UCSF
University of California
San Francisco

Weill Institute for Neurosciences

Department of Neurological Surgery

Chang Lab

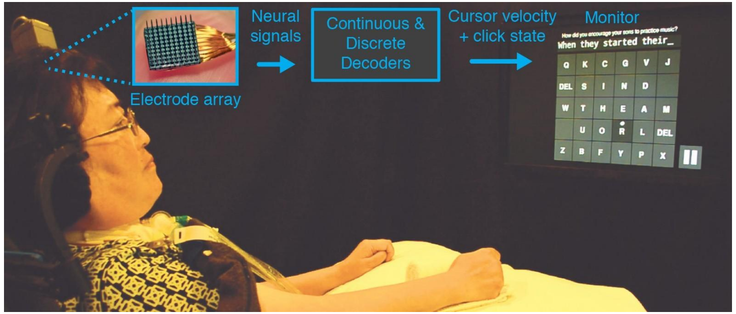
Brain-to-text technology

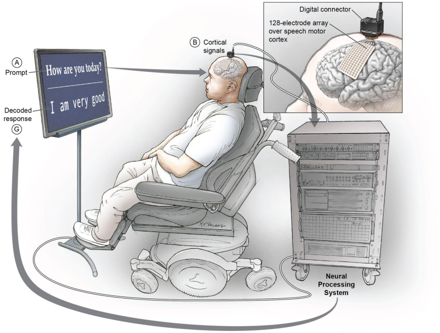
Presenters from Dr. Edward Chang's lab at UCSF:
David Moses, Margaret Seaton, Jessie Liu, Max Dougherty

CommunicationFIRST Webinar - October 19, 2022

Brain Computer Interfaces (BCIs)

- BCI technology collects neural activity directly from the brain and decodes this activity to commands which allow for control of various devices or the environment
- Communication based BCIs have the potential to
  - Restore movement and communication capabilities to individuals with impaired speech and movement due to a variety of neurological causes
  - Generally improve interactions with technological devices and the environment
  - Meaningfully improve future user independence





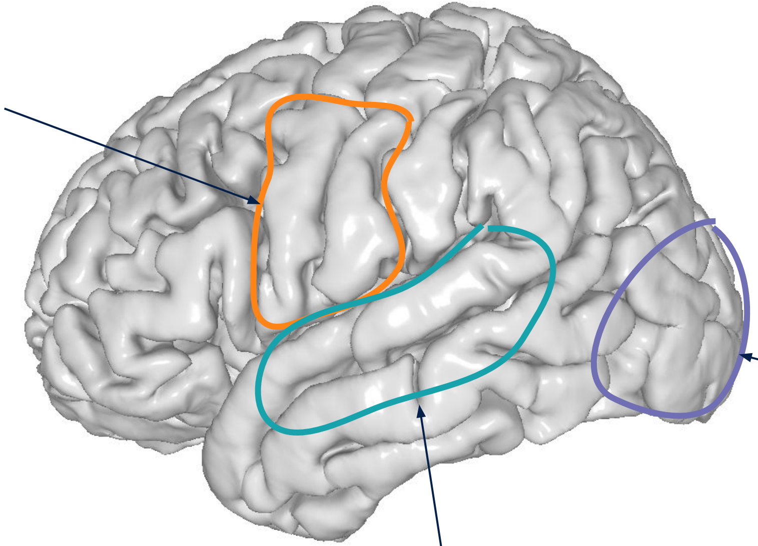
Pandarinath et al. (2017)

(Moses, Metzger, Liu et al. 2021)

Our brains act as a control center

"Cortex" means the outer layer of the brain

Motor cortex controls our voluntary movements (moving your arms, moving your mouth to speak)



Visual cortex helps interpret what our eyes see

The temporal lobe plays a role in understanding what we hear

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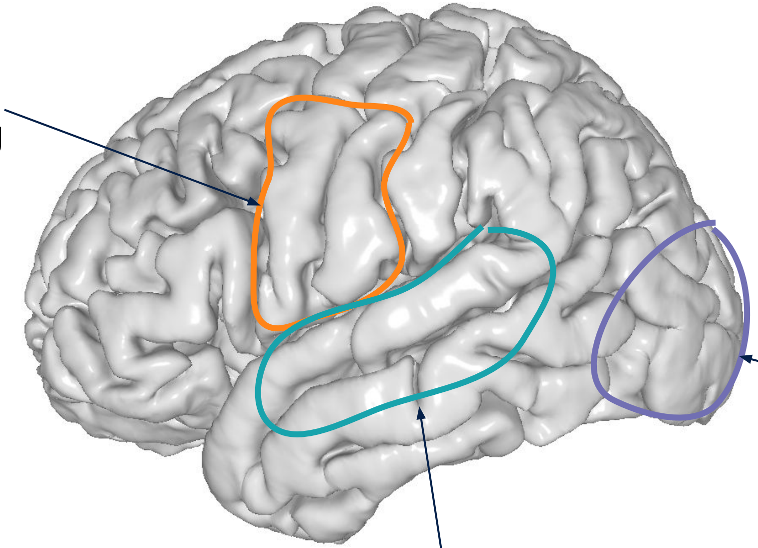
Motor cortex controls our voluntary movements (moving your arms, **moving your mouth to speak**)



Visual cortex helps interpret what our eyes see

The temporal lobe plays a role in understanding what we hear

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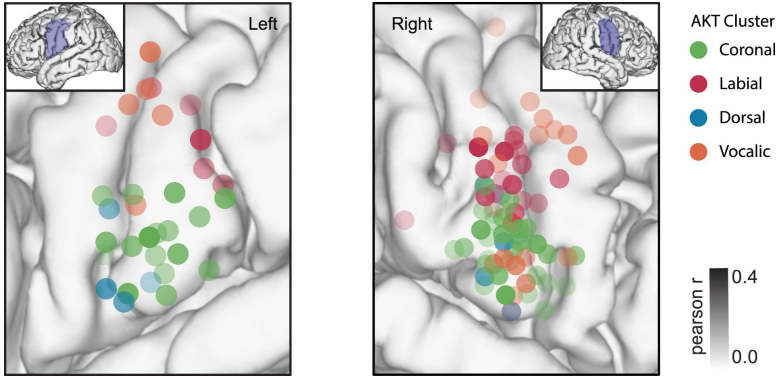
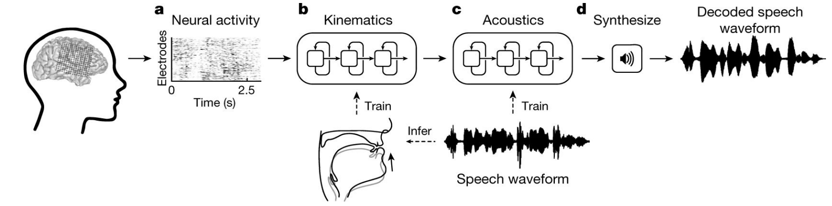
Work with epilepsy patients has helped us map the part of motor cortex that controls our face

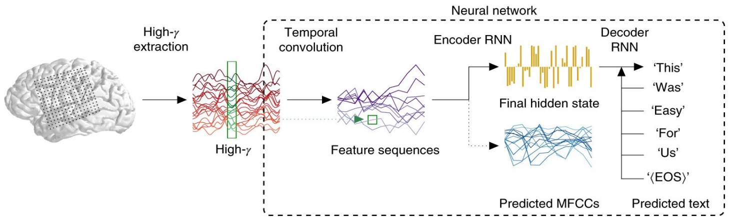
Different areas control slightly different movements



We can use this to predict what a person said out loud



Or to predict it as text on a screen



Chartier*, Anumanchipalli* et al. 2019. Anumanchipalli and Chartier et al. 2019. Makin et al. 2020.

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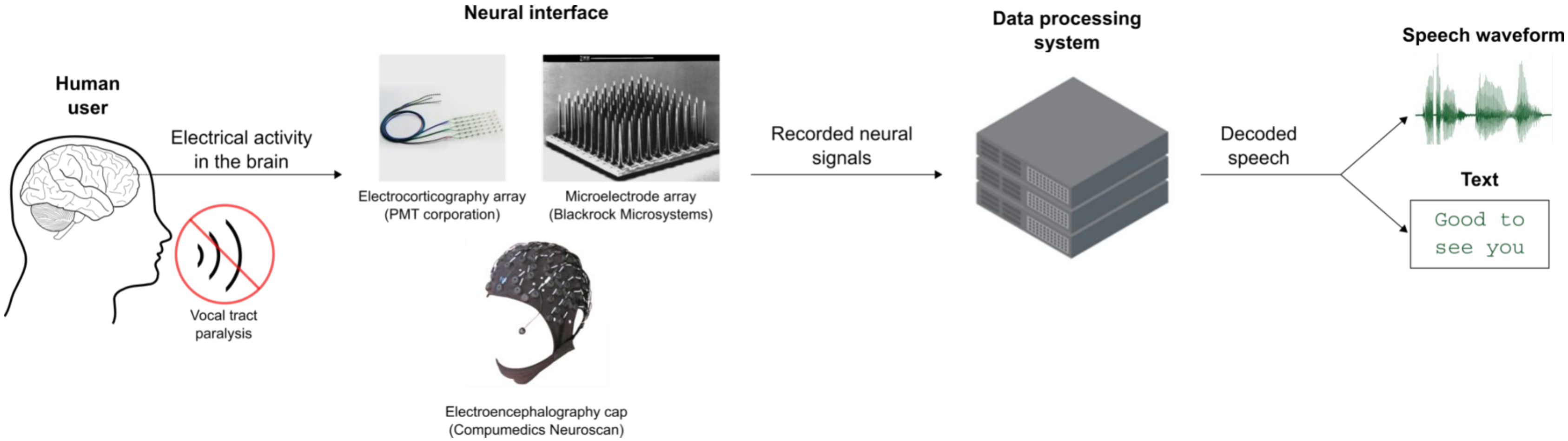
Extending our work to patients who need the technology

- All of these findings have been with able speakers.

- If a person with LIS tried to speak, would we find similar patterns in the motor cortex?

- If so, can we still use these representations to decode intended messages?

Brain-to-speech technology can help us decode the brain patterns of someone trying to speak, even if their facial muscles can't execute those patterns.



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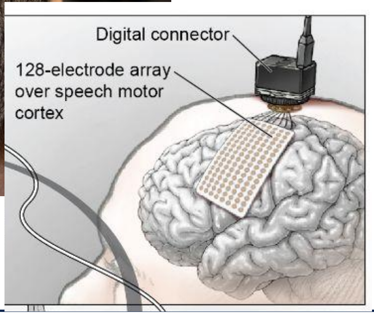
BRAVO: BCI Restoration of Arm and Voice

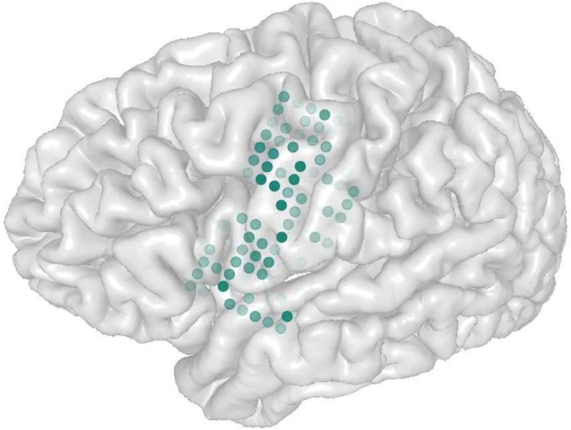
- Clinical trial jointly led by Edward Chang, MD and Karunesh Ganguly, MD, PhD at UCSF

- Chang Lab goals:
  - Study neural representations of **speech in people with paralysis**
  - Validate the **safety** and **long-term viability** of our BCI approach
  - **Develop a speech neuroprosthesis** to help these patients communicate

Electrocorticography (ECoG) records electrical activity from the surface of the brain.

Mike Kai Chen for The New York Times





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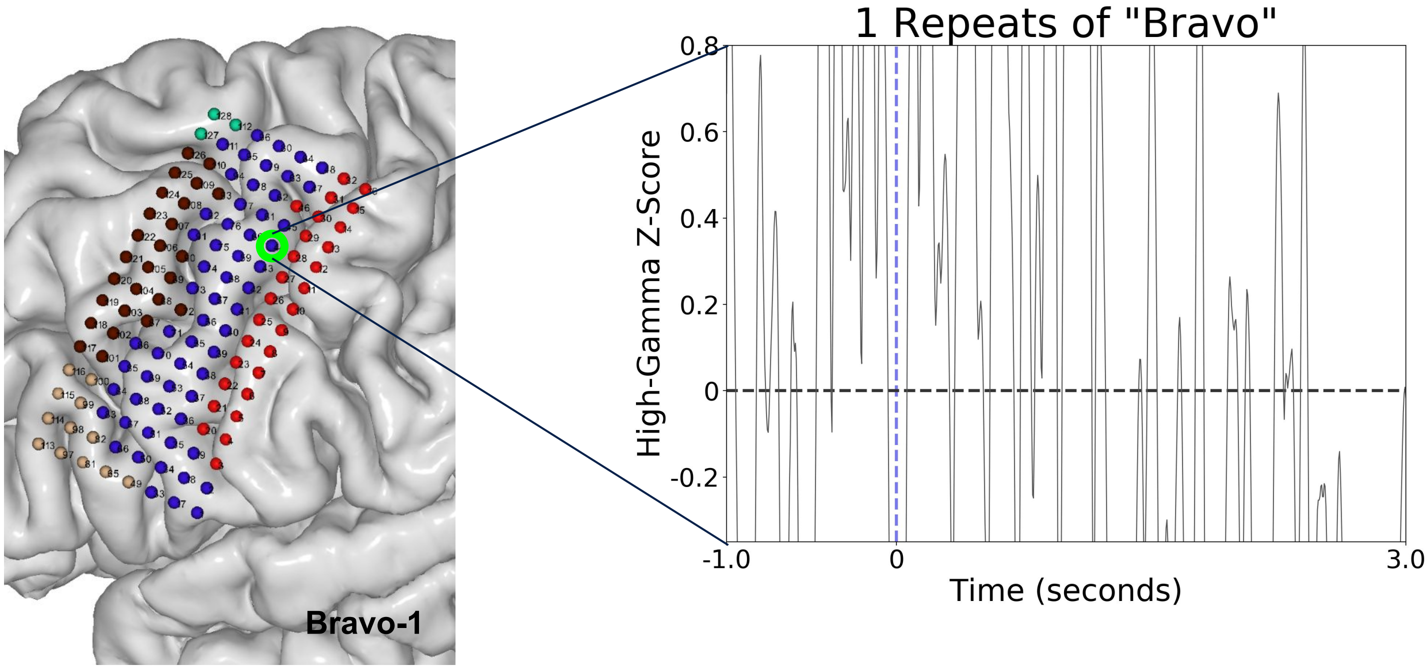
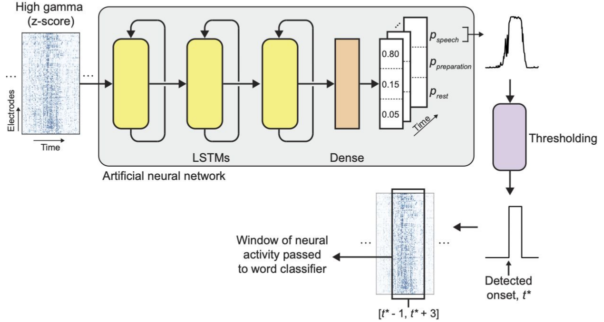
1000 snapshots of the brain captured every second

Many repeats needed for a "clear" picture



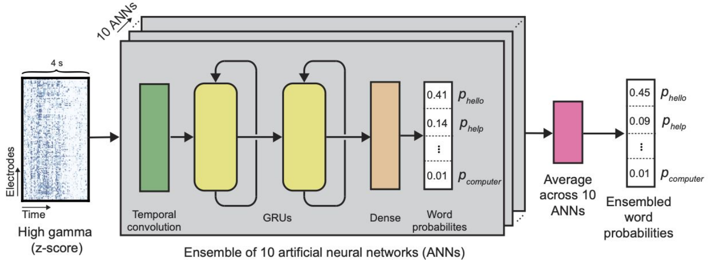
Using machine learning to decode intended speech

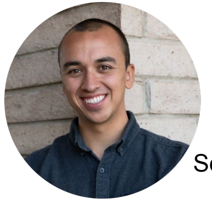
We detect speech attempts from the neural activity...



Me (Jessie Liu)

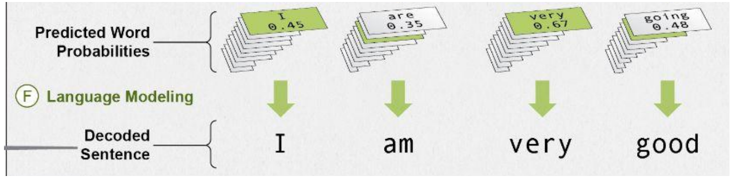
…classify which word was attempted by Bravo-1…





Sean Metzger

…and use natural language modeling to correct improbable phrases.



David Moses

UCSF

Isolated words task

Training data collected as Bravo-1 attempted to say individual words

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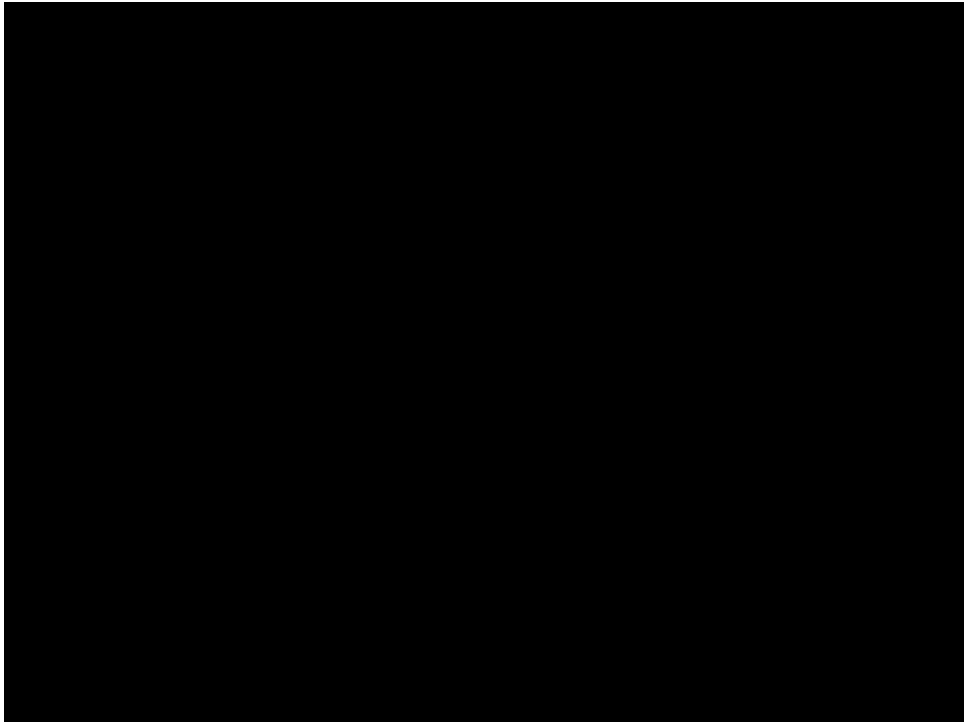
Translating Pancho's brain signals into words



[13]

13.Moses, D. A. et al. Neuroprosthesis for Decoding Speech in a Paralyzed Person with Anarthria. N Engl J Med 385, 217–227 (2021).

Decoding results

Target

Hello how are you?
I need my glasses.
Please bring my glasses here.
Yes.
What do you do?
It is comfortable.
My family is here.

[13]

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Decoding results

Target	Without LM	With LM
Hello how are you?	You am are you	Hello how are you
I need my glasses.	I need my thirsty	I need my glasses
Please bring my glasses here.	Please please my glasses good	Please bring my glasses here
Yes.	Yes	Yes
What do you do?	What do you do	What do you do
It is comfortable.	Is it comfortable	It is comfortable
My family is here.	My family is here	My family is good

Overall: ~75% accuracy at 15 words per minute

[13]

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How do we go beyond 50 words

- There's a natural way to scale up to tons of words, one that's already being used in existing assistive technology: **Spelling**

- But, we wanted to try spelling with a twist:
  - Just like how single letters might get lost due to noise over a phone line or in a loud environment, it might be hard to identify single letters in brain signals.
  - So, we had Pancho use the NATO alphabet instead!

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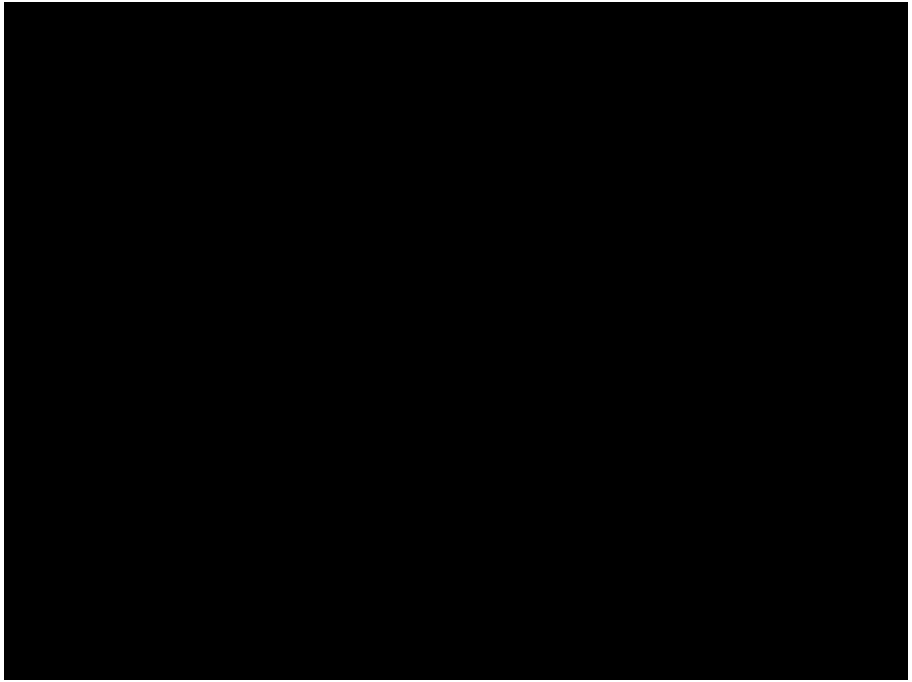
A Alpha	B Bravo	C Charlie	D Delta	E Echo
F Foxtrot	G Golf	H Hotel	I India	J Juliette
K Kilo	L Lima	M Mike	N November	O Oscar
P Papa	Q Quebec	R Romeo	S Sierra	T Tango
U Uniform	V Victor	W Whisky	X X-ray	Y Yankee
		Z Zulu		

Pancho using our system to spell



Spelling results

Only neural decoding

Idonotwantthat
Thankytu
Yeucanyaythatagain
Tellmeaboutyoulfamily
Fonftoothatagajn
Ithinkthiyibpreteygrod
Easyfomwvutrsle
Weaavetobtop
Youraiigittobekvvding

Spelling results

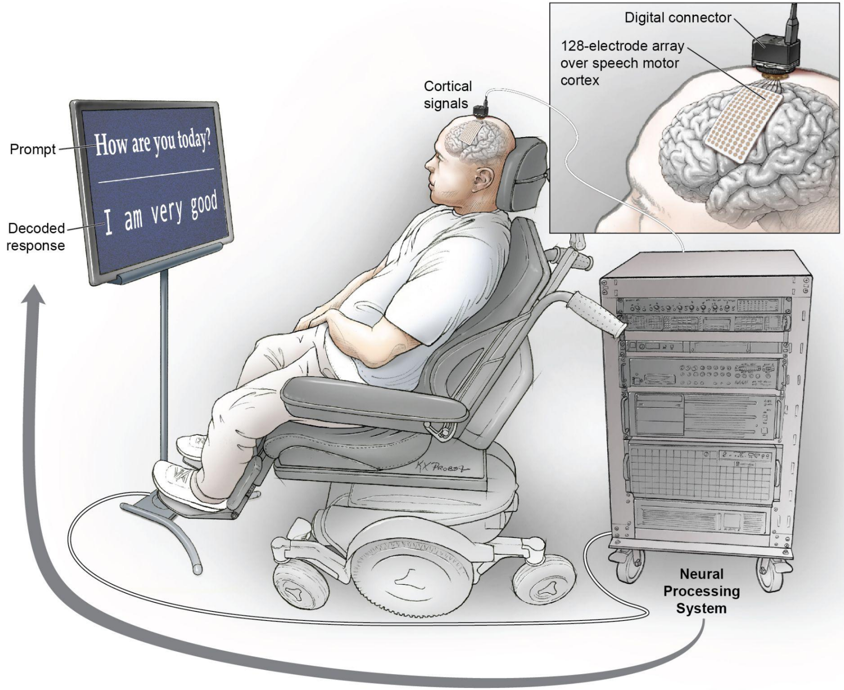
Only neural decoding	+ LM (Real-time results)
Idonotwantthat	I do not want that
Thankytu	Thank you
Yeucanyaythatagain	You can say that again
Tellmeaboutyoulfamily	Tell me about your family
Fonftoothatagajn	Do not do that again
Ithinkthiyibpreteygrod	I think this is pretty good
Easyfomwvutrsle	Easy for you to say
Weaavetobtop	We have to stop
Youraiigittobekvvding	You have got to be kidding

Overall: ~90% accuracy at 6 words per minute, with over 1,000 possible words in the vocabulary!

Next steps

Generalizability
We want to show that our approach can work for many languages, not just English!

Expressivity
We want to go from brain signals straight to a synthetic voice so that users can express themselves more than they could with just text!



Hardware design
Neural-implant hardware is constantly improving; we want to use the best hardware we can!

Validation
We want to make sure this technology can work for many people, not just Pancho!

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Thank you!