Neuroscience Campus Amsterdam

Influence of heart rate variation on second-level fMRI group differences in a cognitive planning paradigm

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Introduction

fMRI signals during resting state are strongly correlated with variations in heart rate (De Munck et al., 2008). These heart rate/fMRI correlations are present in many regions of the brain and consequently may also form an important confound in case-control studies of fMRI during active task conditions, where groups systematically differ in heart rate. To assess the impact of heart rate on group effects, we co-registered the electrocardiogram with event-related fMRI during performance of a tower of London (ToL) cognitive planning paradigm in 12 twins discordant for obsessive compulsive symptoms (OCS). OCS related differences in fMRI brain activation were computed using GLM models with and without inclusion of heart rate data as nuisance regressors.

Methods

Participants: 12 monozygotic twin-pairs discordant for OCS (7F/ 5M; 32.8 ± 8.1 Yrs) were selected based on high scores in one twin (OCS-high) and low scores in the co-twin (OCS-low) on a 12-item version of the OCS Padua Inventory.

Task and data acquisiton: fMRI and the electrocardiogram were measured during performance of the ToL task, that consisted of 1 baseline condition (fig. 1A; BL: counting beads of specified colors) and 5 planning conditions (1-5), corresponding to the minimal number of bead swaps required to achieve a goal from a begin configuration *(fig. 1B).*

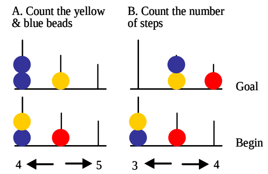

Fig. 1

Inter Beat Interval (IBI) regressors: we computed for each EPI scan, the mean of all inter beat intervals (time between 2 heart beats) during that scan (i.e., the heart rate inverse). To account for time differences between IBI and fMRI changes, we constructed 7 IBI regressors (IB-1 to IB-7) by shifting the basic IBI time series over multiples of the repetition time (TR = 2.3s) between successive EPI scans: [-2,-1,0,1,2,3,4].

Results

Influence task load on IBI: IBI was hardly affected by task load (fig. 2). The OCS high twins however did show a tendency for faster heart rates (lower IBI) across the whole experiment.

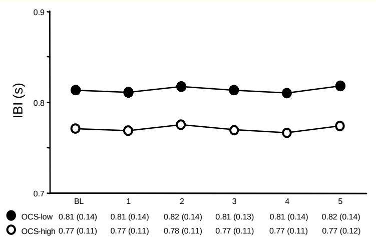

Fig. 2

Correlations IBI regressors with fMRI: fig. 3 shows that significant fMRI/IBI correlations were found especially for fMRI changes that followed IBI changes between 3 and 4*TR (=IBI-6: 6.9-9.2s delay).

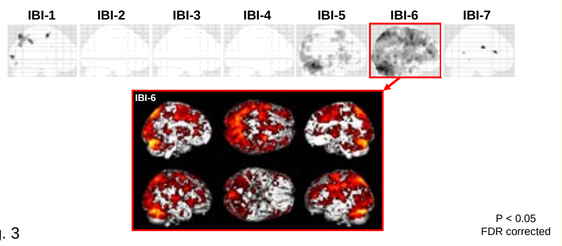

Fig. 3

Influence IBI regressors on task main effects: fig. 4 shows fMRI main effects (p<0.05, FDR corrected) for a 'planning vs. baseline' contrast (top row: all planning conditions vs. baseline) and 'task load' contrast (bottom row: fMRI correlated with planning difficulty). Addition of IBI regressors in the computation of 1st-level results did not meaningfully change the main effects across OCS high twins (compare first 2 columns on the left) or OCS low twins (last 2 columns on the right).

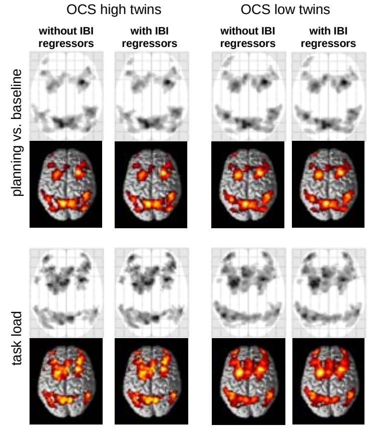

Fig. 4

Influence of IBI regressors on OCS related differences: Table 1 shows results from OCS high versus OCS low within twin-pair comparisons for the 'planning vs. baseline' contrast (on the left) and 'task load' contrast (right). In line with the marginal influence on group main effects, additional inclusion of IBI regressors (bottom panels) yielded outcomes practically identical to those obtained without IBI regressors (top panels: and published recently by den Braber et al., 2008).

Without IBI regressors

'planning vs. baseline'								
Cluster label	Anatomical location	BA	MNI coordinates x	y	z	Z score	p-value	# voxels
A	R. frontal gyrus	6	15	-3	63	4.17	0.000	29
B		8	15	24	48	3.08	0.001	9
C	L. frontal gyrus	6	-30	0	51	3.00	0.001	15
E		9	-36	21	30	3.15	0.001	4
D	L. inferior parietal gyrus	40	-39	-51	48	3.32	0.000	17
F	L. precentral gyrus	6	-21	-15	69	3.10	0.001	6
G	R. postcentral gyrus	1	36	-39	69	3.33	0.000	6
H	R. supramarginal gyrus	40	51	-54	21	3.35	0.000	22
I	L. inferior temporal gyrus	37	-48	-57	-3	3.64	0.000	16

'task load'								
Cluster label	Anatomical location	BA	MNI coordinates x	y	z	Z score	p-value	# voxels
A	L. frontal gyrus	46	-48	39	18	3.95	0.000	14
B	R. pulvinar	--	18	-36	9	3.07	0.001	5
C	R. medial frontal gyrus	8	21	30	36	3.24	0.001	11

With IBI regressors

'planning vs. baseline'								
Cluster label	Anatomical location	BA	MNI coordinates x	y	z	Z score	p-value	# voxels
A	R. frontal gyrus	6	15	-3	63	4.23	0.000	28
B		8	15	24	48	3.21	0.001	9
C	L. frontal gyrus	6	-30	0	51	3.00	0.001	15
D	L. inferior parietal gyrus	40	-36	-51	45	3.21	0.001	7
F	L. precentral gyrus	6	-21	-15	69	3.16	0.001	8
G	R. postcentral gyrus	1	36	-39	69	3.37	0.000	5
H	R. supramarginal gyrus	40	51	-54	21	3.36	0.000	24
I	L. inferior temporal gyrus	37	-48	-57	-3	3.71	0.000	16

'task load'								
Cluster label	Anatomical location	BA	MNI coordinates x	y	z	Z score	p-value	# voxels
A	L. frontal gyrus	46	-48	39	18	4.04	0.000	14
B	R. pulvinar	--	18	-36	9	2.97	0.001	6
C	R. medial frontal gyrus	8	21	30	36	3.28	0.001	9

Table 1.

Conclusions

Our findings confirm significant hemodynamic effects associated with heart rate variations during task performance. However, despite a systematic difference in inter beat intervals between the OCS high and OCS low scoring twins, the impact of ignoring temporal variations in heart rate on the group comparison of functional brain activation during performance of the tower of London task was negligible. It cannot be excluded however that heart rate variations do have a significant impact in studies with block designs, or studies where patients and controls show different IBI responses to changes in task difficulty, or studies with larger hemodynamic differences in patients compared to controls than in the present twin comparison. Therefore, considering the small effort of deriving IBI-regressors from the electrocardiogram and large explanatory power of fMRI in terms of heart rate variations, we still recommend the inclusion of IBI data as standard nuisance regressors.

References:
de Munck JC et al., Neuroimage. 2008, 42: 112-121.
den Braber A et al., Biol Psychol. 2008, 79: 91-102.

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