Multiple spotlights of visual attention?

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Objective

Visual scenes contain a variety of different and complex objects, which cannot be fully processed at once because of the limited processing capacity of the visual system. Attentional mechanisms determine the selection of information that is relevant to our current behaviour. Different models have been proposed to account for the distribution of attentional resources in visual space: "zoom lens", "single spotlight", and "multiple spotlights" theory. Several recent studies demonstrated that the attentional spotlight can be split among multiple, spatially separated locations over more extended time periods [1-3] and that multiple spotlight processing is associated with retinotopically specific enhanced activation in striate and extrastriate visual areas [4, 5]. The present study aimed at the verification of previous reported findings for more peripheral visual stimuli.

Methods

Twelve right-handed, healthy volunteers (6 male, mean age: 26.5 years) participated in the study. The visual stimuli consisted of letters and digits displayed in rapid visual serial presentation (RVSP). Five RVSP streams were presented simultaneously, one peripheral stream was placed in each visual field quadrant centered 8.5° diagonally from central fixation. Each stimulus was displayed for 164ms. Targets appeared all 1800 - 2000ms. Stimuli were presented via LCD-goggles and eye movements were controlled.

BOLD fMRI was performed at 3 Tesla (Siemens TRIO, whole-brain-EPI, TR 2000ms, TE 36 ms, 2x2x4mm³) contrasting two attentional tasks: In the ***Attend1***-task subjects were trained to monitor only one RVSP (lower left of the visual field) stream for the appearance of a predefined target while maintaining fixation on the central stream whereas in the ***Attend2***-task participants had to detect digits among two letter streams (upper left and lower right) and report if the digits matched or mismatched. Next to the attentional tasks another two blocked conditions, passive viewing and fixation, were implemented in the experimental design. One block consisted of 4 conditions repeated for 3 times during one scan. One condition lasted 40s (instruction: 6s; task: 34s). Scans were repeated 4 to 6 times. Tasks and blocks were presented in a pseudo-randomized order.

Classical retinotopic mapping experiments were performed using flickering checkerboards to determine the peripheral regions of interest (ROI) for the attentional tasks, the eccentricity and the meridians of the visual field.

After preprocessing including motion correction, linear trend removal, temporal high pass filter (3 cycles/run) and spatial smoothing (Gaussian filter = FWHM 8mm), analysis was performed using the general linear model approach (BrainVoyager QX).

Results

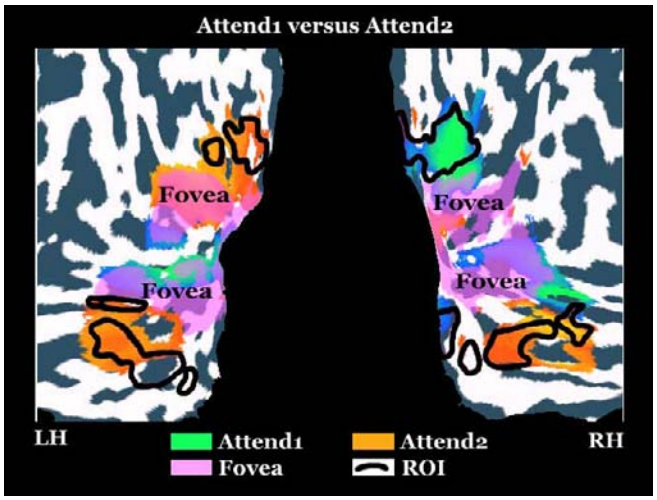

Fig. 1: fMRI activation map of a single subject comparing Attend1 versus Attend2 conditions (p = 0.05).

Before the experimental runs in the scanner, subjects were trained on the attentional tasks. During training subjects performed significantly better in the Attend1 than in the Attend2 task ($F [1, 12] = 17.08$; $p = 0.002$) and had significantly more misses than incorrect answers ($F [1, 12] = 35.60$; $p < 0.001$). The same was observed during scanning, $F [1, 12] = 14.89$, $p = 0.003$ and $F [1, 12] = 9.73$, $p = 0.010$, respectively.

In a first step of fMRI-analysis no main effect of attention could be determined in the functionally defined ROIs contrasting the attentional tasks versus passive viewing. However the contrast between the two attentional tasks revealed an attentional modulation in striate and extrastriate visual areas (V1, V2, V3/VP, V3a/V4v). In all subjects increased activation was observed in the ROIs according to the attended RSVP streams. Intervening (fovea) and task-irrelevant regions (upper right) were activated as well *(Fig. 1)*.

Discussion

Our findings are in contrast to previous reports [4, 5] and the multiple spotlight theory, supporting the classical view of a single spotlight of spatial attention where a unitary beam illuminates anything that is located within the region covered by it.

References

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