Neuroscience Campus Amsterdam

Influence of heart rate variation on second-level fMRI main task effects

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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 of fMRI during active task conditions. To assess the impact of heart rate on 2nd level group main effects we co-registered the electrocardiogram with fMRI in 46 subjects during a color-word Stroop task, which was administered using a block design, and a Tower of London (ToL) cognitive planning task, administered using an event-related design. fMRI brain activations were computed using general linear models with and without inclusion of heart rate data as nuisance regressors.

Methods

Participants: 46 neurologically healthy subjects (13M/33F: mean age 36.9 ± 8.9 yrs)

Task and data acquisiton: fMRI and the electrocardiogram were measured during performance of the Stroop and ToL task. During the Stroop task, subjects had to report the ink color of written color words. Word meaning and ink color could be either congruent (e.g. the word "green" written in green) or incongruent (e.g. the word "red" written in blue). The ToL consisted of 5 planning conditions (1-5), corresponding to the minimal number of bead swaps required to achieve a goal from a begin configuration (fig. 1; left), and 1 baseline condition (fig. 1; right : counting beads of specified colors) . Here we focus on the comparison of 4 steps planning versus baseline, because it showed the largest modulation of heart rate.

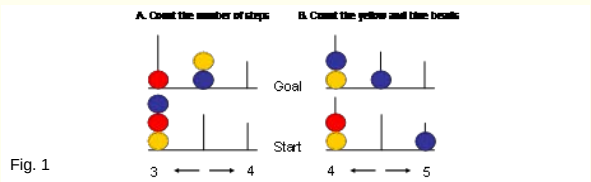

Fig. 1

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. To account for time differences between IBI and fMRI changes, we constructed 7 IBI regressors (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: Both Stroop interference (fig. 2: top) and ToL planning (fig. 2: bottom) were associated with significantly reduced reaction accuracies and significantly increased reaction times. Furthermore, reduced performance in both tasks was accompanied by significantly shorter IBI's (= increased heart rate), creating the potential for a confounding effect on fMRI responses.

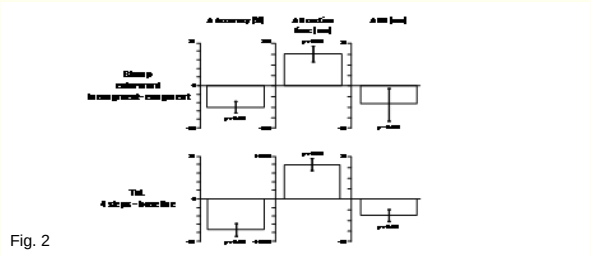

Fig. 2

Correlations IBI regressors with fMRI: Figure 3 shows fMRI main effects of the 7 individual IBI regressors when interpreted as effects of interest. The correlation patterns across the regressors appear similar for the Stroop task (top) and the ToL task (bottom), but most robust for recordings during the ToL. For the unshifted regressor (0*Tr) and the regressor with a positive time shift of 1*Tr, co-variations between heart rate and fMRI (i.e., negative correlations between IBI and fMRI variation) are evident across the whole brain, with posterior dominance. In contrast for larger positive shifts of 2, 3 and 4*Tr, heart rate and fMRI are inversely related (positive correlations). Inverse heart rate versus fMRI associations are also observed for shifts of the IBI regressor back in time, in particular for a shift of -1*Tr.

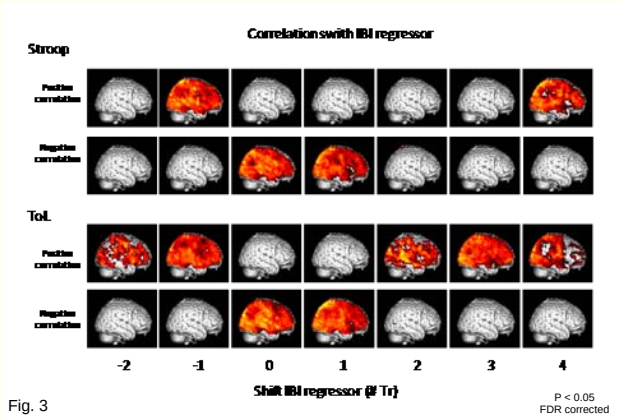

Fig. 3

P < 0.05
FDR corrected

Influence IBI regressors on task main effects: Figure 4 shows glass brain projections of Statistical Parametric Maps (SPMs) and lists of significant clusters for Stroop color-word interference (top panels) and Tol planning (bottom). The SPMs computed without the IBI-regressors as confounders (fig.4: left) were highly similar to the SPMs obtained with the IBI-regressors as nuisance effects (fig.4: right), although in general SPM T-scores and number of suprathreshold voxels were slightly reduced after including heart beat regressors in the GLM. In particular for Stroop color-word interference, which was statistically less robust (smaller T-scores and less suprathreshold voxels) compared to the main effect of ToL planning, this was exemplified by a number of larger fMRI clusters being split into 2 or 3 smaller ones and a dropout of the 5 smallest and least significant clusters.

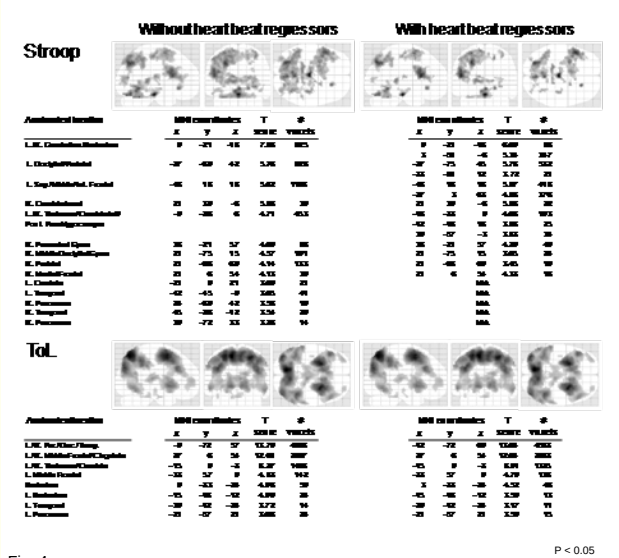

Fig. 4

P < 0.05
FDR corrected

Conclusions

Our final conclusion is that during performance of cognitive tasks there are substantial correlations between heart rate and fMRI signal changes across large parts of the brain. However, the fMRI signals associated with heart rate variations do not impact strongly on higher-order fMRI task effects even when heart rate is significantly modulated by task demands. This applies both for paradigms administered in a blocked design as well as for task presented in an event-related design.

References: **de Munck JC et al., Neuroimage. 2008, 42: 112-121.**

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