Title: Investigation of phase imaging for venous suppression in high-resolution functional MRI

Trainee Name: Olivia W Stanley

Supervisor(s): Ravi S Menon

Structured Abstract:

Introduction: High resolution functional MRI has the potential to unlock a greater understanding of cortical organization and to bridge the gap between invasive animal work and large scale network studies. One current consideration when using high resolution fMRI is the choice of which sequence to use during imaging, as every sequence comes with sensitivity and specificity trade-offs. The most commonly used fMRI sequence gradient-echo echo planar imaging (GE-EPI) has the highest sensitivity but is not specific to microvasculature (Yacoub et al. 2007). This results is a pial vessel bias located towards the surface of the cortex which increases complexity of performing studies targeted at structures within the cortex. Fortunately, GE-EPI phase is expected to show signal changes only in voxels that contain large vessels. This work seeks to explore the use of MRI signal phase as a macrovascular filter via phase regression (Menon, 2002).

Methods: As a first step to investigating this question an in-house phase combination method was designed and implemented on the 7T MRI system. This was done to ensure high quality phase combination free of destructive interference. This method, the Fitted SVD Sensitivities Method uses a low resolution singular value decomposition and solid harmonic interpolation to provide computationally efficient, phase sensitive, coil combination. Our next study was a direct comparison of GE-EPI, GE-EPI with phase regression (GE-EPI-PR), and spin echo EPI. Spin echo EPI is a control sequence sensitive to microvasculature. Seven subjects observed an 8Hz contrast reversing checkerboard in order to activate the visual cortex. All functional imaging was completed at 0.8 mm isotropic. Structural imaging was completed and used to create cortical surfaces. Functional results were projected onto these surfaces to allow for comparison across cortical depths.

Results: The GE-EPI-PR surface profiles showed higher spatial similarity with SE-EPI than GE-EPI and also produced laminar activity profiles approaching that of the SE-EPI. Furthermore, when the GE-EPI and GE-EPI-PR distributions were compared to SE-EPI it was shown that GE-EPI-PR had a similar distribution mean to SE-EPI and that this relationship was consistent across layers. Finally, we showed that this technique has a higher contrast-to-noise ratio than SE-EPI, making it a useful method in low SNR studies such as high-resolution fMRI. Future work will examine the relationship between cortical orientation and GE-EPI-PR as reducing pial bias could reduce orientation effects commonly found in GE-EPI data (Viessman et al. 2019).

Discussion: This work demonstrates that phase regression reduces signal contributions from pial vessels and will improve specificity in layer fMRI studies. This method can be completed easily with complex fMRI data which can be created using our Fitted SVD Sensitivities method or another phase combination method.