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Topography of human visual object areas revealed by functional magnetic resonance imaging

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A central aspect of human visual perception is the departure from the physical properties of the optical image which is formed on the retina. This process brings visual perception into close correspondence with the objective layout of the visual environment, however, it is poorly understood at the neural level. With the recent advent of human neuro-imaging techniques, particularly fMRI, it is now possible to study this process in a rigorous way. We present results from our work which explore several issues regarding neural correlates of human perception, and more specifically, object recognition .

Using functional imaging it is now possible to show that different regions in the cortical surface are specialized for different visual stimuli. In particular, we have found a cortical region which appears to be specialized for object recognition tasks. How is the information transformed from the retinal image to recognition-related representations? - a central principle in visual cortical research is that such transition occurs in a hierarchical manner - by gradually building more and more complex organizations. By breaking object images to smaller and smaller fragments in a gradual way, we were able to map in detail the neuro-anatomical layout of the hierarchical transformation. Our main finding is that indeed a sequence of anatomically conjugated cortical areas are involved in representing increasingly complex object images.

In another line of study, we took advantage of visual phenomenon which depend on a global percept of object images - including the Rubin vase-face illusion, and object completion effects. Using such images we were able to demonstrate that global effects, which do not depend solely on local image features or shape elements, are able to modulate neuronal activity in high order object areas.

Recent findings have claimed the existence of specialized regions within high order object representations that are sensitive to specific object categories such as faces and buildings- however, the principle underlying this specialization remains highly controversial. This is due to the fact that there could be numerous dimensions by which two object categories may differ - from shape elements to different tasks involved in the use of such images. Recently we obtained a surprising result that bears important consequences to this question. We have found that there is an orderly map of retinal eccentricity (distance from the fovea) in high order object representations. Interestingly, different object categories show a different level of association with this eccentricity map. In particular - faces show a consistent association with central (foveal) visual field bias, while houses show an association with peripheral visual field bias. What could be the source of such differential association?

We hypothesize that this organization is related to resolution demands, i.e. object images whose analysis requires fine detail (e.g. faces) will be associated with foveal representations, which specialize for fine analysis, while object images that depend on large scale integration (such as houses) will be associated with low resolution, peripheral representations.

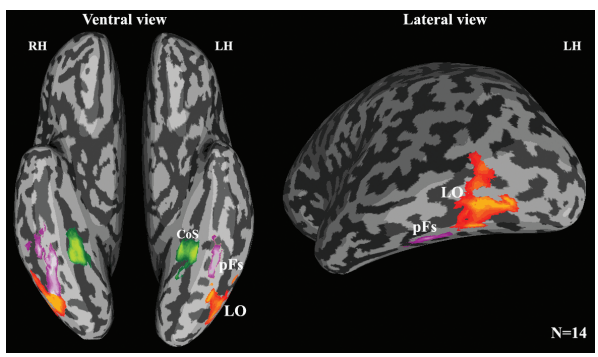

Fig. 1 *Occipito-temporal Object-related areas in the human ventral visual pathway.*

One prediction stemming from this hypothesis is that letters and words should be selectively associated with central-biased representation since reading is a highly resolution-dependent and foveal task. Indeed, our results clearly show such association. This association is not a common property of all object images since another object category (tools) did not show such selective association. Thus, our results demonstrate a new and unexpected principle of organization of human object areas, which can put in a coherent framework much of the previous findings in these ares.

To conclude, functional mapping of the human brain using MRI has allowed us to study in great detail an important part of the human visual cortex involved in visual processing. Our results begin to outline the neuronal principles by which the retinal image is gradually converted to a precise model of the outside environment.

Selected Publications

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