Functional Magnetic Imaging of Neural Activity in Rat CNS in Response to Chromatic Stimuli.

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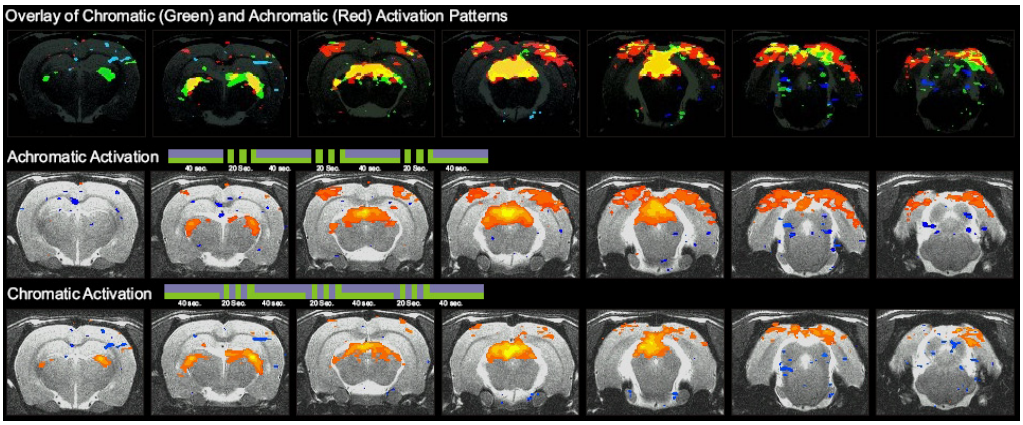
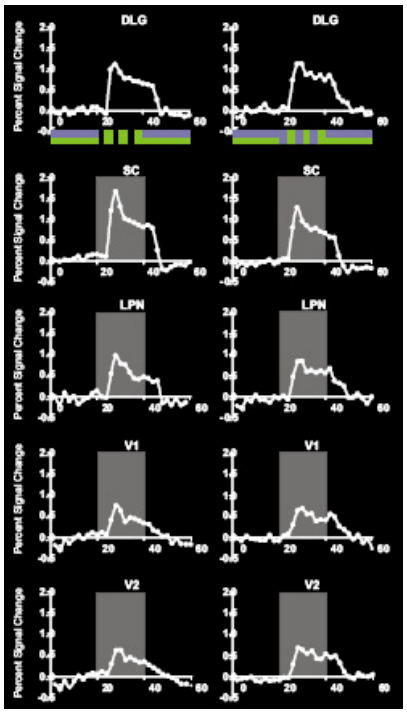
Purpose: In rodents, dichromatic color vision is based on comparisons of M-cones and UV-cones. However, little is known about the location and distribution of cortical regions carrying color information in the rodent. Therefore, we used functional magnetic resonance imaging (fMRI) to measure the blood-oxygenation level dependent (BOLD) signal generated by a heterochromatically modulated stimulus.

Materials and Methods: 6 Sprague Dawley rats (300 –380g) were used in the fMRI study. The right femoral artery and vein were cannulated and used for invasive blood pressure monitoring and for continuous IV drug administration. A tracheotomy allowed for mechanical ventilation with 30% O2-70% N2. Surgery was performed under isoflurane (1.4%) vaporized into the ventilatory gas. After surgery, isoflurane was gradually reduced to zero as a continuous infusion of Domitor (0.1mg/kg/hr) and pancurium bromide (2mg/kg/hr) was started. (1,2) The physiologic parameters - mean arterial blood pressure, arterial blood gases, pulse oximetry, pulse, temperature, respiratory rate, inspired / expired O2 and CO2 - were maintained under normal physiologic ranges throughout all experiments. Gradient echo scans (Single shot EPI, TE = 18.39 ms, TR = 2 ms, MTX 96 x 96, FOV = 3.5 cm, Number of repetitions = 110, 15 contiguous scans 1 mm slice thickness, acquisition time = 3 minutes 40 seconds) were acquired on a 9.4T Bruker MRI scanner.

Results: Two stimulus conditions were designed to favor either luminance or chromatic pathways individually. M-cone quantal catches of an ultraviolet light (DW=365 nm) were adjusted to match those of a green light (DW=545 nm). The lights were modulated in counter-phase at 1 Hz to isolate chromatic signals produced by S-cones. To acquire a response to luminance increments and decrements, 545 nm light was modulated at 1 Hz without the 365 nm light. BOLD responses were measured for each stimulus condition. Diffuse activation in V1 with lesser activation in the superior colliculus and the dorsal lateral geniculate (DLG) nucleus was observed in response to the chromatic condition. The luminance condition produced a more robust activation of the superior colliculus and DLG. This approach will allow us to evaluate the functional consequences of newly introduced opsin molecules targeted to either M- or S- photoreceptors in rodents.



fMRI responses were compared under two stimulus conditions: one designed to modulate the S-cones and the other the M-cones. S-cone isolating conditions employed heterochromatically alternating, in counter-phase at 1 Hz, the 365 nm (uv) and 545 nm (green) light adjusted to produce equal quantal catches in the M-cones. M-cone isolating conditions modulate the 545 mm light at 1 Hz (50% duty cycle).



Regions of interest (ROIs) were defined in functional images overlying the dorsal lateral geniculate nucleus (DLG), the lateral posterior nucleus (LP), the superior colliculus (SC), the primary visual cortex (V1), and higher visual cortex (V2). The percent change in BOLD signal for each of these ROIs are shown for each stimulus condition.

Conclusions: fMRI in rodents allows visualization of brain areas that respond to S-cone and M-cone modulation. Robust, visual stimulus driven activity was observed in the midbrain, thalamus, and cortex. The two different stimulus conditions produced very different patterns of activity in the thalamus and cortex. Assuming that S-cones only contribute to circuits carrying chromatic information while the M-cone stimulus strongly stimulates circuits carrying achromatic information, these experiments can help define brain regions that make use of these two different types of information differentially.

fMRI in adult rodents can provide a way to monitor plastic changes in CNS mediated by introduction of new opsins to cone photoreceptors in experiments designed to better understand the circuitry for color vision.

References: 1.) MRM 58:901-909 2.) J. Neurophysiol 95:3164-3170