Introduction: As the neuroanatomical substrates that implement specific attention operations are learned (pulvinar thalamus for visual selection), a question arises: can changes in organismic state such as high arousal alter basic attentional operations, and if so, how? This project investigates arousal’s effect on visual selective attention processes and, in so doing, directly addresses the information processing consequences of drug abuse and other clinical disorders (schizophrenia) that bring with them alterations in arousal. The project predicts that arousal narrows the window of selected information surrounding a point of focus (reduces the size of the attentional “spotlight”). The project had two specific aims: (1) determine the functional neuroanatomy associated with a narrow versus wide attentional spotlight, and (2) determine if arousal alters the size of the spotlight. Thalamic (posterior and lateral) and posterior parietal cortex provide, respectively, information about the stimuli to be suppressed or enhanced prior to further processing, and the spatial coordinates for the spotlight. Thus, narrow and wide spotlights were hypothesized to show spatially distinct fMRI responses in these regions. Arousal (verified by skin conductance) was predicted to consistently induce brain activation reflecting a narrowed spotlight.

Methods. Functional Magnetic Resonance Imaging (fMRI) at 1.5 T standard gradient echo sequence: 128×128×7 mm, 20 axial slices, TR=4 s, TE=54 ms, FOV=22 mm, flip angle=90° was used to examine standard gradient echo sequence: 128×128×7 mm, 20 axial slices, TR=4 s, TE=54 ms, FOV=22 mm, flip angle=90° was used to examine the brain’s response to a Letter Discrimination Task under aroused and non-aroused conditions. Arousal was induced through aversive noise and random, unpredictable trial delivery. The Letter Task involved “same” or “different” judgements about letters presented simultaneously (left and right on horizontal axis) at a narrow or wide distances from a central point of focus. The aroused and non-aroused conditions were presented in separate fMRI runs that were identical in structure and composed of 80 letter trials per run (40 narrow, 40 wide eccentricity, blocked design, with initial and ending periods of rest). Letter discrimination accuracy scores (percent correct) were collected. Skin conductance is a sympathetic nervous system response that has been found to be sensitive to cognitive factors and for this reason was used as the measure of autonomic arousal. Study participants (n=8) were normal, healthy adults (18-45 yrs., mean=32.5, sd=9.5). SPM analyses utilized a random effects model (multi-study, different conditions) with adjusted mean volumes as input (volumes “binned” as wide or narrow trial, rest baseline, or arousal/aversive noise alone). Contrasts were thresholded at a height of p<0.01 and spatial extent of k=5 voxels.

Results. The pattern of the behavioral data indicated accuracy was lower during aroused than non-aroused condition (with wide eccentricity trials the lowest of all), but these effects did not reach statistical significance. Subjects produced greater autonomic activity (skin conductance) during the aroused condition (p<0.05).

Conclusions. Spatially distinct fMRI responses in parietal cortex were observed for the narrow (inferior only) and wide (both inferior and superior) eccentricity trials. Arousal alone produced posterior lateral thalamic activation. Notably, only under arousal did the wide eccentricity trials produce this posterior thalamus activation. The latter suggested a propensity to gate the visual field and invoke a narrowed attentional window, despite the attention system maintaining adequate accuracy at processing more eccentric stimuli.

The study’s significance stems from: (1) its demonstration of the interaction of two major attention systems (arousal and selective attention), and (2) its preliminary step toward specifying one of the information processing consequences of altered arousal.

Arousal alone compared to rest (not shown) revealed left lateral thalamic activation (max z=3.6; -22, -20, 4) consistent with the predicted role of the lateral reticular thalamic nucleus in arousal. Left inferior temporal activation was also present. Skin Conductance run as mean-centered covariate was associated with anterior medial thalamic (max z=4.3; 6, -16) and brain stem activation (see Fig. 3), in addition to lingual gyrus (BA 18), superior frontal (BA10), pons and striate cortex (BA 17) activity. Conjunction analysis (height p<0.01, extent=6 v) using narrow eccentricity trials minus baseline (rest or arousal alone) for the aroused and non-aroused conditions revealed posterior lateral thalamus (Fig. 1) and left inferior parietal cortex (Fig. 2) activation. The analogous conjunction for the wide eccentricity trials was conducted (not shown). This revealed no thalamic activation and regions of activity in both inferior (BA 40) and superior parietal cortex (BA 7). The final analysis focused on the brain regions significantly active for wide eccentricity trials during arousal (wide arousal trials minus arousal alone). Data indicated posterior lateral thalamic activation (see Fig. 4) similar to what was determined to be characteristic of the narrow trials. The wide, aroused trials continued to show the same set of inferior and superior parietal activations (see Fig. 5) also present during the wide, non-aroused trials. A contrast reflecting subtraction of the wide non-aroused from the wide aroused trials revealed the same area of posterior lateral thalamic activation seen in Fig. 4.

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