Connectivity Analysis of Human Cortical Networks for Mapping and Decoding

by

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Abstract

During cued speech and movement, information propagates from primary sensory areas, through association areas, to primary and supplementary motor and language areas. Traditionally, the neural activity in each region has been probed independently at the level of individual neurons or small neuronal populations. This approach suffers from a lack of information about how different neuronal populations interact to relay information through the cortical network, actuate movement or speech, and monitor feedback. Recently, however, advances in computational capacity have permitted the modeling of dynamic neural propagation with high spatial and temporal resolution. These dynamic network models may contain new information about processing that can inform cortical mapping for clinical and scientific purposes, or improve the ability to decode movement or speech from neural signals. Such decoded movement or speech may be used as a control signal for brain machine interfaces.

This dissertation explores the utility of time-varying neural connectivity features for mapping the neural correlates of movement and speech, and decoding movement and speech from neural signals. All neural data are recorded from human subjects using electrocorticography, and the directional flow of neural activity is computed with multivariate autoregressive models. First, I characterize motor connectivity maps during hand movement, and demonstrate that connectivity computed from both temporal and spectral features varies with movement. Then I compare a grasp decoder based on traditional neural features to one based on connectivity features, and show that the connectivity-based decoder improves on the performance of the traditional decoder. Next, I characterize connectivity networks during speech, and use them to show that top-down modulation of neural processing may contribute to behavioral priming. Finally, I decode articulatory features during speech using traditional and connectivity features at multiple spatial scales (clinical ECoG and microECoG). I show that connectivity features within and between these spatial scales can improve speech decoding. This work demonstrates that effective connectivity models computed from human neurophysiological data are a rich source of features with the potential to improve both clinical and scientific mapping of the cortical activity underlying movement and speech, and brain machine interfaces that decode control signals from cortical activity.

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