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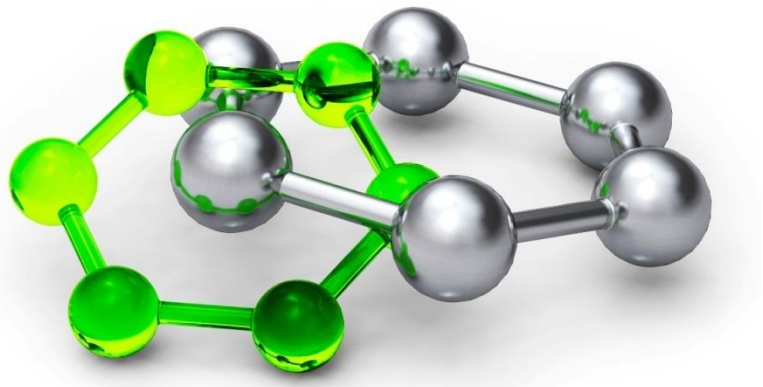
Physiological artifacts

Bartoň, M.

CEITEC MU, Masarykova univerzita



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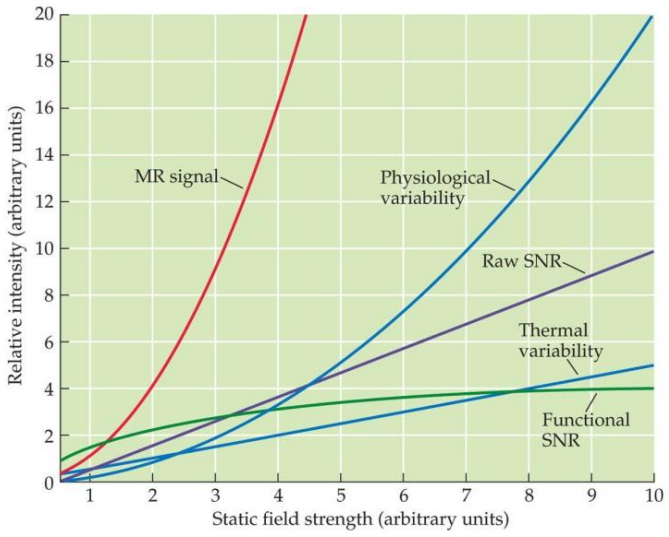
Noise in fMRI time series

- Thermal noise (additive)
  - Brownian motion; contributions from everywhere (FOV, scanner)
  - „white“ spectrum; whole scanned volume (background/air too)
- Scanner instabilities (multiplicative)
  - Imperfections in the slice selection, fluctuations in RF amplifiers‘ gain, not exactly the same trajectory of k-space filling during acquisition, instability of shimming, RF interference, „spikes“
  - Complicated spatiotemporal structure
- Head motion (multiplicative)
  - Frequently as a consequence of other body parts motion (transfer)
  - Relaxation of back muscles (drift)
  - Manifestations mainly in areas with borders of different T2*-relaxation “enviroments” (surroundings of ventricles, edges of brain)

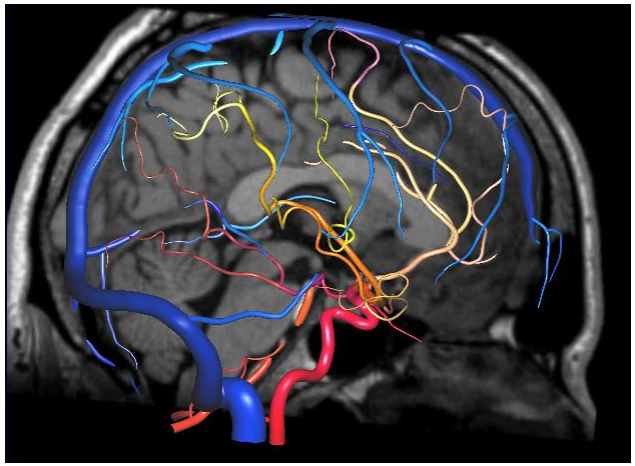
Noise in fMRI time series

- Physiological noise (multiplicative)
  - Processes linked with heart action, breathing
  - Complicated spatiotemporal structure, localized mainly in CSF areas and large vessels (heartbeat) and edges of brain (breathing)

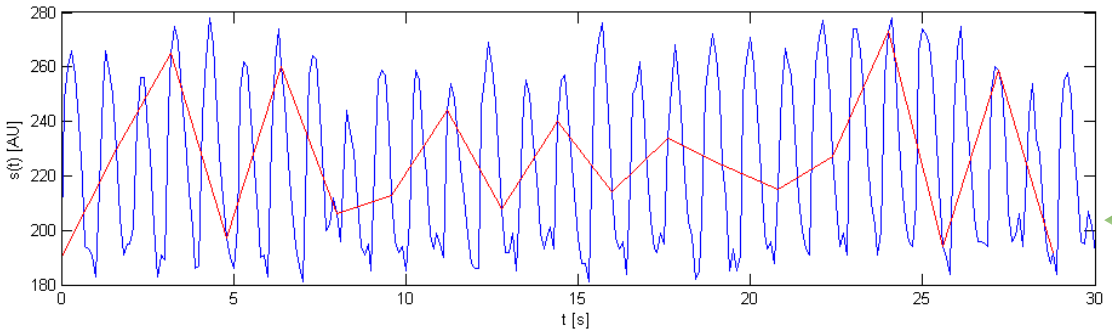
- Direct impact of B0 value on “composition” of fMRI noise
  - MRI signal increases quadratically
  - Thermal noise increases linearly
  - Physiological noise increases quadratically

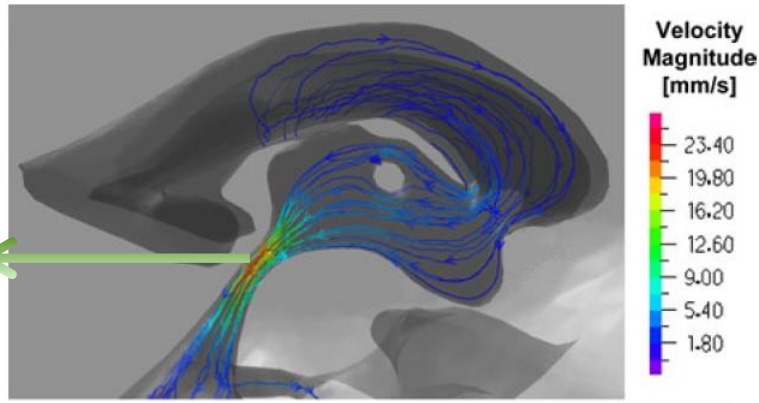


Physiological artifacts, heartbeat



- Fixed volume of cranial cavity
- During systolic phase:
  - Arterial blood inflows
  - Part of the liquor outflows from subarachnoid space (inside skull) to central canal (around spinal cord)
  - liquor outflow from IV. ventricle, outflow of venous blood (sinuses)
  - liquor outflow from lat. ventricles to III. and IV. ventricles
- During diastolic phase
  - - reversed motions of liquor (compared with systole)
- Example (TR=0.1 s; TR=1.6 s):



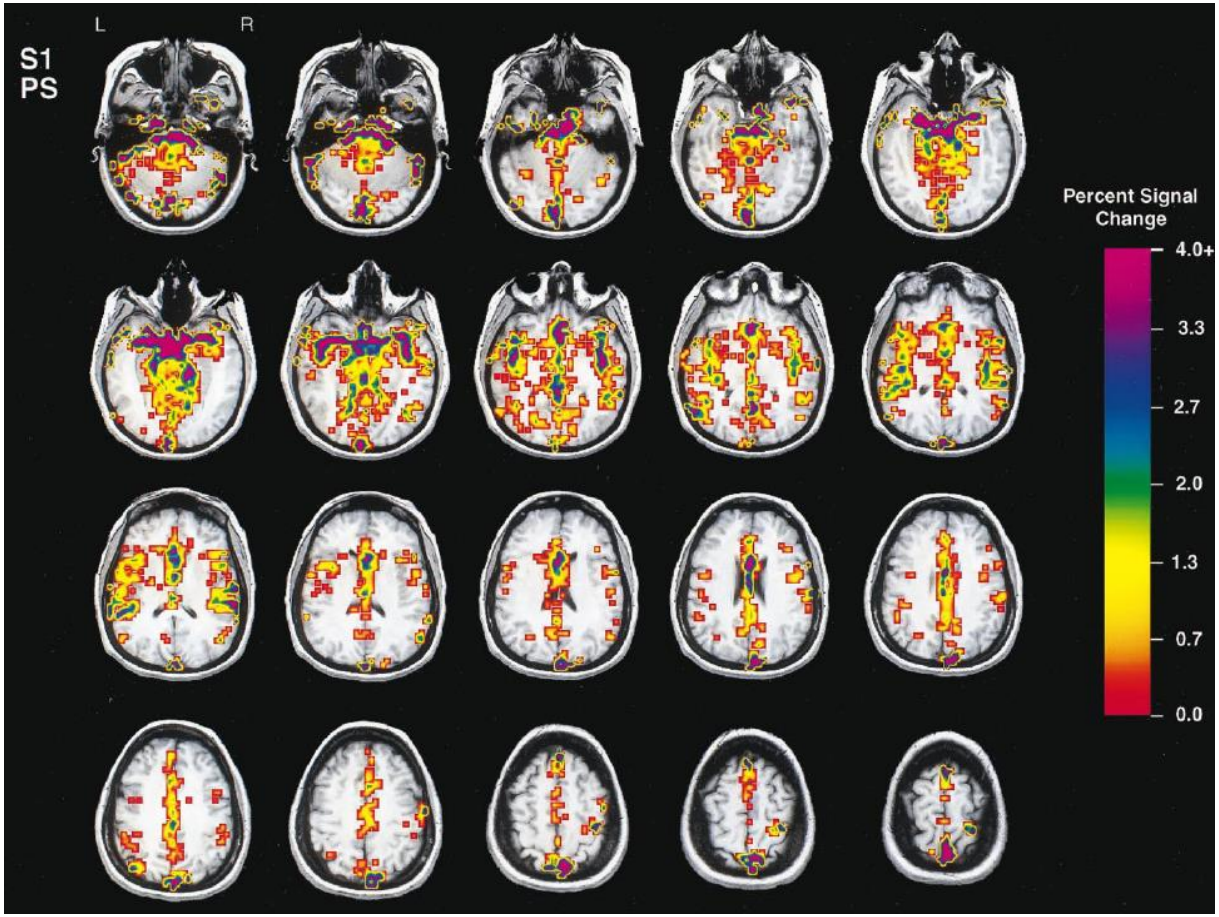


SWEETMAN, B., LINNINGER A. A.,Cerebrospinal Fluid Flow Dynamics in the Central Nervous System, 2010

Physiological artifacts, heartbeat

- Weisskoff et al., 1993
  - TR=133 ms; spectral peaks linked with heartbeat in V1 observed; in sup. sag. sinus and CSF second harmonics too
- Dagli et al., 1998
  - TR=3 s; pulse wave reconstructed from data (phase of ECG during particular scans)
  - significant manifestation in >25 % of voxels
  - consisted observation (topography and amplitude) among all 6 subjects
  - large vessels and CSF compartments

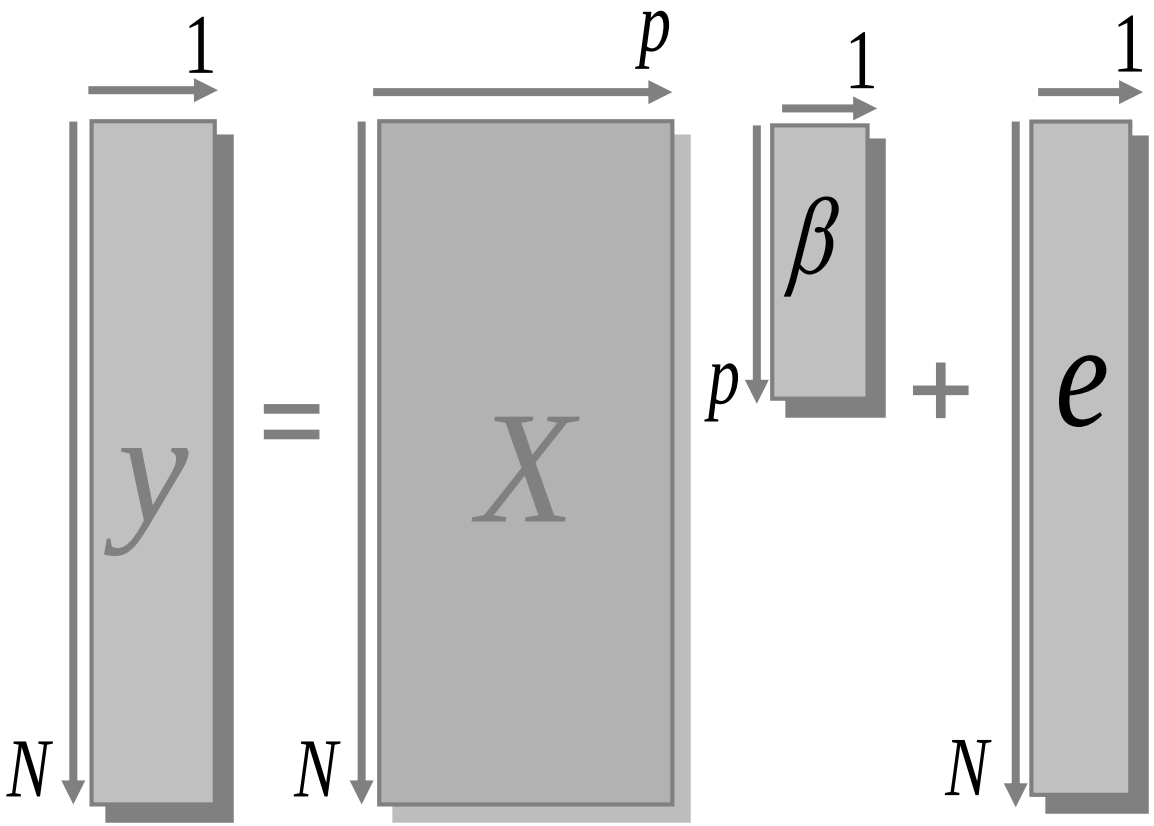
Physiological artifacts, heartbeat



Physiological artifacts

- Lund et al., 2006
  - effects localization:
    - heartbeat – large vessels, CSF
    - breathing – large vessels, CSF, edges of brain
    - head motion – edges of brain
    - nf. oscilations – great extent across whole cortex
  - undersampled physiological artifacts introduce time autocorrelated character of fMRI data
  - this situations may violate assumptions of statistical tests (independence of residuals);
    despite the correction procedures, the autocorrelations persist

Mass-univariate analysis: voxel-wise GLM - assumptions



$$y = X\beta + e$$

$$e \sim N(0, \sigma^2 I)$$

Model is specified by
1. Design matrix X
2. Assumptions about e

N: number of scans
p: number of regressors

The design matrix embodies all available knowledge about experimentally controlled factors and potential confounds.

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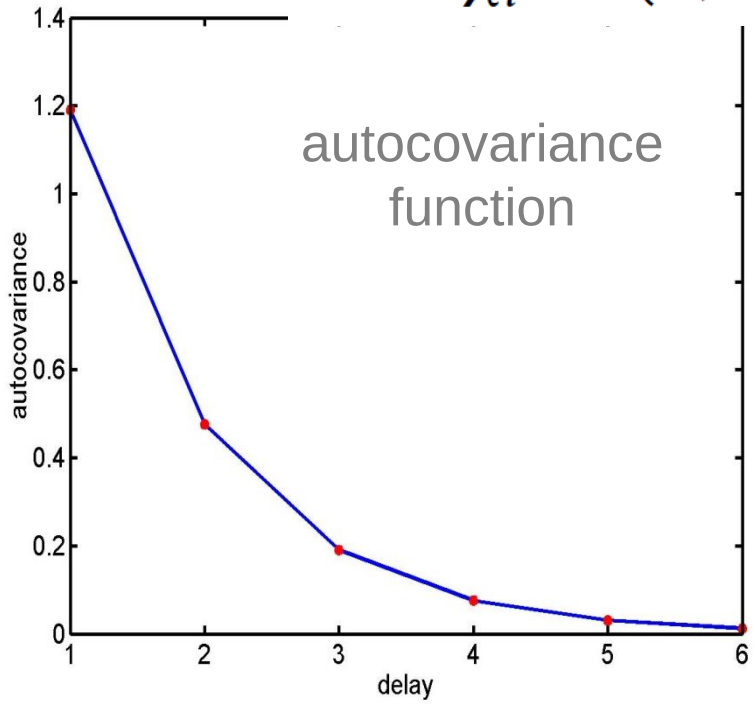
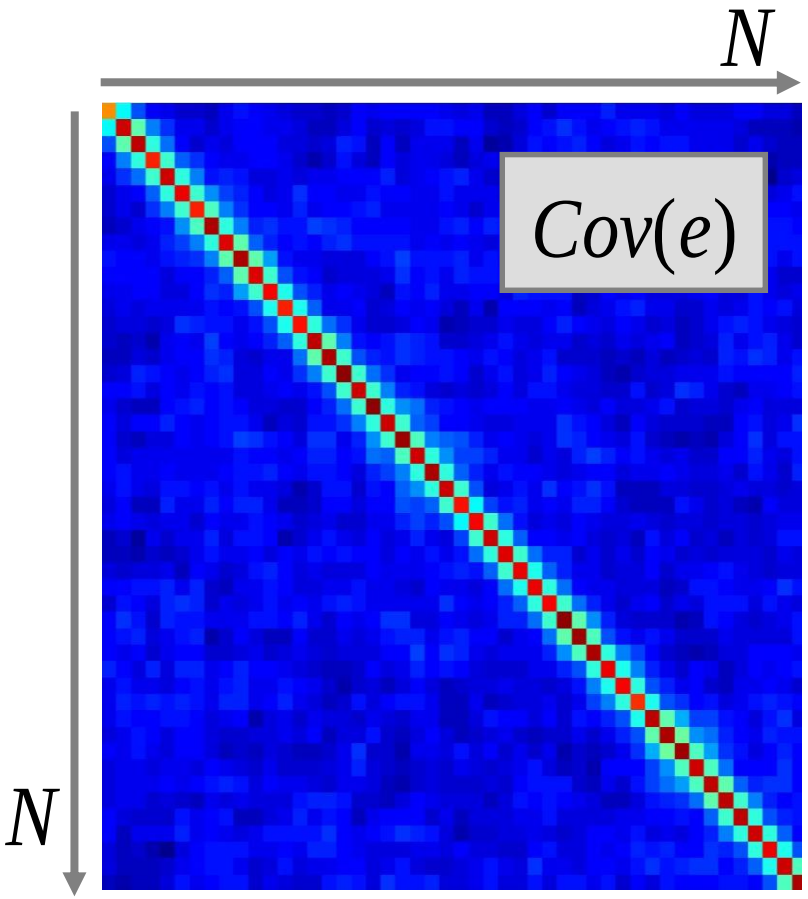
Non-white noise in fMRI data

i.i.d: $e \sim$

$$\varepsilon_i = \rho\varepsilon_{i-1} + \chi_i$$

with $\chi_i \sim N(0, \sigma_\chi)$





Non-white noise and the statistical interpretation of fMRI data

M. Welvaert, Y. Rosseel / Journal of Neuroscience Methods 211 (2012) 125–132

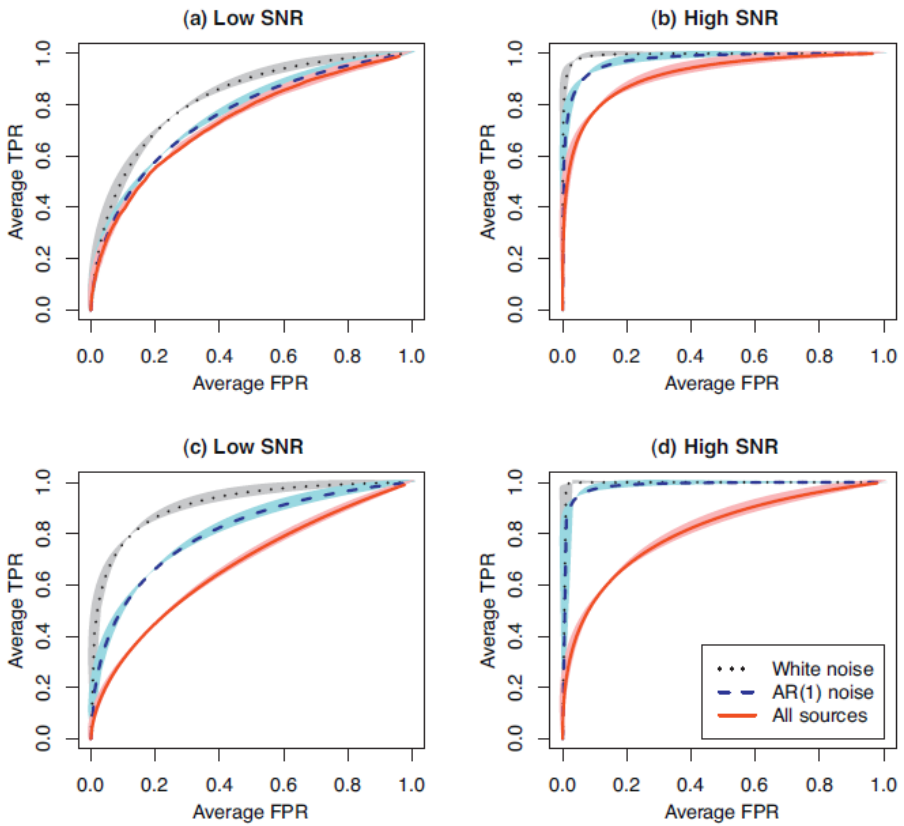
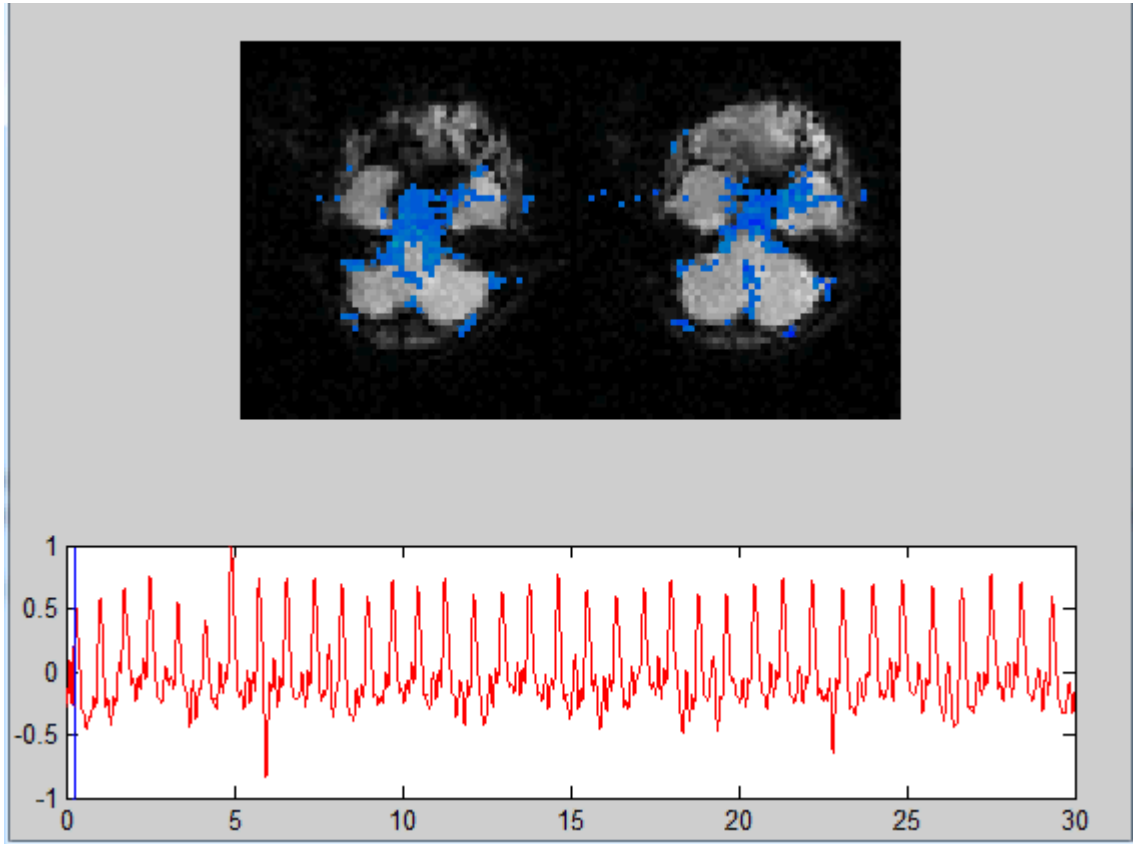


Fig. 2. ROC curves representing the average TPR and FPR in the three noise conditions in simulation study I. Shaded areas represent the 95% confidence intervals. The upper panel shows the results for the Bloch equations method and the lower panel contains the results for the time series method. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Our observations, heartbeat

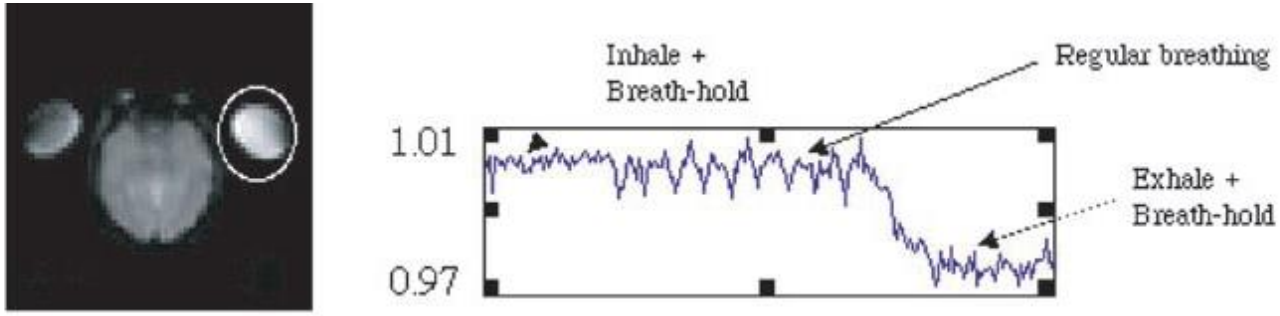
- 1.5 T Siemens Symphony
- 2 slices, matrix 56x64, 4x4x4 mm with 0.5 mm gap between slices
- TR 167 ms, TE 35 ms, FA 25°

Heartbeat manifestation, example



Physiological artifacts, breathing

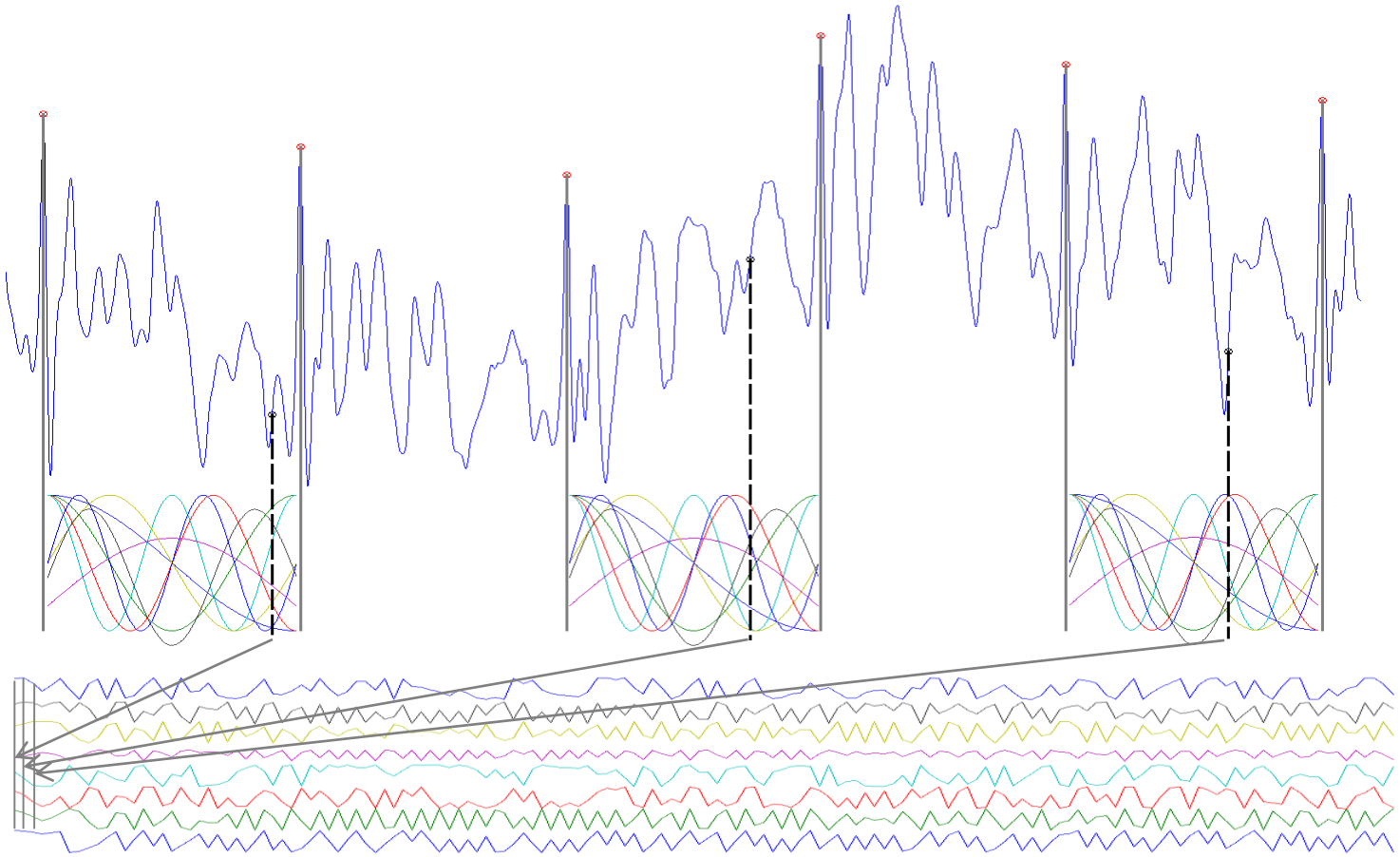
- Breathing
  - changes in location, compressing of scanned structures
  - changes in B0 homogenity in the rhytm of motion and bulk changes of chest



Raj D et al. (2001) Respiratory effects in human functional magnetic resonance imaging due to bulk susceptibility changes. Physics in Medicine and Biology 46:3331.

Principle of heartbeat and breathing artifacts detection, filtering – RETROICOR (Glover 2000)

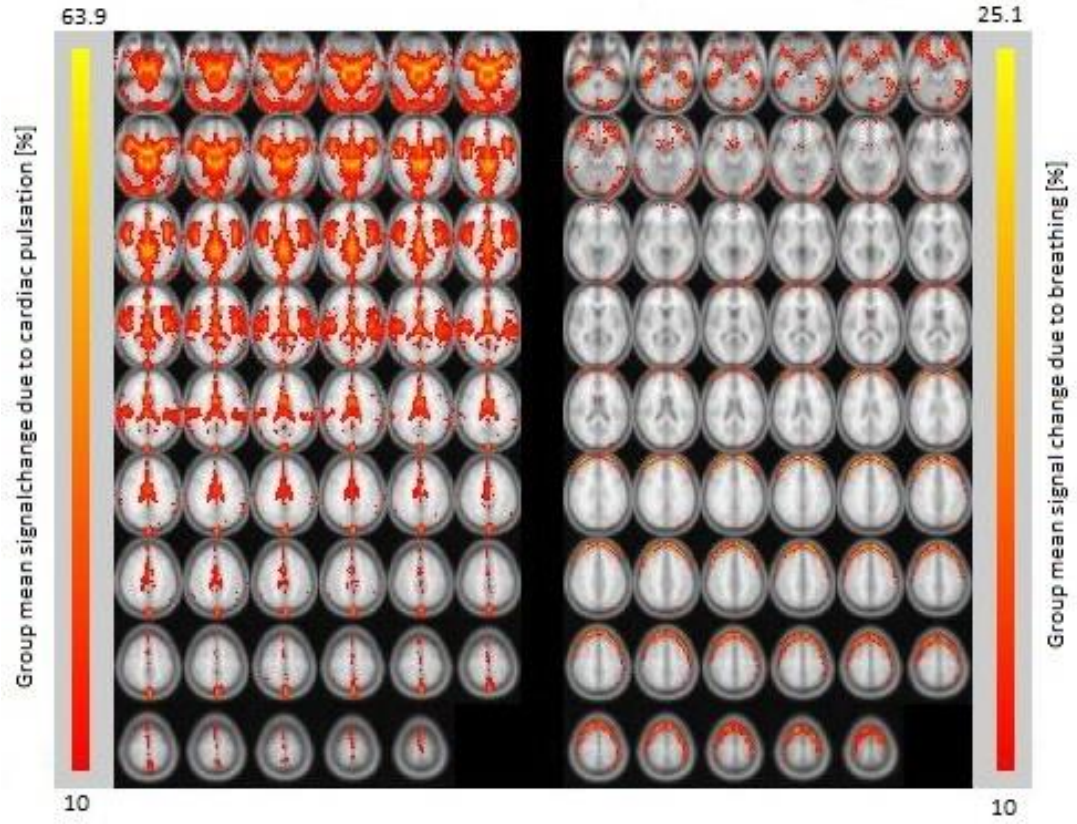
These signals are (almost everytime) undersampled in fMRI
=> construction of regressors from basis functions undersampled in the same way (for every slice separately)



Our observation – quantification of heartbeat/breathing effects

- Eleven subjects undergone resting-state fMRI scanning on 1.5T Siemens Symphony scanner. Measurement consisted of 300 scans with the following settings: TR=3 seconds, 32 oblique slices, 64x64 in plane resolution. High-resolution anatomical T1-weighted scans were also acquired. ECG and accelerometric breathing curves were recorded during fMRI scanning with BrainVision recording system.

- We used RETROICOR to fit the variability induced by heart activity and breathing in fMRI data. Each of these phenomena was modeled with Fourier set of 8 basis functions. These functions were for particular slices undersampled with respect to the corresponding phases of cardiac and breathing cycles. Calculations of percentual variability of these two kinds of PN were done for every intracranial voxel, then we coregistrated these parametric maps to the standard MNI template.



Physiological artifacts

- Changes in breathing volume/time (Birn et al. 2009) and heart rate (Chang et al. 2009) and the changes of BOLD signal?
  - → vasodilatation (CBV, CBF)
  - ← neuronal activity (changes of emotional state)

  - almost everywhere (whole brain volume)

Thank you for your attention

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