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Theatre of the mind: Organization of the human cortex during natural sensory stimulation

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The introduction of non-invasive imaging methods has prompted a rapidly growing understanding of the function and organization of high order human visual areas. In particular, a complex, albeit consistent network of functionally distinct object areas have been described along the entire extent of human occipito-temporal cortex (see figure 1).

It is important to note here, that almost invariably all the data which underlies these various models, is based on the use of extremely constrained, and far form natural, visual stimuli. Typically, the functional properties of object areas are defined using static, temporally and spatially isolated object images which are briefly flashed on the screen while the subjects do their best to maintain fixation on a small central target.

However, it is clear that natural vision is drastically different from such highly controlled stimuli, along at least four fundamental dimensions: A. Objects are not presented in isolation and are embedded in a complex scene. B. Object images change and move continuously within the complex scene. C. Subjects are free to move there eyes. D. Stimuli are multi-modal, particularly including auditory stimulation. Thus, it is of interest to examine to what extent the functional architecture of human occipito-temporal object areas is maintained under stimulus conditions that mimic these more natural dimensions.

We approached these questions by studying the functional organization of human visual cortex during what likely constitutes the richest and most complex of daily visual experiences: a movie. Thus, in the present study, subjects were allowed free viewing of a long segment of a completely un-edited audio-visual movie, during which their brains were scanned using fMRI.

The results indicate that that while watching the movie, a highly correlated, spatio-temporal activity pattern could be detected across about 30% of the cortical surface in different individuals (see figure 2). Thus, there was a voxel by voxel synchronization in brain activity between individuals watching the same movie. Interestingly, the synchronization extended far beyond known sensory areas, into

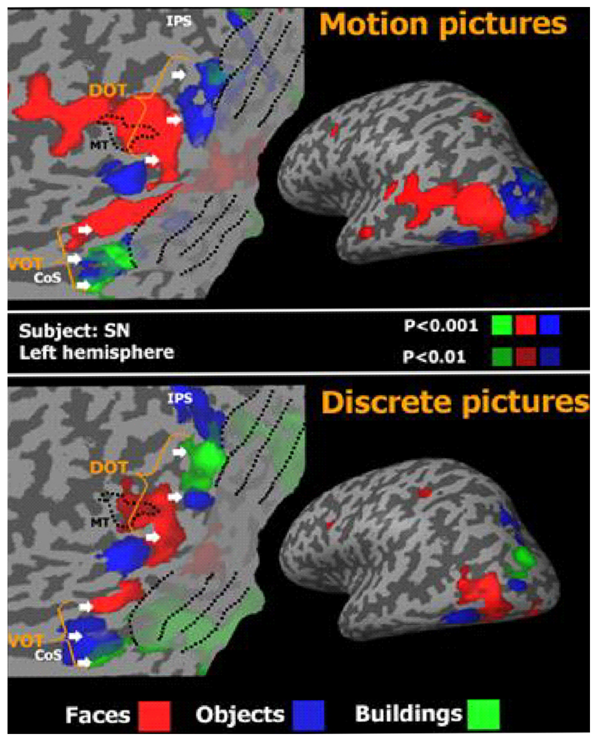

Fig. 1 Comparison of free viewing vs. controlled viewing: *Activation maps for conventional mapping using line drawings of static objects (A) and free viewing of pre-edited, category-specific movie clips (B) of faces (red), objects (blue) and buildings (green). The DOT and VOT subdivisions are indicated by dashed rectangles. Colors indicate contrast of each category with the other two (e.g. faces vs. buildings and objects). Note clear similarity between the maps generated by conventional and category-specific movie clips within the occipito-temporal cortex.*

as yet unexplored association and limbic cortices. The inter-subject synchronization consisted of two components: 1. A widespread cortical activation pattern correlated with emotionally arousing scenes. 2. A regionally selective component, which showed a high degree of differential stimulus selectivity.

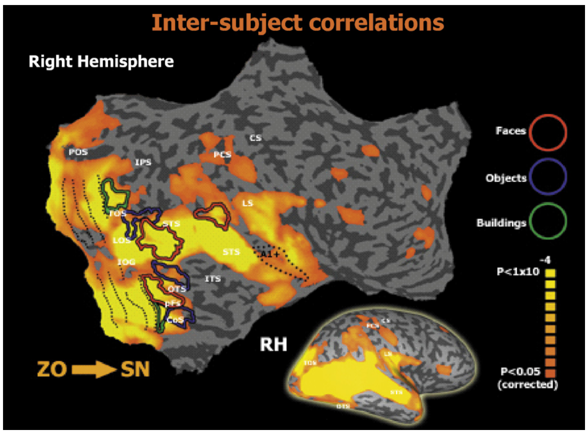

Fig. 2 *Inter-subject correlation during free viewing of a movie: Voxel by voxel inter-subject correlation between the source subject (ZO) and the target subject (SN). Correlation maps are shown on unfolded left and right hemispheres. Color indicates the significance level of the inter-subject correlation in each voxel. Black dotted lines denote borders of retinotopic visual areas V1, V2, V3, VP, V3A, V4/V8 and estimated border of auditory cortex (A1+). The face, object and building -related borders (red, blue and green rings respectively) are also superimposed on the map. Note the substantial extent of inter-subject correlations, and the extension of the correlations beyond visual and auditory cortices.*

To examine the stimulus selectivity of the regional activity, we have applied a “reverse correlation” tool, which , in effect, inverted the conventional analysis approach. In the reverse correlation- instead of selecting optimal stimuli and presenting them to the subject to examine how brain areas react to them, you look at the activity in different areas, and find out what images in the movie were correlated to peaks of activation within these areas. Thus, you in essence, allow each area to “select” its own optimal movie clip from the entire movie sequence.

Using this approach we have found that well known object areas, such as the face and building related regions in the temporal lobe, maintain their selectivity during the movie. Furthermore, we found an unexpected functionalities, such as a cortical area, located in the parietal lobe, which was activated whenever delicate hand movements appeared in the scene.

Thus, our study demonstrates that natural vision elicits a surprisingly robust and consistent activation patterns in the human cortex. It also points to natural vision as a powerful new direction in which to study the functional organization of the human cortex.

Selected Publications

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