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Optimizing feature selection for word decoding with high-density ECoG

Julia Berezutskaya[1*], Lennart Müller[2], Erik J. Aarnoutse[1], Zachary V. Freudenburg[1], Nick F. Ramsey[1], Mariska J. Vansteensel[1]

[1]Brain Center, Department of Neurology and Neurosurgery, University Medical Center Utrecht, Utrecht, the Netherlands; [2]University of Aachen, Germany

*P.O. Box 85500, 3508 GA Utrecht, the Netherlands. E-mail: y.berezutskaya@umcutrecht.nl

Introduction: Speech decoding remains one of the key applications of brain-computer interface (BCI)technology in individuals with severe motor paralysis. Latest work has demonstrated successful decoding of phonemes, words and full sentences from high-density electrocorticography (ECoG) brain activity. Undoubtedly, many factors contribute to high accuracy of decoding, yet for the purposes for developing long-term fully implantable BCI devices, in this study, we focus on two factors: 1) the number of intracranial electrodes necessary for obtaining best decoding results, and 2) the location of best performing electrodes on the human cortex. The goal of this study is to optimize the channel selection procedure for high-accuracy word decoding and to identify where best performing electrodes are located.

Methods and Results: Five able-bodied Dutch human participants underwent temporary implantation with 128-channel high-density (1 or 1.2 mm diameter) ECoG grids over the sensorimotor cortex. Each participant performed a word production task, in which they pronounced twelve individual Dutch words ten times. Microphone speech data was obtained simultaneously with high-density ECoG activity, and we ensured that no audio contamination of ECoG data took place. Per subject, using high-gamma component of brain activity (70-170 Hz), we trained a word decoder using a linear support vector machines and a leave-one-out cross-validation scheme. The decoder was set up to prevent overfitting by optimizing its regularization hyperparameter. The resulting accuracy varied considerably across subjects: .83, .73, .63, .87 and .39 (chance is 8%) for subjects S1, S2, S3, S4 and S5, respectively.

For channel selection, we used various versions of recursive feature elimination (RFE) that iteratively dropped one channel at a time based on different signal properties of the channel and the decoder weights. We found that in all subjects, decoding accuracy increased by at least 10% after the channel selection resulting in values of .98, .87, .72, .98 and .60 for S1, S2, S3, S4 and S5, respectively. Per subject, no more than 32 electrodes were needed to achieve this results.

Channel distribution on the cortex varied but appeared to favor electrodes placed over the ventral sensorimotor cortex (face area, both on the motor and somatosensory side). In addition, we explored an alternative channel selection approach with constraints of a smaller grid that is more likely to be used in a long-term BCI implant. For this, we slid a mask of 8x4 electrodes (vertical and horizontal placement) over the full 128-channel (16x8) grid and retrained the decoder on subsets of channels in the mask. The resulting accuracy was somewhat lower compared to the distributed RFE approach: .95, .84, .66, .95 and .54 for S1, S2, S3, S4 and S5, respectively. In all subjects, it covered the ventral sensorimotor cortex (face area). A vertical mask placement that covered inferior dorsal motor cortex was preferred.

Significance: The present study suggests that 1) the use of fewer electrodes may be a powerful way to improve classification results, and 2) both ventral and inferior dorsal parts of sensorimotor cortex may contribute to the best decoding performance. The results of this work will serve as guidance in planning BCI device implantation and positioning of ECoG electrodes for ensuring best speech decoding results. Furthermore, these results improve our understanding of neural signals in relation to decoding for BCI and overall contribute to the discussion about speech motor processing in the brain.

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