Donders Institute
for Brain, Cognition and Behaviour

FAM DCCN, January 8, 2015

Principles and implementation of physiological noise correction using RETROICOR

Thanks to Bas Neggers, Matthijs Vink, Mariët van Buuren (UMC Utrecht)

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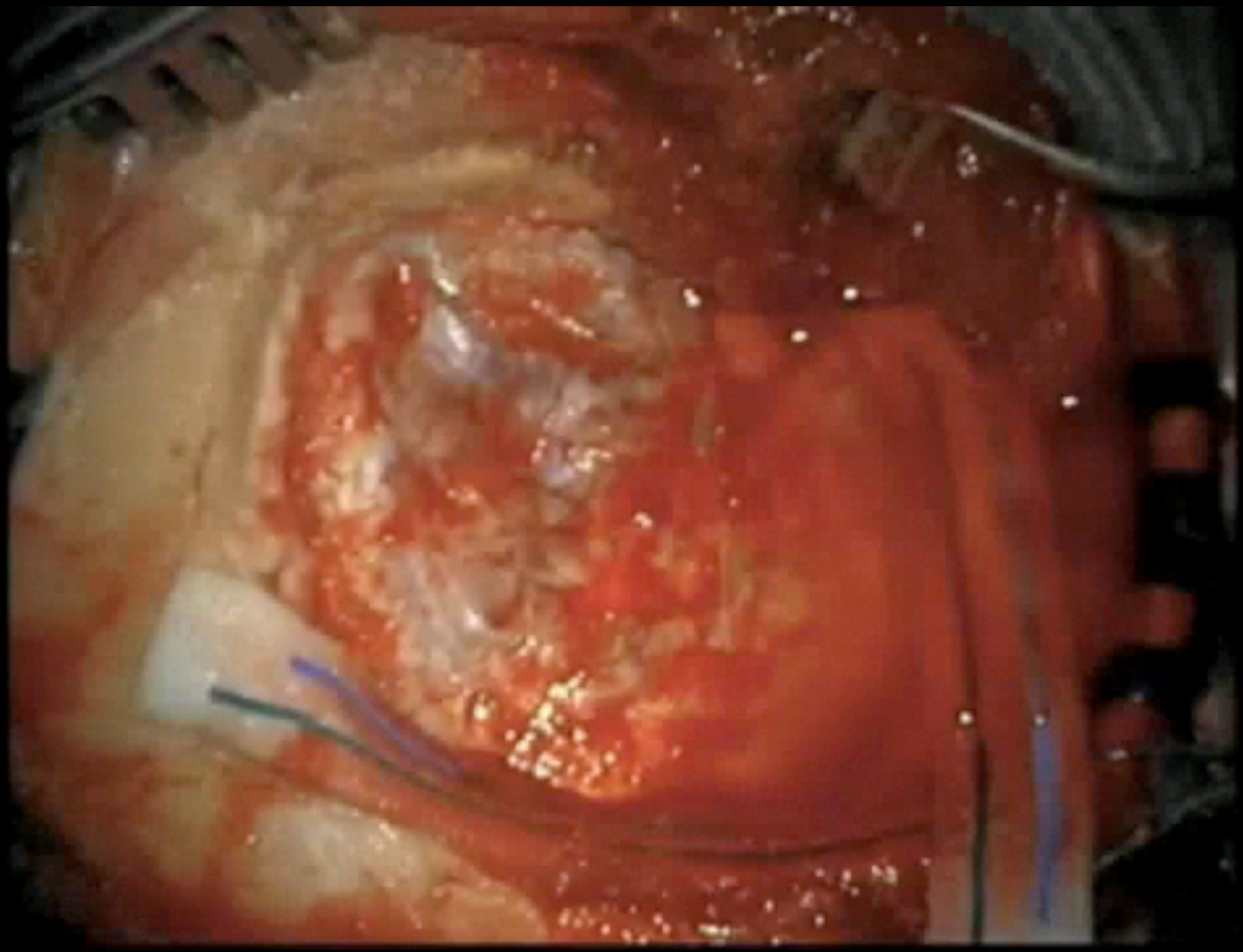
Radboudumc
university medical center

Overview

- Principles of RETROICOR

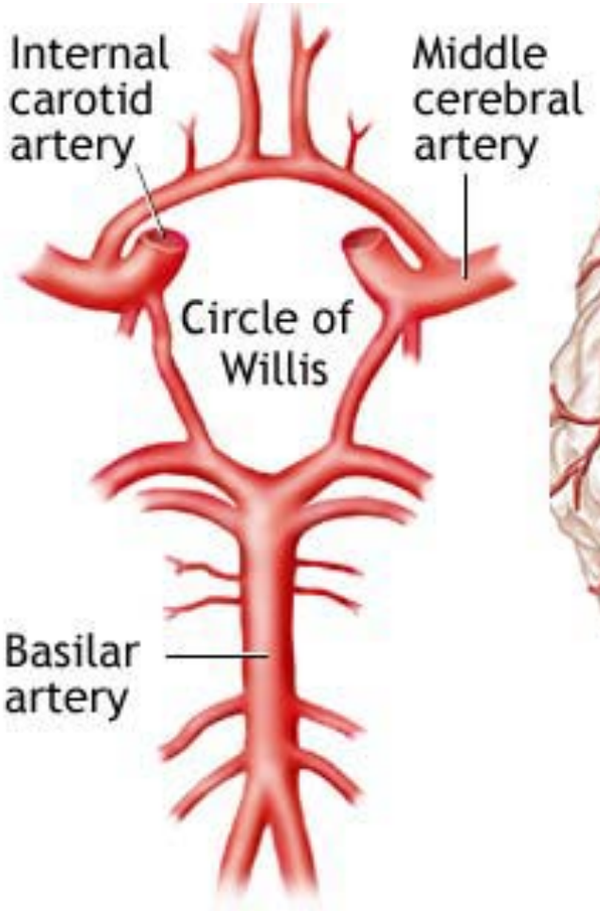
- Implementation using DCCN equipment

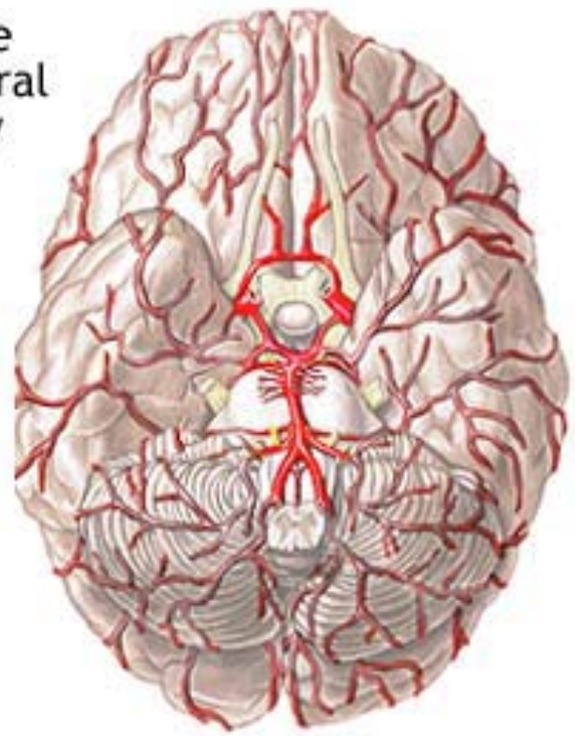
- Discussion



Physiological pulsations: Cardiac

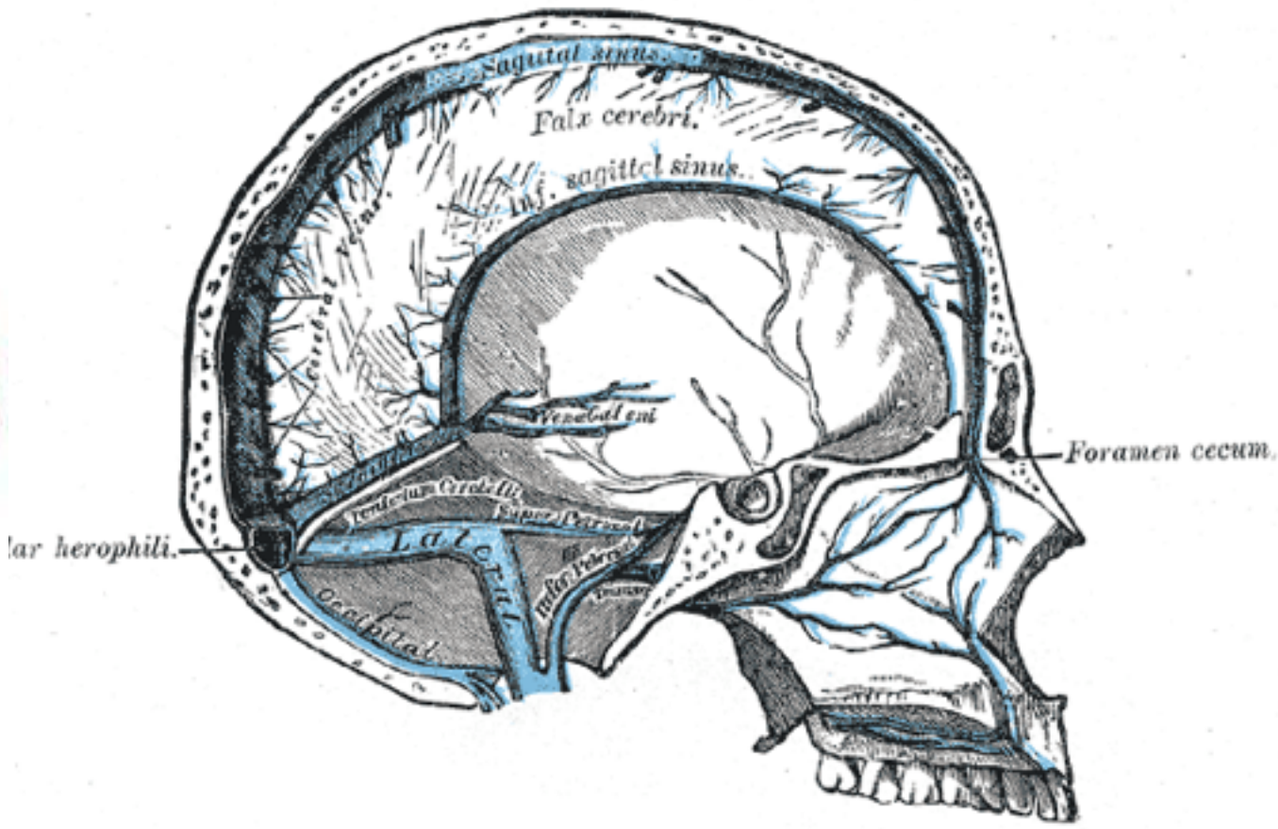
- Cardiac phase fluctuations (around blood vessels)
- Cardiac frequency effects on oxygenation
- Cardiac frequency variability fluctuations





Bottom view of brain

A.D.A.M.



Physiological pulsations: Respiration

Respiratory artifacts due to:

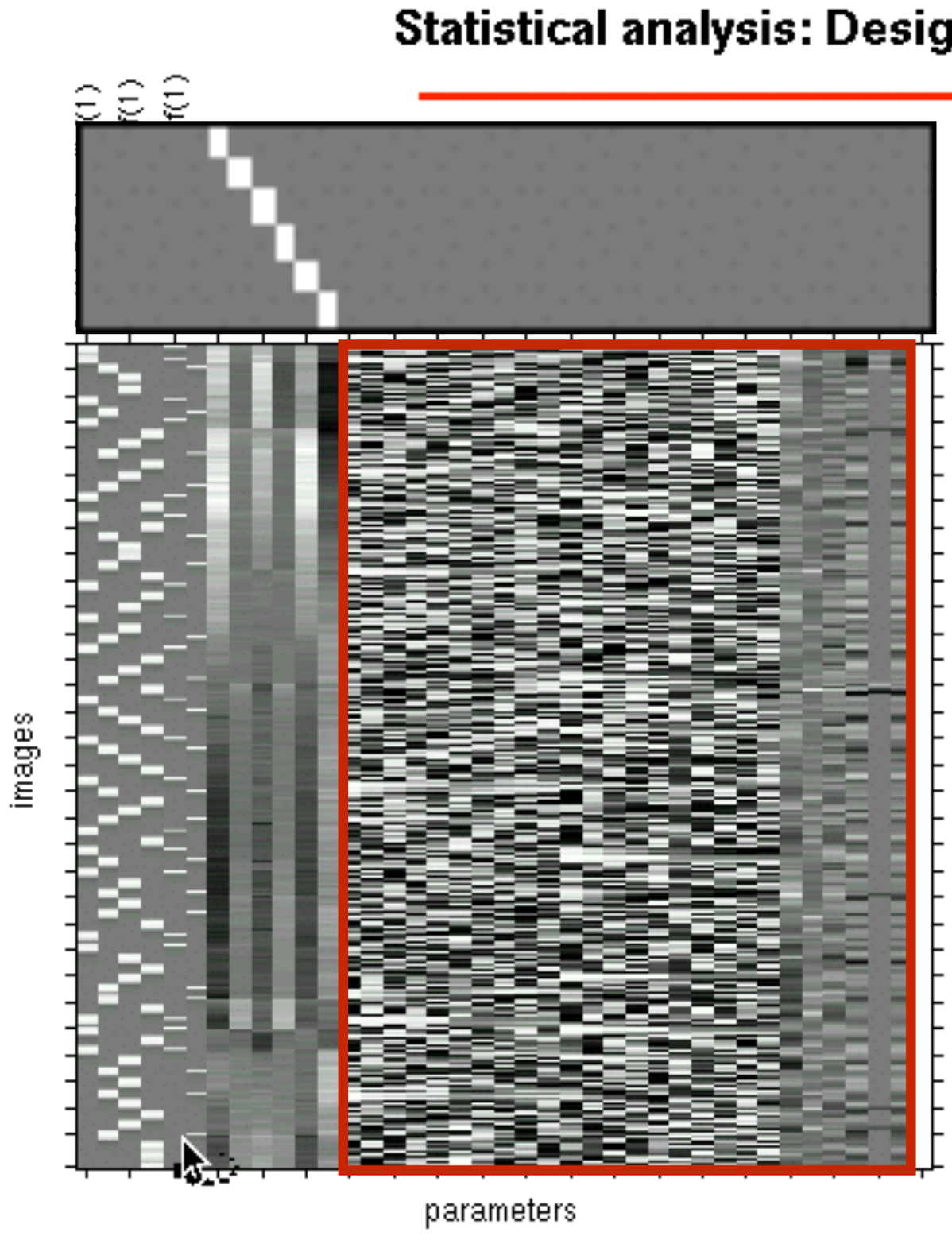
- Head movement
- Magnetic field homogeneity changes due to moving organs
- Intra-thoracic pressure differences
- Respiration-dependent vasodilation / oxygenation changes

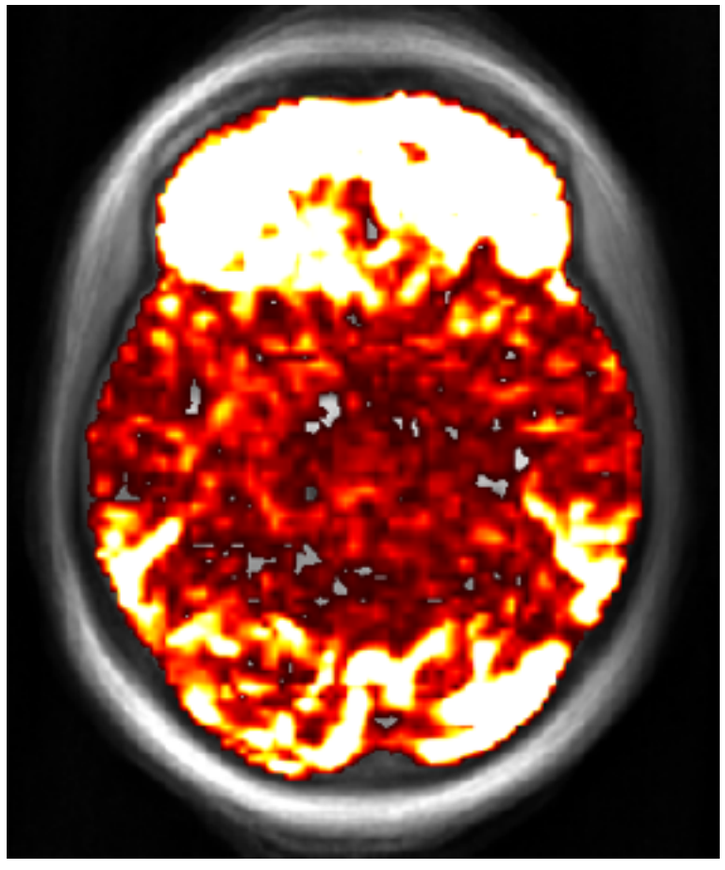
Signal modulations resulting from respiration:

- Respiratory phase
- Respiratory frequency
- Respiratory amplitude

Windischberger et al 2002 MRM

Nuisance regressors in GLM context





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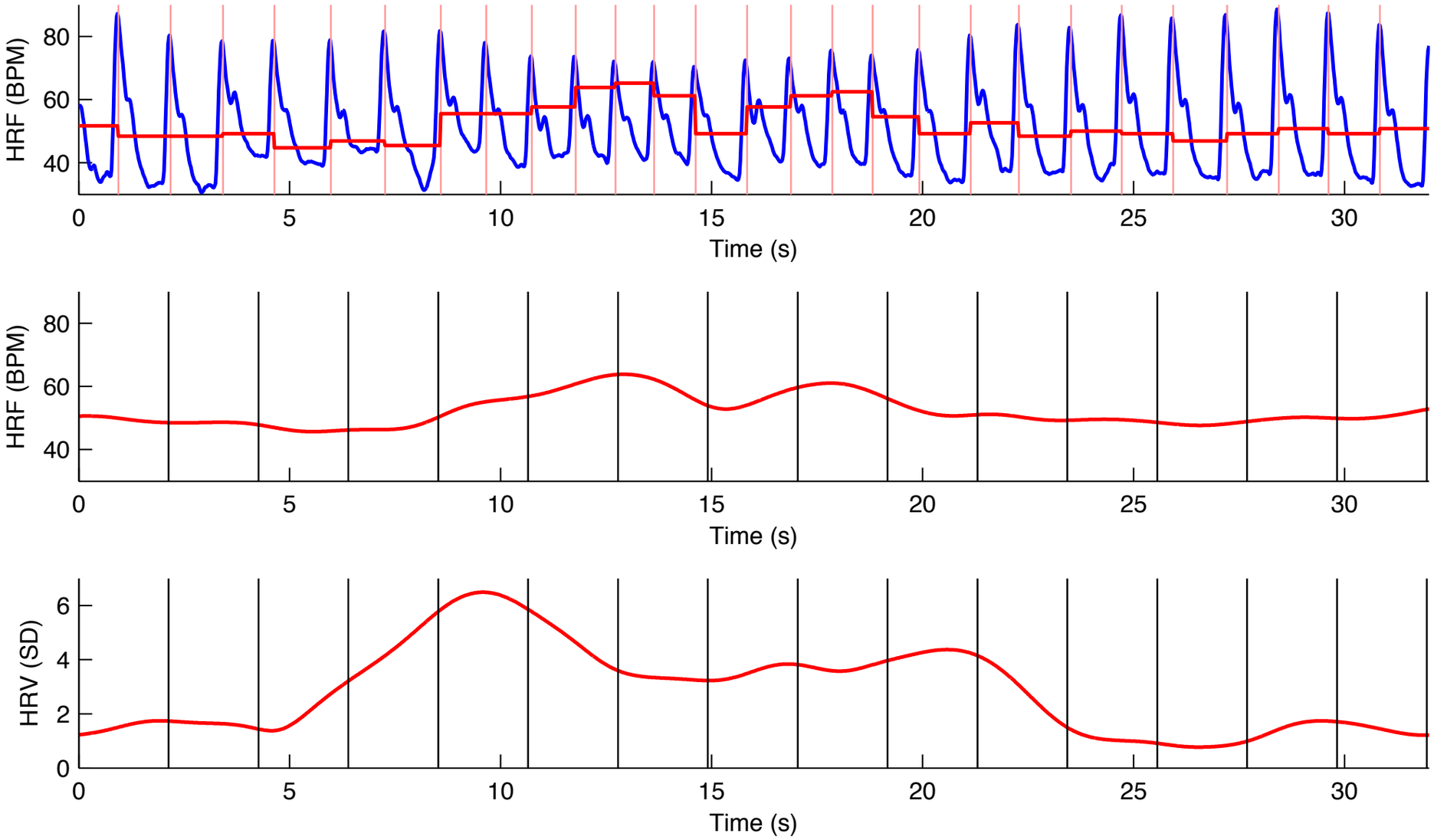
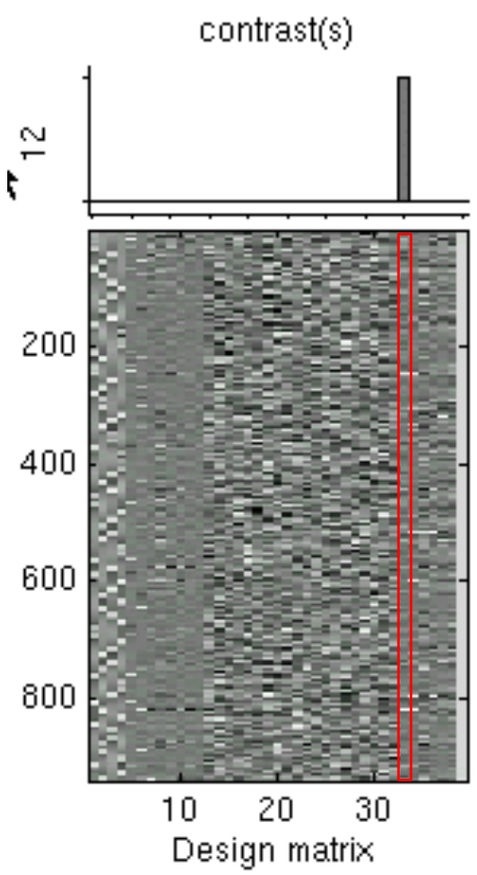
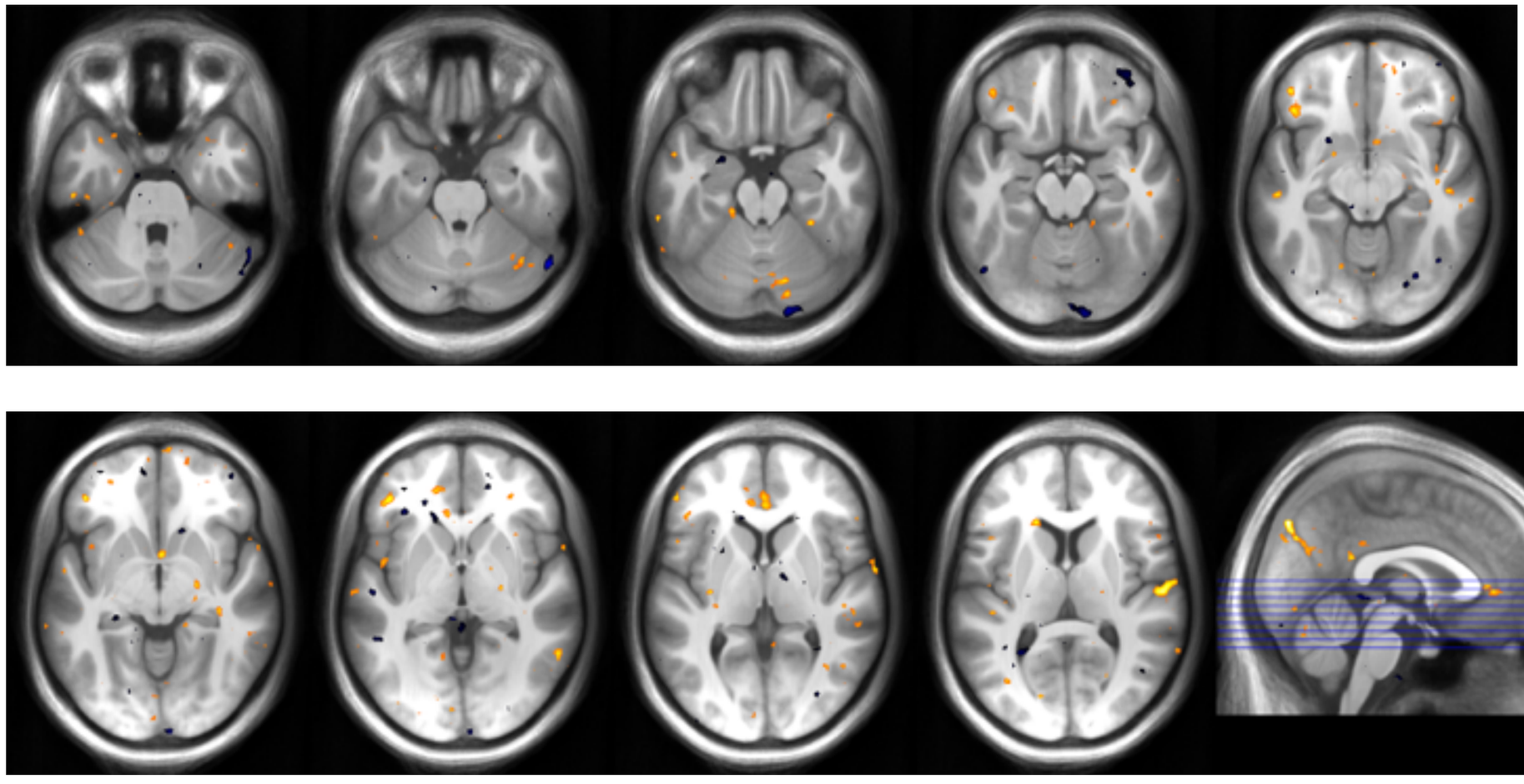
Modelling cardiac frequency and variability



Cardiac frequency signal modulations





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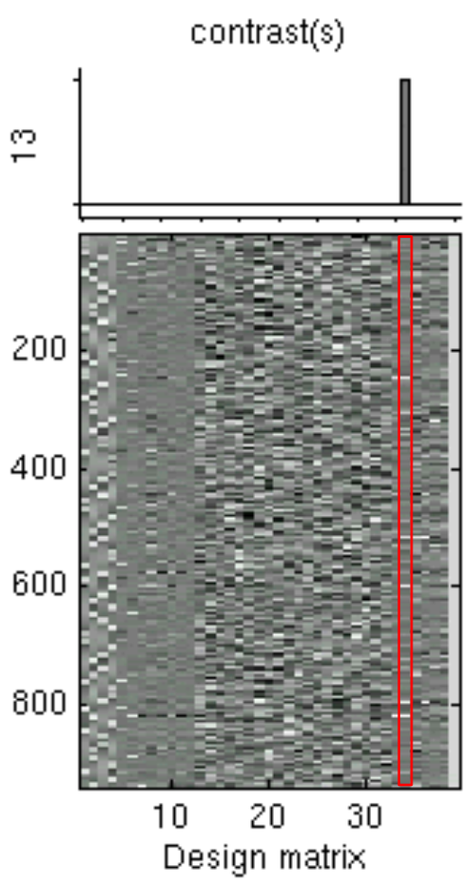
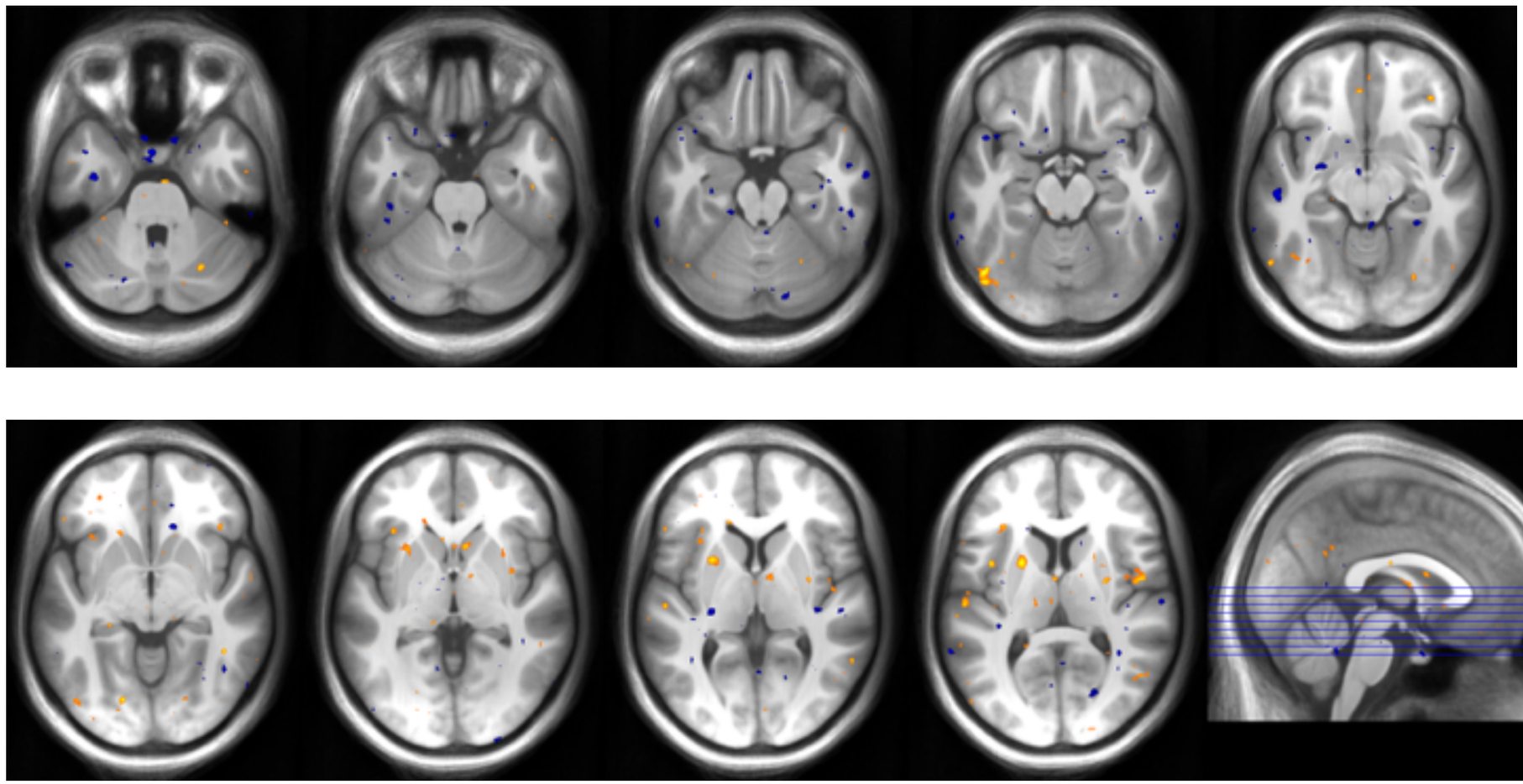
Cardiac variability signal modulations





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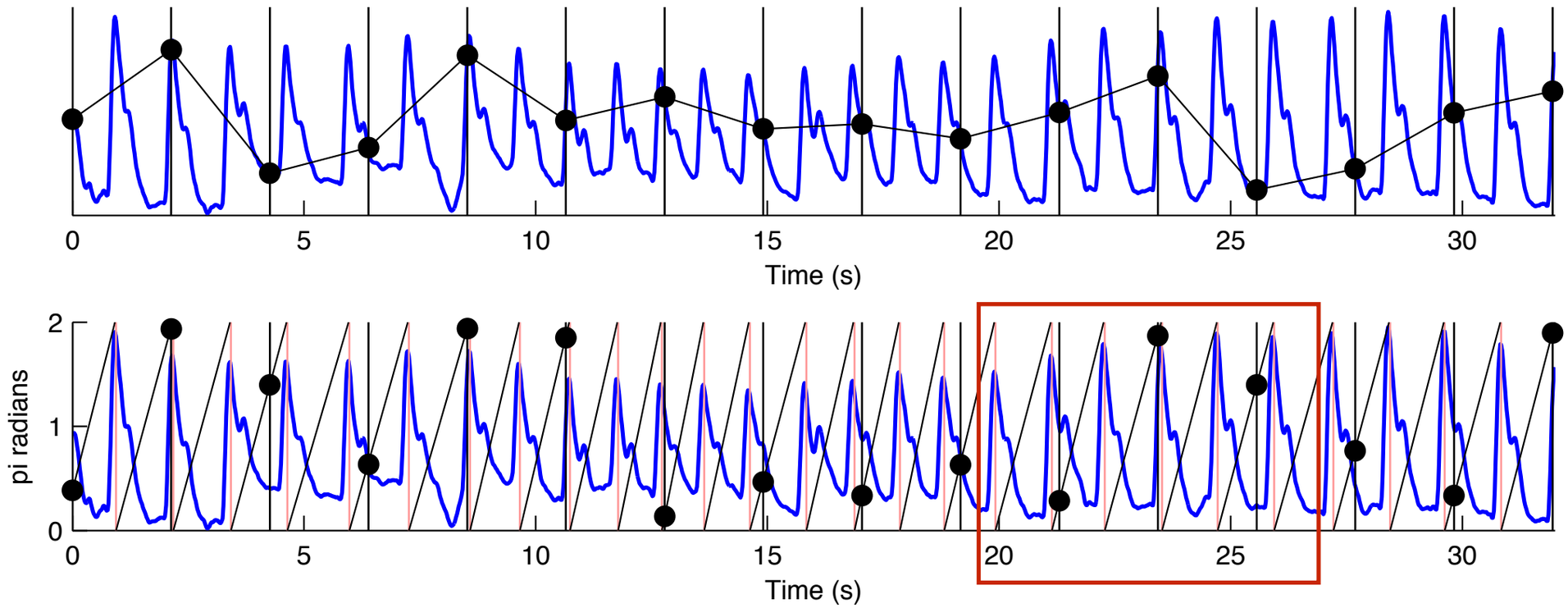
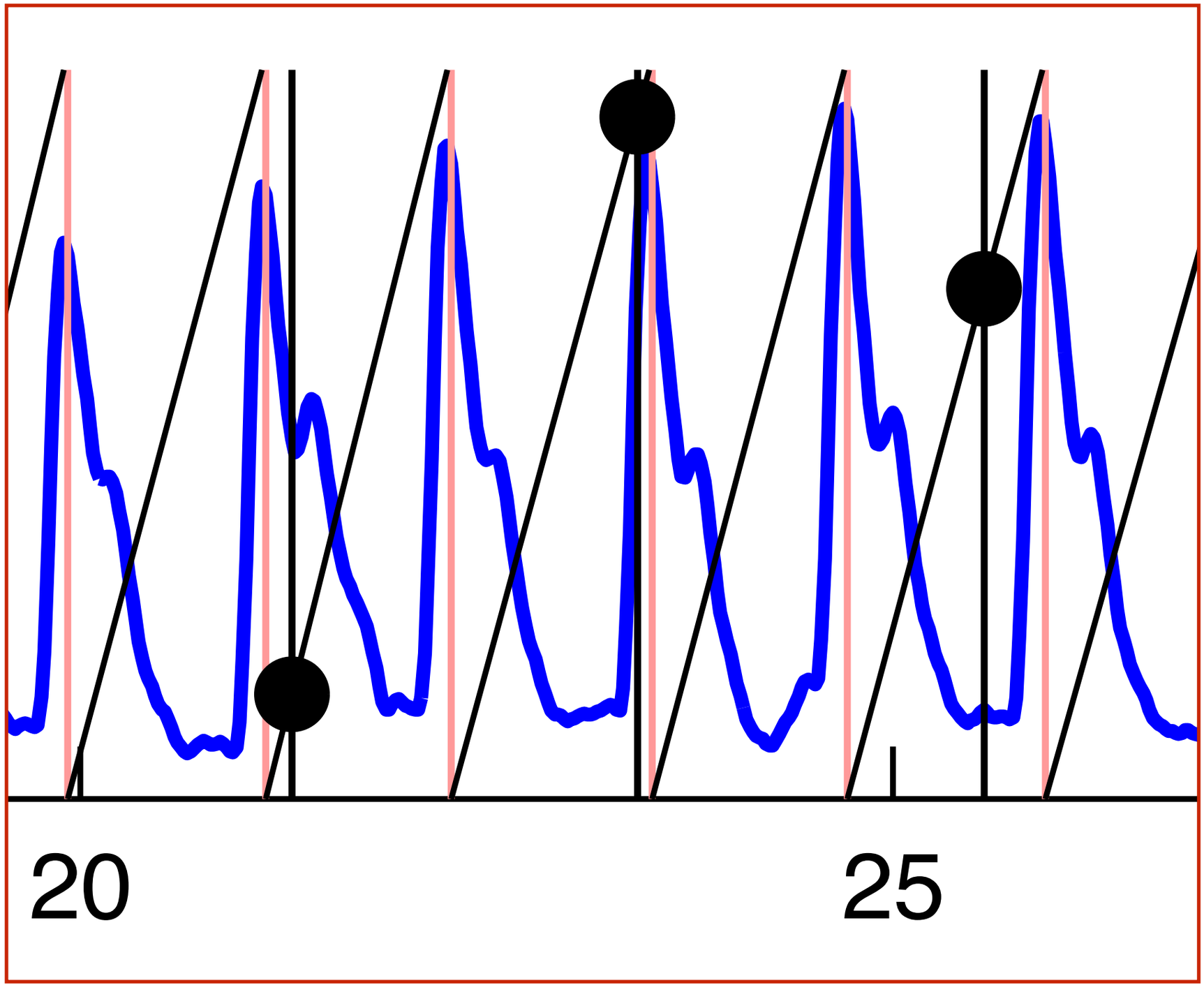
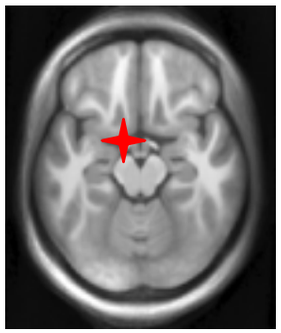
Modelling cardiac phase

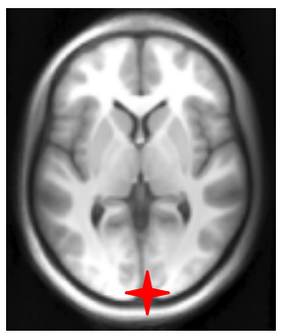


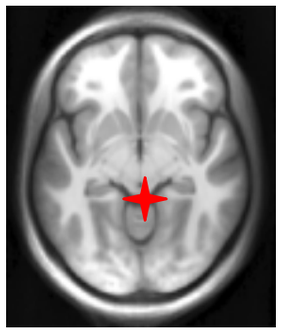
Modelling cardiac phase

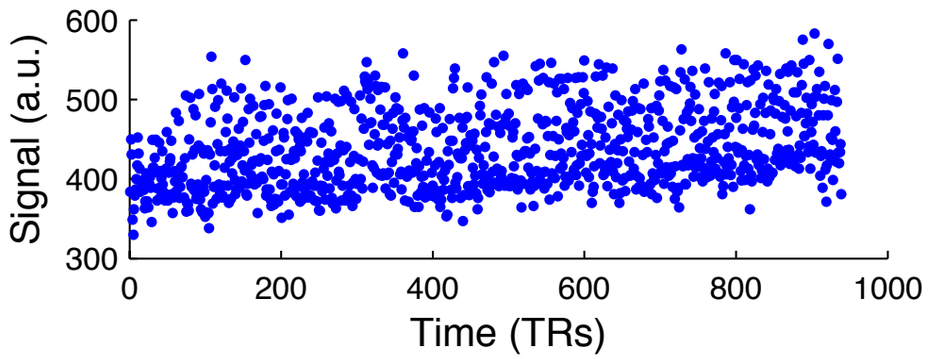


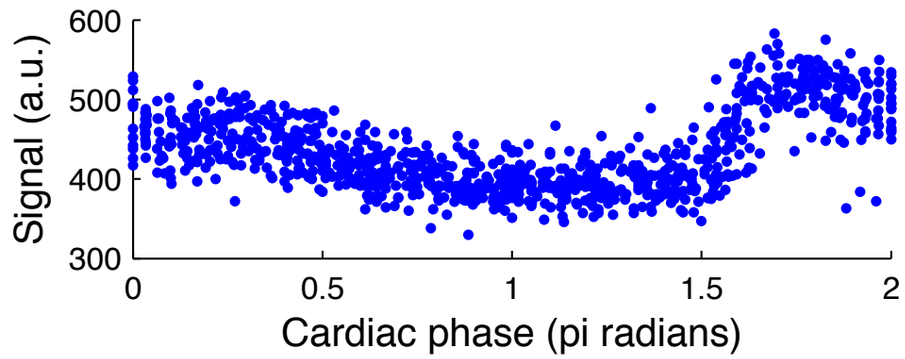
BOLD as a function of cardiac phase

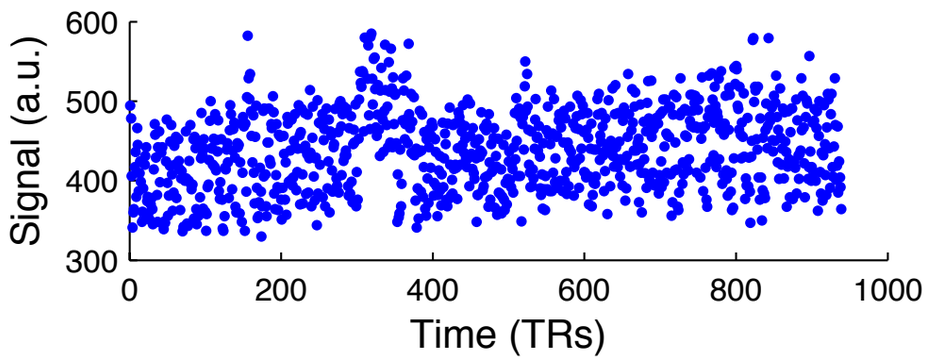


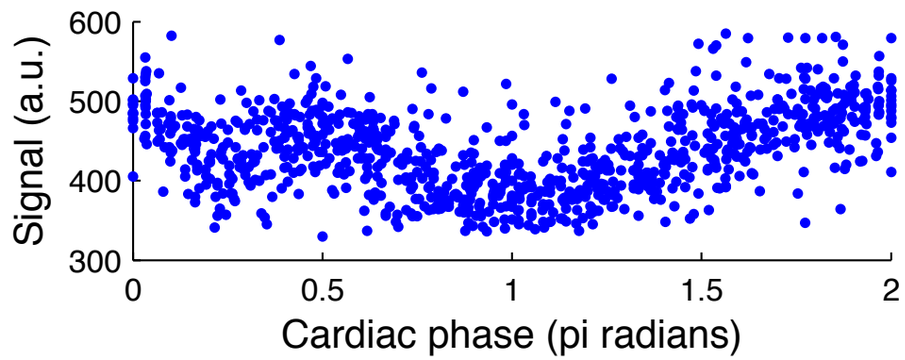


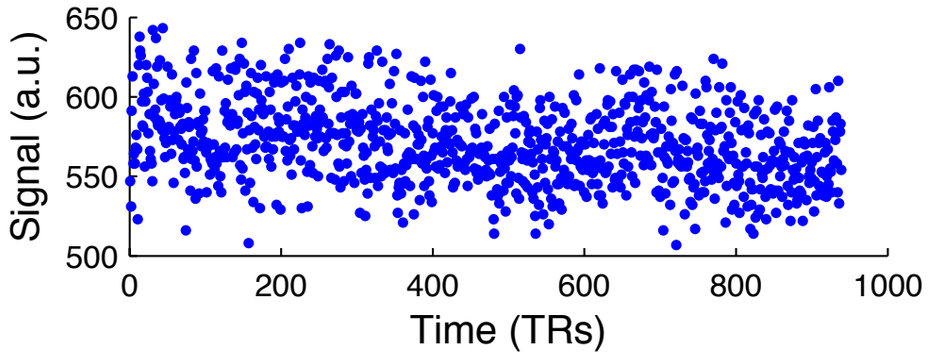


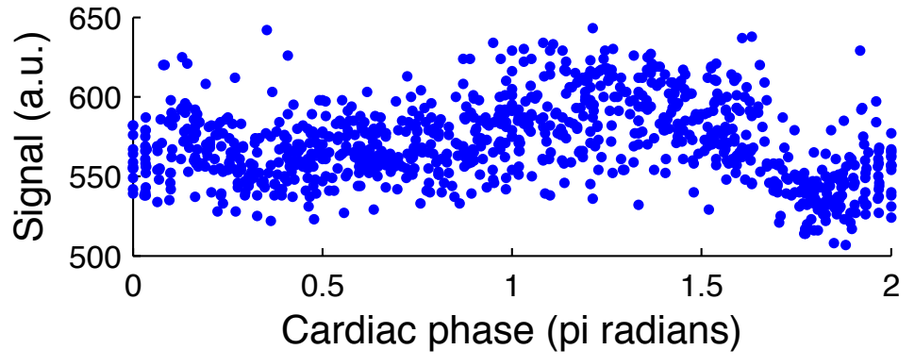




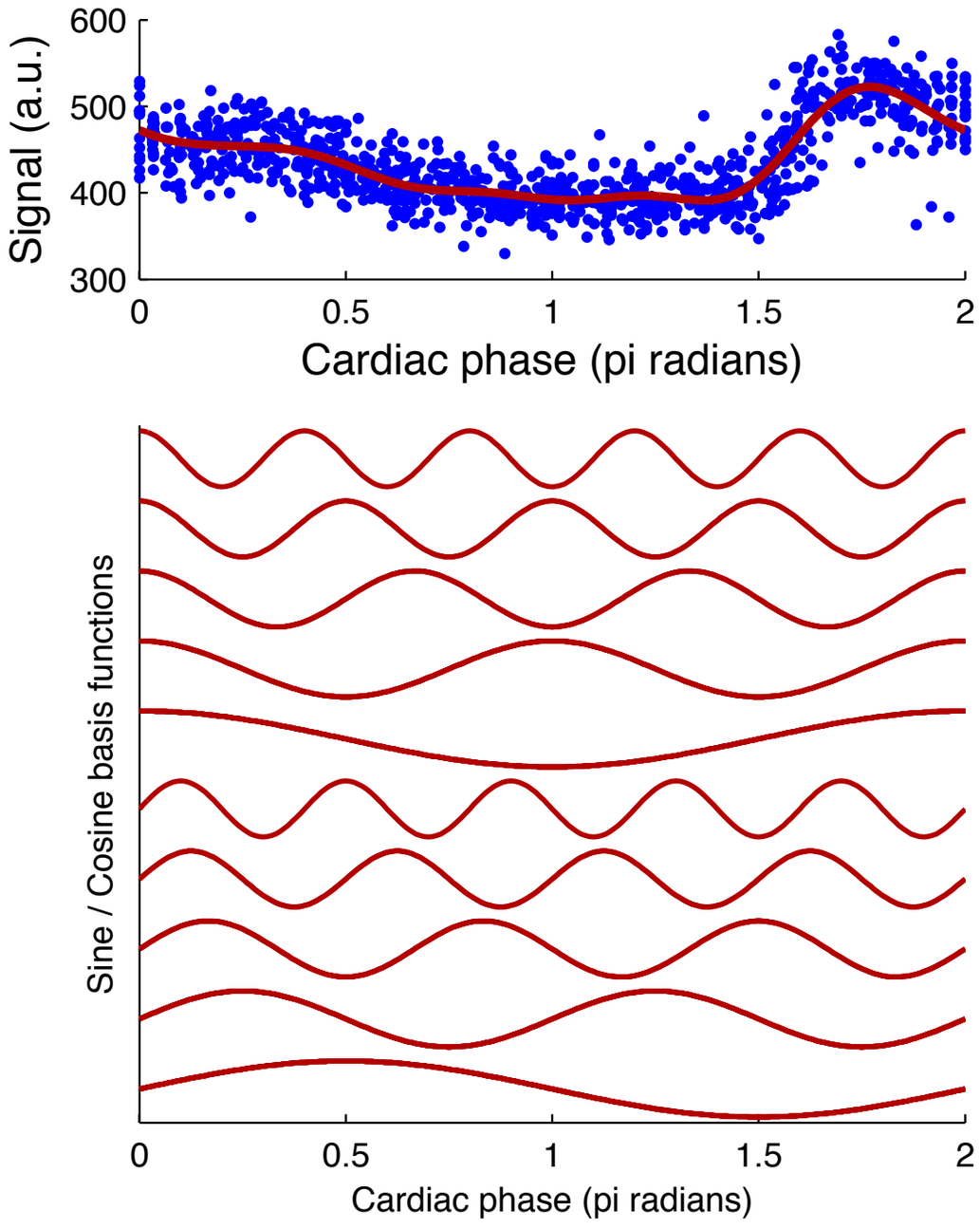


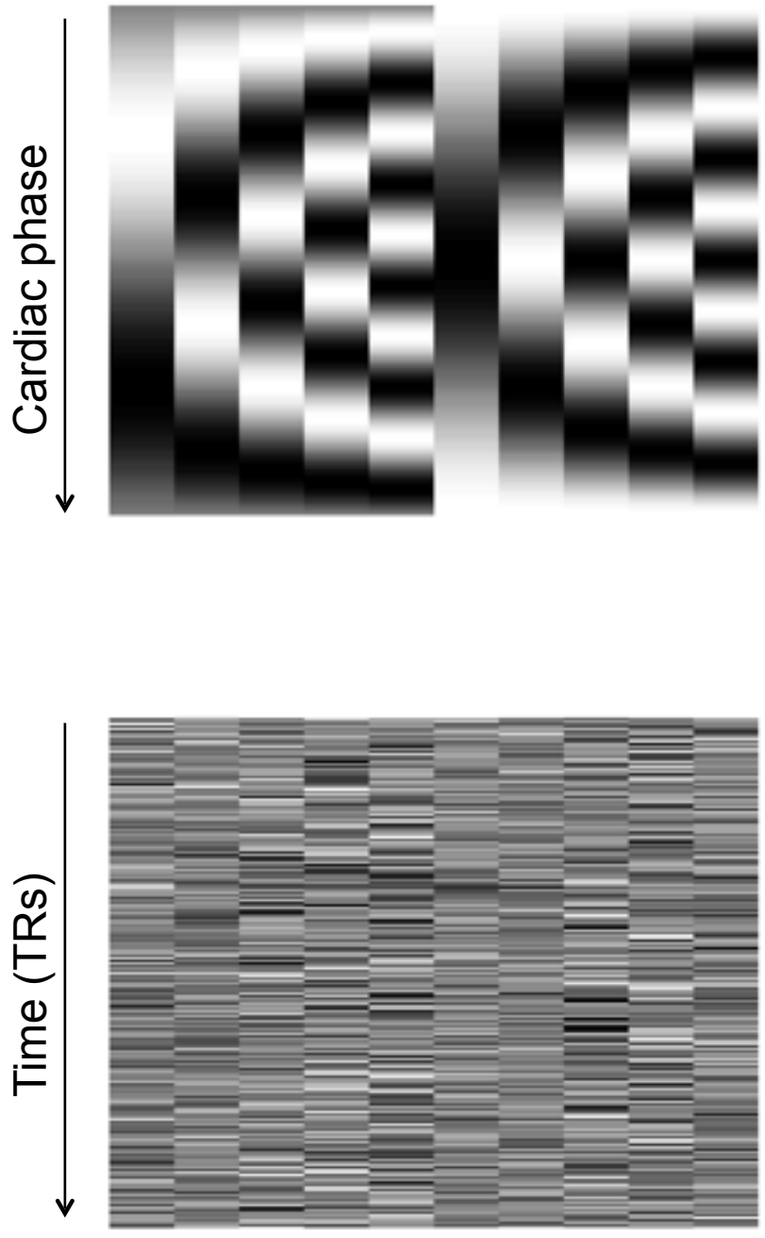






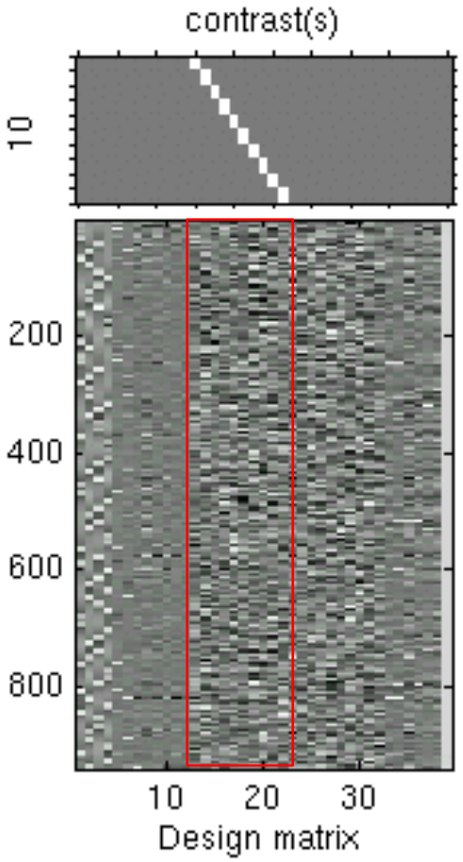
Fourier series

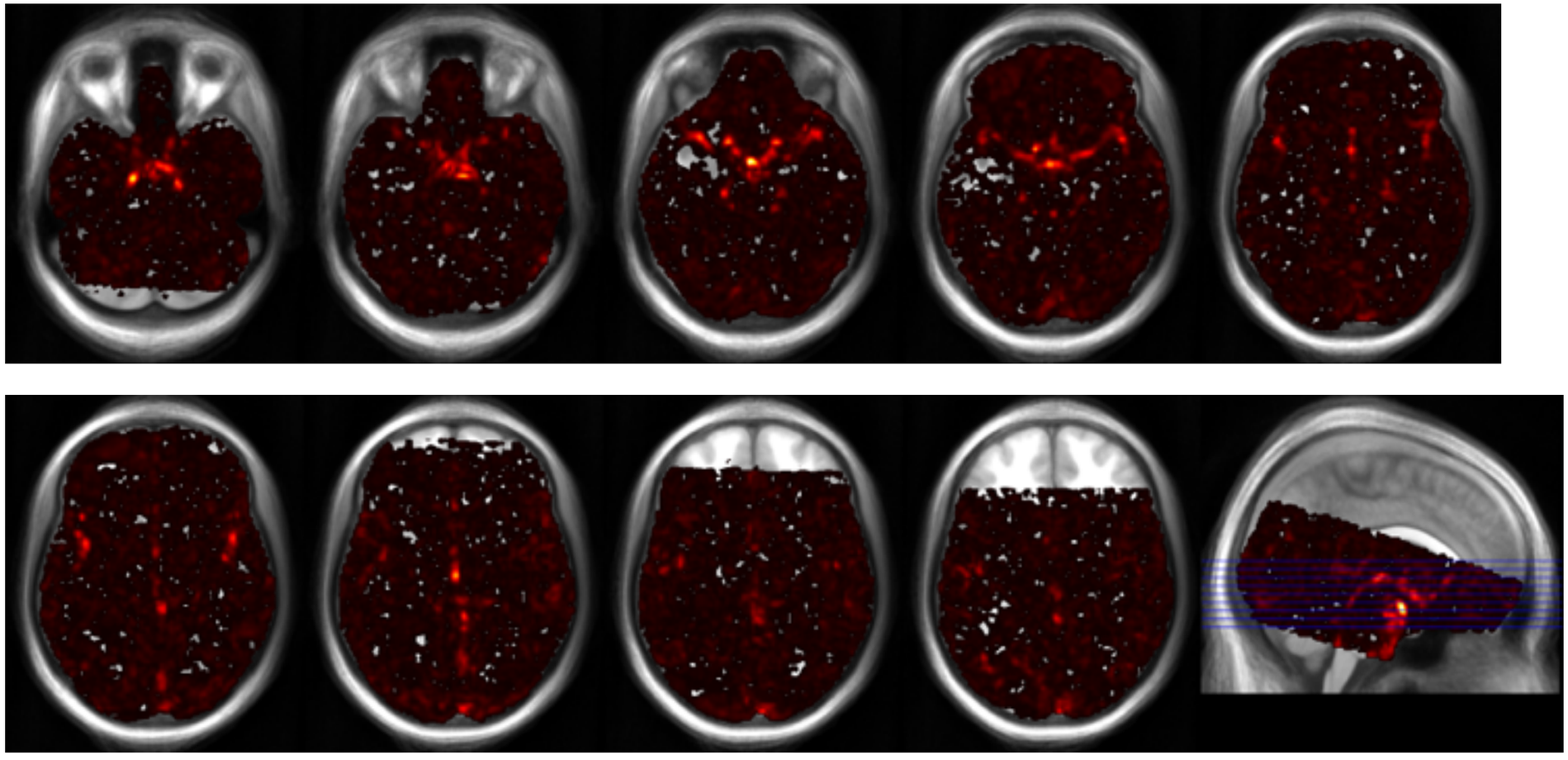




Fifth order Fourier series RETROICOR model; see Glover et al 2000 MRM; van Buuren et al 2009 HBM

Cardiac phase signal modulation





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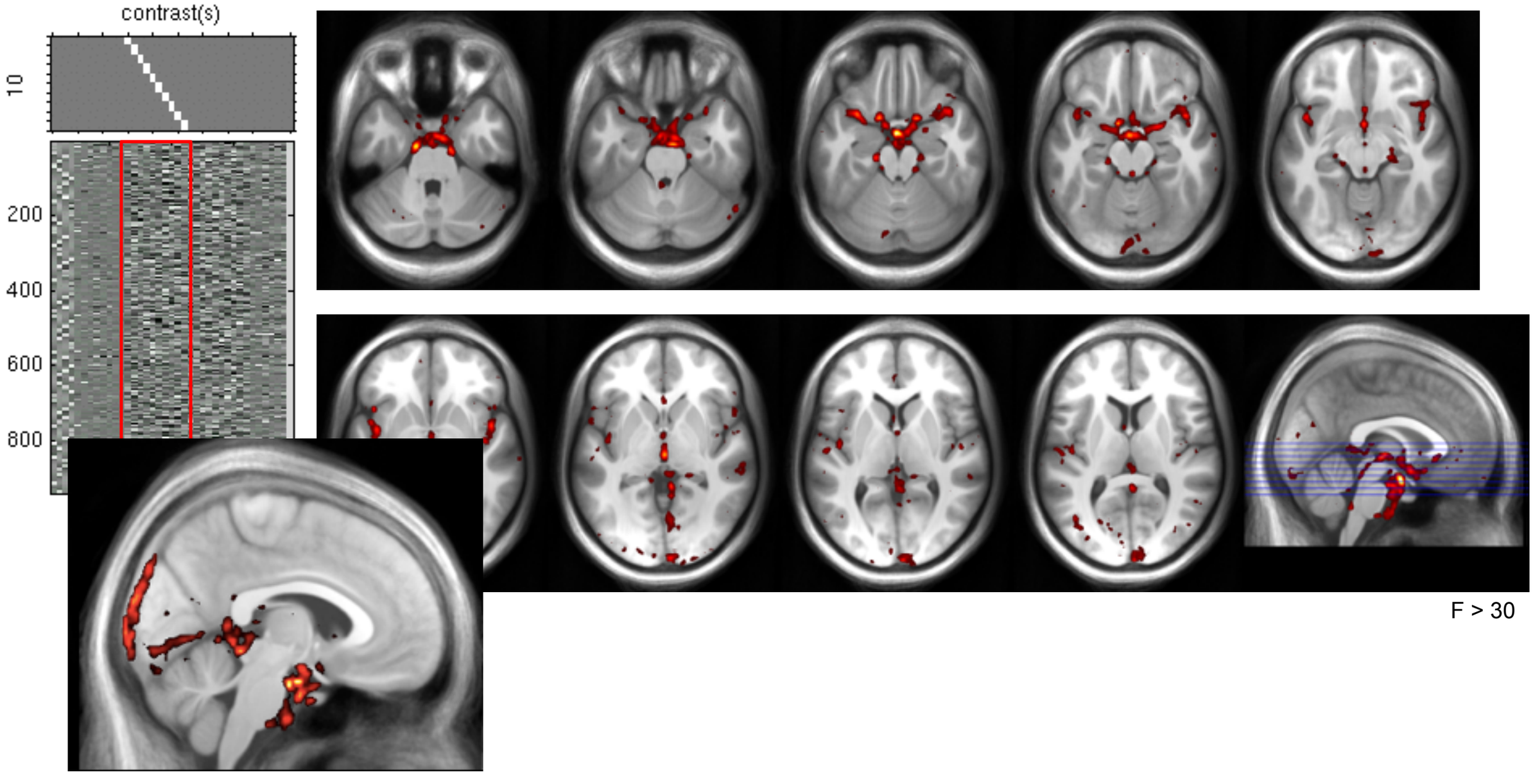
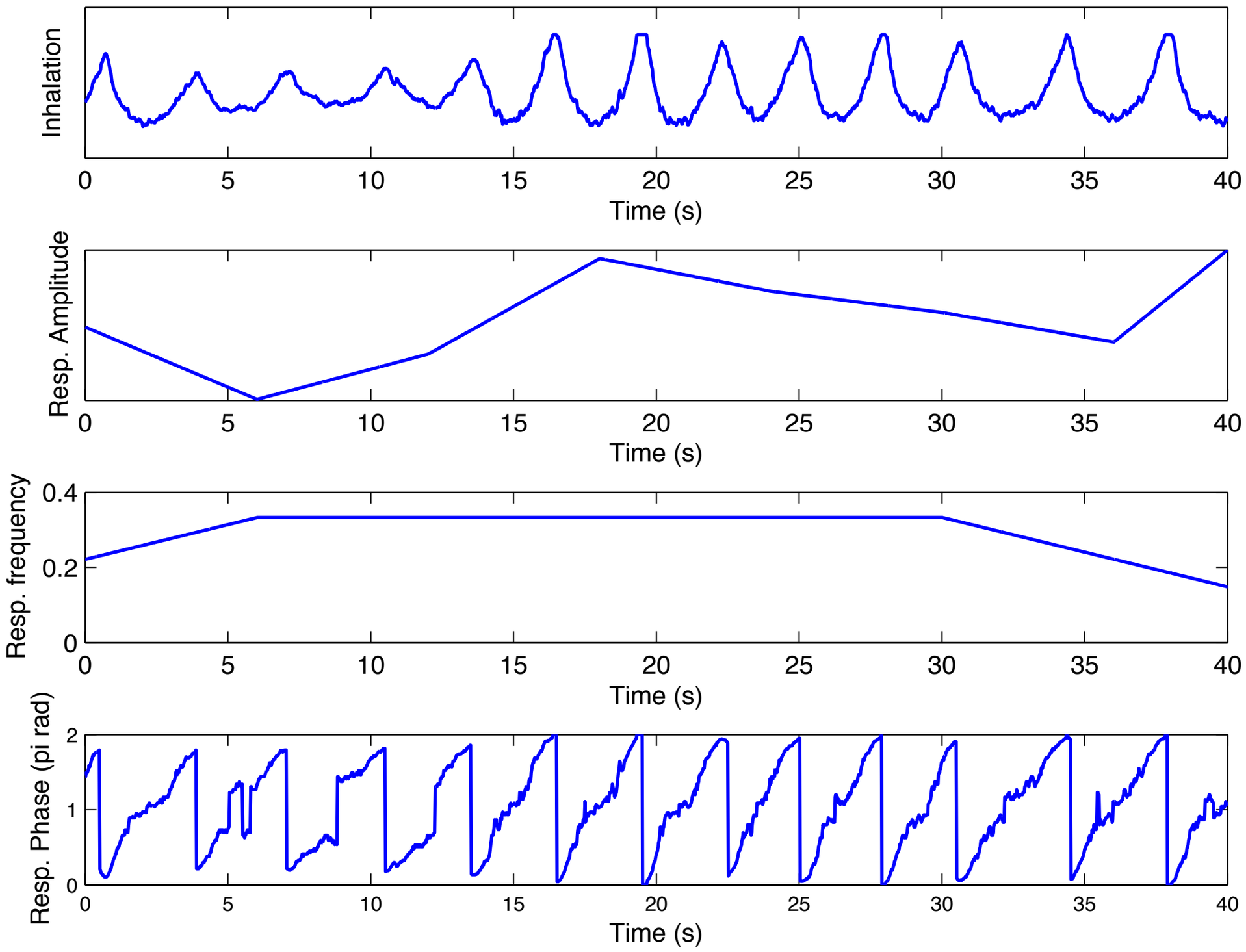
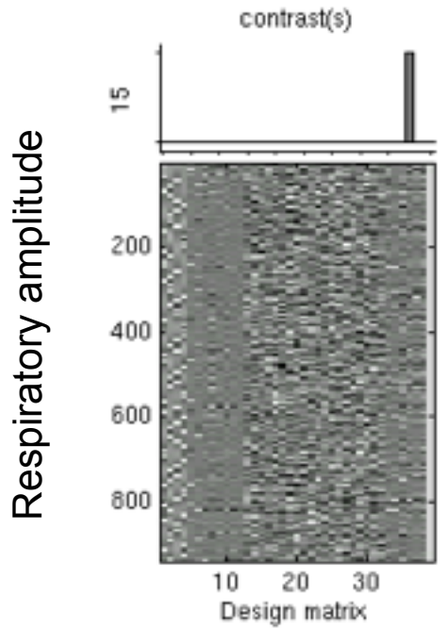
Cardiac phase signal modulation

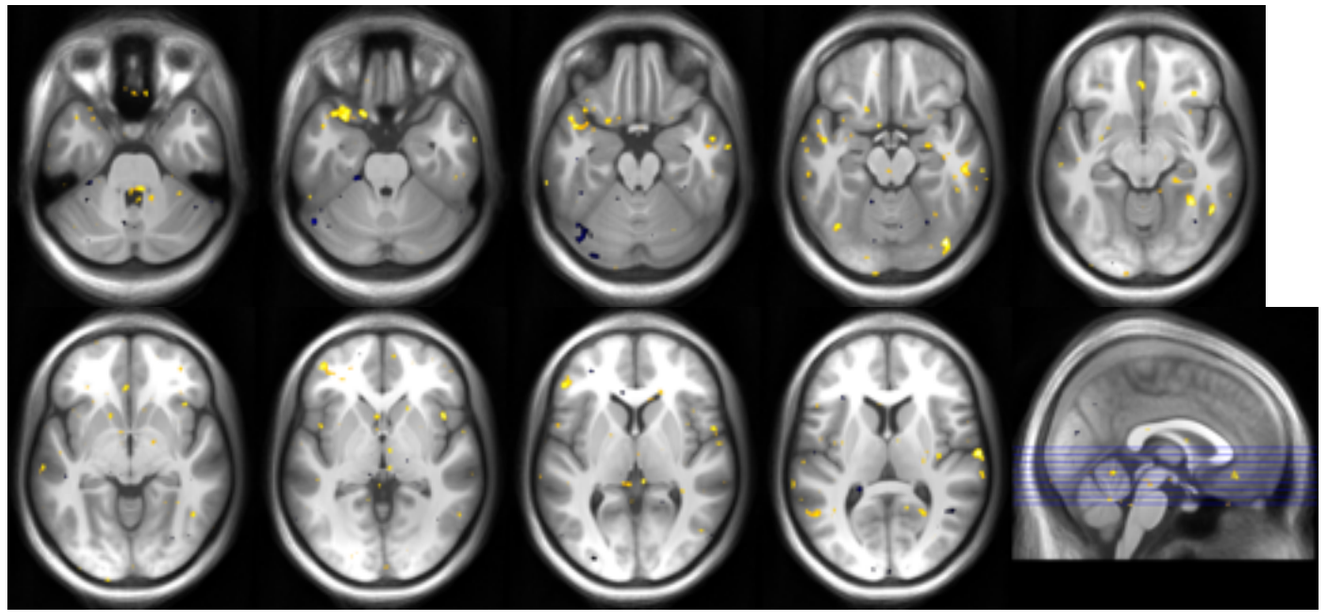


Modeling respiratory noise



Respiratory signal modulation





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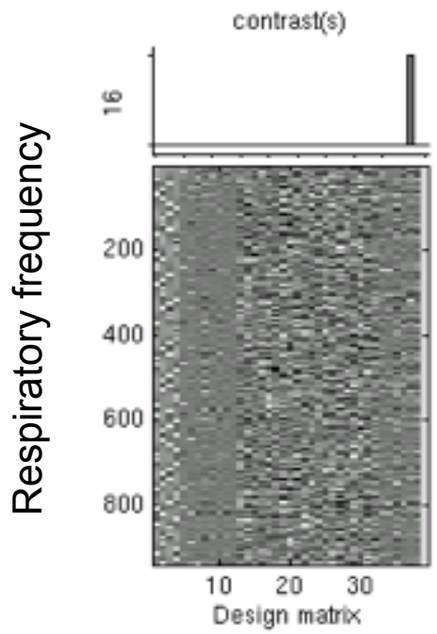

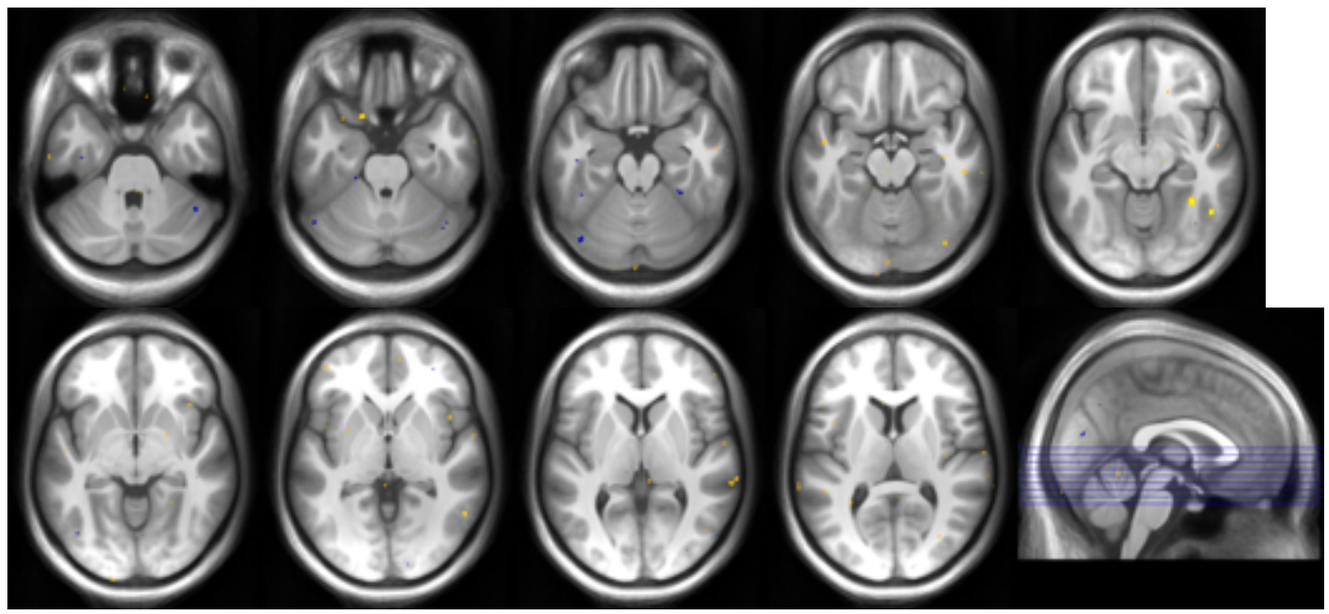

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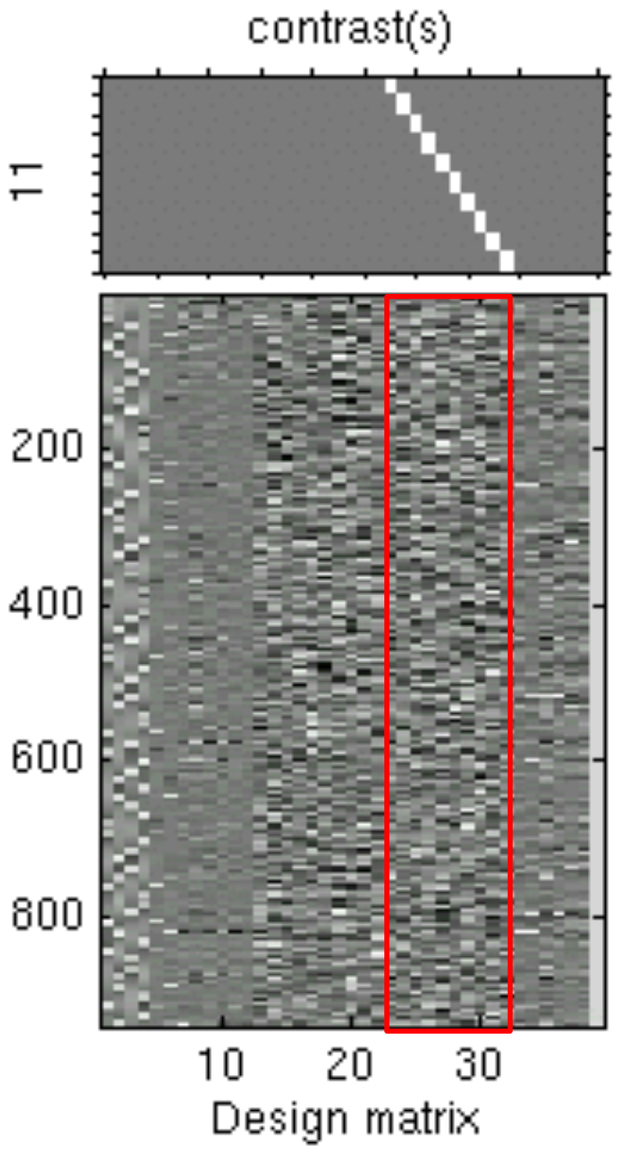
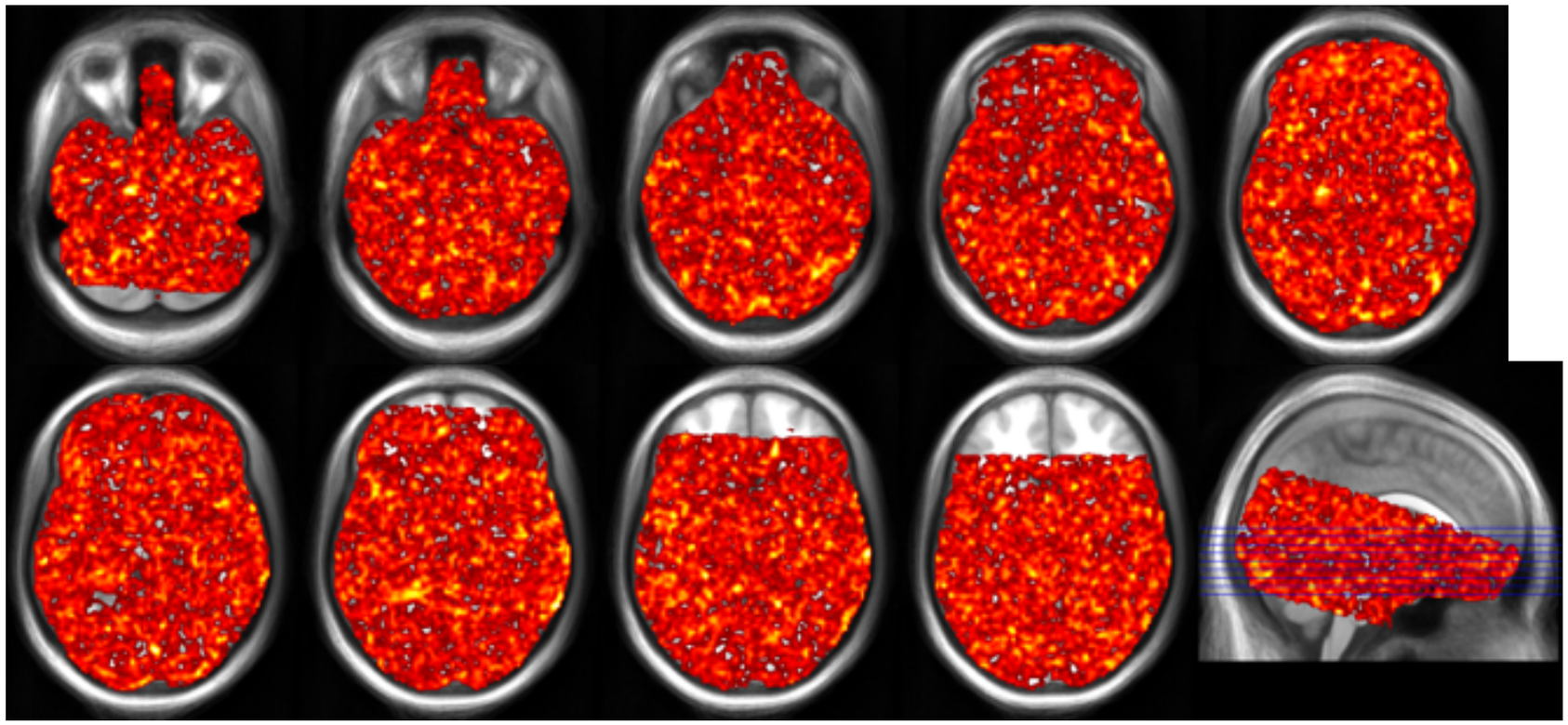
Respiratory phase signal modulation





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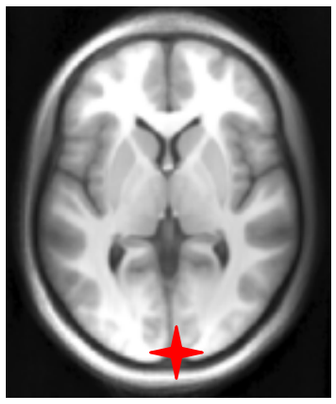
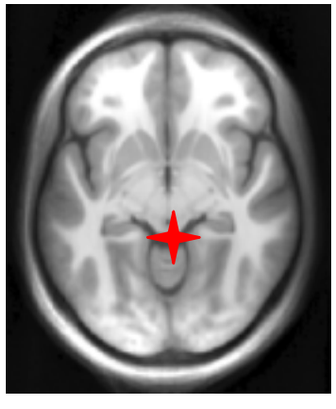
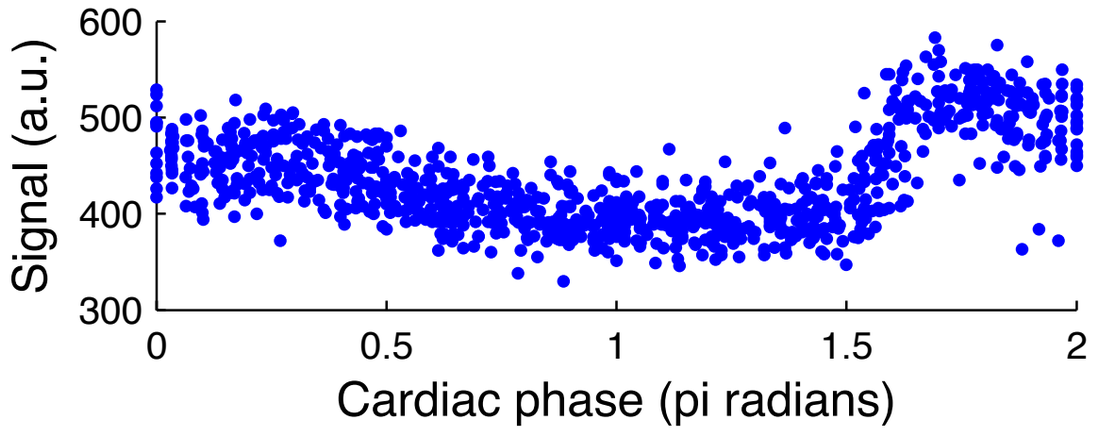
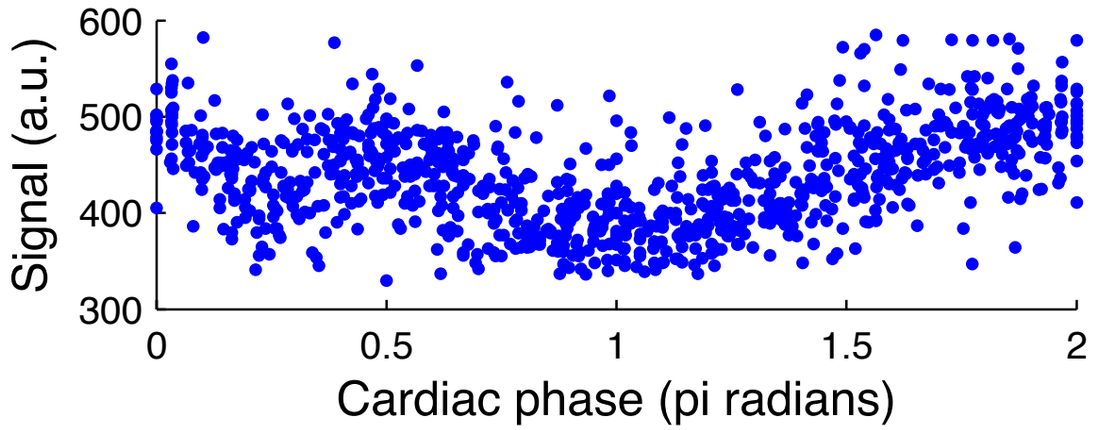
Fifth order Fourier series RETROICOR model; see Glover et al 2000 MRM; van Buuren et al 2009 HBM

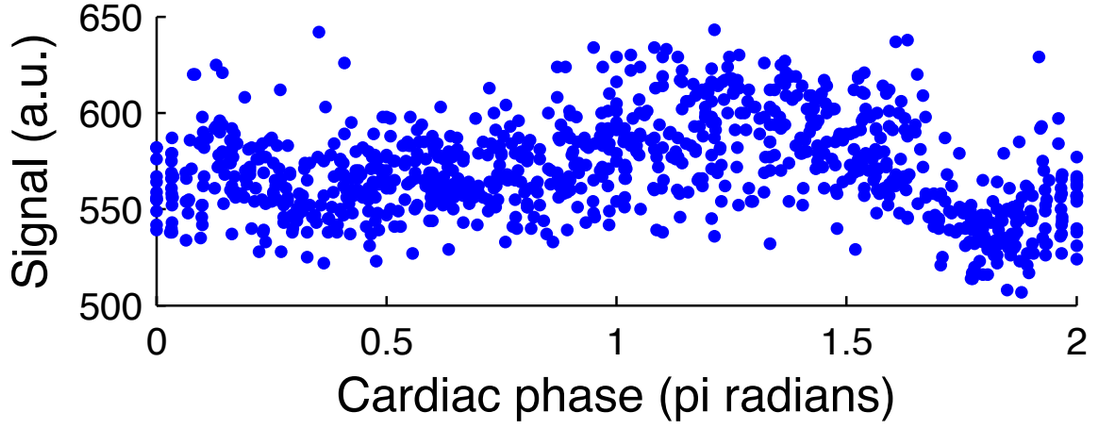
Visualizing cardiac noise



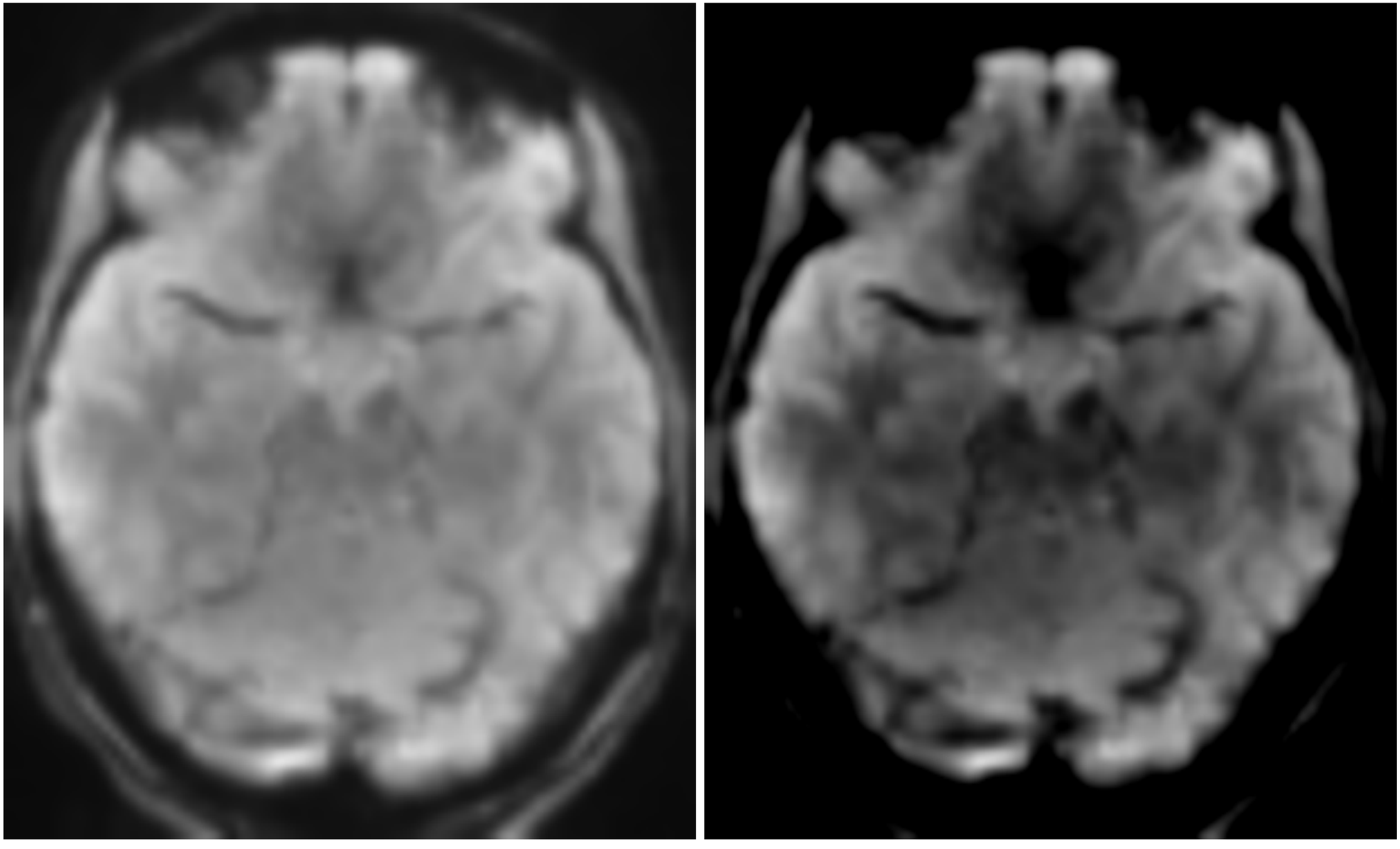








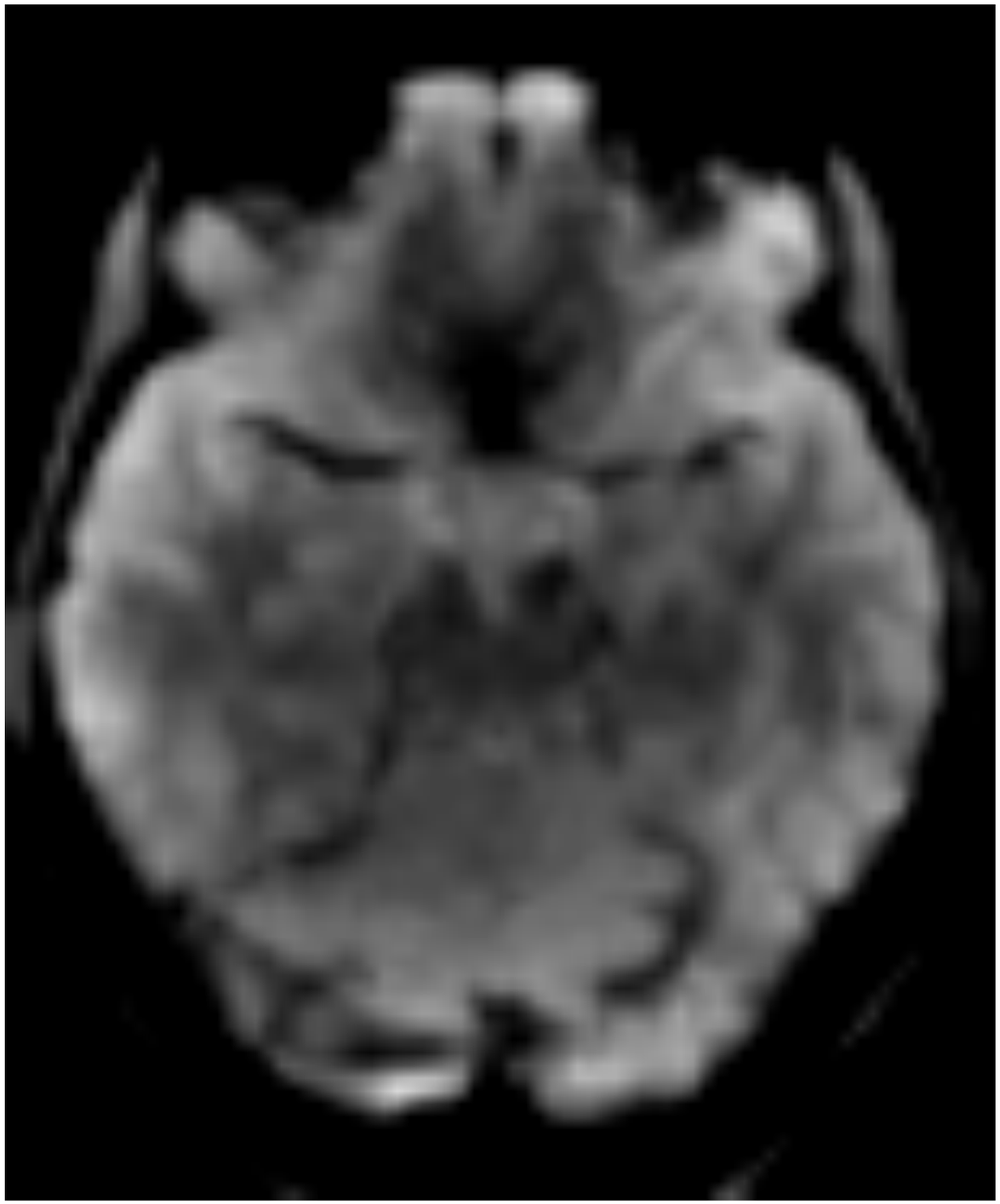
Visualizing cardiac noise



Reconstructed cardiac phase modulation at 60 BPM (1 Hz)

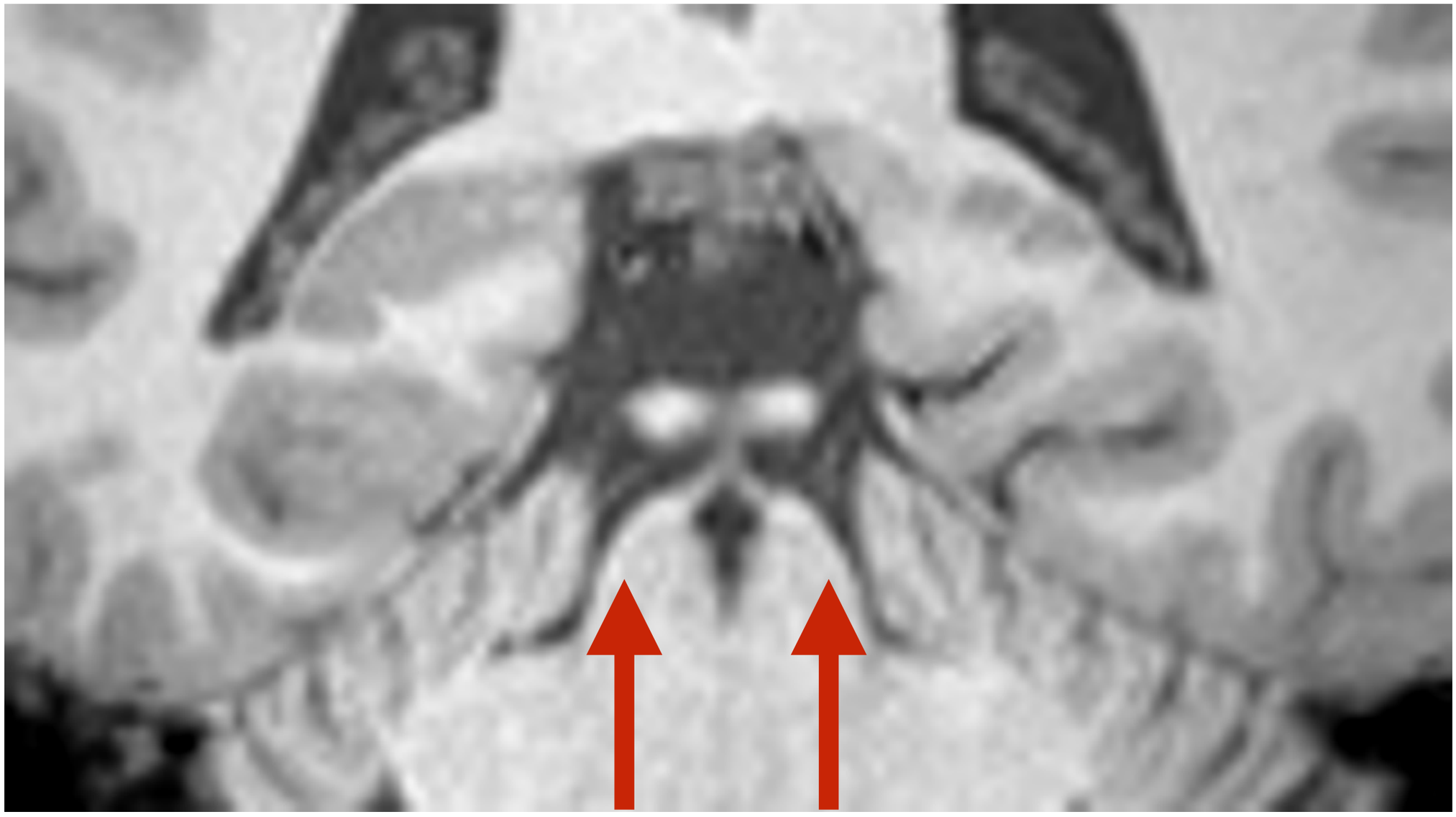
Enhanced contrast (1.5*)

Visualizing cardiac noise



Reconstructed respiratory phase modulation (played at .2 Hz; contrast enhanced 1.5*)

Cardiac noise in high-resolution brainstem imaging



Collin et al. in prep

Cardiac noise in high-resolution brainstem imaging

Collin et al. in prep

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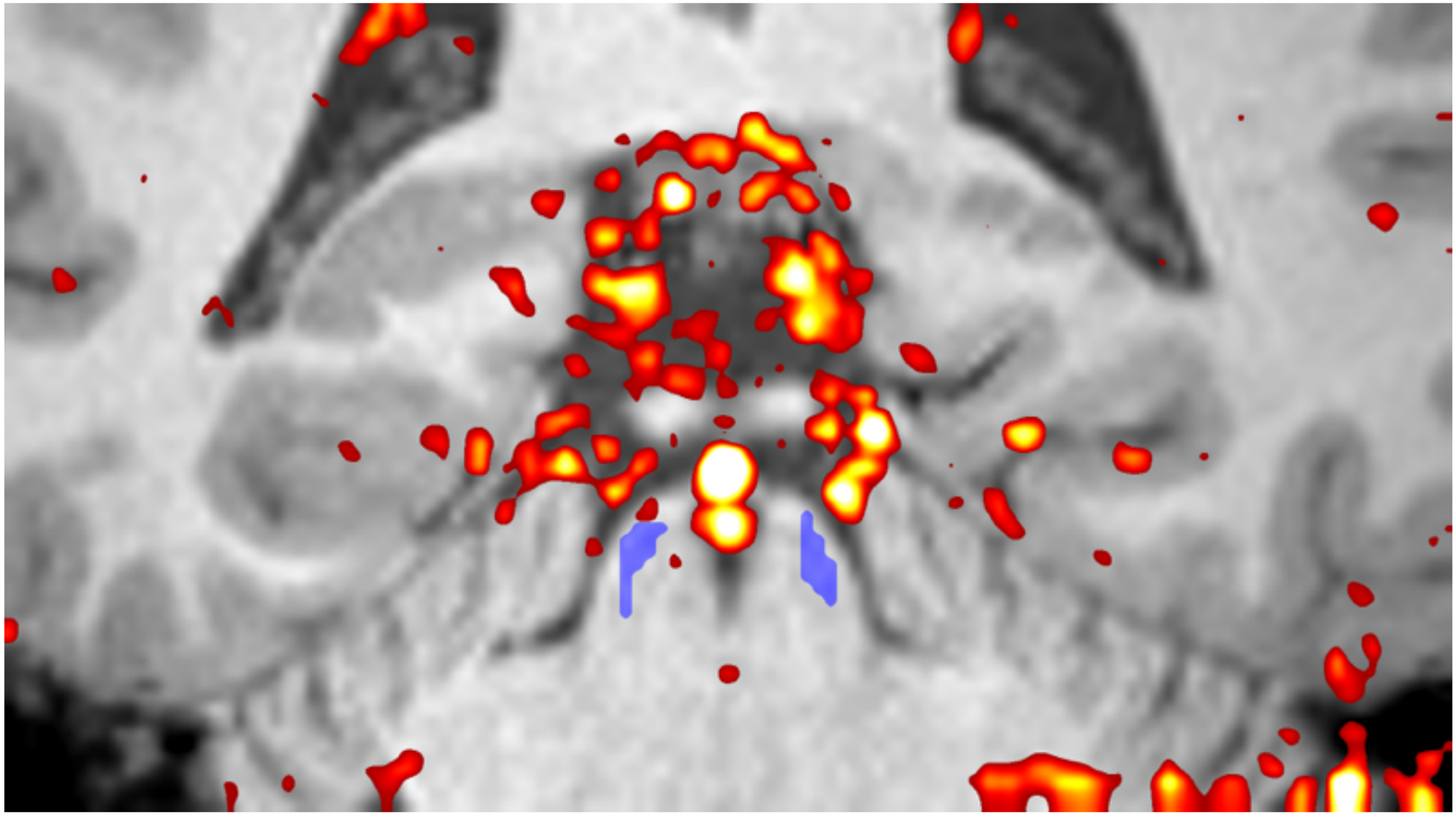
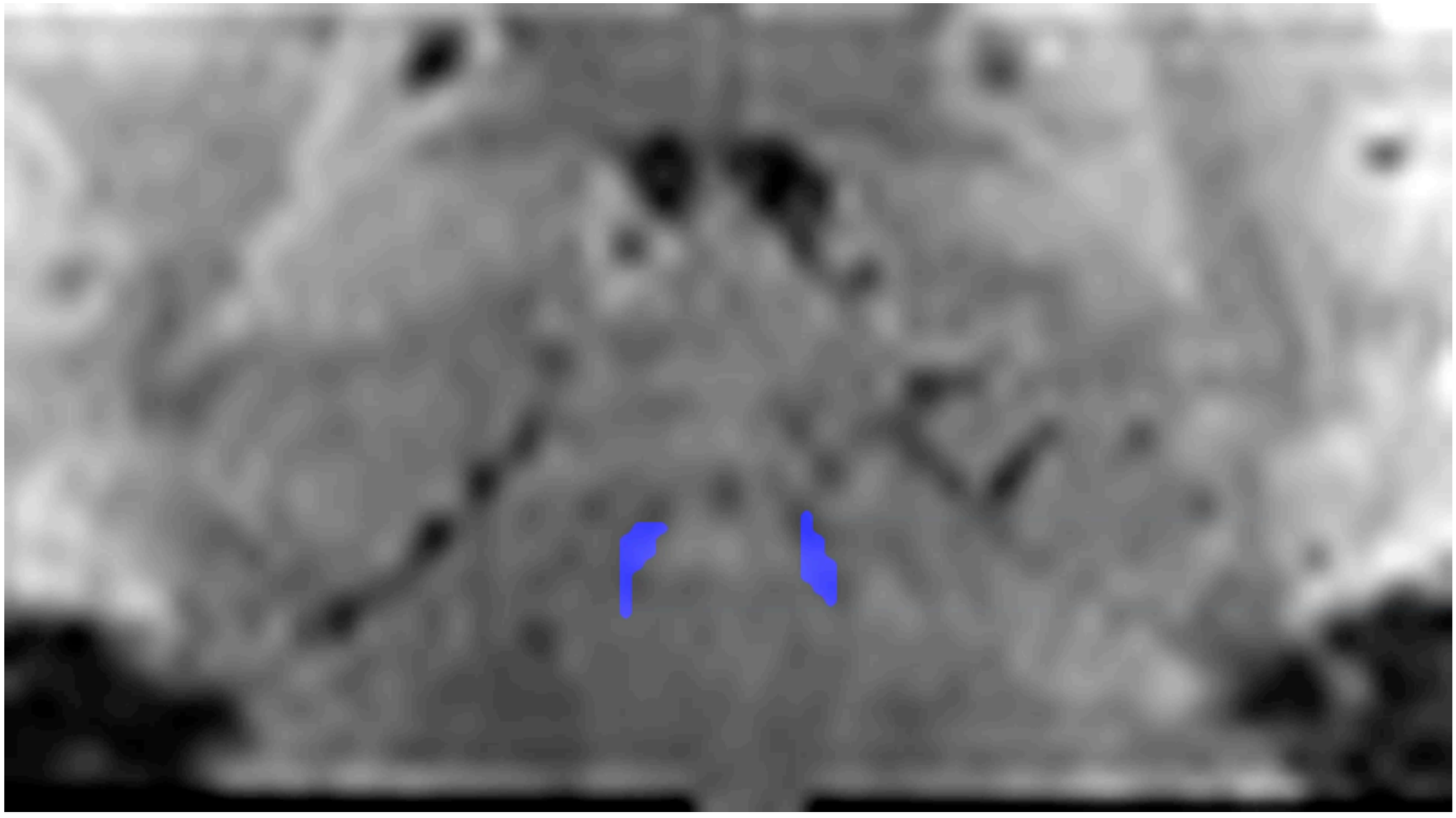


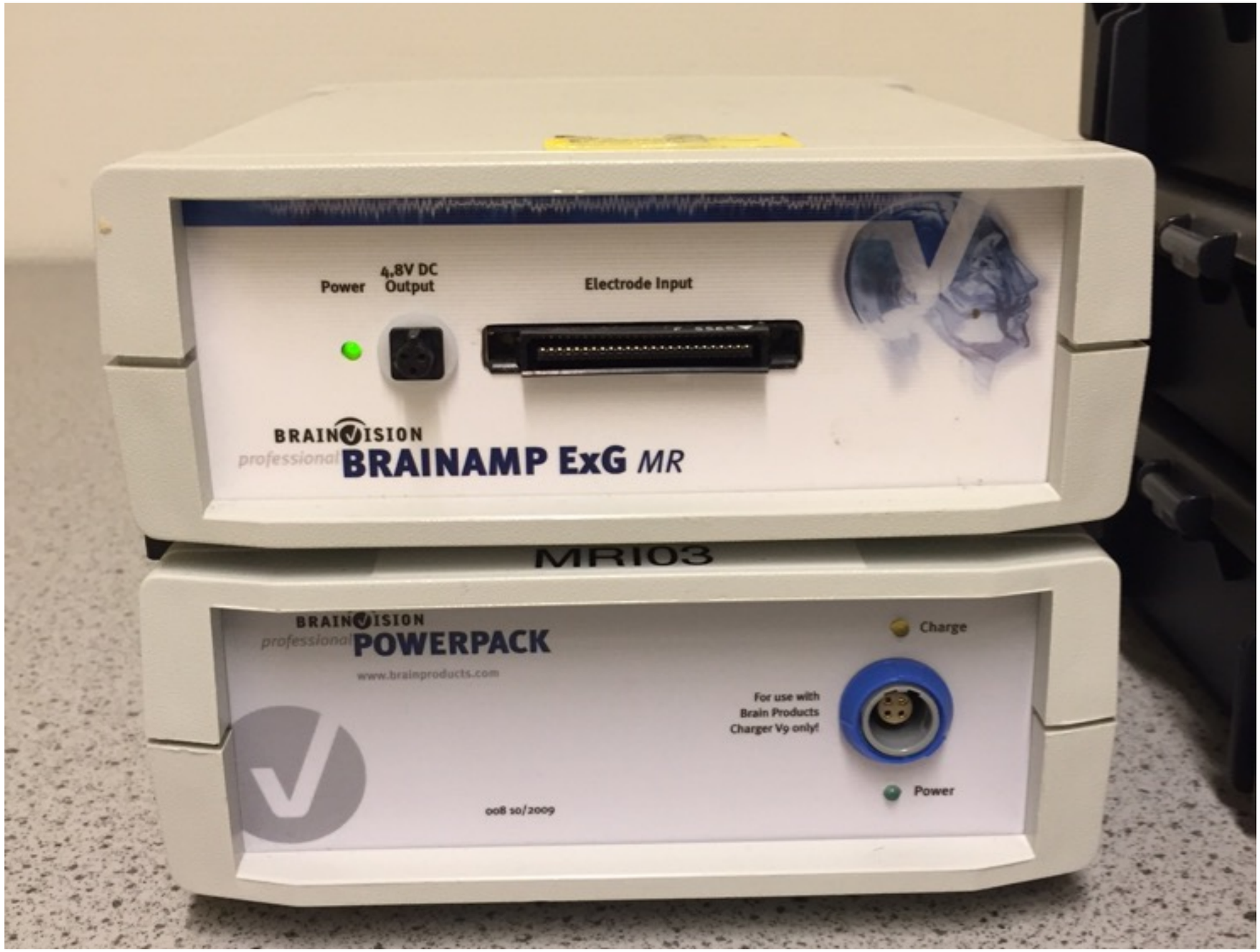
Collin et al. in prep

Cardiac noise in high-resolution brainstem imaging



Collin et al. in prep

Implementation using DCCN equipment



Implementation using DCCN equipment

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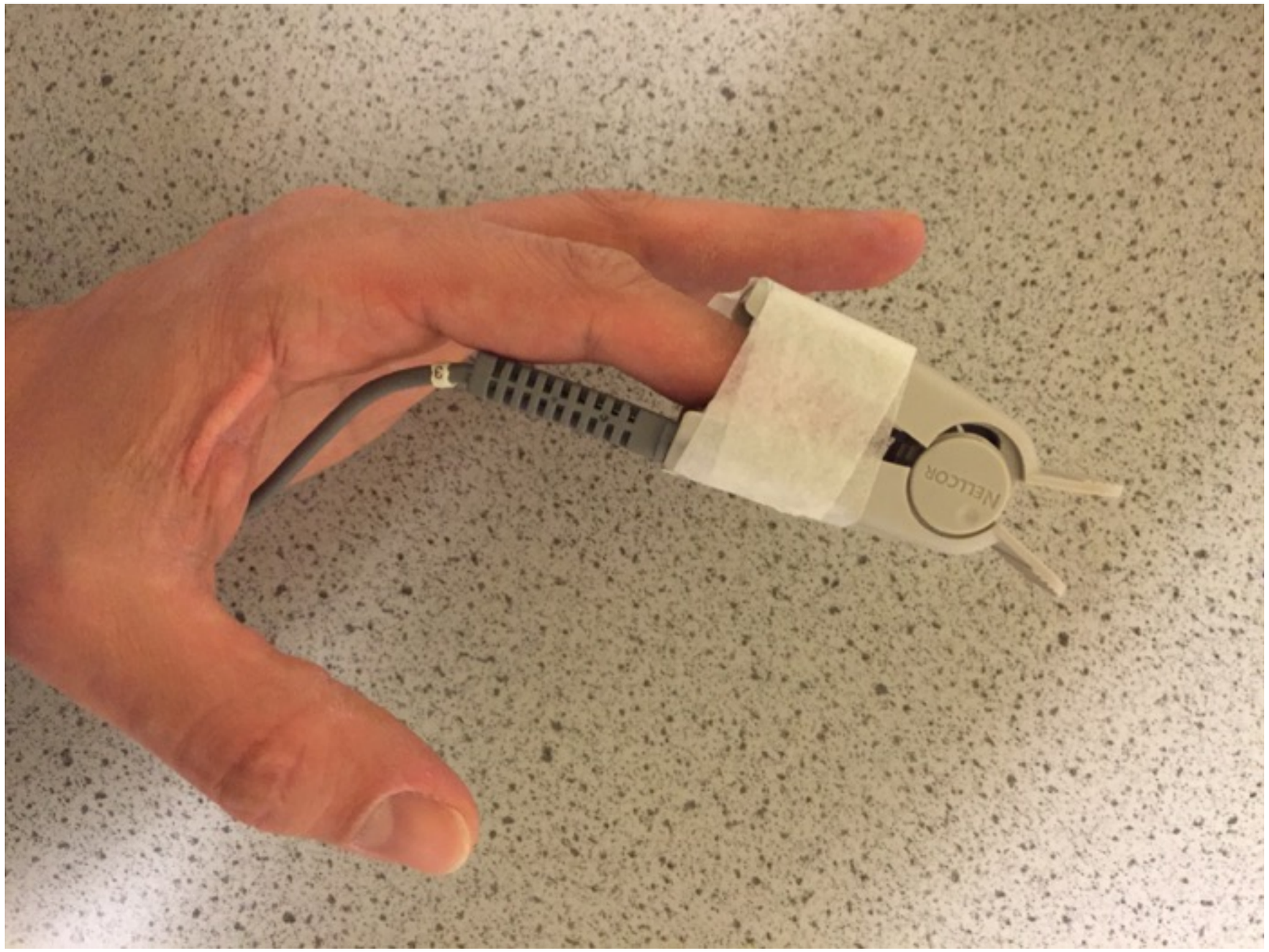

Implementation using DCCN equipment

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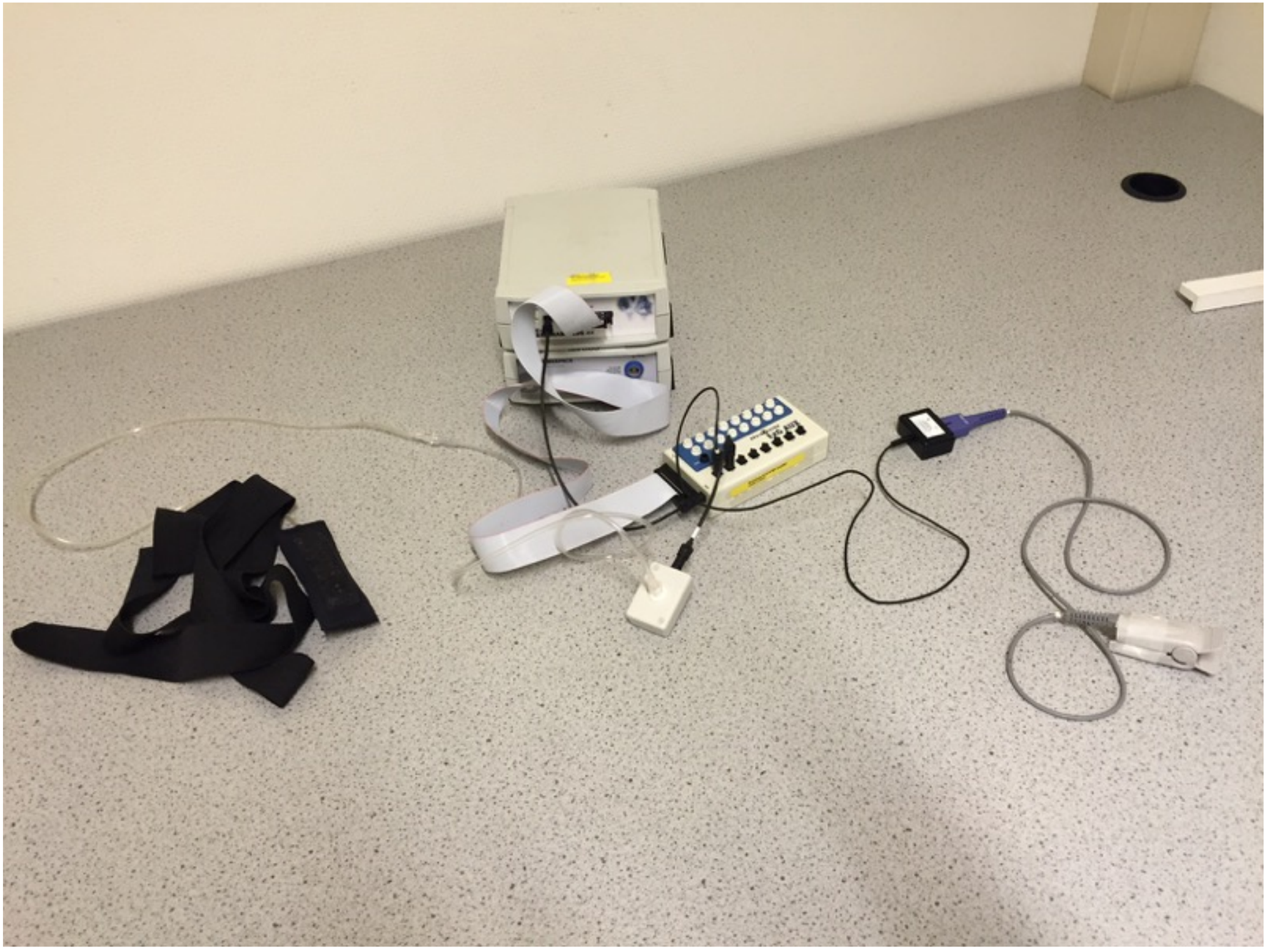
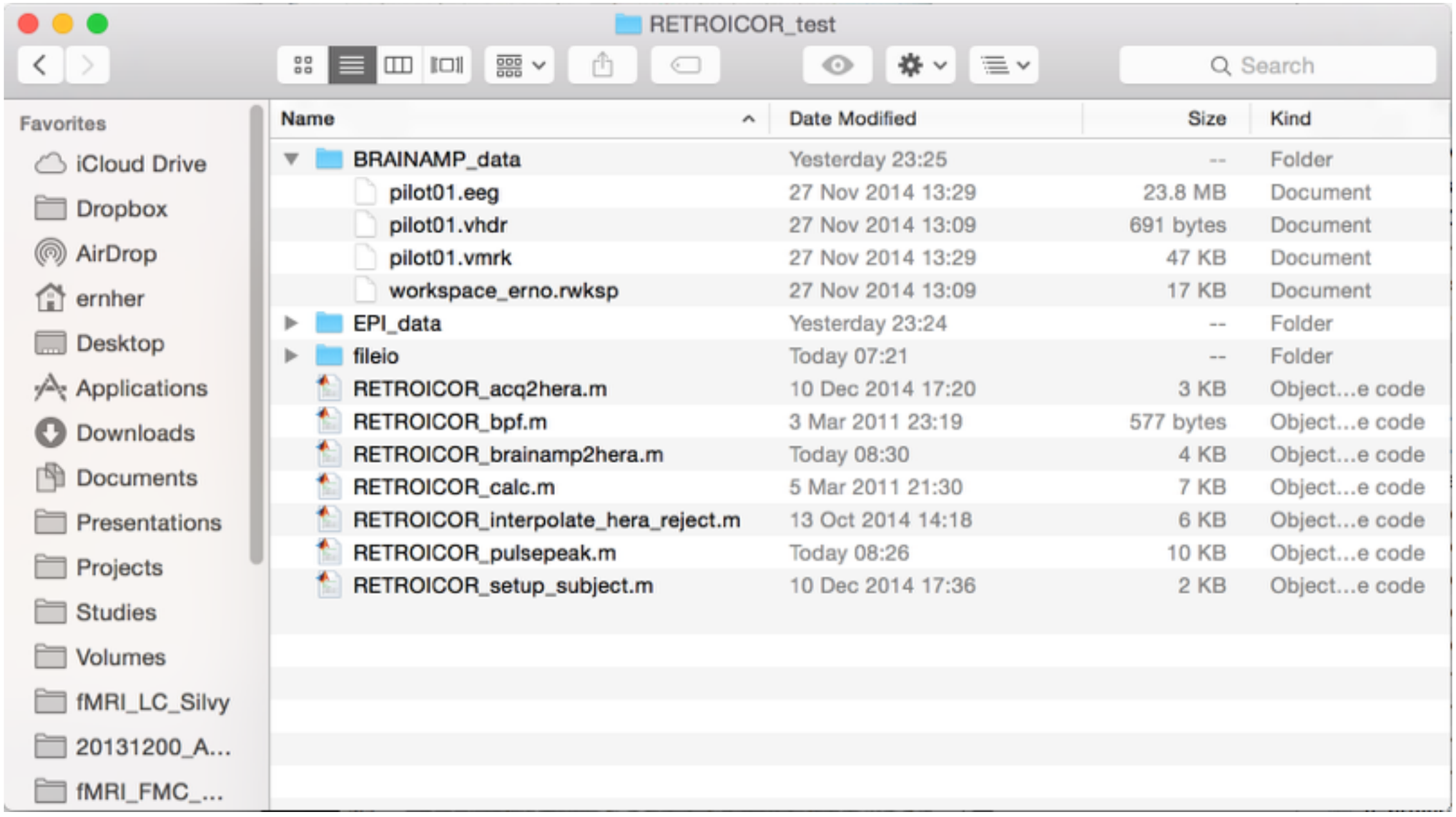


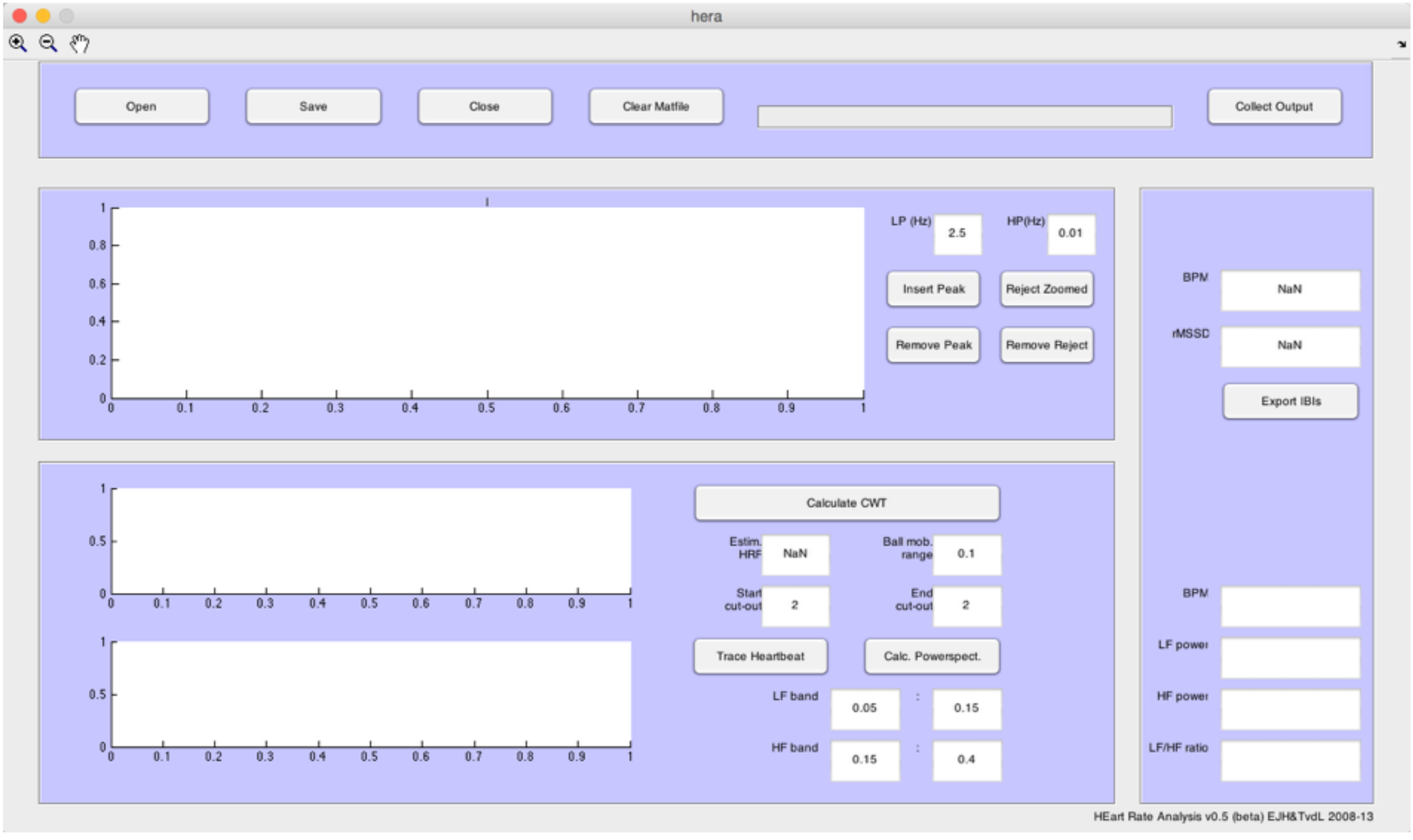
Implementation using DCCN equipment

.. but then with HR and respiration channels …

Implementation using DCCN equipment



HeRa toolbox



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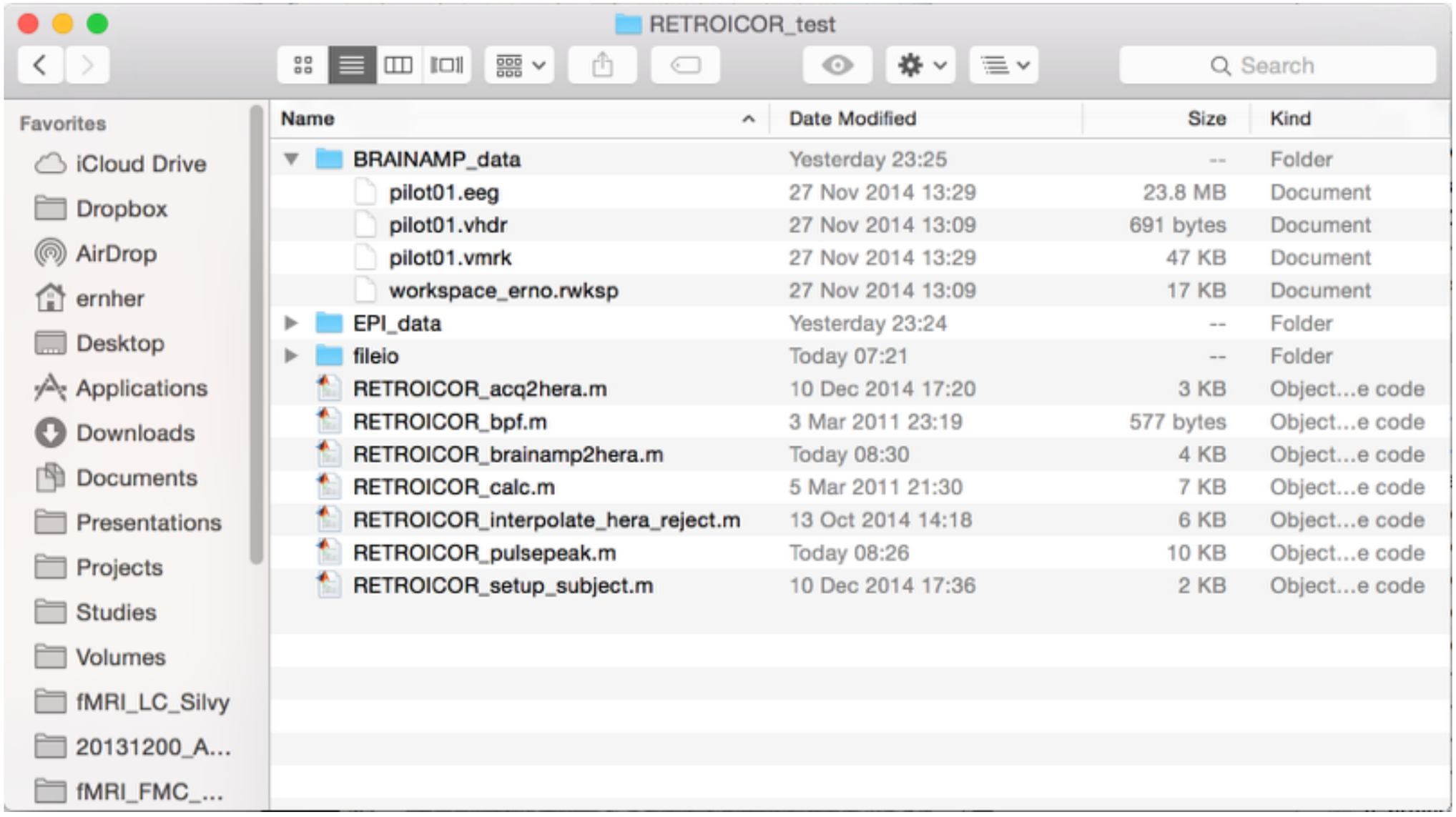

Conclusion / Discussion

- Connectivity with regions containing physiological noise may be problematic without physiological correction.
- Increasingly relevant for low-TR (eg multiband) imaging?
- Conventional task-based fMRI can gain reliability from physiological corrections (esp. first-level).
- Simple regression of heart rate / respiration frequency does not suffice, higher-order fourier series modeling is crucial (especially for heart rate).
- Physiological noise produces not only signal *modulation*, but also *movement*.
- Given differences in phase-locking of physiological signals across the brain, methods such as ICA may not fully capture cardiac noise.