Cognitive Modes Detectable with Task-Based fMRI

Chantal M. Percival[1,2] &Todd S. Woodward[2,3]

[1]Department of Psychiatry, University of British Columbia, Vancouver, BC, Canada
[2]Faculty of Medicine, University of British Columbia , Vancouver, BC, Canada
[3]BC Mental Health and Substance Use Services, Vancouver, BC, Canada

COGNITIVE MODES are task-general cognitive, sensory, or motor processes which reliably elicit specific fMRI blood-oxygen-level-dependent (BOLD) anatomical pattern configurations.

Introduction

In contrast to traditional coordinate-based fMRI methodology, cognitive modes are distinguished by specific and replicable anatomical patterns. By capitalizing on associated temporal information across a range of tasks and conditions, the task-general cognitive processes underlying the anatomical patterns are determined through empirical evidence.

Methods

Task-Bain Brain Networks

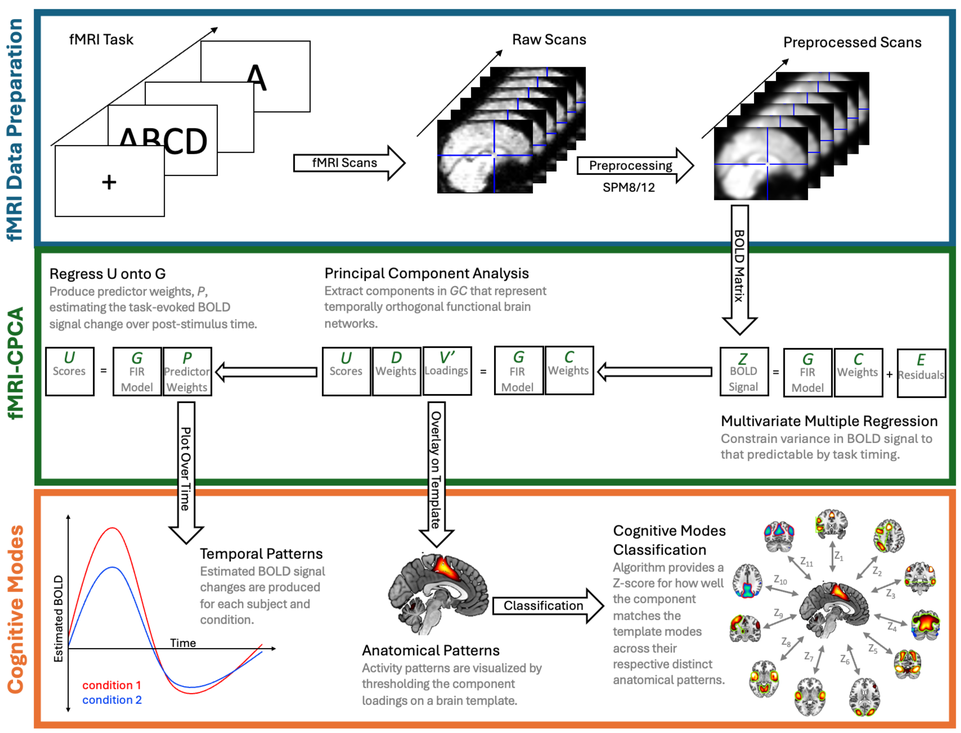
Networks were acquired through constrained principal component analysis for fMRI (fMRI-CPCA)[1]. fMRI-CPCA produces both component loadings (BOLD-based anatomical patterns) and component scores that are transformed into predictor weights (estimated BOLD signal changes over post-stimulus time).

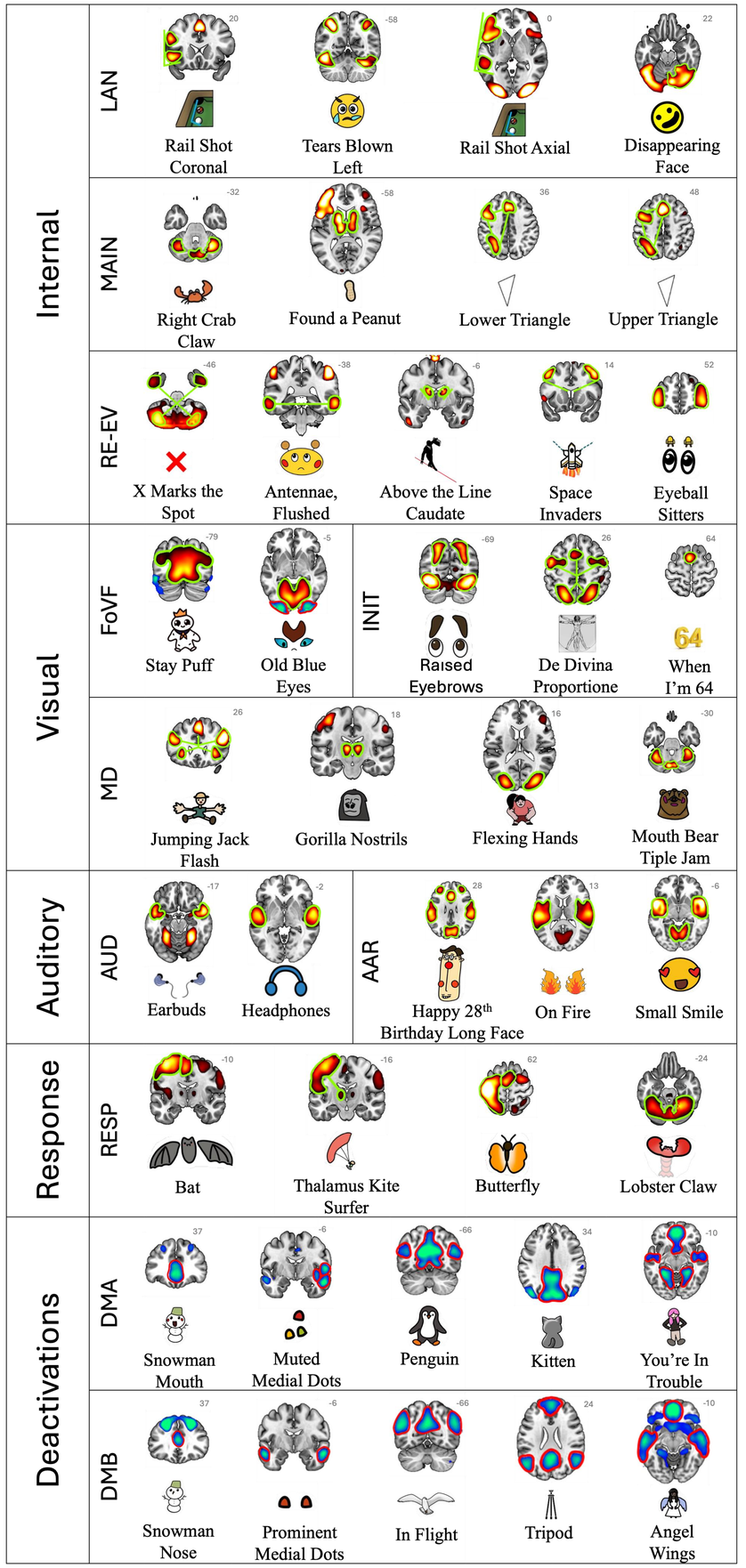
Cognitive Mode Creation and Classification

11 cognitive modes were identified by distinct and uniform anatomical activity patterns. Whole-brain anatomical template images were created for each mode by averaging the images of several fMRI-CPCA components demonstrated to be excellent anatomical examples of the mode. A MATLAB-based algorithm was developed to classify any brain image into these cognitive mode templates. A Z-score is assigned to the to-be-classified brain image, reflecting how well its activity pattern matches the mode templates across respective anatomical patterns. Over 321 components, or whole-brain network images, from 74 fMRI-CPCA analyses, with different combinations of 27 tasks were matched to the 11 templates.

BOLD Temporal Patterns

Following anatomical classification, temporal patterns of associated BOLD changes were analyzed with RM-ANOVAs of predictor weights.





Results

The 11 cognitive modes can be grouped into 5 sub-categories: Internal, Visual, Auditory, Response, and Deactivations. BOLD temporal patterns across task conditions evidence the below cognitive processes.

Internal: The Language mode (LAN) demonstrates varying activity dependent on the linguistic information processing required[2]. Maintaining (MAIN) is elicited during tasks requiring volitional internal attention[3]. The Re-Evaluation mode (RE-EV) is activated when evaluating, re-considering, or regulating mental states[4].

Visual: The Initiation mode (INIT) demonstrates activity when restarting cognitive processes involving visual stimuli after brief, undemanding periods[5]. Multiple Demands (MD) is activated when devoting attention to individual parts of a complex task, and deactivated during internal attention[6]. Focus on Visual Features (FoVF) is activated during attention to visual details and deactivated when visual details detract from task performance[7].

Auditory: Auditory Perception (AUD) displays activation when perceiving auditory information[8]. Auditory Attention for Response (AAR) is activated when attending to auditory stimuli with the intention of responding, and deactivated when attending to visual stimuli[9].

Response: The Response mode (RESP) is elicited during motor responses[10].

Deactivations: The Default Mode A and B (DMA, DMB) increase activity during self-reflective thought and are otherwise deactivated in other tasks[11,12].

Conclusions

1. Task-induced BOLD signal changes appear to reliably arrange into a relatively small set of anatomical patterns - the cognitive modes.
2. By interpreting the temporal BOLD signal changes across a wide range of tasks and conditions, we converge on the cognitive processes underpinning each mode, moving towards a nearly one-to-one mapping between BOLD anatomical patterns and fMRI-specific task-general cognitive processes.
3. Cognitive modes provide a tractable solution to the reverse-inference hesitancy (assignment of cognitive processes to anatomical patterns) inherent to task-based fMRI.

CNoS Cognitive Neuroscience of Schizophrenia Lab

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