



Effect of Acquisition Parameters on Physiological Noise in fMRI at 1.5T, 3T and 7T



Christina Triantafyllou¹, Richard D. Hoge¹, Gunnar Krueger², Christopher J. Wiggins¹,
Andreas Potthast², Graham C. Wiggins¹, Lawrence L. Wald¹

¹MGH/MIT/HMS A.A. Martinos Center for Biomedical Imaging, Charlestown, MA, USA

²Siemens Medical Solutions, Erlangen, Germany

christin@nmr.mgh.harvard.edu

AIM:

Investigate dependence of resting brain Physiological Noise (PN) amplitude on:

Field Strength (1.5T, 3T, 7T)

Flip Angle

Image SNR

Image Resolution

Image TE

Model the time-course noise in fMRI and estimate the individual PN components. Model follows: [*Krueger, MRM 46, p631, 2001*]

Noise Modeling

$$\sigma = \sqrt{\sigma_0^2 + \sigma_P^2}$$

$$\sigma_P = \sqrt{\sigma_B^2 + \sigma_{NB}^2}$$

Thermal
→ Subject
→ Electronics

Physiological
→ Cardiac
→ Respiratory
→ Basal Cerebral Metabolism, CBF, CBV System
→ Gain instabilities

BOLD-like
→ R_2^* fluctuations, causing signal changes in T_2^* -weighted images.
Hemodynamic fluctuations that alter images by same mechanism BOLD does

Non-BOLD
→ Respiratory
→ Cardiac effects

Signal Independent

Scales with Signal (S)

$$\sigma_B = c_1 \cdot \Delta R_2^* \cdot TE \cdot S$$

$$\sigma_{NB} = c_2 \cdot S$$

tSNR : SNR across time series
SNR₀ : Image SNR

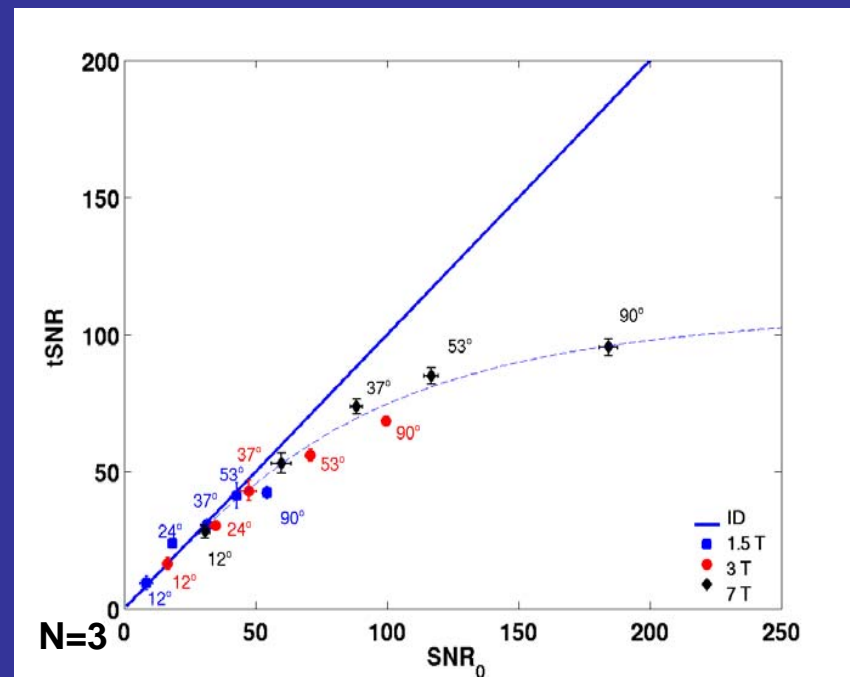
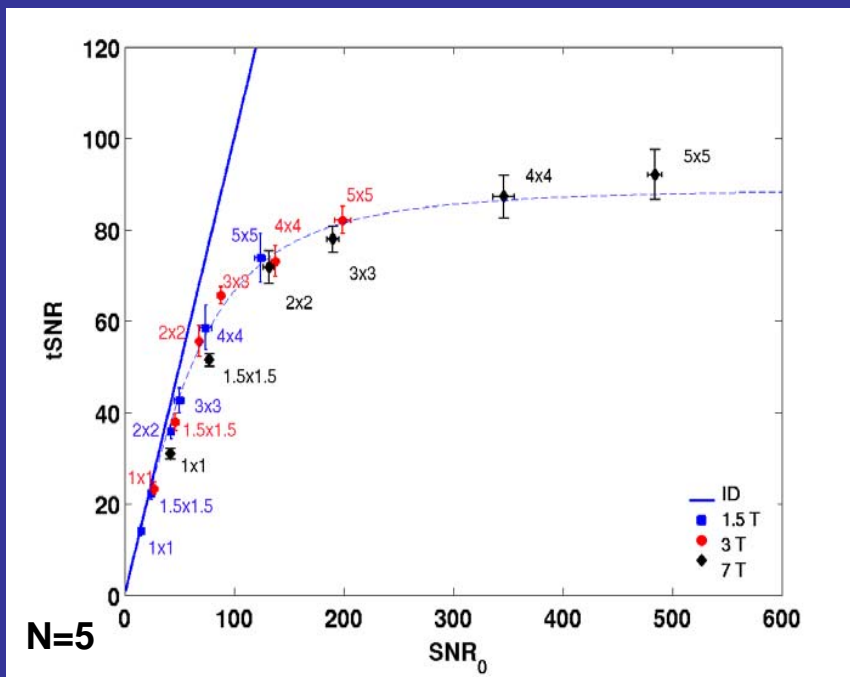
$$tSNR = \frac{SNR_0}{\sqrt{1 + \lambda^2 \cdot SNR_0^2}}$$

$$\frac{\sigma_P}{\sigma_0} = \sqrt{\left(\frac{SNR_0}{tSNR}\right)^2 - 1}$$

$$\lambda^2 = c_1^2 \cdot \Delta R_2^{*2} \cdot TE^2 + c_2^2$$

For typical fMRI parameters at 3T: σ_P is ~3 fold higher than σ_0 (GM), σ_B ~2 fold higher than σ_{NB} (GM)
[Krueger, MRM 46, p631, 2001]

Image SNR modulated by in-plane spatial resolution (3mm slice), flip angle and field strength

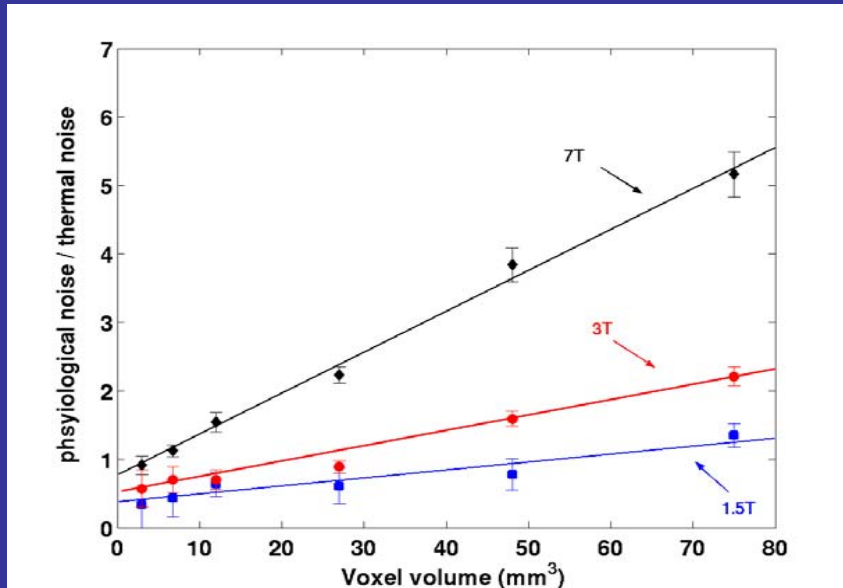


σ_p / σ_0 as a function of spatial resolution

Resol. (mm ²)	7T σ_p / σ_0	3T σ_p / σ_0	1.5T σ_p / σ_0
1.5x1.5	1.12±0.09	0.70±0.19	0.43±0.27
3x3	2.23±0.12	0.89±0.09	0.61±0.26
5x5	5.16±0.33	2.21±0.14	1.35±0.17

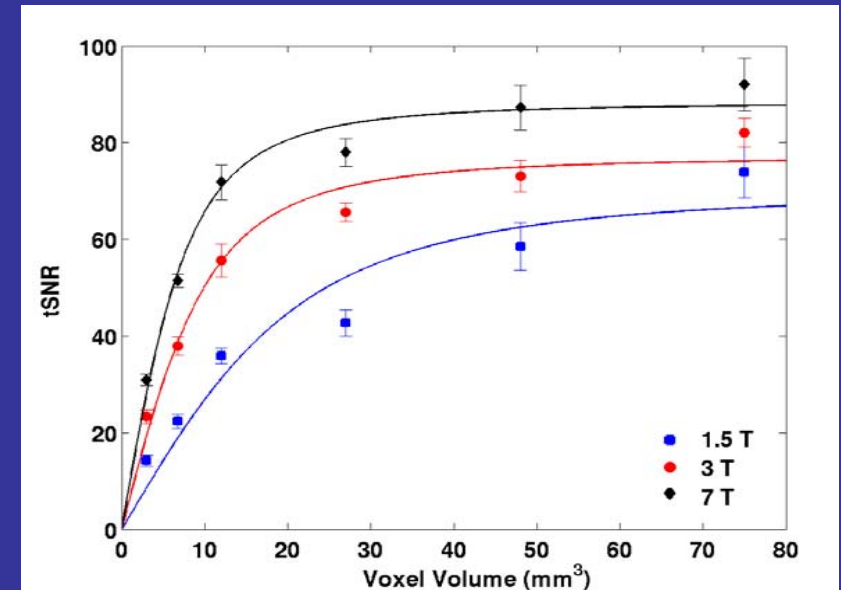
Acquiring fMRI images at higher resolution, we operate in a regime where thermal image noise dominates physiological noise. Increased image SNR (at 7T) still translates improved time-course SNR.

σ_p / σ_0 as a function of voxel size



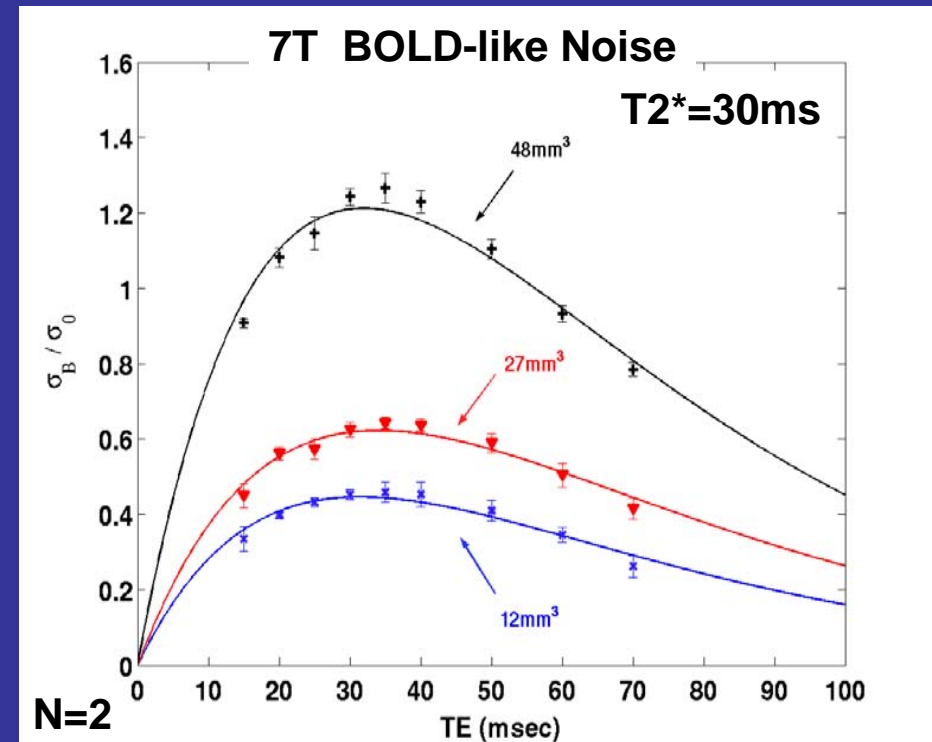
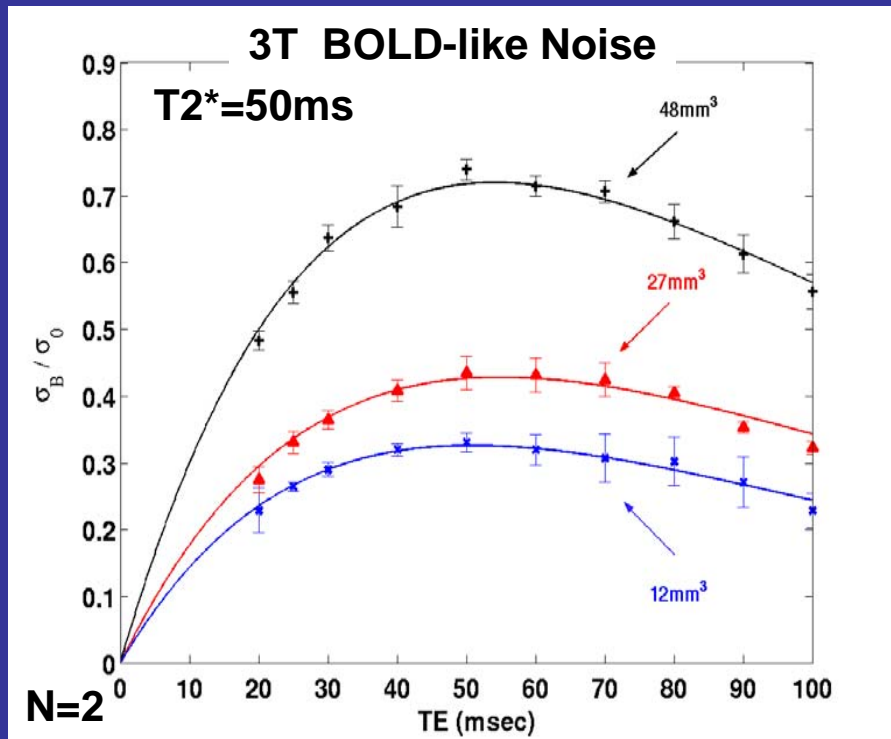
- Thermal noise dominance can be achieved at any field strength with high enough spatial resolution.
- Improvements in image SNR (RF coils, 7T etc.) translate to improved tSNR.

tSNR as a function of voxel volume



- Biggest gain in tSNR occurs at higher resolutions.
- At all field strengths tSNR is asymptotic for coarser resolutions.

'BOLD – like' physiological noise as a function of TE



- Modulate TE to separate relative contribution of the 'BOLD-like' and 'nonBOLD-like' components of the physiological noise.
- Maximum occurs at $TE=T2^*$, as imposed by the BOLD contrast model.
- The 'BOLD-like' component increases relative to the thermal noise for bigger voxel size and field strength.

- Temporal SNR plateaus at high image SNR; especially bad at low spatial resolutions and high field strengths (7T).
- At high spatial resolutions tSNR is not dominated by physiological noise.
- With appropriate imaging parameters can obtain thermal noise dominated images at all field strengths.
- Hemodynamic fluctuations in gray matter (σ_B) are dominant at 7T;
 - Might reveal important information about*
 - resting brain physiology*
 - resting brain neuronal activity - connectivity revealed in the spatial and temporal correlations of the PN*
 - [Biswal B, MRM 34, p537, 1995].*