience

·June 11, 2023

Summary: A novel artificial intelligence system, the semantic decoder, can translate brain activity into continuous text. The system could revolutionize communication for people unable to speak due to conditions like stroke.

This non-invasive approach uses fMRI scanner data, turning thoughts into text without requiring any surgical implants. While not perfect, this AI system successfully captures the essence of a person's thoughts half of the time.

Key Facts:

1. The semantic decoder AI was developed by researchers at The University of Texas at Austin.
2. It works based on a transformer model similar to the ones that power Open AI's ChatGPT and Google's Bard.
3. The system has potential for use with more portable brain-imaging systems, like functional near-infrared spectroscopy (fNIRS).

Source: UT Austin

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Credit: Neuroscience News
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Later, provided that the participant is open to having their thoughts decoded, their listening to a new story or imagining telling a story allows the machine to generate corresponding text from brain activity alone.

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For example, in experiments, a participant listening to a speaker say, “I don’t have my driver’s license yet” had their thoughts translated as, “She has not even started to learn to drive yet.” Listening to the words, “I didn’t know whether to scream, cry or run away. Instead, I said, ‘Leave me alone!’” was decoded as, “Started to scream and cry, and then she just said, ‘I told you to leave me alone.’”

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About this AI research news

Author: Marc Airhart
Source: UT Austin
Contact: Marc Airhart – UT Austin
Image: The image is credited to Neuroscience News

Original Research: Closed access.
"Semantic reconstruction of continuous language from non-invasive brain recordings" by Jerry Tang et al. *Nature Neuroscience*

Abstract

Semantic reconstruction of continuous language from non-invasive brain recordings

A brain–computer interface that decodes continuous language from non-invasive recordings would have many scientific and practical applications. Currently, however, non-invasive language decoders can only identify stimuli from among a small set of words or phrases. Here we introduce a non-invasive decoder that reconstructs continuous

language from cortical semantic representations recorded using functional magnetic resonance imaging (fMRI). Given novel brain recordings, this decoder generates intelligible word sequences that recover the meaning of perceived speech, imagined speech and even silent videos, demonstrating that a single decoder can be applied to a range of tasks. We tested the decoder across cortex and found that continuous language can be separately decoded from multiple regions. As brain–computer interfaces should respect mental privacy, we tested whether successful decoding requires subject cooperation and found that subject cooperation is required both to train and to apply the decoder. Our findings demonstrate the viability of non-invasive language brain–computer interfaces.

Understanding Brain Waves: A Comprehensive Guide

May 9, 2023 by nhnscr

Have you ever wondered how your brain works? How it processes and stores information? The brain is one of the most complex organs in the human body, and studying its functionality has led to the discovery of many fascinating things, including brain waves.

In this blog, we'll explore everything you need to know about brain waves, including what they are, how they affect us, and how we can control them.

What Are Brain Waves?

Brain waves are electrical impulses that flow through the brain, creating patterns of activity. They are measured in cycles per second, or hertz (Hz). There are four main types of brain waves: alpha, beta, delta, and theta.

Each type of brain wave is associated with a different state of consciousness. Beta waves, for example, are associated with wakefulness and alertness, while delta waves are associated with deep sleep.

Here's a breakdown of the different types of brain waves and their associated frequencies:

- **Beta Waves (12-30 Hz)**

  – These brain waves are associated with alertness and wakefulness. They are most commonly observed in the frontal lobe of the brain.
- **Alpha Waves (8-12 Hz)**

  – These brain waves are associated with relaxation and calmness. They are most commonly observed in the occipital lobe of the brain.
- **Theta Waves (4-8 Hz)**

  – These brain waves are associated with meditation, creativity, and dreaming. They are most commonly observed in the temporal lobe of the brain.
- **Delta Waves (0.5-4 Hz)**

  – These brain waves are associated with deep sleep and unconsciousness. They are most commonly observed in the parietal and frontal lobes of the brain.

What Do Brain Waves Affect?

Brain waves have a significant impact on our overall well-being. They affect everything from our mood to our ability to concentrate.

Here are some of the things that brain waves can affect:

- **Mood**

  – Different types of brain waves are associated with different moods. For example, alpha waves are associated with relaxation and calmness, while beta waves are associated with stress and anxiety.
- **Concentration**

  – Brain waves can affect our ability to concentrate and focus. For example, theta waves, which are associated with meditation and creativity, can help us focus and be more productive.

- **Sleep**

  – Brain waves play a crucial role in sleep and can impact the quality of our sleep. Delta waves, which are associated with deep sleep, can help us get a restful night's sleep.
- **Memory**

  – Brain waves are also associated with memory. Theta waves, in particular, are believed to help with memory consolidation and recall.

Brain Waves During Sleep

Brain waves play a critical role in sleep, with each type of brain wave serving a different function.

During deep sleep, the brain produces delta waves, which help us rest and recharge. As we move into lighter stages of sleep, the brain produces more alpha and theta waves, which can help us transition back into wakefulness.

REM sleep is associated with beta waves, which can make our brains more active and generate vivid dreams.

Theta Brain Waves Benefits

Theta waves have been shown to have a range of benefits, including:

- **Reducing Anxiety**

  – Theta waves have a calming effect on the brain and can help reduce anxiety.
- **Boosting Creativity**

  – Theta waves are associated with creativity and can help stimulate the imagination.
- **Improving Memory**

– Theta waves have been shown to improve memory consolidation and recall.

Gamma Brain Waves

Gamma brain waves are another type of brain wave, measuring between 25 and 100 Hz. They are associated with high levels of concentration, focus, and problem-solving.

Gamma waves have been shown to have a range of benefits, including:

- **Improved Cognitive Function**

  – Gamma waves can help improve cognitive function, including memory, perception, and attention.
- **Reduced Anxiety**

  – Gamma waves have a calming effect on the brain and can help reduce anxiety.
- **Enhanced Learning**

  – Gamma waves can help improve learning and information processing.

Brain Waves for Studying

Brain waves can be used to improve study habits and enhance learning. Here are some tips for using brain waves to study:

- **Alpha Waves**

  – Listening to alpha waves can help you relax and stay focused while studying.
- **Theta Waves**

  – Theta waves can help stimulate creativity and improve memory consolidation. Try listening to theta waves while studying.

- **Gamma Waves**

  – Gamma waves can help improve cognitive function and learning. Try listening to gamma waves while studying difficult or challenging material.

How to Measure Brain Waves at Home

Measuring brain waves used to require specialized equipment and expertise, but thanks to advances in technology, it's now possible to measure brain waves at home.

Here are some tools that you can use to measure brain waves at home:

- **Electroencephalogram (EEG)**

  – EEG devices are used to measure brain waves and provide detailed information about brain activity.
- **Brain-Sensing Headbands**

  – There are a variety of headbands on the market that can measure brain waves, including Muse and NeuroSky.
- **Mobile Apps**

  – There are a variety of mobile apps that can measure brain waves, including Brain Waves and Brainify.

Which Frequency Is Best for the Brain?

There is no one-size-fits-all answer to which frequency is best for the brain. Different frequencies are associated with different states of consciousness and can have different effects on the brain.

Here are some general guidelines:

- **Beta Waves**

– Use beta waves when you need to be alert and focused.

- **Alpha Waves**

  – Use alpha waves when you need to be relaxed and calm.

- **Theta Waves**

  – Use theta waves when you want to stimulate creativity and improve memory consolidation.

- **Delta Waves**

  – Use delta waves when you want to promote rest and relaxation.

How to Change Brain Waves at Will

Changing brain waves at will is challenging, but it's not impossible. Here are some tips for changing brain waves:

- **Meditation**

  – Practicing meditation can help you learn to regulate your brain waves and enter different states of consciousness.

- **Breathing Exercises**

  – Controlled breathing exercises can help you regulate your brain waves and reduce stress and anxiety.

- **Brain-Training Games**

  – There are a variety of brain-training games and exercises that can help stimulate different types of brain waves.