# A closed-loop brain-computer interface that synthesizes intelligible words for a clinical trial participant with amyotrophic lateral sclerosis

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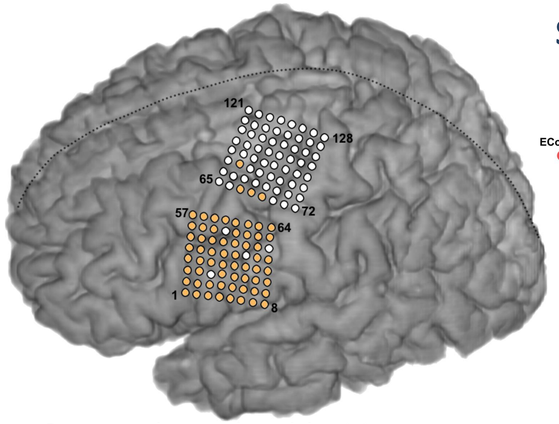
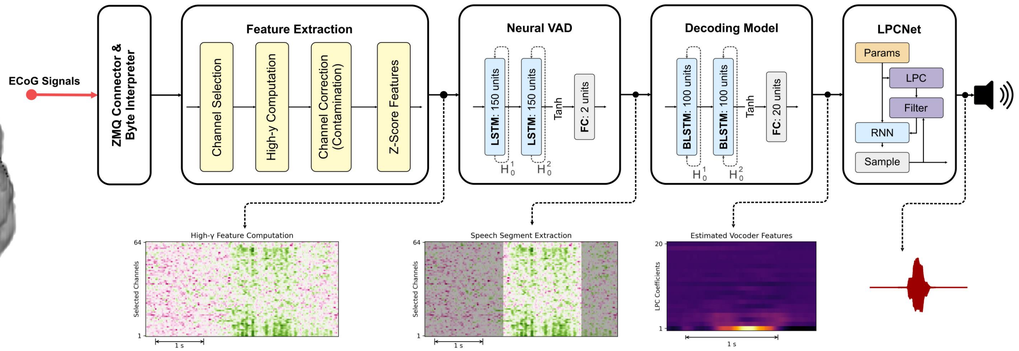
Preprint

## Motivation

- Neurological disorders such as ALS can weaken muscles critical for speech
  - Reduced intelligibility or loss of speech altogether
- Implantable Brain-Computer Interfaces (BCIs) can potentially restore acoustic speech
  - By translating neural signals from speech production directly to acoustic waveforms
  - If speech is still possible, can use it for acoustic target in machine translation
- Many studies and models focus on epilepsy patients being monitored in EMU
  - Recover acoustic speech signals retrospectively
  - Not exposed to same challenges when it comes to real-time usage
  - Different neurological disorder
- Online speech synthesis from participant with amyotrophic lateral sclerosis (ALS)
  - Study participant enrolled in ongoing clinical trial (ClinicalTrials.gov, NCT03567213)
  - Approved by the Johns Hopkins Institutional Review Board (IRB) and the FDA under an investigational device exemption (IDE)
  - Speaking capabilities gradually deteriorating, individual words often intelligible

## Speech synthesis approach



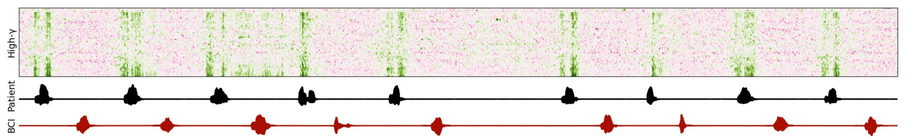

**Deep neural network model training:**

- Extraction of time-aligned neural and acoustic frames across training days
- High-gamma (High-Y) activity features (70-170Hz) from ECoG signals
- Voice activity detection (VAD) information for each frame for neural VAD
- Linear Predictive Coding (LPC) coefficients for LPCNet vocoder

**Inference:**

- Real-time streaming system on top of node-based computational graph
- ECoG signals are streamed via BCI2000 and converted to High-Y activity
- Neural VAD identifies segments of spoken speech in High-Y activity
- Decoding model estimates vocoder features used for waveform generation

## Experimental Design

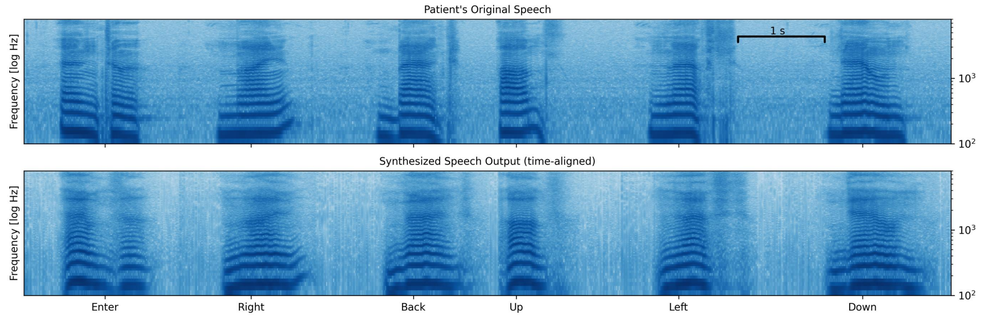

**Data Collection:**

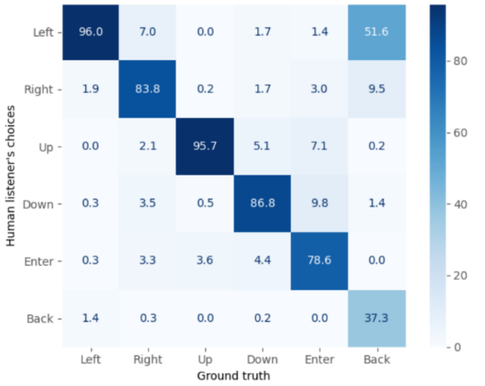
- Single words from a 6-word vocabulary
- Presented on screen in front of participant
- Participant instructed to read them out aloud
- Data normalized on day-specific calibration data

**Online speech synthesis**

- Participant repeats experiment
- Synthesized audio is played back
- Simultaneously, stored on disc for offline evaluation

## Results




- Evaluation of the intelligibility of the synthesized speech indicates that many words can be correctly recognized by human listeners (80%), share similar characteristics to original speech
- Our results provide further evidence that previous speech BCI demonstrations with epilepsy patients may be generalizable to speech-impaired individuals, particularly those with ALS.

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