The posterior cingulate BOLD duty cycle during meditation predicts attentional skills

Submission No:

4233

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Introduction:

Recent findings about the human brain's wakeful resting state suggest a link between the spontaneous generation of task-unrelated thoughts (mind-wandering)[1,2], and the slow fluctuations of activity in the 'default mode network' (DMN)[3], a consistent set of brain regions with a major hub in the posterior cingulate cortex (PCC)[4]. Meta-awareness and regulation of mind-wandering are core cognitive components of many meditation practices, and to study their relationship to the DMN activity we collected fMRI data from a cohort of experienced Zen meditators and meditation-naive controls engaging in a simple meditative protocol, along with their performance on a computerized sustained attention task. By introducing a simple duty cycle measure for the fMRI BOLD signal from the PCC, we hypothesized that this could be taken as an endophenotype[5] of the individual capacity to regulate mind-wandering and would thus correlate with performance in the sustained attention task.

Methods:

Subjects: 12 Zen meditators with > 3 years of daily practice and 12 control subjects, matched for age and education level.
Meditative task: subjects were asked to maintain their attention on their breathing throughout the scan and gently redirect attention to breathing every time they found themselves distracted or mind-wandering.
MRI acquisition: a single series of gradient-echo EPI volumes (200 scans, TR=2.35s, 35 3x3x3mm axial slices) and a T1-weighted hi-res volume (MPRAGE, 176 1x1x1 mm sagittal slices) were acquired on a 3.0 Tesla Siemens Magnetom Trio scanner.
Imaging analysis: The EPI series were corrected for slice-timing and head motion, and warped to MNI space using the T1-weighted image to estimate the warping parameters. The time series were then band-pass filtered (0.01-0.1 Hz), along with least-square removal of the global signal and estimated motion parameters. The average processed BOLD time courses from a PCC region of interest (center-of-mass MNI coordinates: -6, -56, 22; size=82 voxels), identified by a previous study on the same subject sample using a conceptual processing task[6], were extracted and a duty cycle measure was computed as the ratio of the cumulative time that the signal lay above its temporal mean and the total scanning time.
Sustained attention task: each subject completed the Rapid Visual Information Processing (RVIP) task from the CANTAB neuropsychological computerized battery[7]. Performance was assessed in terms of reaction times (RT) and A-prime, a nonparametric sensitivity index ranging from 0 to 1 based on the number of hits and false alarms (1=perfect performance).
Correlation analysis: Pearson's correlation tests were computed between individual scores in the RVIP task (RT and A-prime) and the PCC duty cycle values.
Image processing and statistics were performed with the software packages AFNI, SPM5, and R.

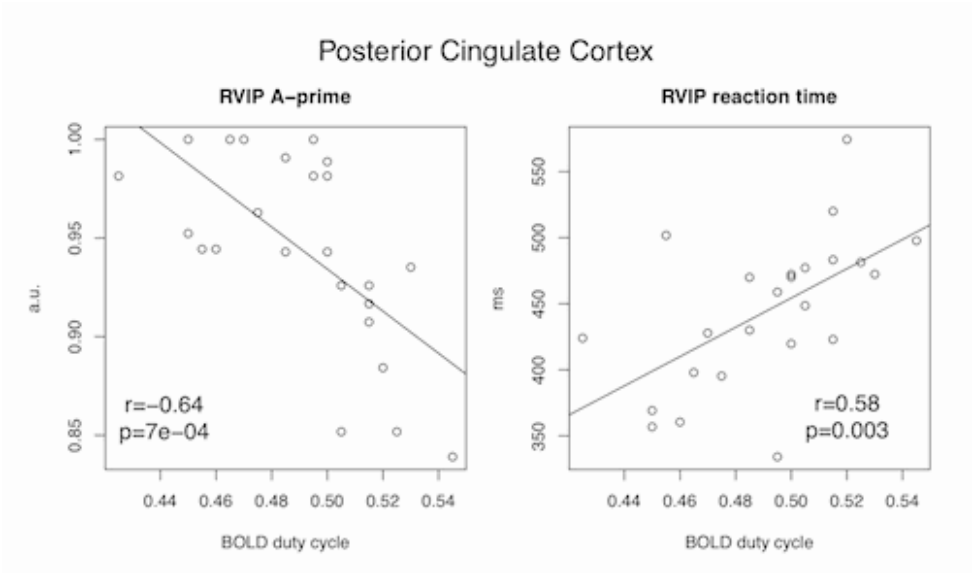
Results:

We observed a significant correlation between the values of the PCC BOLD duty cycle during the meditative procedure and the individual scores in the RVIP task (A-prime: r=-0.64, p= 0.0007; RT: r=+0.58, p=0.003): subjects with a lower PCC duty cycle tended to respond faster and more accurately on the sustained attention task (see Figure).

Conclusions:

Although these findings need to be confirmed by a larger study, they support the notion that individual capacity for top-down attentional control and resistance to mind-wandering is inversely related to the relative abundance of high levels of activity of the central DMN node, the PCC, when such activity is mobilized by the processes of meta-awareness and regulation of spontaneous

mentation that characterize the meditative exercise. The simple time-domain measure of the PCC BOLD activity proposed here, i.e. its duty cycle while subjects attempt to keep their attention on their breathing, appears as a promising candidate for an endophenotype of individual attentional skills.



Higher Cognitive Functions

Executive Function

Abstract Information

References

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