How did the evolution of color vision impact V1 functional architecture

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Color vision was lost in mammals during the *nocturnal bottleneck* when our ancestors were small, dark–dwelling animals between 205 to 65 Million years ago (Ma). Among modern mammals only old world monkeys and great apes (re–)invented trichromacy 30 – 40 Ma [1]. The newly developed color vision inserted new pathways into cortical functional architecture, most obviously potentially perturbing the orientation domains through non–orientation selective CO–Blobs [2]. How much impact color vision had on the overall functional visual cortical architecture remains unclear.

Here, we investigate this question focusing on orientation domains, a key characteristic of V1 functional architecture [3] allowing quantitative analysis [4]. Orientation domains are arranged around pinwheel singularities, whose spatial distribution in ferrets, shrews, and galagos is quantitatively indistinguishable. At least for dichromats, there exists a *common design*, characterized by the statistical identity of (i) pinwheel density, (ii) pinwheel density fluctuations as a function of subregion size, and (iii) nearest neighbor distance distributions.

Against a background of normal (N=82) and dark-reared (N=21) ferret, shrew (N=25), galago (N=9), and cat (N=13) we compared macaque (N=9) OPMs exhibiting 1183 pinwheels and found that their layout adheres to the common design. Most notably, the pinwheel density $\rho = 3.19\,[3.04, 3.39]$, is extremely close to the mathematical constant π verifying the prediction of a universal solution set of a large symmetry defined class of self-organization models. This class also predicts the measured exponent of pinwheel density fluctuations $\gamma = 0.40\,[0.33, 0.43]$ and the mean distance $d = 0.35\,[0.33, 0.37]$. Our quantitative results indicate that the evolutionary invention of the color vision machinery induced only a minor perturbation of the system of orientation domains. The selective forces that favor the common design might thus be so powerful as to preserve it under major transformations of the retinocortical pathway.

References

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