Artefact Removal (Physiological)

Rasmus M. Birn, Ph.D.
Overview

• The Problem
  – Cardiac Fluctuations
  – Respiration

• Solutions

• Issues to consider
  – How can correction be improved?
  – What about global signal regression?
  – Should we correct for physiological noise?
Functional MRI

- Task-related Neuronal Activity
- Spontaneous Neuronal Activity
- Physiologic noise (cardiac, respiration)
- Subject motion
- Scanner instabilities
- Image reconstruction errors

Hemodynamics

resting state

Scanner
Physiological noise

Cardiac

M.S. Dagli et al., NeuroImage 9, 1999

Respiration

Field Map

$\Delta \Phi = 90^\circ$

TIME = 110 s

Figure courtesy of J. Bodurka
Physiological Noise

The brain is not a rigid body

Physio. fluctuations can occur at low frequencies

Variations in breathing during rest \(\rightarrow\) \(\Delta\)BOLD signal

\[ \Delta P_{ET} CO_2 \text{ correlated with } \Delta BOLD \]

R.G. Wise et al., NeuroImage 21, 2004
Resting fluctuations in respiration

$RVT = \frac{\text{Respiration Volume}}{\text{Time}}$

RVT-related changes

group (n=11)
Effects of Heart Rate

C. Chang et al., Neuroimage 2009
Heart Rate

Birn et al. (unpublished)
Impact of Physiological Noise

...on fMRI

Resting-state Functional Connectivity
Resting-state Functional Connectivity

resting state

\[ t \]

\[ t \]
Independent Component Analysis

space (voxels) \( \rightarrow \) time \( \rightarrow \) components

\( \text{x} \)

space (voxels) \( \rightarrow \) time \( \rightarrow \) components

Component #1

Component #2
Tools to correct for physiological noise

- Filtering - Works only if TR is short enough (< 400ms)
- IMPACT \( (\text{Chuang et al., 2001}) \) – if TR short enough
- Retrospective correction (k-space) \( (\text{X. Hu et al., 1995}) \)
- RETROICOR \( (\text{Glover et al., 2000}) \)
- CORSICA \( (\text{V. Pelbarg, et al., 2007}) \)
- PESTICA \( (\text{E.B. Beall, et al., 2007}) \)
- RVTcor \( (\text{R.M. Birn, et al., 2006}) \)
- RVHRcor \( (\text{C. Chang, et al., 2009}) \)
- ANATICOR \( (\text{H-J. Jo, et al.,}) \)
- APPLECOR, PEARCOR \( (\text{M Marx, et al., 2013}) \)
- PSTCor \( (\text{J.S. Anderson, et al., 2011}) \)
- CompCor \( (\text{Y. Behzadi, et al., 2007}) \)
- FIX \( (\text{L. Griffanti, et al., 2014}) \)
Can filtering (<0.1Hz) reduce cardiac noise?

- Not always: **Aliasing**
Correction of physiological noise


---

Additional Regressors:

\[
\begin{align*}
\sin( \phi_c ) \\
\cos( \phi_c ) \\
\sin( 2\phi_c ) \\
\cos( 2\phi_c ) \\
\sin( \phi_r ) \\
\cos( \phi_r ) \\
\sin( 2\phi_r ) \\
\cos( 2\phi_r )
\end{align*}
\]
Correction of physiological noise

Reshuffle the data based on its cardiac or respiration phase
Resting fluctuations in respiration

$RVT = \text{Respiration Volume per Time}$

RVT-related changes

“Connectivity” with Post.Cing.

group (n=11)

R.M. Birn et al. 2006
RVHRcor (Respiration Volume + Heart Rate)

C. Chang et al., Neuroimage 2009
Nuisance Regression

H.J. Jo et al., NeuroImage 52, 2010
PSTCor (Phase-shifted Soft Tissue Corr.)

J.S. Anderson et al., HBM 32, 2011
“FIX” (FMRIB’s ICA-based X-noisifier)

L. Griffanti, et al., Neuroimage 2014
Issues
Removing RVT results in only small differences

Correlation (of PC) at Rest after RETROICOR

Correlation (of PC) at Rest after RETROICOR + RVTcor

... on group maps

Group (n=10)

R.M. Birn et al. 2006
Std. Dev. maps

R.M. Birn et al. 2006
RRF varies across the brain

Optimal latency of Respiration Response Function (RRF)

Birn et al., 2008
Optimal latency of Respiration Response Function (RRF)

Birn et al.
Subject Specific physiological models

M. Falahpour et al., Neuroimage 2013
What about global signal regression?

Connectivity maps

without global regression

with global regression
Global Signal Regression

**Can introduce anti-correlations**

*K. Murphy, et al., Neuroimage, 2008*
Global Signal Regression

Can alter group differences …under certain conditions

Illustrative Model 3:
Contrast of correlations between groups A and B
‘long-range’ correlations in Group B only

Pre-GSReg  Post-GSReg  Post-GSReg

Group A
Local Corr. Only

3
2
1

Group B
Local and Long Range Corr.

"local" correlations  "long-range" correlations

$r^*_B - r^*_A$

$\ r\text{-value}$
Alternatives to Global Signal Regression

Regress out white matter and CSF

1: Left Lateral
2: Right Lateral
3: Third
4: Fourth

H.J. Jo et al., NeuroImage 52, 2010
At what stage should physio correction be done?

• Preprocessing
  – Motion correction
  – **Physiological noise correction**
  – Slice time correction
  – Nuisance Regression
  – Spatial Smoothing
  – Convert to percent signal change
  – Temporal filter
• Define ROI (seed)
• Average EPI time course over ROI
• Regression

*T.B. Jones et al., Neuroimage 42, 2008*
Should we perform physio corrections?

- Reduces fluctuations related to heart beat and respiration
  - Reduce false positives
  - Reduce false negatives

- Some physiological fluctuations are associated with neuronal activity
  - E.g. Heart rate variability

_This is still an open question in the field_