#**1438** - Prospective Motion Correction of Functional MRI Using Markerless Tracking

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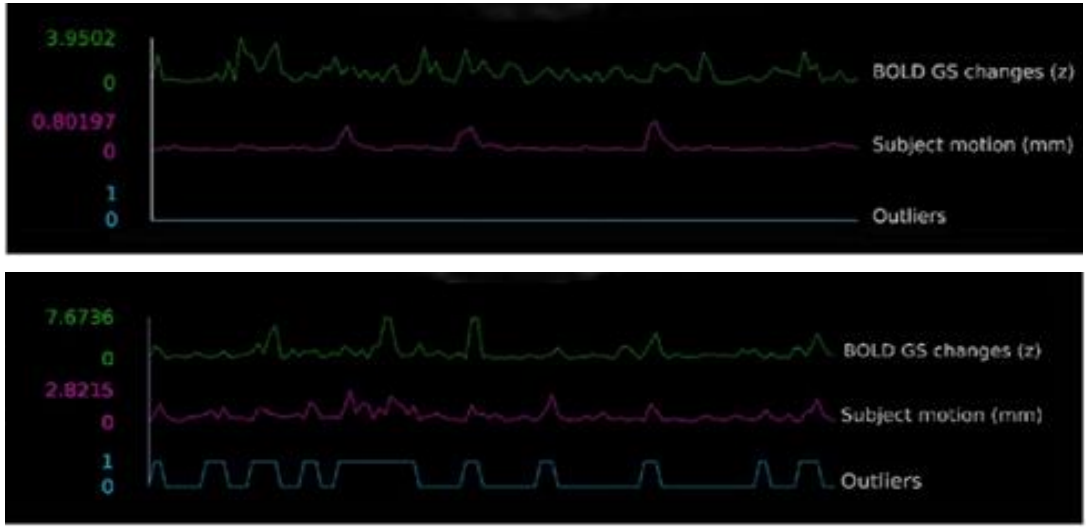
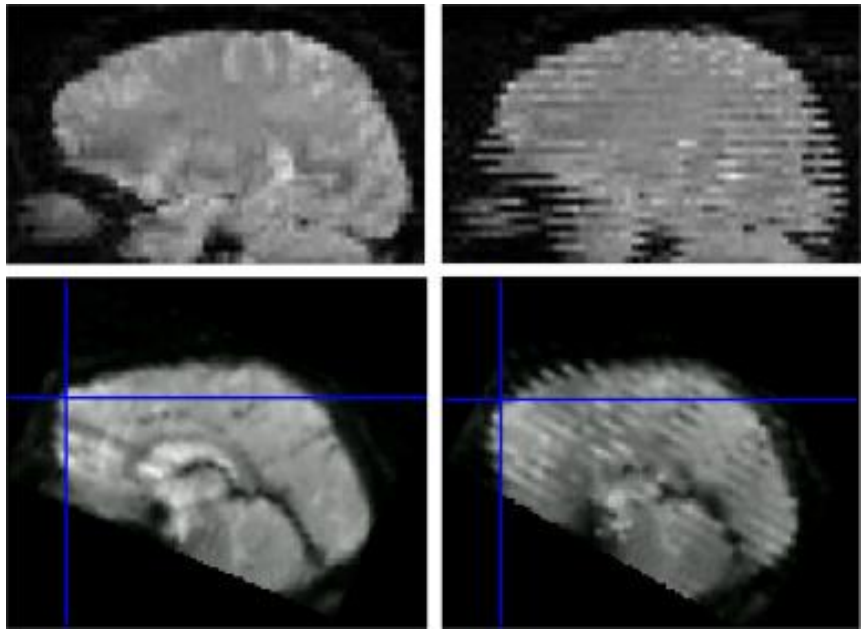
Motivation

- Subject motion is a main source of temporal instability in fMRI data.
  - Even small movements can degrade data quality and mask neural activation.
- Volume alignment and outlier rejection only a partial solution.
  - Spin history effects and slice-to-volume relation remain uncorrected.



Example of BOLD signal variation during mild and severe motion.



Example of remaining motion artifacts after volume alignment.

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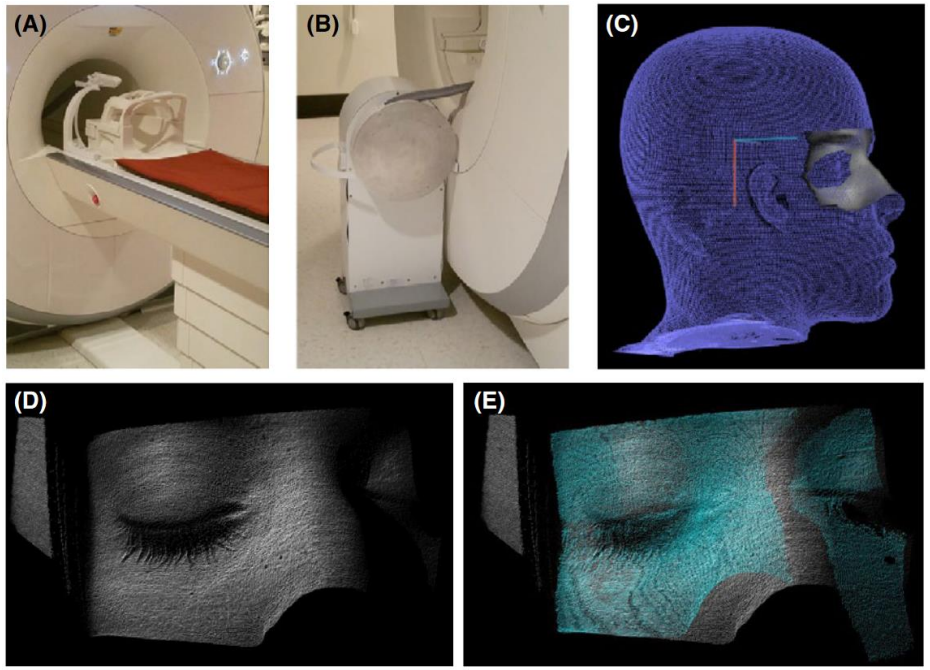
Methods

- Motion tracking with external optical motion tracker.
  - *Tracoline TCL 3.2* (2).
- Prospective motion correction (PMC) of BOLD fMRI.
  - Prototype BOLD EPI sequences with PMC capabilities (3).
  - Per-slice updates of FOV and frequency/phase of excitation during scanning.
- "Standard" fMRI processing pipeline.
  - fMRIPrep preprocessing.
- Siemens Prisma 3T (1) 64ch head coil (1).



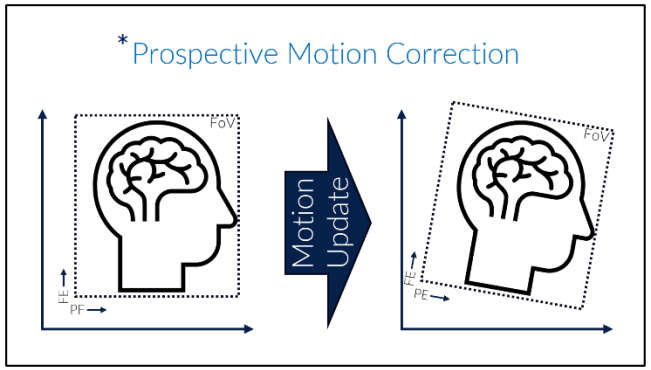
Tracoline TCL 3.2 motion tracker in use (3)

(1) Siemens Healthcare GmbH, Erlangen, Germany
(2) TracInnovations, Ballerup, Denmark

(3) Frost et al 2019 "Markerless high-frequency prospective motion correction for neuroanatomical MRI" [doi:10.1002/mrm.27705]

Goal

- Evaluate the effectiveness of optical motion tracking and per-slice PMC in fMRI during controlled motion conditions.
- For each participant, we evaluated across conditions:
  - Data quality of EPI time series
  - Activation patterns



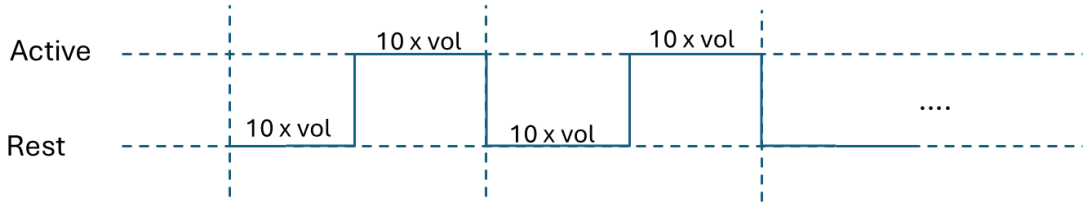
Approach

- 3 healthy adults scanned using a prototype 2D-BOLD-EPI sequence with PMC capabilities.
  - Block-design non-dominant-hand finger-tapping task performed under 4 conditions:

	Motion Condition	
PMC	Still as possible + PMC OFF	Heavy breathing + PMC OFF
	Still as possible + PMC ON	Heavy breathing + PMC ON

Experimental Setup

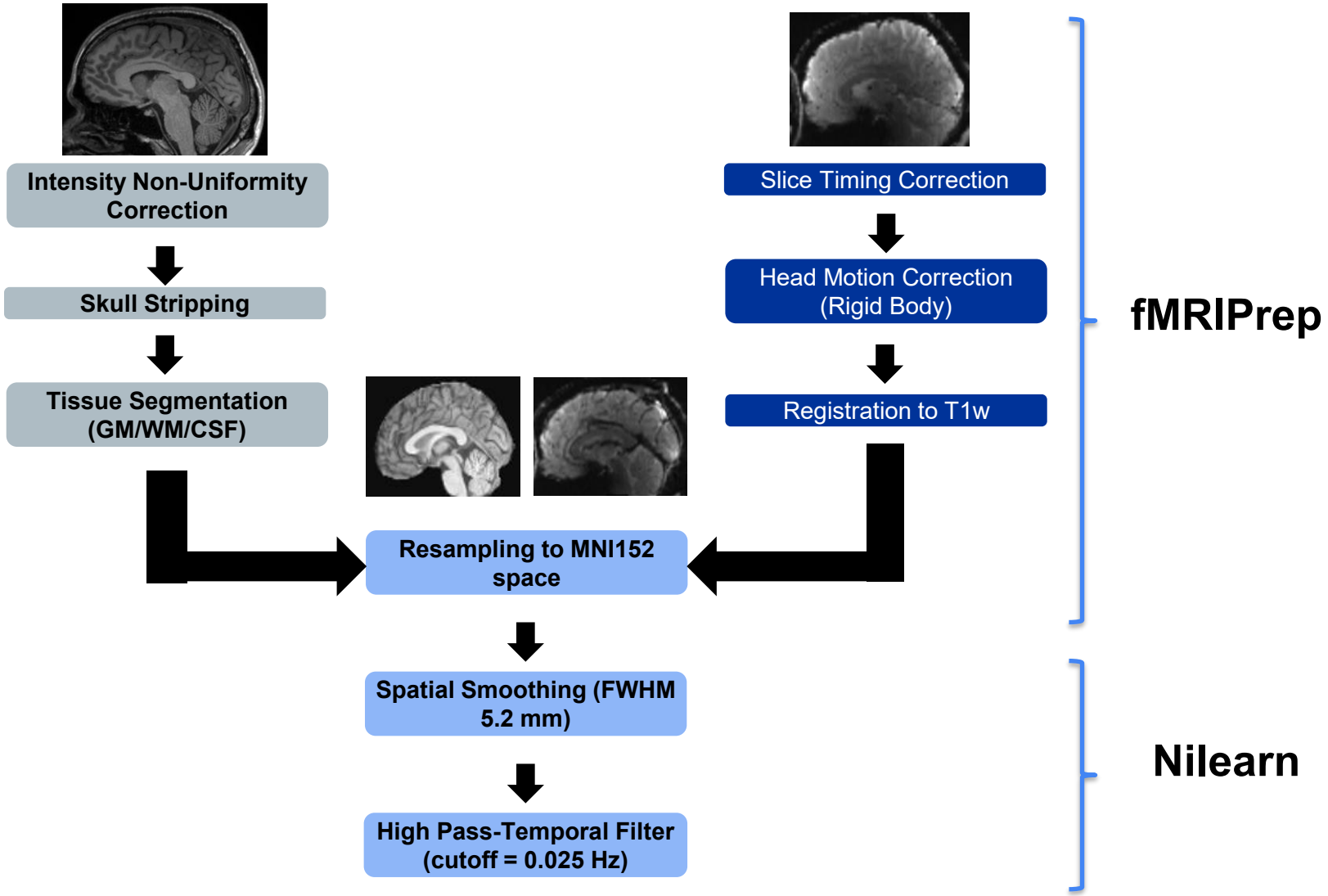
3 healthy male volunteers performed finger-tapping task using their non-dominant hand:



Scanned on 3T Prisma (Siemens) MRI system with PMC-compatible 2D-BOLD-EPI sequence:

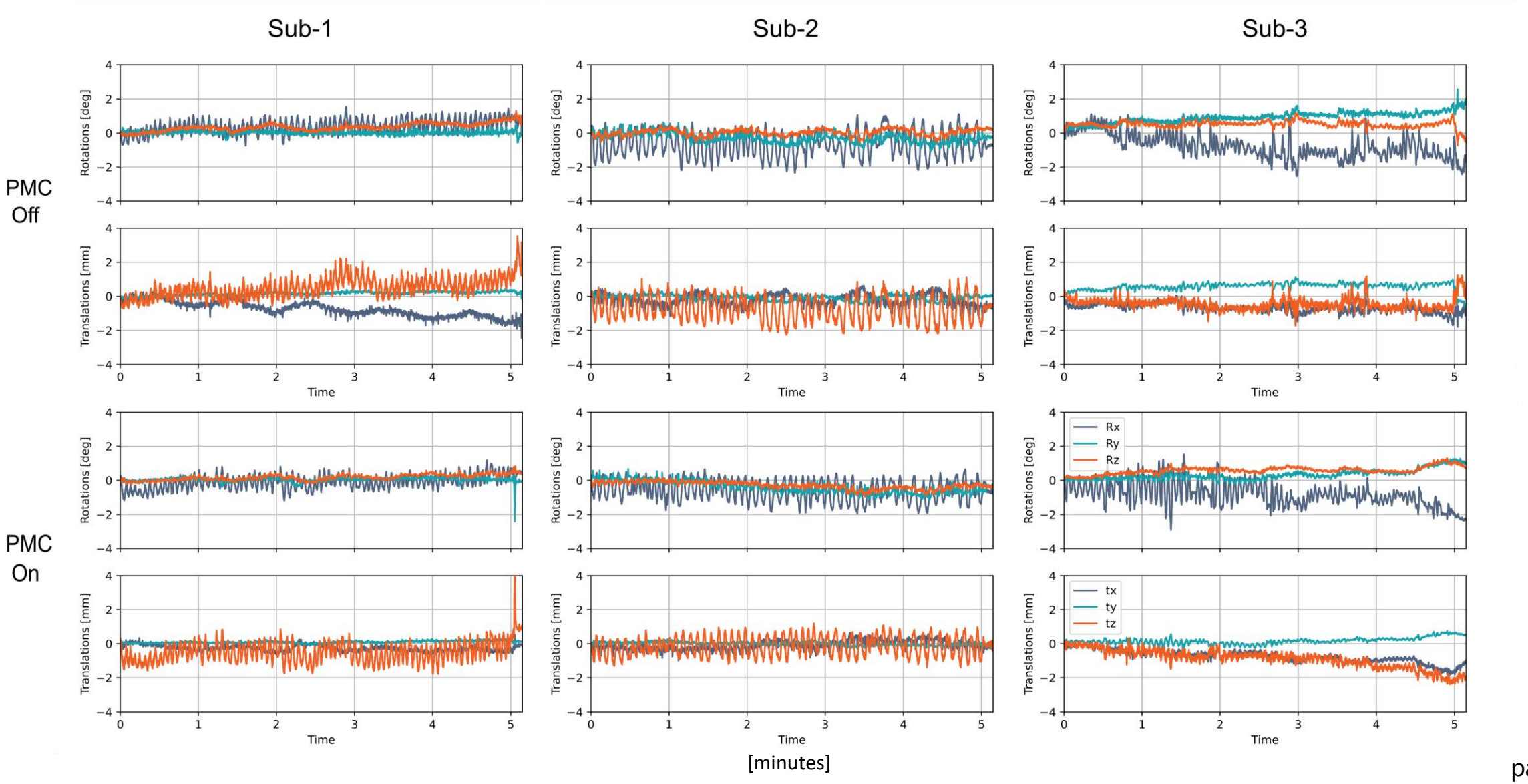
Parameter	Value
TE	30ms
FOV	192x192x128mm3
Voxel Resolution	2.04x2.04x2.62mm3
Volumes per Scan	100
Slices per Volume	49 interleaved slices
TR	3s
Flip Angle	90
Pixel Bandwidth	2315Hz

Experimental Setup

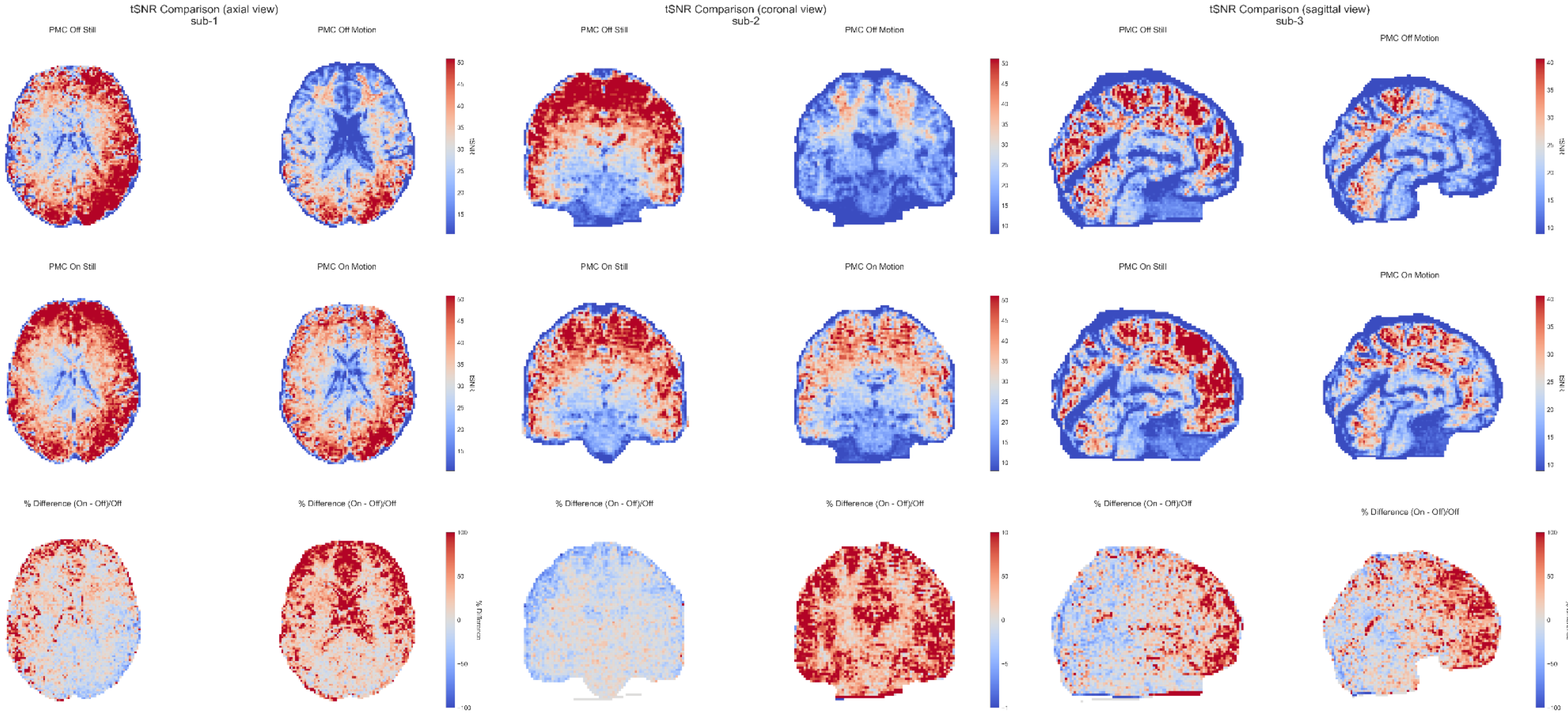


Results

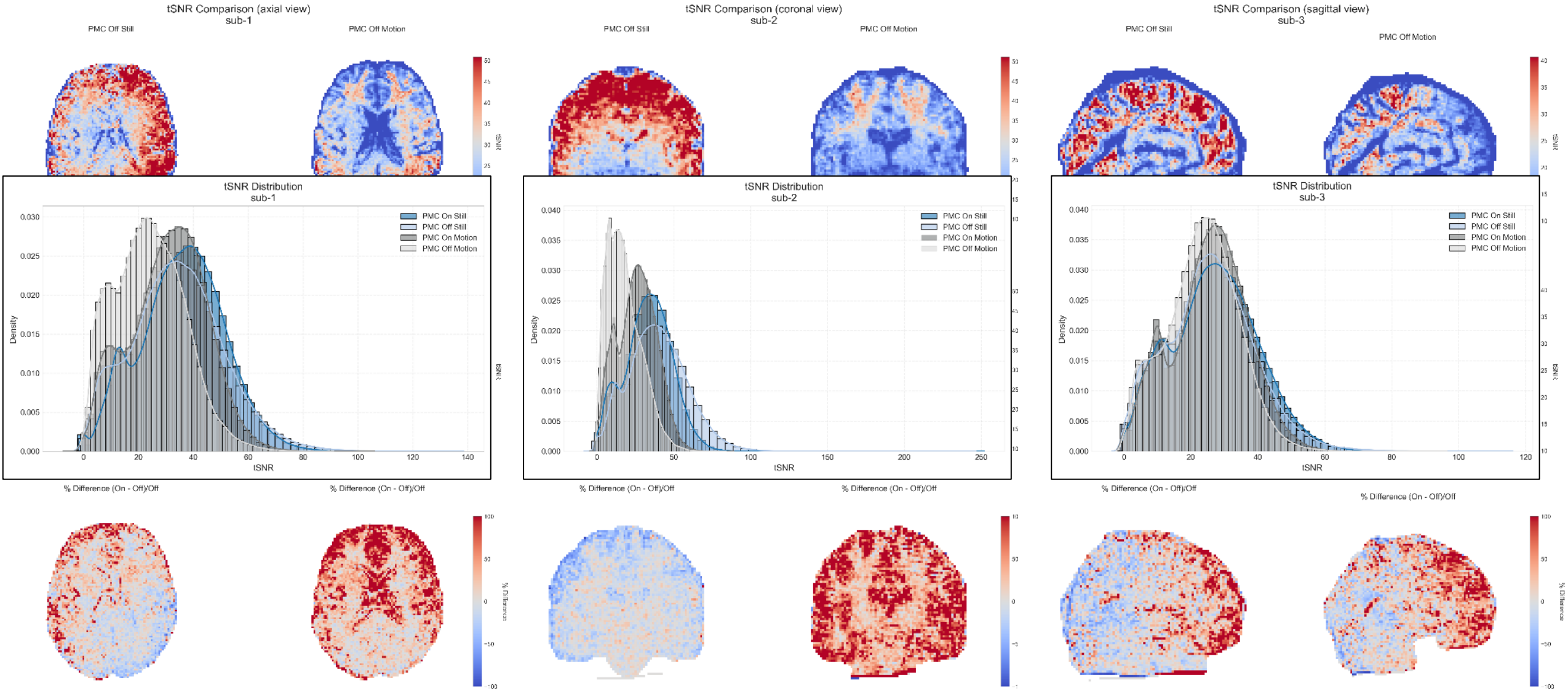
- 30Hz motion parameters (3 translations, 3 Euler angles) from external motion tracker
- 15-point moving average filter applied before PMC



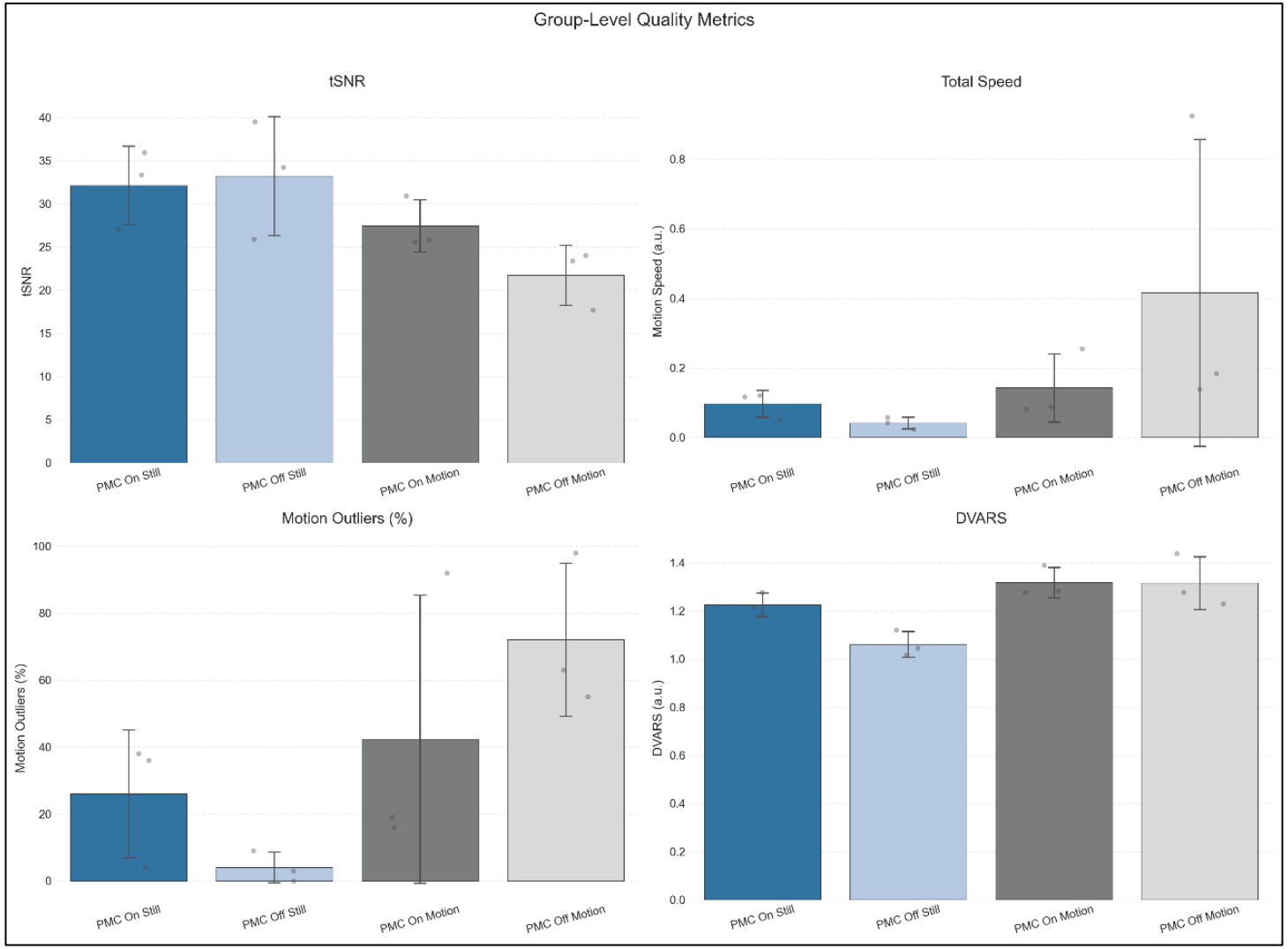
Results


tSNR Comparison (axial view)
sub-1
PMC Off Still
PMC Off Motion
PMC On Still
PMC On Motion
% Difference (On - Off)/Off
% Difference (On - Off)/Off
tSNR Comparison (coronal view)
sub-2
PMC Off Still
PMC Off Motion
PMC On Still
PMC On Motion
% Difference (On - Off)/Off
% Difference (On - Off)/Off
tSNR Comparison (sagittal view)
sub-3
PMC Off Still
PMC Off Motion
PMC On Still
PMC On Motion
% Difference (On - Off)/Off
% Difference (On - Off)/Off

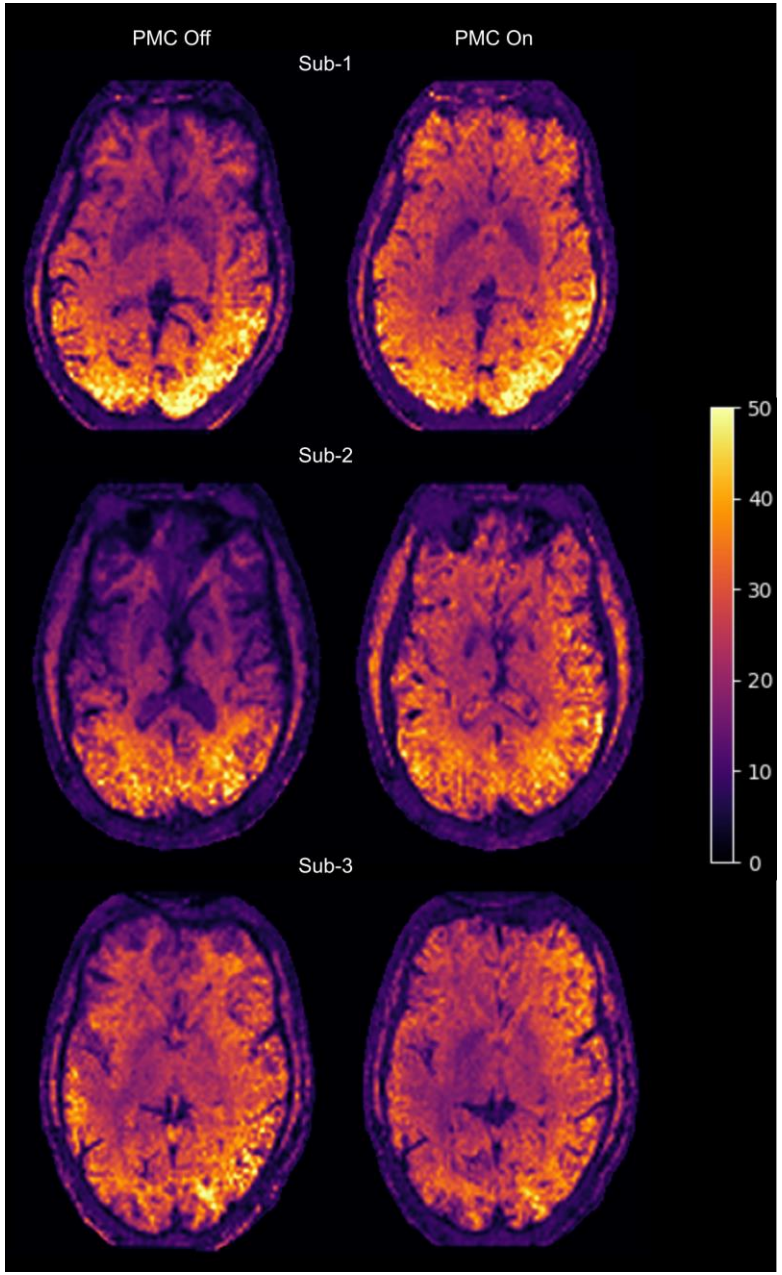
Results

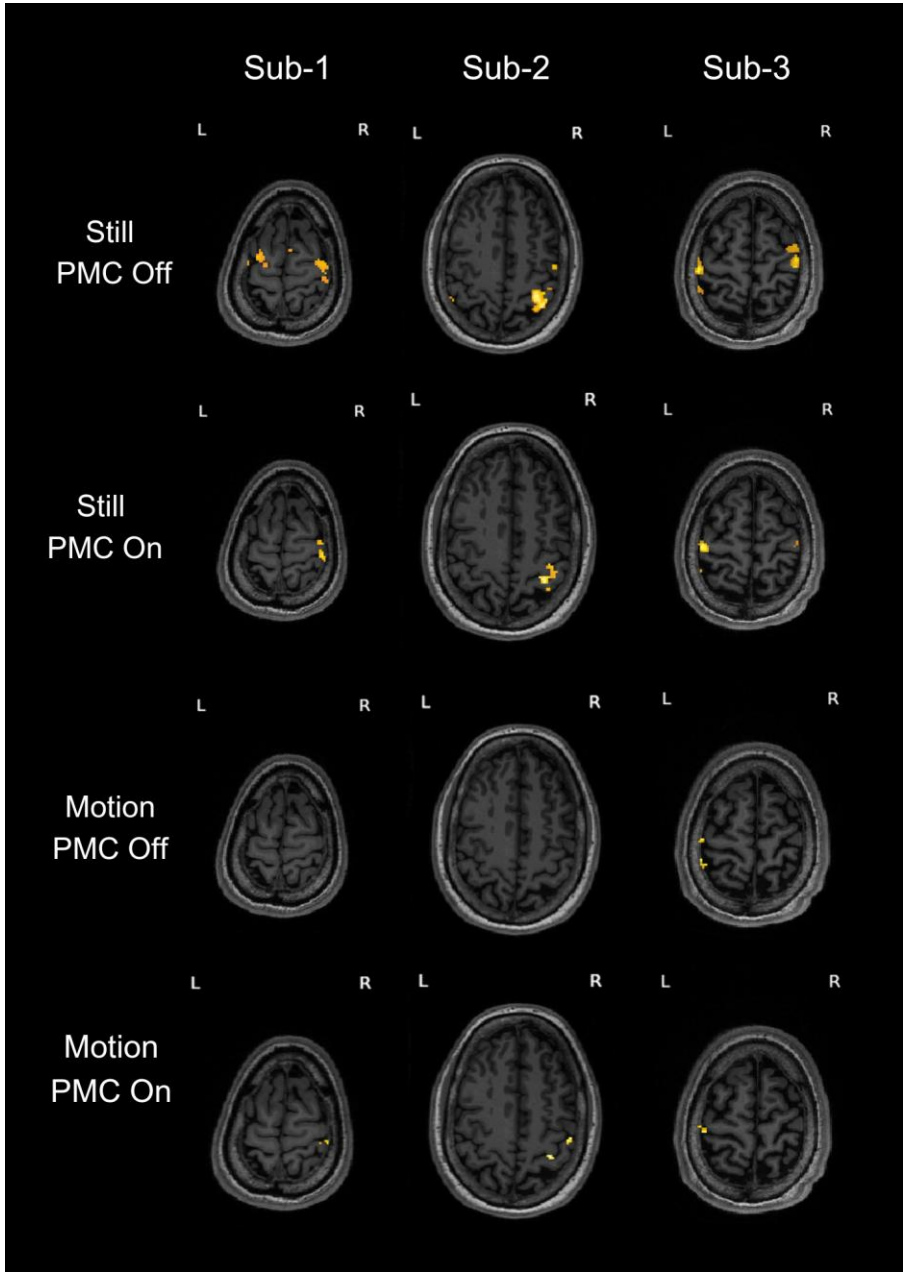

tSNR Comparison (axial view)
sub-1
PMC Off Still
PMC Off Motion
tSNR Distribution
sub-1
PMC On Still
PMC Off Still
PMC On Motion
PMC Off Motion
Density
tSNR
% Difference (On - Off)/Off
tSNR Comparison (coronal view)
sub-2
PMC Off Still
PMC Off Motion
tSNR Distribution
sub-2
PMC On Still
PMC Off Still
PMC On Motion
PMC Off Motion
Density
tSNR
% Difference (On - Off)/Off
tSNR Comparison (sagittal view)
sub-3
PMC Off Still
PMC Off Motion
tSNR Distribution
sub-3
PMC On Still
PMC Off Still
PMC On Motion
PMC Off Motion
Density
tSNR
% Difference (On - Off)/Off

Results


Group-Level Quality Metrics
tSNR
tSNR
Total Speed
Motion Speed (a.u.)
Motion Outliers (%)
Motion Outliers (%)
DVARS
DVARS (a.u.)
PMC On Still
PMC Off Still
PMC On Motion
PMC Off Motion

Results


PMC Off
PMC On
Sub-1
Sub-2
Sub-3
50
40
30
20
10
0


Sub-1
Sub-2
Sub-3
Still
PMC Off
Still
PMC On
Motion
PMC Off
Motion
PMC On
L
R

Conclusion

Benefits

- Slice-by-slice real-time motion correction
  - Can limit impact of non-contiguous slices and spin history effects due to motion.
- Improved image quality metrics during motion – especially in frontal region
  - Increase in tSNR maps and tSNR histograms.
  - Decrease in number of outliers, and Total Speed.
- Activation patterns more confined to expected area during motion
  - Expected activation in the primary motor cortex increased with PMC during motion.
  - Less spurious activation during motion.

Conclusion

Limitations

- Proof of concept: Low sample size and subject diversity
  - Small effect size on individual activation maps for well-behaved healthy subjects
  - More data needed to confirm effect on group-level
- Testing needed on different modes of motion

Impact

- More reliable fMRI on motion-prone groups
  - Pediatric, elderly, or clinical populations
- Less outliers
  - Shorter overall scan time to reach desired number of volumes

Thank You!