University of Zurich UZH
ETH zürich
Translational
Neuromodeling
Unit

Noise Models and Correction for fMRI

- *an Introduction to the PhysIO Toolbox*

Matthias Müller-Schrader

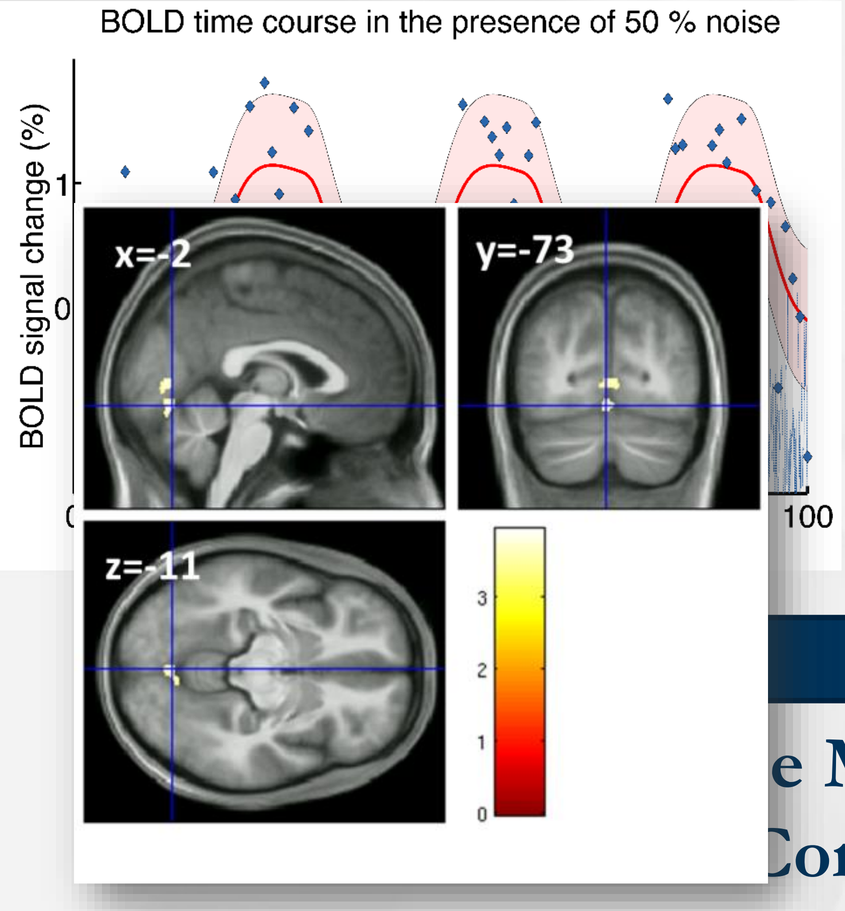
Nov 19th, 2019

Generous slide courtesy

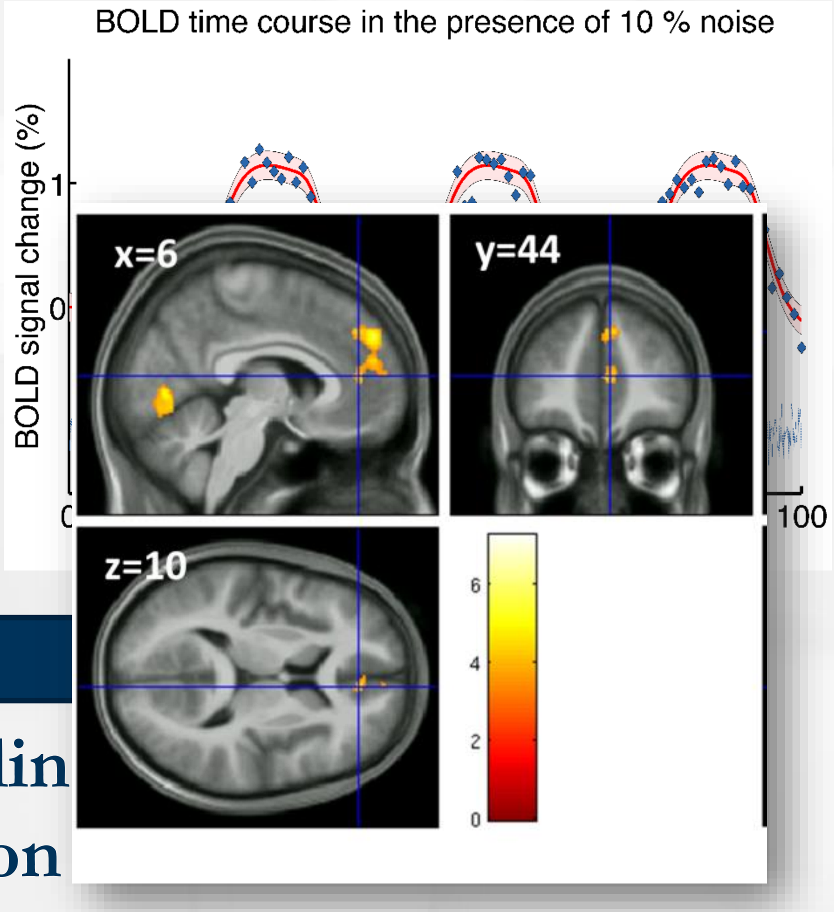
Lars Kasper

The Goal of Noise Correction

Before


BOLD time course in the presence of 50 % noise

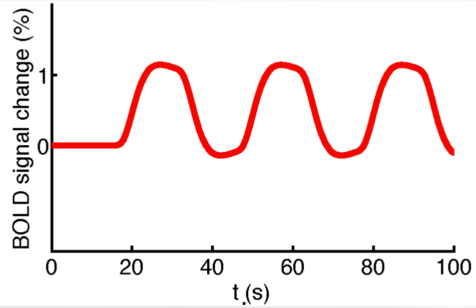
After

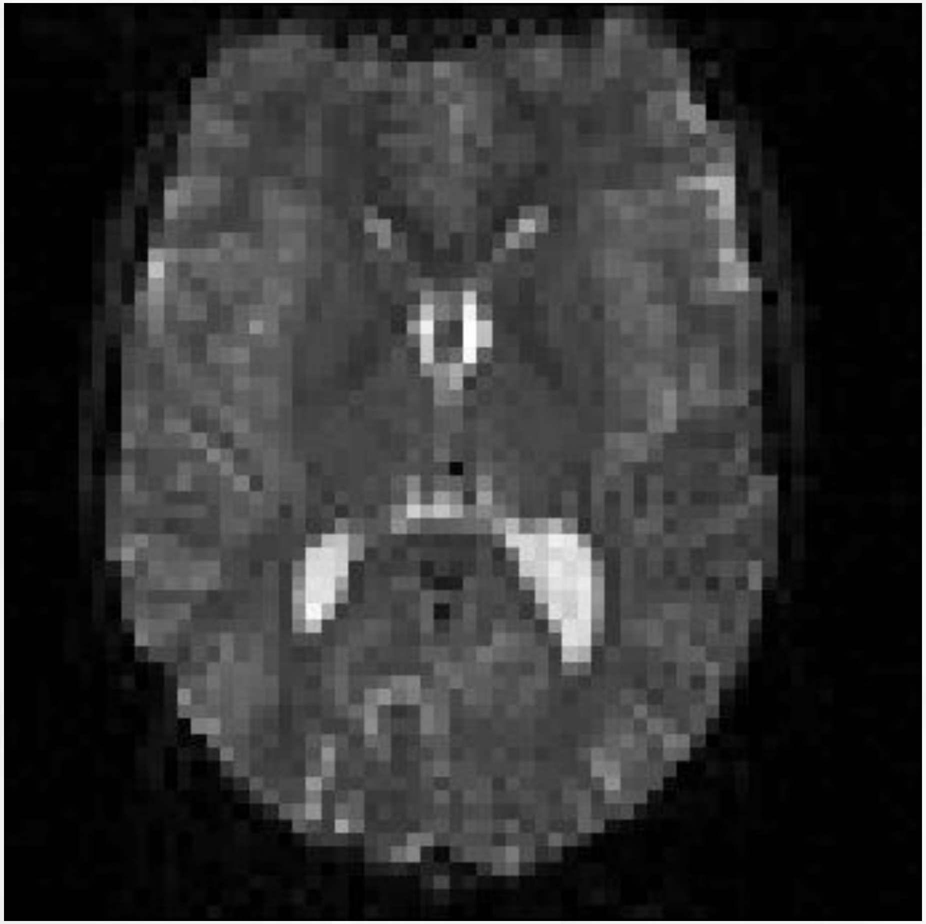

BOLD time course in the presence of 10 % noise

e Modelin

Correction

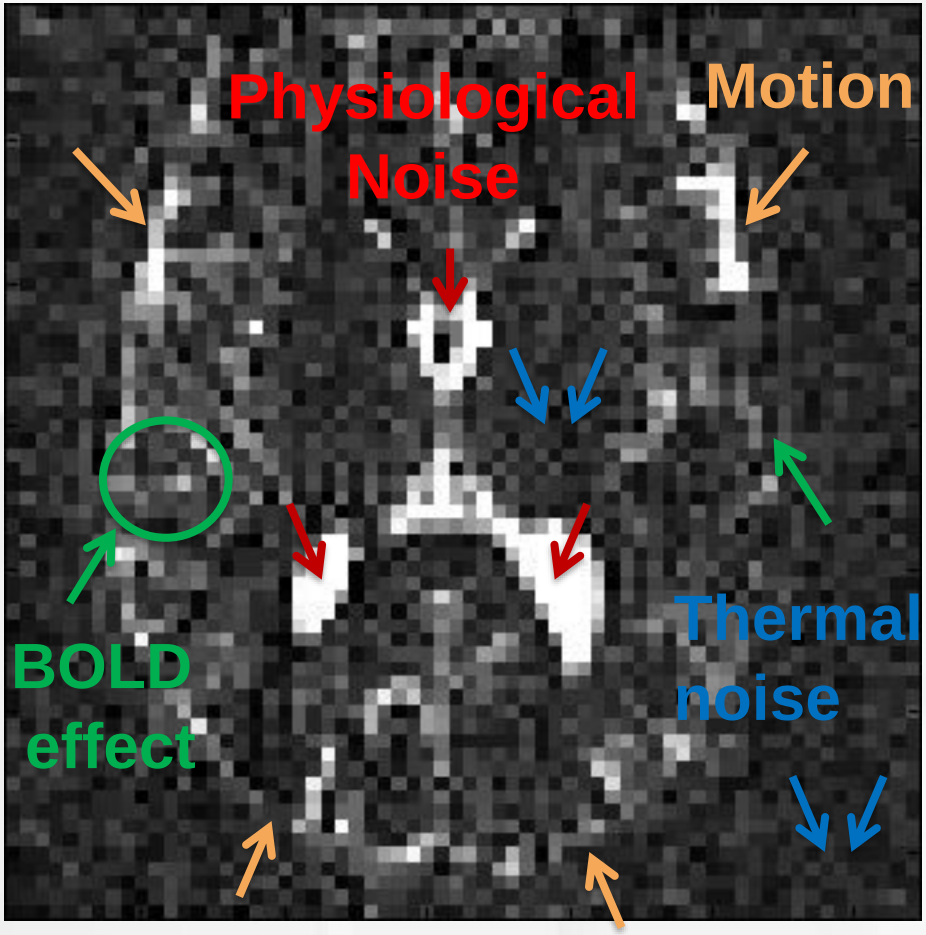
Reminder: fMRI Data is noisy…





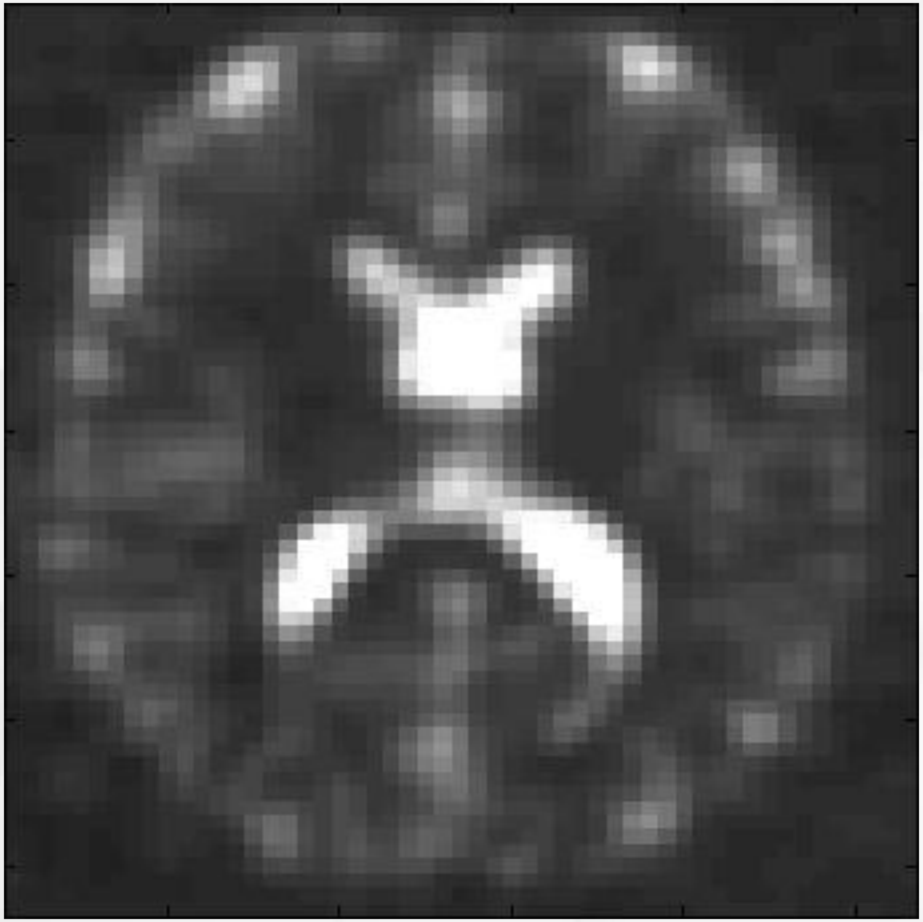
fMRI Data is noisy…

- Interest in fluctuations only: Subtract the mean



Previously…

- How we ended 6 weeks ago (after preprocessing)
- After smoothing… still some fluctuation



Recap: Imaging pathway

- See blackboard.

Physiological noise

- Noise: «Fluctuations we are not interested in.»
  - Often random
- Sources of noise
  - MR-System
    - Heating of gradient coils
    - Noise in amplifiers
    - Spikes in coils
  - Subject in the Scanner
    - Motion
    - Physiological noise
      - Cardiac cycle
      - Breathing cycle
    - **Not the BOLD-signal**

Outline

- Why denoising?
- Pathways of physiological noise
  - Recap: MR image encoding
  - Cardiac effects
  - Respiratory effects
- Noise correction approaches

Method	Preprocessing vs modeling
Input	fMRI data vs. peripheral measure

- Effects of noise correction
- Limitations

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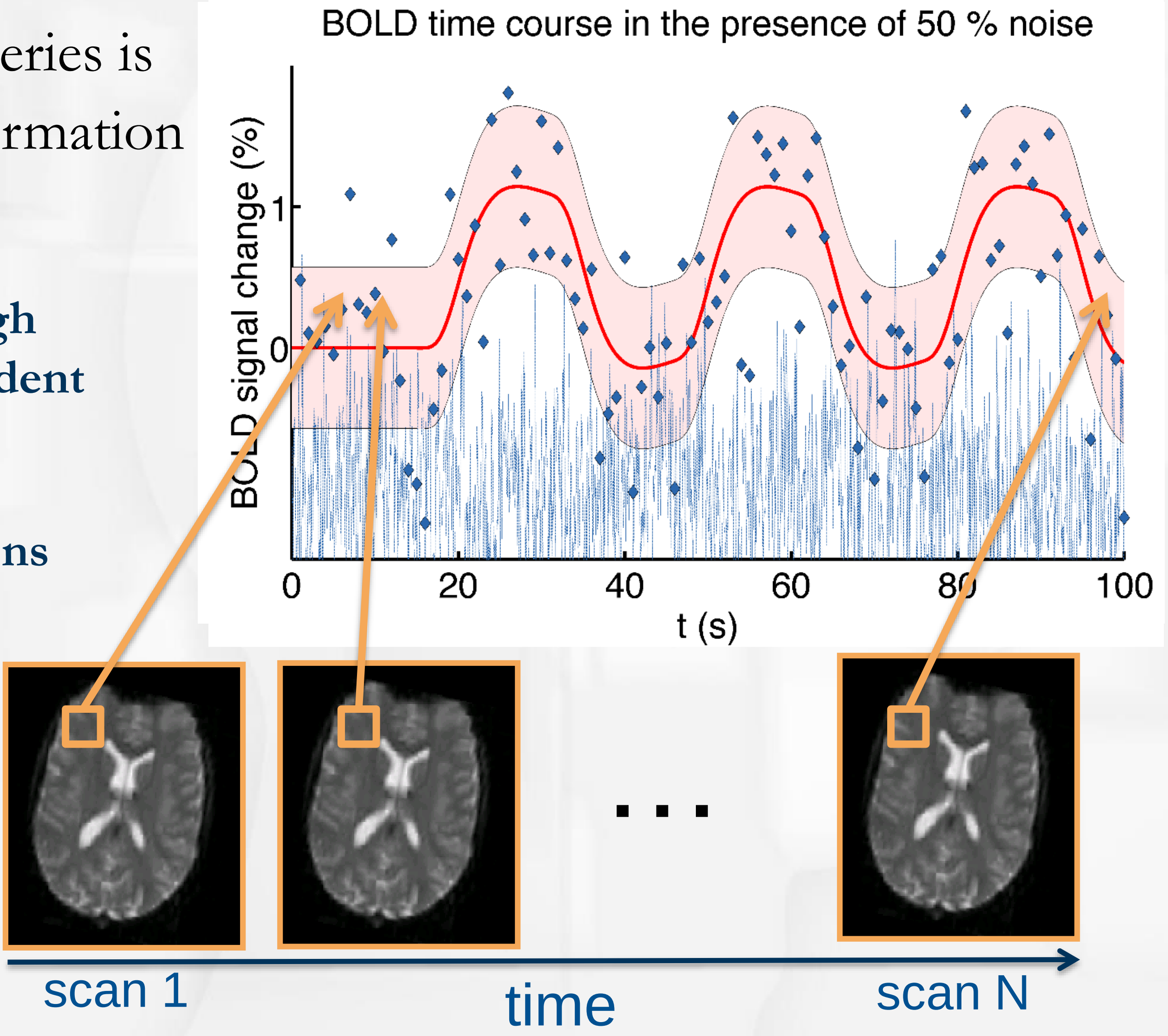
fMRI = Acquiring Movies

- The Localized Time-series is the Fundamental Information Unit of fMRI

Signal: Fluctuation through Blood oxygen level dependent (BOLD) contrast

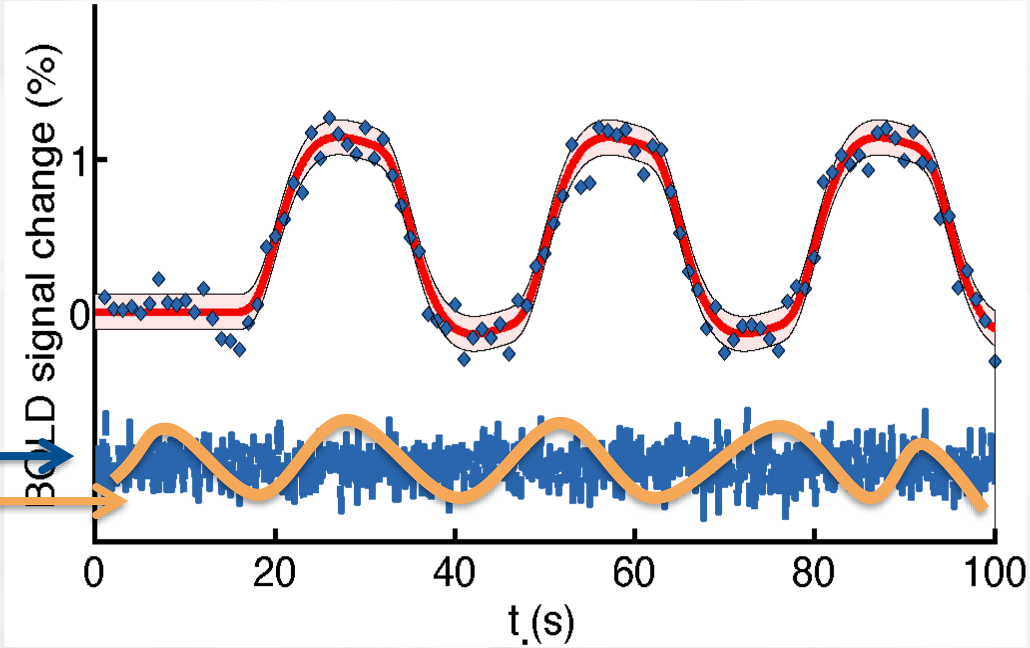
Noise: All other fluctuations

- Run/Session: Time Series of Images



Noise Categories

- Thermal Noise
  - temporally uncorrelated
  - reduced SNR ➔ risk of false negatives
  - Remedy: Spatial Smoothing



Noise: All other fluctuations

- “Structured” Noise
  - temporally correlated
  - reduced SNR ➔ risk of false negatives
  - correlated with task ➔ risk of false positives
  - Remedy: Noise modeling (e.g. GLM)

Inference = Signal-To-Noise

$$t = \frac{\beta}{\sqrt{\hat{\sigma}_\varepsilon^2 (X^T X)^{-1}}} = \frac{\beta \|\boldsymbol{x}\|}{\hat{\sigma}_\varepsilon}$$

$$F = \frac{N-M}{M_1} \cdot \frac{(\sigma_S^2 + \sigma_N^2) - \sigma_N^2}{\sigma_N^2}$$

False positives in resting state fmri

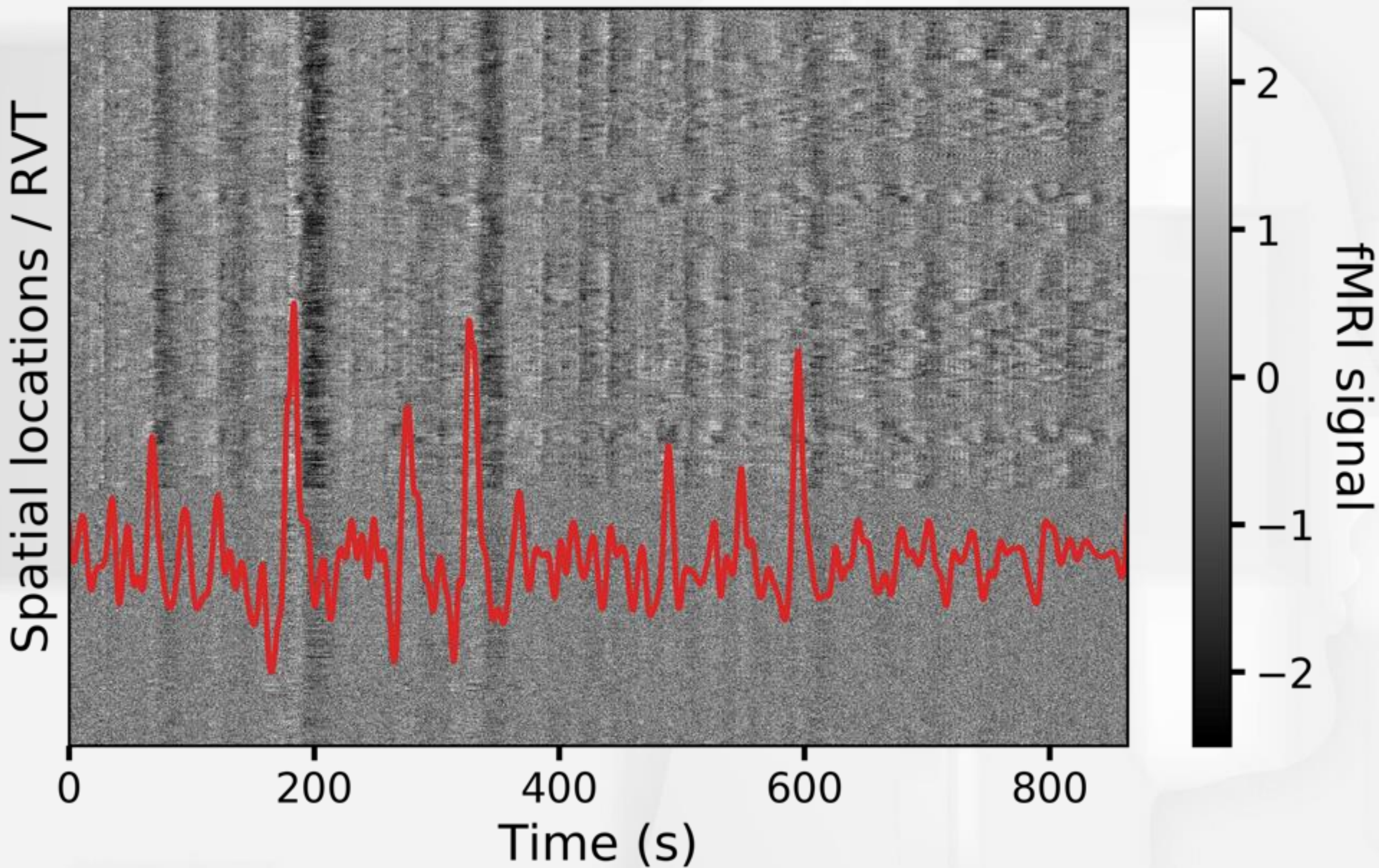


Image from Sam Harrison

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Recap: MR Image Encoding

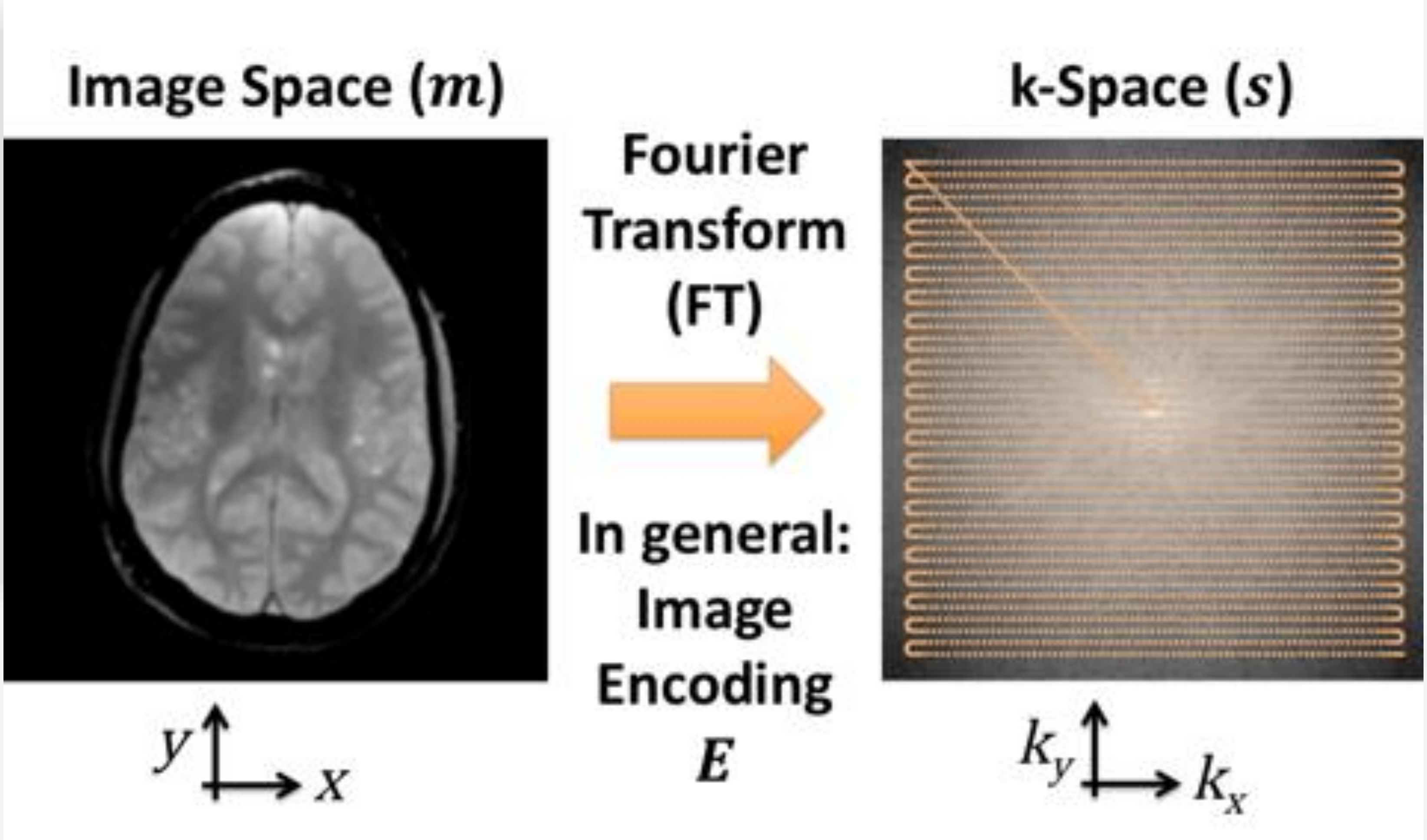
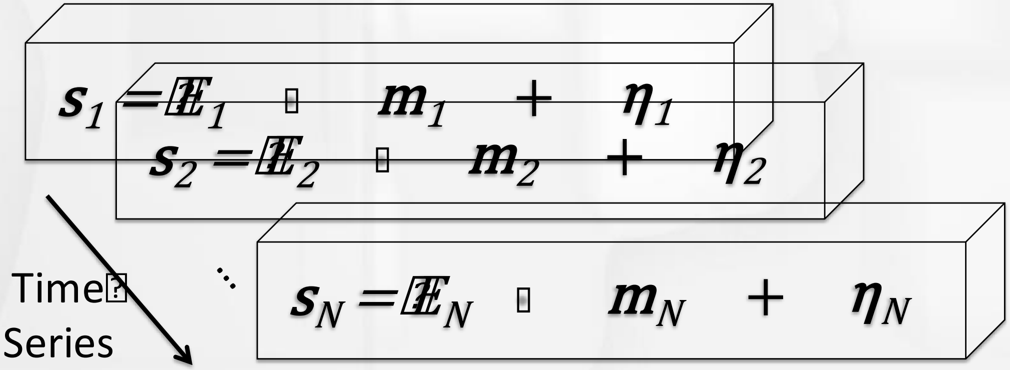


Image Reconstruction & Noise

$$\underbrace{\mathbf{s}}_{\text{Coil Signal}} = \underbrace{\mathbf{E}}_{\text{Encoding Matrix}} \cdot \underbrace{\mathbf{m}}_{\text{Object Magnetization}} + \underbrace{\boldsymbol{\eta}}_{\text{Thermal Noise}}$$

- Image reconstruction is also a *huge* GLM, ~10^5-10^6 rows
  - 3 mm slice, 8 chan: $64^2*8 = 512\text{k}$
  - 1 mm slice, 32 ch: $256^2*32 = 2\text{M}$
- Any change between volumes in encoding matrix (field), object magnetization and thermally induces image noise

$$\hat{m} = (E^H E)^{-1} E^H s$$



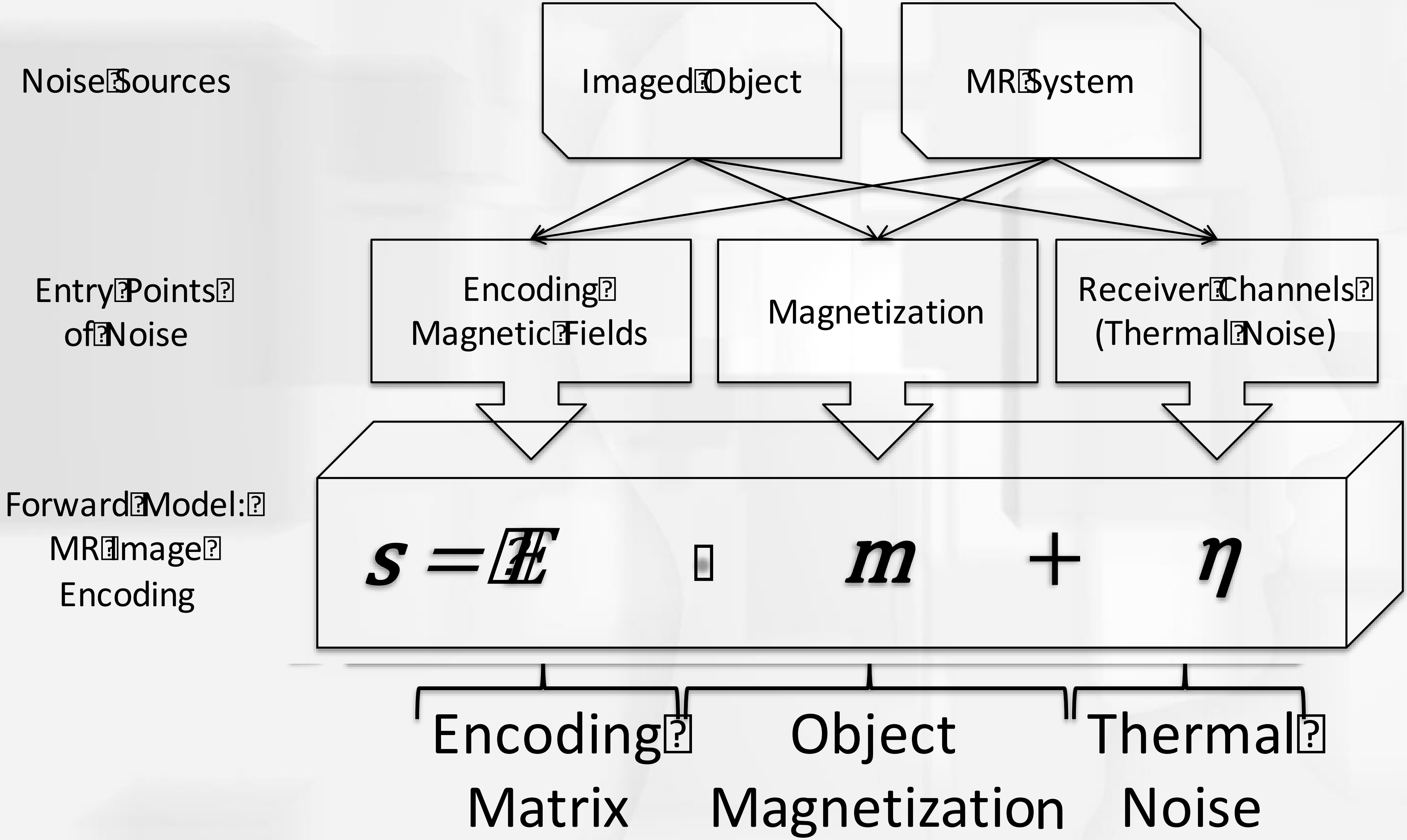
$$\mathbf{s}_1 = \mathbf{E}_1 \cdot \mathbf{m}_1 + \boldsymbol{\eta}_1$$

$$\mathbf{s}_2 = \mathbf{E}_2 \cdot \mathbf{m}_2 + \boldsymbol{\eta}_2$$

$$\vdots$$

$$\mathbf{s}_N = \mathbf{E}_N \cdot \mathbf{m}_N + \boldsymbol{\eta}_N$$

What fluctuates?



Noise Sources

Imaged Object

MR System

Entry Points of Noise

Encoding Magnetic Fields

Magnetization

Receiver Channels (Thermal Noise)

Forward Model: MR Image Encoding

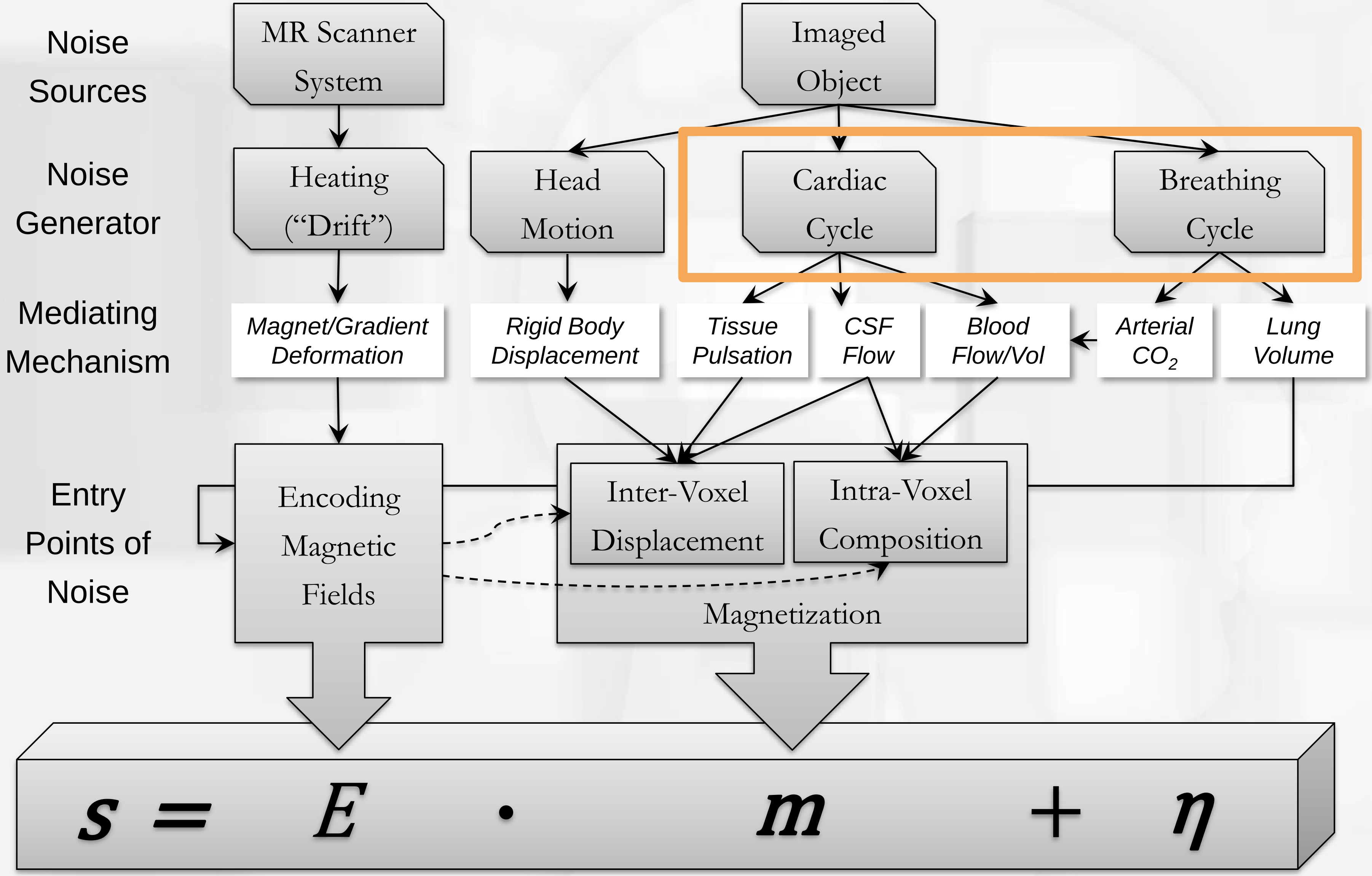
$$s = E \cdot m + \eta$$

Encoding Matrix

Object Magnetization

Thermal Noise

Structured Noise in MRI



Noise Sources

Noise Generator

Mediating Mechanism

Entry Points of Noise

MR Scanner System

Imaged Object

Heating (“Drift”)

Head Motion

Cardiac Cycle

Breathing Cycle

Magnet/Gradient Deformation

Rigid Body Displacement

Tissue Pulsation

CSF Flow

Blood Flow/Vol

Arterial CO_2

Lung Volume

Encoding Magnetic Fields

Inter-Voxel Displacement

Intra-Voxel Composition

Magnetization

$$s = E \cdot m + \eta$$

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Cardiac effects: CSF pulsation

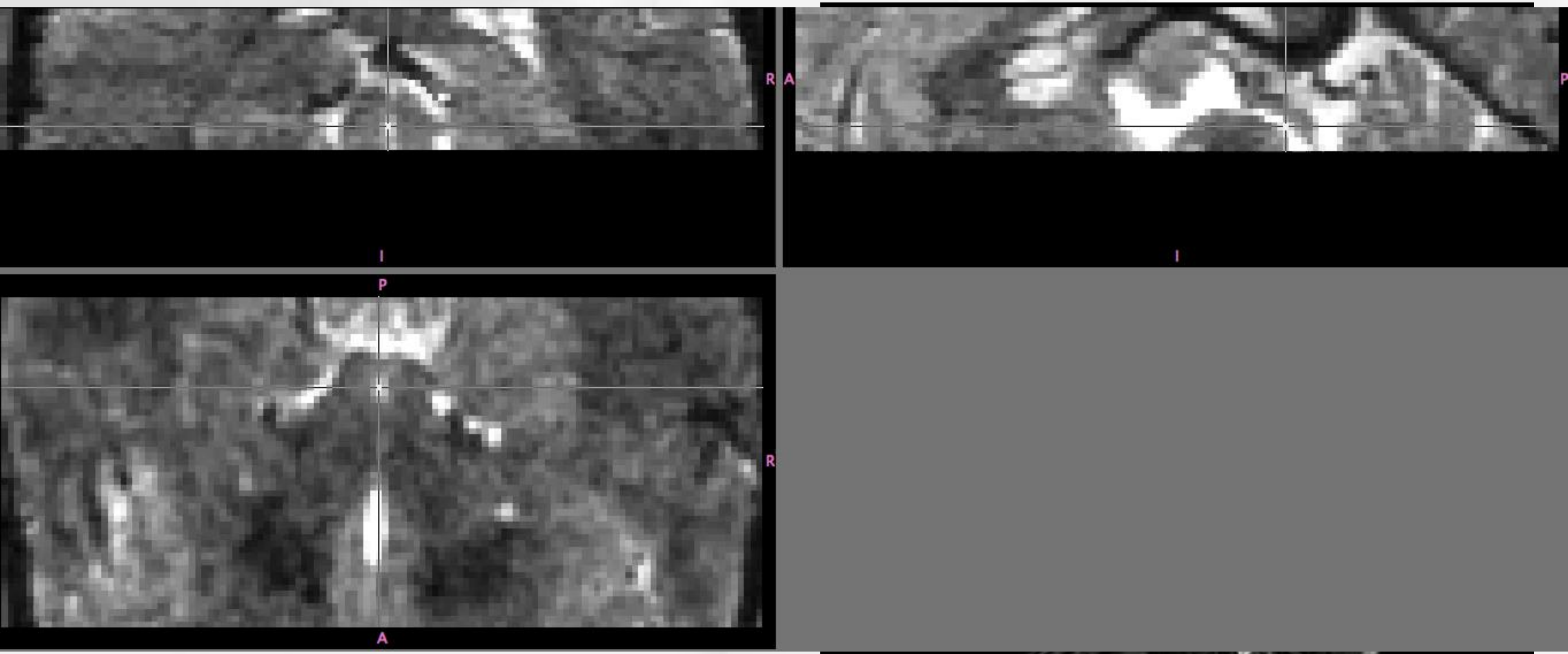
- CSF pulsation:
  - Systole:
    - Blood pumped into brain, vessel volume increases: pulsatile vessels
    - CSF pushed down: pulsatile CSF
  - Diastole:
    - Vessel volume decreases
    - CSF flows back into “void” brain volume

A Cardiac Cycle in the Brain

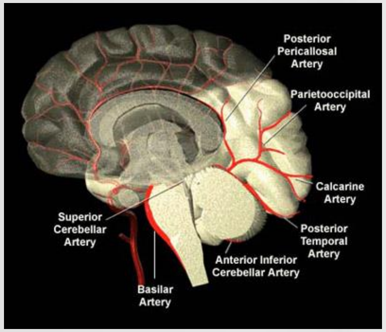
Cardiac effects

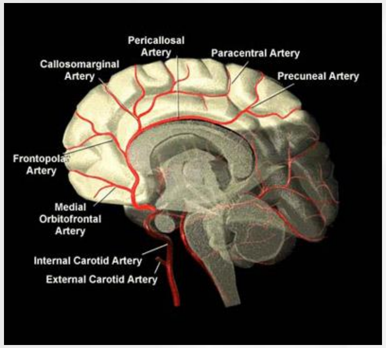
Triggered High-Resolution fMRI

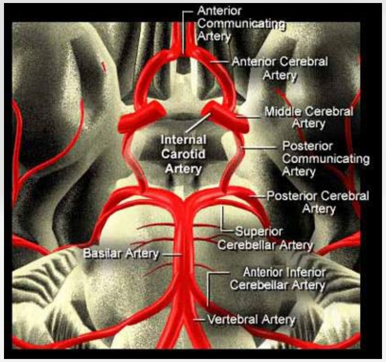
A Cardiac Cycle in the Brain



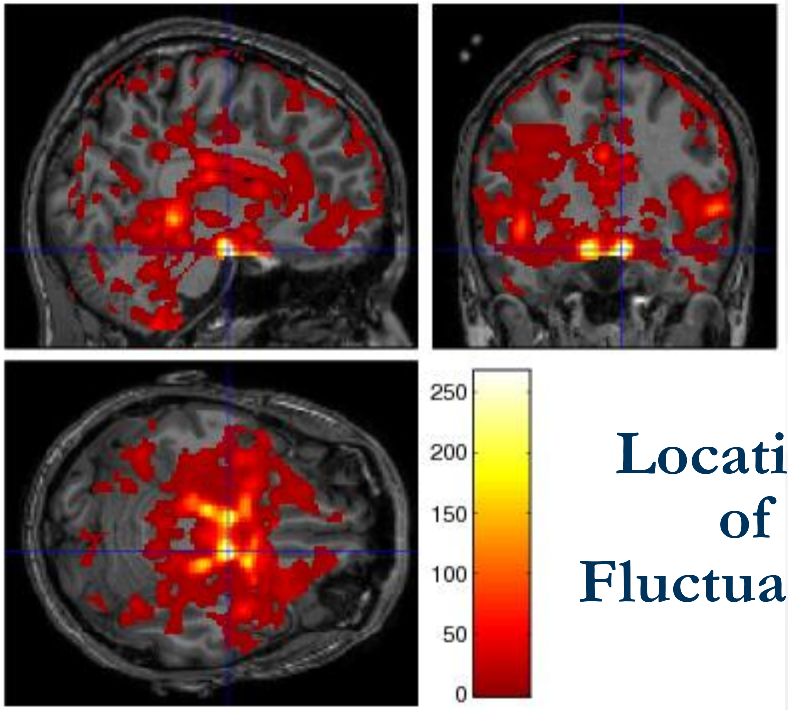
Cardiac effects







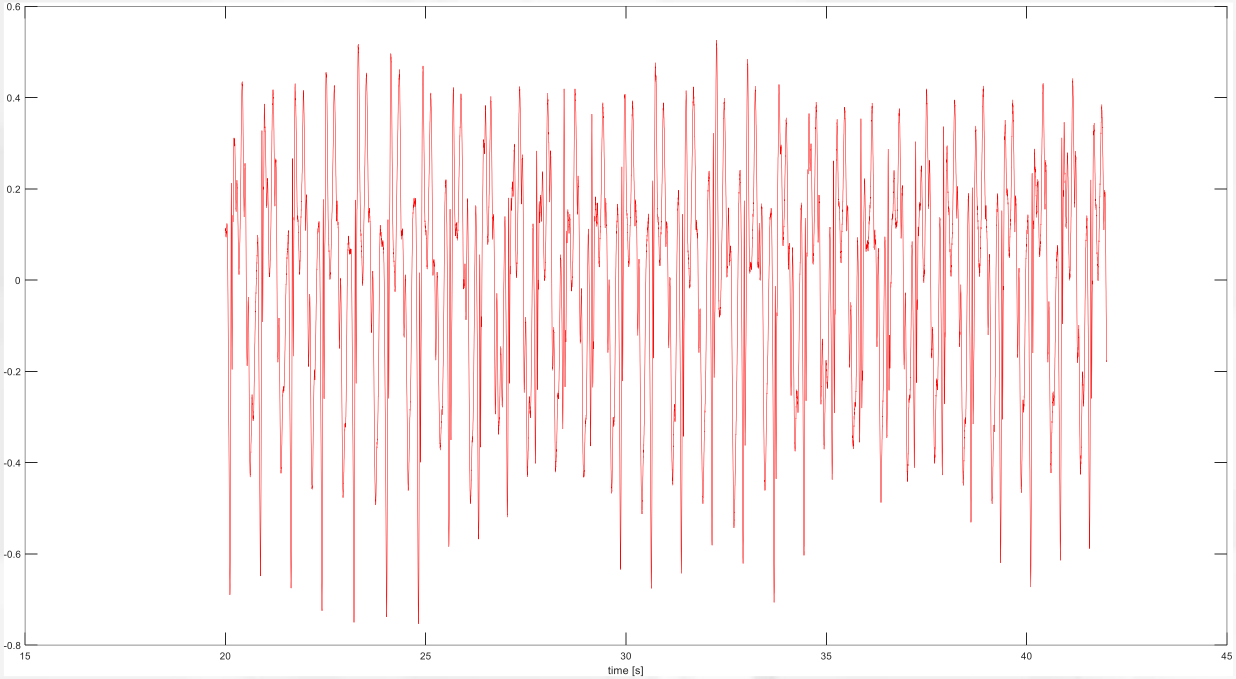
Vessel Anatomy



Locations of Fluctuations

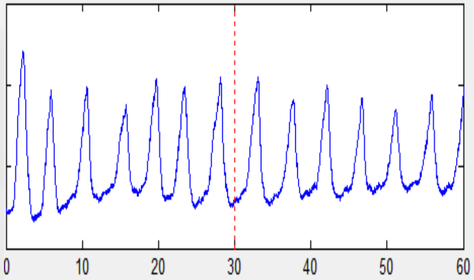
Cardiac signal

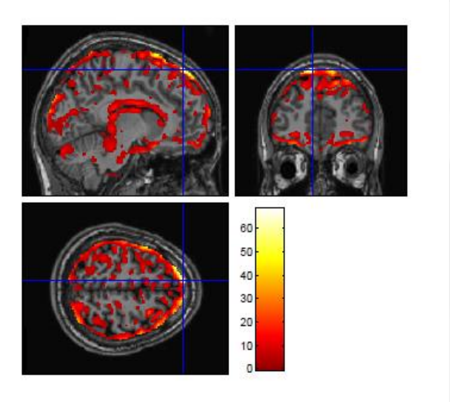
- (almost) periodic

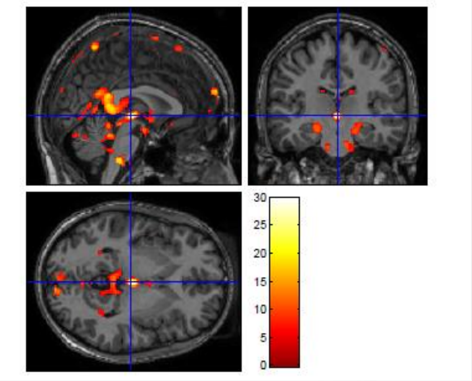


- But:
  - Fluctuations in BOLD-level due to heart-rate variability (HRV)

Respiratory effects







- Changes in lung volume change encoding magnetic field for MR
  - Chest (&head) moves with respiratory cycle
  - Geometric distortion/scaling
- Change in oxygenation of blood
- Respiratory-sinus arrhythmia
  - Heart beats faster during inhalation

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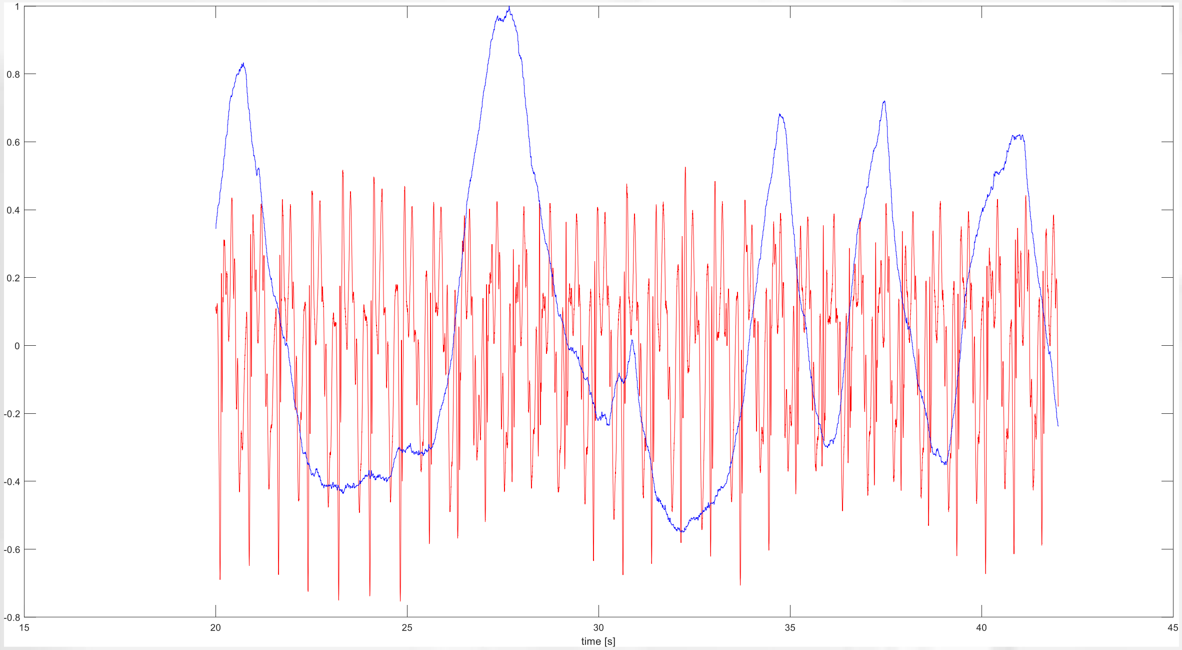
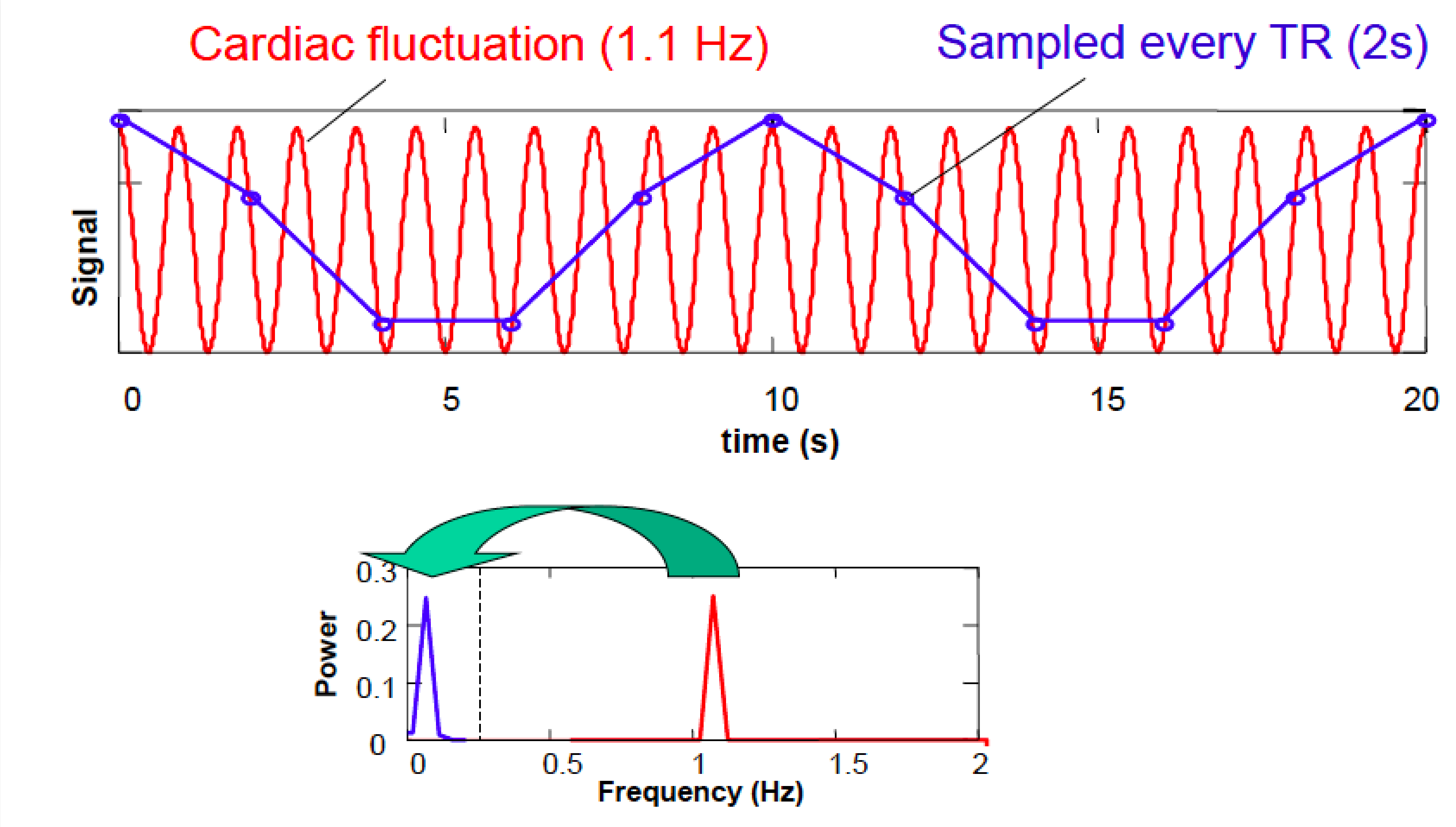
Why not just filtering?



- Cycles are (almost)periodic
  - Could filter frequencies
    - 0.2-0.4 Hz respiration
    - 0.8 – 1.2 Hz heart beat (main)
- Problem: Aliasing

Aliasing of Physiology



Courtesy: R. Birn, HBM 2015

Modeling VS Preprocessing

- Modeling:
  - Filters, projections (e.g. to independent components) etc. are all linear operations
  - Combination in one design matrix, together with task
  - Simple test of correction efficacy: F-test on nuisance regressors
- Preprocessing:
  - The data y entering the GLM is altered $\Rightarrow y' = X\beta + \varepsilon$
  - For non-linear changes of y or inter-voxel dependencies, alteration outside GLM necessary

The Problem with Preprocessing

- Problem: No inherent measure of efficacy (F-test in GLM), correlation with task regressors undetected
- "Advantage": No loss of degrees of freedom (sensitivity of F-test)
  - But it it only a hidden loss, statistics for inference is biased, if performed modeling is not incorporated
- Modeling via GLM recommended, if possible
  - Drifts, Motion Regressors
  - RETROICOR, HRV, RVT
  - aCompCor, (ICA)

Motion: Preprocess & Modeling

- Correction for motion artifacts is actually a combination of Preprocessing and modeling
- Preprocessing cannot correct spin-history effects, intra-volume movements (non-rigid!), small partial volume effects
- Preprocessing:
    - Realignment
    - Motion "Scrubbing"
- Modeling (from estimated realignment parameters)
    - Retrospective Modeling: Motion Regressors
    - Motion Censoring

Retrospective Motion Correction

- Best: Avoid subject motion in the first place
- Better: Use Prospective Motion Correction
- Standard: Perform rigid-body realignment, use parameters as nuisance regressors
    - 6 parameters: translation+rotation
    - 12 parameters: include derivatives (for temporal shifts)
    - 24 parameters: include squared regressors
- 24-parameter model known as Volterra expansion

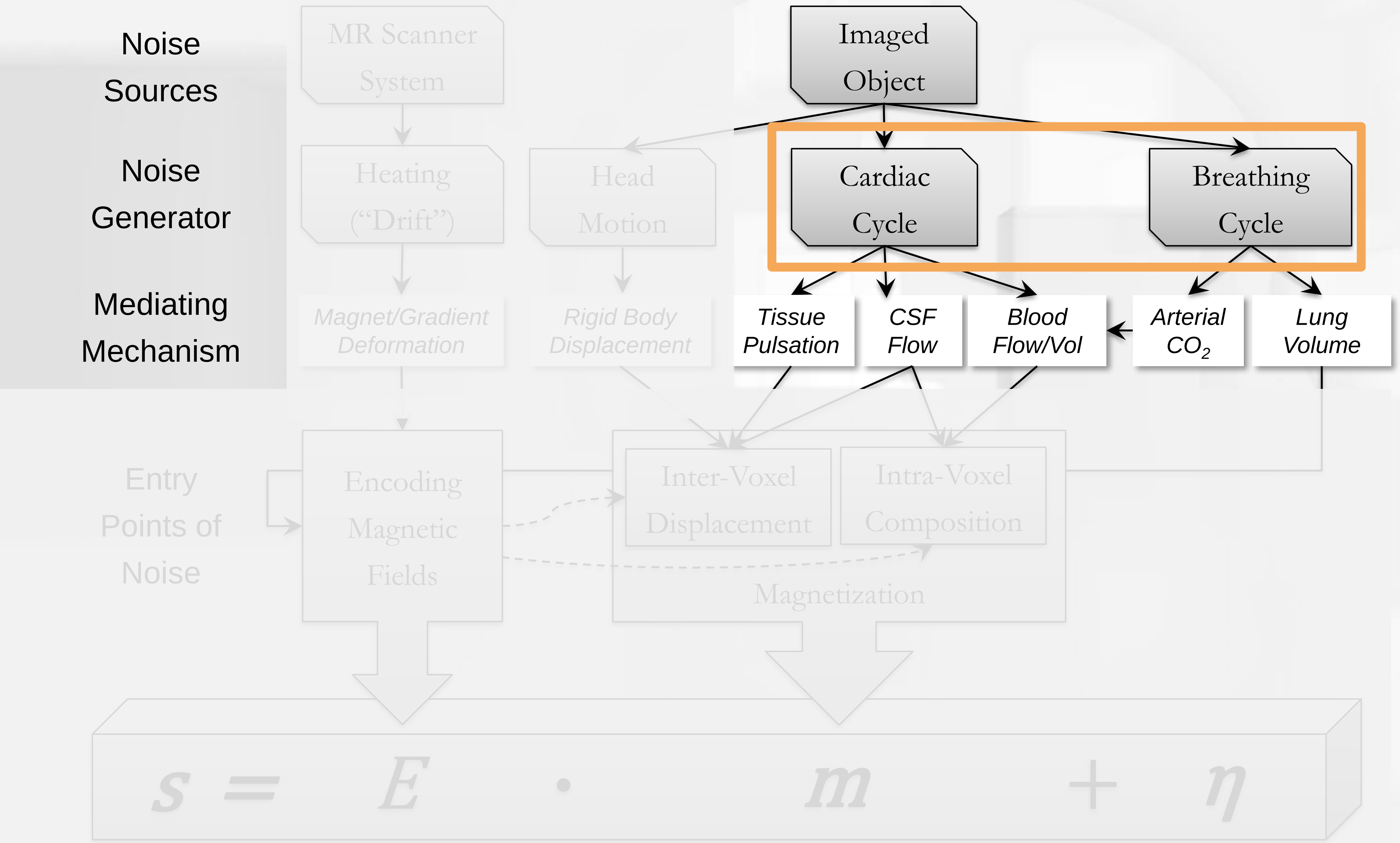
Friston, MRM,1996

Motion Censoring = "Scrubbing"

- Detect outlier volumes (strong movement, but also spikes, RF flip angle fluctuations)
- Inform the GLM of these bad volumes via stick regressors (zero everywhere else, 1 at volume)
  - Will absorb all variance of that volume
- Problem: Temporal filtering before GLM might create Gibbs ringing of outliers into neighbors
- Alternative: censoring during preprocessing
  - interpolate faulty volume by neighbors

Power, NeuroImage, 2012

Noise Correction Targets



Noise Sources

Noise Generator

Mediating Mechanism

Entry Points of Noise

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Imaged Object

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Cardiac Cycle

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Tissue Pulsation

CSF Flow

Blood Flow/Vol

Arterial CO_2

Lung Volume

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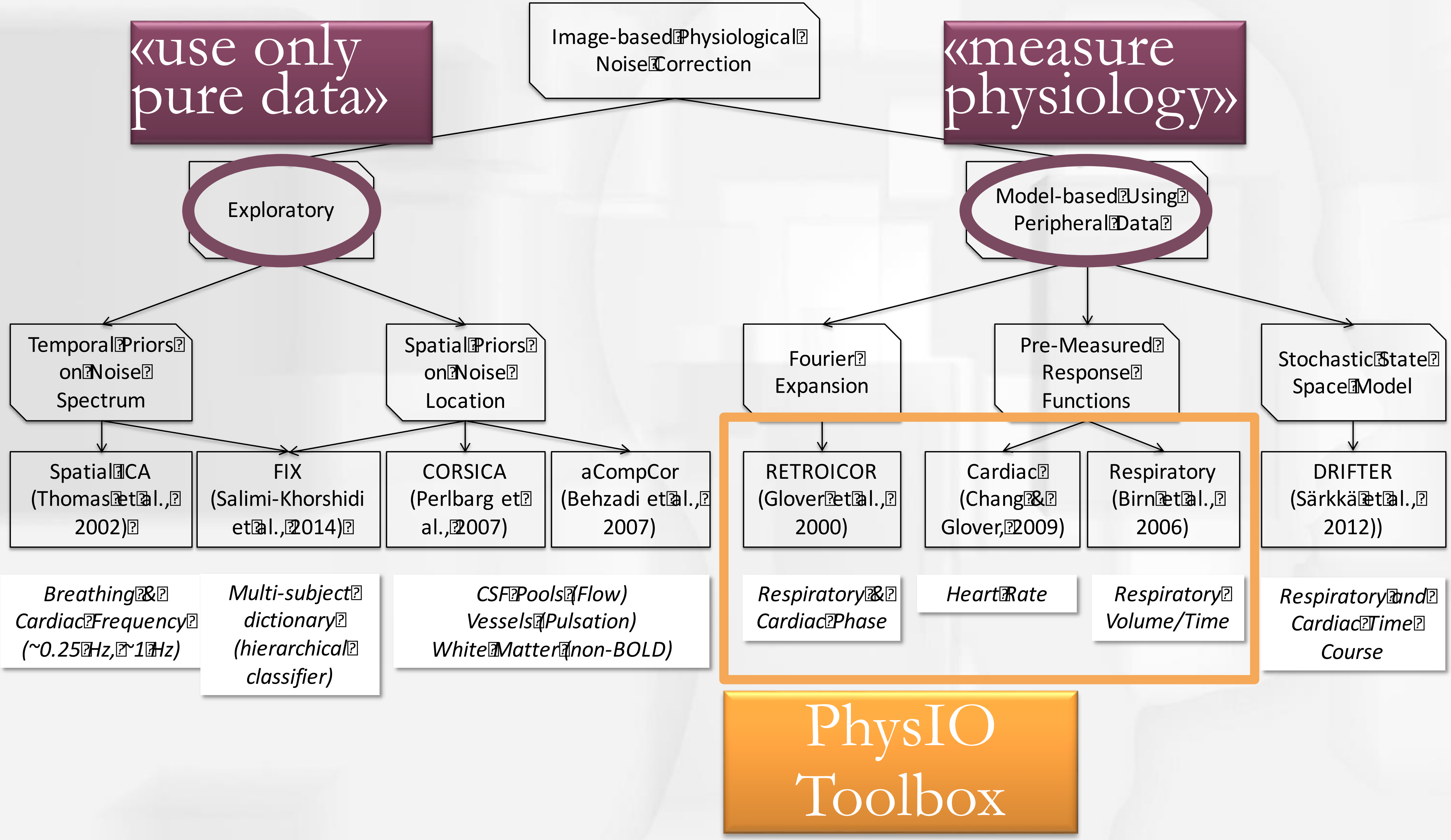
$$s = E \cdot m + \eta$$

Image-based Noise Correction



«use only pure data»

«measure physiology»

Image-based Physiological Noise Correction

Exploratory

Model-based Using Peripheral Data

Temporal Priors on Noise Spectrum

Spatial Priors on Noise Location

Fourier Expansion

Pre-Measured Response Functions

Stochastic State Space Model

Spatial ICA (Thomas et al., 2002)

FIX (Salimi-Khorshidi et al., 2014)

CORSICA (Perlbarg et al., 2007)

aCompCor (Behzadi et al., 2007)

RETROICOR (Glover et al., 2000)

Cardiac (Chang & Glover, 2009)

Respiratory (Birn et al., 2006)

DRIFTER (Särkkä et al., 2012))

Breathing & Cardiac Frequency (~0.25 Hz, ~1 Hz)

Multi-subject dictionary (hierarchical classifier)

CSF Pools (Flow) Vessels (Pulsation) White Matter (non-BOLD)

Respiratory & Cardiac Phase

Heart Rate

Respiratory Volume/Time

Respiratory and Cardiac Time Course

PhysIO Toolbox

Noise Modeling

RETROspective Image CORrection	Cardiac Response Function	Respiratory Response Function
Cardiac/respiratory phase φ_c φ_r	Heart Rate	Resp. Volume per Time
Fourier expansion (cosine/sine)	convolved with CRF	convolved with RRF

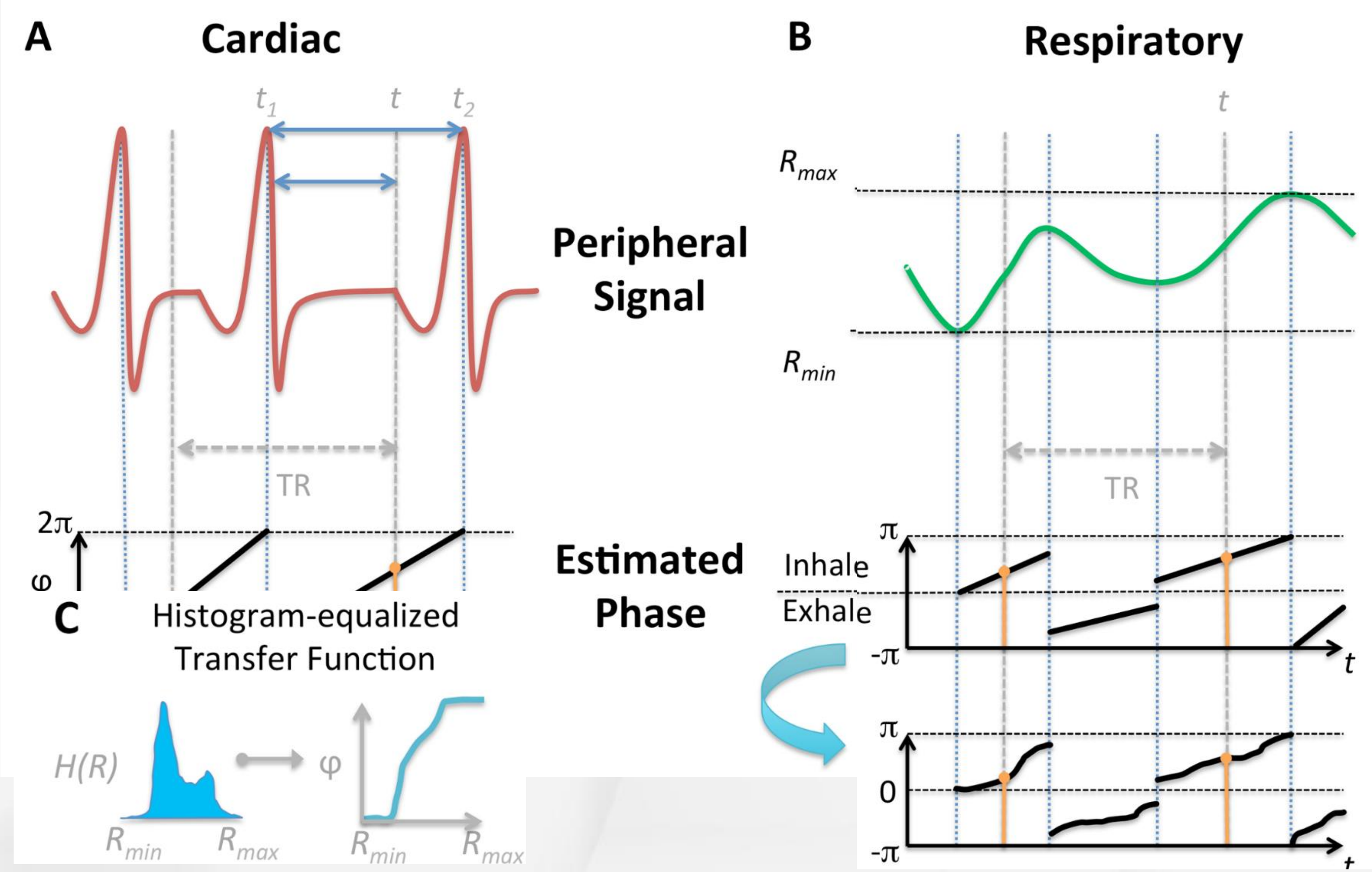
- evaluated at 1 time point (slice) per volume = regressor

Noise Modeling

RETROspective Image CORrection

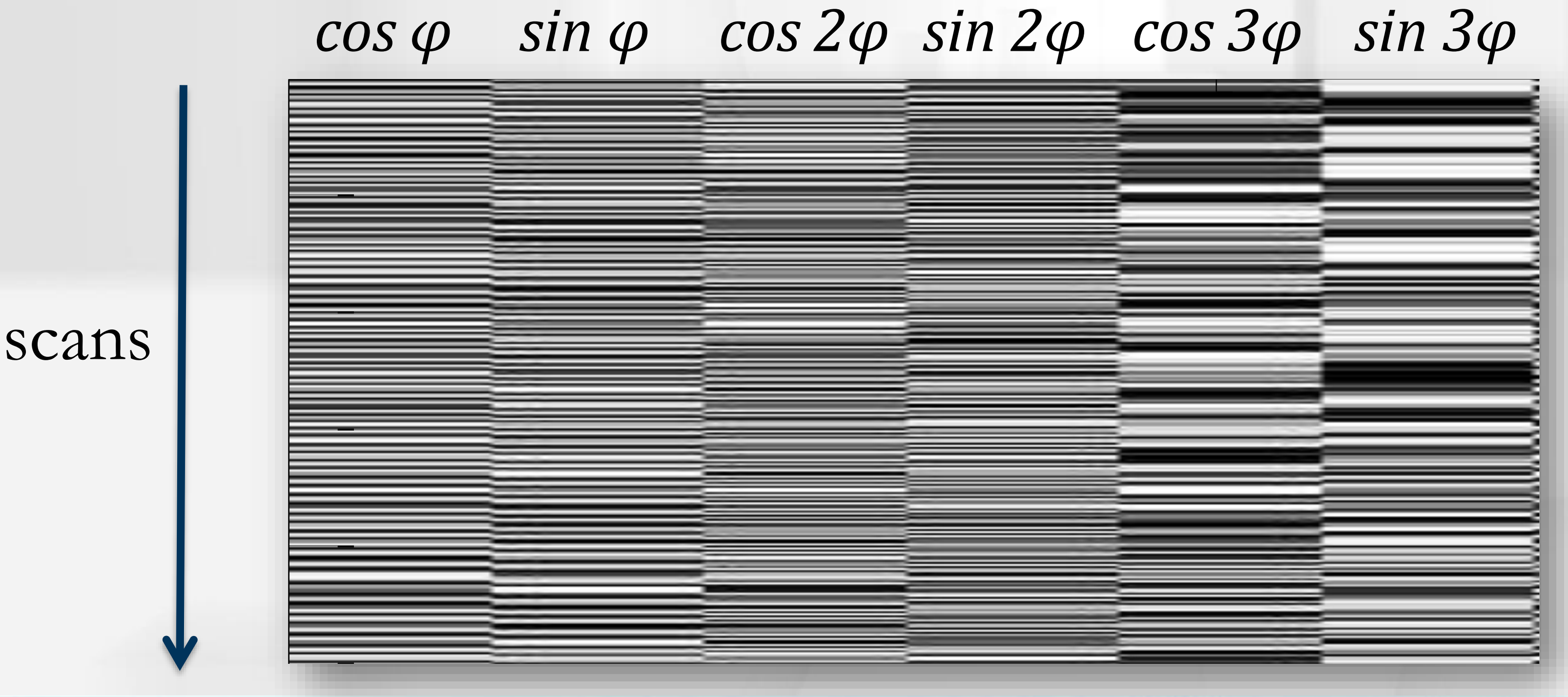
Cardiac Response Function φ_c

Respiratory Response Function φ_r



Model: Fourier Phase Expansion

- Cosine and sine to allow for constant phase shifts per voxel
- Higher model orders to account for under-sampling of physiological frequencies with typical TR in fMRI



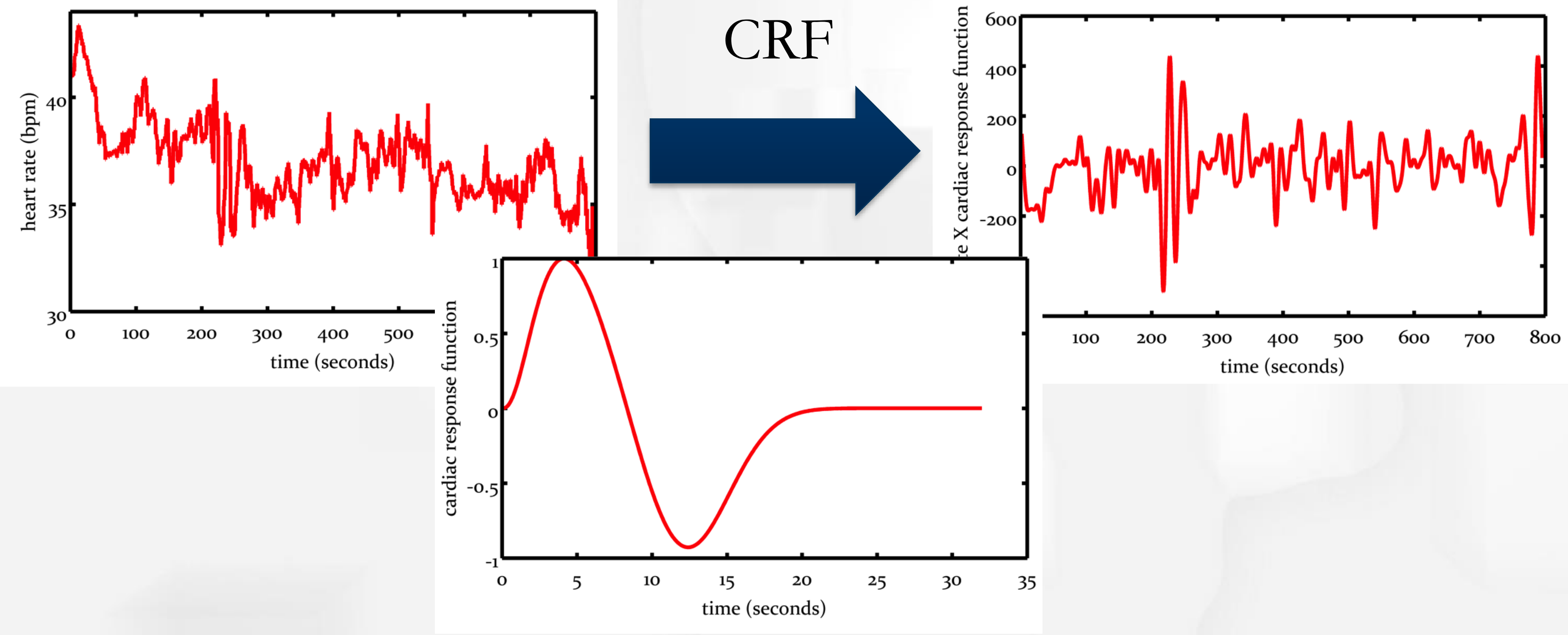
Noise Modeling

RETROspective Image CORrection

Cardiac Response Function

Respiratory Response Function

- Heart Rate
- Heart Rate Variability
- convolved with CRF
- Response Regressor



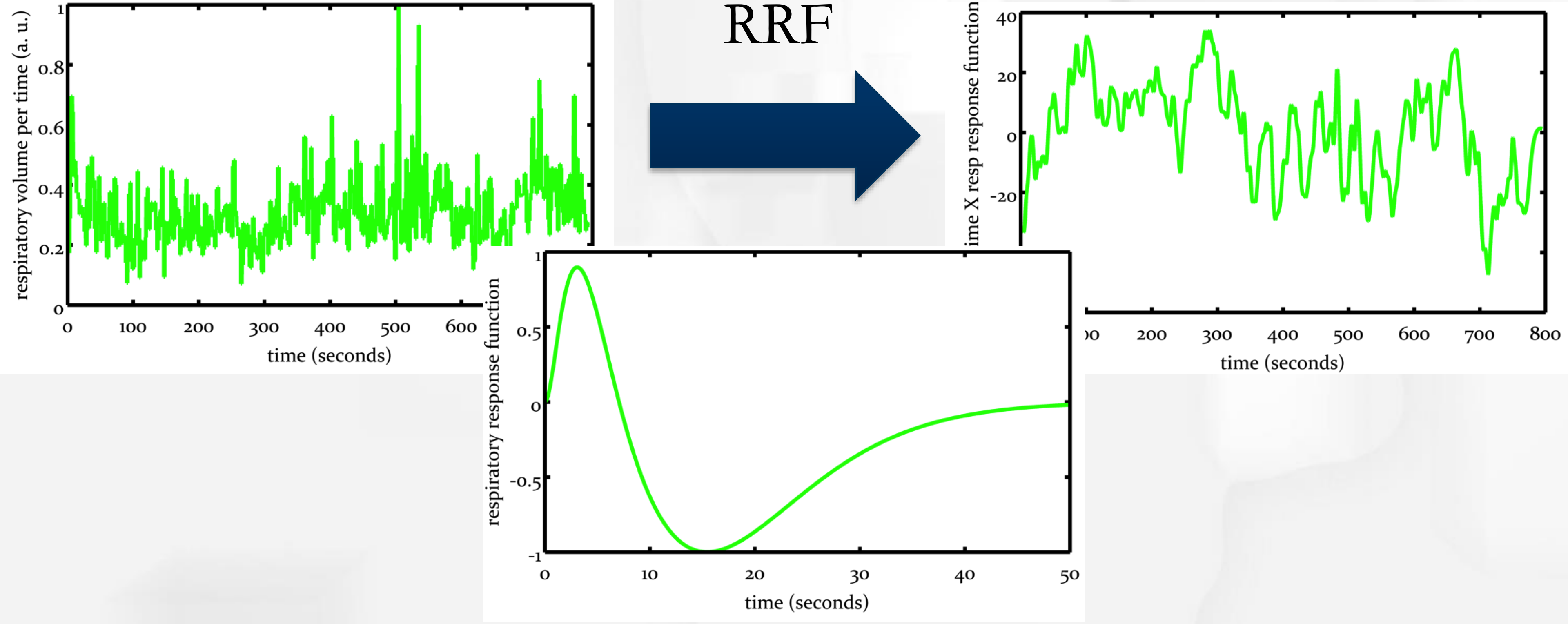
Noise Modeling

RETROspective Image CORrection

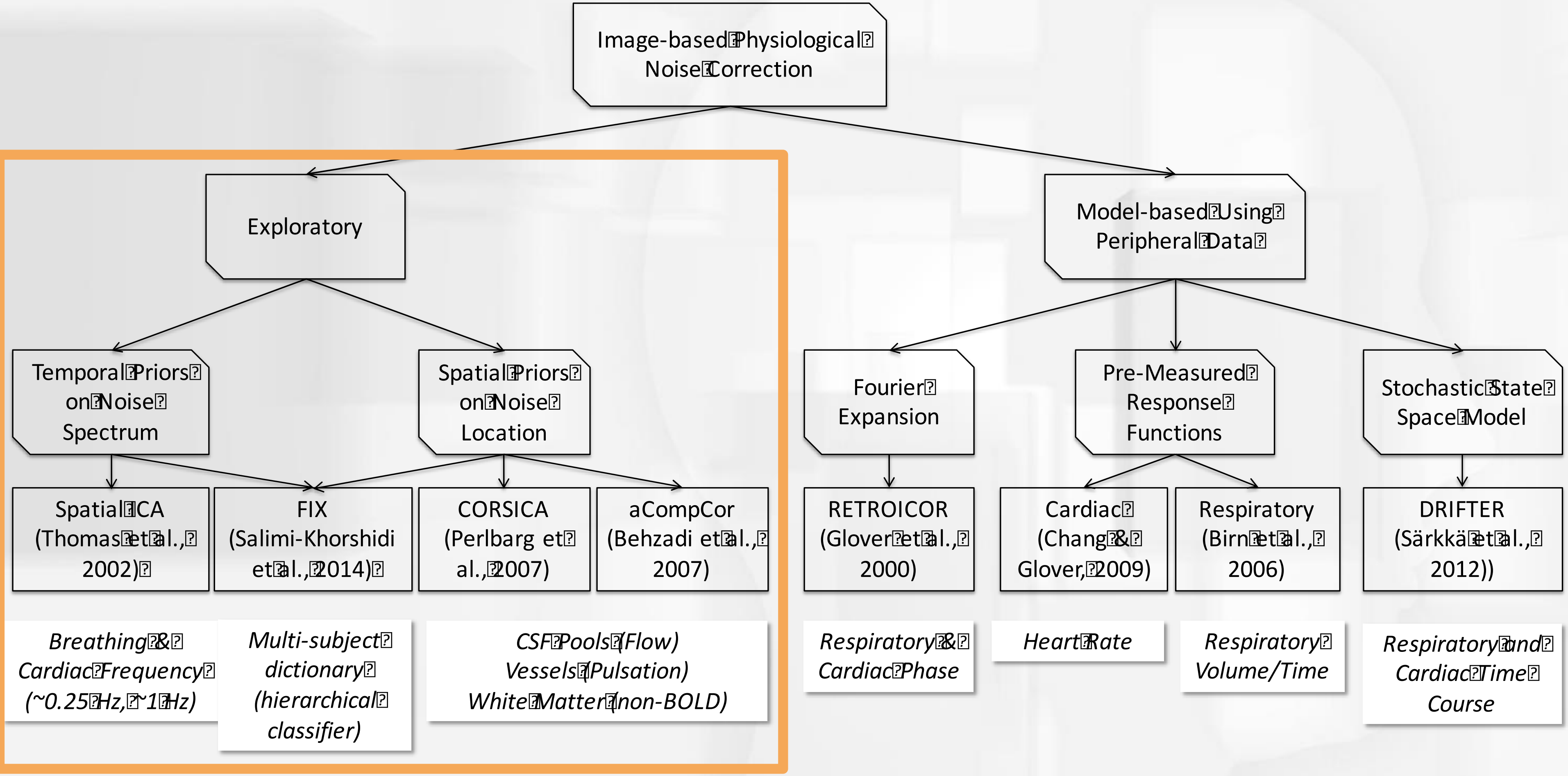
Cardiac Response Function

Respiratory Response Function

- Respiratory Volume per Time
- convolved with RRF
- Respiratory Volume per Time Regressor



Exploratory Phys Noise Correction



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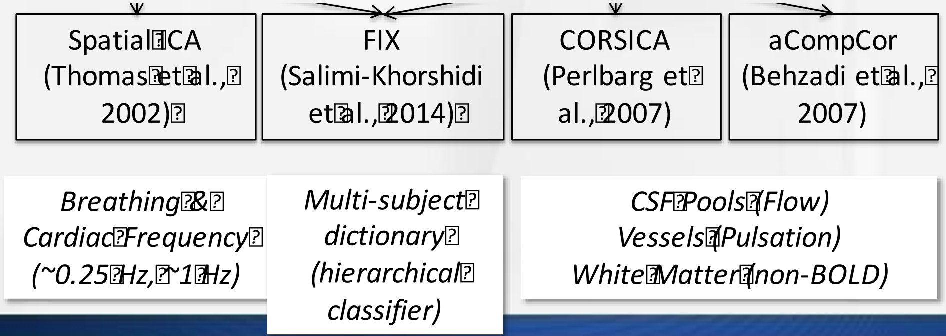
Noise Component Modeling

- Use priors about physiological noise to identify noise components (time series)
  - Spatial Priors: Mechanisms of physiological noise implicate physiological noise in CSF, blood vessels
  - Temporal Priors: Knowledge about typical physiological frequency contents (heart ~ 1Hz, breathing 0.2-0.4 Hz)
    - Note that simple filtering is impossible (cf. aliasing)
  - Population Priors: Use dictionary learning from manually labellled training set of subjects (FIX)



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Vessels (Pulsation)
White Matter (non-BOLD)

PCA VS ICA

- Methods to extract components (i.e. summarize ROIs/spectra) differ:
  - Maximum variance time series: Principal Component Analysis (PCA) from region of interest (aCompCor, Behzadi 2007)
  - Maximally independent time courses/sites: spatial/temporal ICA, FSL MELODIC, FIX
- aCompCor is basically identical to a seed-based correlation analysis in resting-state fMRI
  - Here: seed is in region-of-no-interest and correlated time series regressed out
  - See previous talk (resting state analysis) for more details

Other Physiological Corrections

- Non-linear models
  - DRIFTER: Kalman Filter, Bayesian, *Joint* Stochastic State-space model of peripheral physiology and BOLD
- Identify noise via task test-retest reproducibility
  - PHYCAA: e.g. via high-freq. autocorrelation, anatomy
  - GLMDenoise: PCA of noise regressors
- MEICA: Multi-Echo ICA
  - Use diff. TE-images to decompose proton density from T2* changes

Särkkä, NeuroImage, 2012

Churchill, NeuroImage, 2012/13

Kay, Front. Neurosc., 2013

Olafsson, NeuroImage, 2015

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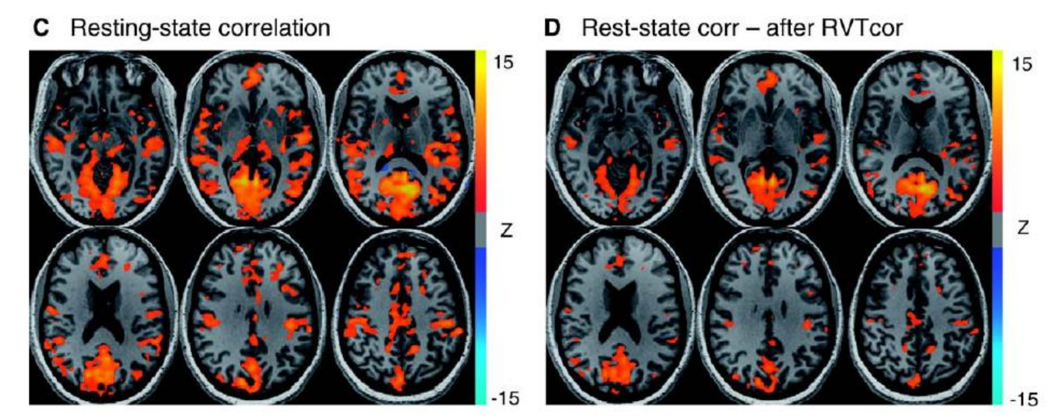
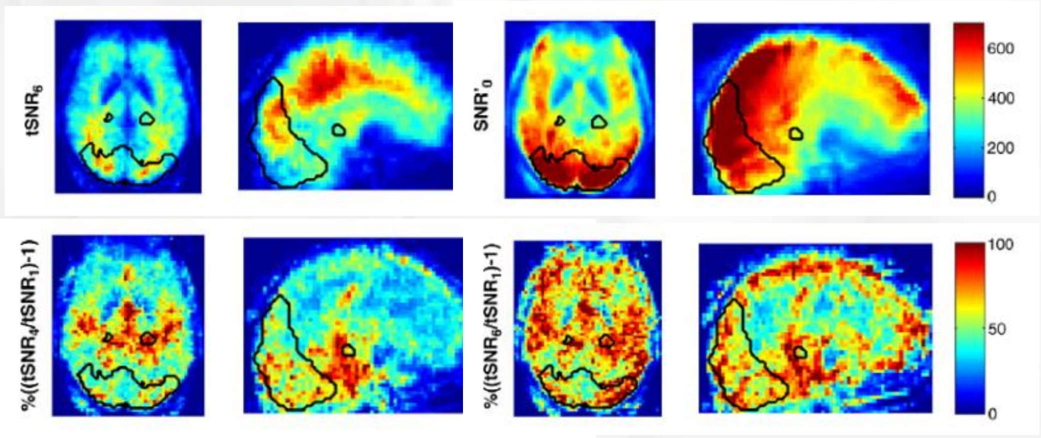
When? – Literature Evidence

- Resting-state:
  - Birn, R. M. “The Role of Physiological Noise in Resting-state Functional Connectivity.” *NeuroImage 62*, 2012
  - Birn, R. M., et al. “Separating Respiratory-variation-related Fluctuations from Neuronal-activity-related Fluctuations in fMRI.” *NeuroImage 31*, 2006



- Task-based:
  - Hutton, C., et al. “The Impact of Physiological Noise Correction on fMRI at 7 T.” *NeuroImage 57*, 2011:

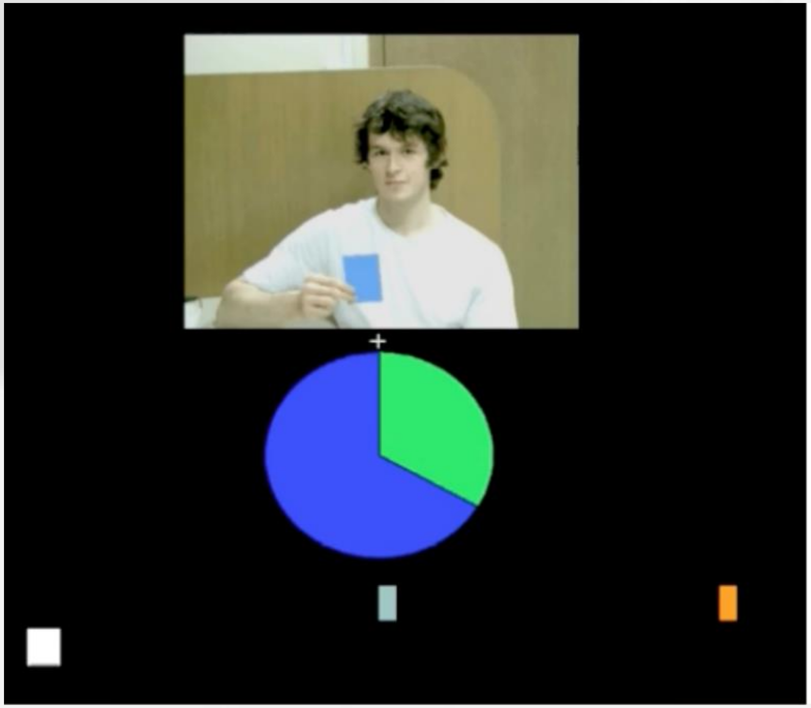


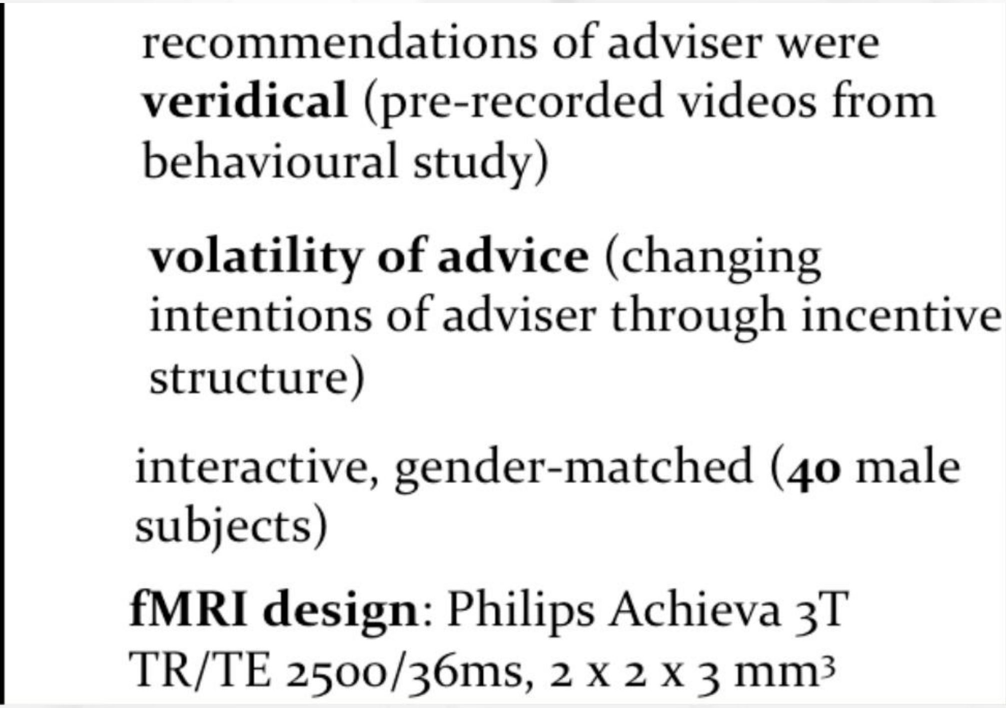
All these methods, but…

- Physiological noise correction not a default pre-processing step in task-based fMRI
- Reasons
  - Impact on group level fMRI
    - no reports for non-trivial paradigms
  - Existing Toolboxes lack…
    - robust, automatic implementation
    - dealing with variable peripheral data quality

Paradigm: Learning from Advice

- Hierarchical learning of trustworthyness of advisor over time
- Contrasts: Prediction and Prediction Error about advice





recommendations of adviser were **veridical** (pre-recorded videos from behavioural study)

volatility of advice (changing intentions of adviser through incentive structure)

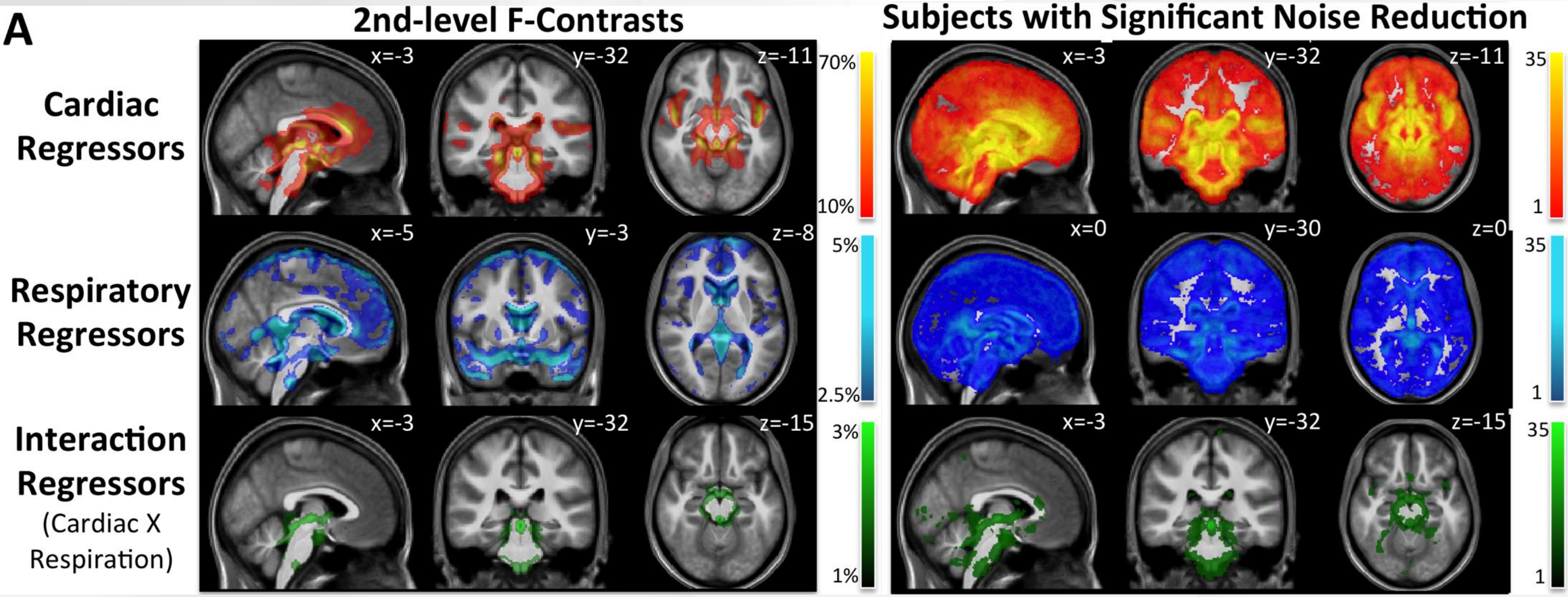
interactive, gender-matched (**40** male subjects)

fMRI design: Philips Achieva 3T
TR/TE 2500/36ms, 2 x 2 x 3 mm^3

Diaconescu et al, 2014, PLoS Comp. Biol.

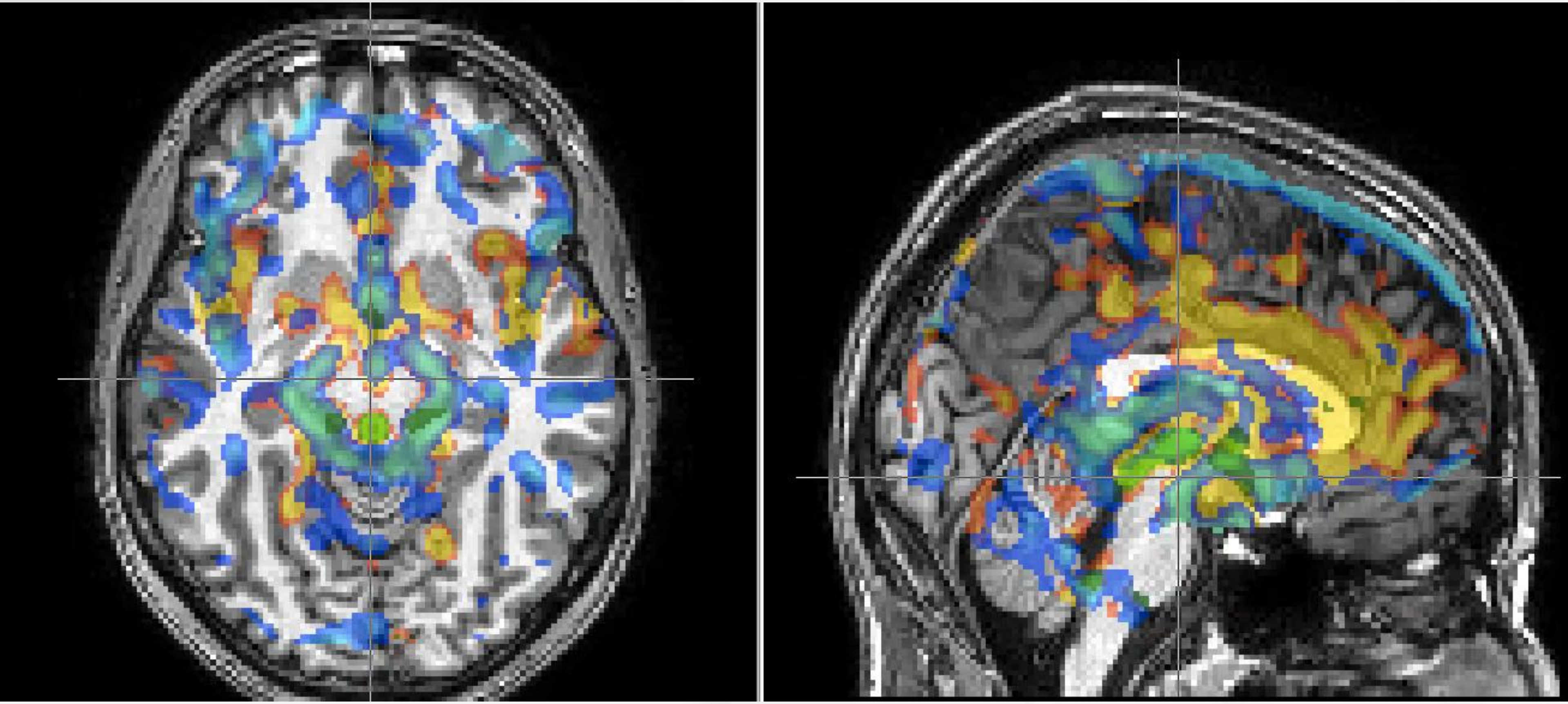
Group Level Impact PhysIO

- Andreea Diaconescu (TNU): Social Learning Experiment 2012-2014, (N=35)
- F-contrast: Where does physiological noise model explain significant variance?



Relevance for Neuromodulation

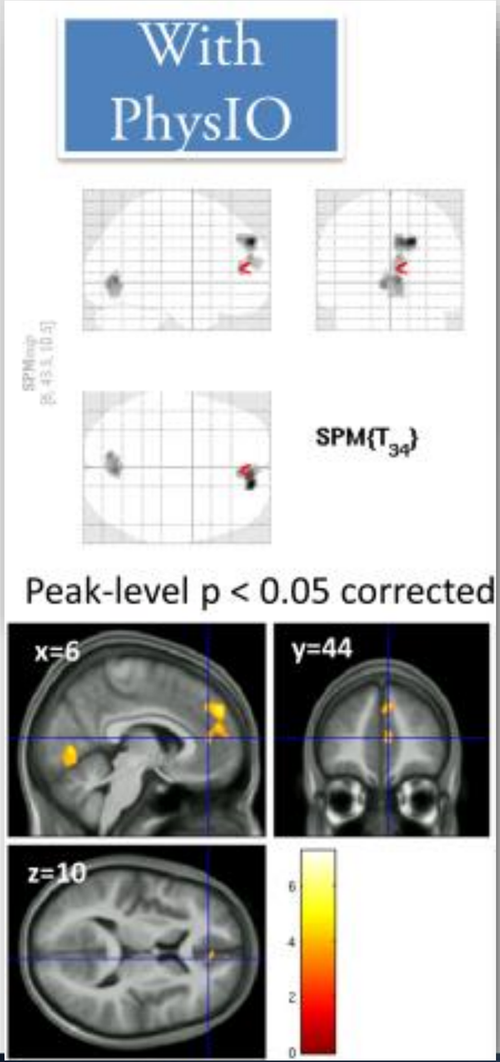
- cardiac (red), respiratory (blue), cardXresp (green)



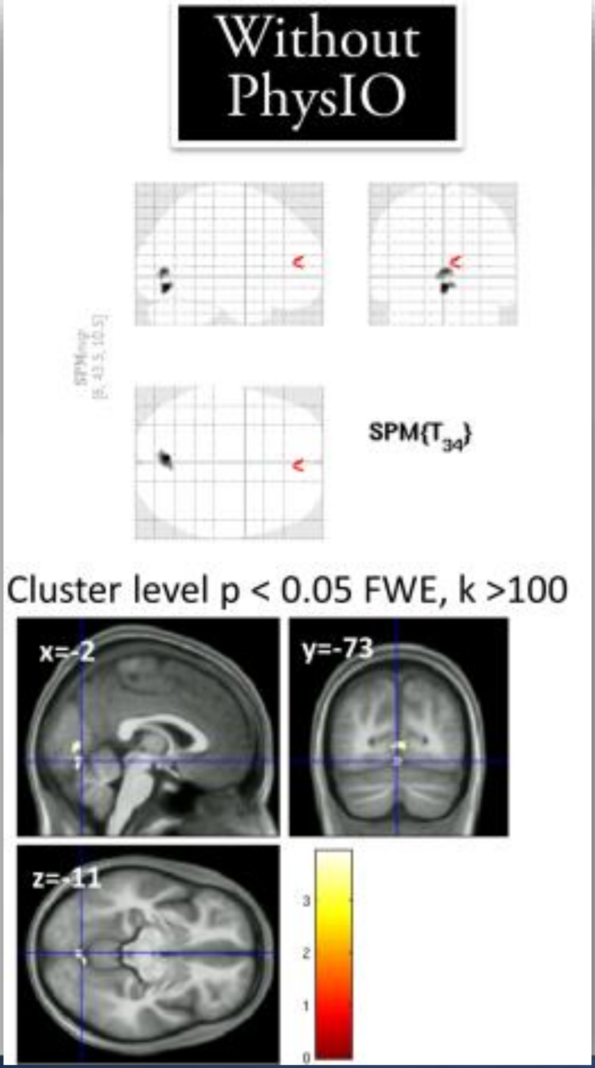
Effects on Group Contrasts

Higher Sensitivity

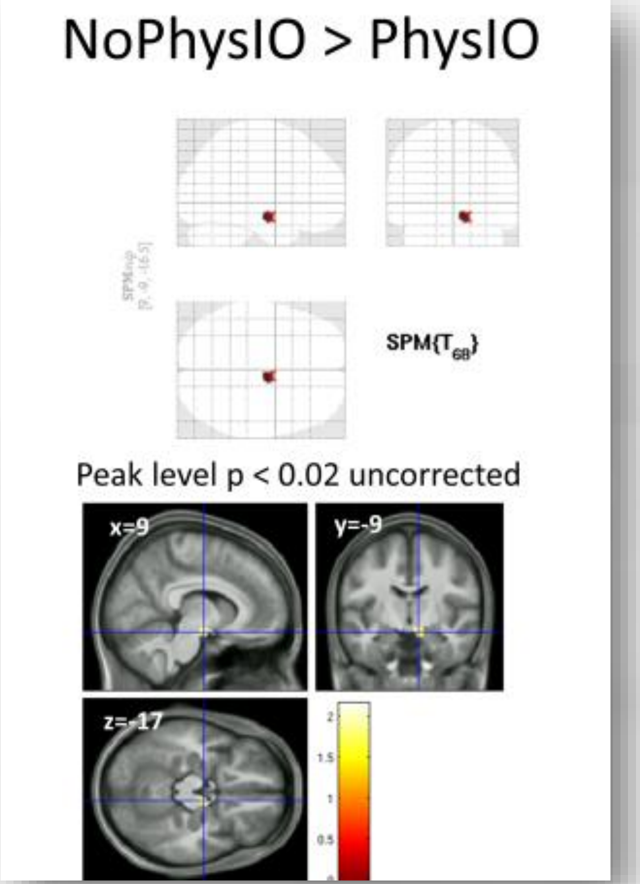
False Positives



Peak-level $p < 0.05$ corrected



Cluster level $p < 0.05$ FWE, $k > 100$



Peak level $p < 0.02$ uncorrected

2nd level t-contrast

Social Prediction Error

Outline

- Why denoising?
- Pathways of physiological noise
  - Recap: MR image encoding
  - Cardiac effects
  - Respiratory effects
- Noise correction approaches

Method	Preprocessing vs modeling
Input	fMRI data vs. peripheral measure

- Effects of noise correction
- Limitations

Limitations of Noise Modeling

- Degrees of freedom, sensitivity reduced by too many ineffective regressors
  - F-test informative
- Intrinsic correlations of functional areas of interoception and peripheral physiology
  - E.g. Amygdala, Insula, ACC
  - Controversial reading: [fMRI of the Amygdala: All In Vein? – Neuroskeptic]()
  - Alternative: Masking, Pure anatomical priors removing CSF, angiography (vessels)

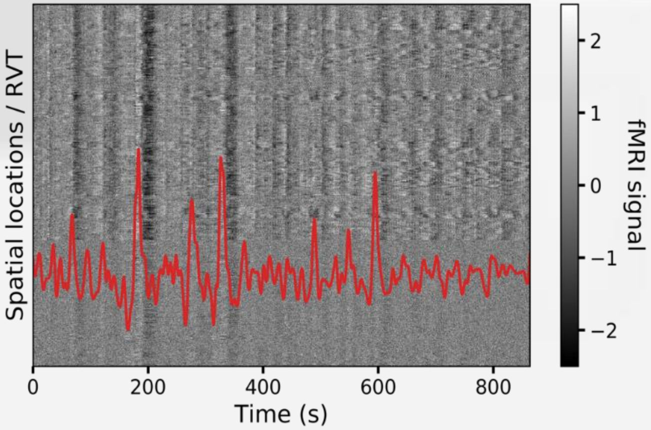
Conclusion

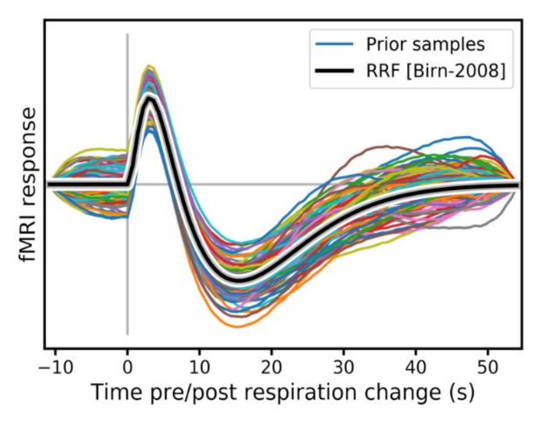
- MRI Time Series and Physiological Noise
- Image-Based Correction in the GLM
- Noise Modeling Prospects: Group FX
- The PhysIO Toolbox

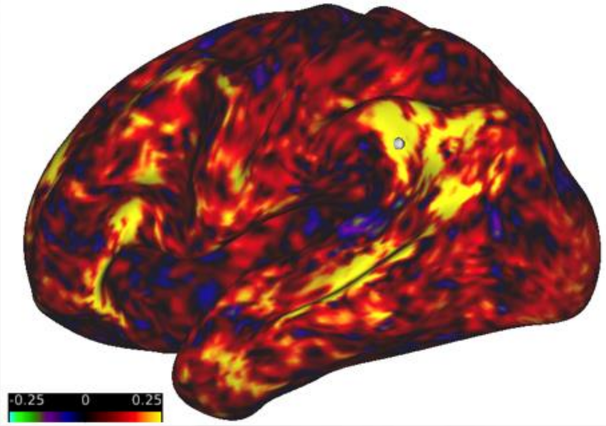
- Structured noise through cardiac/resp cycle (70%)
- Nuisance regressors from Fourier expansion, response functions
- Increase group sensitivity (low inter-subject variability), fewer false positives
- Correction in SPM/Matlab in practice => **NOW!**

Wanna do more?

- "Subject-specific physiological noise removal with deep Bayesian inference"
  - Semester / Master thesis
  - Start early next year
  - harrison@biomed.ee.ethz.ch







Thank you for your attention

- … and
  - TNU
  - Lars Kasper

Practical Session

- **Demo: The PhysIO Toolbox for Physiological Noise Correction in fMRI**
  - Features and Workflow
  - Image-based physiological noise correction in the GLM
    - RETROICOR, HRV, RVT
    - Noise-ROIs
  - Practical Demo (SPM Batch)
    - Estimating different Models
    - Understanding the Preprocessing Plots
    - Automatic Model Assessment, Diagnostics on Contrast

Image-based Noise Correction

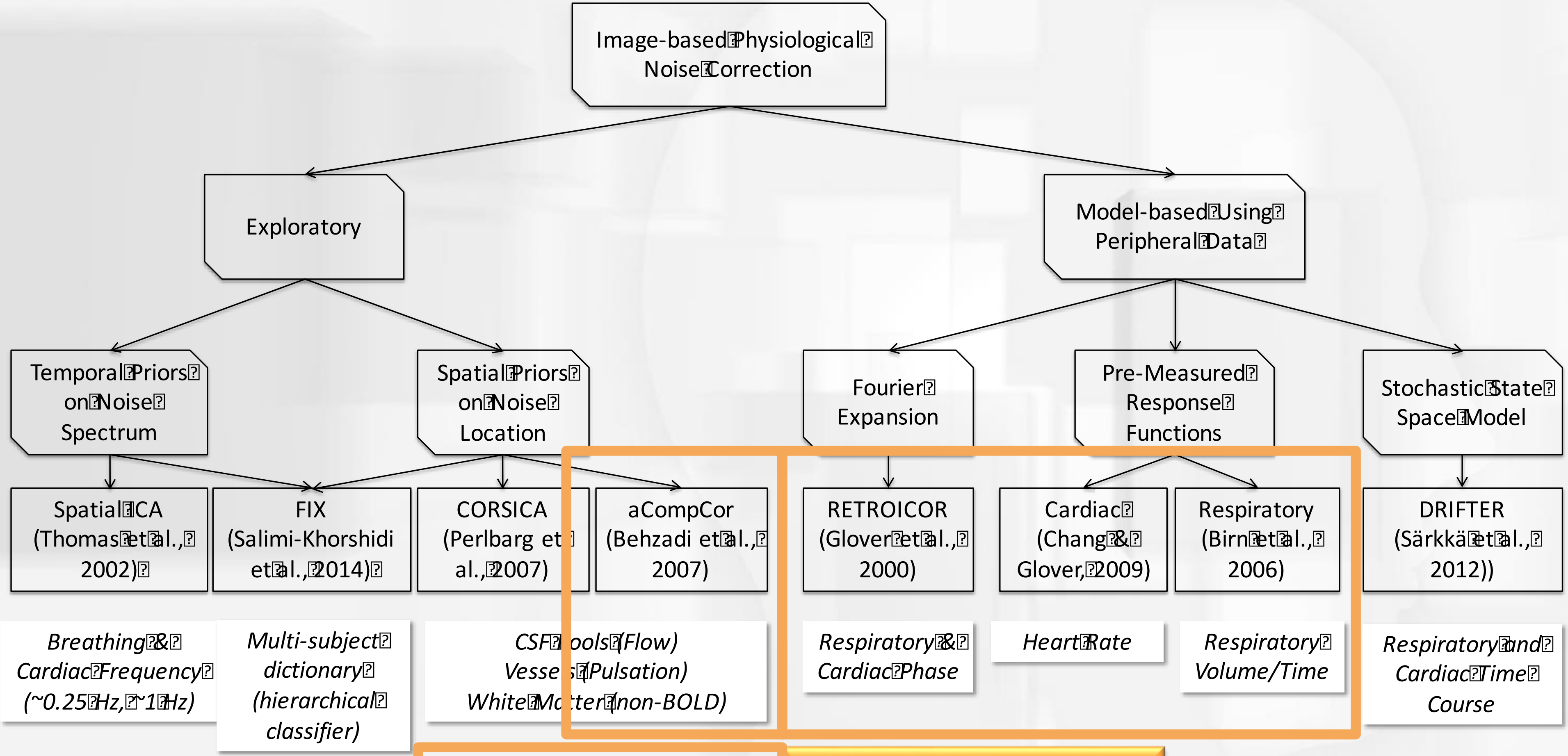


Image-based Physiological Noise Correction

Exploratory

Model-based Using Peripheral Data

Temporal Priors on Noise Spectrum

Spatial Priors on Noise Location

Fourier Expansion

Pre-Measured Response Functions

Stochastic State Space Model

Spatial ICA (Thomas et al., 2002)

FIX (Salimi-Khorshidi et al., 2014)

CORSICA (Perlbarg et al., 2007)

aCompCor (Behzadi et al., 2007)

RETROICOR (Glover et al., 2000)

Cardiac (Chang & Glover, 2009)

Respiratory (Birn et al., 2006)

DRIFTER (Särkkä et al., 2012))

Breathing & Cardiac Frequency (~0.25 Hz, ~1 Hz)

Multi-subject dictionary (hierarchical classifier)

CSF Pools (Flow) Vessels (Pulsation) White Matter (non-BOLD)

Respiratory & Cardiac Phase

Heart Rate

Respiratory Volume/Time

Respiratory and Cardiac Time Course

Motion Models + Censoring

PhysIO Toolbox

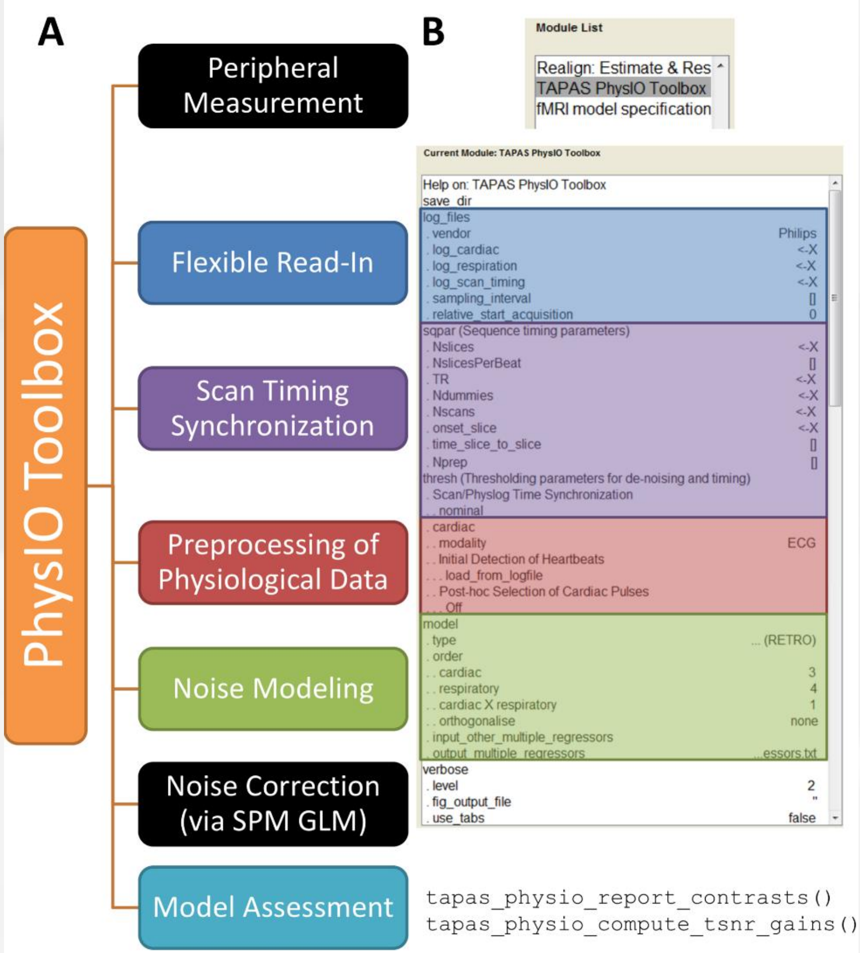
The PhysIO Toolbox

- Developed at the Translational Neuromodeling Unit (TNU) since 2008
  - Lead programmer: Lars Kasper (TNU)
  - Contributors: Jakob Heinzle (TNU), Steffen Bollmann (KiSpi Zurich)
- Part of the TNU «TAPAS» software suite
- Used at the TNU, in Zurich and beyond by ~50 researchers
  - Iglesias 2013, Neuron; Kasper 2014, NeuroImage; Bollmann 2014, PhDThesis; Sulzer 2013, NeuroImage; Hauser 2014, NeuroImage; Grueschow 2015, Neuron
- Download & Example Data:
  - https://www.tnu.ethz.ch/en/software/tapas.html
  - https://www.tnu.ethz.ch/en/software/tapas/data.html

Installing TAPAS

- Download as zip:
  https://translationalneuromodeling.github.io/tapas/#download
- Git/SVN:
  https://github.com/translationalneuromodeling/tapas.git
- Run `tapas/tapas_init.m` (adds tapas folder to path)
- Run `tapas_physio_init.m` (for SPM integration)

Workflow of the PhysIO Toolbox

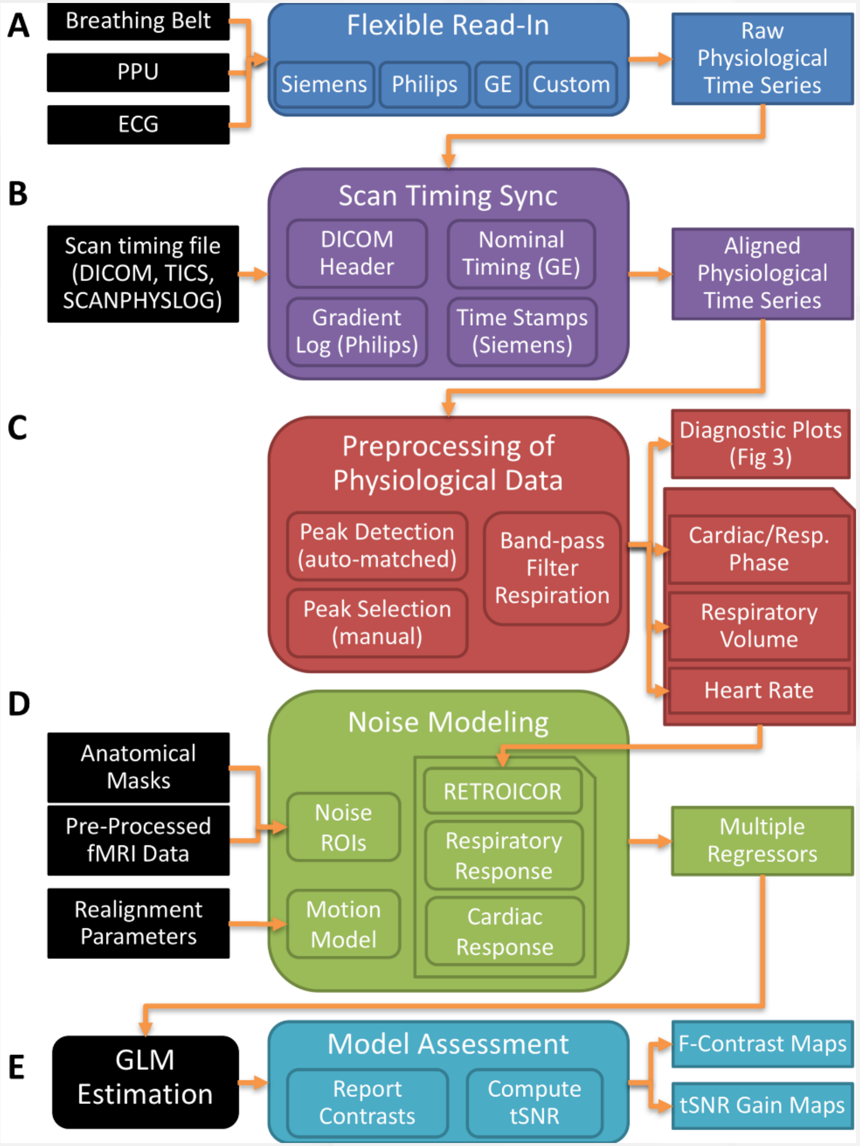


```
Current Module: TAPAS PhysIO Toolbox

Help on: TAPAS PhysIO Toolbox
save_dir
log_files
. vendor                                            Philips
. log_cardiac                                           <-X
. log_respiration                                       <-X
. log_scan_timing                                       <-X
. sampling_interval                                      []
. relative_start_acquisition                              0
sqpar (Sequence timing parameters)
. Nslices                                               <-X
. NslicesPerBeat                                         []
. TR                                                    <-X
. Ndummies                                              <-X
. Nscans                                                <-X
. onset_slice                                           <-X
. time_slice_to_slice                                    []
. Nprep                                                  []
thresh (Thresholding parameters for de-noising and timing)
. Scan/Physlog Time Synchronization
. . nominal
. cardiac
. . modality                                            ECG
. . Initial Detection of Heartbeats
. . . load_from_logfile
. . Post-hoc Selection of Cardiac Pulses
. . . Off
model
. type                                         ... (RETRO)
. order
. . cardiac                                               3
. . respiratory                                           4
. . cardiac X respiratory                                 1
. . orthogonalise                                      none
. input_other_multiple_regressors
. output_multiple_regressors                  ...essors.txt
verbose
. level                                                   2
. fig_output_file                                        ''
. use_tabs                                            false
```

```
tapas_physio_report_contrasts()
tapas_physio_compute_tsnr_gains()
```

Flowchart of Noise Correction


A

Breathing Belt

PPU

ECG

Flexible Read-In

Siemens

Philips

GE

Custom

Raw Physiological Time Series

B

Scan timing file (DICOM, TICS, SCANPHYSLOG)

Scan Timing Sync

DICOM Header

Nominal Timing (GE)

Gradient Log (Philips)

Time Stamps (Siemens)

Aligned Physiological Time Series

C

Preprocessing of Physiological Data

Peak Detection (auto-matched)

Peak Selection (manual)

Band-pass Filter Respiration

Diagnostic Plots (Fig 3)

Cardiac/Resp. Phase

Respiratory Volume

Heart Rate

D

Anatomical Masks

Pre-Processed fMRI Data

Realignment Parameters

Noise Modeling

Noise ROIs

Motion Model

RETROICOR

Respiratory Response

Cardiac Response

Multiple Regressors

E

GLM Estimation

Model Assessment

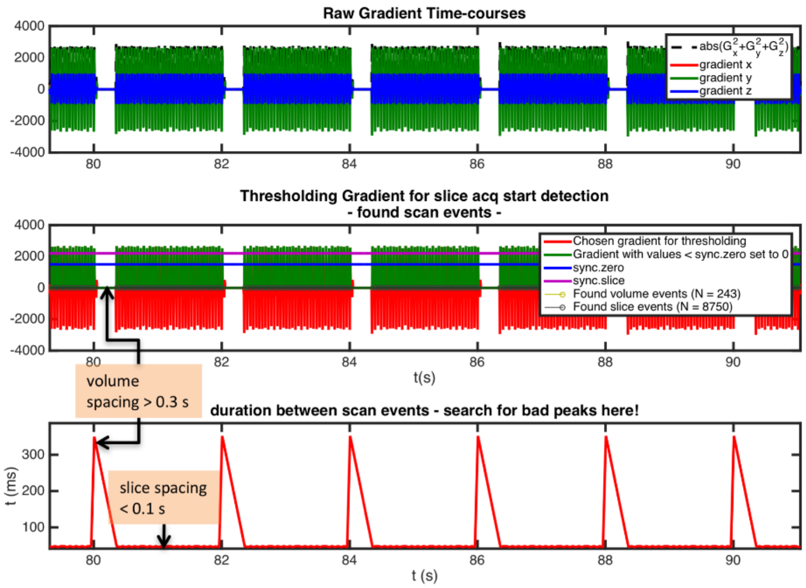
Report Contrasts

Compute tSNR

F-Contrast Maps

tSNR Gain Maps

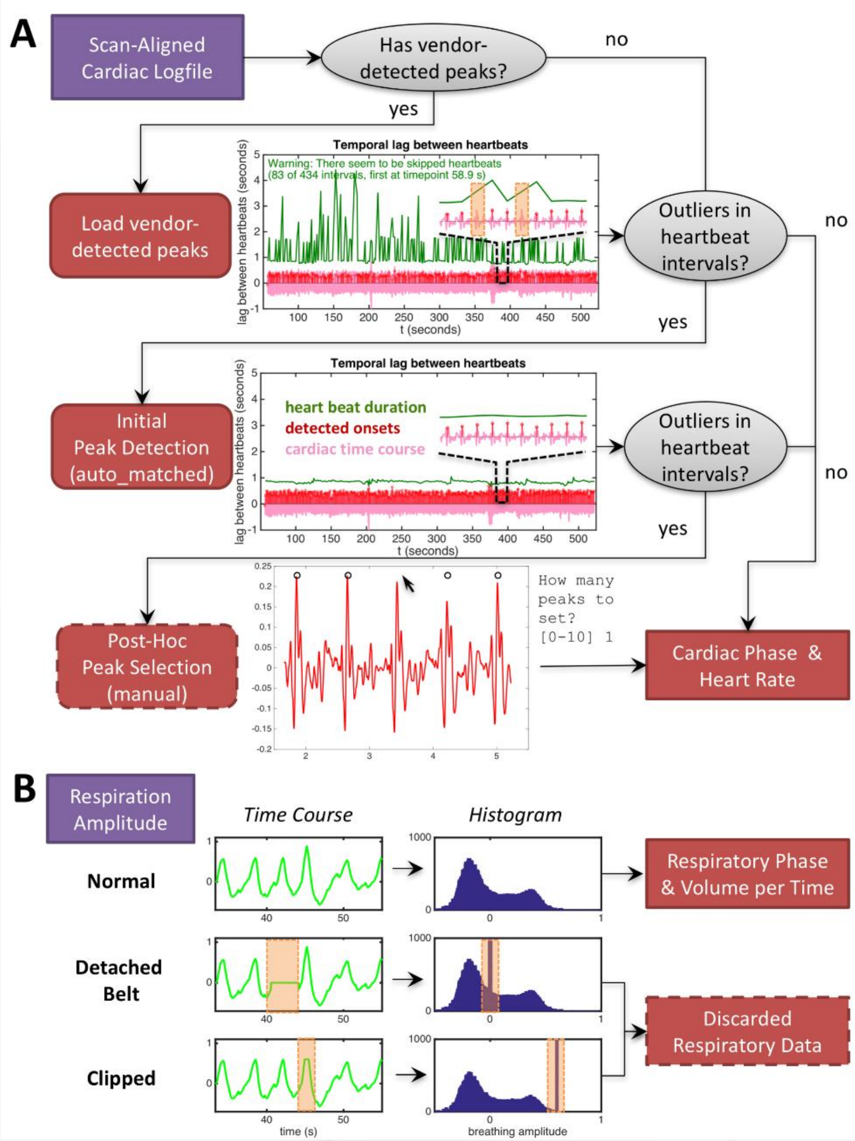
Scan Sync with Philips Gradients



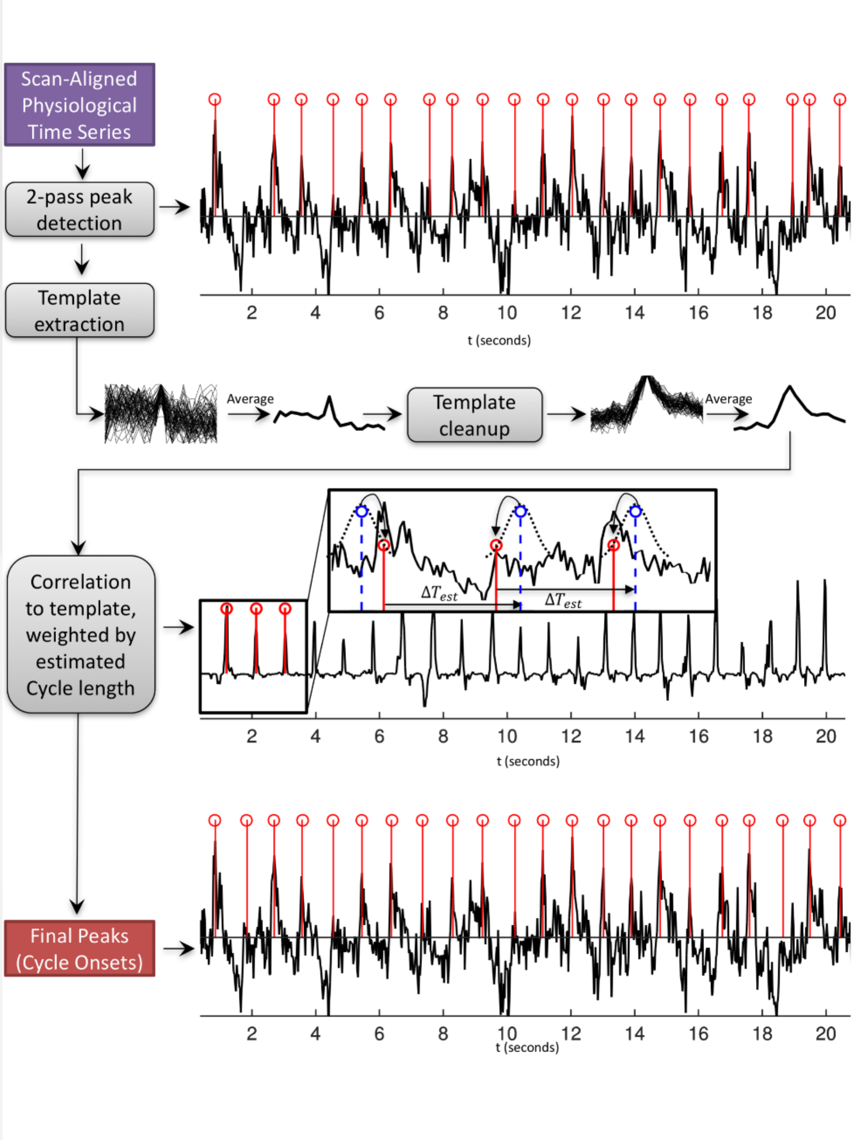
volume spacing > 0.3 s

slice spacing < 0.1 s

Data Preprocessing Overview



Preprocessing: Peak Detection



Scan-Aligned Physiological Time Series

2-pass peak detection

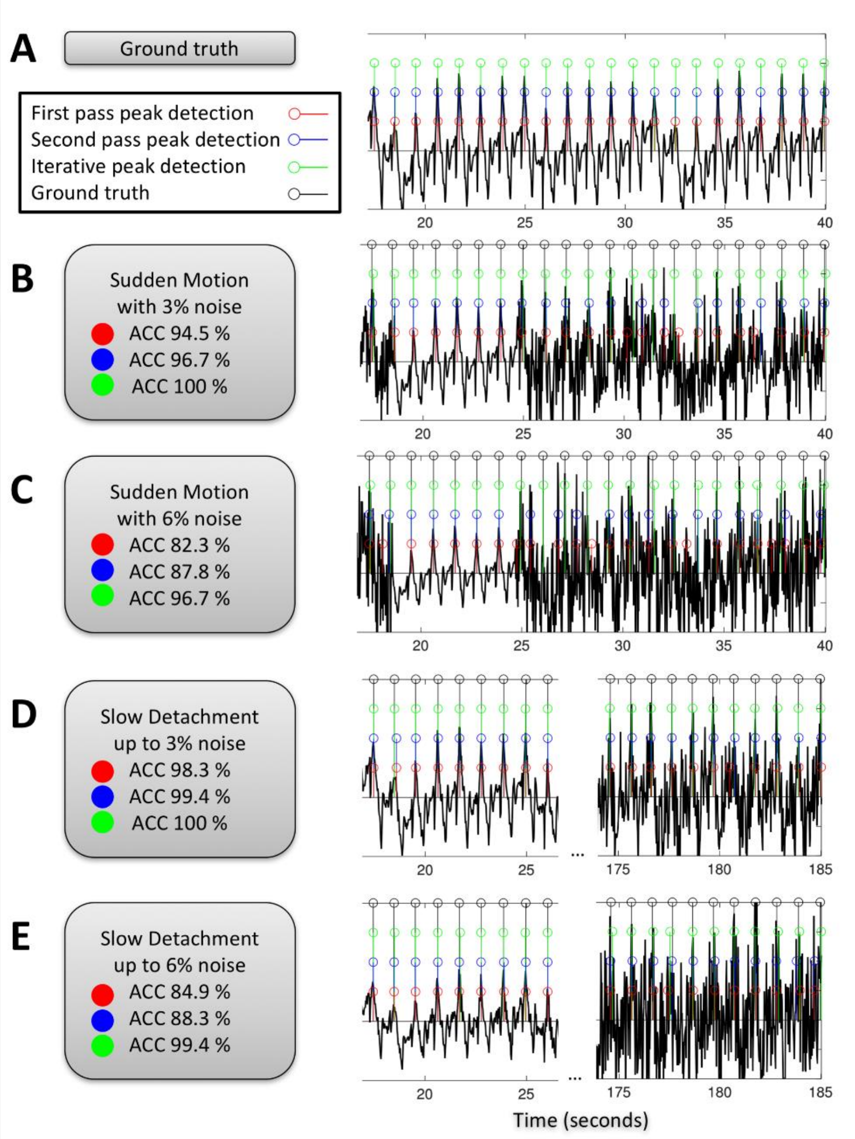
Template extraction

Template cleanup

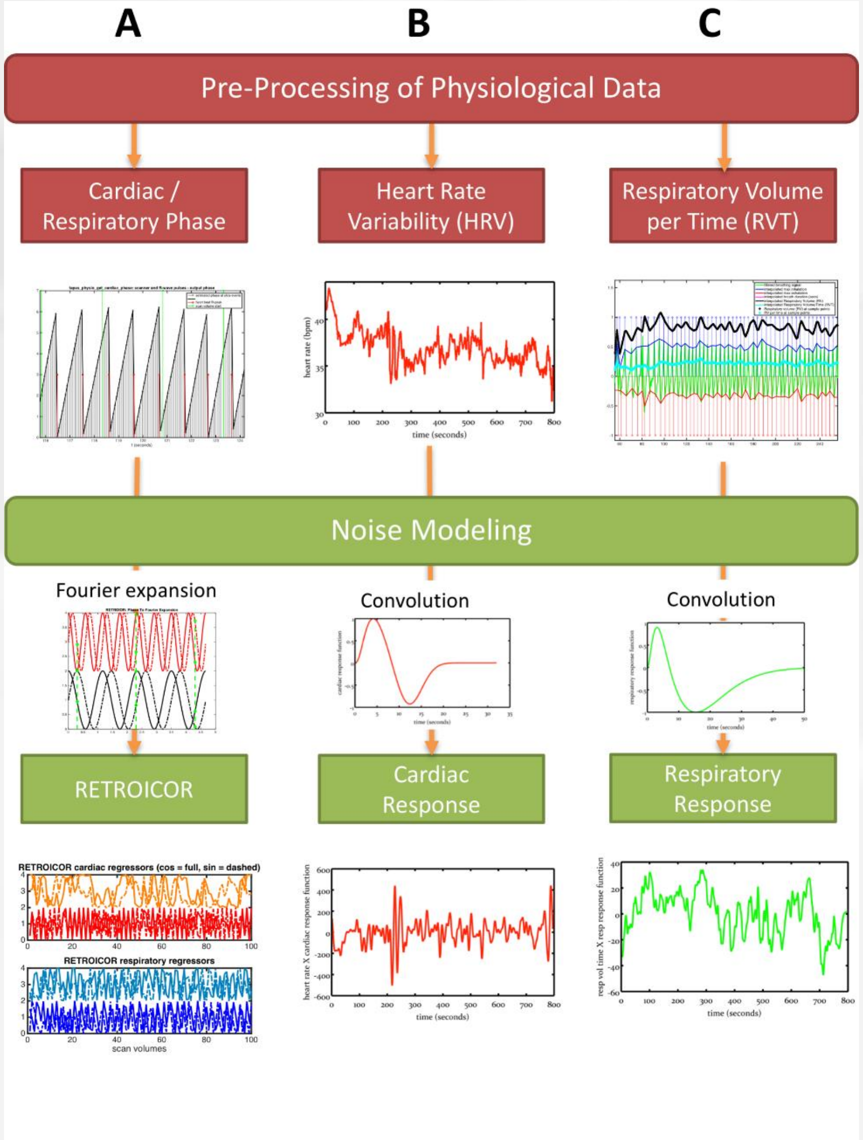
Correlation to template, weighted by estimated Cycle length

Final Peaks (Cycle Onsets)

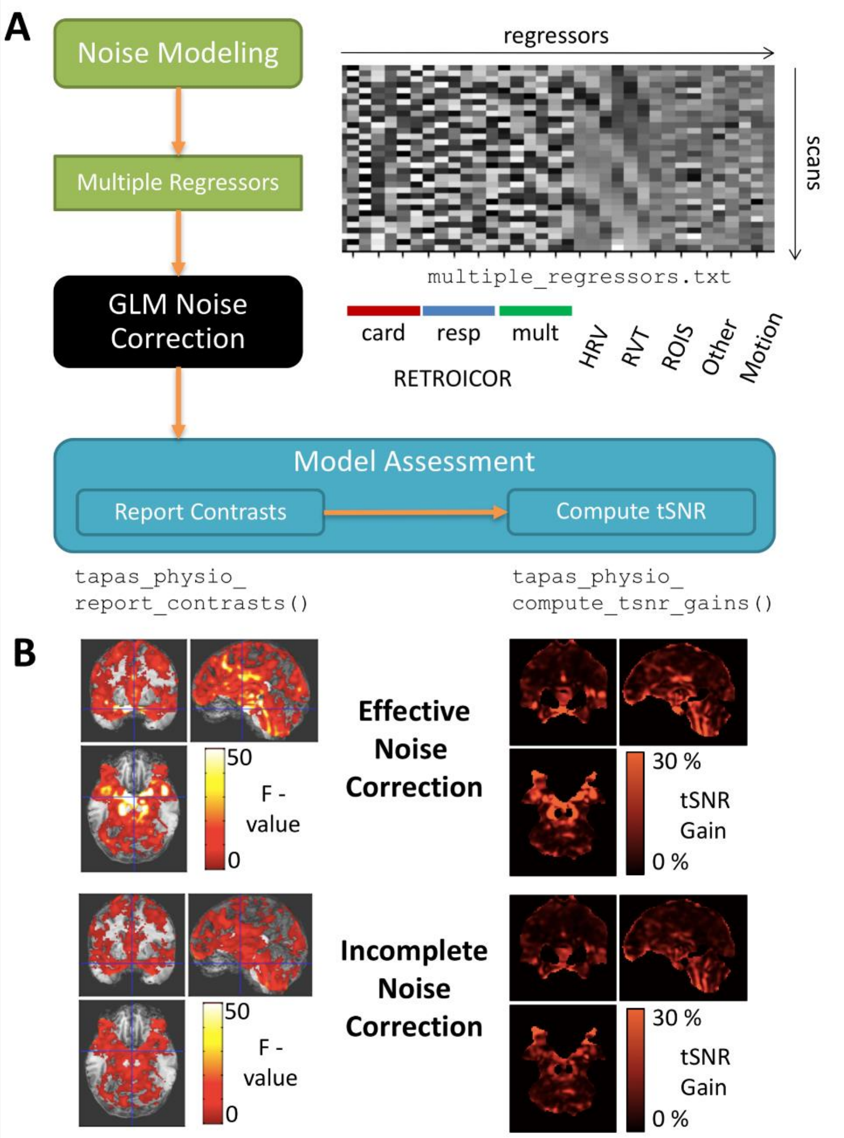
Peak Detection: Robustness



Noise Modeling

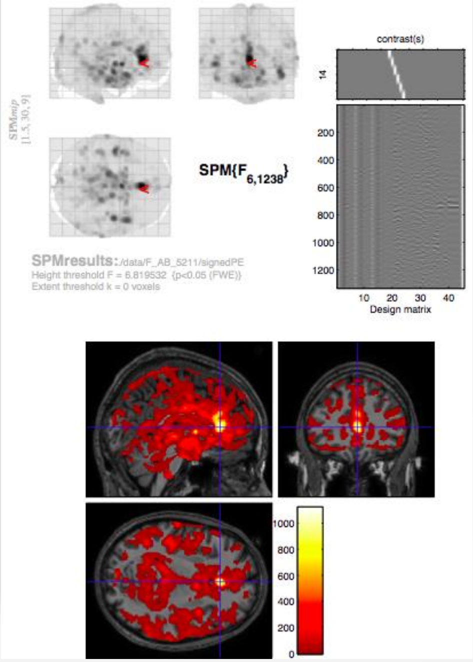


Diagnostics: Model Assessment

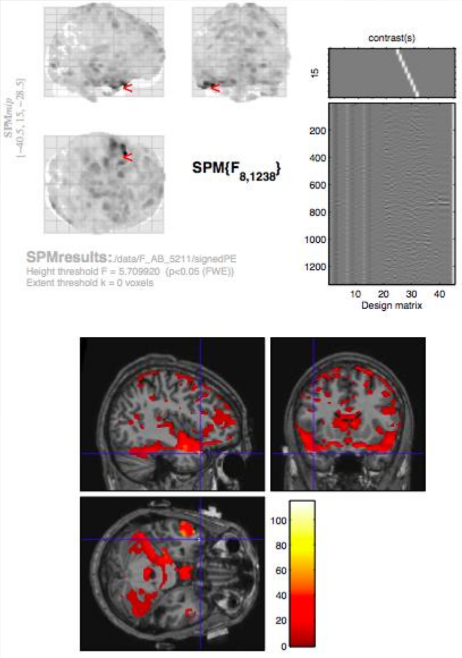


Model Check: SPM F-contrasts

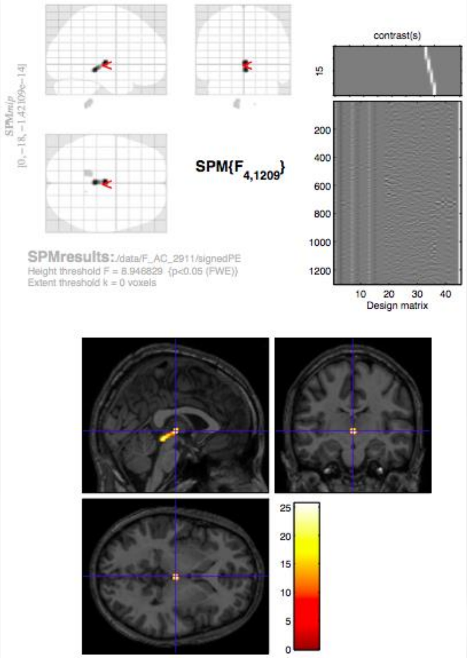
Cardiac regressors



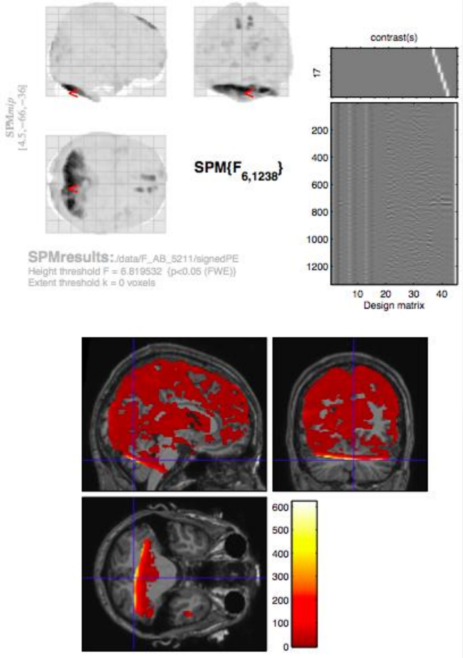
Respiratory regressors



Cardiac x Respiratory



Movement regressors

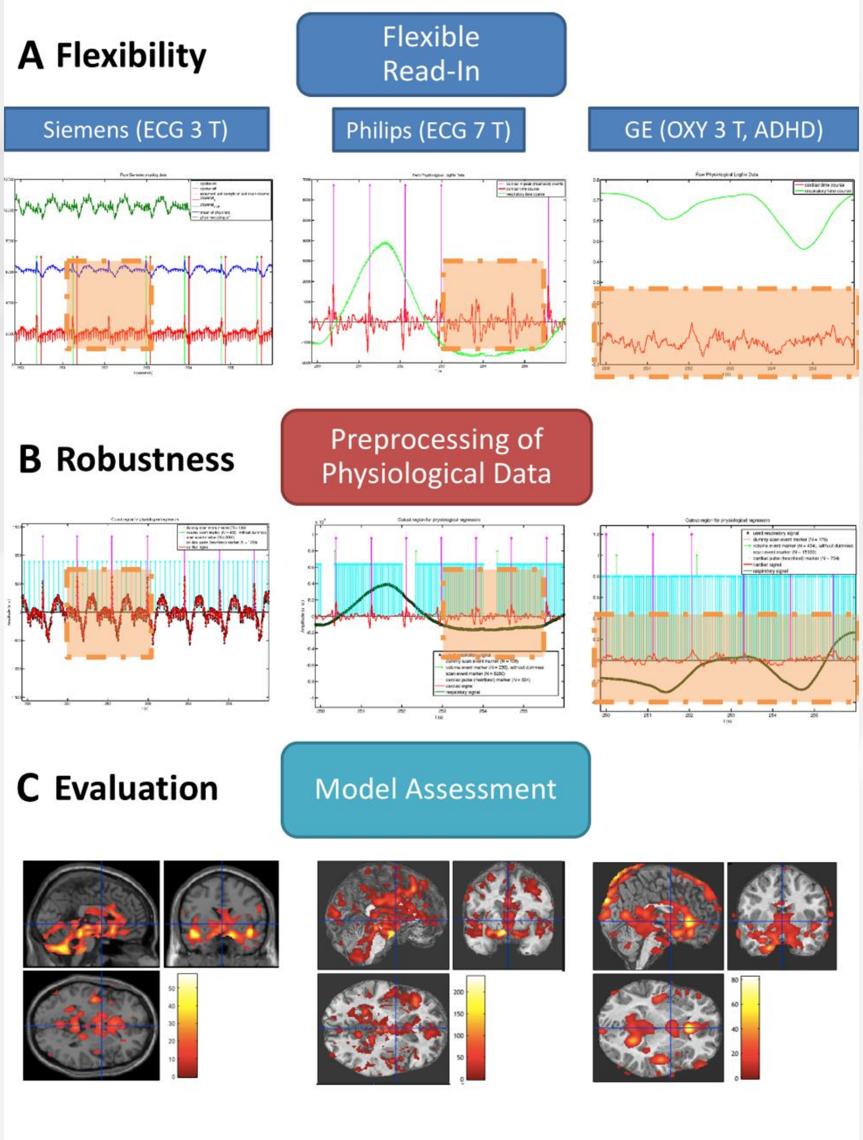


Finally:

Check Influence of Physiological Noise (Correction) on Data

- SPM
- F-contrast on 1st and second level

Flexibility: Scanner vendors



References

- **Birn**, Rasmus M., Jason B. Diamond, Monica A. Smith, and Peter A. Bandettini. 2006. "Separating Respiratory-variation-related Fluctuations from Neuronal-activity-related Fluctuations in fMRI." NeuroImage 31 (4) (July 15): 1536–1548. doi:10.1016/j.neuroimage.2006.02.048.

- **Glover**, G H, T Q Li, and D Ress. 2000. "Image-based Method for Retrospective Correction of Physiological Motion Effects in fMRI: RETROICOR." Magnetic Resonance in Medicine: Official Journal of the Society of Magnetic Resonance in Medicine / Society of Magnetic Resonance in Medicine 44 (1) (July): 162–7.

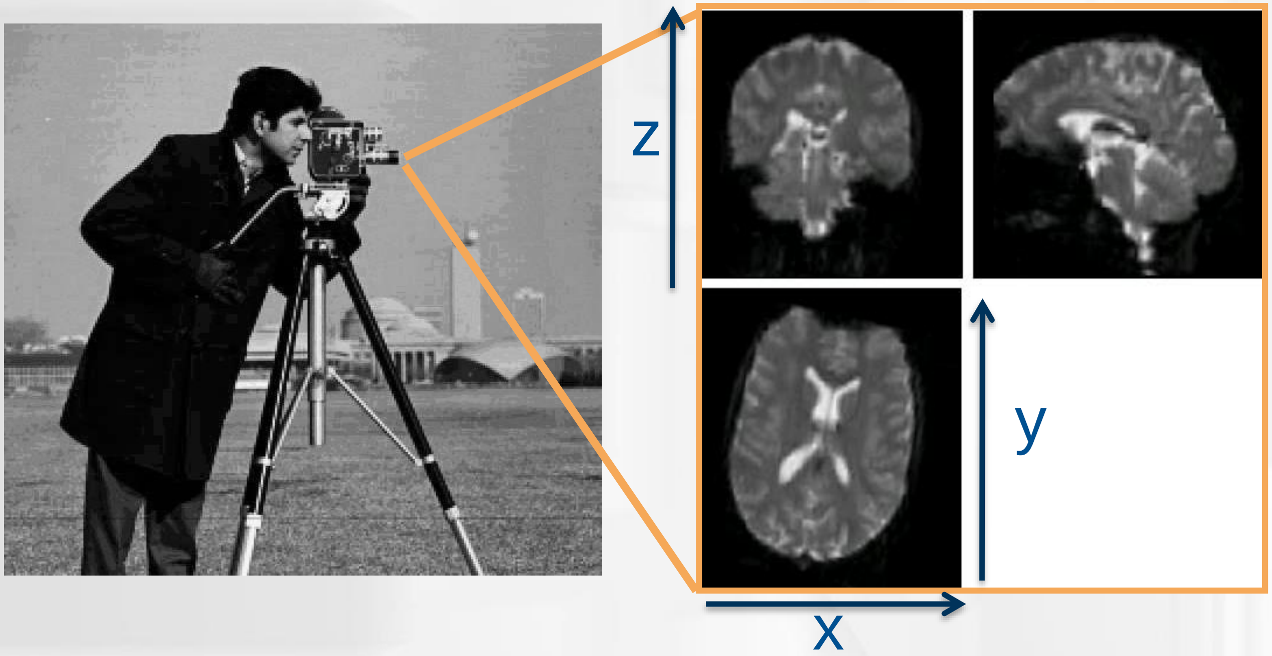
- **Harvey**, Ann K., Kyle T.S. Pattinson, Jonathan C.W. Brooks, Stephen D. Mayhew, Mark Jenkinson, and Richard G. Wise. 2008. "Brainstem Functional Magnetic Resonance Imaging: Disentangling Signal from Physiological Noise." Journal of Magnetic Resonance Imaging 28 (6): 1337–1344. doi:10.1002/jmri.21623.

- **Hutton**, C., O. Josephs, J. Stadler, E. Featherstone, A. Reid, O. Speck, J. Bernarding, and N. Weiskopf. 2011. "The Impact of Physiological Noise Correction on fMRI at 7 T." NeuroImage 57 (1) (July 1): 101–112. doi:10.1016/j.neuroimage.2011.04.018.

- **Josephs**, O., Howseman, A.M., Friston, K., Turner, R., 1997. "Physiological noise modelling for multi-slice EPI fMRI using SPM." Proceedings of the 5th Annual Meeting of ISMRM, Vancouver, Canada, p. 1682

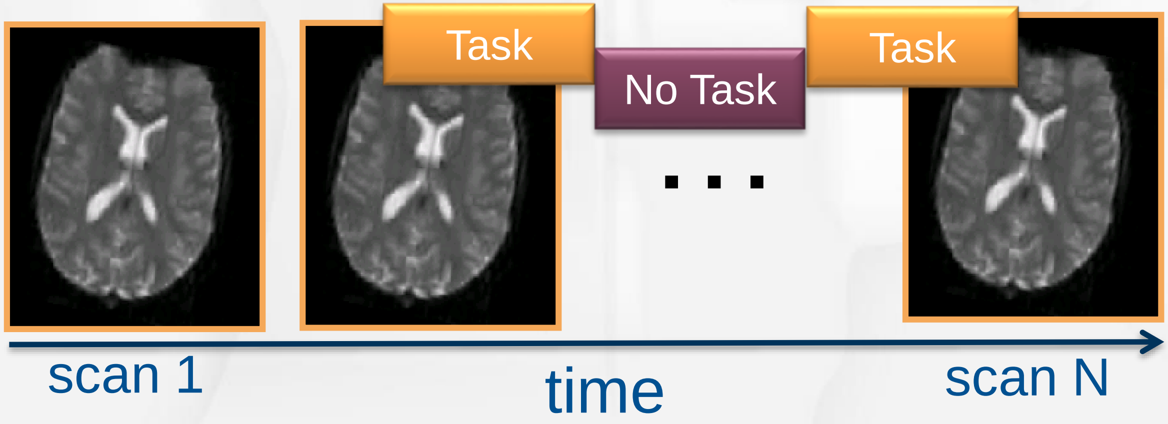
- **Kasper, L.,** Bollmann, S., Diaconescu, A.O., Hutton, C., Heinzle, J., Iglesias, S., Hauser, T.U., Sebold, M., Manjaly, Z.-M., Pruessmann, K.P., Stephan, K.E., 2016. The PhysIO Toolbox for Modeling Physiological Noise in fMRI Data. Journal of Neuroscience Methods *accepted*. doi:10.1016/j.jneumeth.2016.10.019

fMRI = Acquiring Movies



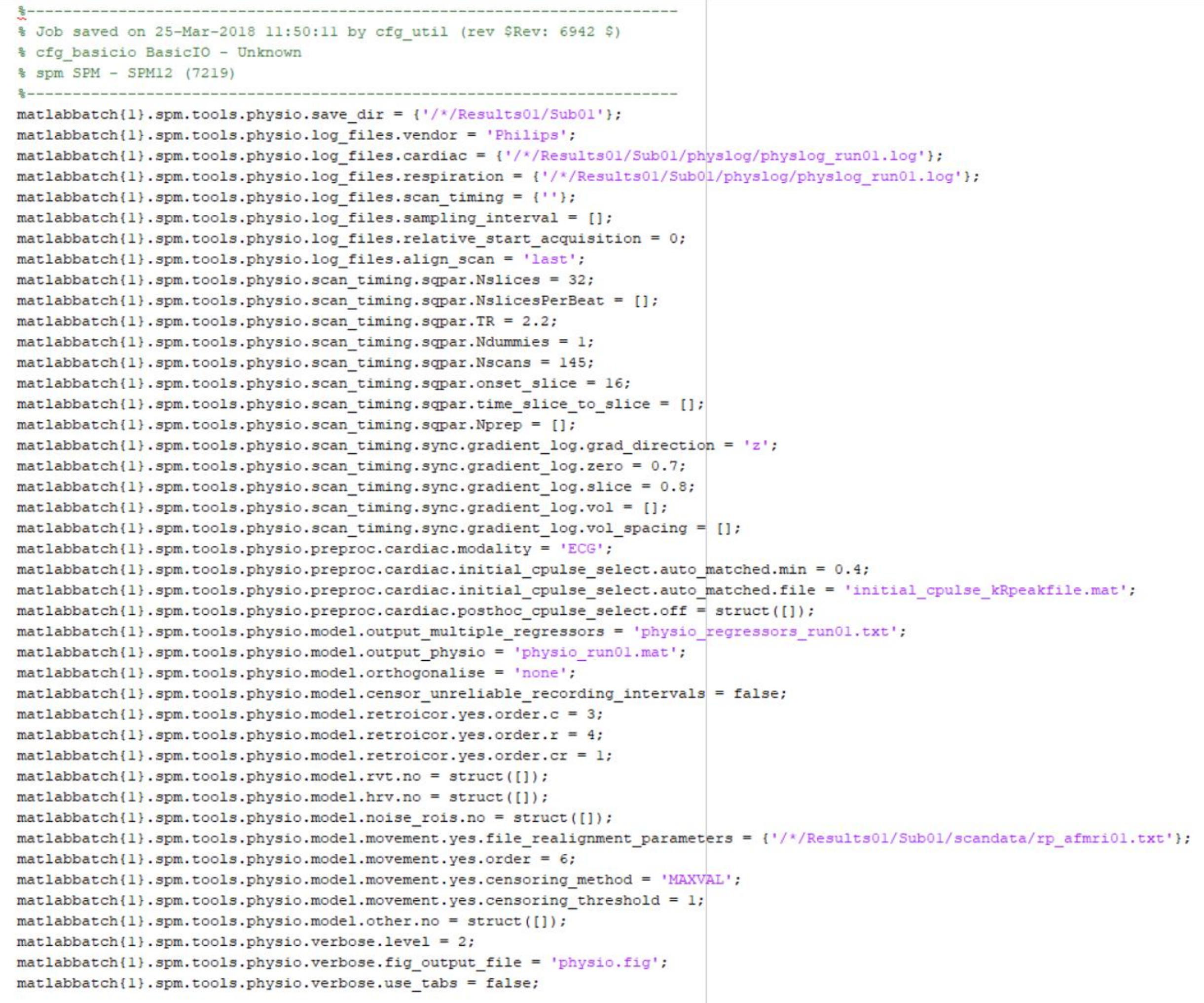
- …of three-dimensional Blood Oxygen-Level Dependent (BOLD) contrast images

- Run/Session: Time Series of Images



Help for the exercises

- Old version of an batch. OR: physio = tapas_physio_new();



```
%-----------------------------------------------------------------------
% Job saved on 25-Mar-2018 11:50:11 by cfg_util (rev $Rev: 6942 $)
% cfg_basicio BasicIO - Unknown
% spm SPM - SPM12 (7219)
%-----------------------------------------------------------------------
matlabbatch{1}.spm.tools.physio.save_dir = {'/*/Results01/Sub01'};
matlabbatch{1}.spm.tools.physio.log_files.vendor = 'Philips';
matlabbatch{1}.spm.tools.physio.log_files.cardiac = {'/*/Results01/Sub01/physlog/physlog_run01.log'};
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matlabbatch{1}.spm.tools.physio.model.retroicor.yes.order.r = 4;
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matlabbatch{1}.spm.tools.physio.model.noise_rois.no = struct([]);
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matlabbatch{1}.spm.tools.physio.verbose.level = 2;
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```