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Reliable BMI control using epidural ECoG by an hemiplegic user

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Introduction: Currently, most of invasive brain-machine interfaces (BMI) rely on signals recorded using electrodes implanted intra-cortically or subdural electrocorticography (ECoG) arrays. Barring a few studies [1,2], epidural electrodes–often used for chronic stimulation to alleviate neuropathic pain—are seldom used for this purpose. Here we report their use to successfully control a brain-machine interface over several days.

Methods: Experiments were performed with a 50 years old male patient who suffered a left brachial plexus avulsion 30 years prior to the surgery and recordings leading to a complete left arm plegia. Two epidural leads (4 channels each) were implanted above central sulcus on the primary motor and sensory cortex contralateral to the plegic hand to apply epidural stimulation to treat deafferentation pain. Contact leads were temporarily externalized for 9 days allowing recording and decoding of cortical activity during attempted movements.

Five experimental sessions were performed (1, 3, 4, 8 and 9 days after the operation). The subject was asked to attempt to move his plegic hand as if controlling the cursor with a mouse towards one target location in a screen. After a cue shows the target the subject should wait until it becomes green before starting the movement, then stopping once the target is reached (Fig 1 *Left*). Each session lasted less than 2 hours and yielded about 80 trials.

ECoG signals were recorded at a sampling rate of 512 Hz (8 channels corresponding to the 2 implanted leads; reference and ground electrodes located at the two mastoids). Data was processed in real time by extracting the spectral power in the range of 2-40 Hz. Data from the first day was used to train an initial classifier to discriminate between resting and movement periods. From the second day onwards, the classifier output was used to control the movement of the cursor. Whenever the classifier identified the neural activity as corresponding to the movement, the cursor was displaced towards the target location. Before each session, the classifier was updated using the data from previous sessions to assess the stability of the decoder.

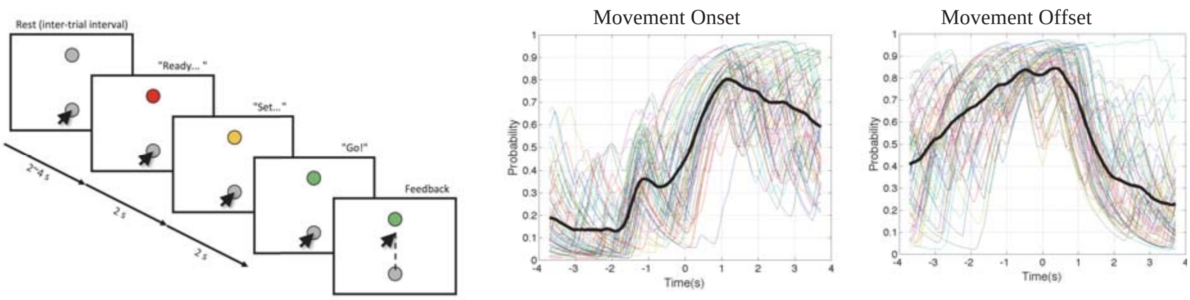

Figure 1. *Left: Experimental protocol. Middle & Right; Online movement decoding (one session: 60 trials). Y-axis shows the decoder output (A value of 1 corresponds to movement detection). Thin lines: Single trials. Thick line: Average across trials. In the Middle and Right plots t=0: corresponds to movement onset and offset, respectively.*

Results: Discriminant movement-related modulations were found in the mu band (8-12 Hz). Activity in this band allowed consistent recognition of attempted movements (onset and offset) in all trials (Fig. 1 *Middle*,*Right*). Critically false detections (i.e., movements detected after the warning but before the GO cue) were below 6%. Remarkably, the subject exhibited reliable BMI control since the first online session, achieving tasks of increasing complexity over days (data not shown due to space limitations). Importantly, classifiers were trained on the data of previous days without any recalibration on the same day, showing that the selected features are highly reliable and stable across days and that the subject could rapidly acquire a level of control.

Discussion: Neural activity from epidural ECoG can be successfully used to control a BMI device. Accurate and stable detection of movement attempts was achieved across several days by a subject suffering from hemiplegia for three decades. Online feedback enabled the subject to complete tasks of increasing complexity over days.

Significance: Epidural ECoG yielded reliable information to decode attempted movement of the plegic limb in a subject who has been paralyzed for over 30 years. This supports using epidural ECoG as a reliable, less invasive, alternative for BMI.

References

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