High temporal resolution fMRI-study of trial-by-trial brain function in Visual attention

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Introduction:
Attentional control refers to the regulatory processes that ensure that our actions are in accordance with our goals. In experimental psychology, reaction time (RT) obtained by pressing a button is one of the most widely used measures of attention performance. Our aim was to use a new approach to acquire whole-brain fMRI data at a high temporal resolution of 100ms [1, 2] to investigate trial-by-trial fluctuations between BOLD signal and RT.

Methods:
Seven healthy volunteers participated in the experiment. Data were acquired by a 3T Trio Tim scanner (Siemens, Germany) using a 32-channel head coil (TR=100ms, 64×64×64 matrix, 4mm voxel size). During the scans, subjects were instructed to perform the *Spatial Attentional Resource Allocation Task* (SARAT) in which an initial cue stimulus indicates that a subsequent target stimulus is more likely to appear at the cued location (predicted stimulus as top-down attention stimulus) than at other locations (unpredicted stimulus as bottom-up attention stimulus). Subjects were asked to press a button as quickly and accurately as possible upon appearance the target stimulus. The motion-corrected fMRI data were analyzed in the general linear model framework by modeling the fMRI signal as a canonical HRF at each stimulus time point. Motion, cardiac, and respiratory regressors were included as confounds. The mean HRF data obtained from each voxel in activated regions of interest (ROI) was calculated in order to find the grand average. Within the time range of the averaged responses, the trial-by-trial responses were determined and the amplitude and delay for each response was extracted and correlated with the RT.

Results:
The threshold for the activation maps was determined for each subject using a permutation test with randomly chosen event times ($p<0.001$). All brains were co-registered with the standard MNI space and commonly activated regions in at least 50% of subjects were considered for further exploratory investigation (Fig.1). Grand averaged HRF-responses within each region showed a significantly ($p<0.05$) shorter delay in predicted compared to unpredicted stimuli in the following areas: bilateral Cuneus and Precuneus; Frontal Middle Lobe, Fusiform gyrus and Parietal Inferior Lobe in the left hemisphere and Occipital Inferior, Parietal Superior and Temporal Middle lobes in the right hemisphere. The trial-by-trial correlations of RT and the HRF parameters are depicted in table 1 (also see Fig. 2.).

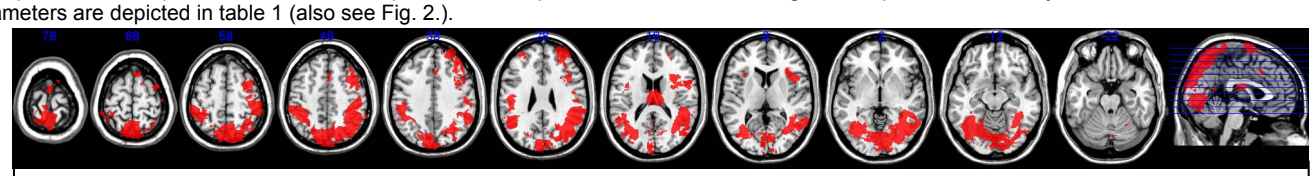
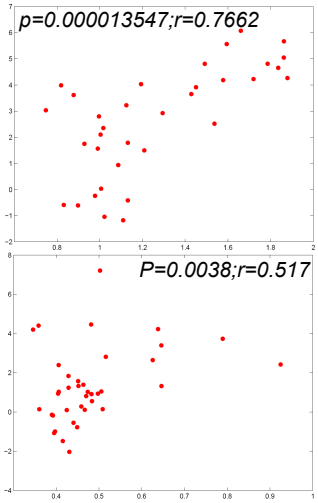


Fig.1. Commonly activated brain regions while doing SARAT task. All activated regions in 4 out of 7 subjects were overlaid and the active regions in all 4 subjects were chosen for the next step in order to obtain the haemodynamic response.

Conclusion:
This study shows that high temporal resolution fMRI can successfully measure small fluctuations in trial-by-trial BOLD signal correlated with RT in order to identify the emergence of functional networks in the brain during the execution of a cognitive task. Our result is consistent with previous reports [3] showing frontal-parietal stream is highly related to top-down attentional modulation.



ROI	PA	UA	PD	UD
L-Parietal Sup.	+	+	+	0
L-Precuneus	+	0	+	+
L-Occipital Inf.	0	0	+	+
R-Frontal Mid.	0	0	+	0
R-Occipital Mid.	+	0	0	0
R-Parietal Inf.	+	0	0	0
R-Parietal Sup.	0	0	+	0
R-Precuneus.	0	0	+	+
R-Frontal Inf.	+	-	0	0
R-Temporal Mid.	0	0	+	0
R-Frontal Sup.	+	0	0	0
R-Fusiform	0	0	0	+
Anterior Cingulate	0	0	0	+

Tab. 1. Brain regions showing positive or negative correlation of reaction time (button press) with HRF amplitude and delay.
(ROI) Regions of Interest; *(PA)* Predicted amplitude; *(UA)* Unpredicted amplitude; *(PD)* Predicted delay; *(UD)* Unpredicted delay; *(L)* Left; *(R)* Right.

(+) Positive correlation
(-) Negative correlation
(0) No significant correlation

Fig.2. Spearman's rank correlation of reaction time (x-axis) and HRF delay (y-axis) in predicted stimuli in the left parietal superior region in two subjects.

References:
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3. Ozaki TJ. Frontal-to-Parietal Top-Down Causal Streams along the Dorsal Attention Network Exclusively Mediate Voluntary Orienting of Attention. PLoS ONE 6(5): e20079. doi:10.1371/journal.pone.0020079.