rowding alters the spatial distribution of attention modulation in human primary visual cortex

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Crowding effect is the visibility reduction of a target when presented with neighboring distractors. It has been explained by either lateral inhibition at a pre-attentive level or coarse spatial resolution of attention. To test these theories, high-resolution fMRI was used to measure V1 response to the target in the presence or the absence of the distractors in both attended and unattended conditions. We found the cortical response to the target was not affected by the presence of distractors in the unattended condition. However, the spatial distribution of attention modulation in the target and its surrounding area



Fang & He

Figure 1. Example stimuli and experimental design. (A) Example stimuli used in the experiment. A target was always positioned on the right horizontal meridian. It was presented either alone or with two distractors positioned either tangentially (above and underneath the target) or radially (left and right of the target). (B) Schematic description of the experiment. Stimulus blocks were interleaved with blank intervals. A stimulus block consisted of ten trials, in which subjects were asked to perform either a luminance discrimination task at the fixation point (attend-to-fixation condition) or a contrast discrimination task to the target (attend-to-target condition).





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MRI data acquisition



MRI data processing and analysis





Figure 2. Regions of interest. (A) Five flickering round checkered patches with a full contrast were used to define the ROIs (central, upper, lower, left and right). They occupied the same spatial extents as the target and the distractors. (B) Cortical activations by the five patches are depicted in a representative inflated brain. The red, green, blue, yellow, and light blue areas correspond to the left, central, right, lower, and upper ROIs, respectively. V1 is defined by retinotopic mapping and its boundaries are indicated by the white dashed lines.

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Eye movement recording

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Figure 3. Behavioral and cortical responses to the target in the single, tangential and radial configurations. (A) Performance in the contrast discrimination task. (B) BOLD responses to the target with the luminance discrimination task at the fixation point. Error bars denote 1 *SEM* calculated across subjects.





Figure 4. BOLD signals in the left, right, upper, lower, and central ROIs in the single, tangential, and radial configurations when subject attended to either the fixation (left part of a panel) or the target (right part of a panel). Error bars denote 1 *SEM* calculated across subjects.





Figure 5. Attention effects at the target location and its surrounding area. (A) Attention modulation in the left, right, upper, lower, and central ROIs in the single, tangential, and radial configurations. Attention modulation was defined as the BOLD signal difference between the attend-to-target condition and the attend-to-fixation condition. Error bars denote 1 *SEM* calculated across subjects. (B) Schematic description of regions showing attention enhancements in the single, tangential, and radial configurations.





Figure 6. Horizontal (A) and vertical (B) eye positions during an fMRI scan averaged across subjects and their corresponding stimulus protocol (C). Red traces are the measured eye positions and the green shaded regions indicate \pm *SEM* across subjects.



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