Simultaneous acquisition of polar and eccentricity mappings of the human visual cortex using fMRI

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Introduction: In order to delimitate the borders between the primary visual areas a visual field sign map is often obtained by using both a polar mapping experiment (rotating wedge) and an eccentricity mapping experiment (expanding ring) [1]. To reduce the acquisition time it has been suggested to use only a rotating double wedge [2]. In this work we suggest showing both stimuli simultaneously to obtain both the polar and the eccentricity mapping thereby reducing the time needed to obtain a visual field sign map or alternatively improving the quality.

Methods: Using a 3T scanner (Magnetom Trio, Siemens, Erlangen, Germany) and the standard birdcage headcoil 528 GRE EPI volumes were acquired. The functional volumes consisted of 20 3 mm slices, oriented along the calcarine sulcus, TR=1.2s, FOV=192, 64x64 matrix, flip angle = 67°.Visual stimulation were presented using a projector (Canon LV-7545) placed outside the Faraday cage. A zoom lens projected the image through a waveguide to a screen behind the subject's head.

A 3D rigid body transformation was used to correct for motion. For the data analysis a general linear model was used to model the time series of each voxel. To account for temporal autocorrelation the following nuisance covariates were included in the model:

High pass filter consisting of discrete cosine transform basis functions with frequencies up to 1/60 Hz, residual motion effects including spin history [3], respiratory and cardiac cycle predictors (RETROICOR) [4].

The effects of interest were modelled with harmonics of the stimulation cycle rate as described in figure 1. To determine the phase of the activation the time to peak (TTP) was found from reconstructed signal for each of the 8 different activation types. The hemodynamic lag was determined and accounted for by comparing the phase of stimuli running in opposite directions with the same frequency. In order to determine activated areas a simple f-test over the effects of interest in question (wedge or ring) was used.

Results: Reasonable values for the hemodynamic lag were obtained as seen in figure 2. Figure 3 shows a phase map whereas figure 4 shows a visual field sign map.

Discussion: The results suggest that it is possible to identify signals from a rotating wedge and an expanding/contracting ring in a single experiment thereby reducing the time needed to construct a visual field sign map. The quality of the mapping was comparable to one obtained by using two separate experiments each with the same duration. Obtaining both the polar and eccentricity mapping simultaneously also has the advantage that noise level in the polar and the eccentricity map is equal. The experimental data suggest that discrimination between two relatively closely spaced frequencies of activation is possible. This might find use in a wide range of different experiments. The present study used a single wedge. If independence between the right and the left hemisphere is assumed further optimisation can be obtained by using a double wedge [2]. During the analysis it is assumed that the BOLD signal adds up linearly. In the present study this is assured using a relatively narrow ring and wedge (stimulation for 1.4-1.8s). At the position of the overlap between the ring and the wedge an error is introduced as the model predicts an additive effect. However, the effect is small as this occurs very rarely for a specific position.

References: [1] Sereno et al. 1994, Cereb Cortex, **4(6)**, 601-20. [2] Slotnick et al. 2003, HBM, **18**, 22-9. [3] Friston et al. 1996, MRM, **35**, 346-55. [4] Glover et al. 2000, MRM, **44**, 162-7. [5] Genovese et al 2002, Neuroimage, **15**, 870-878

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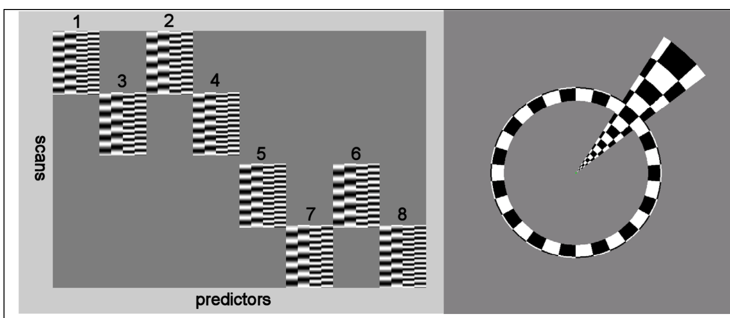

Figure 1 (above): Experimental design

The visual stimulation consisted of a wedge rotating either clockwise (CW) or counter clockwise (CCW) at two different cycle times (time for a full rotation) on a grey background (as shown to the left). Simultaneously an expanding/contracting ring was shown also at two different cycle rates (time for one full expansion/contraction). Within both the ring and wedge a black-white checkerboard flickered at a reversal rate of 8 Hz [1], both stimuli covered a maximum of 18.4° of the subject's visual field. During the first 3 scans the subject viewed a grey screen showing a green circular fixation point covering 0.1° of the visual field; this fixation point remained on the screen for the remainder of the experiment. The stimulation then consisted of the following:

90s CCW wedge cycle rate of 25 s and expanding ring cycle rate of 30s (1 and 2)
90s CCW wedge cycle rate of 30 s and expanding ring cycle rate of 25s (3 and 4)
25s pase with the fixation point only
90s CW wedge cycle rate of 25 s and contracting ring cycle rate of 30s (5 and 6)
90s CW wedge cycle rate of 30 s and contracting ring cycle rate of 25s (7 and 8)

The change in cycle rate assured that the same number of cycles where completed for both the ring and the wedge. The response was modelled with sine and cosine predictors (1. and 2. order harmonics) with the frequency corresponding to each of the cycle rates as shown to the right.

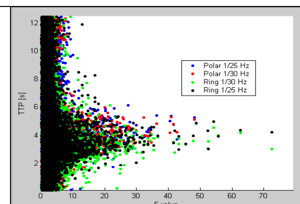

Figure 2 (left):
The figure shows the estimated TTP hemodynamic lag. The lag is seen to be reasonable and consistent for high values of the F-statistics over the different stimuli types.

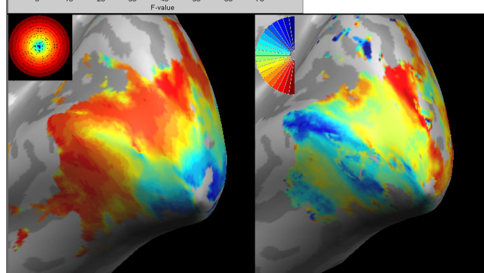

Figure 3 (left): Phase maps shown on an inflated version of the right hemisphere. False discovery rate of 0.01 were used to threshold the maps [5]. Neither the original data nor the statistical maps have been spatially smoothed.

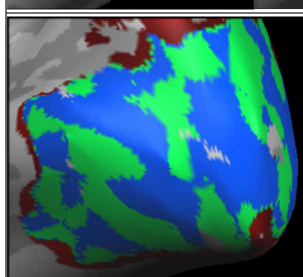

Figure 4 (left): Visual field sign map shown on an inflated version of the right hemisphere. A mirror-representation of visual field is shown in green whereas a non-mirror representation is shown in blue.