



AI Applications In BCIs

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Presentation Topics

BCIs Overview

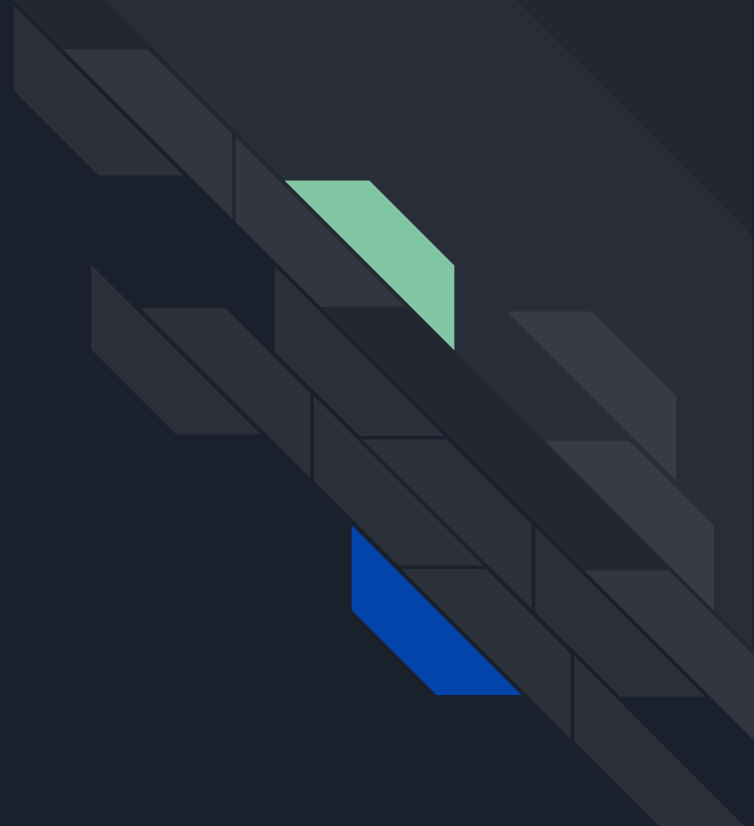
Application 1: Conversational BCI

Application 2: BCI Keyboard

Significance

What the Future Holds

Questions





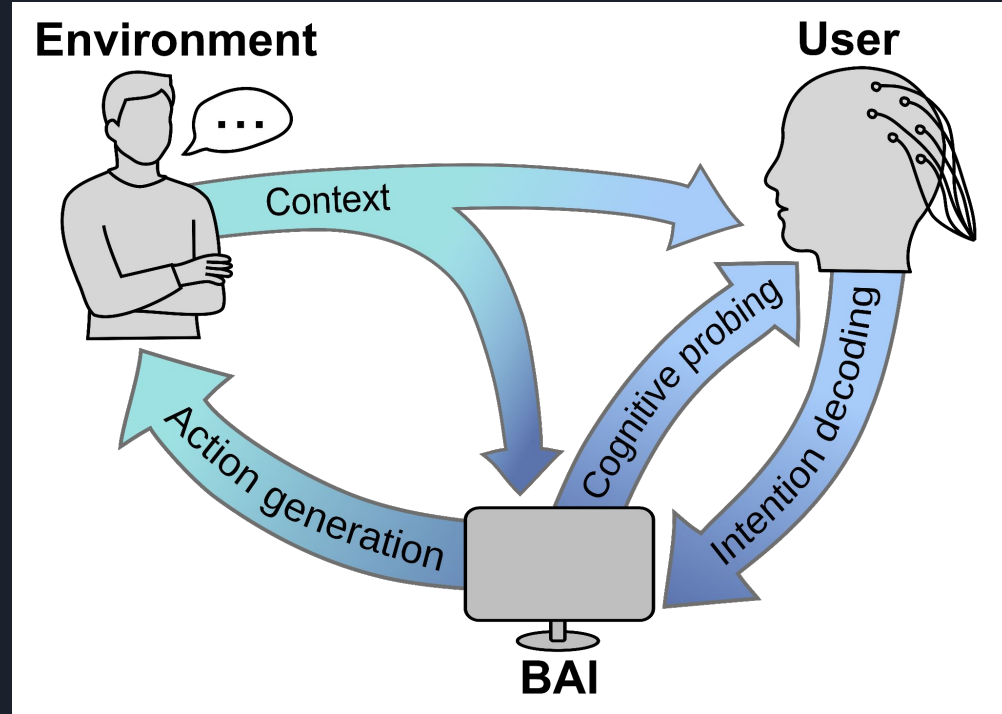
BCI Overview

BCI is a general term for any technology that directly communicates with the brain and extracts information from it for the purpose of translating neural activity into control signals for computer systems and devices.

BCIs fall into one of two classifications based on the way they interact with the brain, the first are active BCIs which act on either the users consciously induced brain activity, such as motor control, or brain activity induced by some form of external stimuli (i.e. sounds, images, smells, ect.). The second classification is passive BCIs which use the passive brain signals dictating the brain's unconscious psychological states and basic functions, which does not require any input or action from the user.

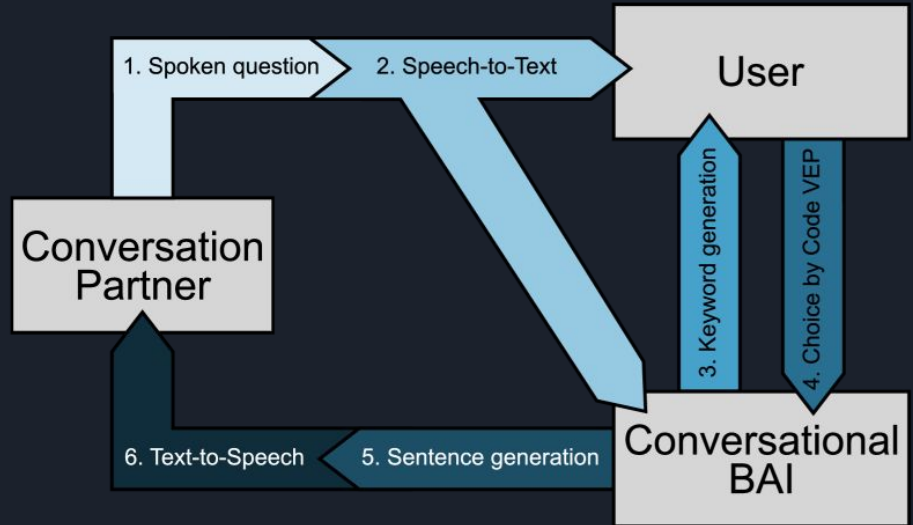
Using AI with a BCI to allow communication

- Allow people who have had a stroke to communicate
- Compensate for brain damage
- Focused on conversations that would help with being independent



How it Works

1. Conversation partner asks a question
2. Transcribed using speech to text
3. An LLM comes up with a set of 12 keywords
4. The user selects a response
5. A full response is generated based on the selected word
6. The response is converted to audio





The User Interface

The user has 6 word choices and 4 fixed choices:

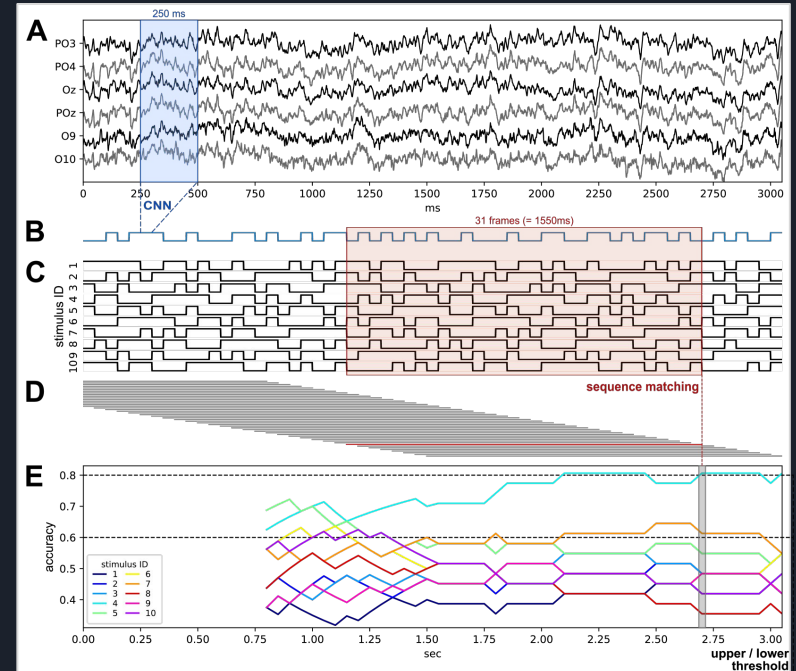
- Correction
 - Indicate a mistake was made
- More
 - Make the other 6 words available
- None
 - In case none of the options are good
- Finished
 - End the conversation

Scenario: Make a reservation for 6 people at the pizzeria for Thursday at 7pm under the name 'Oliver'.

Pizzeria romano how can I help you			Correction
Pickup	Delivery	Menu	More
Hours	Reservations	Specials	None
I would like to make reservations.			Finished

Detecting a Response

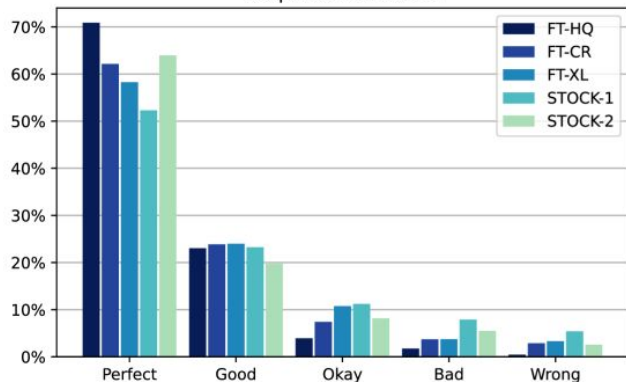
- Each word flashes at 20 Hz
- The user focuses their attention on one
- A CCN looks for the On/Off signal
- A response is recorded when the pattern of on and off matches one of the options



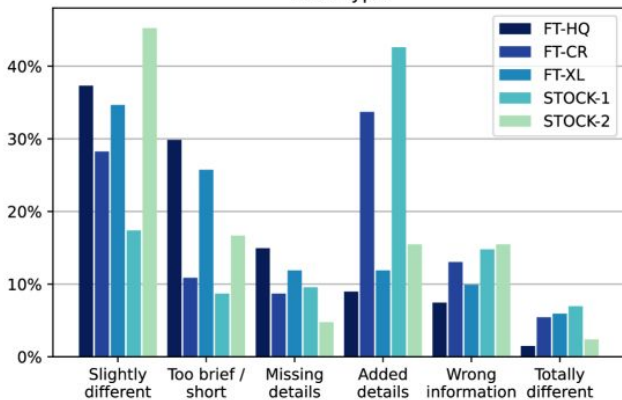
Problems with this Approach

- Does not always capture what the user wanted to say
- Can lead to confusing conversations
- Response time

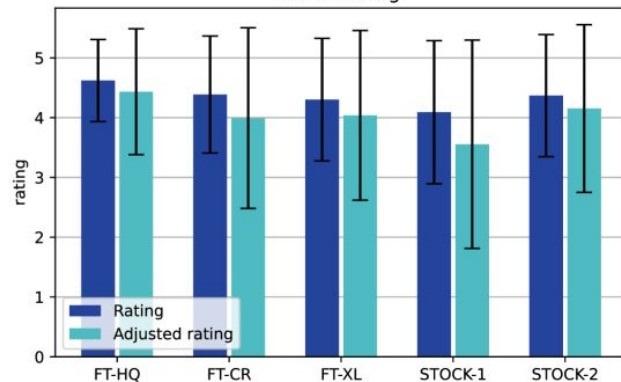
Response evaluation




Error type



Model rating





(EVAL) Call your fitness studio and schedule a session with your trainer Sophia for Tuesday morning under the name Anna Mayer.

Q: Fitness studio get fit how can i help you

KW: Join, Enroll, Sign up, Register, Schedule, Prices, Correction, More, None, Finished

A: Hello, how may I help you?

Q: I'm not sure i was hoping i could help you you called the fitness studio get fit

KW: Yes, No, Maybe, Call, Help, Get Fit, Correction, More, None, Finished

A: I am sorry, I misspoke earlier.

Q: Okay so how can i help you would you like to schedule a session

KW: Yes, No, Maybe, Schedule, Session, Appointment, Correction, More, None, Finished

A: Yes, I would.

Q: Do you already have an account with us or would you like to sign up

KW: Yes, No, Already, Sign up, Create, Existing, Correction, More, None, Finished

A: Yes, I have one.

Q: Okay what's the name of your trainer

KW: Anna, Mayer, Anna Mayer, David Mayer, Laura, Oliver, Correction, More, None, Finished

KW: Peter, Sophia, Tim, Marianne, Maria, Felix, Correction, Previous, None, Finished

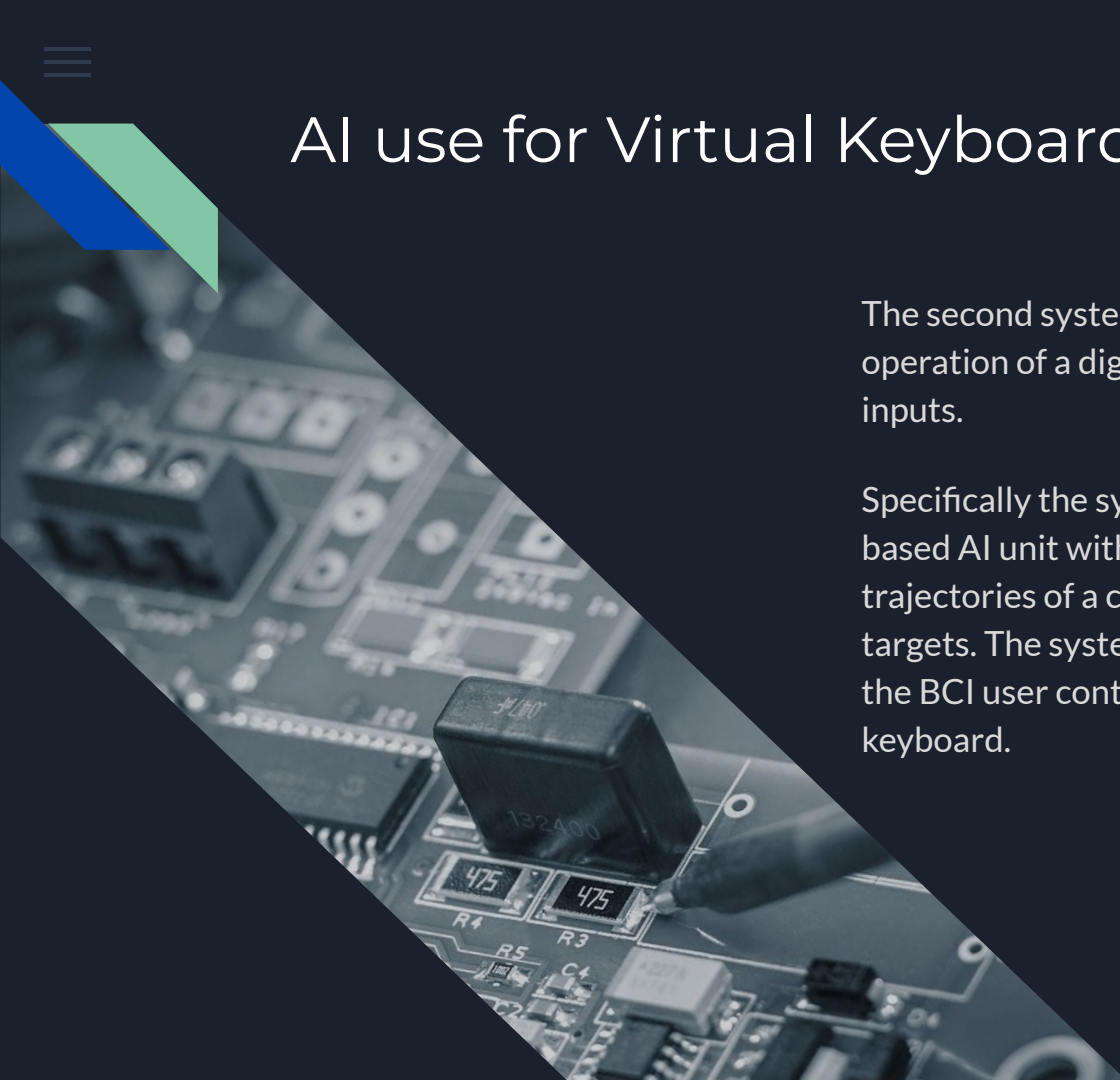
A: Sophia.



AI use for Virtual Keyboard BCIs

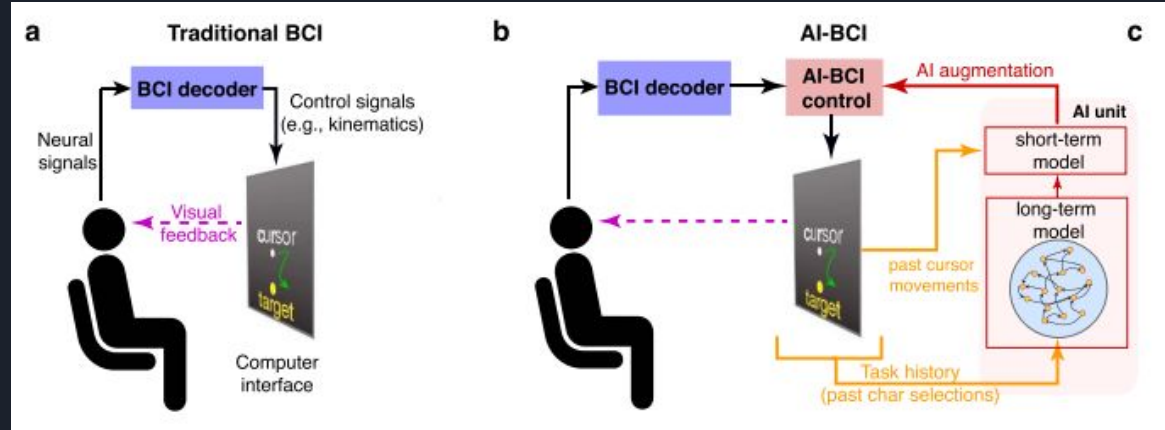
The second system is a BCI designed to allow for the operation of a digital keyboard and mouse via neural inputs.

Specifically the system implemented a deep learning based AI unit with a potential field to guide the trajectories of a computer cursor on screen to different targets. The system was applied to a typing task, where the BCI user controls a virtual cursor to type on a keyboard.

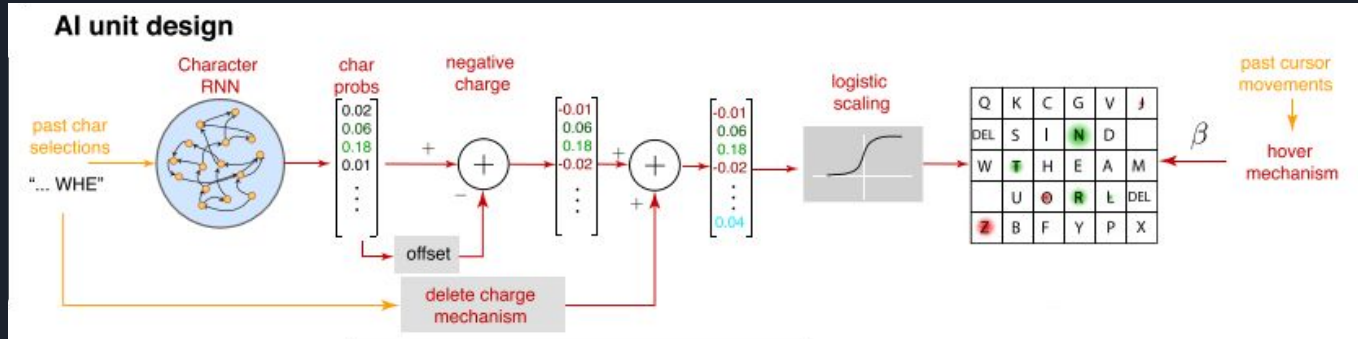


Implementation

Rather than having the AI receive neural information prior to or during the the BCIs decoding stage, where it would usually help with the decoding or classification of the neural inputs, this system forgoes the AI using neural inputs at all, instead opting to have the AI receive the processed results of the decoding and focusing on improving the computer functions of the BCI rather than the brain ones.



How it Works



The purpose of the implemented AI was to model and weigh two different key types of information with relevance to the task, and then use that to adjust the cursor movement trajectories accordingly. For the task of moving a cursor there are two relevant types of information that have bearing on the cursor's movements, Long-term Temporal Dependencies, and Short-term Temporal Dependencies.



Long-term Temporal Dependencies

This refers to how previous movements and selections over a longer period of time, (i.e. previously typed words or even sentences) may influence the probability of the next character selected.

Due to these dependencies being mapped over a larger time scale, the system employs long short-term memory (LSTM) recurrent neural networks (RNNs) for word and character prediction.

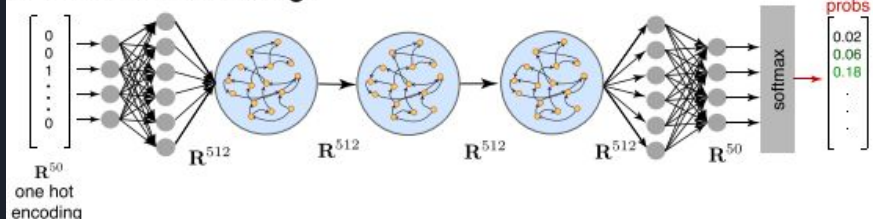
Short-term Temporal Dependencies

This reflects the active movements of the cursor and weight its movements using a potential field and a hover mechanism.

For example, if the user has already typed 'WHE', highly probable next characters include 'R' and 'N'. If the user is moving away from 'R' and towards 'N', then the AI shared control system should cause the trajectory to move more strongly towards 'N'.

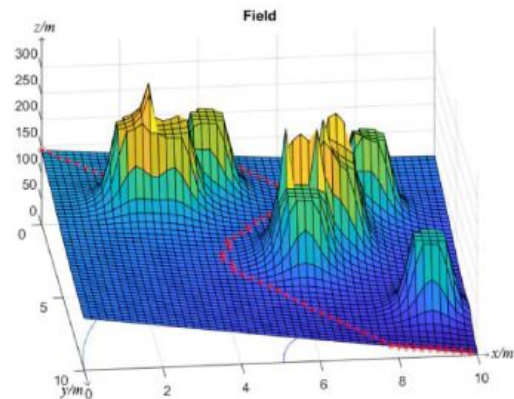
Long-term Temporal Dependencies

e Character RNN design



The character RNN comprises three long short-term memories (LSTMs), each with 512 hidden units. The output of the last LSTM passes through a fully connected layer, which leads to softmax probabilities over next characters

Short-term Temporal Dependencies



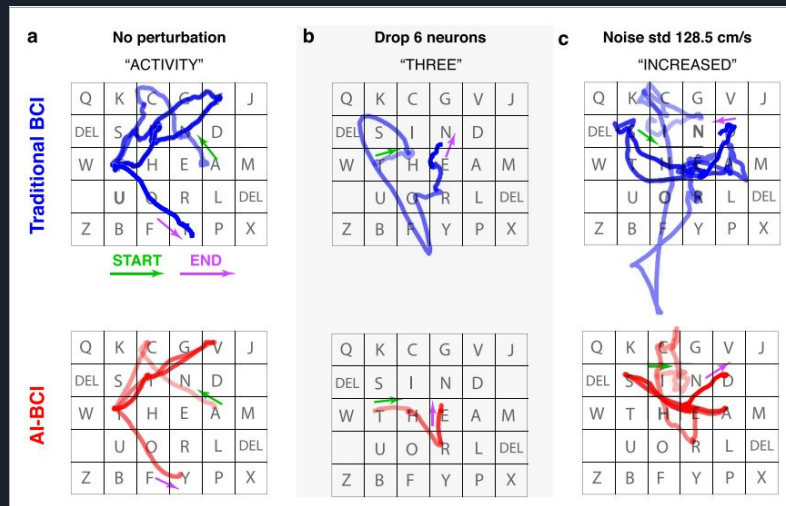
A potential field is a mathematical model that assigns a “potential energy” value to every point in space. Objects or agents within the field experience a force that pushes them toward lower potential values like a ball rolling downhill. Less likely characters will have their potential increased, making them less attractive while more likely characters will have their potential decreased making them more attractive

How Did It Work

The AI-augmented BCI achieved higher information communication rates.

It produced quicker ballistic (large) movements between targets and improved precision when locking onto a target.

The trajectory efficiency improved, less wasted motion, more direct paths.





Significance

- Allowing people who otherwise couldn't to communicate and interact with technology
- Using AI helps get around the limitations of current BCI technology
 - Current BCI performance is often not sufficient for real-world use, AI can improve speed, precision, and reliability



What the Future Holds

- Improved tools to allow more accurate interactions
- Making these tools available to those who need them
- Other BEI systems for alternative interactions
 - Reading words directly from the intention to speak
 - Controlling a mouse for other more general applications
- Advancements in both invasive and non-invasive BCIs
- Smarter more adaptive neural information decoding
 - Custom neural interfaces that learn your specific brain



Thank you!



Sources

A. Meunier *et al.*, “A Conversational Brain-Artificial Intelligence Interface,” Mar. 14, 2024, *arXiv*: arXiv:2402.15011. doi: [10.48550/arXiv.2402.15011](https://doi.org/10.48550/arXiv.2402.15011).

S. Olsen, J. Zhang, K.-F. Liang, M. Lam, U. Riaz, and J. C. Kao, “An artificial intelligence that increases simulated brain–computer interface performance,” *J. Neural Eng.*, vol. 18, no. 4, p. 046053, Aug. 2021, doi: [10.1088/1741-2552/abfaaa](https://doi.org/10.1088/1741-2552/abfaaa).