High-resolution imaging of the human thalamus and superior colliculus during binocular rivalry

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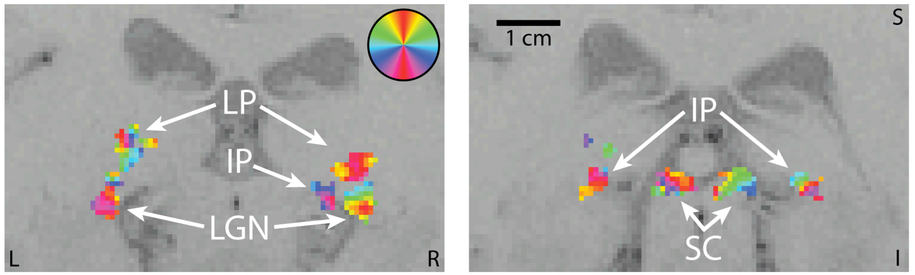
Summary

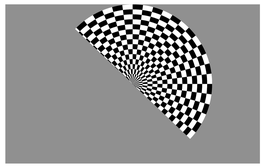
Binocular rivalry is known to suppress the eye-specific layers of the lateral geniculate nucleus (LGN) in humans, but the spatial resolution has been insufficient to discriminate between the magnocellular (M) and parvocellular (P) sections. It is also unknown whether the perceptual alternations during binocular rivalry, and hence our awareness, are reflected in the activity of the pulvinar or superior colliculus. Therefore we employed high-resolution functional magnetic resonance imaging (fMRI) to study binocular rivalry in these structures.

ROIs



LGN = lateral geniculate nucleus, SC = superior colliculus, LP = lateral pulvinar, IP = intergeniculate or inferior pulvinar

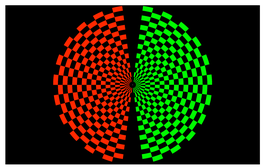
Stimuli



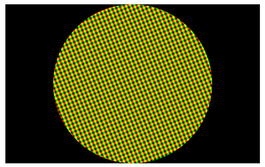
To define ROIs and measure retinotopic organization: rotating hemifield, $\tau = 32$ s, flickering at 4 Hz.

OR

Rotating bow-tie stimulus, $\tau = 40$ s with moving or static colored dot fields, with attention task. Better for pulvinar activation.



To measure eye dominance and segregate the LGN layers: red/green anaglyph glasses, independent hemifields, alternating every 10 or 13 s, flickering at 4.2 or 3.8 Hz.



Binocular rivalry stimulus: red/green anaglyph glasses, rotating orthogonal gratings, $\tau = 1$ s.

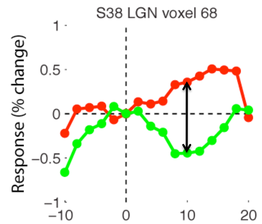
Methods

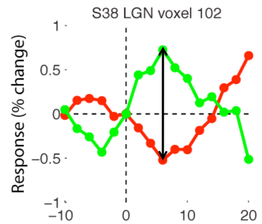
MRI Procedures: Images were acquired using a 3T Siemens Trio scanner with an 8-channel head coil. 18 interleaved coronal slices (2 mm thick, no gap) were acquired with a standard EPI sequence (TR = 2 s, TE = 42 ms, FA = 90º), 192 mm FOV, 128 × 128 matrix (1.5 × 1.5 × 2 mm^3 resolution), partial phase Fourier = 7/8, GRAPPA parallel imaging with 2× acceleration factor and bandwidth = 752 Hz/px. The most posterior slice was positioned near the posterior edge of the corpus collosum.

Stimuli: Observers wore red/green anaglyph glasses and maintained fixation while passively viewing the checkerboard patterns (6–12 runs, 128 or 135 time points). During the binocular rivalry stimuli (8–12 runs, 135 time points), subjects fixated and pressed a button to indicate which of the two gratings was perceived.

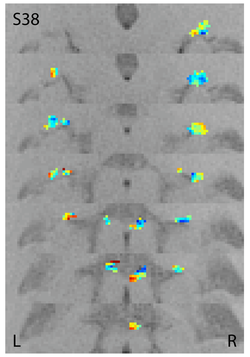
Analysis: The images were registered and interpolated to twice the resolution in each dimension. The first stimulus cycle of the checkerboard stimuli was omitted and a Fourier analysis was performed on the remaining time series to calculate the phase, amplitude and correlation components of each voxel's response. Responses were thresholded at $r \geq .25$. For the binocular rivalry stimulus, the average event-related responses were calculated, registered to the beginning of each button press.

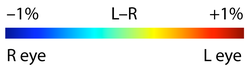
Typical single-voxel rivalry response



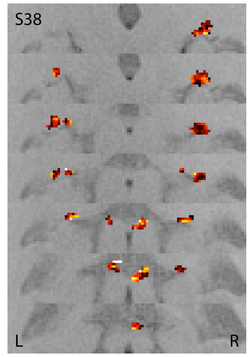


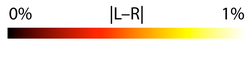
Rivalry amplitude



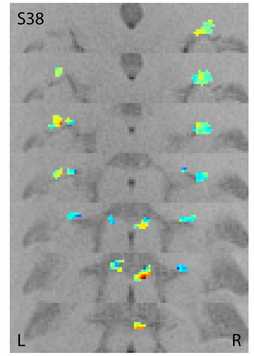


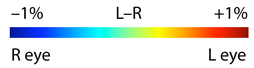
Rivalry magnitude

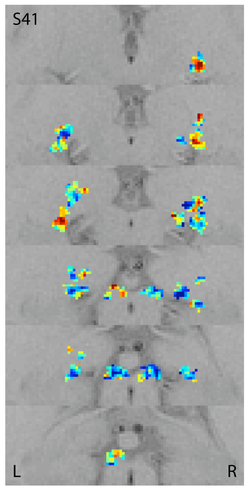


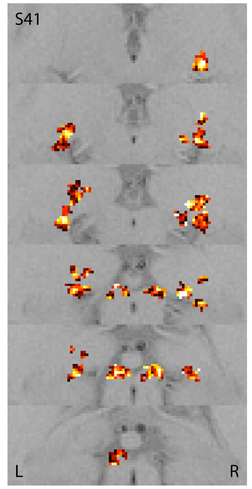


Eye dominance









Conclusions

Binocular rivalry can be measured throughout the human visual system, including the subcortical visual nuclei, suggesting that these structures contribute to our awareness. No special role in binocular rivalry could be attributed to either the M or P sections of the LGN.