THESIS DEFENSE

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Neural dynamics and interactions in the human ventral visual pathway

Abstract:

The ventral visual pathway in the brain plays central role in visual object recognition. The classical model of the ventral visual pathway, which poses it as a hierarchical, distributed and feed-forward network, does not match the actual structure of the pathway, which is highly interconnected with reciprocal and non-hierarchical projections. Here we address three major consequences of this non-classical structure with regard to neural dynamics and interactions: (i) the model does not consider any extended information processing dynamics; (ii) the model does not allow for adaptive and recurrent interactions between areas; (iii) the model only characterizes evoked-response with no state-dependence from the neural context. To begin to address these gaps in the classical model, we focus on the categorical-selective regions in the ventral pathway and study the neural dynamics and interactions using intracranial electroencephalography (iEEG), which overcomes the limitations of spatiotemporal resolution in current non-invasive human techniques.

With respect to the first consequence, we applied multivariate pattern analysis (MVPA) methods to the iEEG signal to analyze the dynamic roles of the word and face sensitive areas. We found that both areas demonstrated a similar multi-stage information processing dynamic wherein the representation in category-selective fusiform gyrus evolves from a gist category-level and s imilarity-based representation to an invariant and highly detailed individual representation over the course of 500 ms. In addition, our results also suggest a dissociation between structural and motion in the face processing streams.

Regarding to the second consequence, we introduced a novel method termed Multi-Connection Pattern Analysis (MCPA) to extract the discriminant information about cognitive states solely from the shared activity between neural populations from the interacting brain areas. Our results on iEEG and fMRI data with MCPA support the hypothesis that individual-level exemplar information is not only encoded by the population activity within certain brain populations, but also represented through recurrent interactions between multiple distributed populations at the network level.

Finally, to address the third consequence, we designed a block-wise generalized linear model to study the relationship between category tuning and the ongoing neural activity in category selective cortical areas. We used this model to demonstrate that pre-stimulus spontaneous activity modulates the category tuning in the post-stimulus evoked response, and the same aspects of pre-stimulus activity that modulate tuning also predict perceptual behavior.

Taken together, in this thesis we develop and apply statistical models to assess the properties of the non-classical structure in the ventral visual stream, and highlight contributions of regions to multiple stages of processing through interactive and distributed computation that is influenced by ongoing neural context.

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