Activation in thalamus predicts state and trait anxiety: An fMRI perspective of attentional control theory

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Introduction: According to the attentional control theory, central executive functions (i.e., shifting and inhibition) are the most affected by anxiety thereby increasing distractibility in anxious individuals [1]. Moreover, different types of anxiety--state or trait--may influence attention differently [2]. fMRI was carried out to study the effect of self reported anxiety on distracter inhibition in attentional performance, using attentional blink paradigm. We regressed the fMRI activation maps against the Spielberger's State–Trait Anxiety Inventory (STAI) [3] scores of the subject samples to determine the areas of the brain that predicted individual differences in anxiety levels.

Materials and Methods: Nineteen right handed healthy subjects [6 male, 13 female, mean age 21.42 + SD 2.01 years) were chosen for the study. fMRI was carried out using 3 Tesla whole-body MRI system (Magnetom Skyra, Siemens, Germany). Functional images were acquired using echo-planar T2*-weighted sequence. Each brain volume consisted of 36 interleaved 3 mm thick slices with 0.6 mm interslice gap and parallel to AC-PC axis (TE = 36 ms; TR = 2450 ms; FOV = 220 mm; flip angle = 90°; voxel size = 3.3 X 3.3 X 3 mm). Block paradigm (BABABABA….) with alternating phases of activation (A) and baseline (B) was chosen. 220 sequential image volumes (belonging to seven cycles + one baseline for eliminating T1 saturation effects and acclimatization of the patient to the gradient noise) were taken. In the activation phase, each trail was based on attentional blink paradigm with a rapid serial visual presentation (RSVP) sequence of 20 alphanumeric characters (black digits and capitalized letters on a white background) presented at a rate of 10 characters per second at the centre of a computer screen. Two of the characters were digits, and the rest were letters, and the subject's task was to report the two digits at the end of the trial. The lag between the two target digits in different trials was varied randomly between 200 msec to 500 msec. A response panel, presented for 3000 ms at the end of the RSVP stream, prompted subjects to enter their response by button press on a four button response device. A blank screen was presented after each trial for 2 seconds. Each active phase consisted of 7 such trails, making each activation block 49 seconds long. In the baseline a fixation cross was presented for 21.5 seconds that increased in size 3 seconds before the start of each activation phase. Stimuli were presented using fMRI hardware from NordicNeuroLab http://www.nordicneurolab.com/Products_and_Solutions/nordic_fMRI_solution/index.aspx) while the subject's response was recorded with the help of a 4 button response grip. Immediately after the scanning sessions, each subject's anxiety level was assessed with the STAI self-report questionnaires. Participants were also asked to perform the task after the scanning session to note their offline response. Pre- and post-processing of the functional MRI scans were performed using SPM8. A one-sample t-test was performed for group analysis with $p<0.0$ (FWE corrected) and voxel threshold of 25 voxels. The anatomical representation of the clusters was related to cytoarchitectonic maps as implemented in the SPM Anatomy Toolbox [4]. Multiple regression was carried out with STAI scores (Y1: state anxiety; Y2: trait anxiety) of the subjects as regressors.

Results and Discussion: Descriptive statistics for self-report measures are as follows: STAI-S = 34.42 + 9.65; STAI-T = 38.75 + 8.24. No correlation was found between accuracy of task performance and any of the test scores (with STAI-Y1: ($r= 0.054$; $p > 0.1$), with: Y2 ($r=0.157$; $p > 0.1$). One sample t test showed significant clusters of activation in BA 18 (calcarine and lingual gyrus bilaterally), left Lobule VIIb (Vermis) of cerebellum, bilateral inferior frontal gyrus (BA44 and 45), left Area 2 (post-central gyrus), left IPC (PFt), bilaterally in thalamus, and left superior parietal lobule. No region showed positive correlation, while right th-temporal (region of thalamus connected to temporal lobe) ($p < 0.01$, $k = 65$ voxels) showed a negative correlation with the Y1 score. On the other hand, right th-temporal ($p < 0.01$, $k = 75$ voxels) showed a positive correlation while bilateral calcarine gyrus (BA 17) ($p < 0.01$, $k = 43$ voxels; $p < 0.01$, $k = 27$ voxels) showed a negative correlation with the Y2 score.

All the regions activated have been implicated in attention processing. Neuronal activity within specialized regions of the extrastriate visual cortex, cerebellum and inferior frontal gyrus can be altered by selective attention and inhibition. The inferior parietal lobe (IPL) has been implicated in a diverse set of neural operations, including spatial attention, multimodal sensory integration, and attention-enhanced visual and oculomotor responses [5]. The posterior parietal cortex comprising of inferior and superior parietal lobule has been shown as a source of topdown signals counteracting suppressive effects of distractors on the target, thereby biasing object competition towards the target and actively inhibiting distractors [6].

Multiple regression analyses revealed some interesting findings in th-temporal. Thalamus is a part of the Ascending Reticular Activation System and has been shown to be involved in mediating the interaction of attention and arousal in humans [7]. Within the limits of the present set of data, our results suggest that activation in thalamus predicts lower levels of state anxiety (arousal) and higher levels of trait anxiety, which may be as a compensatory mechanism to perform the task. Calcarine gyrus activation predicted lower trait anxiety levels suggesting poor visual registration with high trait anxiety levels of subjects. However, experiments on more subjects with further graded anxiety scores is needed to elucidate the findings.

Conclusion: Initial results support the hypotheses that different types of anxiety—state or trait—may influence attention differently and thalamus activity may predict lower state anxiety and higher trait anxiety of an individual.

References:

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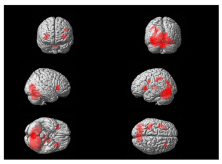

Figure 1: 3D rendered view showing group analysis

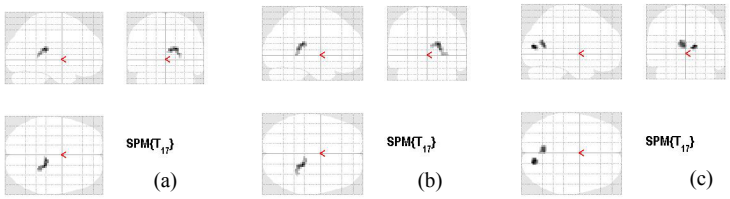

Figure 2: Multiple regression analysis (a) Thalamus activation with lower state anxiety (b) Thalamus activation with higher trait anxiety (c) Calcarine gyrus activation bilaterally with lower trait anxiety