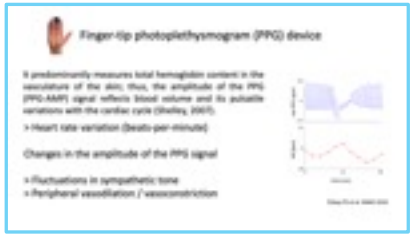
Sympathetic contribution of respiratory effects to the fMRI signal #3719

PS Özbay, C Chang, JA de Zwart, P van Gelderen, JH Duyn
Advanced MRI, NINDS, NIH

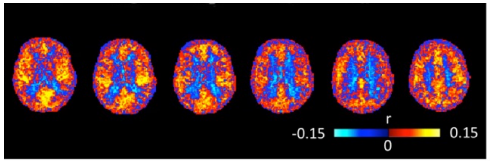
Background & Motivation

Our recent work (1) showed that, *during drowsiness and sleep*, covariations in systemic physiology, as measured by a finger-tip PPG device, and the fMRI signal may be predominantly *sympathetically* mediated.

Intermittent drops in the amplitudes of the PPG signal (PPG-AMP) were attributed to peripheral vasoconstriction events, due to increases in sympathetic tone.



Voxel-wise correlations of PPG-AMP and fMRI



n=8, light sleep

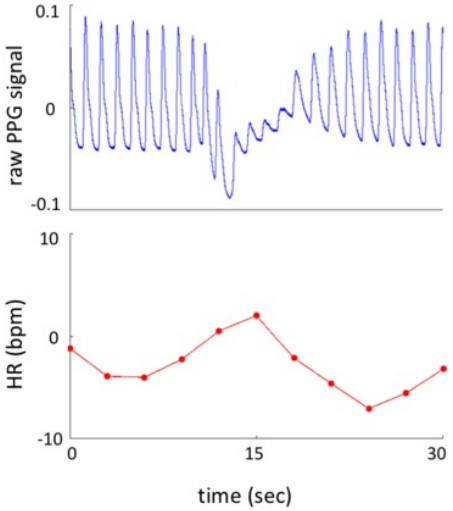
Finger-tip photoplethysmogram (PPG) device

It predominantly measures total hemoglobin content in the vasculature of the skin; thus, the amplitude of the PPG (PPG-AMP) signal reflects blood volume and its pulsatile variations with the cardiac cycle (Shelley, 2007).

> Heart rate variation (beats-per-minute)

Changes in the amplitude of the PPG signal

> Fluctuations in sympathetic tone
> Peripheral vasodilation / vasoconstriction



Özbay PS et al. NIMG 2018

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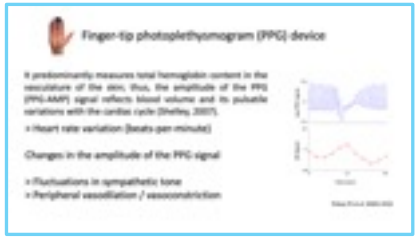

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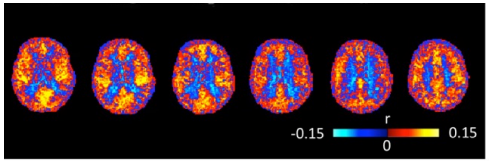


n=8, light sleep

Intermittent drops in the amplitudes of the PPG signal (PPG-AMP) were attributed to peripheral vasoconstriction events, due to increases in sympathetic tone.

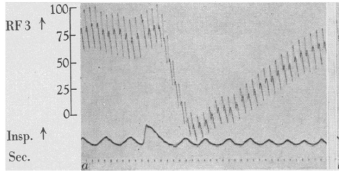
Here, we investigated whether sympathetic mechanisms may be prominent during *alertness conditions* more typical of task fMRI by studying the effects of *voluntary deep breaths during a visual task*.

VASO-CONSTRICTION IN THE FINGER AFTER DEEP INSPIRATION

By R. W. GILLIATT

From the University Laboratory of Physiology, Oxford

(*Received* 24 *March* 1947)



Finger volume was recorded optically by glass plethysmographs.

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Methods

fMRI data:

7T, TR=2s, TE=30ms, 2mm isotropic, acceleration-factor = 2), 32-channel head coil.

Physio data:

Respiratory bellow (Respiratory volume (RV)),

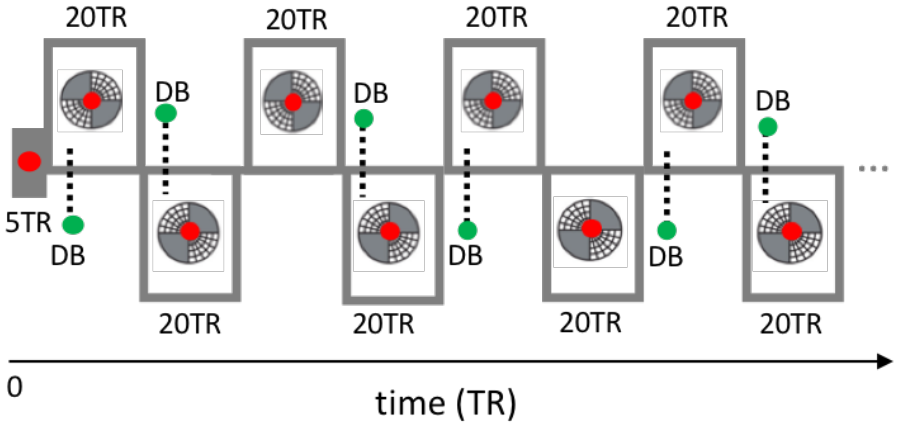
Pulse oximeter (heart rate variation (HR),

PPG amplitude (PPG-AMP))

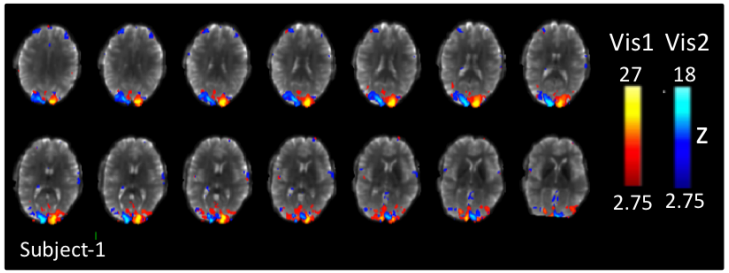
Experiments:

Resting-state (175 TR), visual-task (225 TR), deep breathing (DB) with visual-task (375 TR).

Overall we included n=12 healthy (age range 20-40) subjects.



DB: Green dot replaced the red dot at 5th TR green for 2s.



ICA: Components related to visual task

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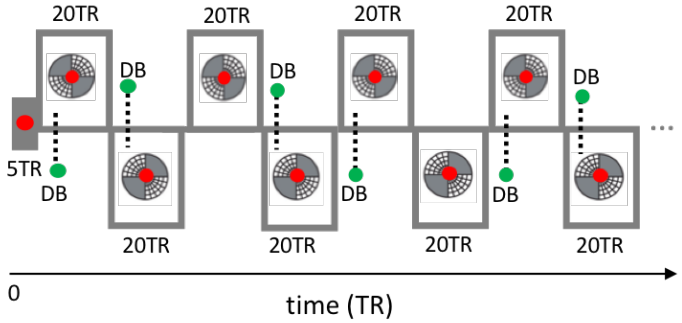
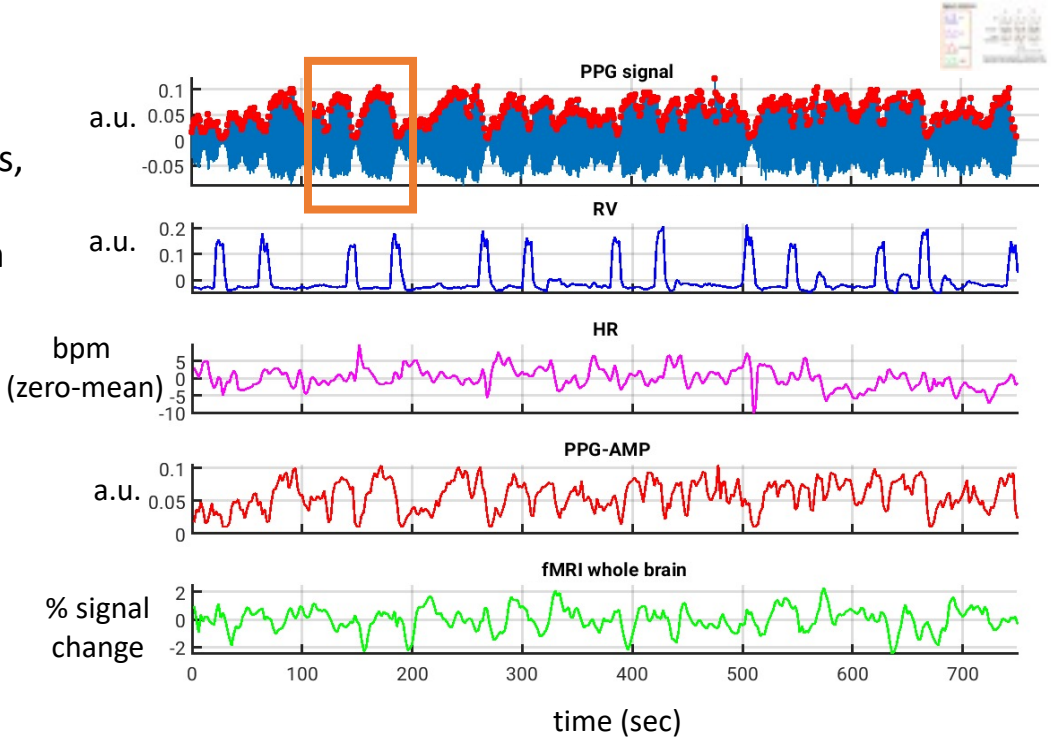
Methods

Preprocessing of fMRI data:

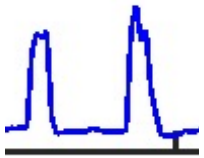
Motion coregistration and regression, polynomial regression of low-frequency signal drifts, and slice timing correction (AFNI). Brain masks are generated (FSL, BET) to calculate % signal change in the whole brain.

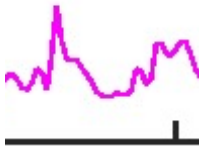


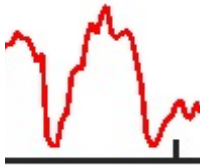
Results

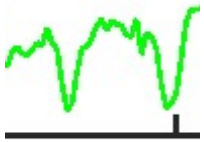


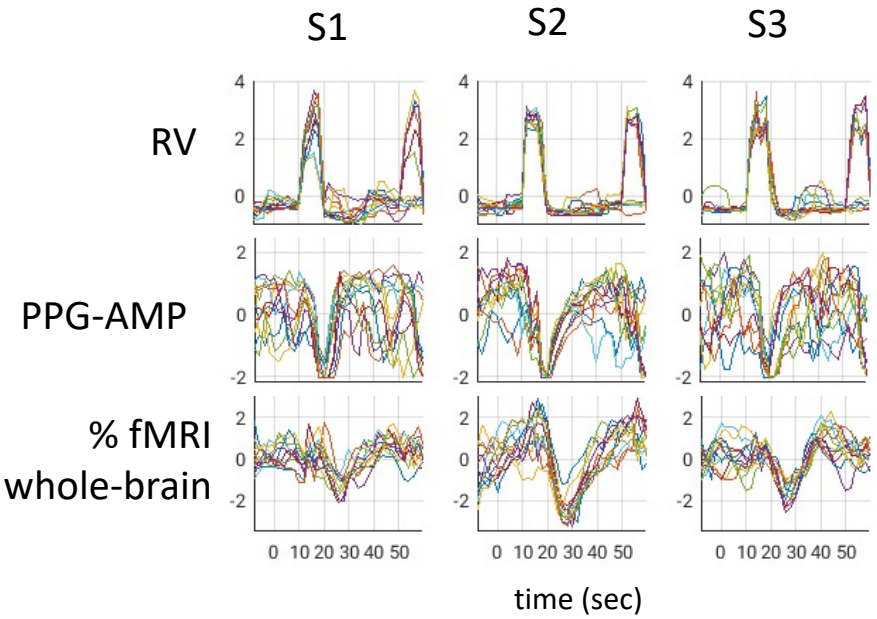
Signal relations


RV


HR


PPG-AMP


fMRI



Colors represent DB events (#12).

RV increase starts around 10th s, followed by PPG-AMP drop (~+6s) and fMRI signal decrease (~+10s).

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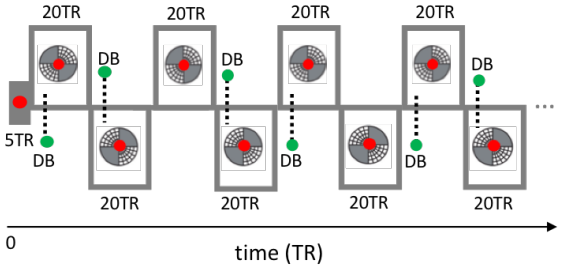
Methods

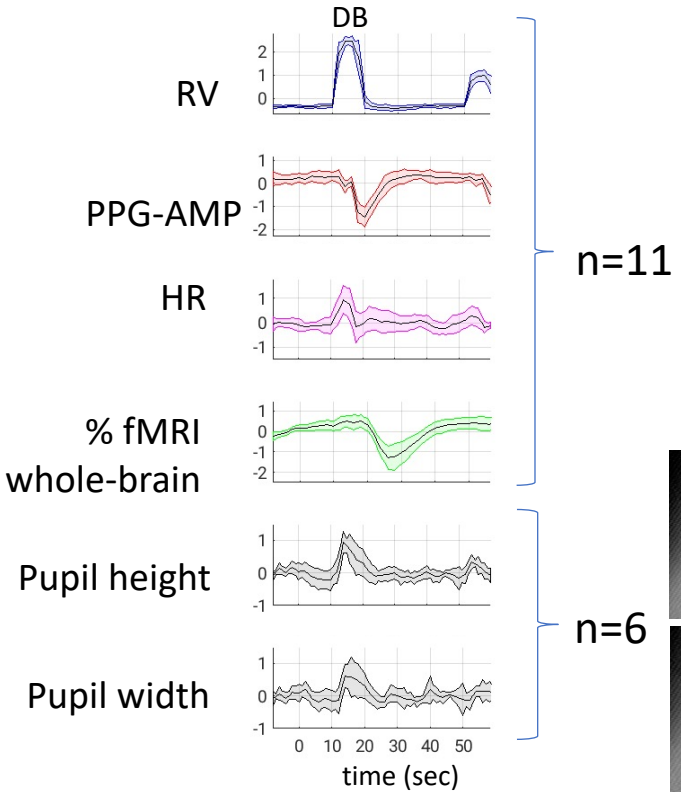
Eye-camera: The camera was fastened directly to the head coil with a custom mount, and was aimed at the subjects' left eye. It was used to track pupil dilation as an indicator of increased sympathetic tone (Critchley H.D. 2009).

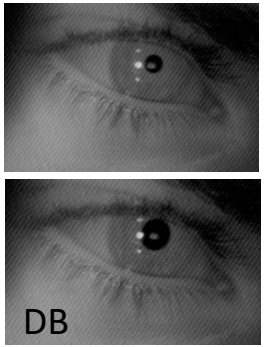
Signals were temporally normalized to zero mean and unit standard deviation prior to averaging.



Results

Event locked signal changes





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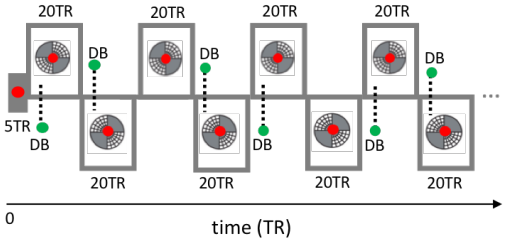
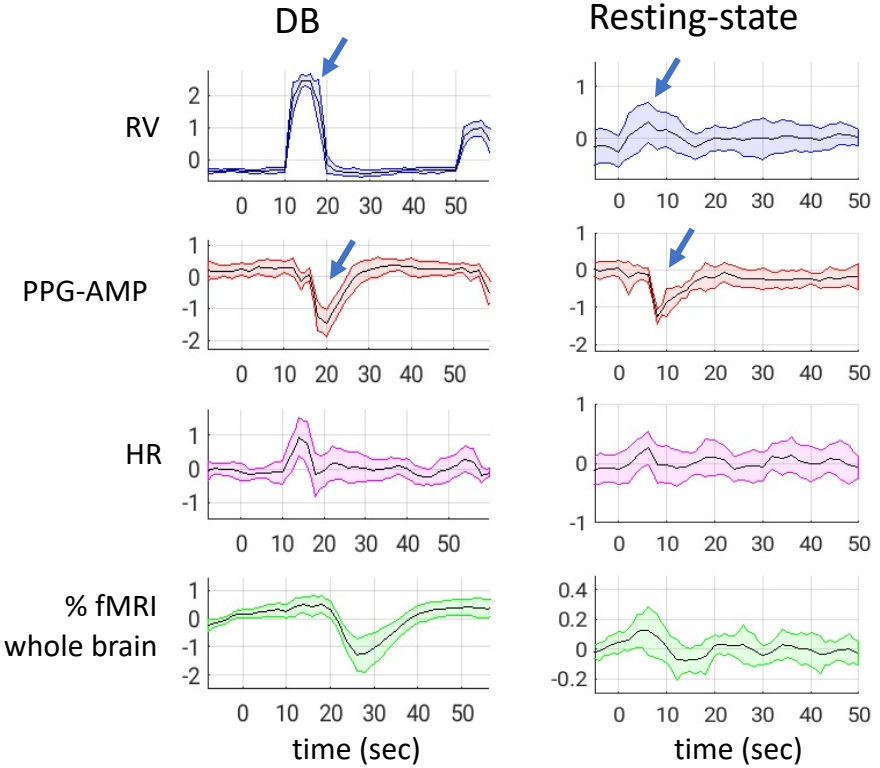


Event locked signals created based on timing of deep breaths for VisDB, and a predefined threshold for PPG dips (less than half of std) for (eyes closed) resting state experiments.

Results

Event locked signal changes



Number of identified dips varied between 12 to 26 between subjects (scan duration = ~6 min).

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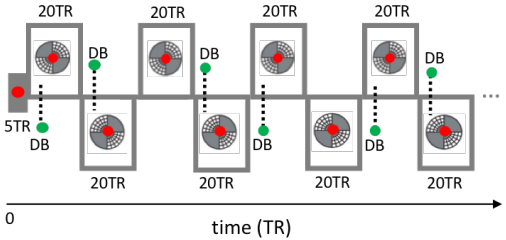
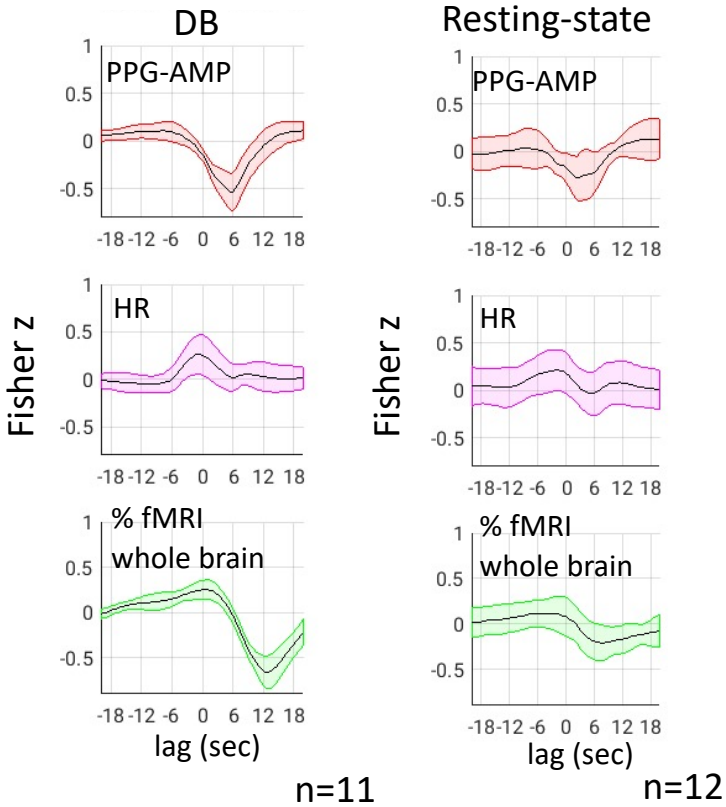


Cross-correlations of RV with other signals were performed at various lags. E.g. for DB experiment, a negative correlation with PPG-AMP at a positive lag indicates an RV increase is followed by PPG-AMP drop.

Results

Lagged correlations with RV



The delay between PPG-AMP dip following RV change is less (2-3s) during resting-state versus deep breaths (5-6s).

Discussion

The time lag observed at the strongest correlation between RV and PPG-AMP was longer for DB than resting-state data. This might give us a hint that the triggering factor of the sympathetic mechanism could be different, such as variations in physiology versus arousal.

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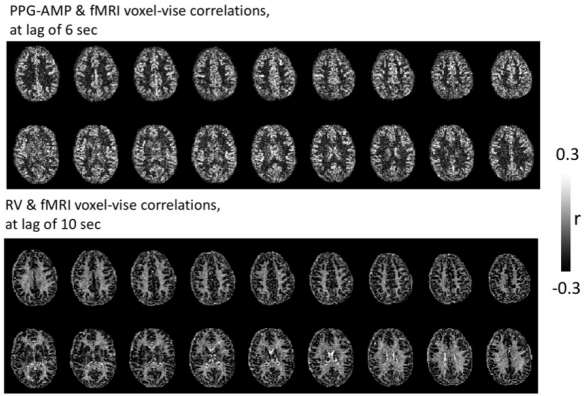

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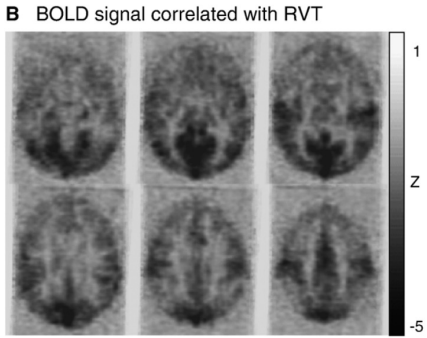
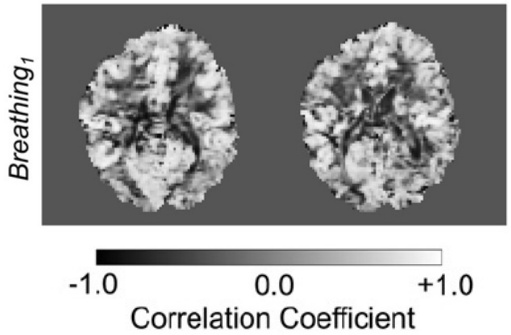


Birn et al. NIMG 2006



Bright et al. NIMG 2014

> Our results support the well-known relation of DB effects on peripheral measures of sympathetic activity, and further illustrate their temporal relationship with fMRI. Observations might explain some of the previous correlations found between RV and fMRI during DB.

> The similarity with light sleep (Ozbay et al. NIMG 2018) is consistent with sympathetic origin, as the arousal variations are accompanied by sympathetic variation.

> It should also be noted that joint PPG-fMRI variations are not always accompanied by changes in RV, e.g. during light sleep. Because of this, physiological noise removal from fMRI data under general conditions may benefit from using additional regressors, including PPG-AMP.