

ENCODING SELF-MOTION AND EXTERNAL MOTION DURING PURSUIT EYE MOVEMENT, A STUDY AT 9.4T

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Introduction:

As eyes move to track a moving object, despite the self-induced retinal motion, the world around us is perceived as still. This multimodal integration of retinal motion signal with non-retinal cues, i.e. efference copies of the eye movement, allows to differentiate between self-motion and external or real motion¹. In a recent study the prominent involvement of areas V3A and V6 in encoding head-centered motion during pursuit eye movements was shown². V6 was suppressed by the retinal component of planar motion, and excited by objective planar motion. V3A lacked retinal responses to planar motion, and signaled exclusively objective planar motion. In the context of resolving differential involvement of cortical layers and/or columnar organizations in the processing of retinal motion, objective motion, and pursuit eye movement, we used ultra high (9.4T) resolution functional imaging to (1) resolve finer structures within V3A, V6, and possibly other areas with different preference in encoding self-motion and external motion during pursuit eye movement, and (2) demonstrate how voxels with different preferences to retinal and objective motion are related to one another.

Methods:

High resolution GRE EPI (0.8 isotropic resolution, TR/TE 2000/21ms, 20 slices, and 4-fold acceleration), T1-weighted MP2RAGE data, and 2DFLAH high resolution (0.4mm isotropic) data were acquired from 8 subjects on a 9.4T whole-body scanner (Siemens Healthcare, Erlangen, Germany) with a custom made 31-channel head coil³. Each scan included four conditions with four repetitions for each. The conditions resulted from a 2x2 factorial design including the two factors pursuit (with levels “on” and “off”) and 2D planar motion (with levels “on” and “off”). Trials lasted 12 s and were presented in pseudo-random sequences. Subjects performed a character repetition-detection task on a fixation disc while the disk, the random-dot background, or both moved across the screen. MP2RAGE images were reconstructed offline⁴ by combining two inversion preparation images, applying a mask to remove the background noise, and re-normalized the intensities with global scaling⁵. Data were analyzed in SPM8 using GLM to separate cortical responses related to the main factors of objective (2D planar) motion and retinal (interaction of pursuit and objective) motion.

Results:

Figure 1 demonstrates opposite preference to retinal motion and to objective motion in 4 selected subjects. A subpopulation of voxels in V3A and V6 is activated by objective motion (Fig.1.A), but shows a negative response to retinal motion (Fig.1.B). On the other hand, a cluster of voxels in the posterior parietal cortex (PPC) shows a positive response to retinal motion (Fig.1.C) while being deactivated by objective motion (Fig.1.D). Figure 1.E. shows that responses to retinal motion and to objective motion are negatively correlated in voxels with higher preference to objective motion (nRpO), and that this negative correlation is reversed in voxels with higher preference to retinal motion (pRnO).

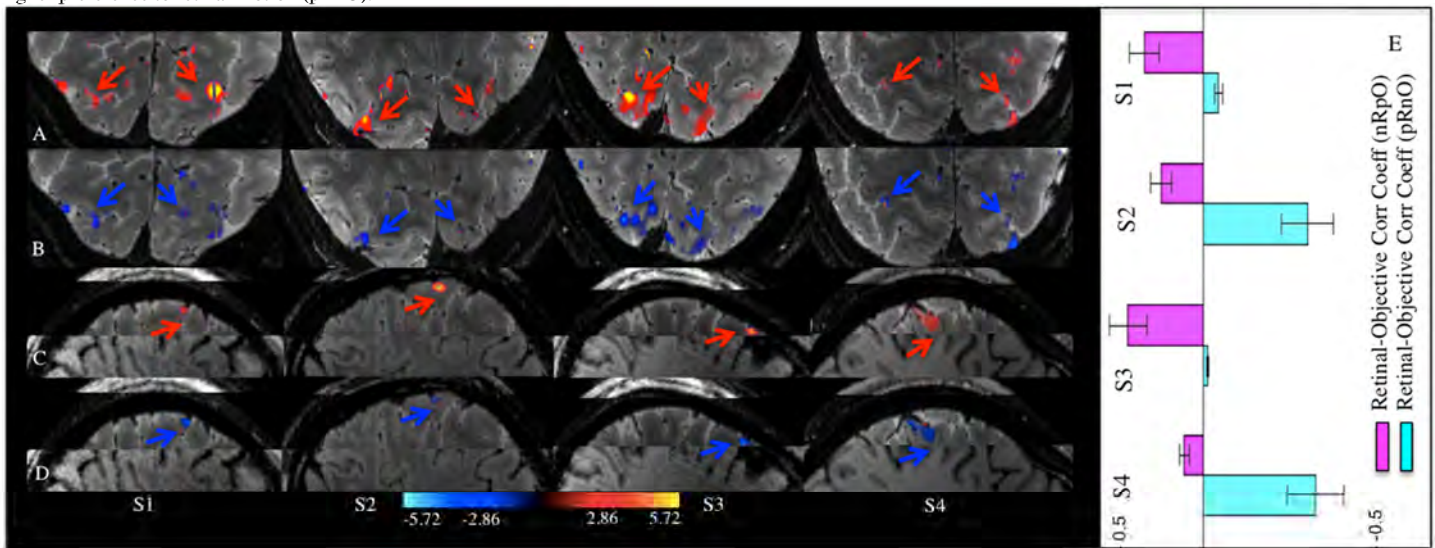


Figure 1. Positive and negative responses to retinal and objective motion in four selected subjects. Slabs of high resolution data overlaid on top of MP2RAGE for accurate visualization. Color bar shows the range of z values in activation maps. Positive response to objective motion (A) and negative response to retinal motion (B) in V3A and V6, pointed to by arrows, shows higher preference of a subpopulation of voxel within these areas to objective motion. Positive response to retinal motion (C) and negative response to objective motion (D) in posterior parietal cortex (PPC), pointed to by arrows, demonstrates how voxels in this area have higher preference to retinal motion. (E) Correlation coefficients between responses to retinal motion and to objective motion. Correlations were measured voxels with negative retinal and positive objective response (nRpO), and in voxels with positive retinal and negative objective response (pRnO). Correlations in (pRnO) population are mainly negative, which are reversed in (nRpO) population.

Discussion and Conclusion:

We conducted the first functional study at 9.4T with regard to visual motion processing. Using 9.4T images with higher signal level (SNR) and smaller voxel size we were able to separate two subpopulations of voxels, in V3A, V6, and PPC with opposing preferences for retinal and objective motion. We also found that responses to retinal and to objective motion in voxels with higher preference to retinal motion are negatively correlated, and this relationship is reversed in voxels with higher preference to objective motion (Fig.1.E). This is a preliminary indication showing that V3A, V6, and regions in PPC may contain subregions with distinct preferences for retinal, objective, and pursuit-related motion signals. Future work will attempt to assign these to distinct cortical areas using retinotopic mapping, and to distinct layers using layer-resolved imaging methods.

References: [1] Ilg et al. Neuron 2004;43(1):145–151. [2] Fischer et al. Neuron 2012;73(6):1228–1240. [3] Shajan G. et al. MRM 2013;71(2):870–879. [4] Marques et al. NeuroImage 2010;49(2):1271–1281. [5] Fujimoto et al. NeuroImage 2014; 90:60–73