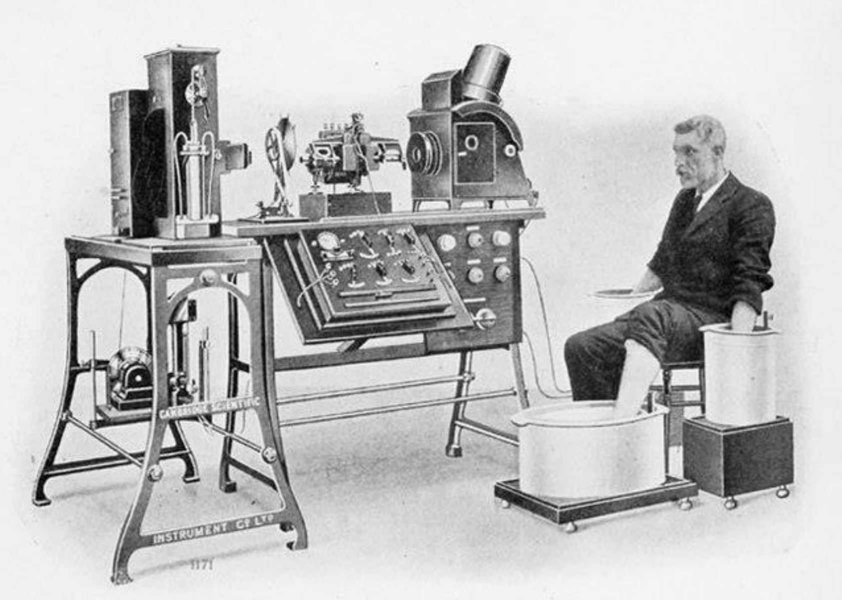


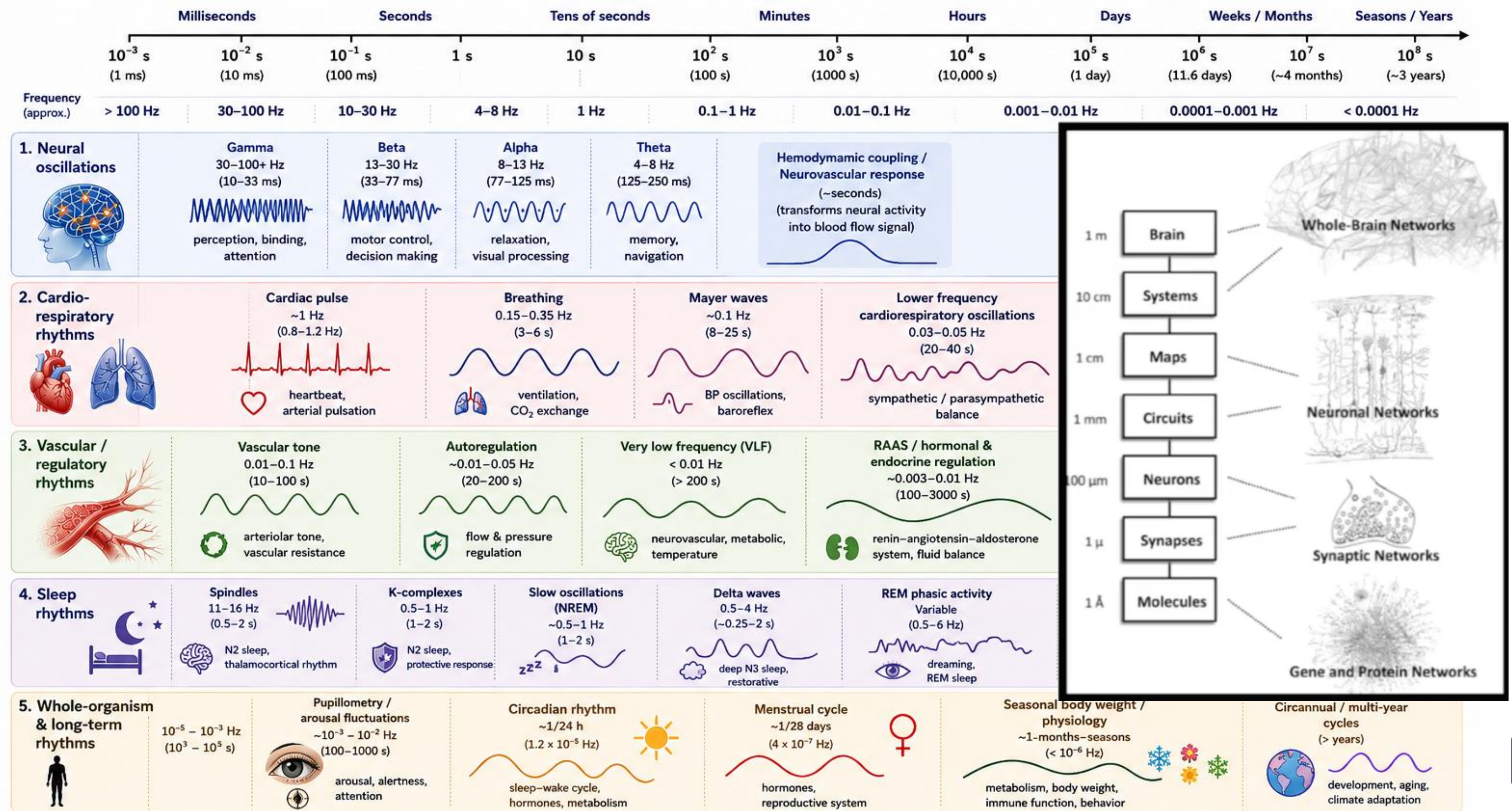
PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

Physiology in time series signal

08/11/26 Burak Akin

SFIM

Biological rhythms



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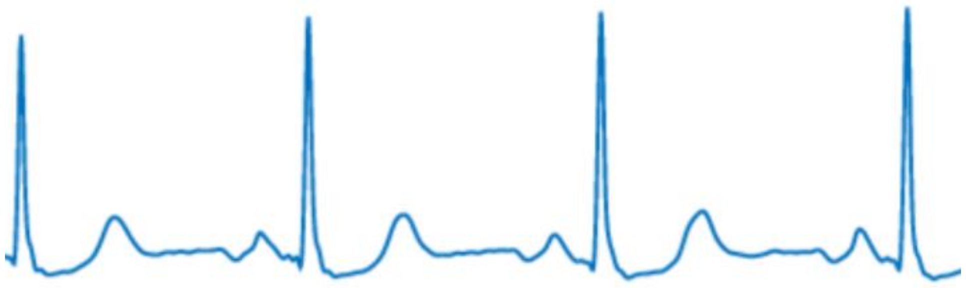
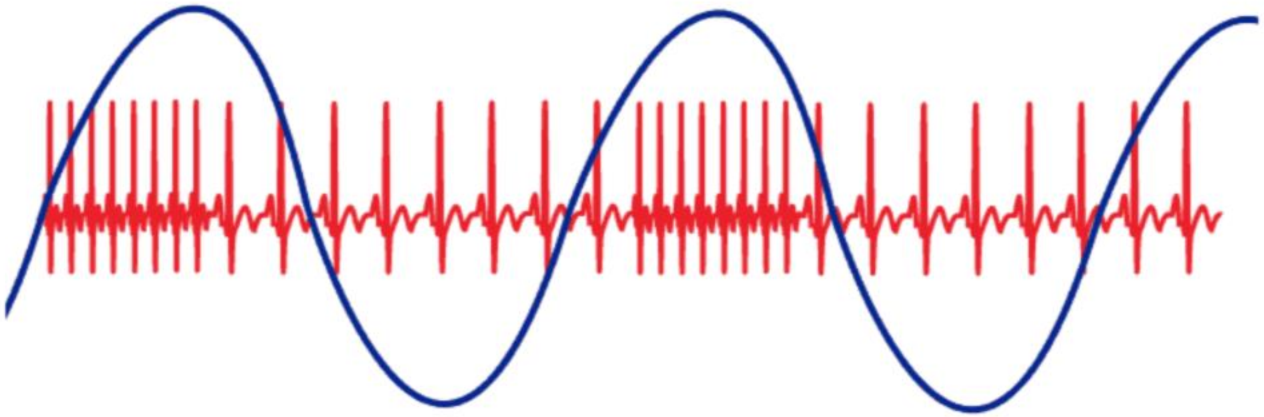
What are the characteristics of physiological signals?

Periodicity

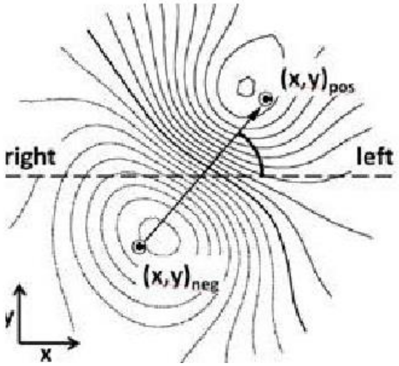


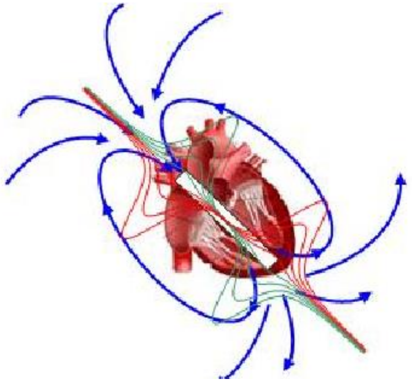
Variability & Interaction

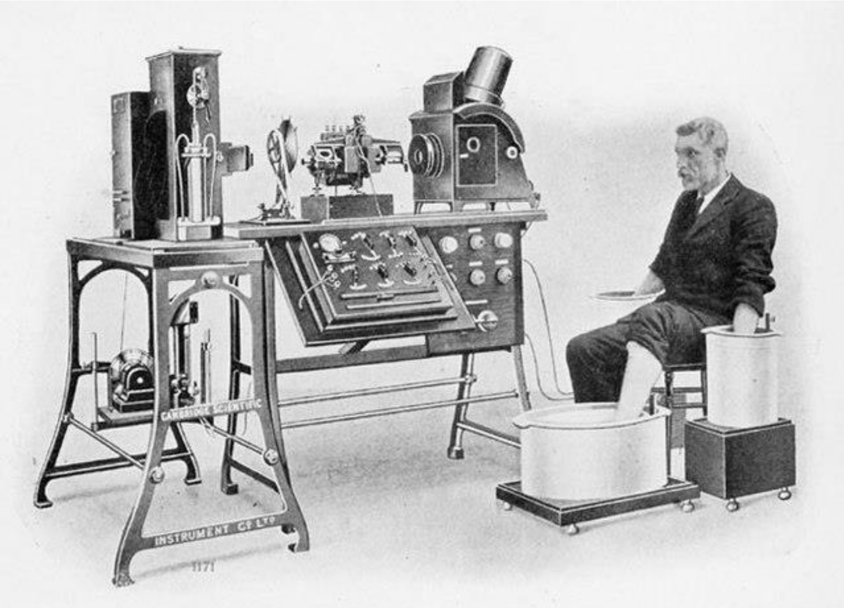


National Institute of Mental Health

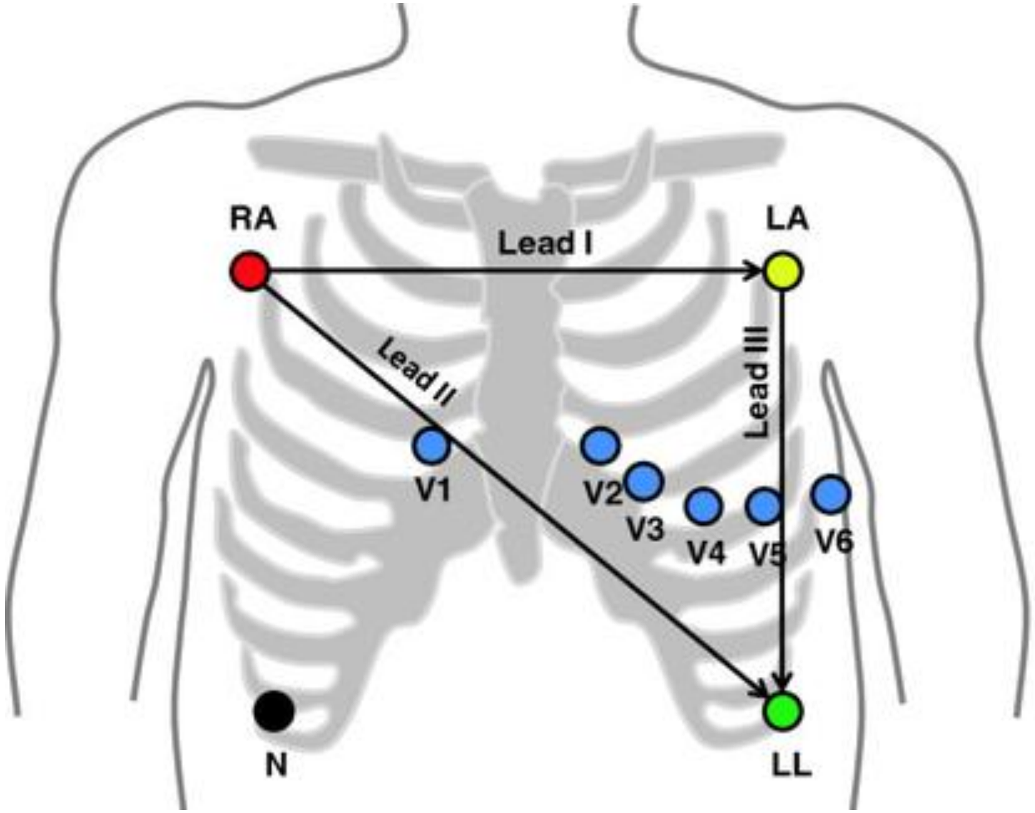
How do we measure physiological signals? Cardiac activity







Photograph of a Complete Electrocardiograph, Showing the Manner in which the Electrodes are Attached to the Patient, In this Case the Hands and One Foot Being Immersed in Jars of Salt Solution



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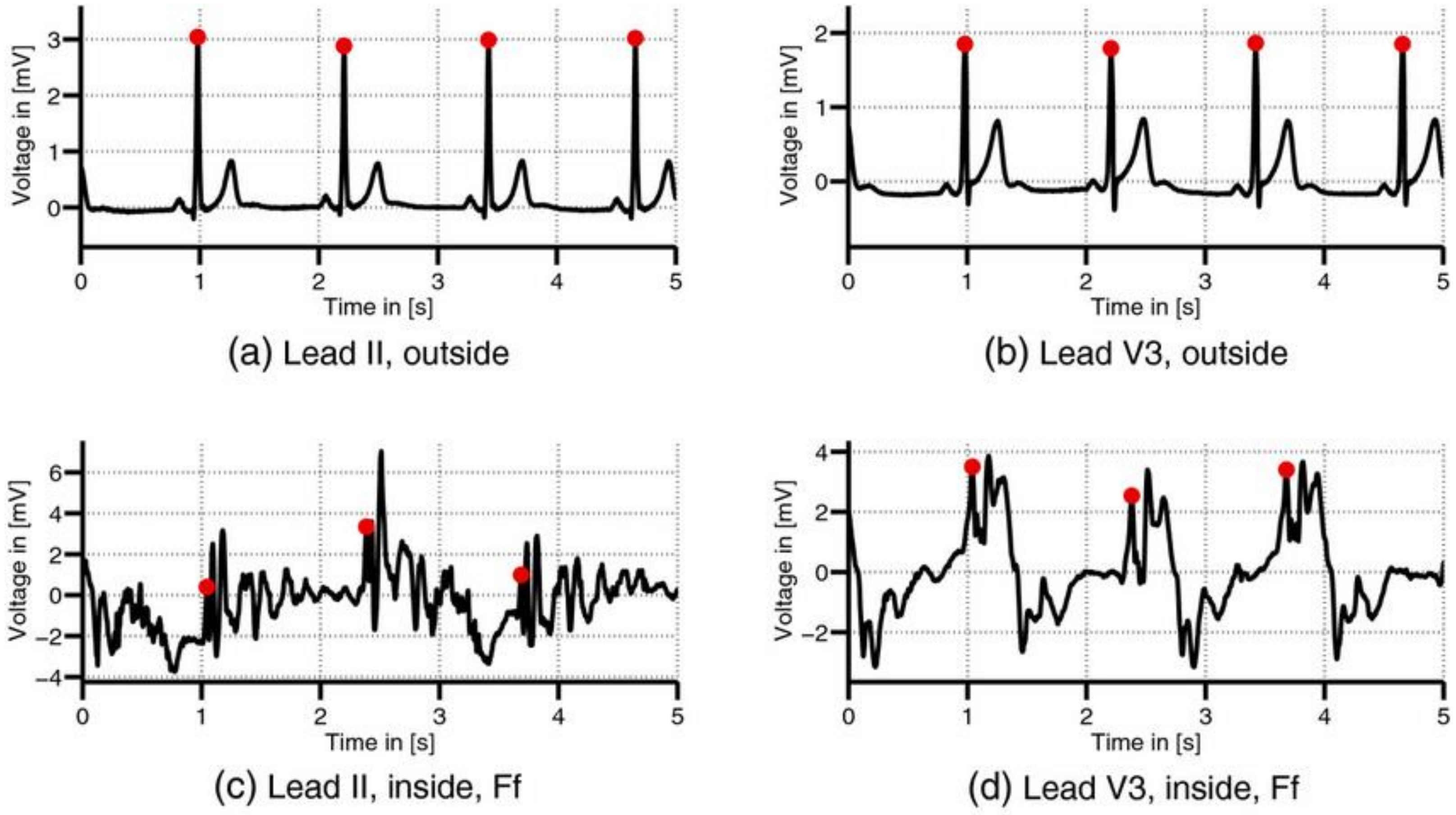
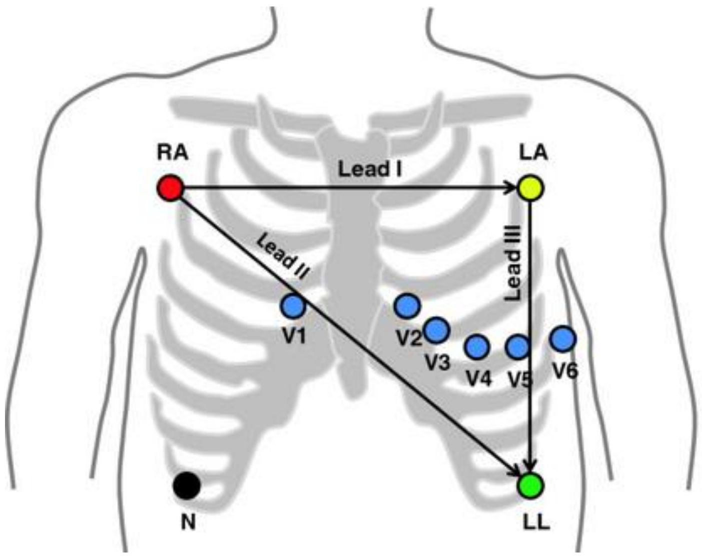
How do we measure physiological signals?

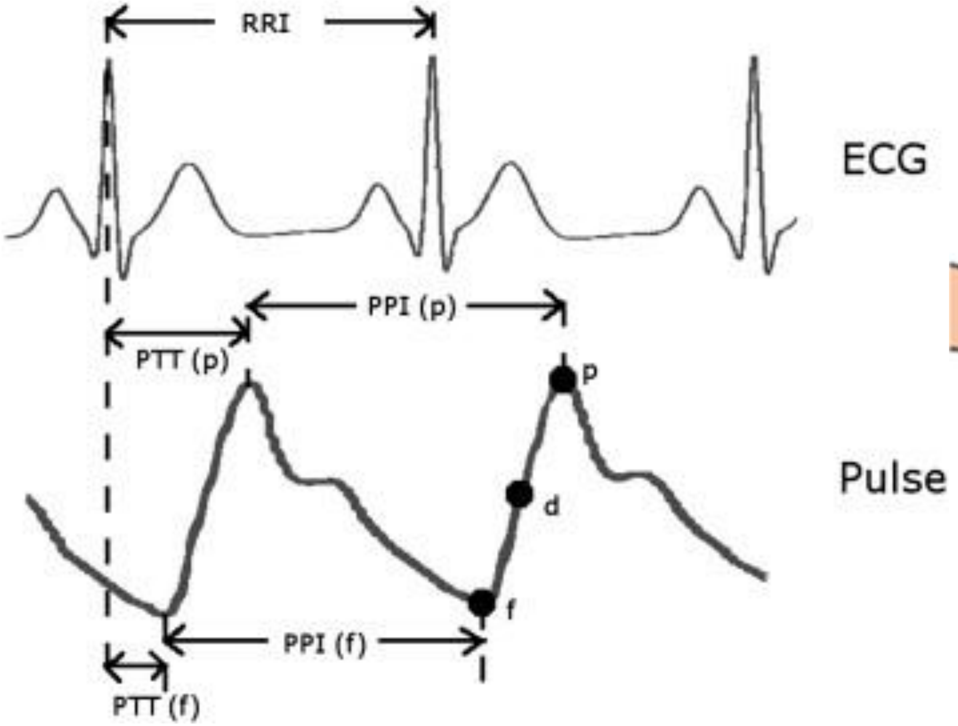
How do we measure physiological signals?

- ECG inside MRI
- The magneto-hydrodynamic effect : the motion of the blood



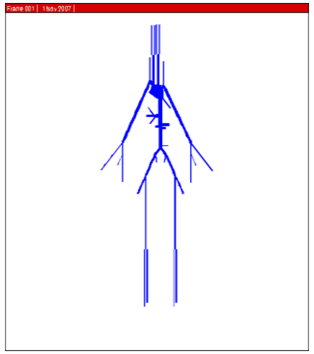


Pulse Oximeter (optical measure)

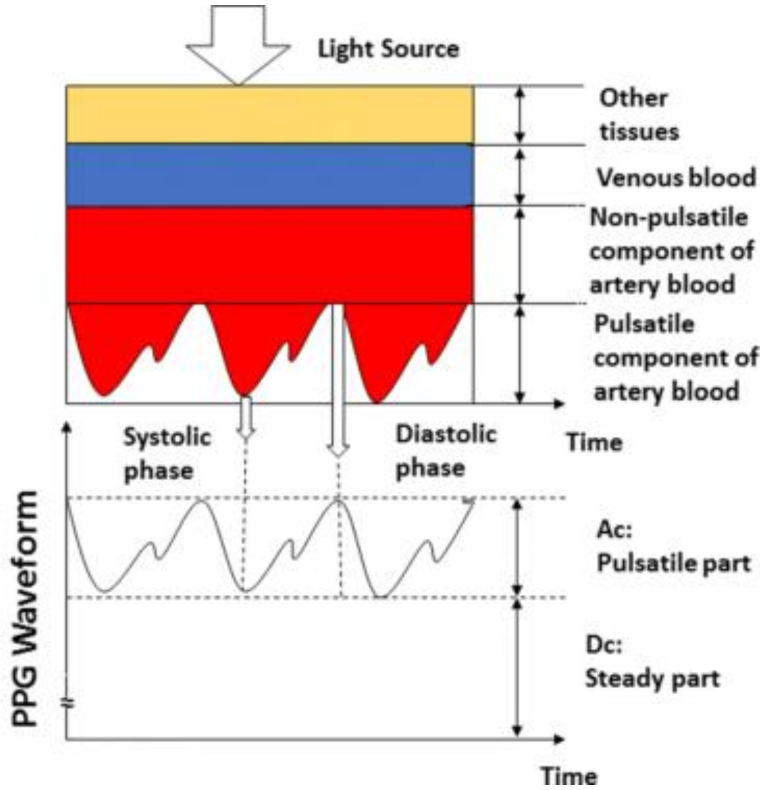


Schäfer et, al.2012

How accurate is pulse rate variability as an estimate of heart rate variability?



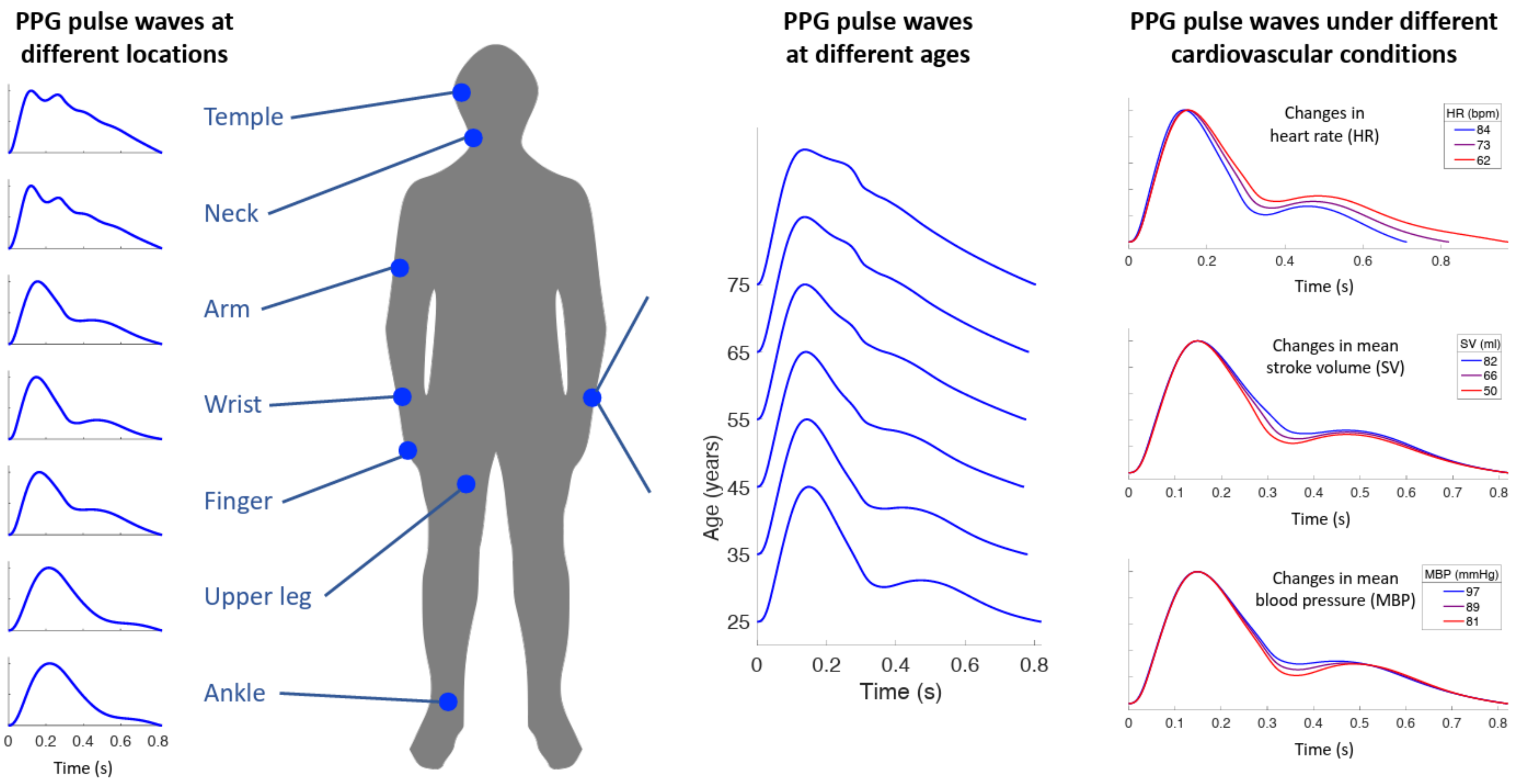
http://haemod.uk/nektar



Pulse Oximeter (optical)

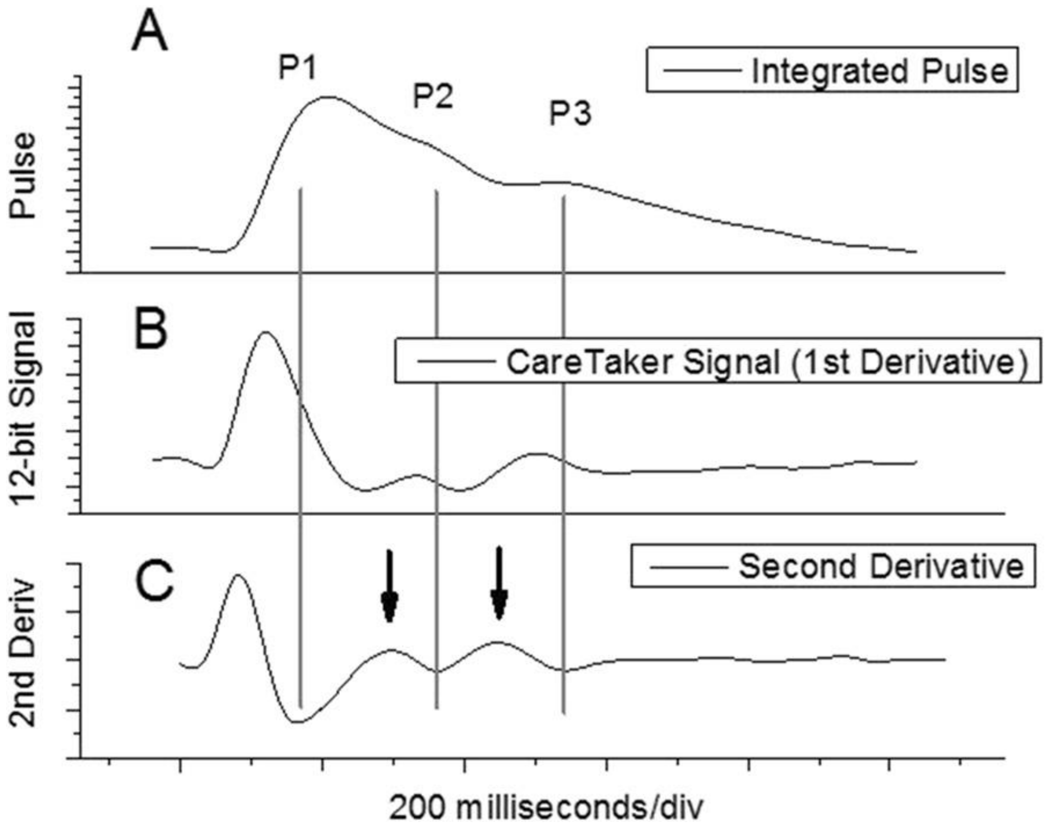
Photoplethysmography Signal Processing and Synthesis

Elisa Mejía-Mejía, John Allen, Karthik Budidha, Chadi El-Hajj, Panayiotis A. Kyriacou and Peter H. Charlton*



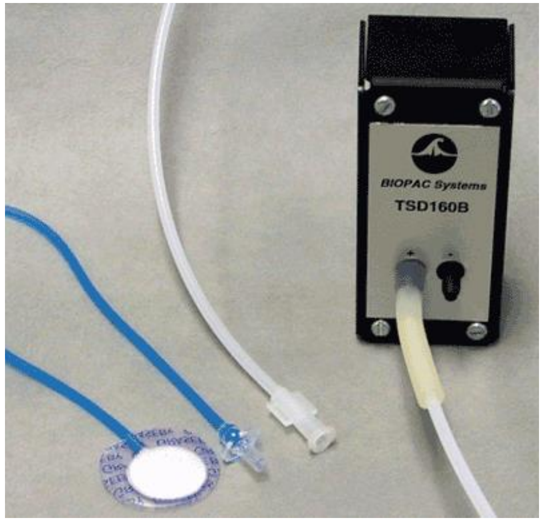
Measuring Blood Pressure (pneumatic)

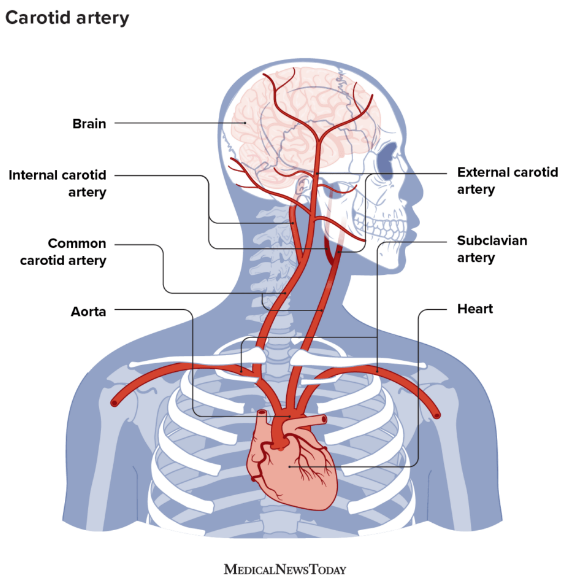
"Continuous" Non-invasive blood pressure monitor(NIBP)



Baruch et, al.2014

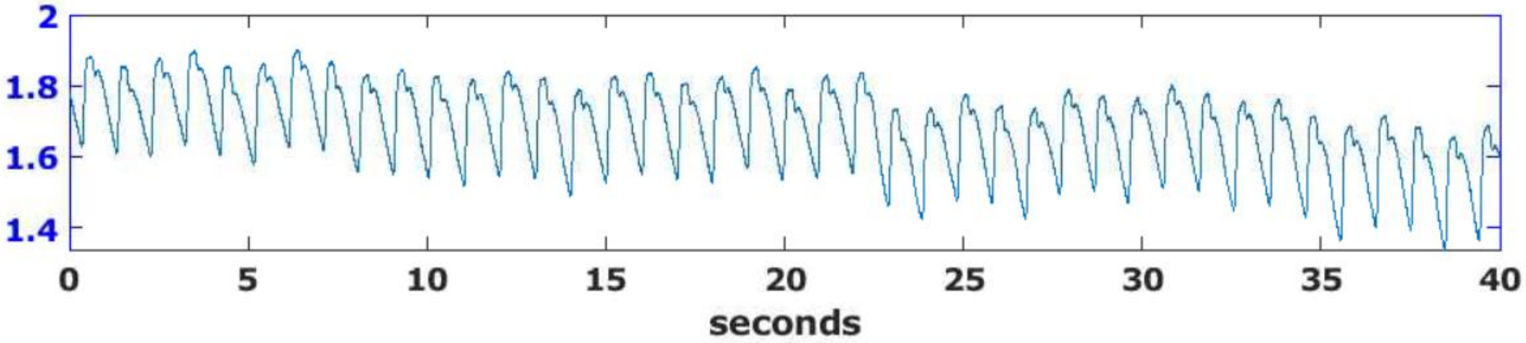
MRI compatible – Pressure pad (pneumatic)



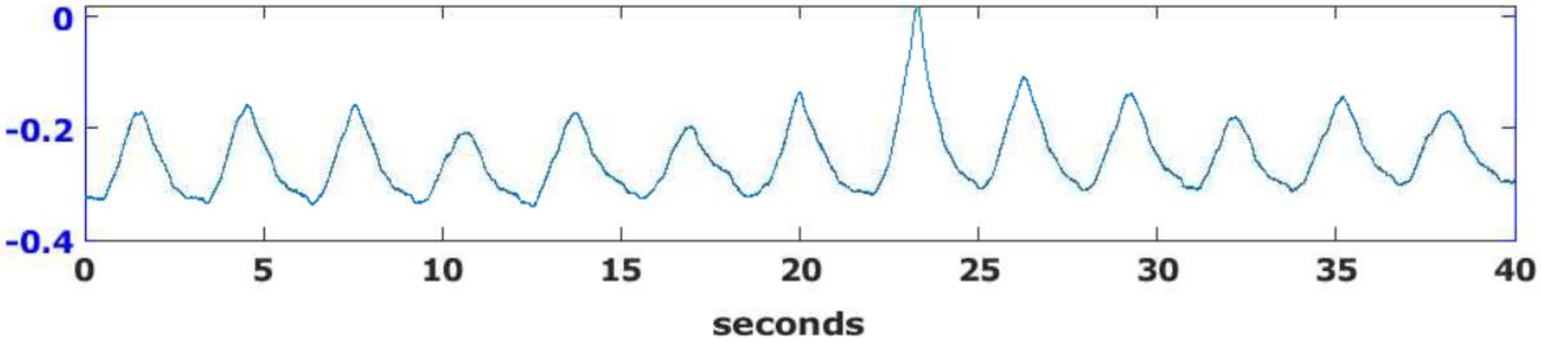


placed on carotid artery

Small pressure pad for surface pulsations



Respiration (pneumatic-piezo)



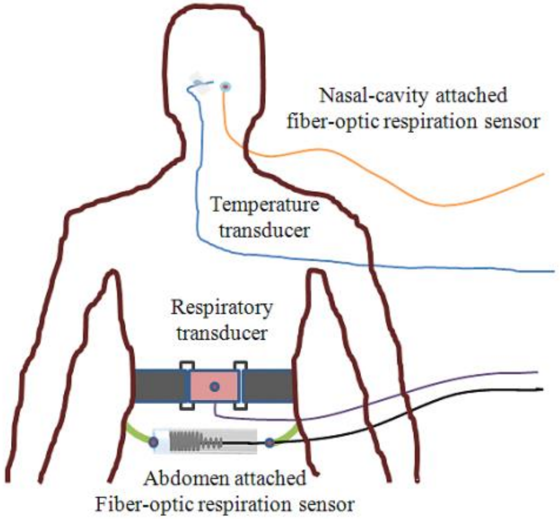


FIG. 4. Experimental setup using fiber-optic respiration sensors and a BIOPAC® system.

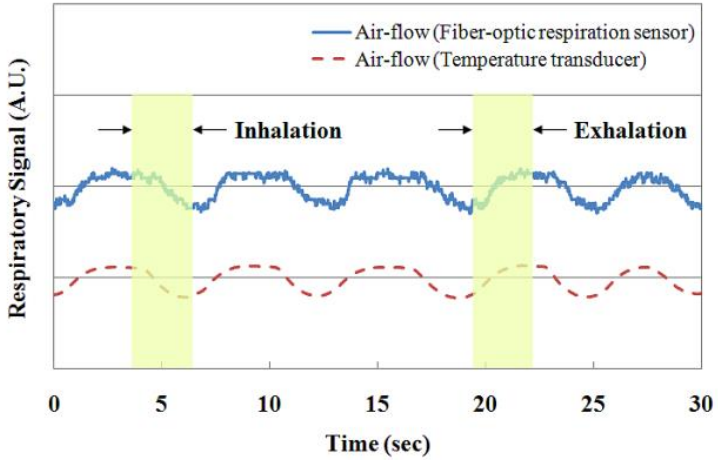
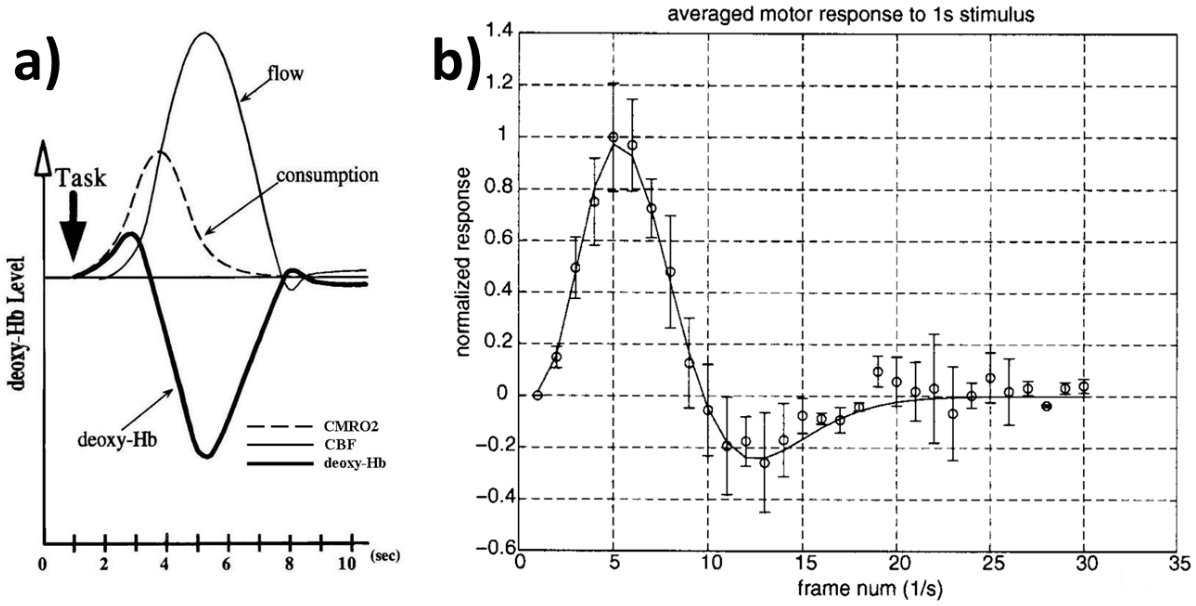


FIG. 5. Comparison of the respiratory signal of a nasal-cavity attached fiber-optic respiration sensor and a temperature transducer.

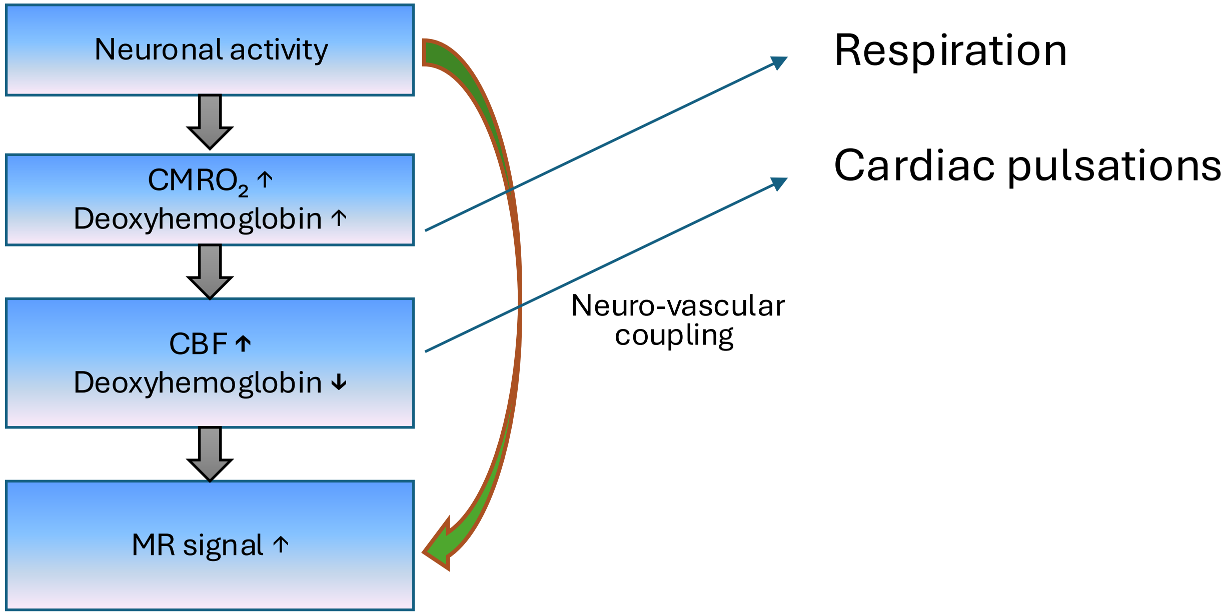
- Diaphramatic
- Shallow breathing

Functional MRI

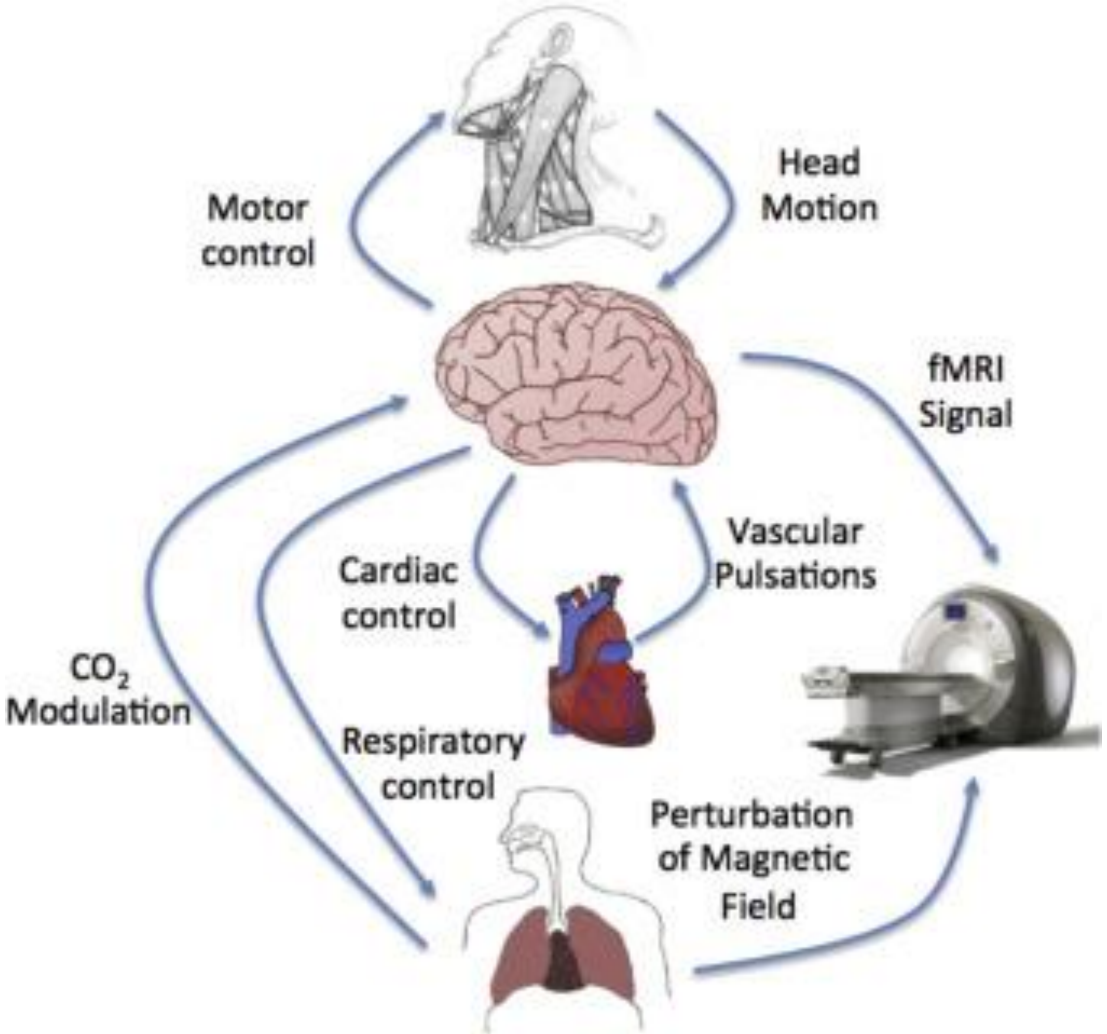
- T2*-weighted imaging sensitive to paramagnetic deoxyhaemoglobin concentration in the blood
- Blood-oxygenation level dependent (BOLD) effect



Glover et.al 1999



What modulates time series in fMRI



Liu TT, Neuroimage 2016

- Noise
  - Hardware related
  - Physiological
  - Motion

- Hardware related
  - Scanner drift
  - Thermal noise

- Motion
  - Respiration related
  - Cardiac related
  - Task related
  - Other head motion

- Physiological
  - Respiration
    - Time-locked
    - B0-field
    - CO_2
    - Blood flow
  - Cardiac
    - Time-locked
    - Motion-related
    - Blood flow

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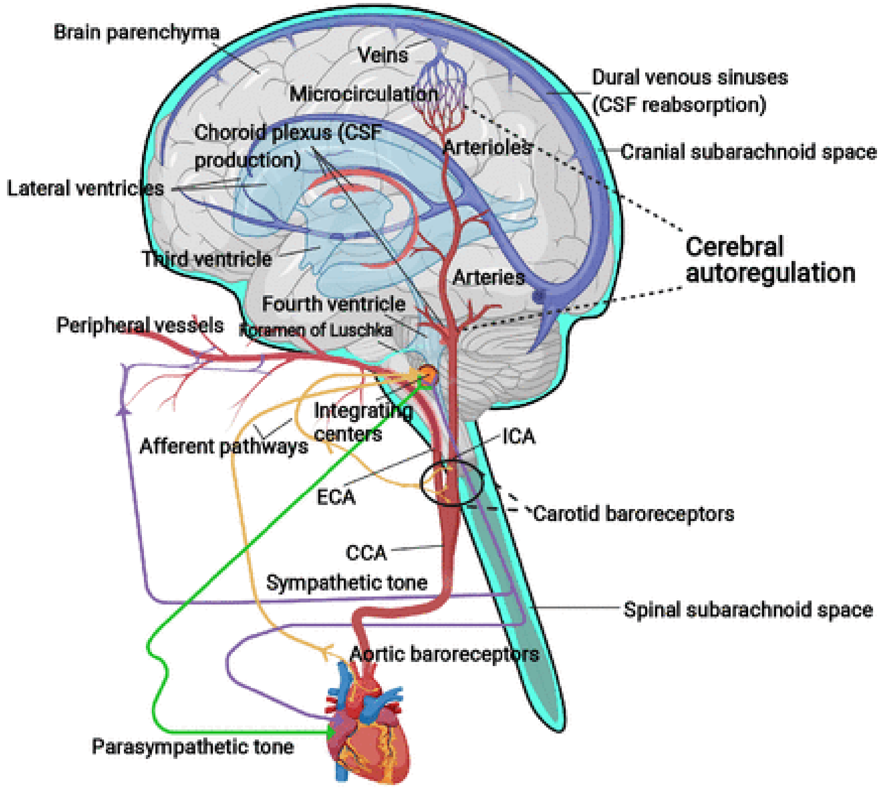
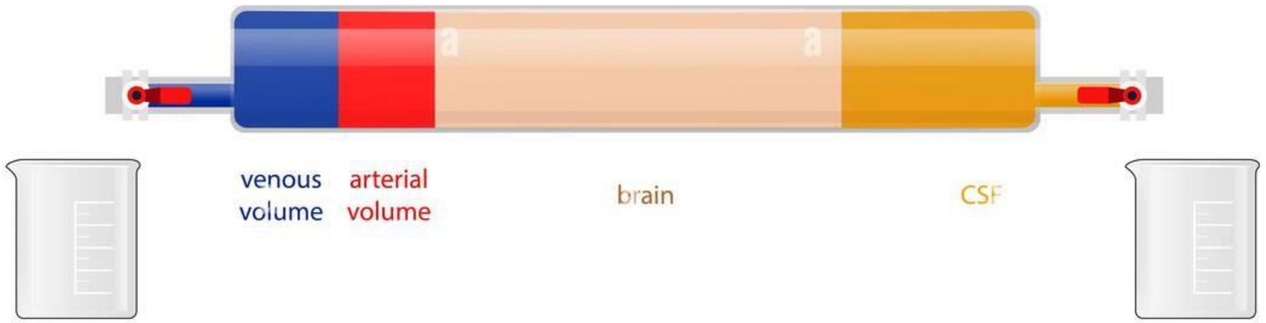
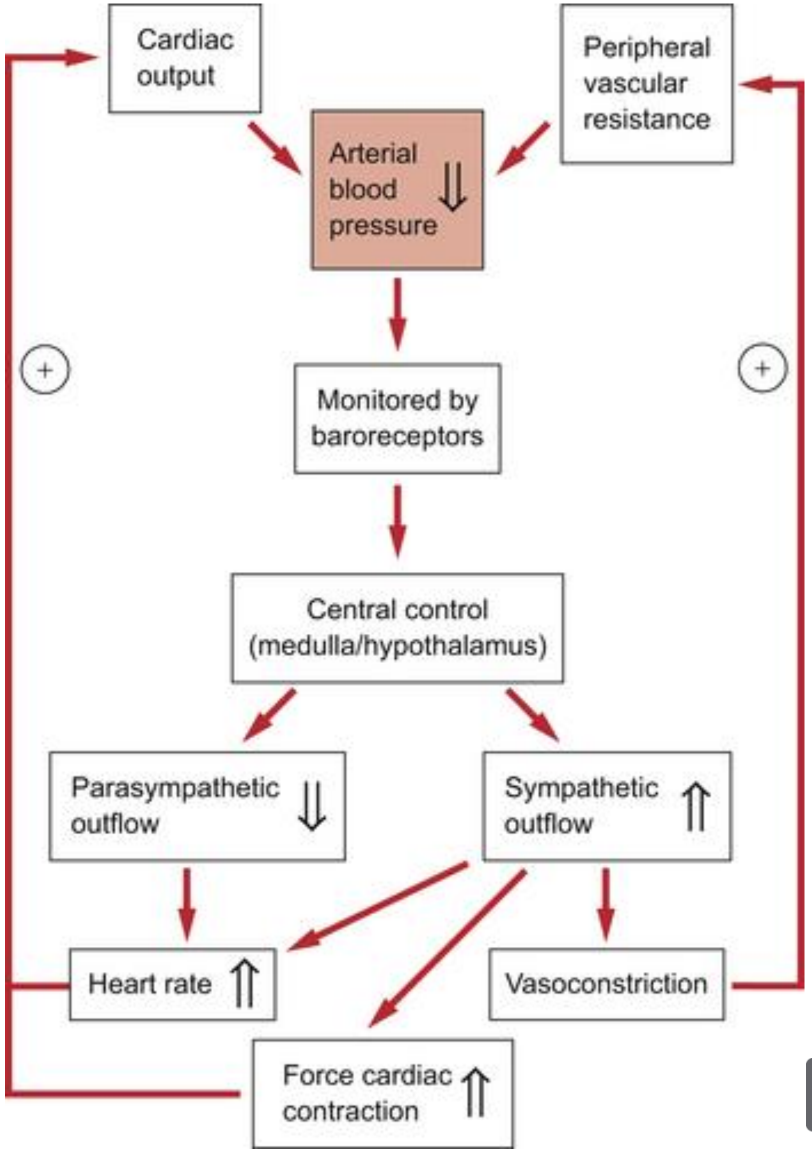
What modulates time series in fMRI



Garcia et, al.2021





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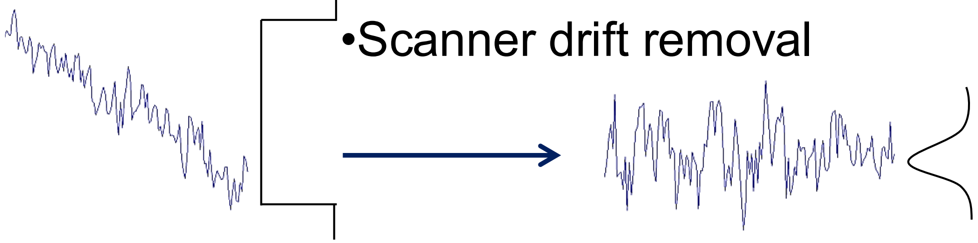
Functional MRI

Preprocessing

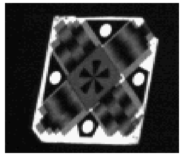
- fMRI images are not ready to do statistics on them.
    - They need to be "conditioned"

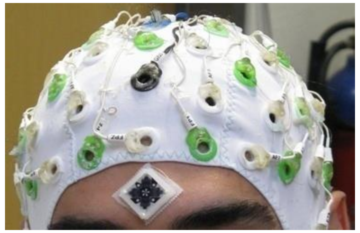


- Baseline wander correction
- Trend removal
- Scanner drift removal

- Physiological noise correction
- Skull stripping
- Spectral filtering
- Smoothing

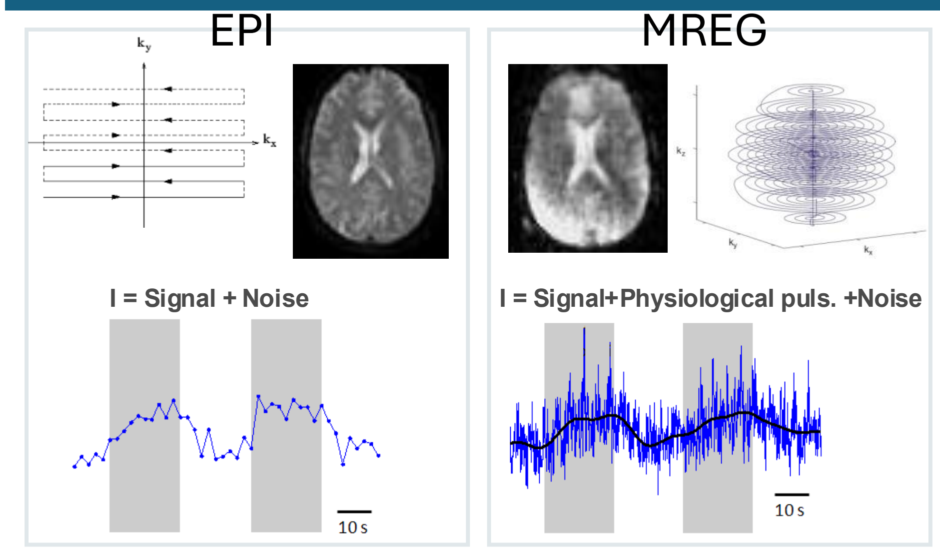
- Image alignment
- Registration
- Motion Correction



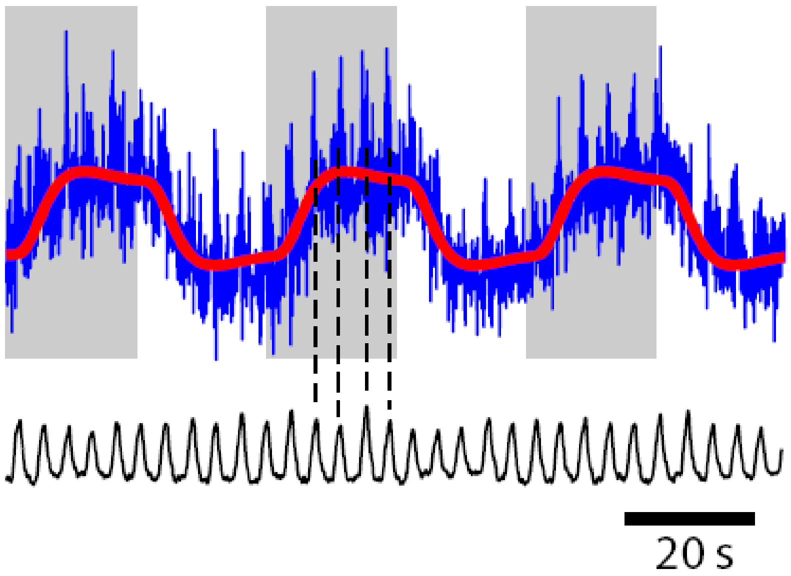


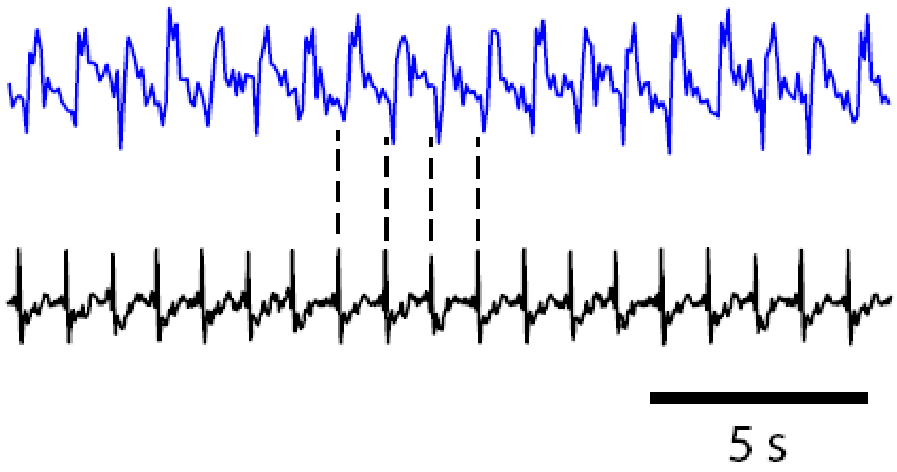
Improving temporal resolution

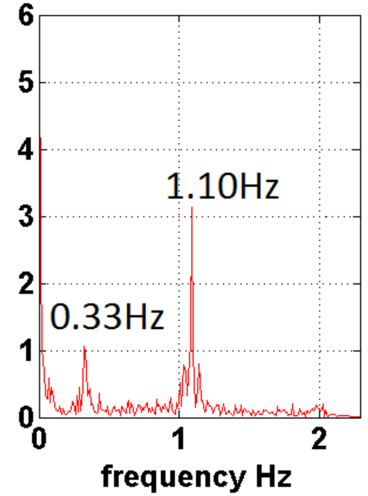
Fast fMRI



- Readout time: ~65ms
- 3D acquisition in ~ 100 ms (in contrast to 2-3 seconds in conventional EPI)
- Iterative image reconstruction with off-resonance correction
- Result: whole-brain data with some blurring, effective spatial resolution ≈ 4 mm)



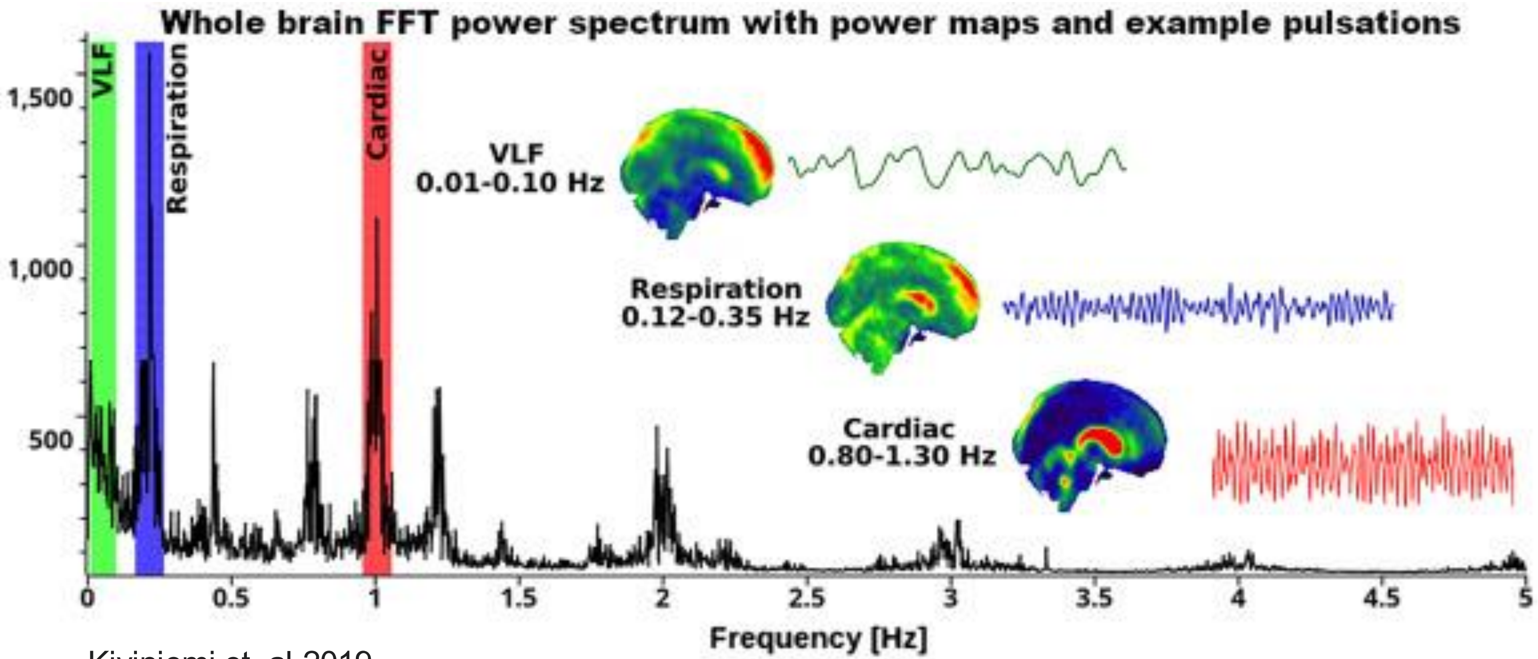




NIH National Institute of Mental Health

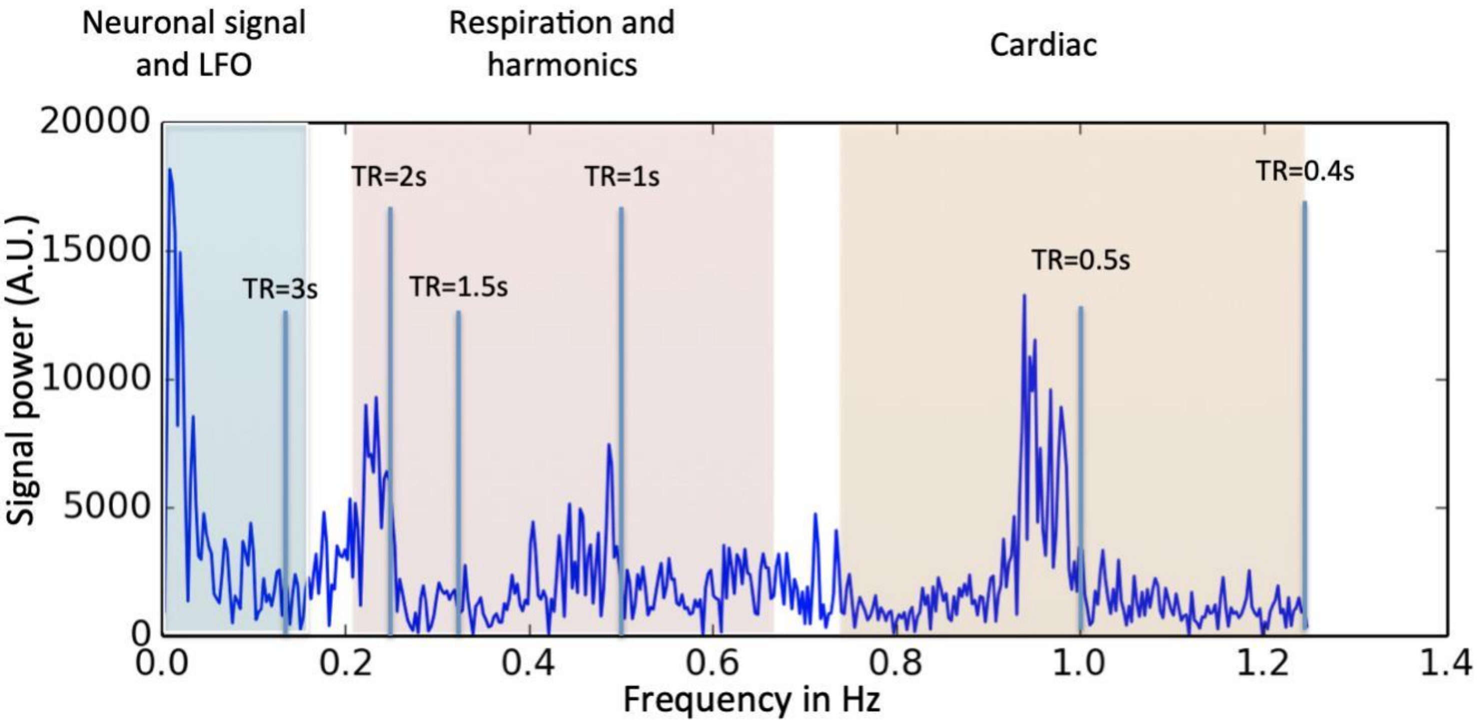
Improving temporal resolution

Fast fMRI

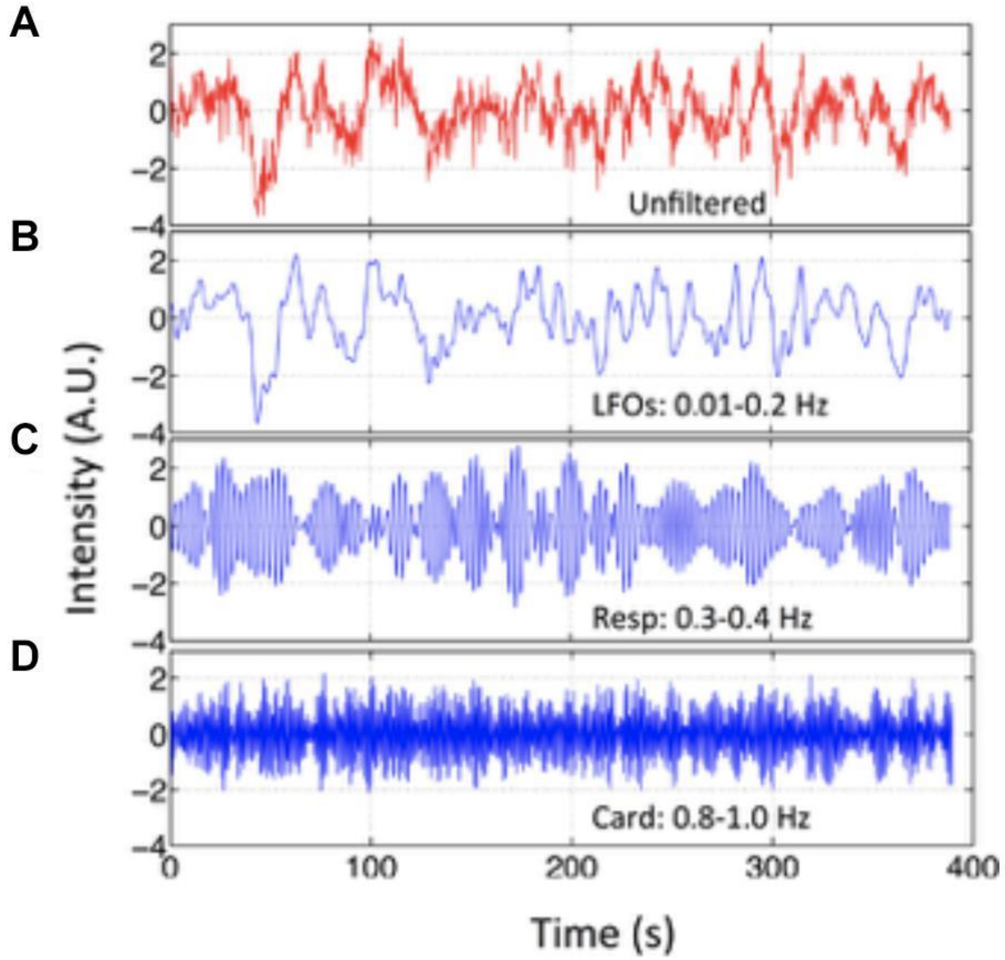


Kiviniemi et, al.2019

Improving temporal resolution
Fast fMRI

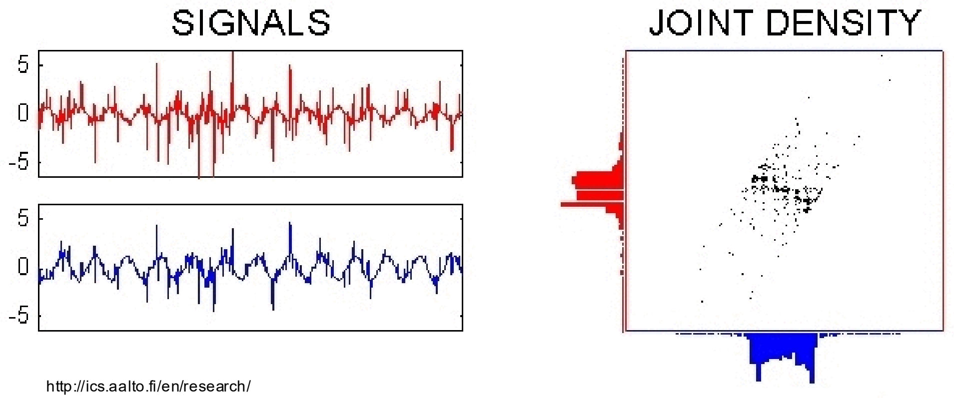


Tong et, al.2019

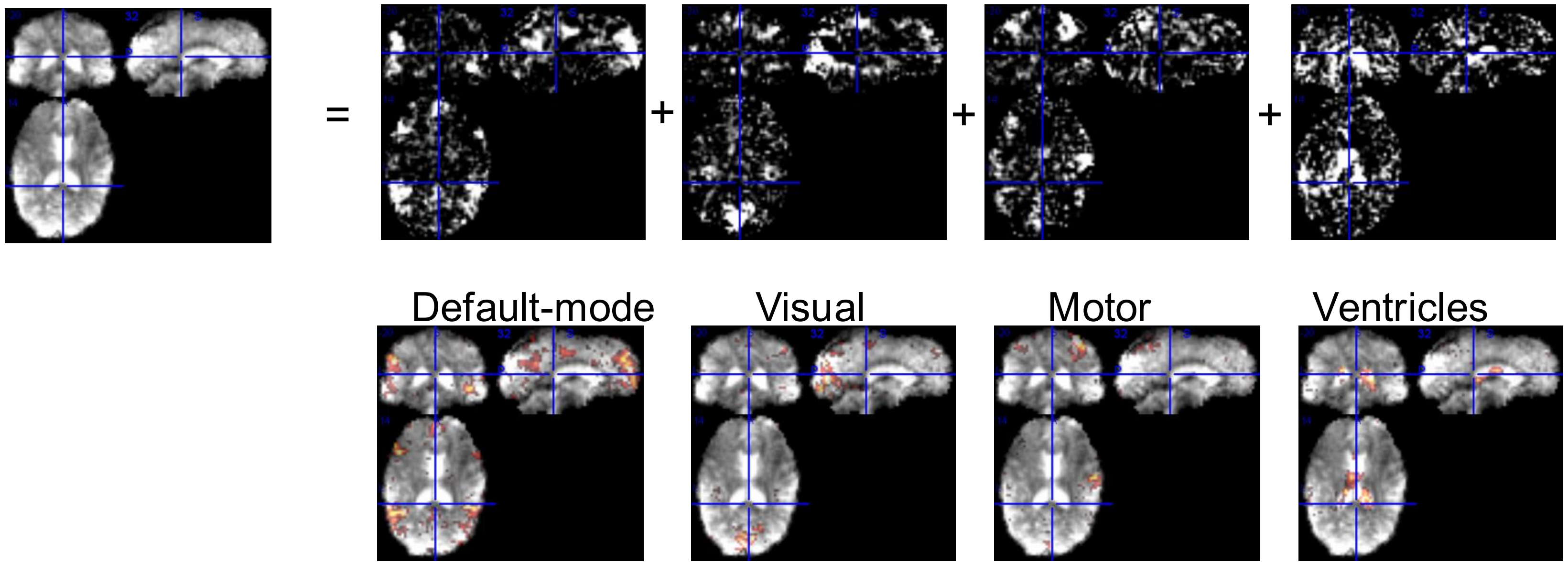


Independent Component Analysis

- ICA is the mathematical approach that performs this so-called “blind source separation”
- In fMRI: at each time point, we measure a mixture of unknown functional networks (as well as artifacts)
- Networks fluctuate and are thus mixed differently at each time point

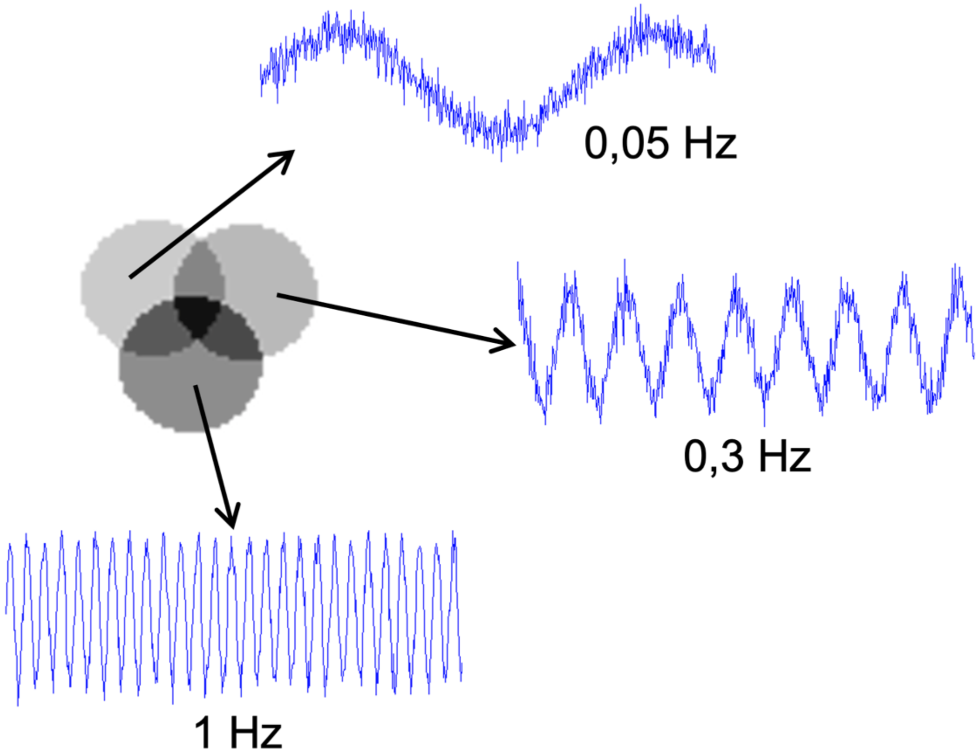


http://ics.aalto.fi/en/research/



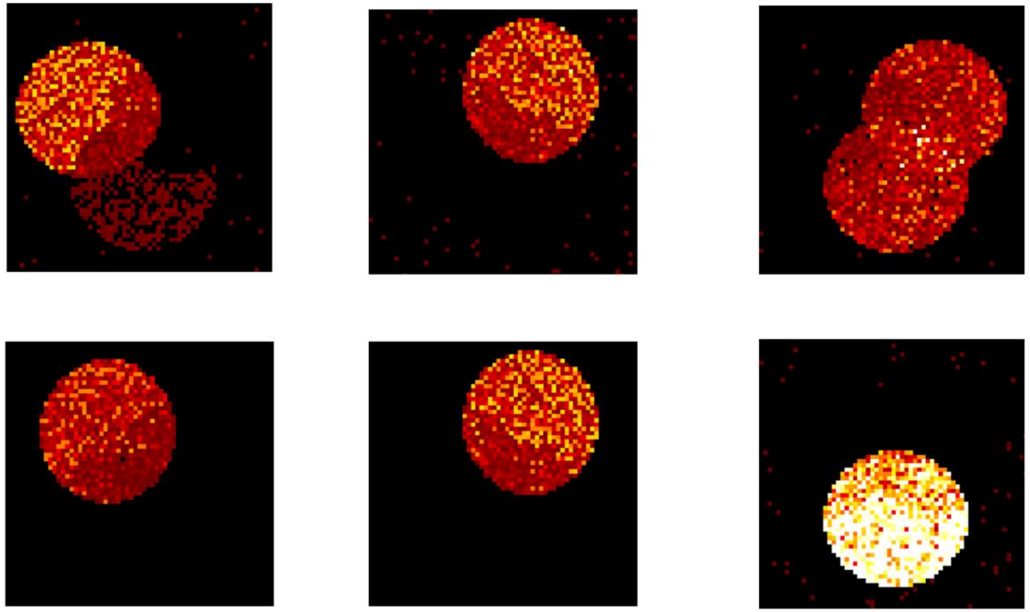
Improving temporal resolution

Fast fMRI



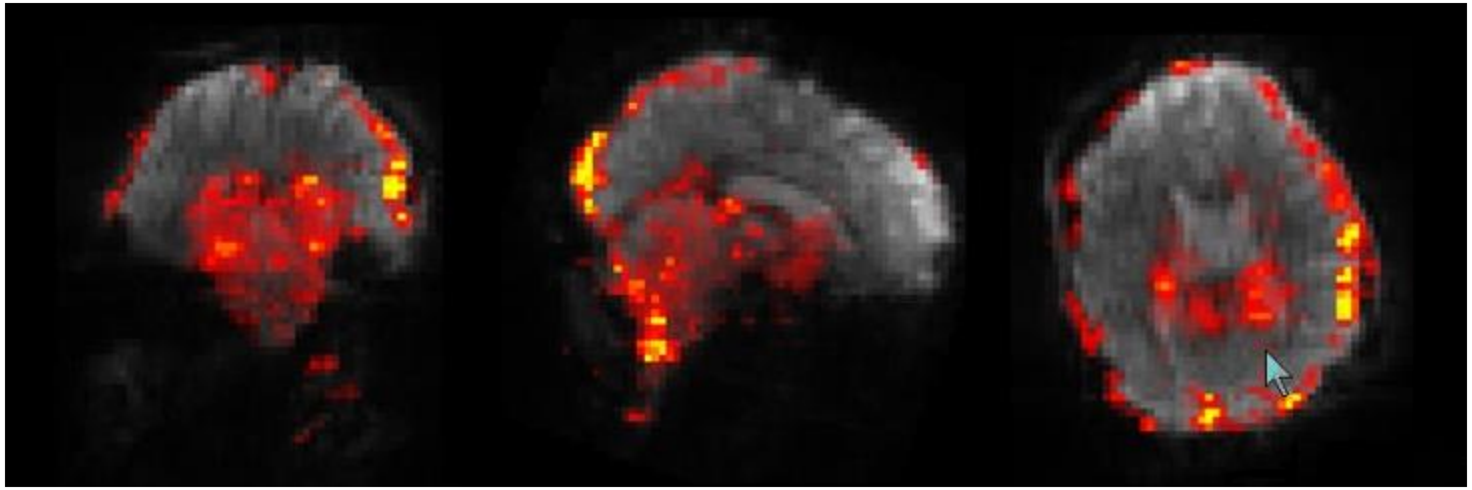
2 sec

0.1 sec

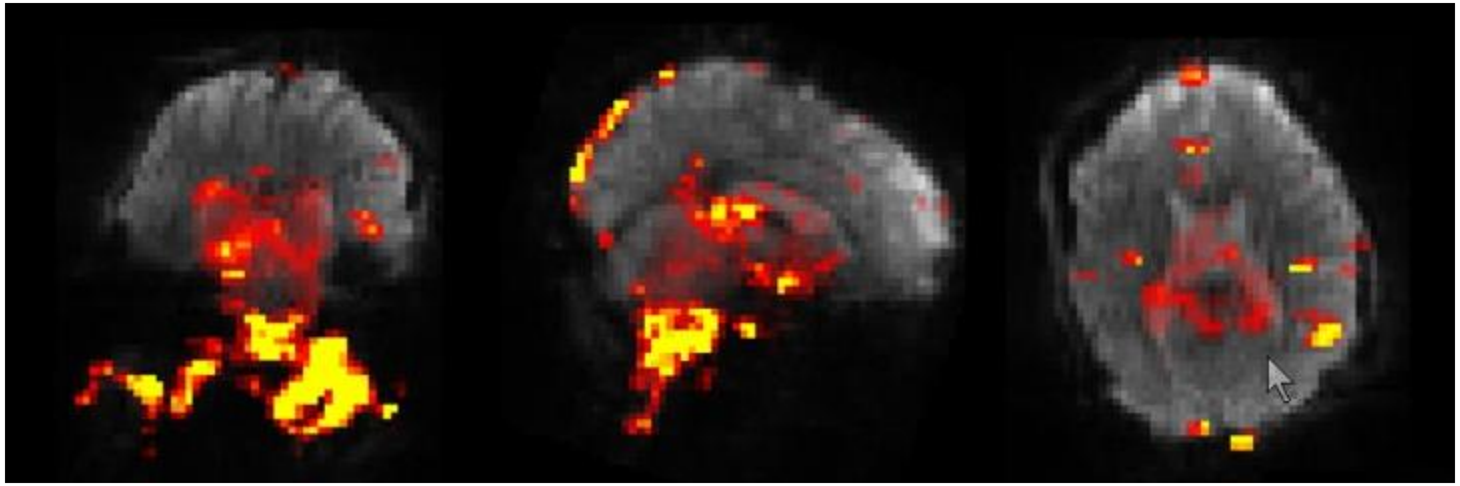


What are the characteristics of physiological signals ?

Respiratory 0.3 Hz



Cardiac 1.3 Hz



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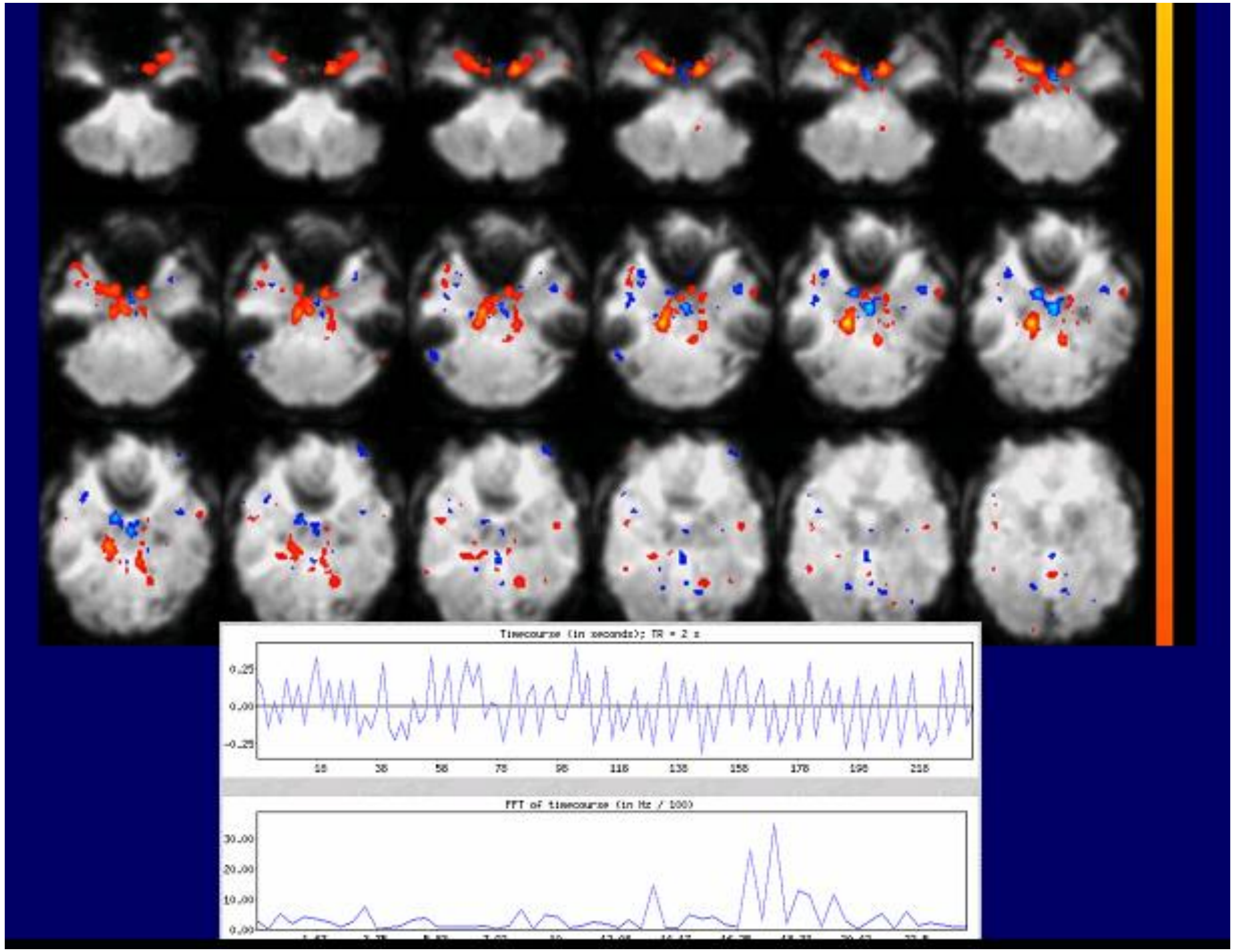
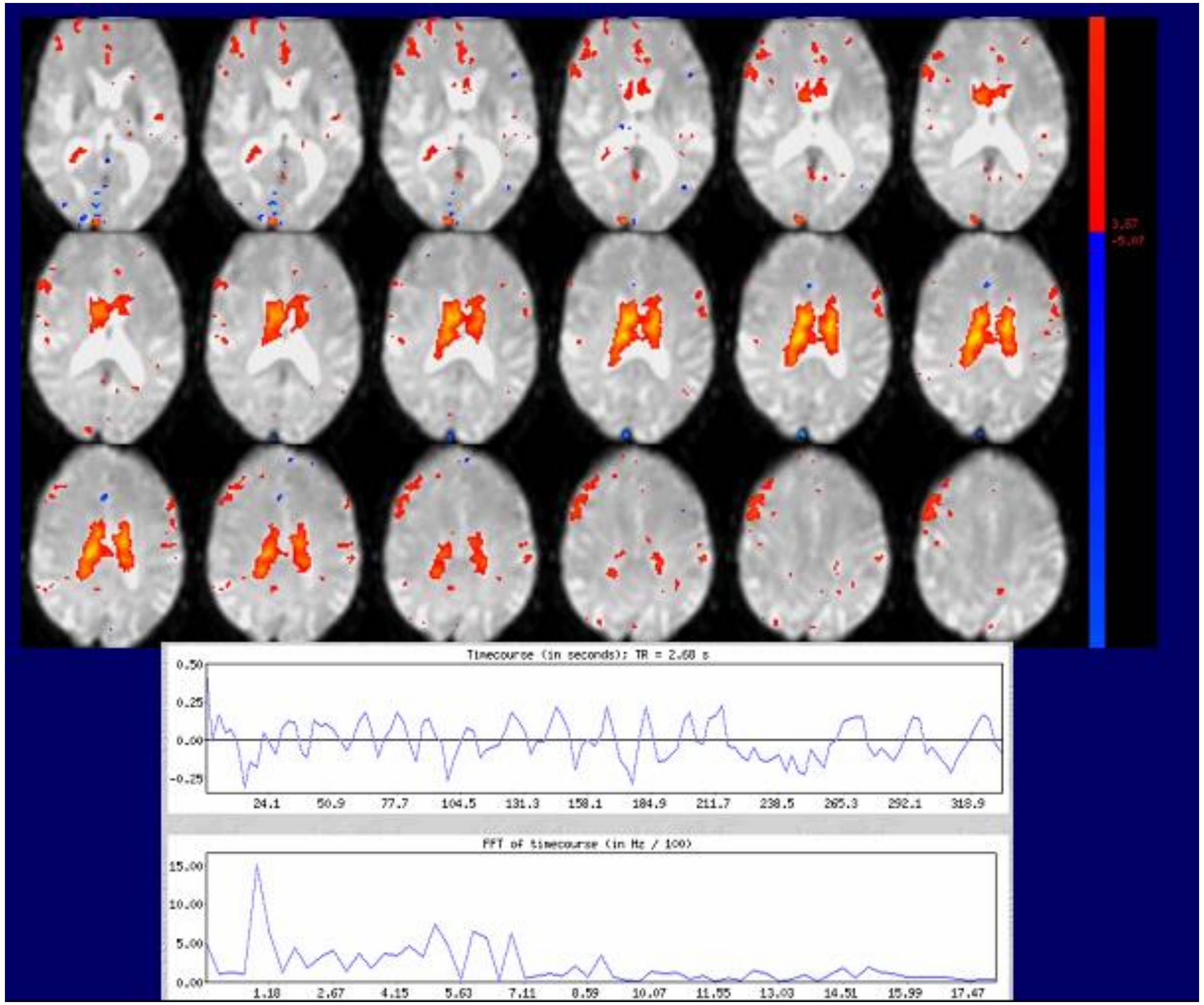
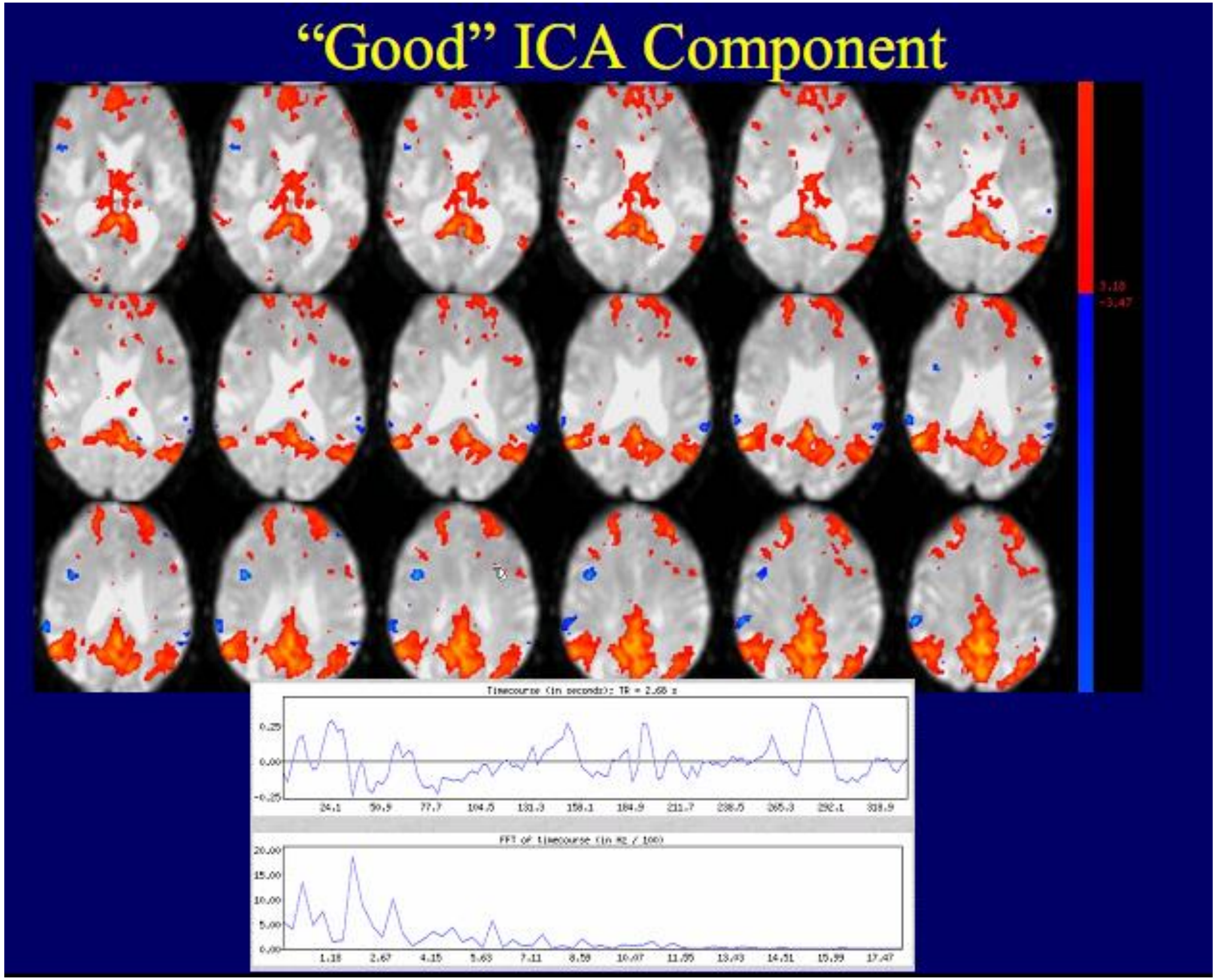
Bad components?

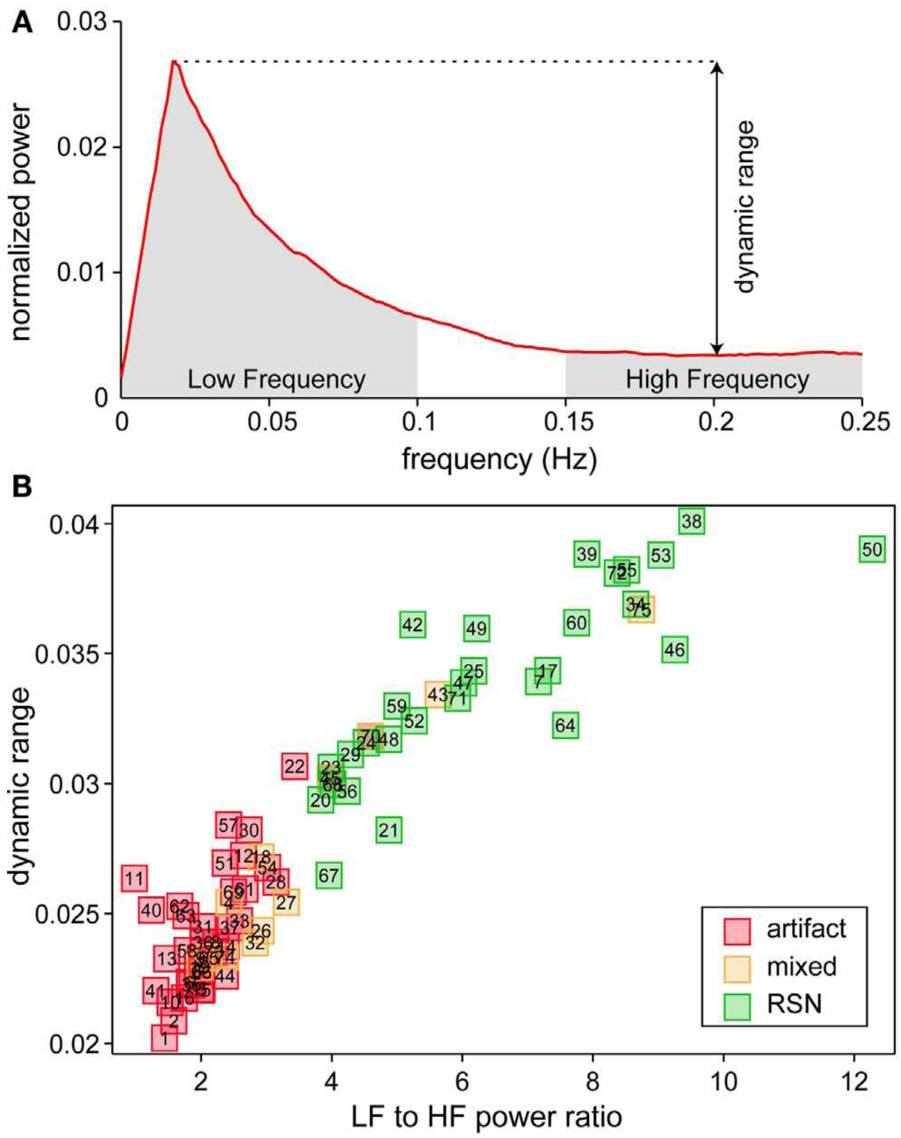




Good components?



How to "denoise" fMRI data?



fALFF

fractional amplitude of lowfrequency fluctuations

summing the oscillatory amplitudes across the typical 0.01-0.08 Hz range, then dividing by the amplitude sum across 0-0.25 Hz

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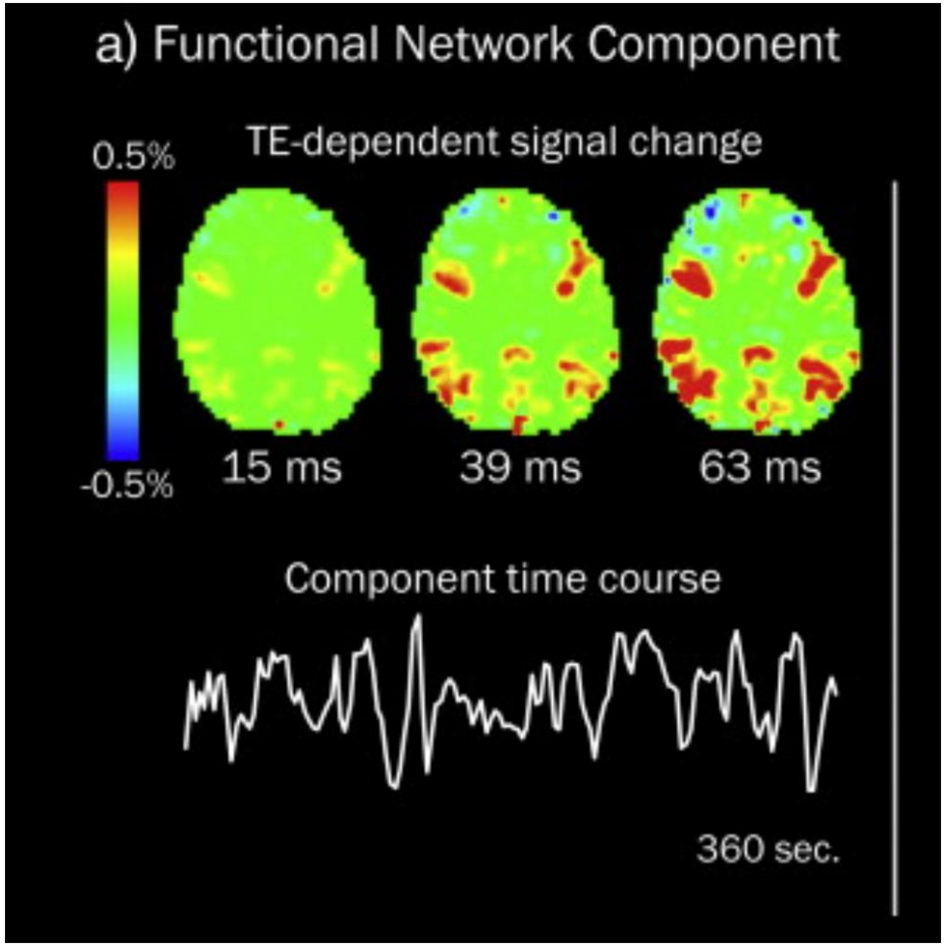
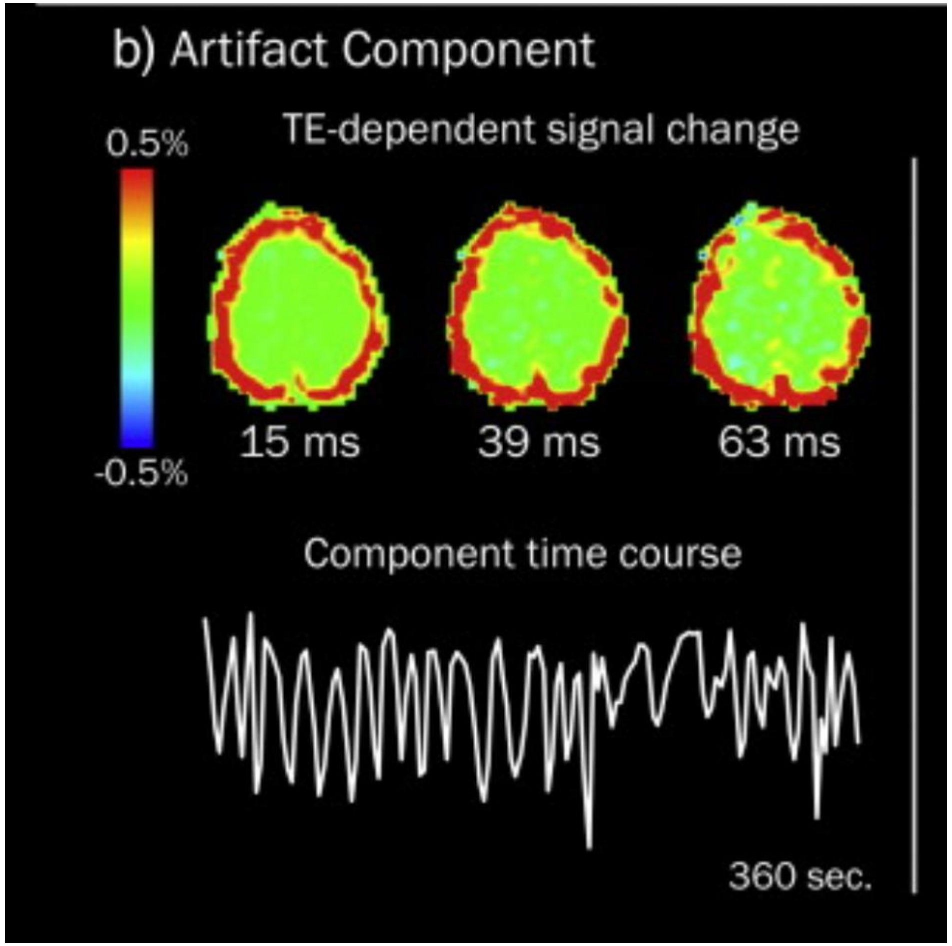
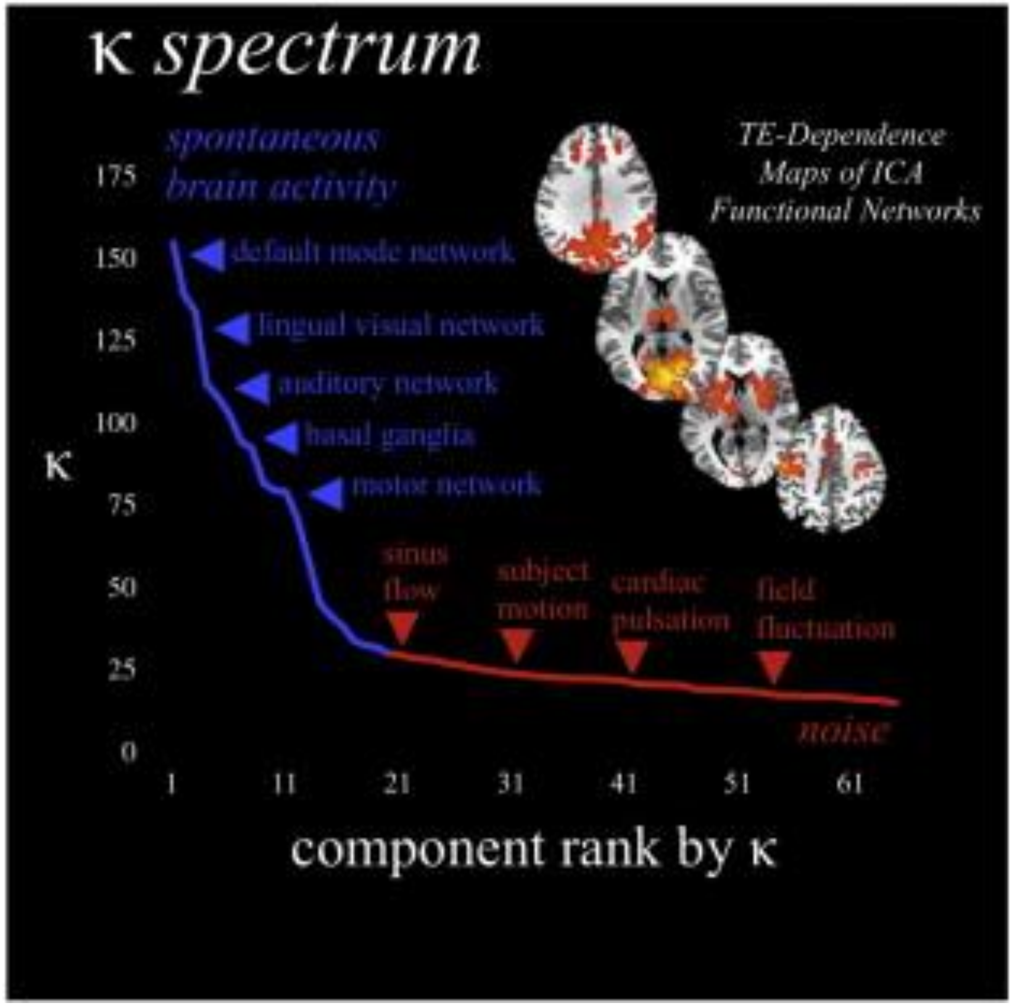
Multi-Echo EPI

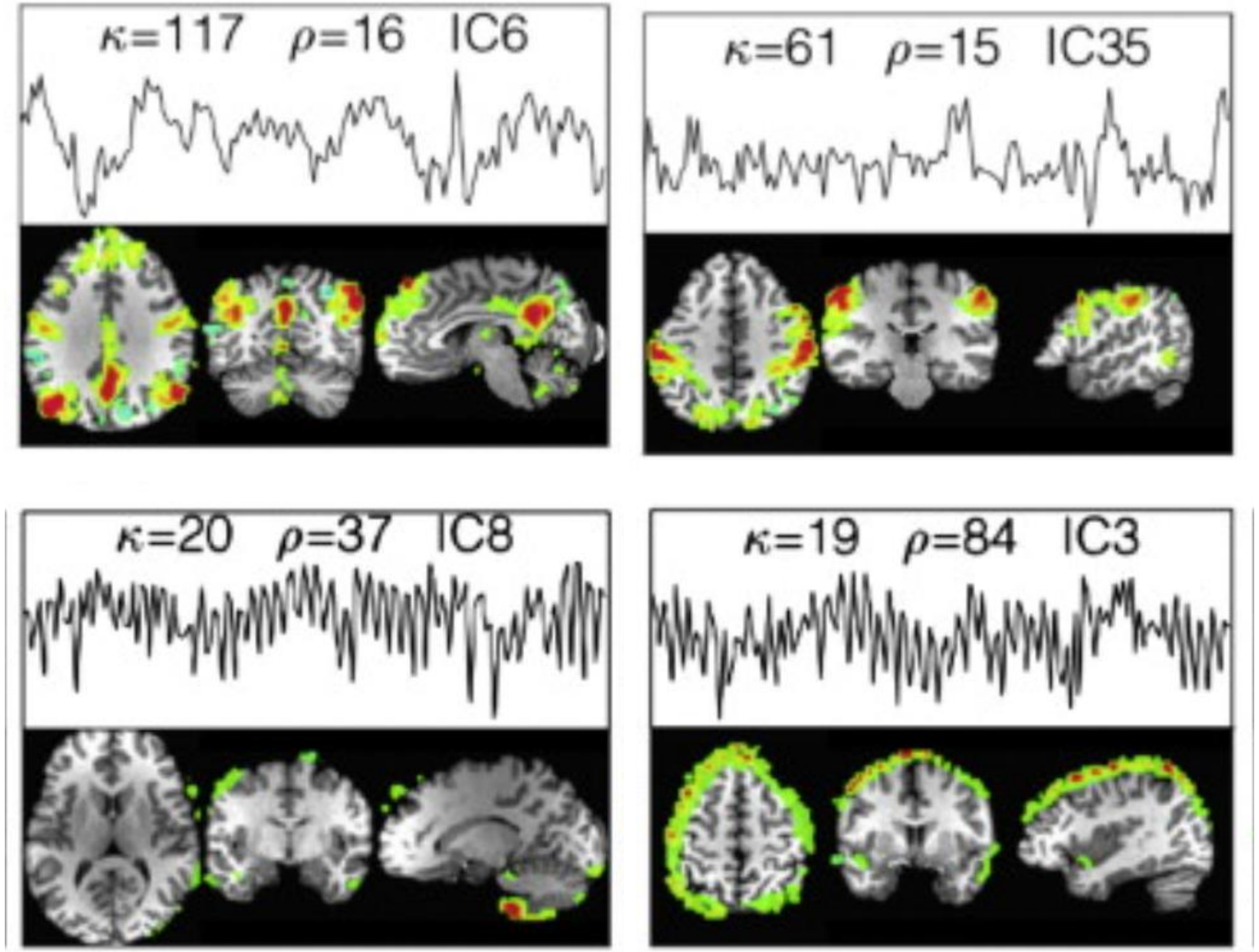




Kundu et, al.2012

Multi-Echo EPI





Kundu et, al.2012

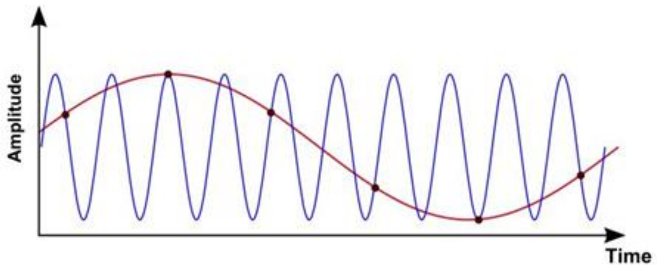
How to “remove” physiological pulsations

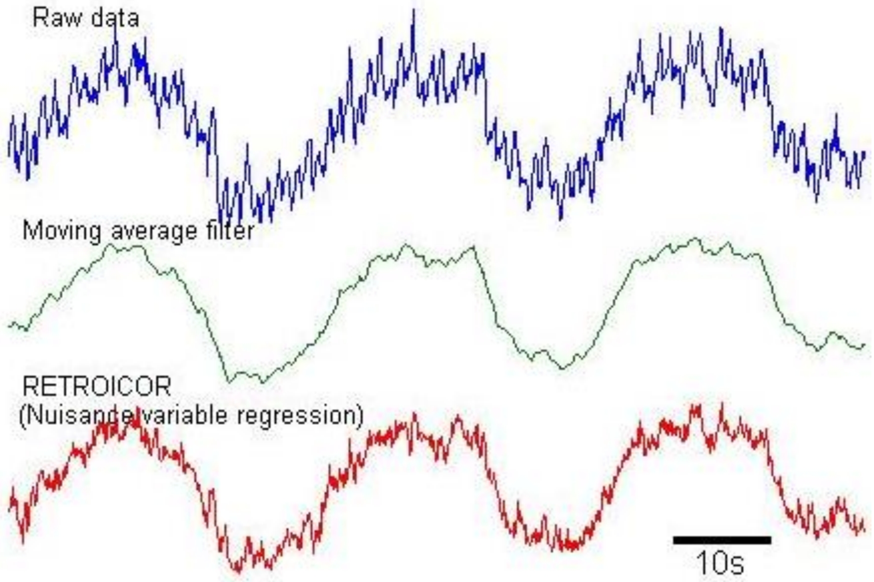
Moving average filter (Lin et al., 2011; Posse et al., 2012)

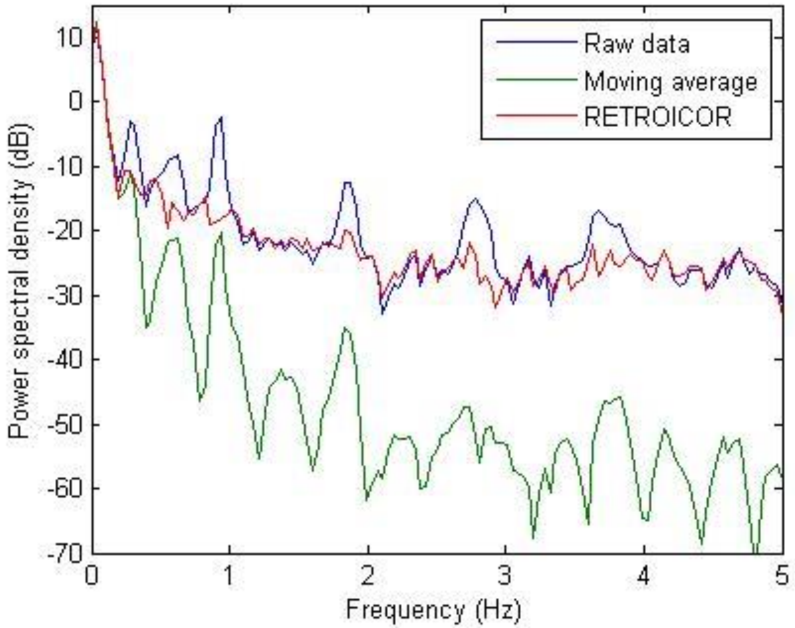
- Removes high frequencies and affects noise properties

Artefact modeling (Glover et al., 2000; Lund et al., 2006)

- Model noise as high-order autoregressive process







Regression

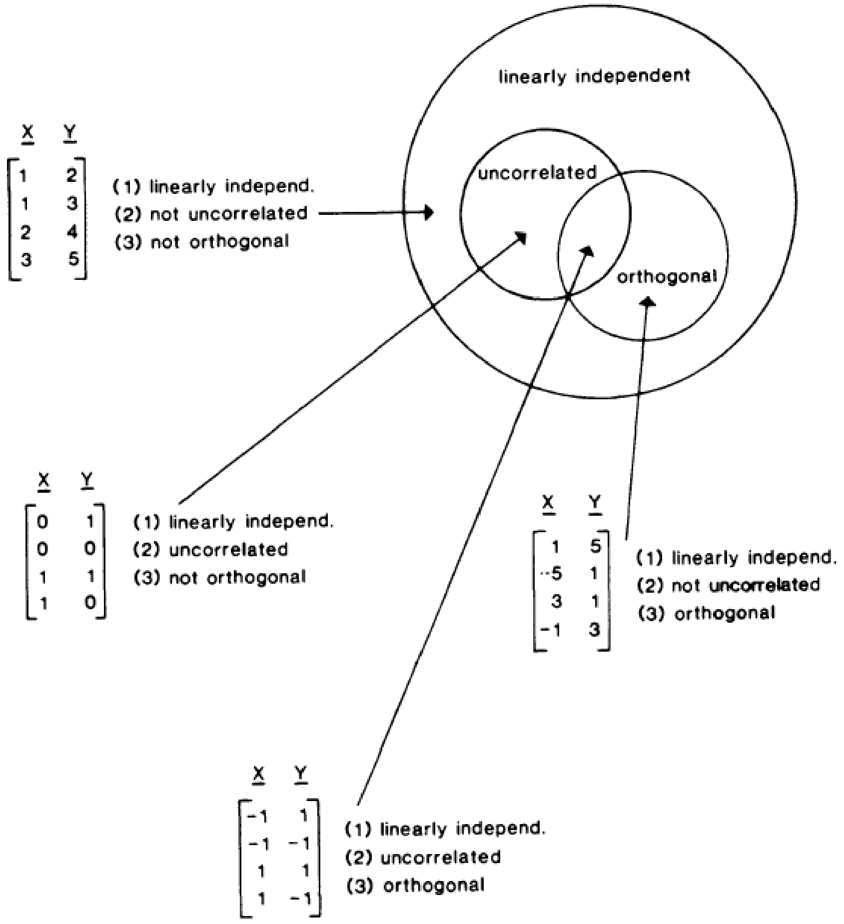
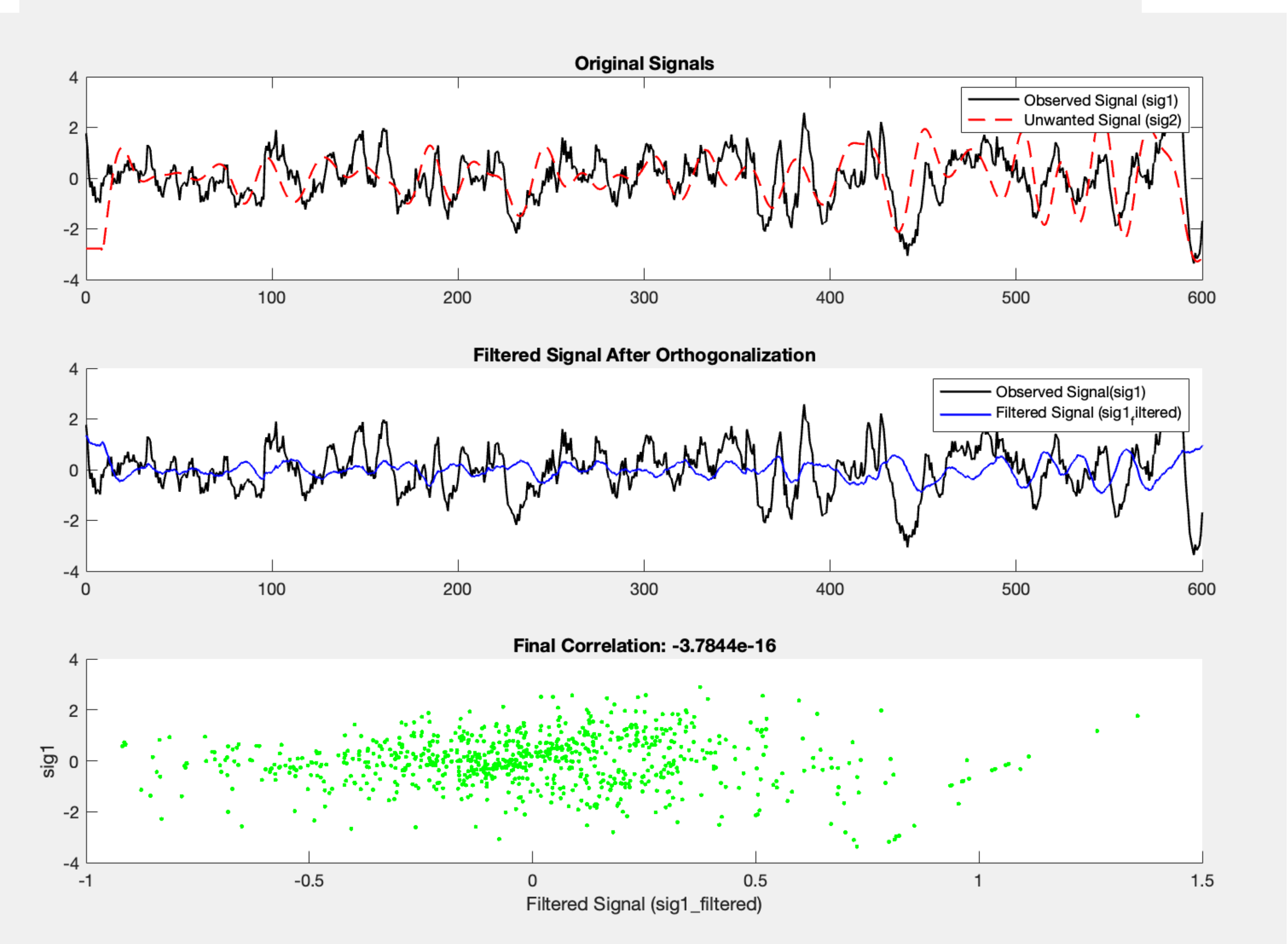
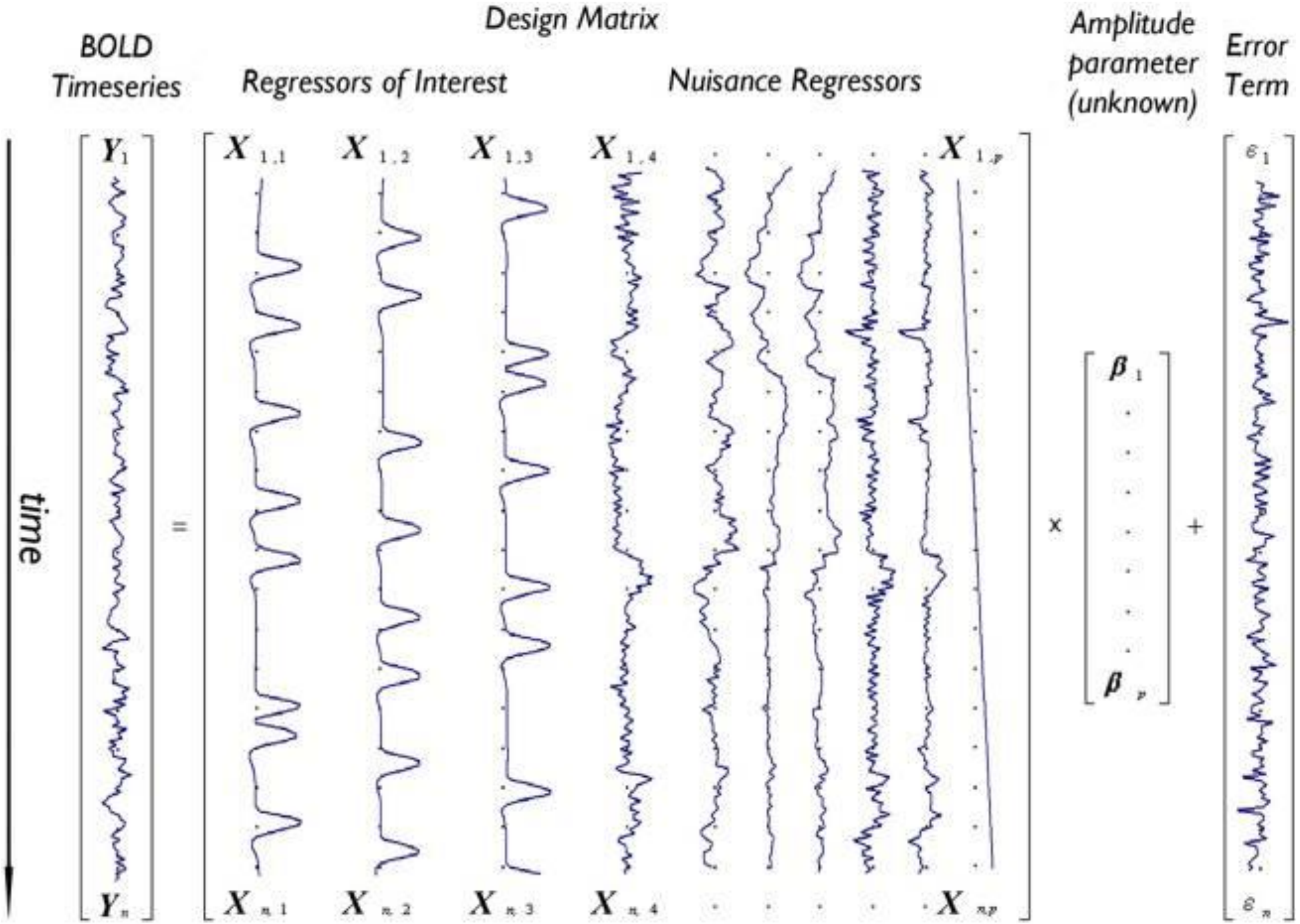


Figure 1. The relationship between linearly independent, orthogonal, and uncorrelated variables.



Regression



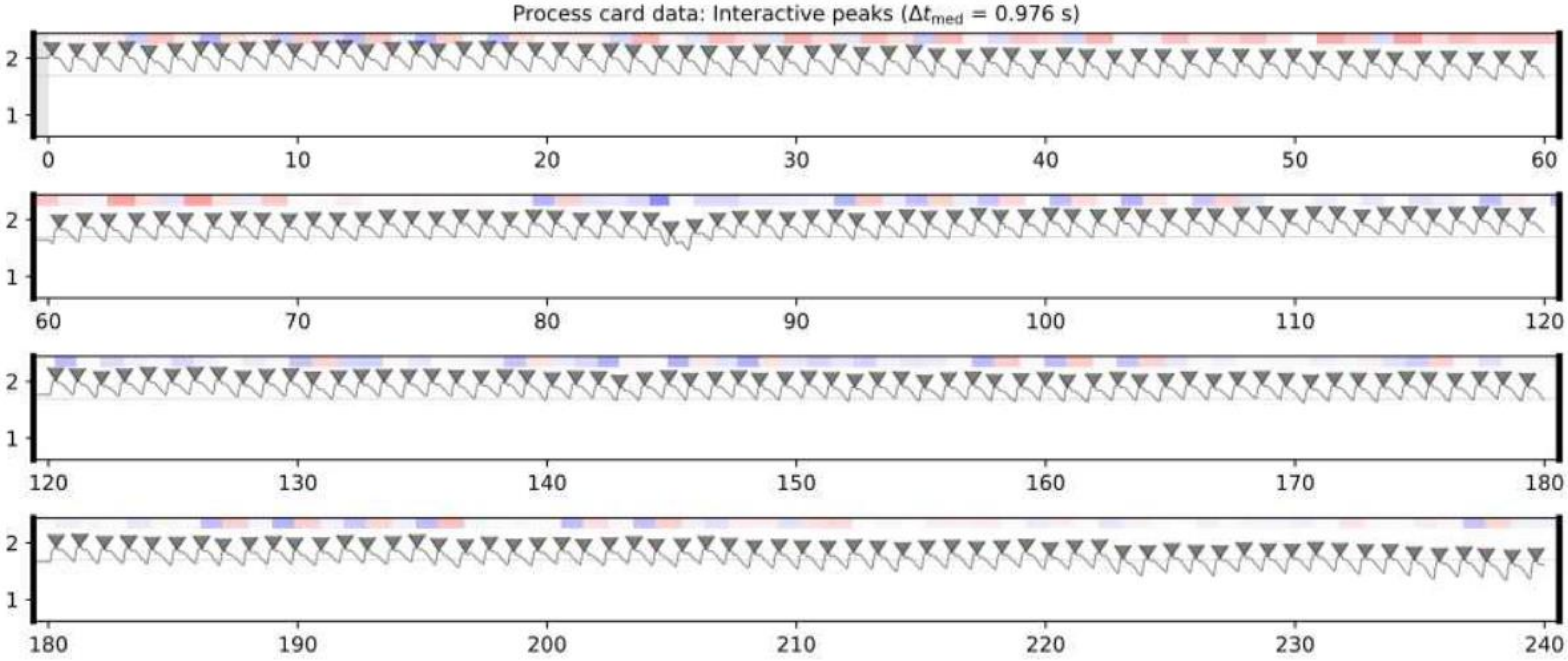
Design Matrix
BOLD Timeseries
Regressors of Interest
Nuisance Regressors
Amplitude parameter (unknown)
Error Term
time
Y_1
Y_n
$X_{1,1}$ $X_{1,2}$ $X_{1,3}$ $X_{1,4}$ $X_{1,p}$
$X_{n,1}$ $X_{n,2}$ $X_{n,3}$ $X_{n,4}$ $X_{n,p}$
β_1
β_p
ε_1
ε_n
=
x
+

AFNI physio_calc.py

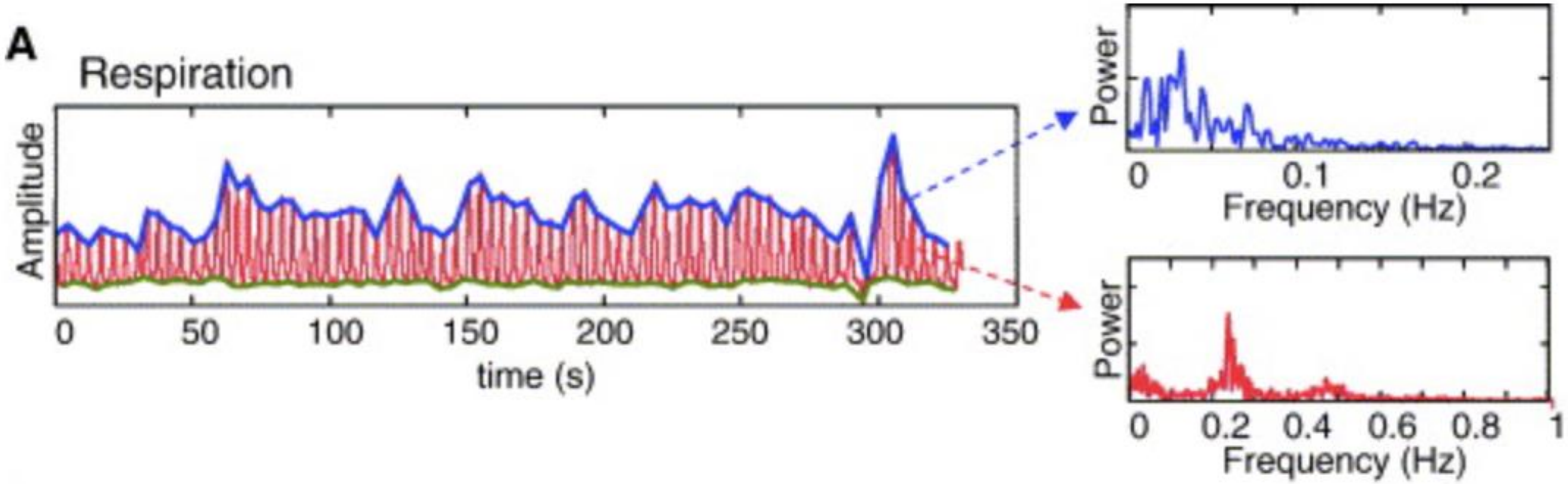
```
physio_calc.py                                                        \
       -card_file          sub-001_ses-01_task-rest_run-1_physio-ECG.txt   \
       -resp_file          sub-001_ses-01_task-rest_run-1_physio-Resp.txt  \
       -freq               500                                              \
       -dset_tr            0.1                                              \
       -dset_nt            219                                              \
       -dset_nslice        33                                               \
```

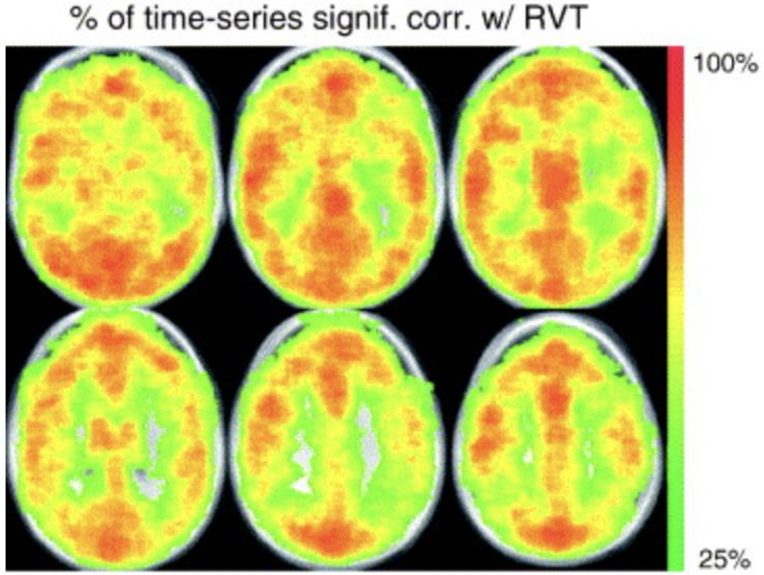
```
afni_proc.py -subj_id bp10 \
             -blocks tcat despike tshift align tlrc volreg mask scale regress \
             -radial_correlate_blocks tcat volreg \
             -copy_anat /data/akinb2/allbp/bp10/anat/anatSS.bp10.nii \
             -anat_has_skull no \
             -anat_follower_ROI aaseg  anat /data/akinb2/allbp/fsurfs/bp10/SUMA/aparc.a2009s+aseg.nii.gz \
             -anat_follower_ROI aeseg  epi  /data/akinb2/allbp/fsurfs/bp10/SUMA/aparc.a2009s+aseg.nii.gz \
             -tcat_remove_first_trs 0                                                              \
             -dsets /data/akinb2/allbp/bp10/rest.nii \
```

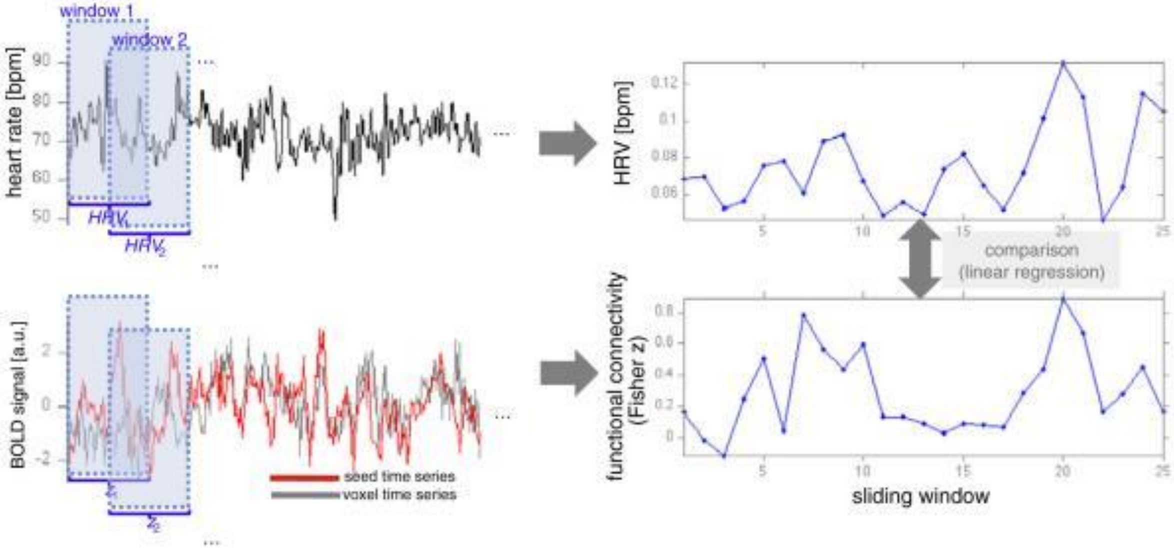
Finger pulsation- peak detection



Indirect modulation







Neuroimage. 2020 Aug 15:217:116907. doi: 10.1016/j.neuroimage.2020.116907. Epub 2020 May 6.

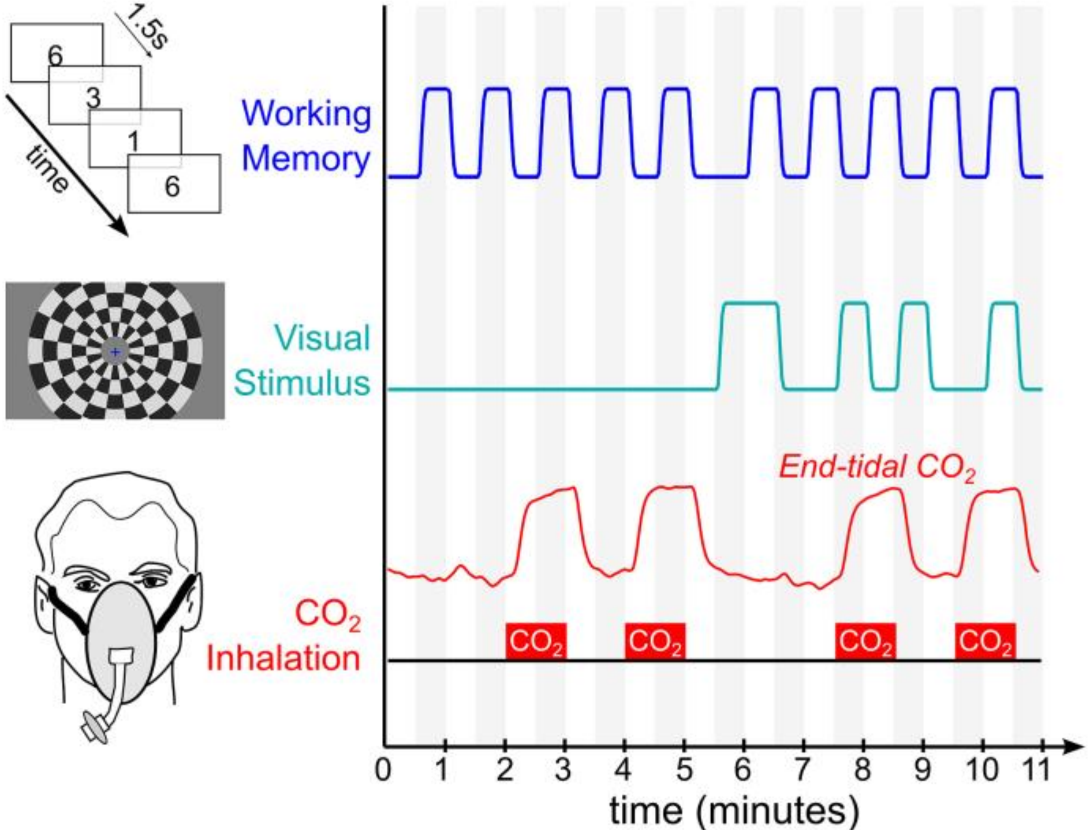
Vascular physiology drives functional brain networks

Molly G Bright [1], Joseph R Whittaker [2], Ian D Driver [3], Kevin Murphy [2]

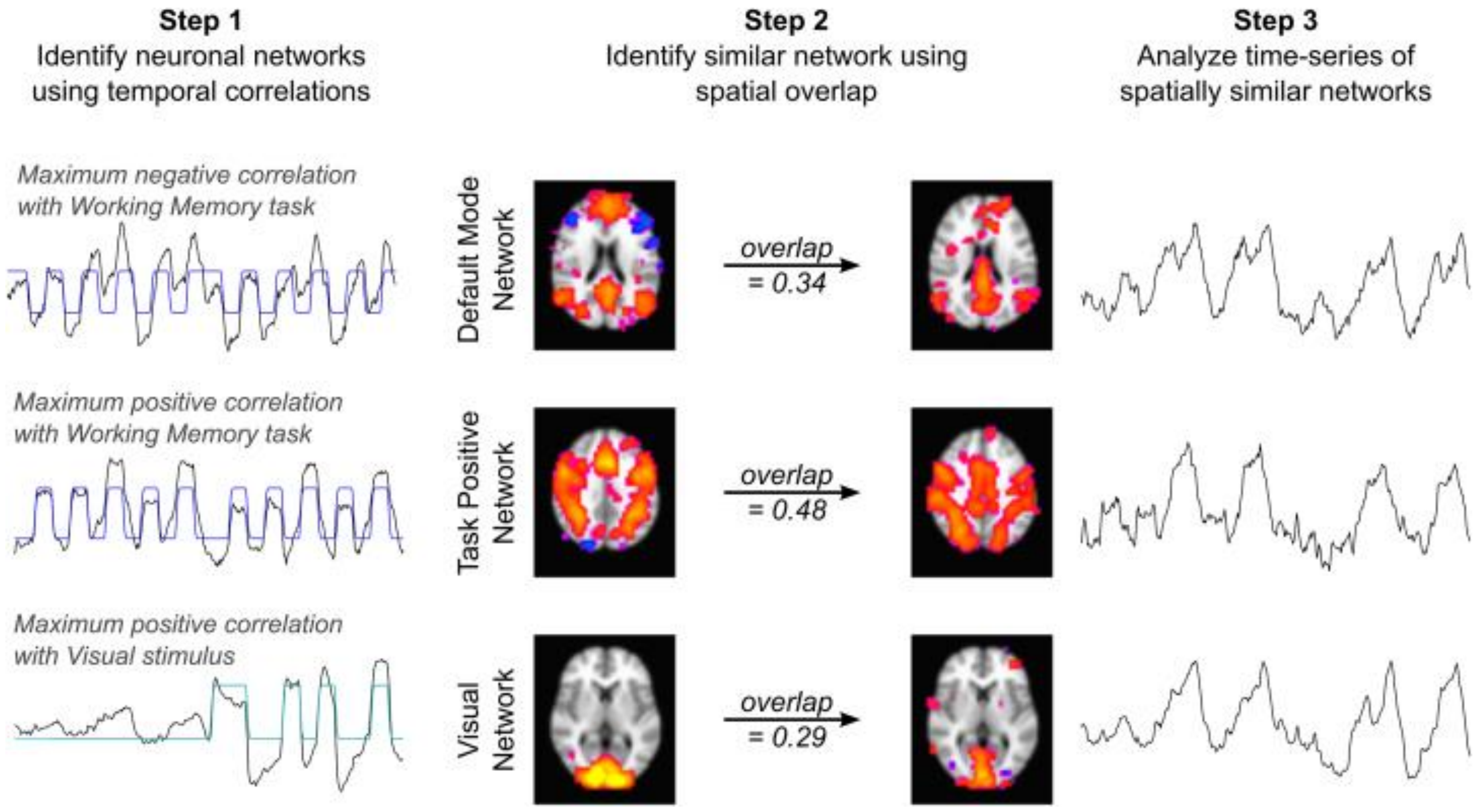
Affiliations + expand

PMID: 32387624 PMCID: PMC7339138 DOI: 10.1016/j.neuroimage.2020.116907

Designing an experiment with distinct tasks



Designing an experiment with distinct tasks



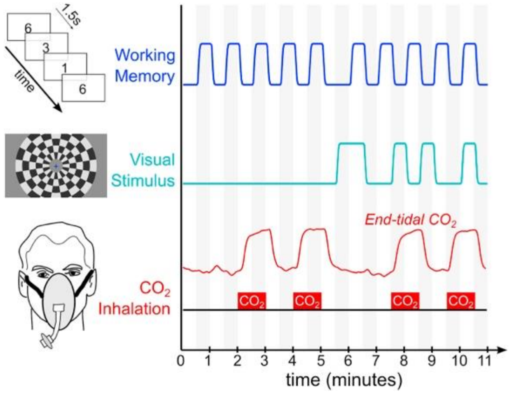


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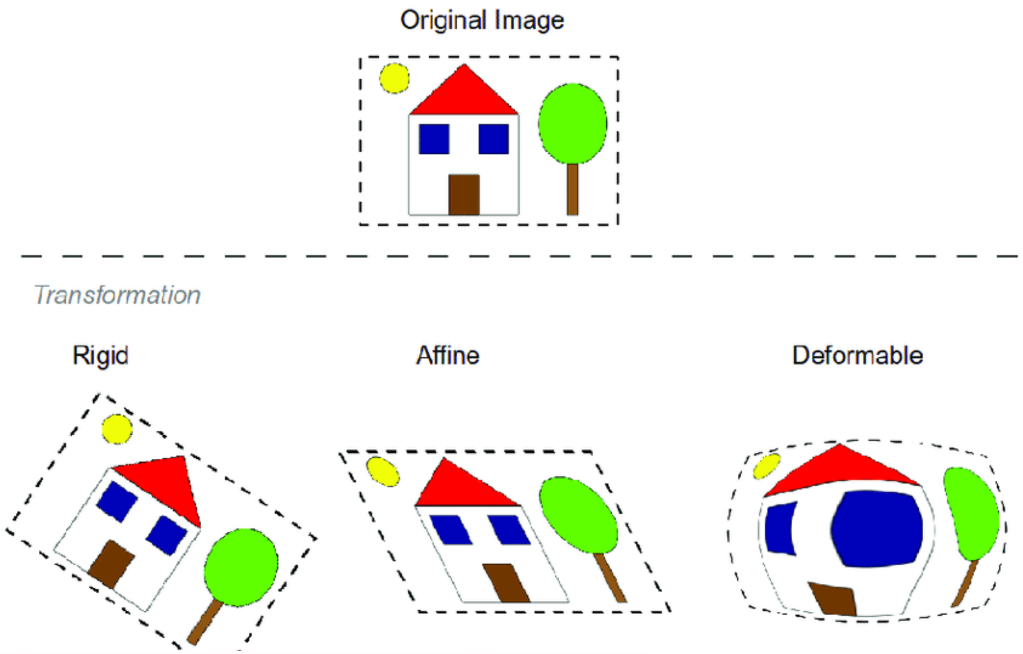
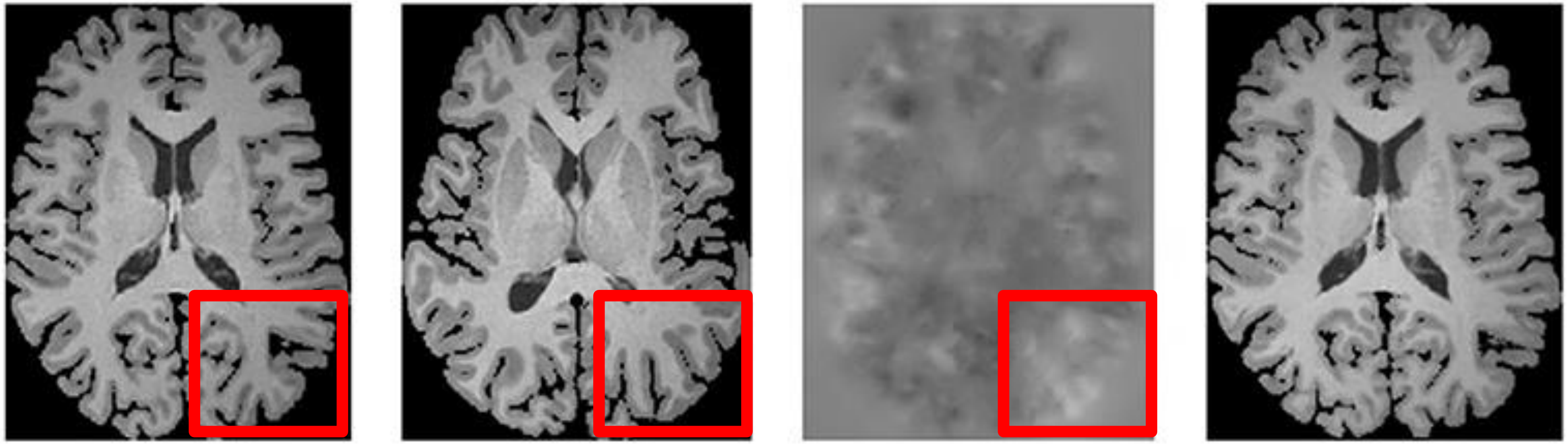
Image registration



Non-linear registration



Fixed Moving Deformation Warped

```
antsRegistration \
  --dimensionality 3 \
  --float 1 \
  --collapse-output-transforms 1 \
  --output [ "${OUTDIR}/warps/vol_${v}_", "$OUTWARP", 0 ] \
  --interpolation Linear \
  --winsorize-image-intensities [0.01,0.99] \
  --use-histogram-matching 0 \
  --initial-moving-transform [ "$REF", "$MOV", 1 ] \
  --transform SyN[0.03,2,0] \
  --metric CC["$REF","$MOV",1,2] \
  --convergence [10x5,1e-5,5] \
  --shrink-factors 2x2 \
  --smoothing-sigmas 1x1vox
```

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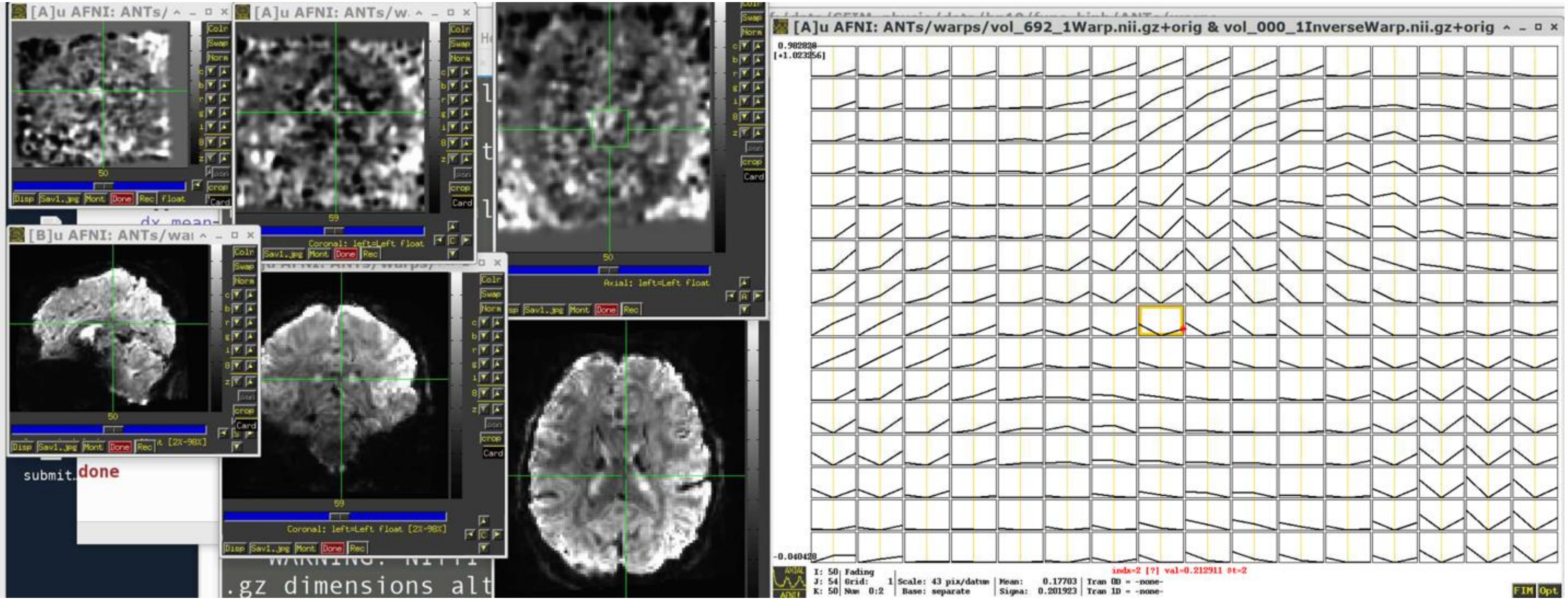
Image registration (T2* fMRI images)



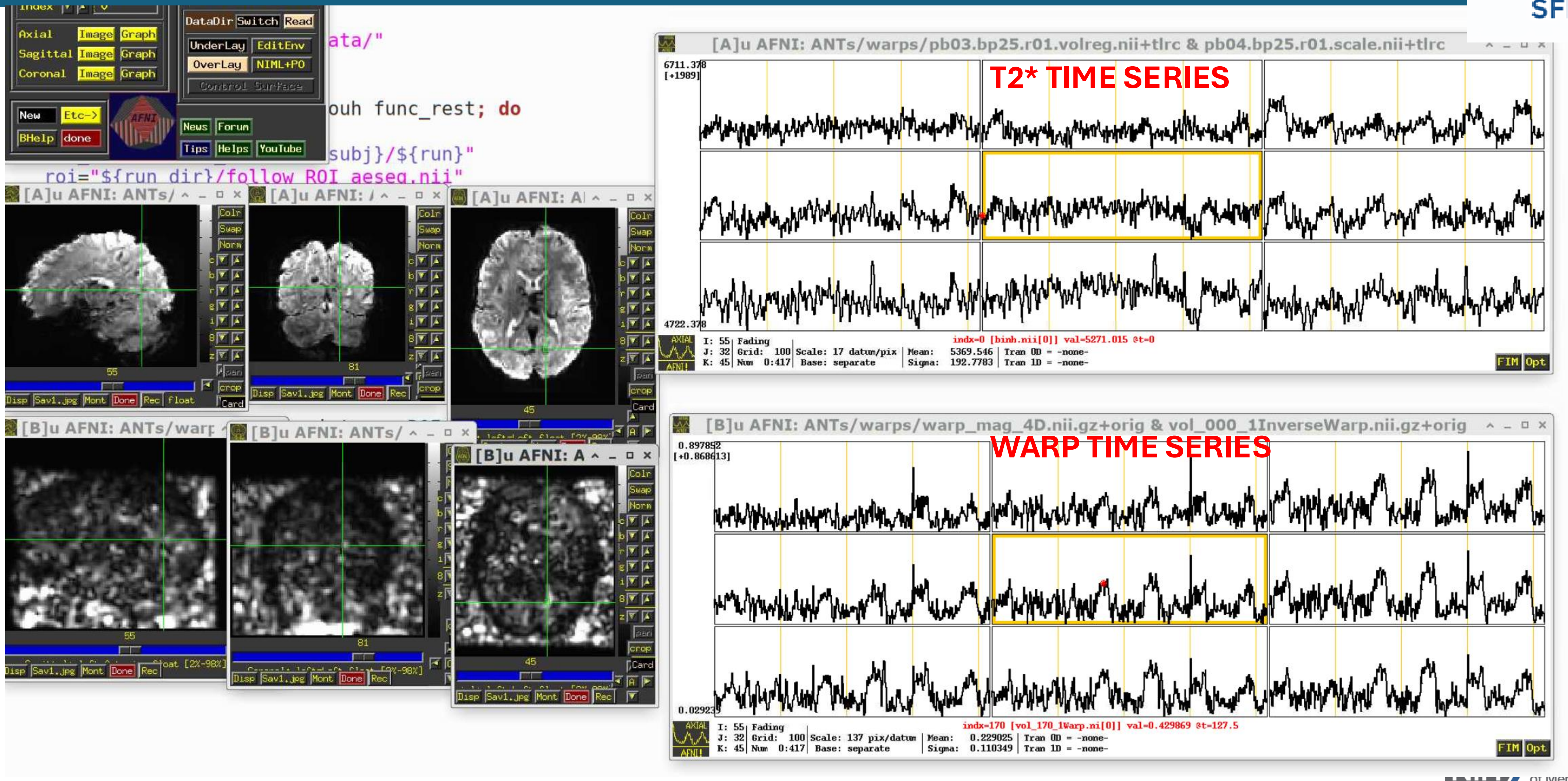
$$\text{Magnitude} = \sqrt{dx^2 + dy^2 + dz^2}$$

$$\theta = \arccos\left(\frac{dz}{\sqrt{dx^2 + dy^2 + dz^2}}\right)$$

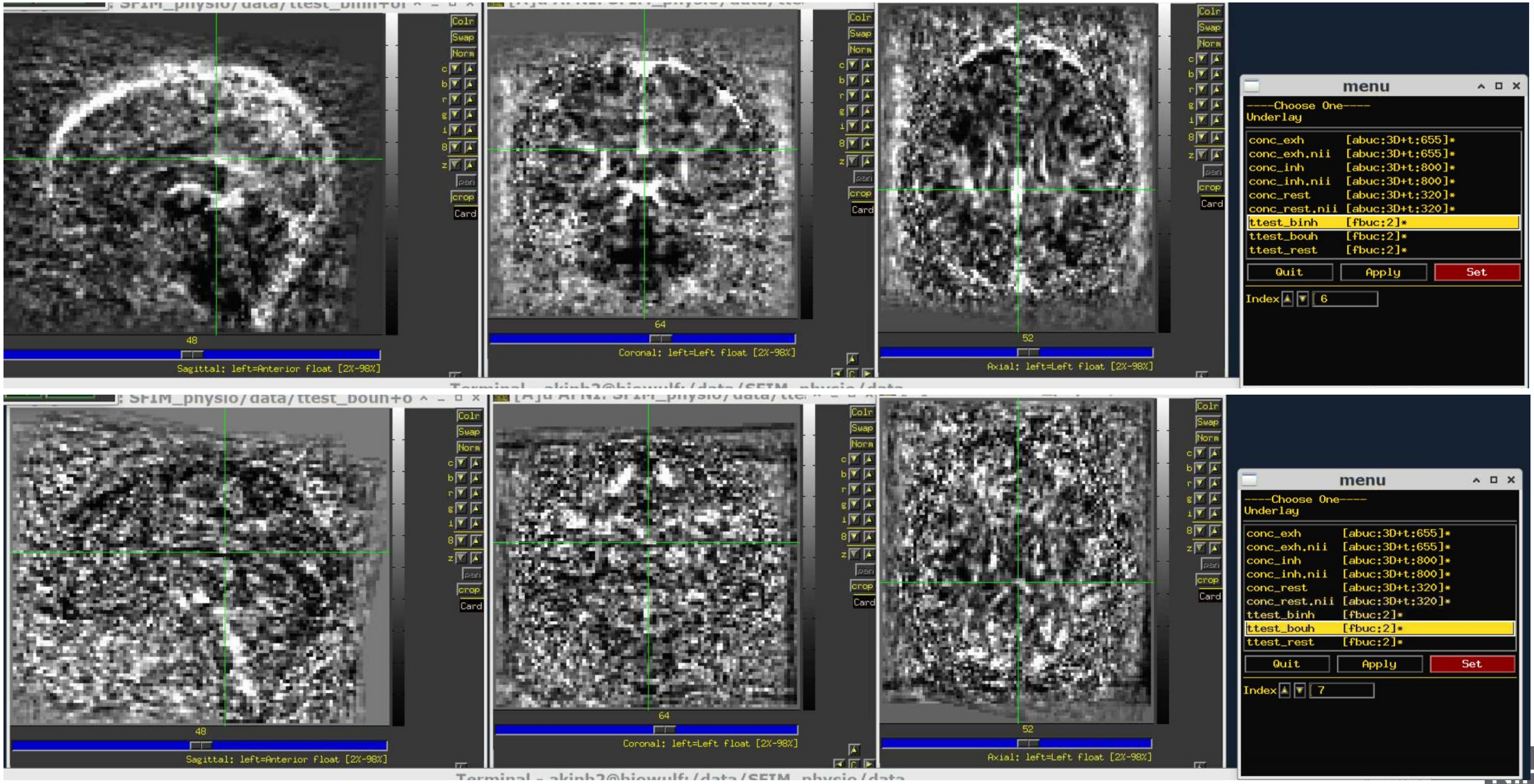
SFIM

NIH National Institute of Mental Health

Warp time series



Group level concordance



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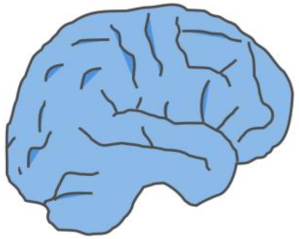
Some take home messages

- Always look at your data
- Always acquire physiology
- Physiology might be both noise or signal
- Design a task paradigm that helps to disentangle sources of signals
- Design a processing pipeline that helps to delineate the task related activity

Thanks to colleagues...



Any questions ?