A Quickly Trainable Electrocorticographic-Based Click Detector is used for High Performance Long-Term Switch-Scan Spelling

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Introduction

Recent brain-computer interface (BCI) studies have shown that electrocorticographic (ECoG) activity can be used to generate computerized "brain clicks" for controlling assistive devices like spelling applications [1,2]. Here a clinical trial (ClinicalTrials.gov, NCT03567213) participant with ALS was implanted with high density (HD) ECoG covering sensorimotor cortex. The participant generated brain clicks by attempting to make grasping movements and used these to select letters and words to spell sentences using a custom switch-scanning spelling application. The click detection model improved on the accuracy and latency of previous studies.

Main Findings

- High density (4-mm pitch) ECoG over upper-limb cortex.
- Long-term (90 days) click detection via attempted grasp using a classification model trained on a small amount of ECoG data (44 min).
- Switch-scanning spelling application with predictive language model
- Improved accuracy of click detection (98%) and click latency (680 msec) compared to previous BCI studies using fewer ECoG electrodes.

Methods

We sought to test the performance and long-term stability of click-decoding using a chronically implanted HD-ECoG BCI with coverage of the sensorimotor cortex in a human clinical trial participant (ClinicalTrials.gov, NCT03567213) with amyotrophic lateral sclerosis (ALS).

We enabled the participant to initiate clicks for a spelling interface (Fig. 1h). A click refers to a discrete event used for binary functional control, caused by a transient increase in neural activity [1]. The participant "clicked" by attempting a brief grasping motion with his right hand (contralateral to the implanted grid). To detect clicks, we used high gamma (HG) power (110-170 Hz) from all 128 electrodes, fed into an RNN-based model for detecting rest or grasp. A 1 min baseline calibration period, recorded on the same day of BCI use, was used for normalizing the HG power.

We used a switch-scanning paradigm, which allowed the participant to click on a desired row, then column, as they were sequentially highlighted (Fig. 1h). The participant was instructed to use clicks to copy-spell sentences [3] visually shown to him on-screen. We also used a predictive language model to allow the participant to select buttons with the most likely next letters or words given what he had spelled.

The grasp vs. rest classification model was trained on data collected from a "Go" task, in which the participant was instructed to attempt a brief grasping motion with his right hand during each trial as soon as the word "Go" appeared on screen. In total, 44 min of data from four days spanning a 15-day period were used for model training. After training, the model weights remained fixed over 90 days of BCI use.

Results

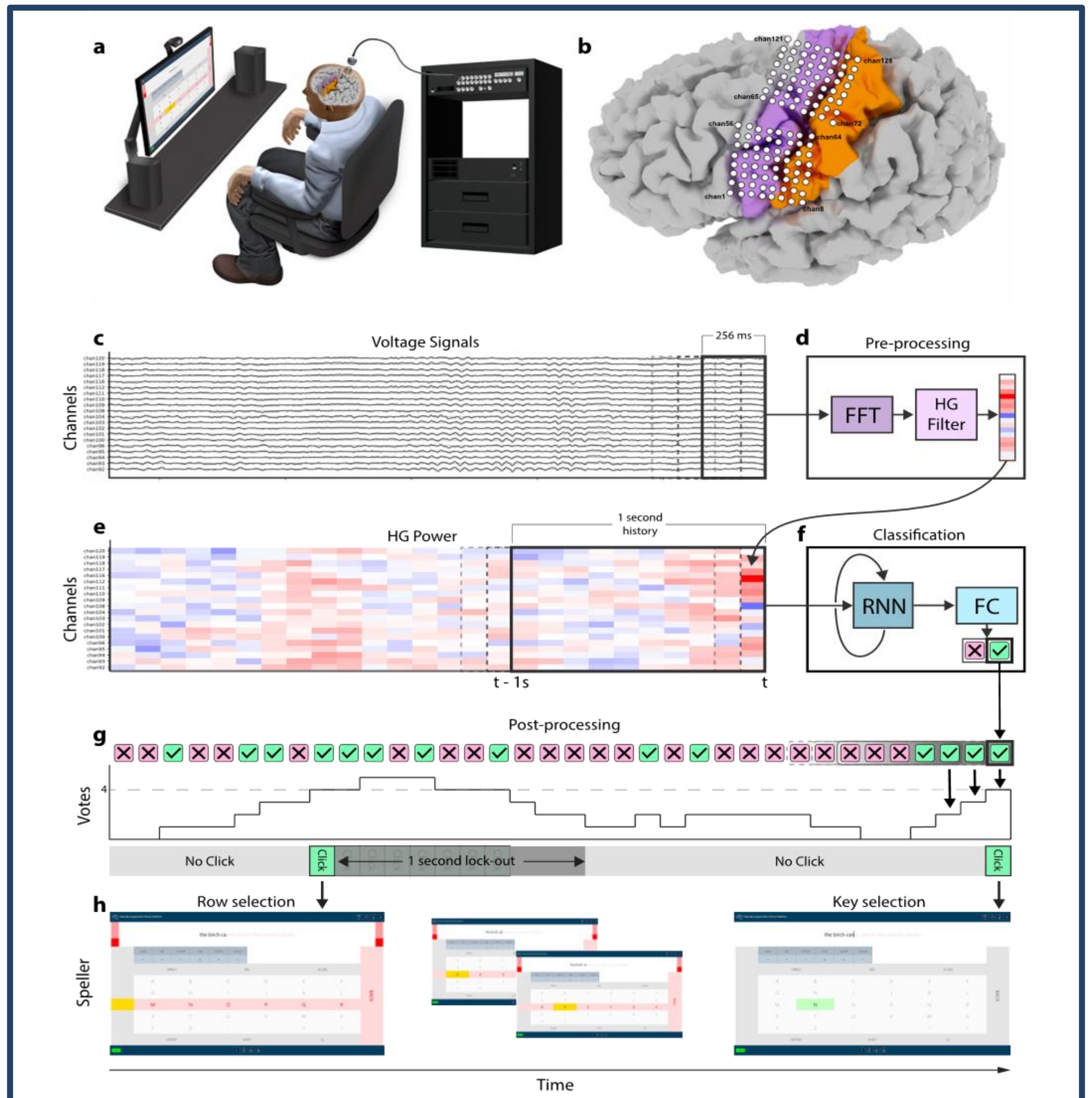

Figure 1. Real-Time Click Detection Pipeline
(a) The participant using the switch-scanning speller application. **(b)** Two 64-electrode grids covered cortical upper limb and face regions. **(c)** ECoG voltage signals (channel subset shown) were streamed in 10- ms packets to update a 256-ms buffer. **(d)** An FFT computed the spectral power from which the HG log-power was placed into a 1-s buffer and used as time history for the recurrent neural network (RNN) **(e)**. **(f)** An RNN-fully connected network predicted rest or grasp every 100-ms. **(g)** Each classification (vote) was stored in a 7-vote buffer where the number of grasp votes had to surpass a voting threshold (4-vote threshold shown) to initiate a click, followed by a 1-s lock-out period to prohibit consecutive clicks. **(h)** Clicks were used with the switch scanning speller to select a row or an element within a row.

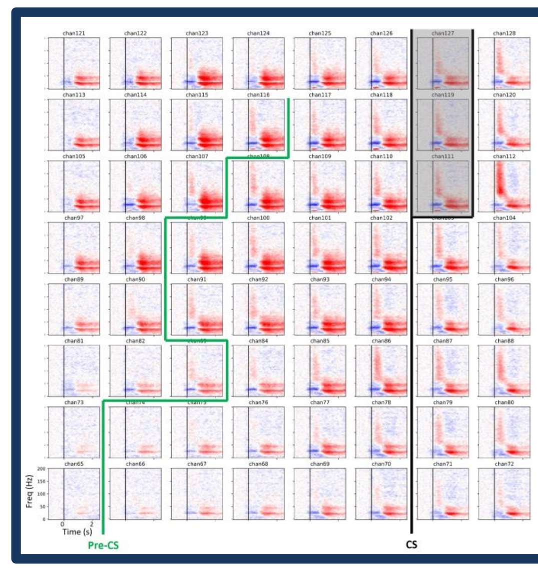

Figure 2. Spectrogram During Attempted Grasp
Trial-averaged spectrogram for all electrodes in the upper-limb grid (-1 to 2.5 s, movement-aligned) during one block of spelling. Spectral power at each frequency was standardized to pre-stimulus baseline. Channel 112 was especially active. The central and pre-central sulci are delineated by thick black (CS) and green lines (Pre-CS), respectively.

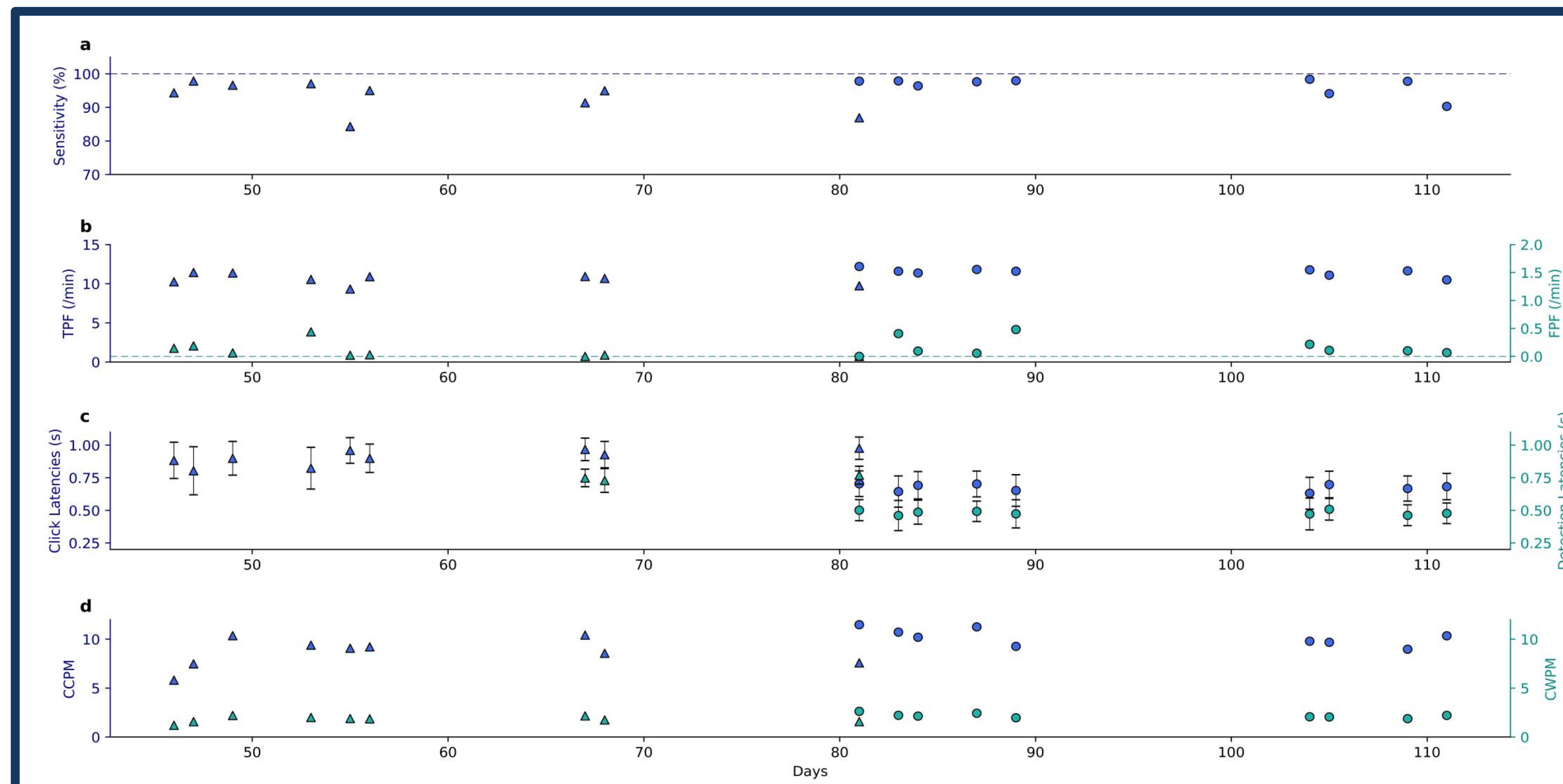

Figure 3. Spelling Performance
Across all subplots, triangular and circular markers represent metrics for 7-vote and 4-vote voting thresholds, respectively. **(a)** Sensitivity of grasp detection for each session. **(b)** True-positive and false-positive frequencies (TPF and FPF) measured as detections per minute. **(c)** Average latencies of grasp onset to algorithm detection and to on-screen click. On-screen clicks happened ~200 ms after detection. **(d)** Correct characters and words per minute (CCPM and CWPM).

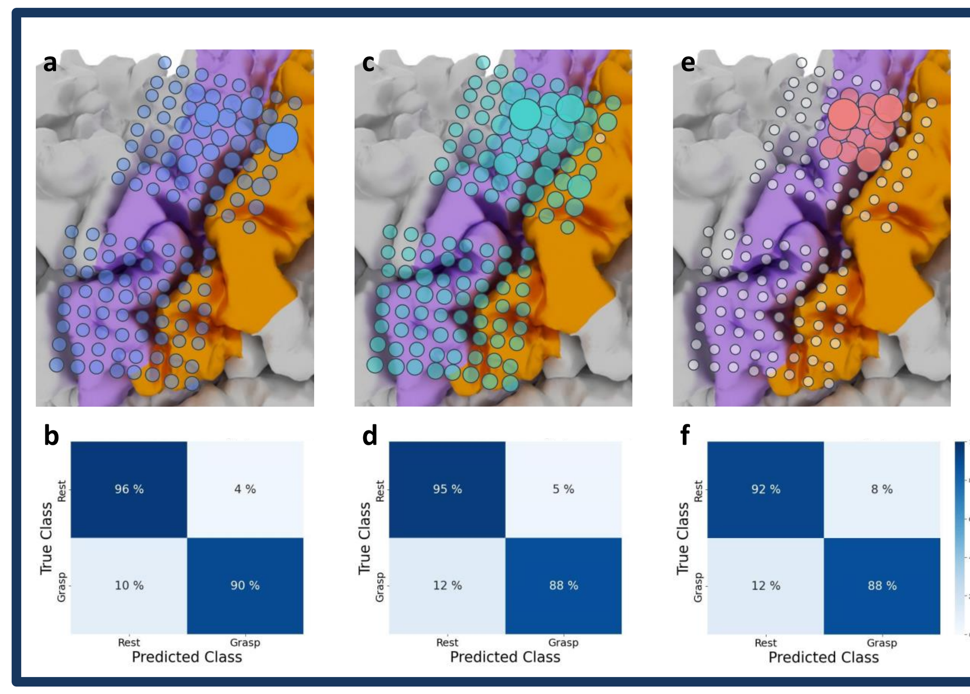

Figure 4. Saliency Maps
Saliency maps for the model used in real-time, a model using HG features from all channels except from one (channel 112), and a model using HG features only from channels covering cortical hand-knob are shown in **(a)**, **(c)** and **(e)**, respectively. Mean confusion matrices of classification of Rest vs. Grasp from repeated 10-fold cross-validation using models trained on HG features from all channels **(b)**, all channels except for channel 112 **(d)**, and channels covering only the cortical hand-knob **(f)**.

Conclusions

Long-term click detection is possible using an attempted grasp vs. rest classification model trained on a small amount of data. Our study suggests that high density ECoG of upper-limb cortex allows good click detection accuracy and latency while maintaining low false positive detections over a period of 3 months. Robust brain click detection coupled with a predictive switch-scanning application can allow high spelling rates over extended BCI use periods in people living with ALS.

References

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