Detailed topographic and functional mapping of areas within the posterior lateral-occipital and hMT/V5 complex at 3T using functional grid analysis

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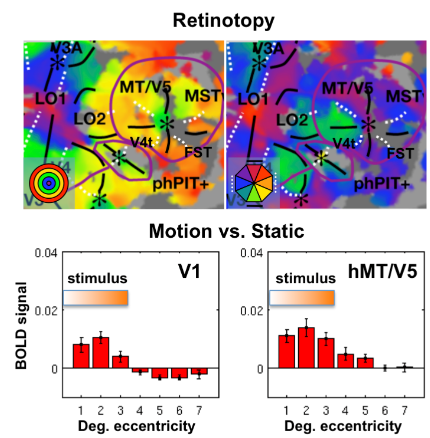
Introduction The human hMT/V5 complex was initially identified as a region that exhibits sensitivity to motion [1, 2] and was in analogy to the monkey believed to consist of several motion sensitive areas [3]. Huk [4] demonstrated the existence of two sub-regions, commonly called hMT/V5 and MST, using ipsilateral stimuli. Kourtzi [5] suggested an additional sub-division of the hMT/V5 complex into two sub-regions based on an observed overlap of motion and shape sensitive regions. This called into question a clear functional distinction between the hMT/V5 complex and the lateral occipital complex (LOC). Later studies yielded field maps for areas LO1 and LO2 within the LOC [6], but maps for areas hMT/V5 have only recently emerged. These suggest two conflicting models for the relationship of hMT/V5 to neighboring areas LO1/2: a discontinuous model with an area of peripheral eccentricity separating hMT/V5 and LO1/2 [7] and a continuous model in which LO1/2, hMT/V5, and MST represent neighboring areas with common eccentricity distribution [8]. In this study, we used functional magnetic resonance imaging (fMRI) to identify and localize areas within the hMT/V5 complex and the LOC and recorded responses to standard localizers to characterize all areas. We further developed a novel approach to group analysis to increase the specificity of the analysis to within a fraction of an individual area.

Materials & Methods *FMRI Measurements:* We performed functional MR measurements using stimuli for phase encoded retinotopy, motion sensitivity (ML), 2D shape sensitivity (LO), and human hand action on 11 human volunteers. Data were collected with a 3T MR scanner (Achieva, Philips Medical Systems). The functional images consisted of gradient-echo echo-planar images with 50 slices and a 80x80 matrix (2.5x2.5x2.5 mm^3, 0.25 mm gap), and parameters repetition/echo time TR/TE 3000 ms/30 ms and flip angle 90^o. Structural images were acquired for all subjects as 3D high-resolution T1-weighted images. For the retinotopic session we acquired 36 tilted coronal slices and a 96x96 matrix (2x2x2 mm^3, 0.2 mm gap), TR/TE of 2000/30 ms. A total of 1024 volumes were acquired in each of 11 subjects for the retinotopic experiment, 240 volumes in each of 8 subjects for the motion localizer (moving versus static dots), 608 volumes in each of 9 subjects for the 2D shape localizer (LO), and 512 volumes in each of 7 subjects for the action experiment.

Functional Grid Analysis: We correlated the functional responses across subjects through the retinotopic data in each subject instead of using an anatomical registration. This allowed the use of unsmoothed functional data and resulted in a specificity of the analysis near the resolution of the functional volumes. Cut conditions were applied to the retinotopic data based on responses in early visual areas that filter regions that respond to a stimulus, thus resulting in a bias-free selection of the functional data for analysis. Here, the single subject average for a selected region within an area was calculated followed by a determination of the group average based on these individual averages.



Results We found consistent representations of eccentricity and polar angle maps in all hemispheres of ten subjects. We have reliably located field maps within the LOC for areas LO1, LO2, and phPIT+, the putative homologue of macaque PIT/TEO, and within the hMT/V5 complex for areas V4t, hMT/V5, MSTv, and FST. The group analysis shows that the functional results for each area, when plotted against the eccentricity, resemble the stimulus as it is presented on screen modified by an increased receptive field size. We found significant responses to the LO stimulus in all areas of both complexes, with MT/V5 and MSTv showing half the response amplitude compared to all other areas. Strong responses to the motion localizer were found in all areas of the hMT/V5 complex and also a weak but significant response in LO1. Responses to the hand action vs. static hand stimulus were strong in all areas of the hMT/V5 complex and not significant in the LOC. For the hand static vs. fixation condition we found strong responses in all areas of the LOC and no significant responses in areas of the hMT/V5 complex.

Discussion The retinotopic organization of the four areas found in the hMT/V5 complex resembles the organization recently found in the macaque [9] and supports the discontinuous model described above. The functional data presented here further suggest that the properties of hMT/V5 in response to LO and ML are very similar to those found in macaque MT/V5 as observed with electrophysiological and fMRI methods [10]. This is a strong indication that the human MT/V5 complex includes the homologue of the macaque field-map cluster consisting of four areas. A strong functional separation between these areas and areas of the LOC is found in the response to the hand action and hand static stimuli, for which a clear on/off distinction can be made. Areas V4t and FST, however, show equally strong shape sensitivity as the areas within the LOC. These two areas are, in terms of functional properties as well as topological location, consistent with the LO-ML overlap region observed in [5].

References [1] Zeki S., J Neurosci 1991; [2] Tootell R., Nature 1995; [3] DeYoe E.A., 1998; [4] Huk A.C., J Neurosci 2002; [5] Kourtzi Z., Nat. Neuroscience 2002; [6] Larsson J., J Neurosci 2006; [7] Georgieva S., J Neurosci 2009; [8] Amano K., J Neurophys. 2009; [9] Kolster H., J Neurosci 2009; [10] Nelissen K., J Neurosci 2009.

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