Seeing in the dark: Evidence for organized activity maps in the human visual cortex in the absence of visual input.

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Introduction:
It is commonly assumed that sensory systems, and particularly the visual system are driven by the sensory stimuli, and should thus become inactive once the stimulus is terminated. Here we examined this issue using fMRI in the human visual cortex, in subjects that were placed in complete darkness with their eyes shut. Our results show a remarkably consistent and structured organization of ongoing activity in the absence of visual stimulation. This organization was manifested in a clear bilateral symmetry of the activation across the two cortical hemispheres.

Methods:
Subjects were instructed to shut their eyes in complete darkness and try to attend to any visual sensation they may have. The experiment lasted 630 seconds, and was conducted using a 1.5T Signa Horizon LX 8.25 GE scanner (Quadrature surface coil, EPI sequence with TR = 3000, TE = 55, flip angle = 90°, field of view 24 * 24 cm2, matrix size 80 * 80, 17 nearly axial slices of 4mm thickness and 1mm gap). The cortical surface was reconstructed and unfolded. Results were analyzed by calculating correlations to sampled time course on a voxel by voxel basis. Brain activity was assessed through Power spectrum calculation (using FFT) and through RMS. Correlation maps were compared in darkness and during visual stimulation (images of various object categories).

Results:
Robust patterns of cortical activity in the visual cortex were revealed as strong fluctuations in the BOLD signal during complete darkness. In fact, these fluctuations were substantially similar during visual stimulation and in darkness. Of particular interest was the fact that the fluctuations manifested a clear and consistent structure in their spatial distribution. Thus, the patterns of correlation within the same hemisphere showed a clearly non-uniform distribution. Furthermore, when comparing the correlation within and across hemispheres, using unfolded-cortical format, a well-defined and consistent bi-lateral symmetry was observed. An example of such patterns is shown in Fig. 1.

Discussion:
Our results reveal robust, structured activation patterns in the human visual system even in the complete absence of visual inputs. The organized, patchy nature of the correlations both within and particularly across hemispheres suggests that the fluctuations are mainly of a neural origin. As to the exact source of the organized activity, possible candidates are visual imagery, fluctuations in attentional states or a very high neuronal gain-control which activates in the absence of sensory inputs.

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Figure 1:
Functional connectivity and bilateral symmetry as seen in a correlation map for a single subject. Green patches mark cortical areas with high correlation to the building-related Collateral sulcus (lower yellow cross), whereas red patches mark areas with high correlation to the face-related Inferior occipital gyrus (upper yellow cross).
White dotted lines mark regions which show clear bi-hemispheric symmetry.