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Detecting fine-grained population codes in human prefrontal cortex

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Western BrainsCAN
Transforming brain research.

Project**Summary**
KNOWLEDGE MOBILIZATION & IMPACT

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Background

Cognitive flexibility is the ability to adapt our thoughts and actions to the demands of the current situation. It allows us to solve problems and adjust quickly to changes in our environment. Impaired cognitive flexibility is a hallmark of many neuropsychiatric disorders, including schizophrenia and autism spectrum disorder. Brain research has shown that the prefrontal cortex plays an important role in cognitive flexibility. However, we do not understand how neurons in the prefrontal cortex work together to support cognitive flexibility. This represents a significant obstacle to isolating major cognitive dysfunctions and selectively treating those dysfunctions without affecting global cognitive ability.

For a long time, we have tried to explain the prefrontal cortex as a set of anatomically distinct brain regions, each specialized for a specific cognitive function. Unfortunately, this modular approach to brain function hasn't been very successful in understanding cognition. Imaging work has shown that a diverse range of cognitive functions (such as working memory or problem solving) activate overlapping prefrontal brain regions.

Mounting evidence is suggesting an alternative view: we can better understand the prefrontal cortex as a versatile population of neurons that together can flexibly implement a wide variety of functions. The ability to multitask is key to cognitive flexibility because it allows the same population of neurons to solve many different problems and adjust quickly to changes in the environment.

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Related

None

To understand the neural mechanisms of cognitive flexibility, we need to measure the prefrontal neural population in action during the performance of cognitive tasks. We expect the activity across the population to dynamically code the specifics of the task, such as a memorized location (e.g. where you will meet a friend for coffee) or what to do next to achieve a behavioural goal (e.g. fix a broken car). Population codes provide a direct window into brain information processing. These

considerations motivate a shift from searching for one-to-one mappings between brain regions and cognitive functions toward analyzing patterns of activity across the prefrontal cortex.

The Problem

Progress towards embracing this understanding has been hampered by the difficulty in measuring neural population codes in the human prefrontal cortex. Prefrontal population codes are fine-grained in both space and time: they exist at a sub-milimeter and sub-second scale. The standard techniques for measuring brain activity in humans do not have enough resolution to detect these fine-grained population codes in the prefrontal cortex.

The Project

In this project, we will develop techniques for improving our measurement resolution so that we can gain access to prefrontal population codes. We will combine high-field fMRI with pattern analysis techniques to unlock population coding in the prefrontal cortex. This is essential for understanding how the brain supports higher-order cognition, and ultimately, for treating dysfunctions of cognitive flexibility in the clinic.

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