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Seeing the brain in action: Exploring higher brain functions by optical imaging

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Objectives

Our long term goal has been to contribute to the discovery of principles underlying perception and cortical processing, higher brain functions and the "neural code".

Background

A precondition to deciphering the "neural code" is to determine the functional architecture of cortex. Clearly one must first understand what is the basic function(s) actually performed by a given neuronal group(s) before one can hope to understand the strategy they employ. Next, one should define how these groups of neurons are organized in space. Subsequently, spatio-temporal patterns of electrical activity should be monitored and only then can the code in these tangled communication networks be deciphered. Long-standing questions related to perception and higher cognitive functions can be finally resolved by direct visualization of the architecture and function of mammalian cortex in unprecedented detail. This advance has been accomplished with the aid of two optical imaging techniques one based on voltage sensitive dyes and one on intrinsic signals (Grinvald et al., 1999). Utilizing these techniques one can "directly see" how the brain functions. Our explorations are combined with traditional neuroanatomical and neurophysiological techniques and are guided by computational theories and modeling. The combination of real time optical imaging and single unit recording have facilitated the direct visualization of neuronal assemblies. Recently, a number of imaging techniques such as PET, EEG, MEG, f-MRI and optical imaging have made feasible many experiments which were considered by neuroscientists' "fantasy" only a decade ago. Among these imaging techniques, optical imaging stands out because it is the only imaging technique offering the temporal and spatial resolutions required to study the functional organization and the dynamics of neuronal assemblies.

Recent Findings

These include establishing the pinwheel- like organization of orientation domains in primary visual cortex responsible for shape perception; description of the cortical point spread function implying that cortical processing is far more distributed than previously estimated; discovery of the functional organization for direction selectivity and its spatial relation to orientation columns in visual areas MT and 18; discovery of two subsystem of spatio-temporal frequency columns; discovery of the relationships between various functional domains in monkey primary visual cortex and in cat visual cortex, underlying visual perception (see illustration); visualization of neuronal assemblies and discovery of the dynamic organization of coherent on going activity; discovery that on going activity of a single neuron is a reflection of the functional architecture rather

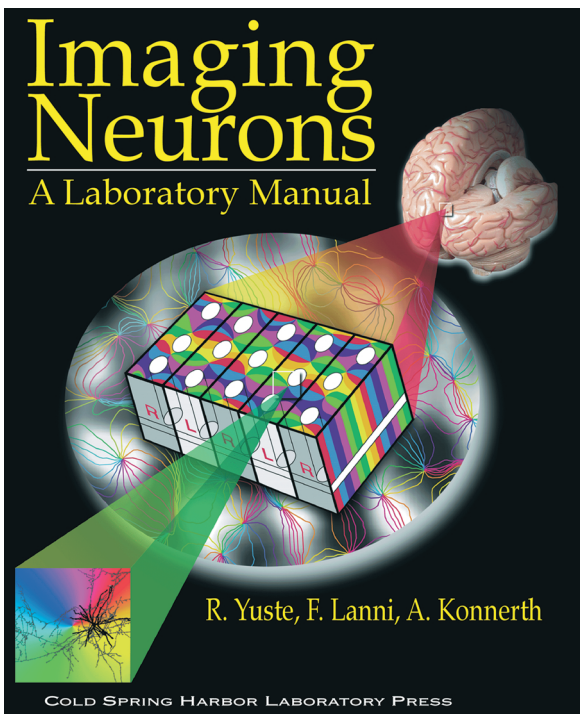

Fig.1 *Mapping of the geometrical relationships between various processing modules underlying visual perception in primary visual cortices of monkeys (the cube) and cats (the ellipse) by Intrinsic optical imaging. Intrinsic optical imaging can be combined with anatomical methods such as biocytin labeling of single neurons thus elucidating the relationship between neuronal structure and function (bottom left square). Figure courtesy of Amiram Grinvald and Tobias Bonhoeffer ("Imaging Neurons" book cover , CSHL Press 1999).*

Fig. 2 *Spatial relationships between three columnar domains. Spatial relationships among three columnar systems in cat area 17 (Cell, February 18, 2000). 1) Gray and white regions are columns of neurons that receive inputs from the left and right eye respectively. This system is responsible for depth perception. 2) The 'pinwheel' spokes are formed by neuronal groups involved in the perception of shape, with each color line marking the border between neurons responsible for detecting a particular orientation in space.*

than stochastic activity; discovery of the relationship between electrical activity and the responses of the microcirculation and its implication for improving of the spatial resolution of f-MRI. Clinical applications of optical imaging for neurosurgery were pursued in local and foreign hospitals.

Selected Publications

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Arieli, A. Grinvald, A., and Slovin H. (2001) An Implant of transparent artificial dura for a long term imaging of cortical activity in behaving monkeys and its clinical implications. J. Neurusci. Methods. In press.

Sharon, D. and A. Grinvald (2001) The dynamics of orientation tuning in cat visual cortex measured by optical imaging. Science, in press.

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