Laminar fMRI at 3 T
A Review of Acquisition Parameters, Data Processing, and Feasibility

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1 Introduction

The cortex is a massively recurrent network, with feedforward, feedback, and lateral connections between neurons organized into approximately six histological layers with stereotyped long-range connectivity profiles: feedforward input arrives predominantly at layer IV, while feedback projections from higher cortical areas terminate in layers I-II and V-VI. Since the different connections affect different layers of a cortical column, the incoming and outgoing signals can be recorded separately with sufficient spatial resolution.

Standard functional magnetic resonance imaging (fMRI) acquires data at 2-3 mm, involuntarily averaging signal across cortical layers and making it impossible to disentangle feedforward and feedback components of the signal. Laminar fMRI employs submillimeter resolution to resolve the cortical structure, opening up empirical access to questions about neuronal communication in visual prediction, attention, working memory, consciousness, and psychiatric disorders that have so far been untestable in living humans (Lawrence et al., 2019).

The distinction between feedforward and feedback signals would also allow the empirical investigation of predictive coding. Predictive coding is a particular aspect of the broader predictive processing framework, which proposes that the brain continuously generates top-down predictions and propagates bottom-up prediction errors. Within this framework, predictive coding describes the communication between neurons necessary for the propagation of prediction and error signals. Testing predictive coding empirically requires dissociating these two signal directions at the level of cortical depth, a requirement laminar fMRI directly addresses (Lawrence et al., 2019). Beyond predictive coding, laminar fMRI also constitutes a methodological basis for studying psychopharmacological agents such as psilocybin, which are hypothesized to modulate the balance between feedforward and feedback processing (Carhart-Harris and Friston, 2019).

2 Methodology

This project conducts a structured literature review using PubMed, the Web of Science and Elsevier databases. Studies reporting empirical laminar fMRI data are included if they used GRE-EPI BOLD contrast at 3 T with isotropic resolution at or below 0.8 mm; studies using other contrasts (VASO, ASL) or acquisition trajectories (spiral, FLASH) at 3 T are excluded. Acquisition parameters are extracted from qualifying studies. Software tools and preprocessing pipelines are surveyed across field strengths, contrasts, and acquisition trajectories, and assessed for compatibility with 3 T data. The goal is to establish a practical reference for labs seeking to implement laminar fMRI on standard 3 T infrastructure.

3 Significance

Laminar fMRI is currently practiced almost exclusively at ultra-high field strengths of 7 T and above, which are not available at most research sites. The majority of MRI scanners in operation worldwide run at 3 T or below. The first demonstration of layer-specific fMRI signals in humans was in fact achieved at 3 T (Koopmans et al., 2010), yet the field has since moved almost entirely to higher field strengths. This leaves a large installed base of 3 T infrastructure effectively unused for laminar research questions. This review examines the constraints that drove that migration and asks whether 3 T remains viable tool for laminar research.

References

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