

Brain activity decoder can reveal stories in people's minds

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Researchers Alex Huth (left), Jerry Tang (right) and Shailee Jain (center) 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 members of the lab, collected in an fMRI scanner. 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.'"

Actual stimulus	Decoded stimulus	
<i>i got up from the air mattress and pressed my face against the glass of the bedroom window expecting to see eyes staring back at me but instead finding only darkness</i>	i just continued to walk up to the window and open the glass i stood on my toes and peered out i didn't see anything and looked up again i saw nothing	
<i>i didn't know whether to scream cry or run away instead i said leave me alone i don't need your help adam disappeared and i cleaned up alone crying</i>	started to scream and cry and then she just said i told you to leave me alone you can't hurt me anymore i'm sorry and then he stormed off i thought he had left i started to cry	Exact
<i>that night i went upstairs to what had been our bedroom and not knowing what else to do i turned out the lights and lay down on the floor</i>	we got back to my dorm room i had no idea where my bed was i just assumed i would sleep on it but instead i lay down on the floor	Gist
<i>i don't have my driver's license yet and i just jumped out right when i needed to and she says well why don't you come back to my house and i'll give you a ride i say ok</i>	she is not ready she has not even started to learn to drive yet i had to push her out of the car i said we will take her home now and she agreed	Error

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.

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.

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."

More information: Semantic reconstruction of continuous language from non-invasive brain recordings, *Nature Neuroscience* (2023). [DOI: 10.1038/s41593-023-01304-9](https://doi.org/10.1038/s41593-023-01304-9)

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