Depth-Dependent BOLD as a Measure of Directed Connectivity During Language Processing

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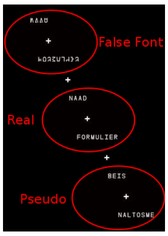
Introduction

- The input/output topology of neocortical circuits is known to be organized with respect to cortical laminae,[4] and blood supply has been shown to be regulated at this level[1,8]
- A growing body of evidence suggests high-field MRI is capable of resolving laminar specific BOLD responses[5,6,8,9]
- Previous investigations of depth-dependent BOLD have focused on low curvature, primary cortices
- The present work is an early attempt to resolve laminar specific BOLD in occitpitotemporal sulcus (OTS), a highly curved region involved in processing orthographic stimuli

Goals

- Demonstrate the acquisition of physiologically realistic data in OTS
- Elicit targeted, depth-specific BOLD responses via modulation of the available top-down information during word reading

Task Procedure



Sample Stimuli

- Event-related fMRI experiment
- Item by item visual presentation
- 1.25s/item presentation time
- Word, pseudo and nonword stimuli
- 60 items per run×12 runs
- Periodic lexical decision task to monitor participant attention
- Top-down information modulated through lexicality manipulation
- Bottom-up information modulated through length manipulation (not analyzed here)

Assumptions

- Differences observed in the lexicality contrast (Real>Pseudowords) are cognitively driven by lexical frequency and semantic access[3]
- Lexical information facilitates orthographic processing in OTS, driving inhibition effects often observed in lexicality contrasts
- Extrinsic top-down connections are inhibitory in nature and disproportionately target nongranular cortex,[2] measured primarily in deeper cortex with GE-BOLD
- In this experimental context, decreasing access to top-down information while holding bottom-up information constant should lead to non-deep BOLD increases
- Increased mid-depth signal may increase deeper signal through intrinsic connectivity, motion and segmentation error, but would also increase variance

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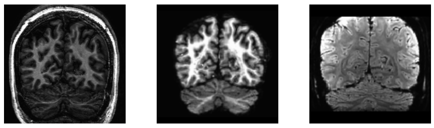
Acquisition and Analysis Procedure



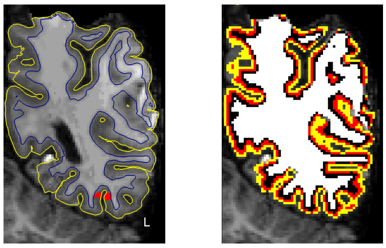
$0.5mm^3$ MP2RAGE

Inversion Recovery EPI. Acquisition protocol and distortions match task data. Used for registration and cortical segmentation

$0.76mm^3$ 3DEPI

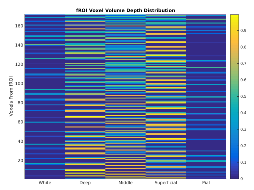
- Data acquired on Siemens 7T scanner at Erwin L. Hahn Institute
- Segmentation and depth parcellation performed on IR-EPI
- Depth parcellation follows level-set method of Waehnert et al.[10,11]
- Single subject laminar signal extracted using spatial GLM on fROIs[10]
- Individual fROIs selected by 1st level Real > False T-Value contrasts

Depth Based Cortical Parcellation



IR-EPI with fROI and FreeSurfer generated white and pial surfaces overlayed

Surfaces are represented as level sets and evolved inward in equivolume intervals. Color differences represent voxels in different depth volumes



Matrix representation of fROI depth-volume distribution

- Voxel-wise depth-volume distribution calculated for each fROI
- Represents the volume distribution across each depth bin
- Distribution regressed against fROI in spatial GLM once per time point
- β-weights interpreted as the contribution of each depth volume to the average signal in the fROI
- Timeseries of β-weights used for statistics on laminar signal

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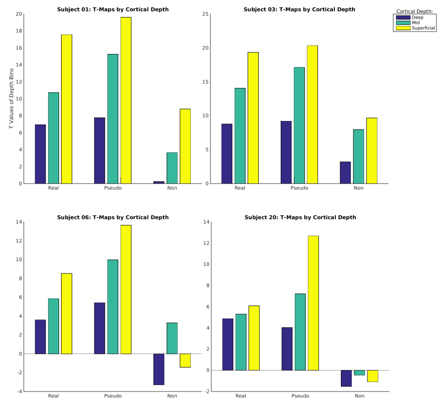
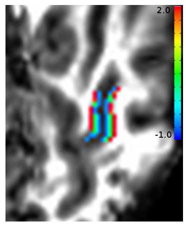
Single Subject Findings



Individual Subject, Depth Specific T-scores from Four Sample Subjects $p<0.01$ at $t>2.6$

- Monotonic signal increase toward the pial surface in conditions of interest
- In line with physiological assumptions and previous work
- Lexicality effect most pronounced in middle and superficial layers
- Cannot be explained by differences in bottom-up signal
- Suggestive of diminished inhibition in Real > Pseudo

Preliminary Group Findings



Real - Pseudo Group T-Scores Visualized on IR-EPI Volume
$p=0.076$ at $t=2.0$

- T-test comparing Real - Pseudo for 10 subjects shows highest values in the deepest cortex and lowest in superficial cortex
- High deep value appears driven by reduced across-subject variability in deeper cortex during real word reading
- Suggestive of increased top-down inhibition of OTS during real word reading
- Results not significant but trending, perhaps due to low sample size

References

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