

Comparison of Oscillating Steady State to GRE BOLD for fMRI

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Declaration of Financial Interests or Relationships

Speaker Name: Shouchang Guo

I have no financial interests or relationships to disclose with regard to the subject matter of this presentation.

Signal-to-Noise Ratio (SNR) for fMRI

- High SNR → high-resolution fMRI

$$\text{SNR} \propto m_0 V \sqrt{T_{\text{Acquisition}}}$$

- Limited SNR improvement from current methods

Array coils suffers from diminished returns

Higher magnetic field system requires costly investment

- **Goal: a new steady-state fMRI acquisition method**
high-resolution fMRI with improved SNR

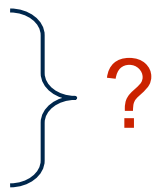
Steady-State Sequences

spoiled steady state

- constant gradient dephasing
- quadratic phase sequences

balanced steady state

- balanced gradients
- constant phase increment



Quadratic Phase Sequence with Balanced Gradients

RF quadratic phase cycling, periodic with cycle length n_c

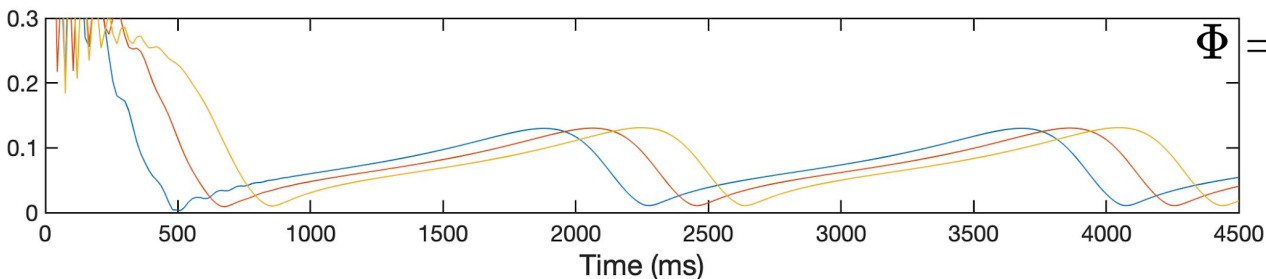
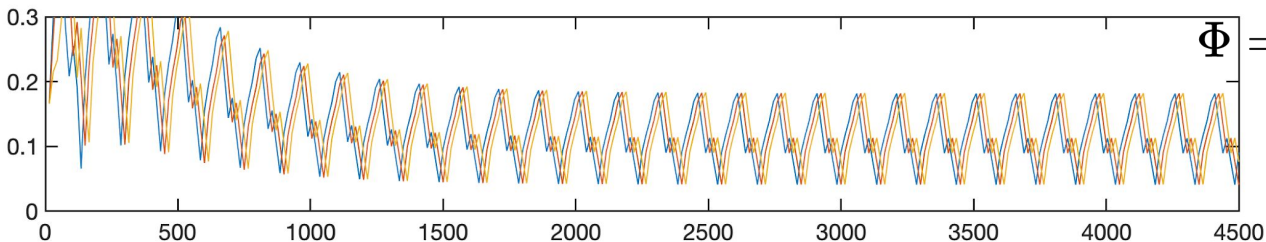
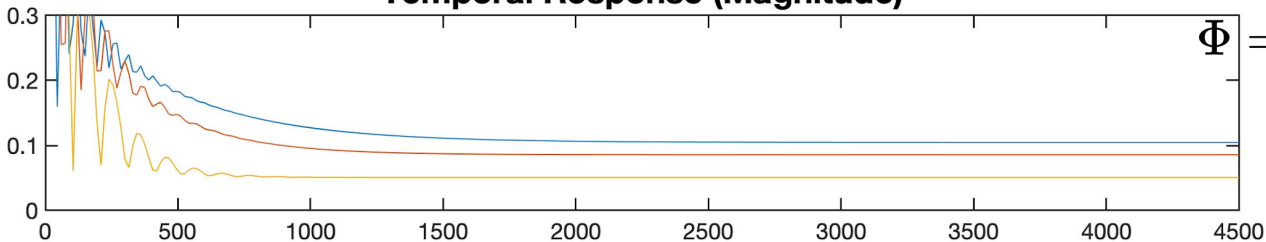
$$\Phi(n) = \frac{\pi}{n_c} n^2$$

- $n_c = 1$, $\Delta\Phi = 180^\circ$, bSSFP, trueFSIP, FIESTA, ...
- $n_c > 120$, very small $\Delta\Phi$, bSSFP equivalent¹
- What if **$1 < n_c < 120$ with large $\Delta\Phi$**

[1] Foxall, MRM, 2002

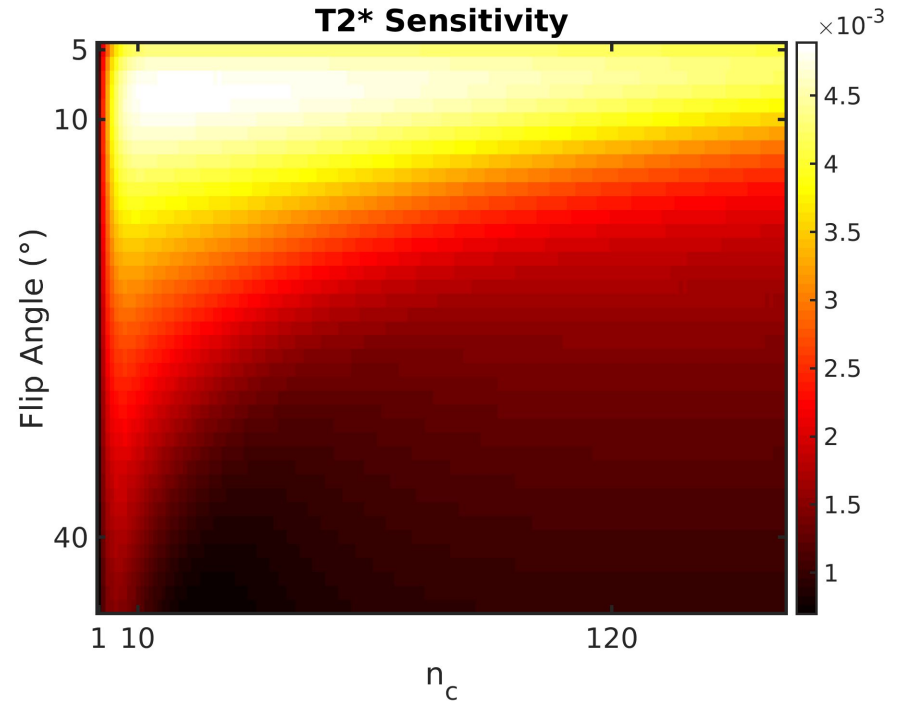
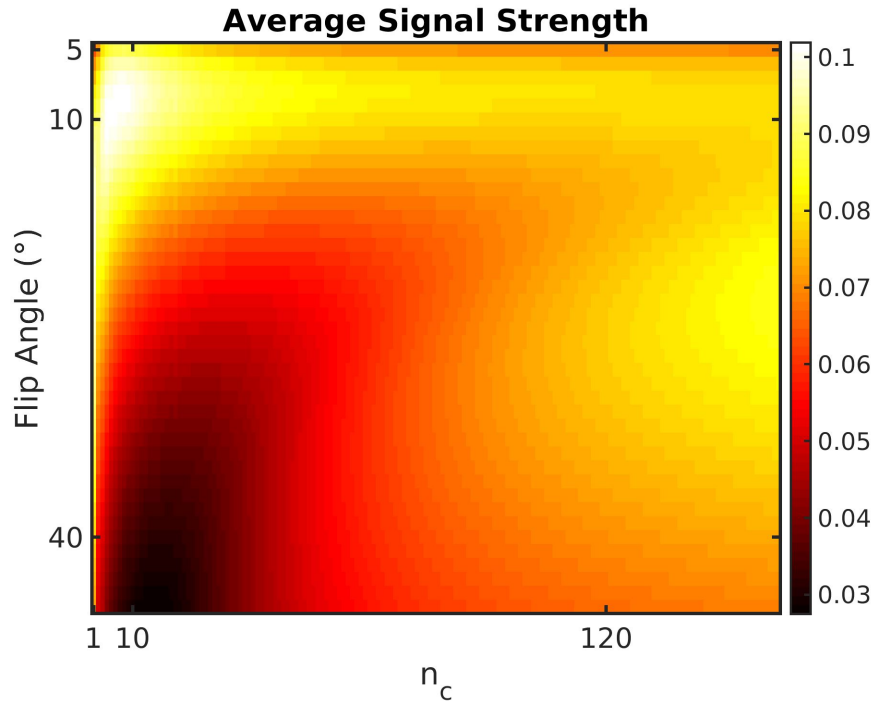
Oscillating Steady-State Imaging (OSSI)

Temporal Response (Magnitude)

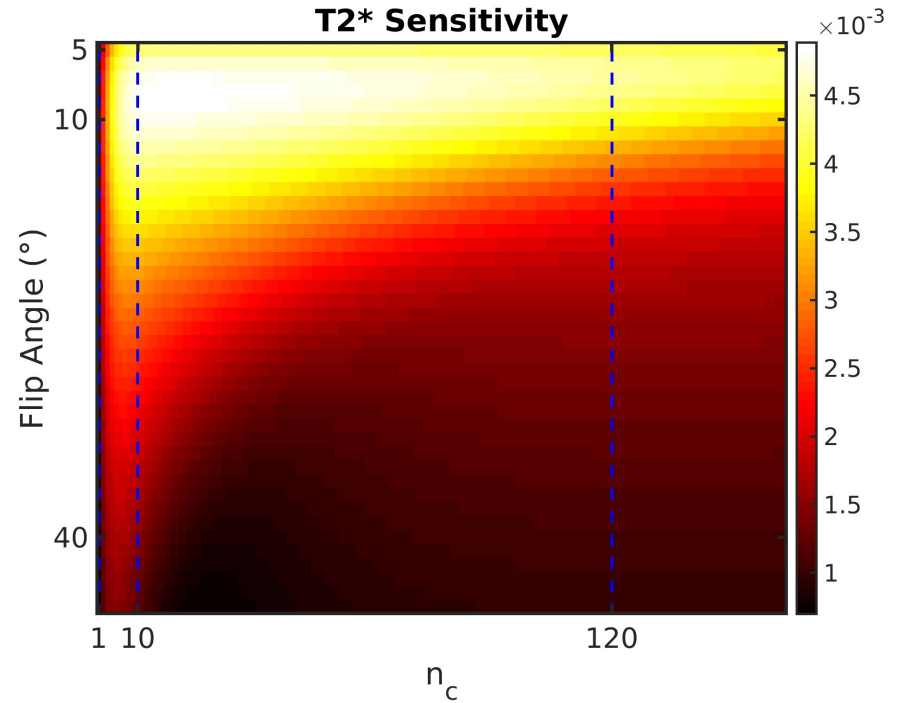
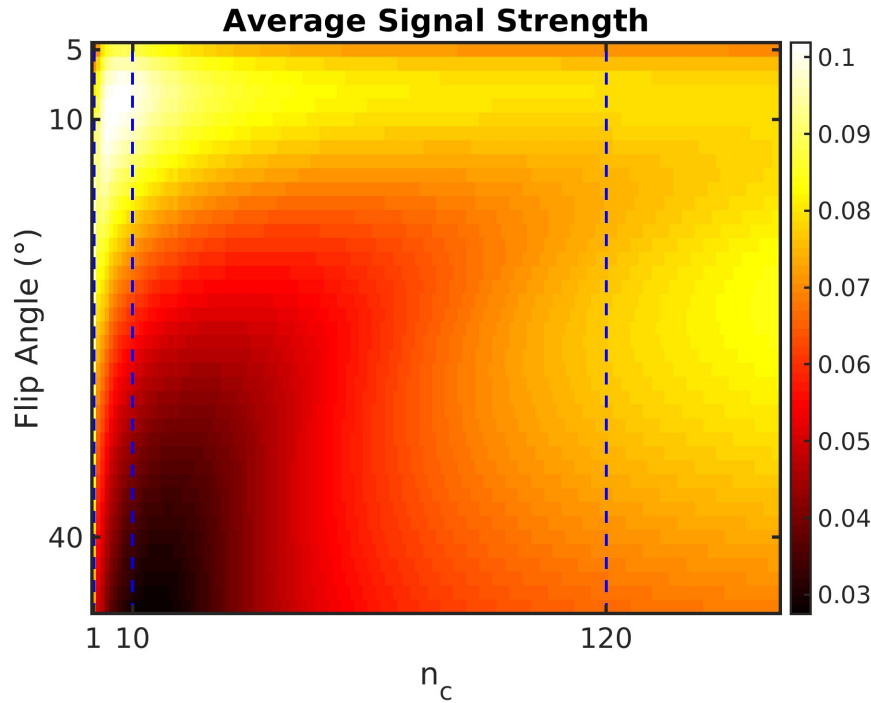


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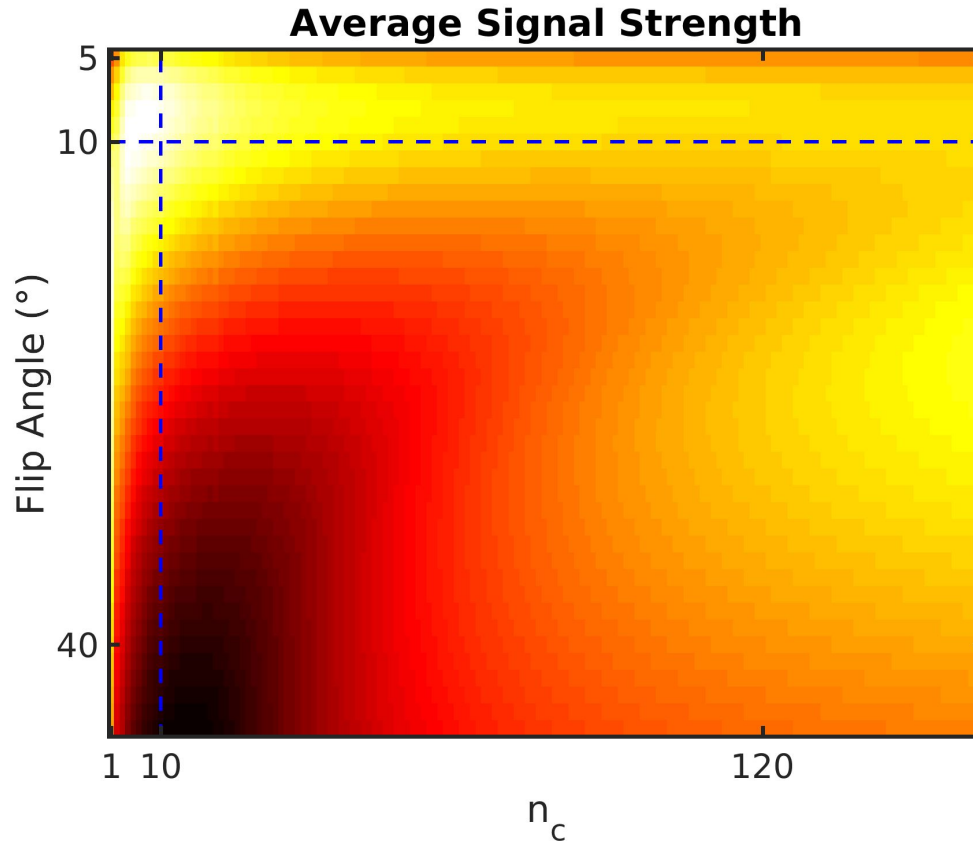
OSSI Signal and T2* Sensitivity



OSSI Signal and T2* Sensitivity

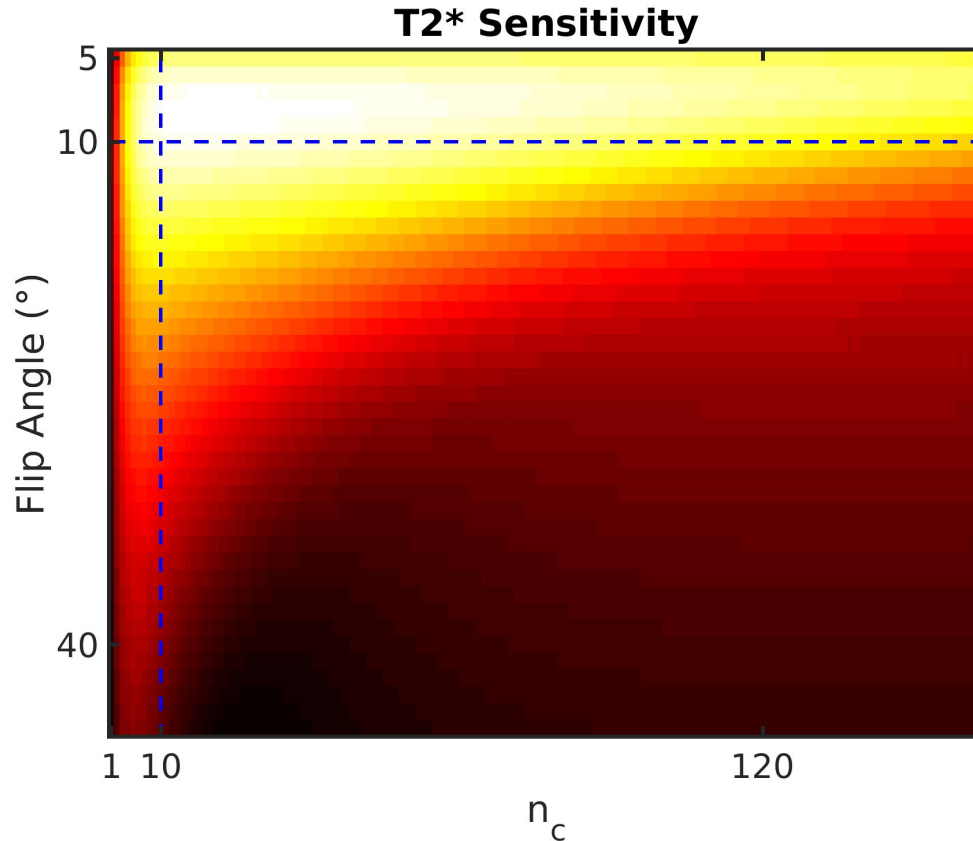


OSSI Parameter Optimization



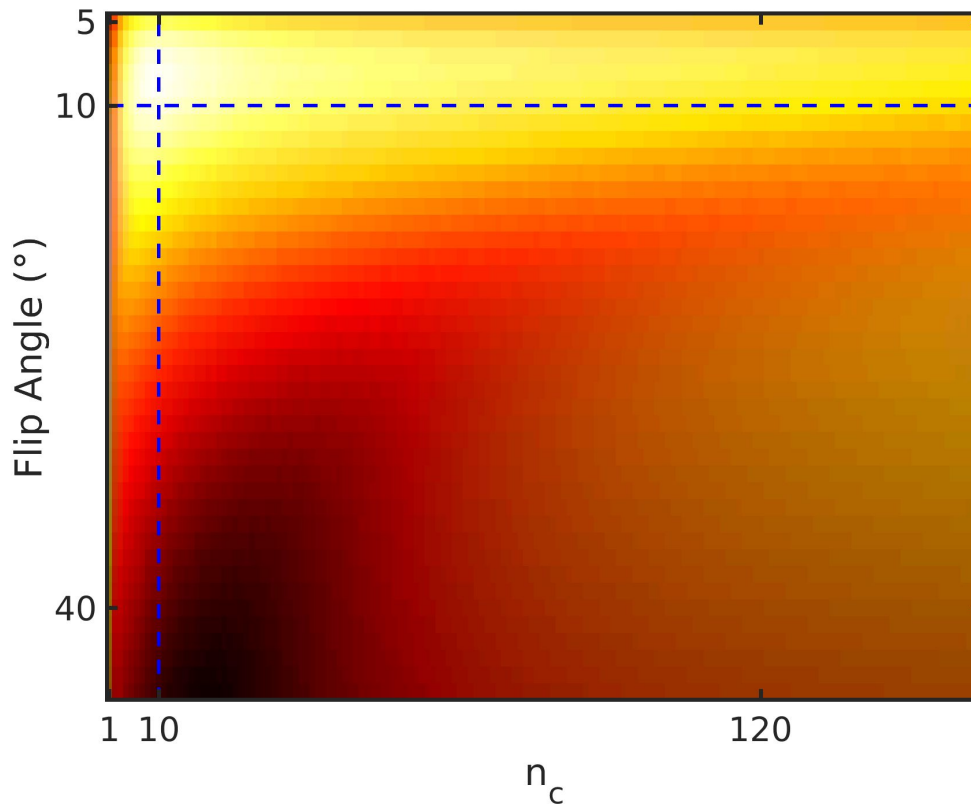
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OSSI Parameter Optimization



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OSSI Parameter Optimization



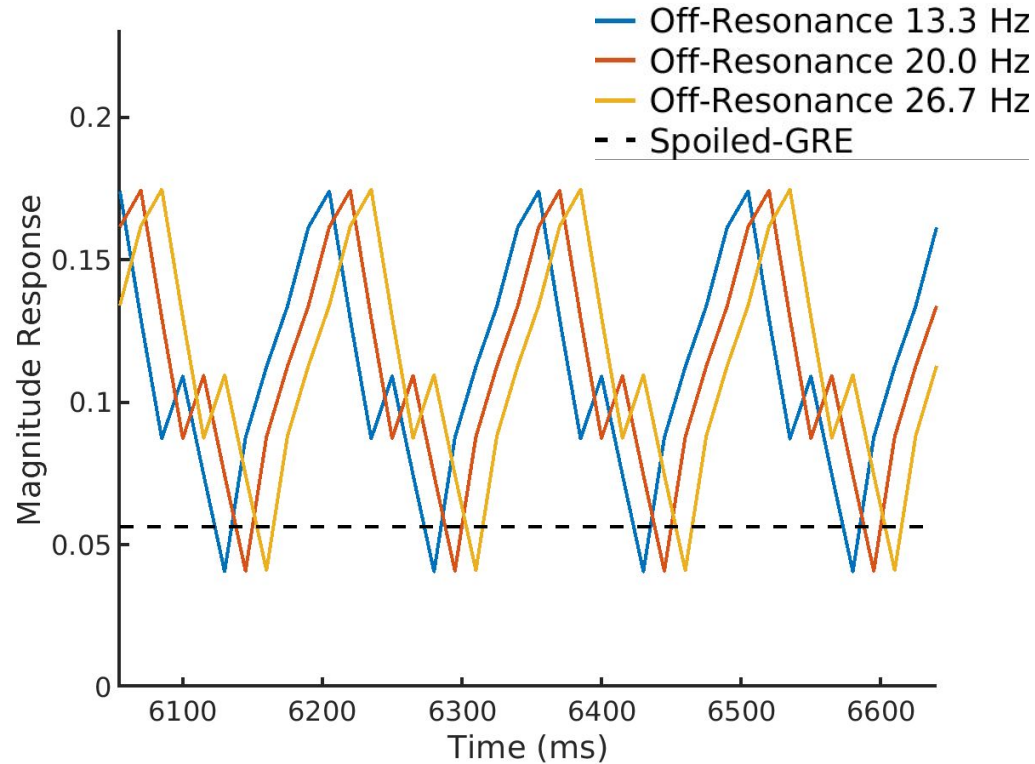
$$n_c = 10$$

$$\text{FA} = 10^\circ$$

$$\text{TR} = 15 \text{ ms}$$

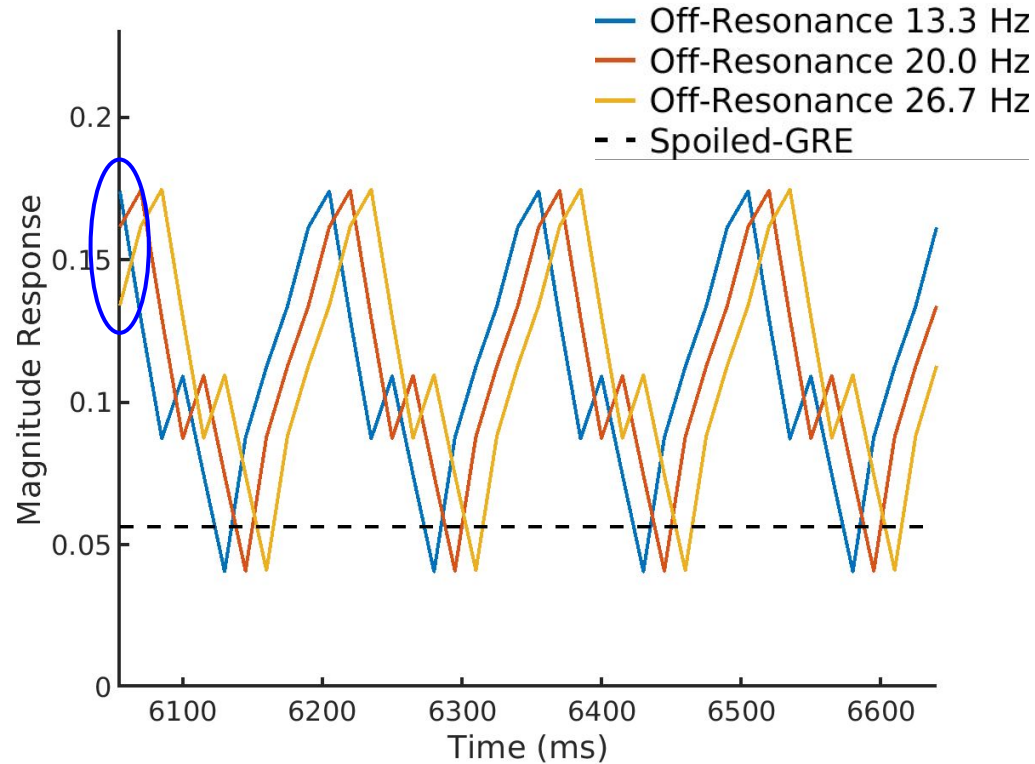
OSSI - compared to GRE

- 2 times larger, oscillates with periodicity $n_c TR$



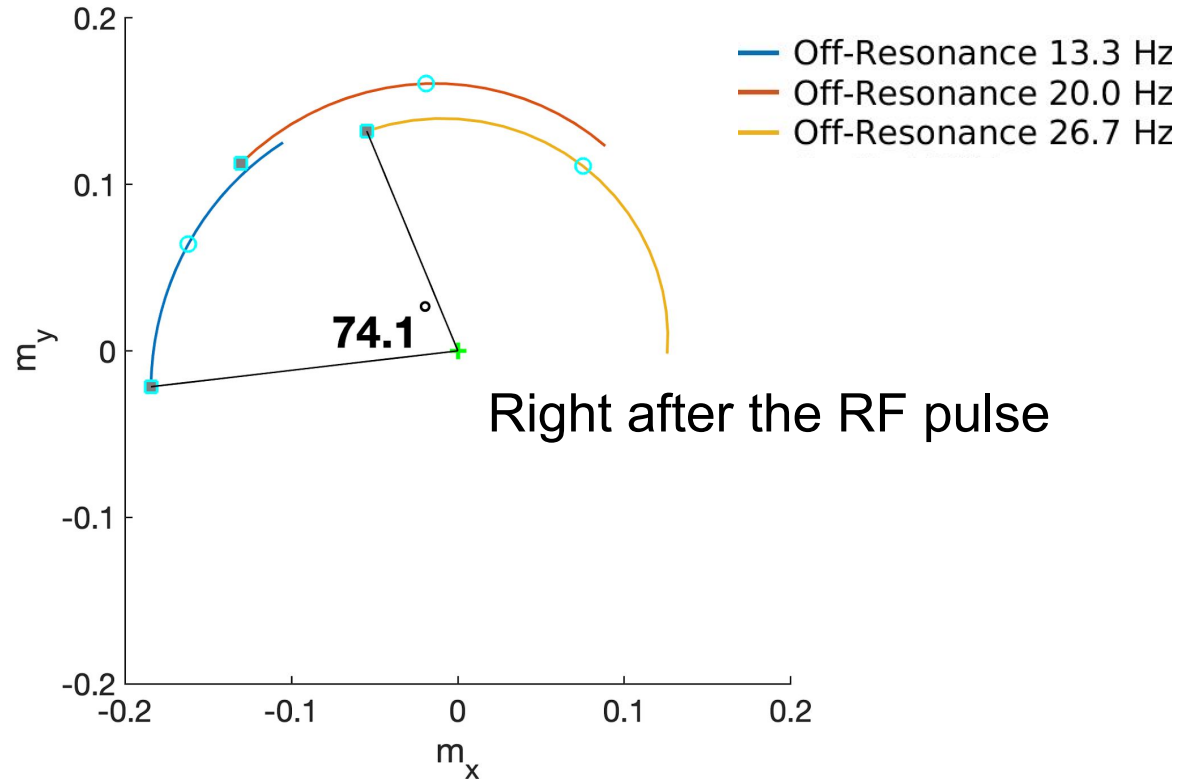
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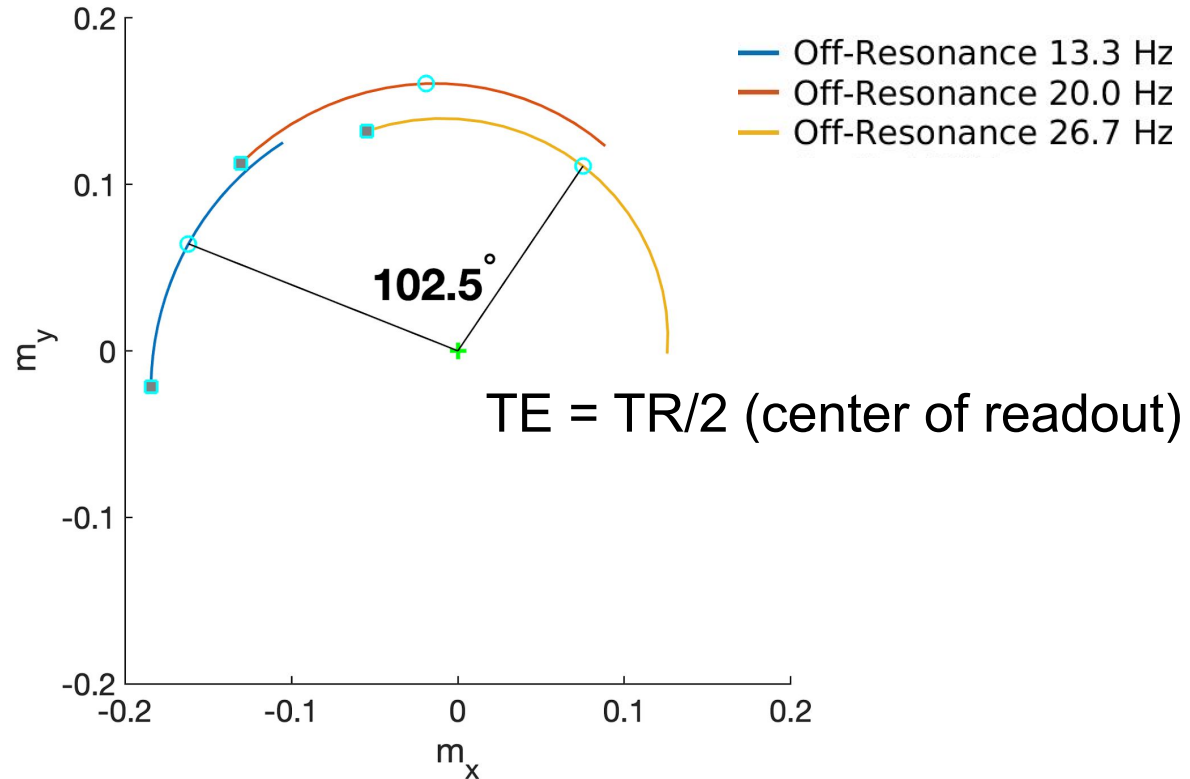
OSSI - T2*-weighting

- MR signal at 1 TR for 3 different isochromats



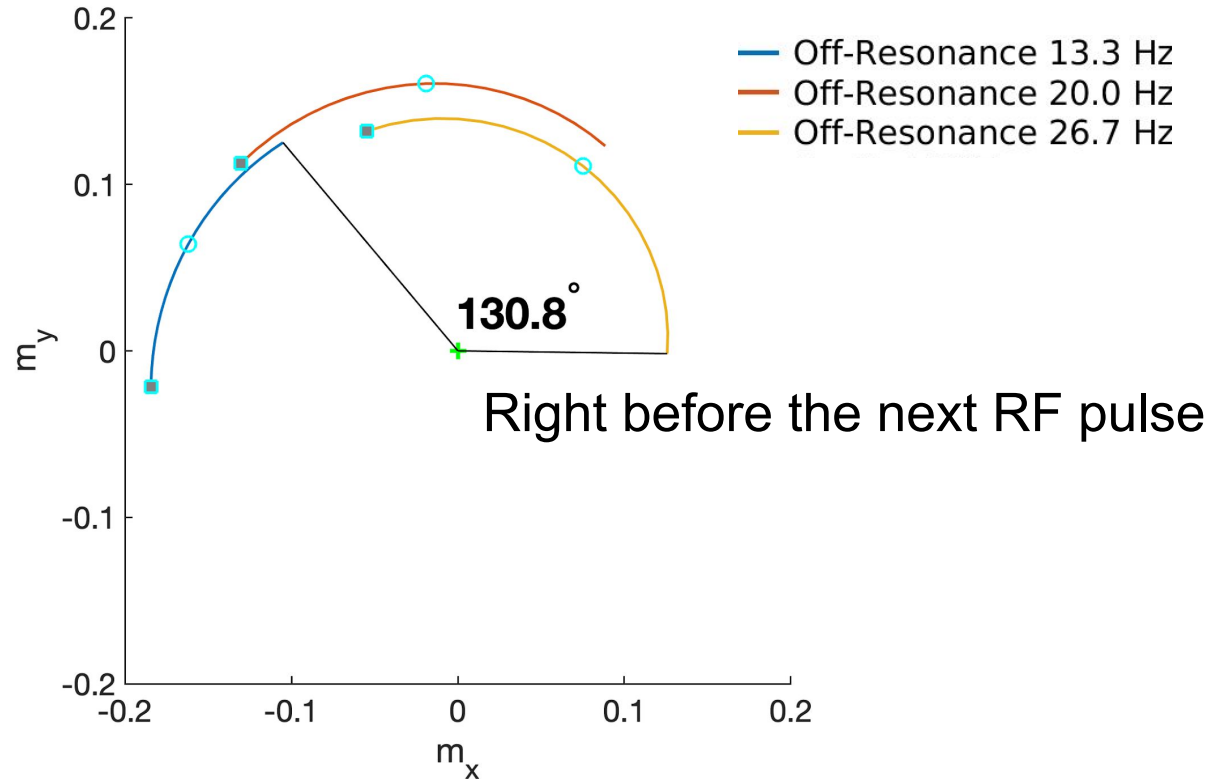
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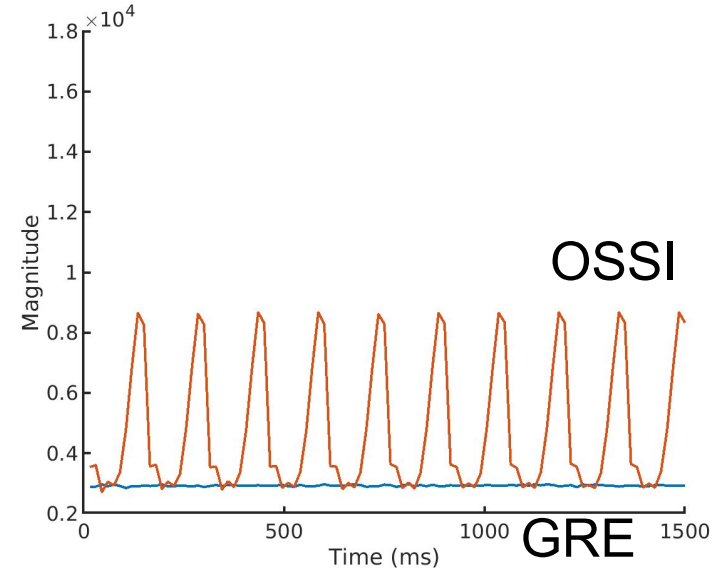
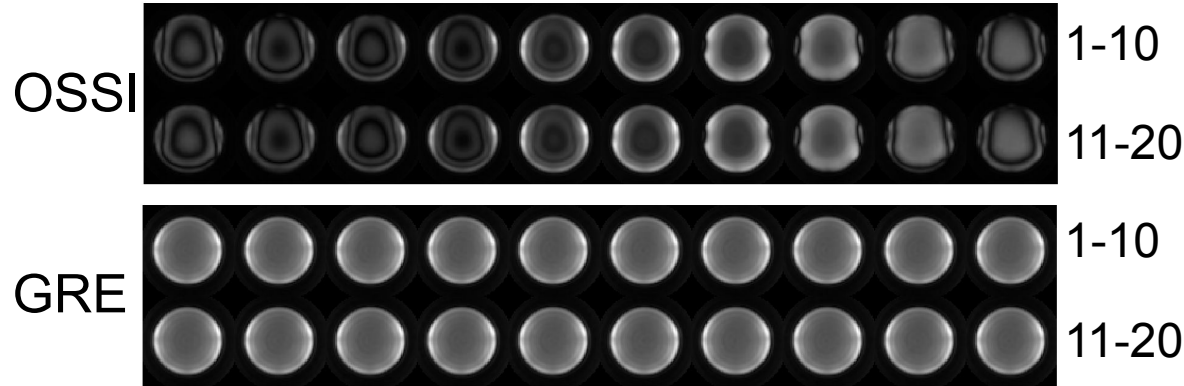
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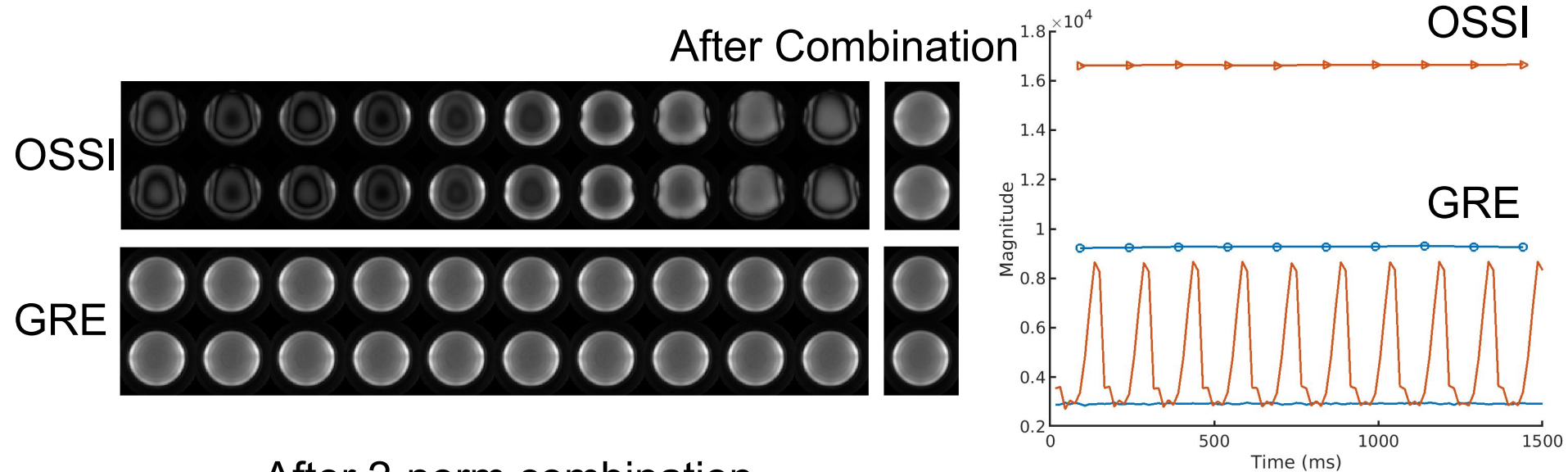
Phantom Experiments

Periodic, reproducible oscillation pattern



Comparison of Oscillating Steady State to GRE BOLD for fMRI

Phantom Experiments



After 2-norm combination

- Stable signal suitable for fMRI
- 2 times larger strength compared to GRE

Comparison of Oscillating Steady State to GRE BOLD for fMRI

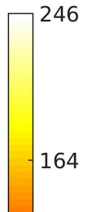
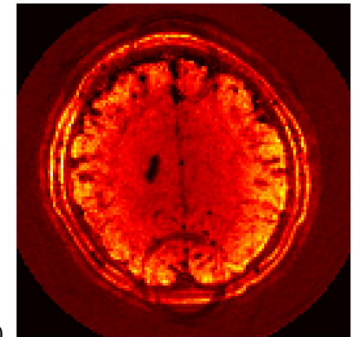
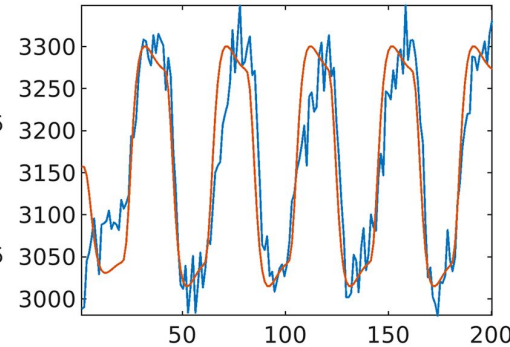
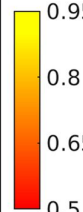
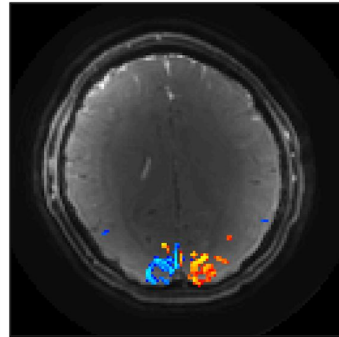
Human fMRI Experiments (Spiral-Out)

Activation Map

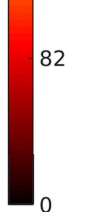
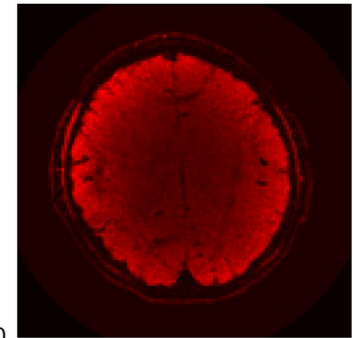
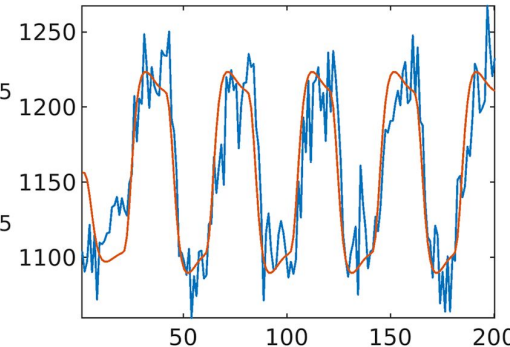
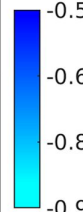
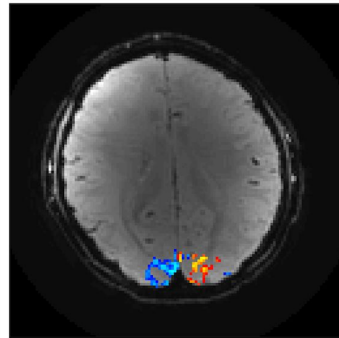
Time Course

tSNR Map

OSSI



GRE



Left vs. right reversing-checkboard visual stimulus

Comparison of Oscillating Steady State to GRE BOLD for fMRI

OSSI TR = 15 ms
nc = 10, FA = 10°
interleaves = 8
TE = 2.7 ms

GRE TR = 150 ms
Ernst FA = 27°
interleaves = 8
TE = 23 ms

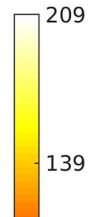
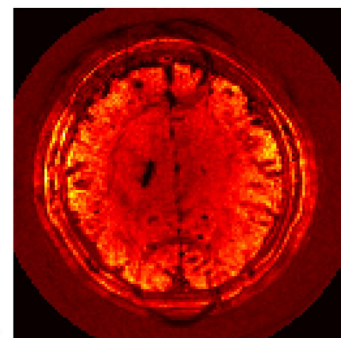
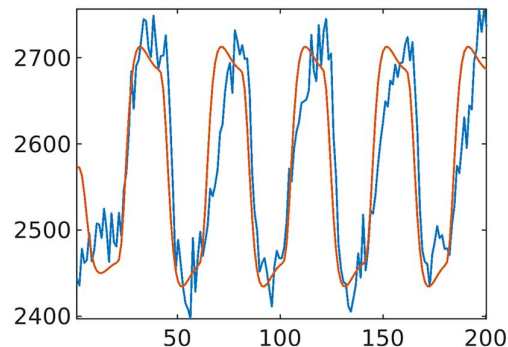
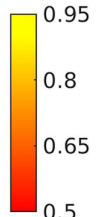
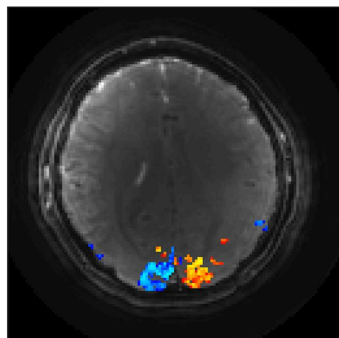
Human fMRI Experiments (Spiral-In)

Activation Map

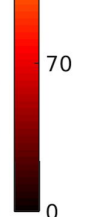
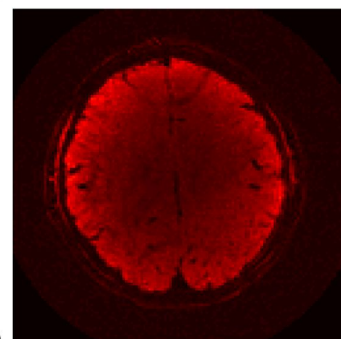
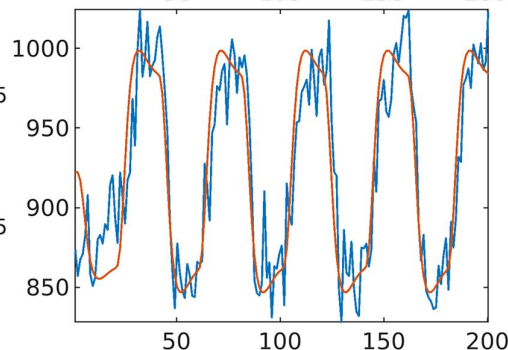
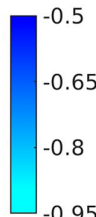
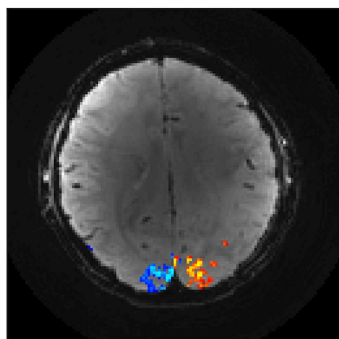
Time Course

tSNR Map

OSSI



GRE



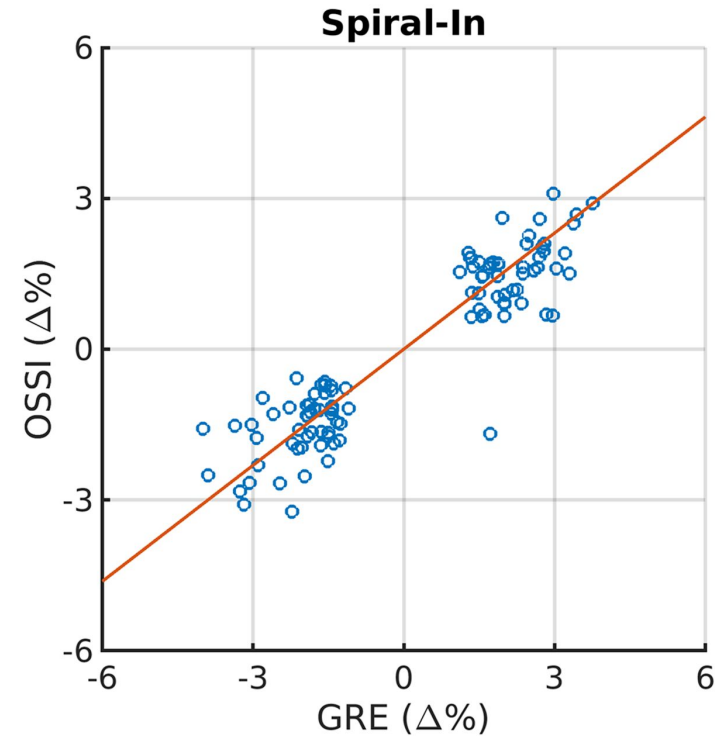
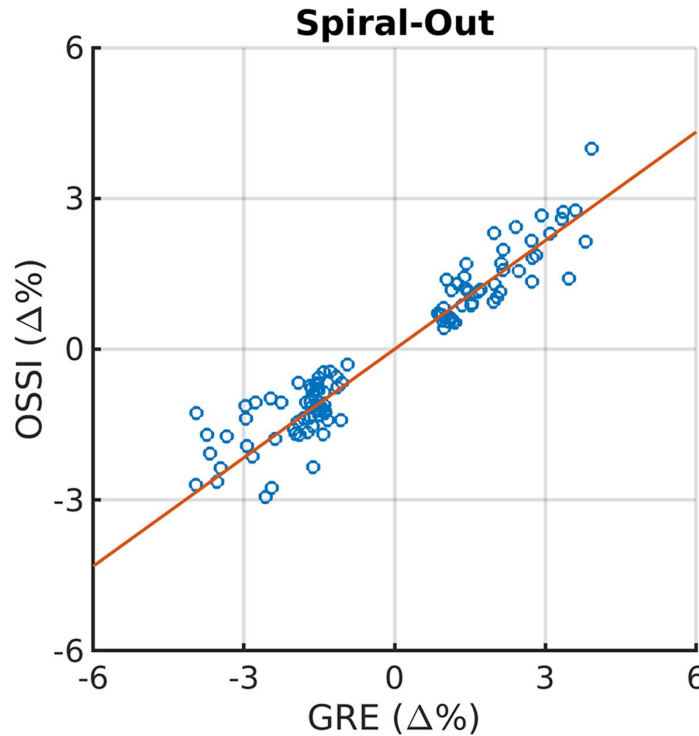
Left vs. right reversing-checkboard visual stimulus

Comparison of Oscillating Steady State to GRE BOLD for fMRI

OSSI TR = 15 ms
nc = 10, FA = 10°
interleaves = 8
TE = 11.6 ms

GRE TR = 150 ms
Ernst FA = 27°
interleaves = 8
TE = 33 ms

OSSI - GRE, Similar Contrast Mechanism



$$\Delta\% = \Delta R'_2 \cdot TE$$

$$TE_{\text{eff}} = b \cdot TE_{\text{GRE}}$$

Extra T2*-weighting of 15 ms right after RF pulse

Comparison of Oscillating Steady State to GRE BOLD for fMRI

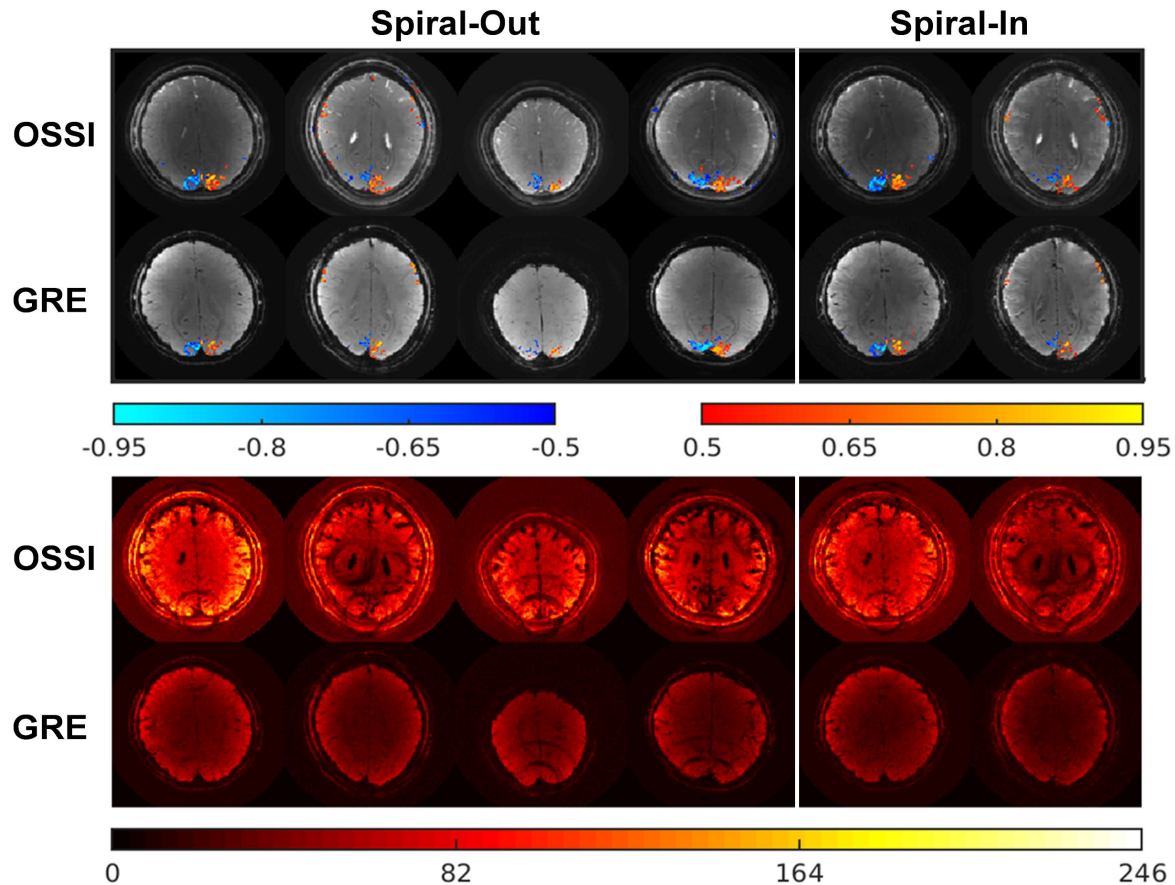
6 Human fMRI Experiments

activated voxels

OSSI-GRE Ratio: 1.5

Average tSNR

OSSI-GRE Ratio: 1.74

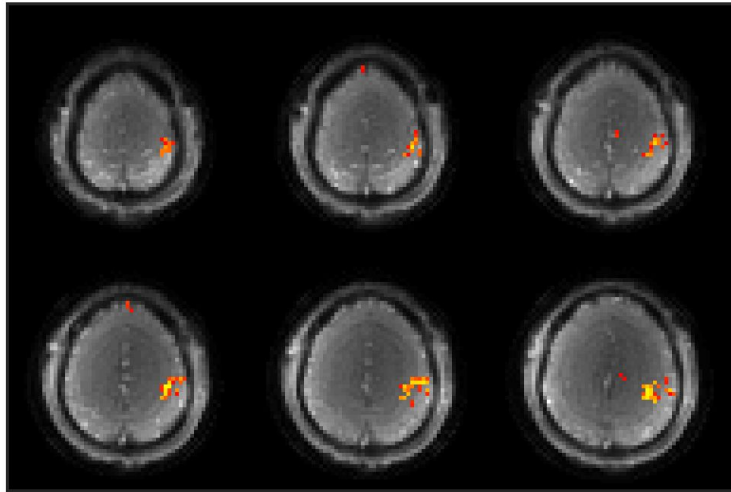


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3D Implementation

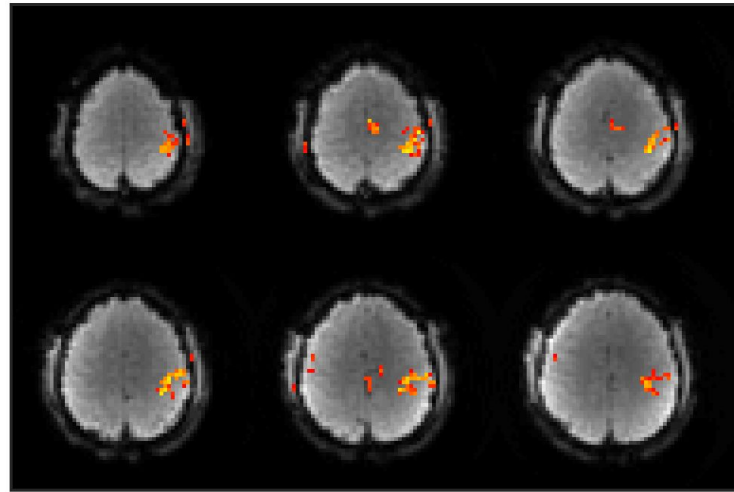
Motor cortex activation, 3D OSSI VS. 2D multi-slice GRE

OSSI

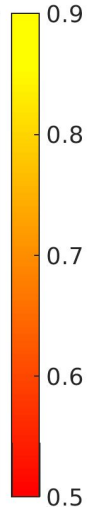


OSSI volume TR = 1.8 s for 12 slices, TE = 2.2 ms
Matrix size = 64, undersampled

GRE



GRE TR = 1.8 s, FA = 75°, TE = 23 ms
Matrix size = 64, fully sampled



Comparison of Oscillating Steady State to GRE BOLD for fMRI

Oscillating Steady-State Imaging (OSSI)

- High SNR fMRI using a novel method: OSSI
- Compared to GRE BOLD

Improved tSNR by 75%

Enlarged activation region by 50%

- Well-suited for high-resolution fMRI
- Reconstruction improves temporal resolution → Talk #1253
Physiological noise correction → Poster #3771

Acknowledgement

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