Motion-Compensated Neuroanatomical Imaging

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April 2013

Motion-compensated MRI sequences allow you to image subjects ***even if they move***, without discarding scans and rescanning.

There are two basic types of motion-compensation:

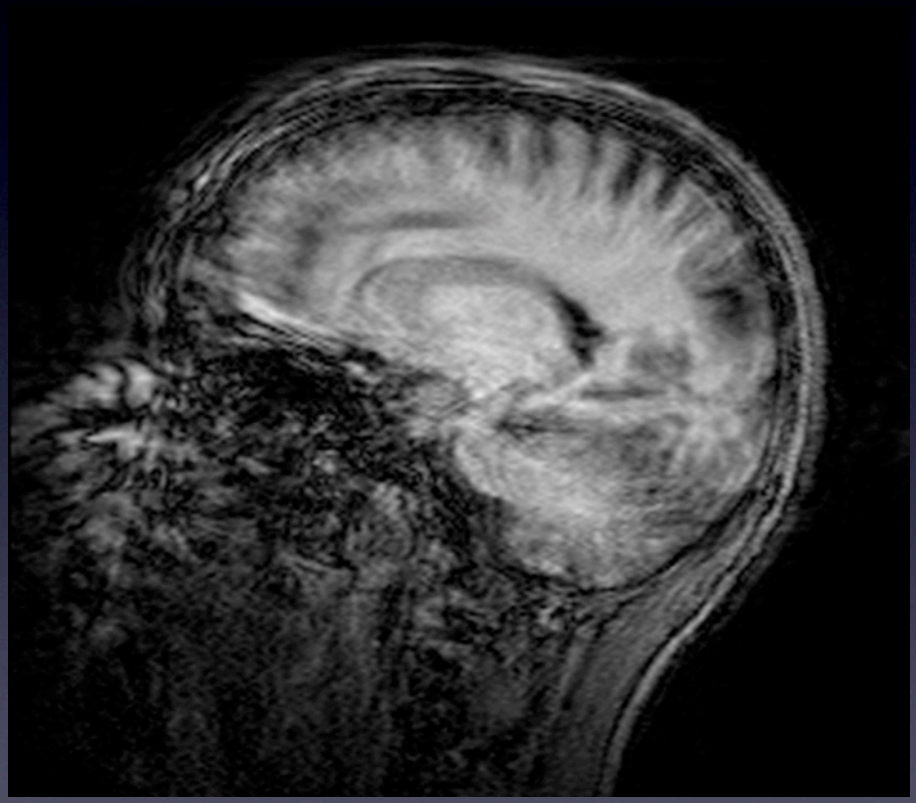
Retrospective

Post-process to estimate data that would have been measured if the subject hadn't moved.
Examples: PROPELLER, SNAILS

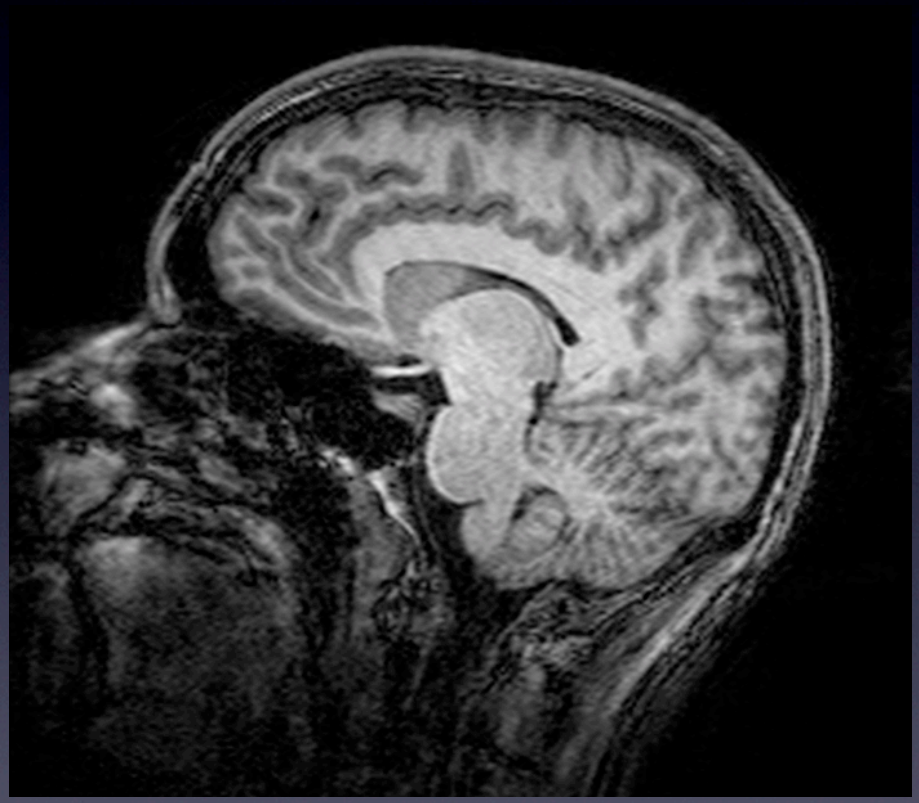
Prospective

Track the subject and alter the acquisition "on-the-fly" to account for subject motion.
Examples: PACE, vNavs, PROMO

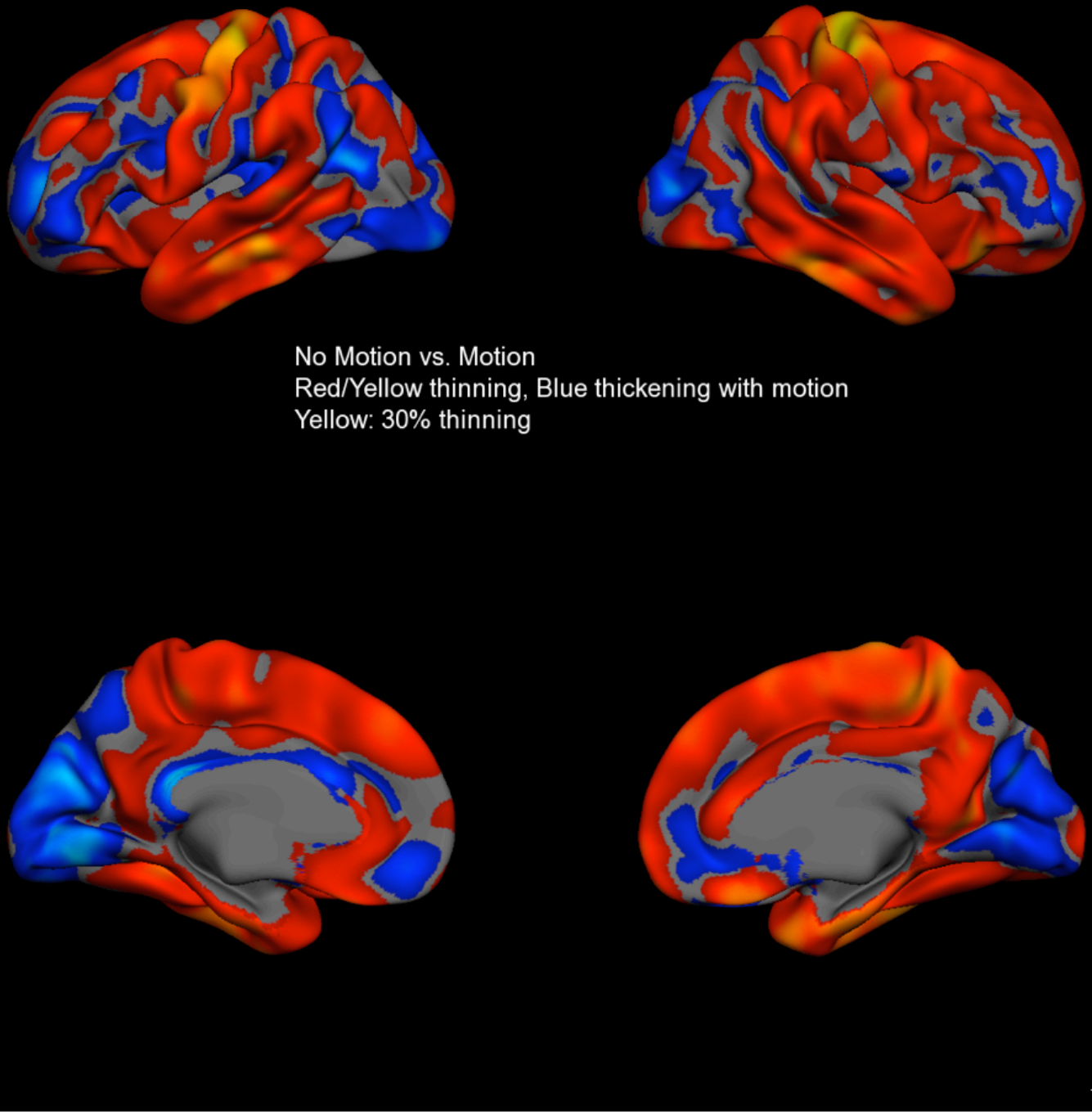
MPRAGE of subject prompted to change position every 45 seconds

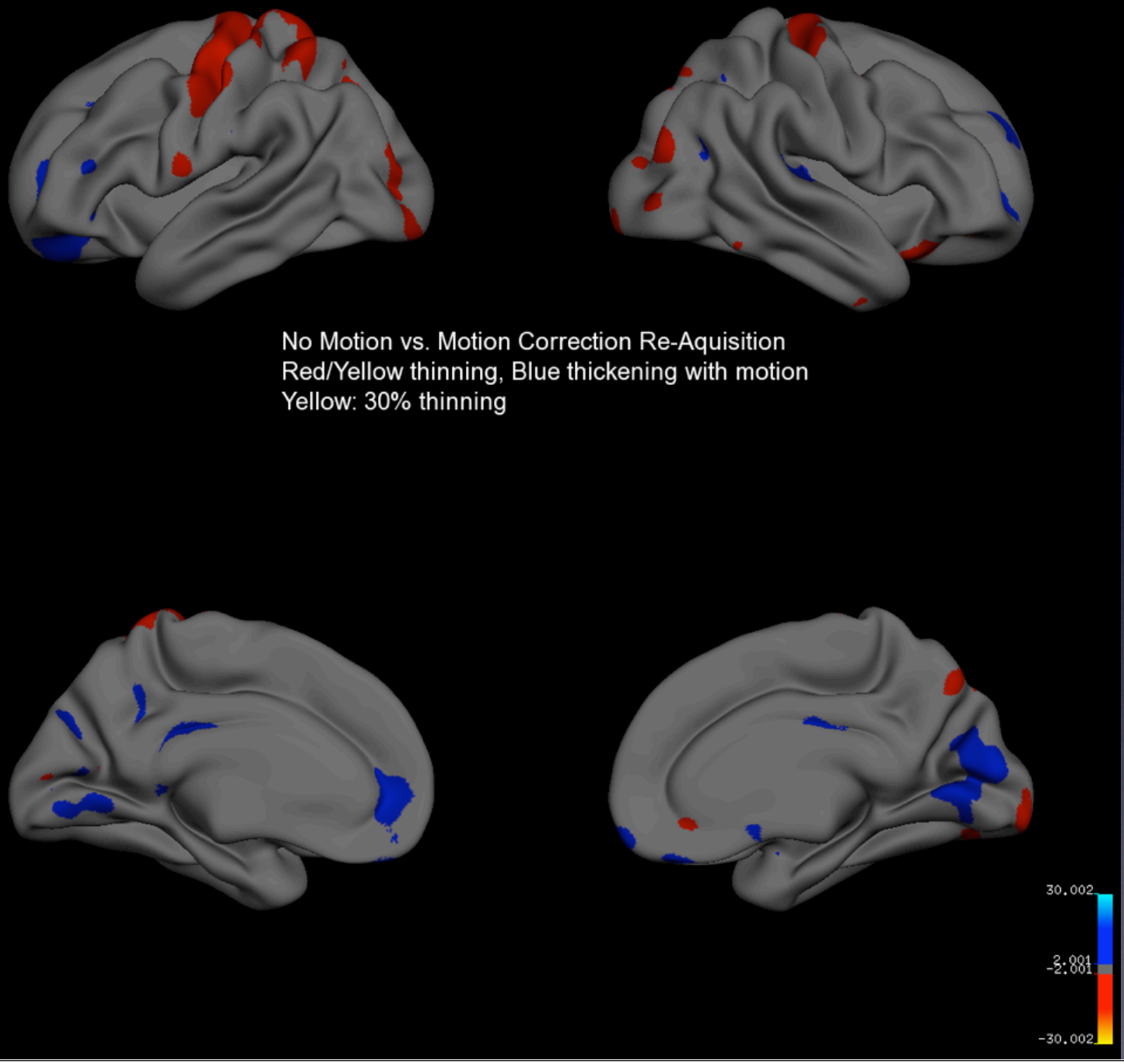


without prospective moco



with prospective moco


No Motion vs. Motion
Red/Yellow thinning, Blue thickening with motion
Yellow: 30% thinning
30.002
2.001
-2.001
-30.002


No Motion vs. Motion Correction Re-Aquisition
Red/Yellow thinning, Blue thickening with motion
Yellow: 30% thinning
30.002
2.001
-2.001
-30.002

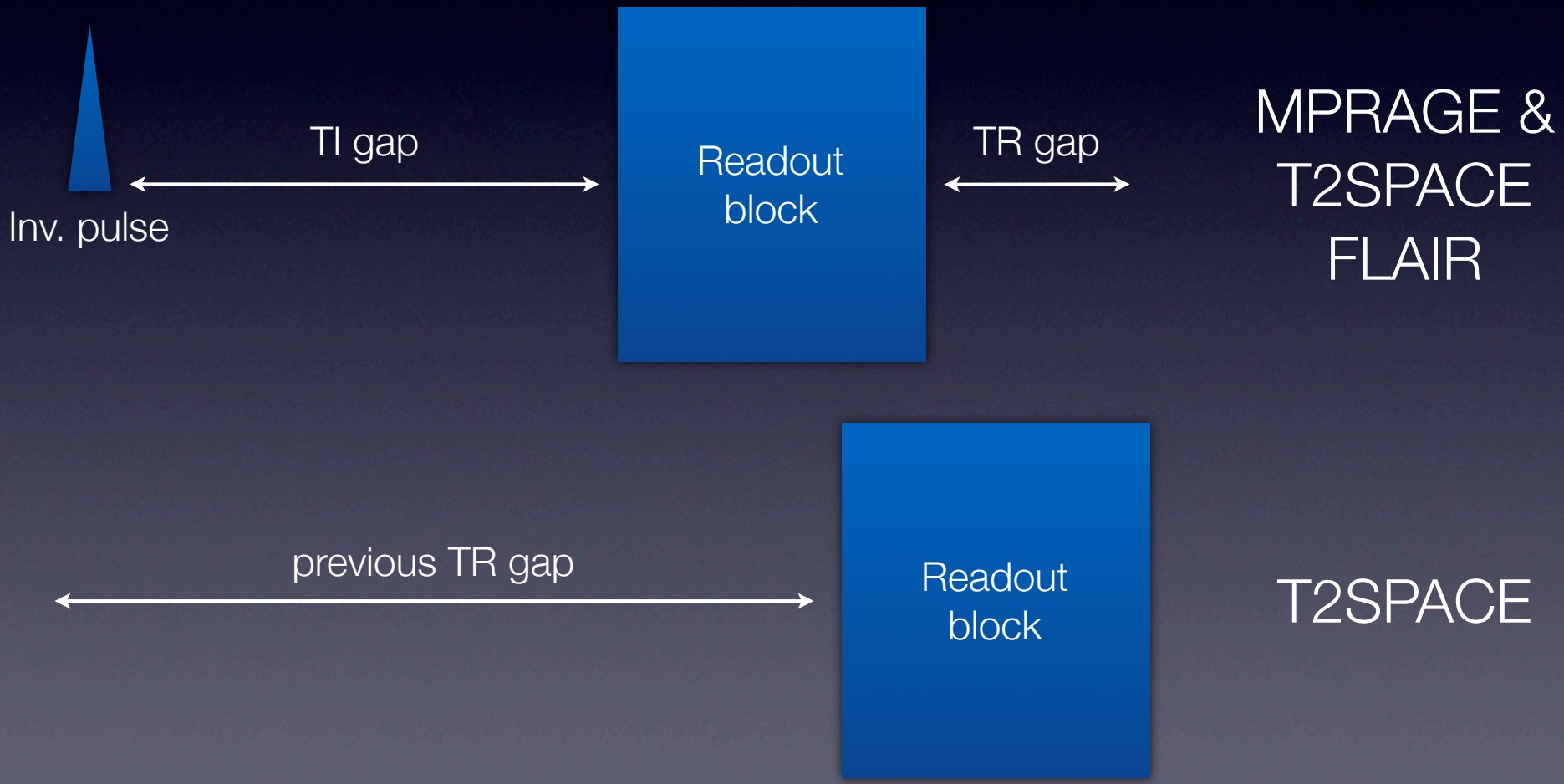
Who should use these sequences? Everyone!

- Our vNav sequences are available now on Siemens scanners (WIP 711).
- Other groups are developing similar techniques on GE scanners (e.g., PROMO).

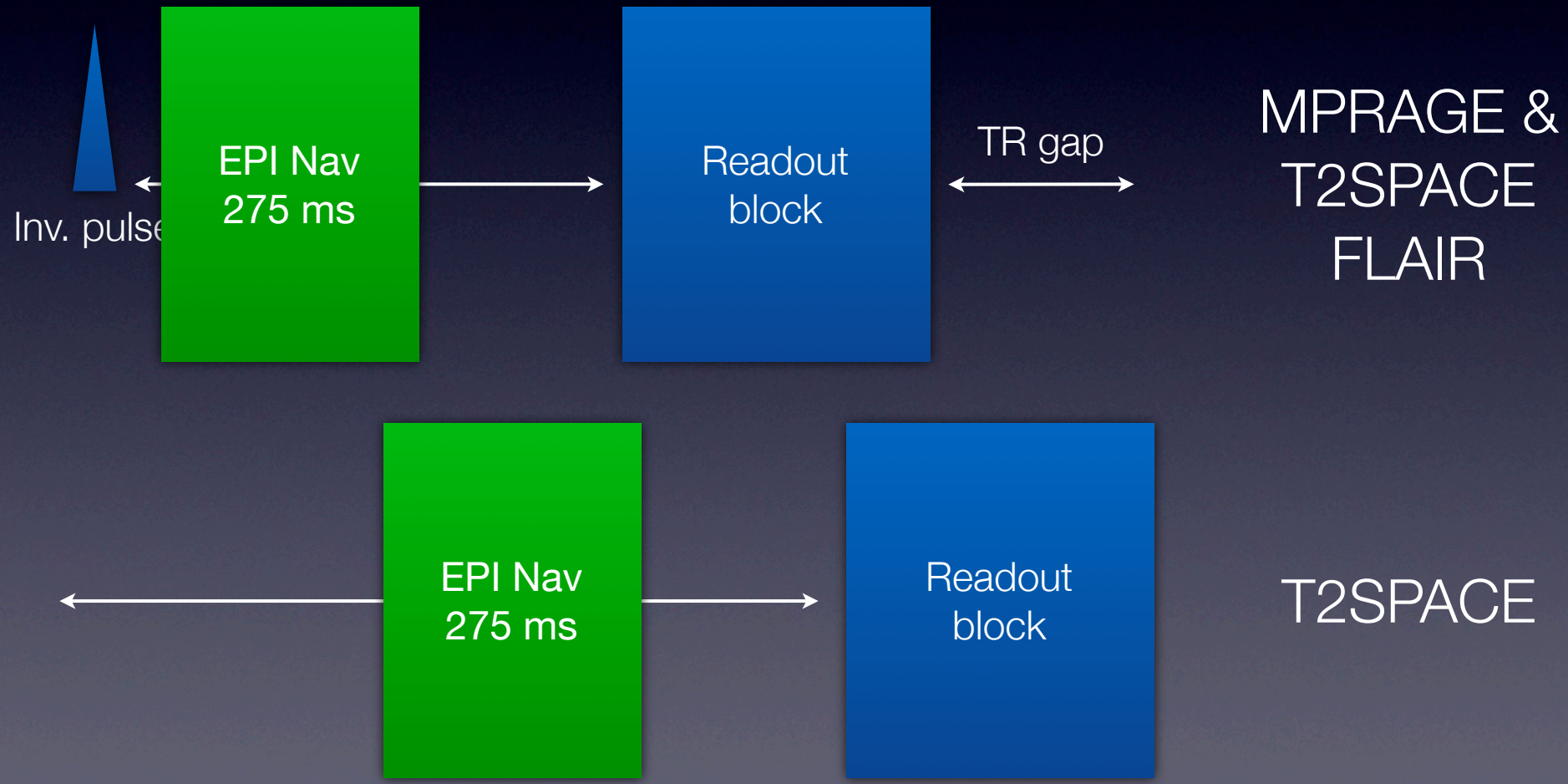
Overview

- **Following the subject:**
  EPI-navigated prospective motion correction
- **More motion-resistance:**
  automatic retrospective reacqusition
- **Using FreeSurfer for validation:**
  longitudinal, cross-contrast analysis

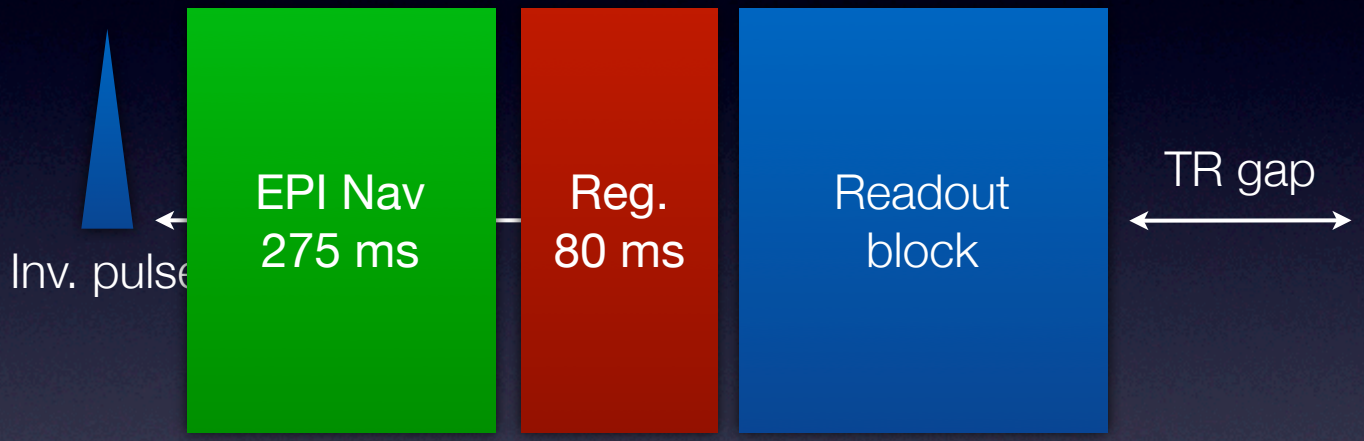
A single TR


Inv. pulse
TI gap
Readout block
TR gap
MPRAGE & T2SPACE FLAIR
previous TR gap
Readout block
T2SPACE

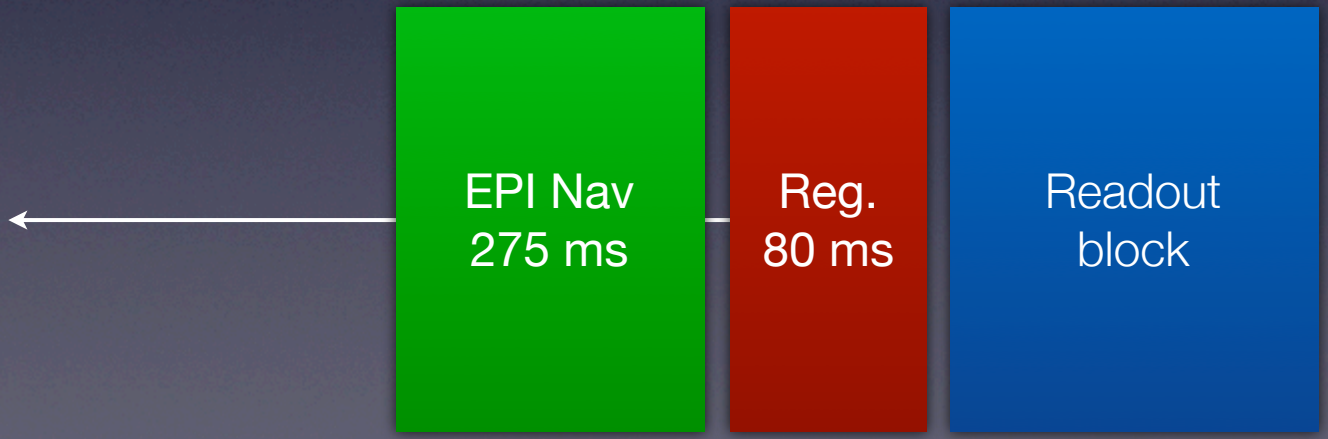
A single TR
+ EPI Navigator



A single TR
+ EPI Navigator
+ Registration and Feedback

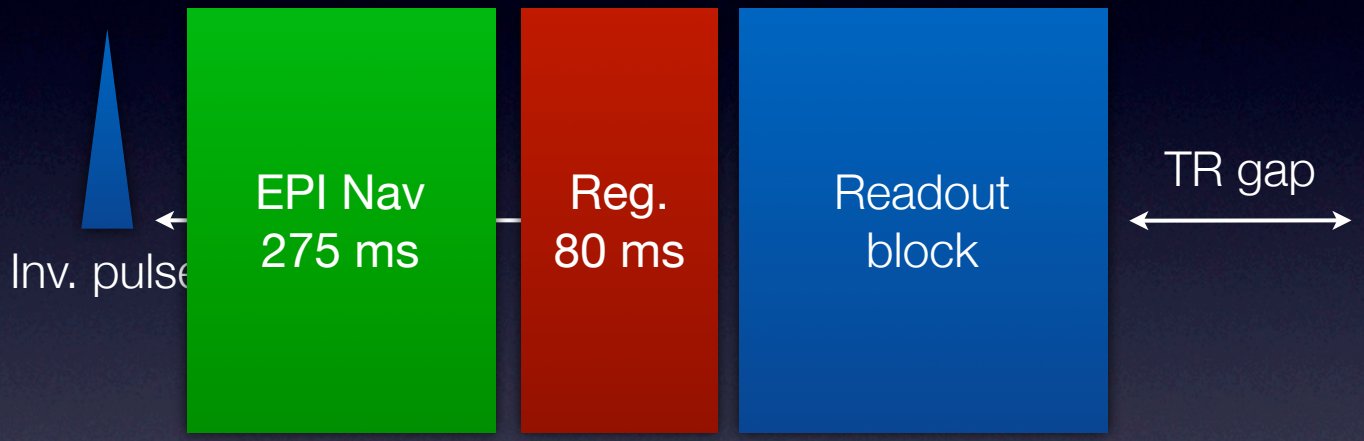


MPRAGE &
T2SPACE
FLAIR

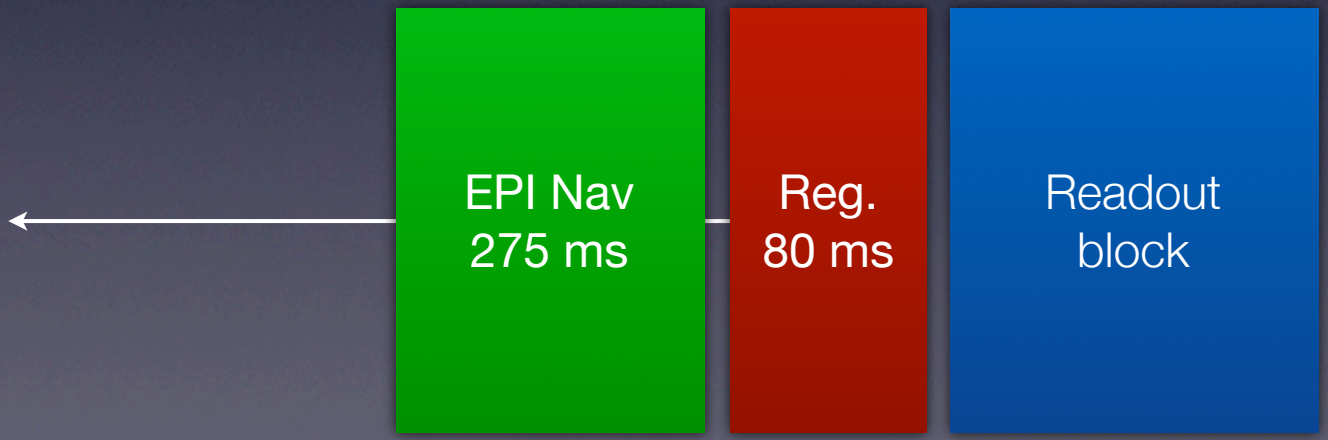


T2SPACE

A single TR
+ EPI Navigator
+ Registration and Feedback
= updated imaging coordinates



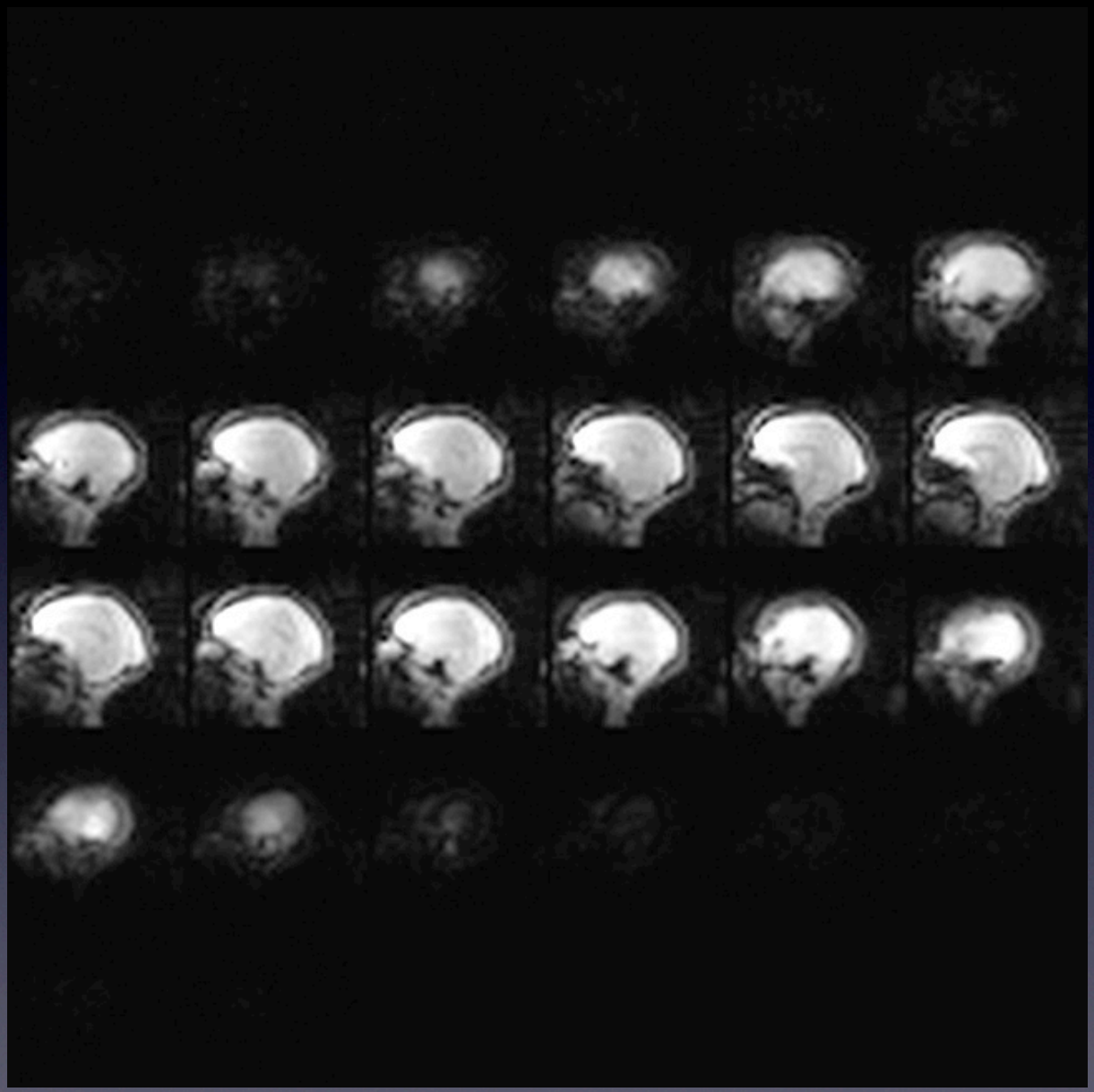
MPRAGE &
T2SPACE
FLAIR



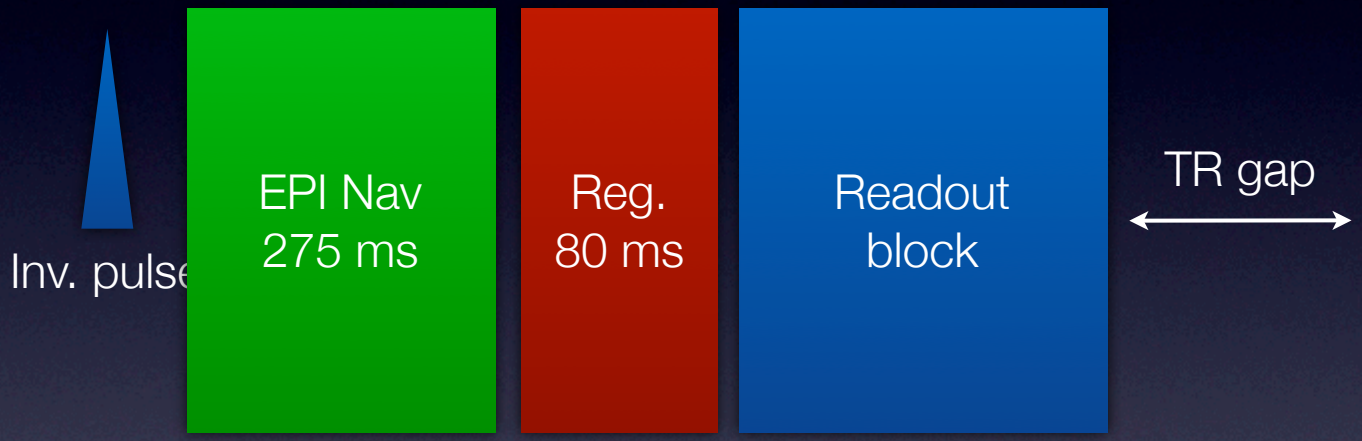
T2SPACE

The Navigator

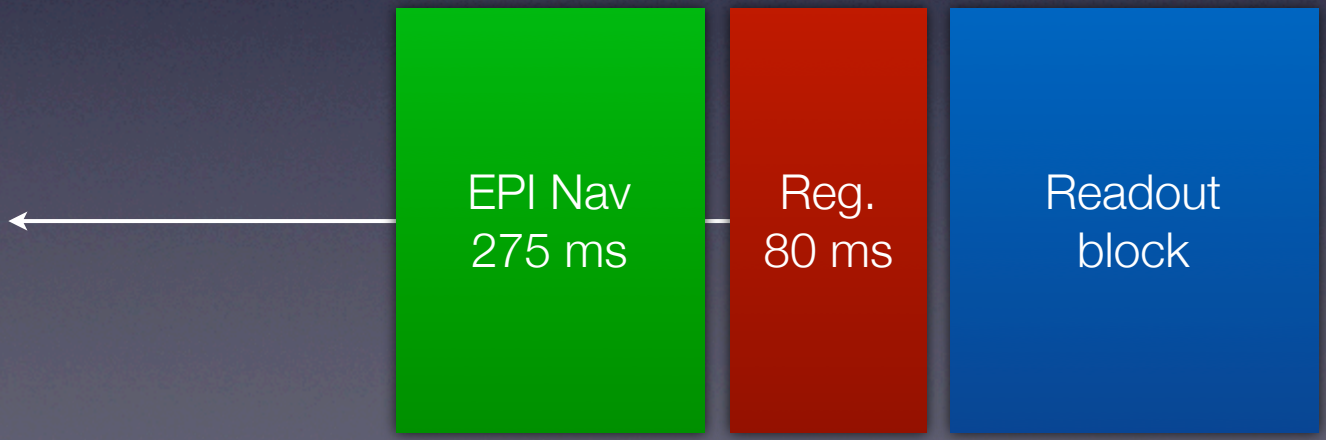
- 32^3 EPI
- 8 mm iso
- 256 mm FOV
- 25 shots
- TE 5.2 ms, TR 11 ms
- **~ 275 ms**



A single TR
+ EPI Navigator
+ Registration and Feedback
= updated imaging coordinates

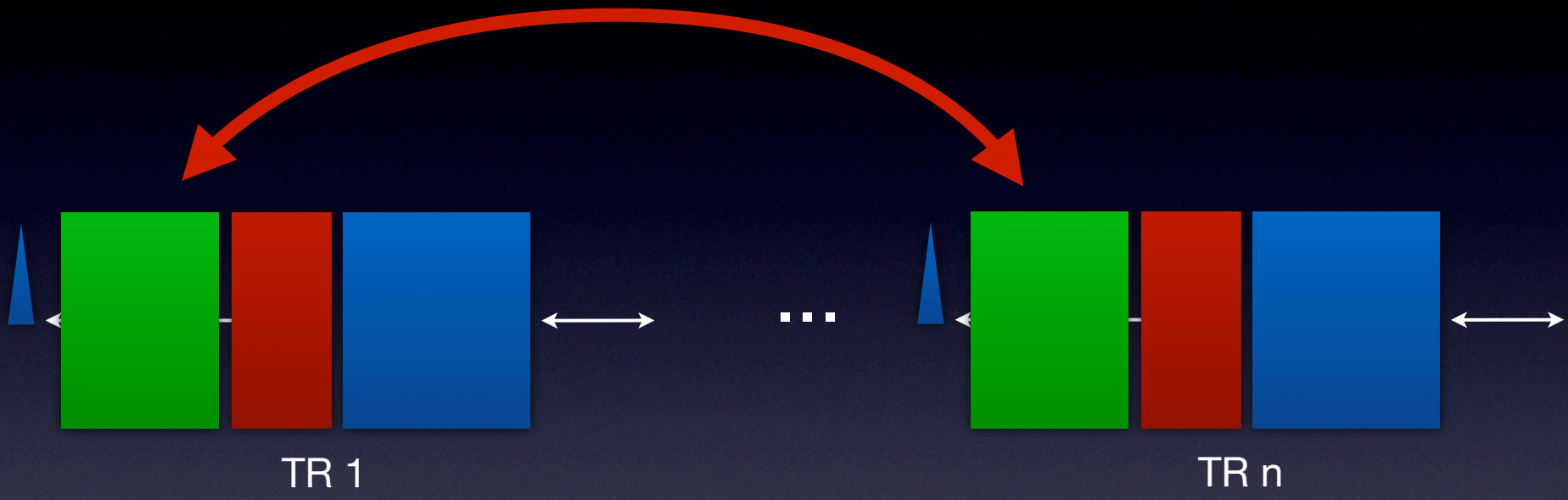


MPRAGE &
T2SPACE
FLAIR



T2SPACE

Register each EPI nav volume back to first TR using Siemens' **PACE** registration algorithm.



At 3T, observed variance of 50 microns with stationary subject (a pineapple).

Accuracy estimated to be **better than 300 microns** in real-world examples.

Unsedated pediatric multi-echo MPRAGE

without moco or navs

with navs and moco

Images courtesy of Ellen Grant, Children's Hospital Boston

Overview

- **Following the subject:**
  EPI-navigated prospective motion correction
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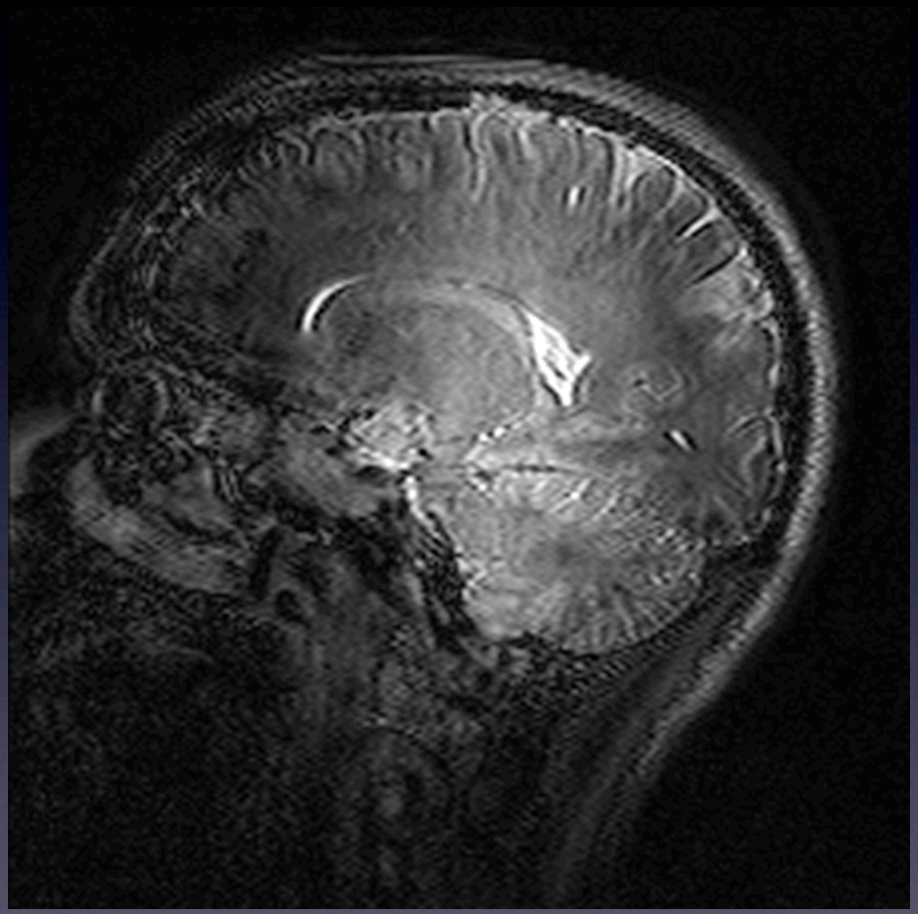
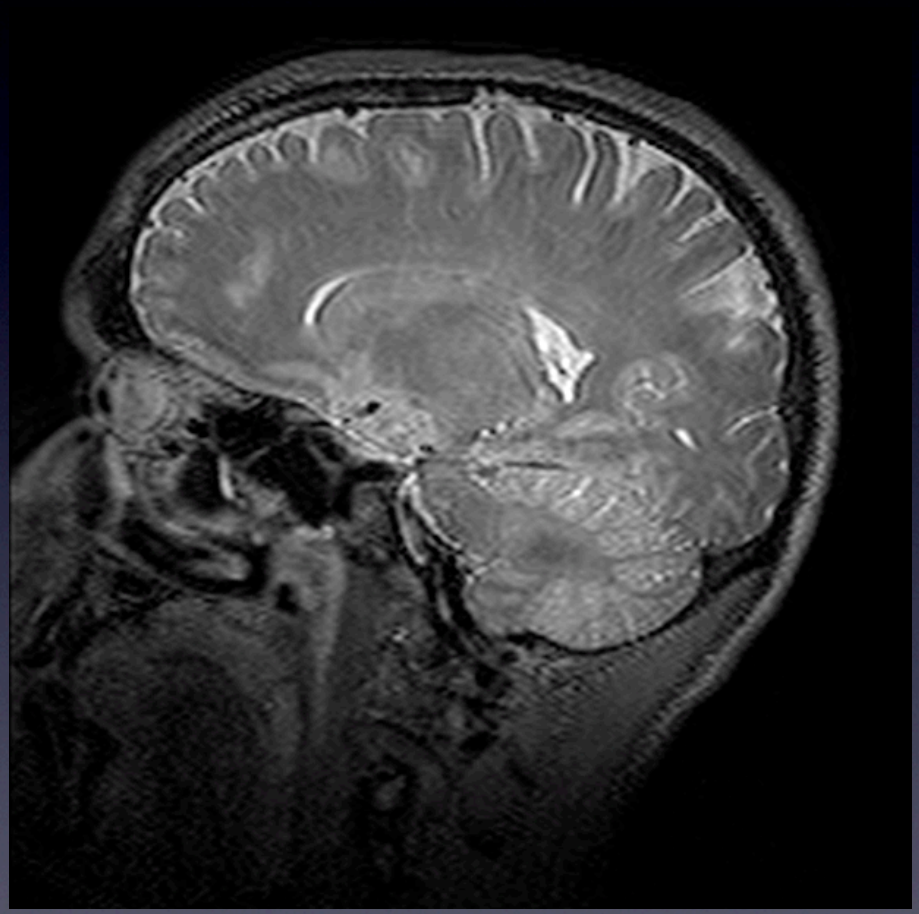
  automatic retrospective reacqusition
- **Using FreeSurfer for validation:**
  longitudinal, cross-contrast analysis

T2SPACE corrupted by 20 seconds of free motion during acquisition of center of k-space

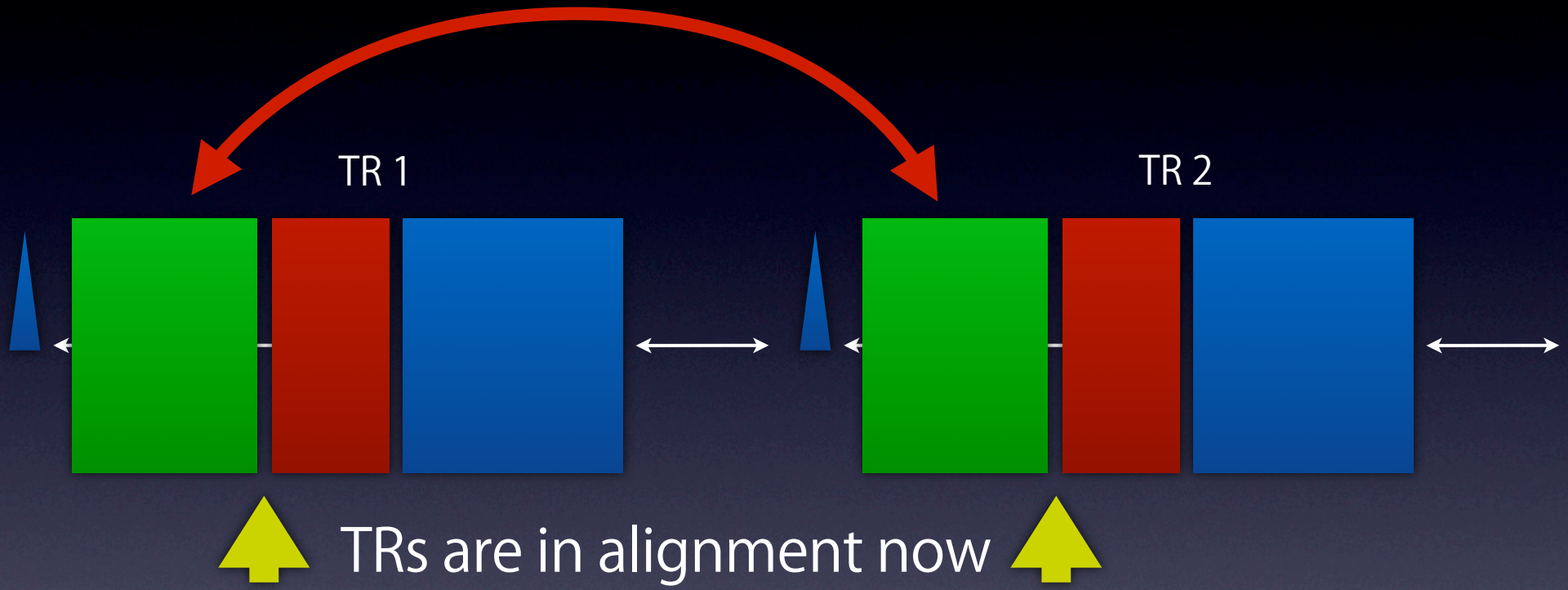


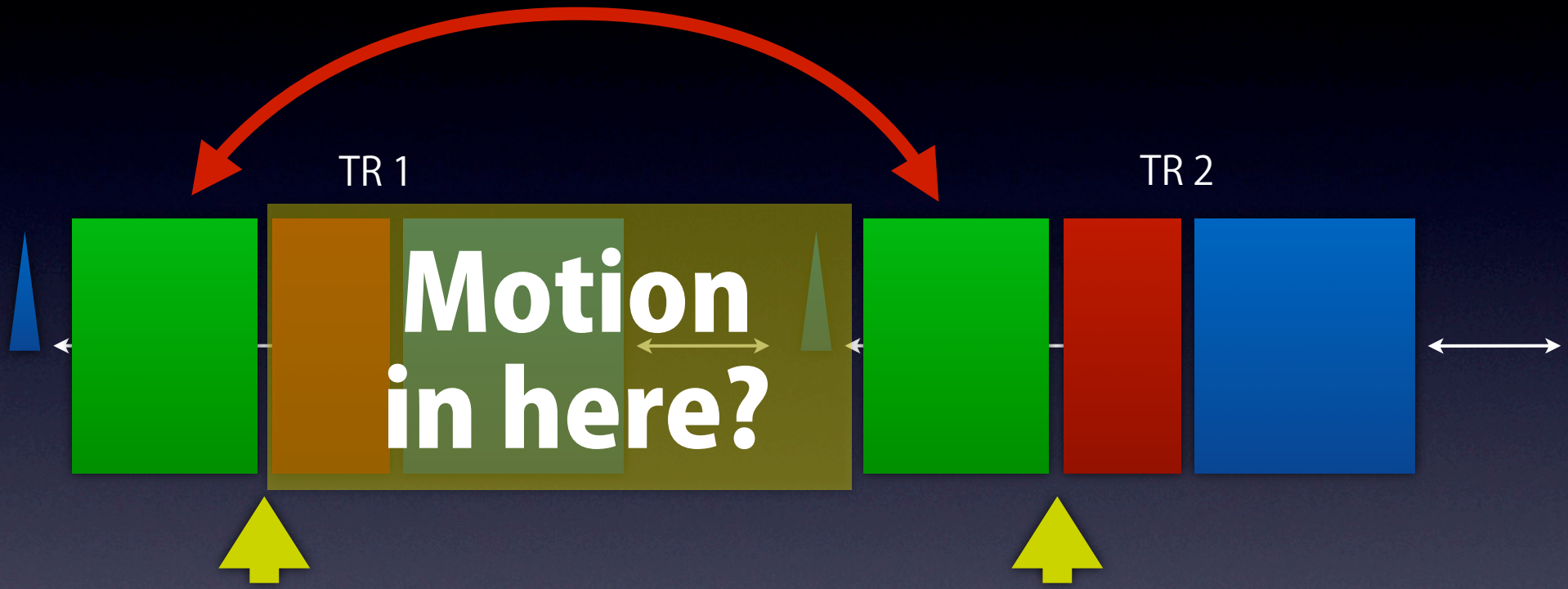
w/ moco
w/o reacquisiton



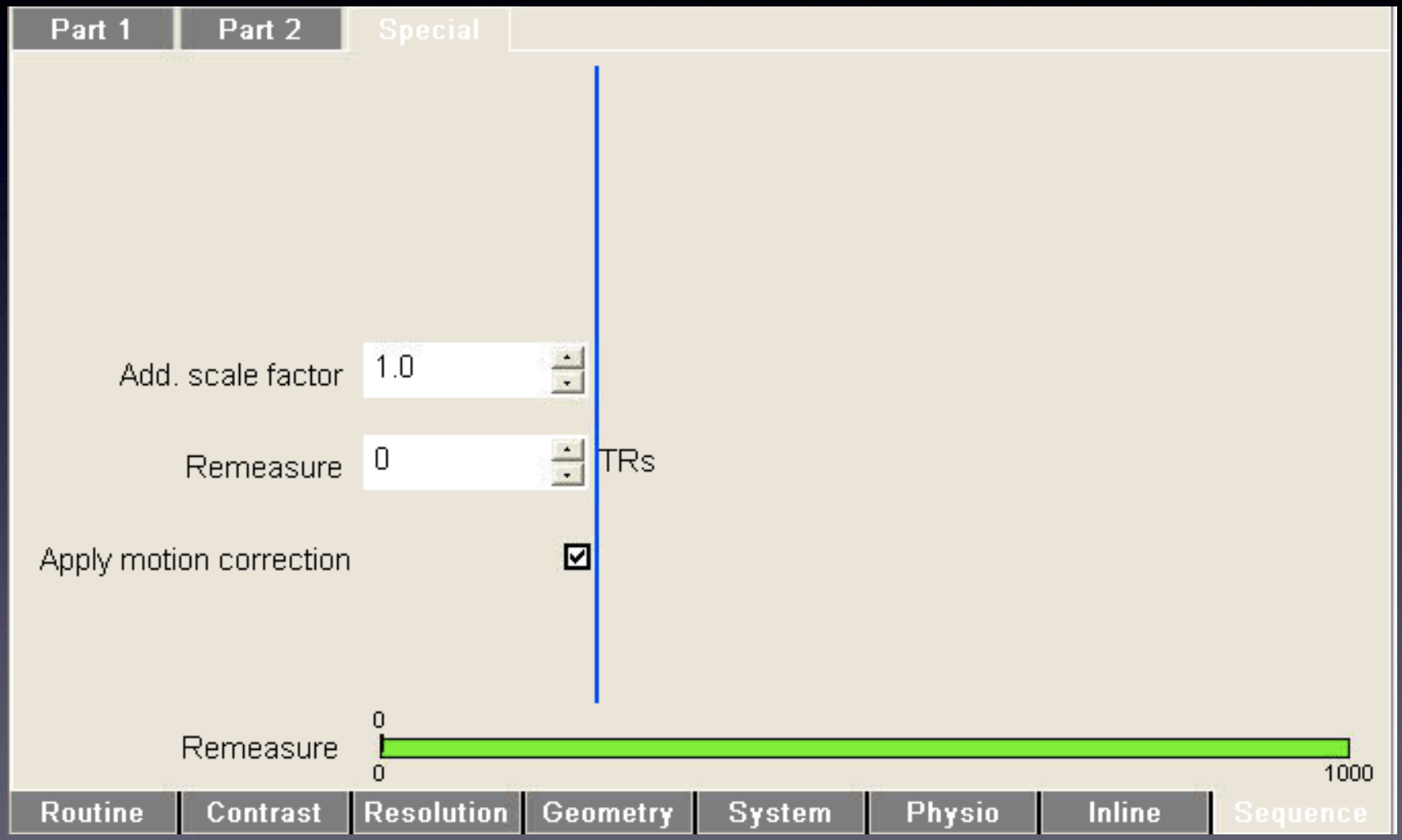
w/ moco
w/ 10 TRs reacquired

Register each EPI nav volume back to first TR using Siemens' **PACE registration algorithm.**




TR 1
TR 2
Motion
in here?

Users configure the number of TRs to reacquire as part of their protocol.



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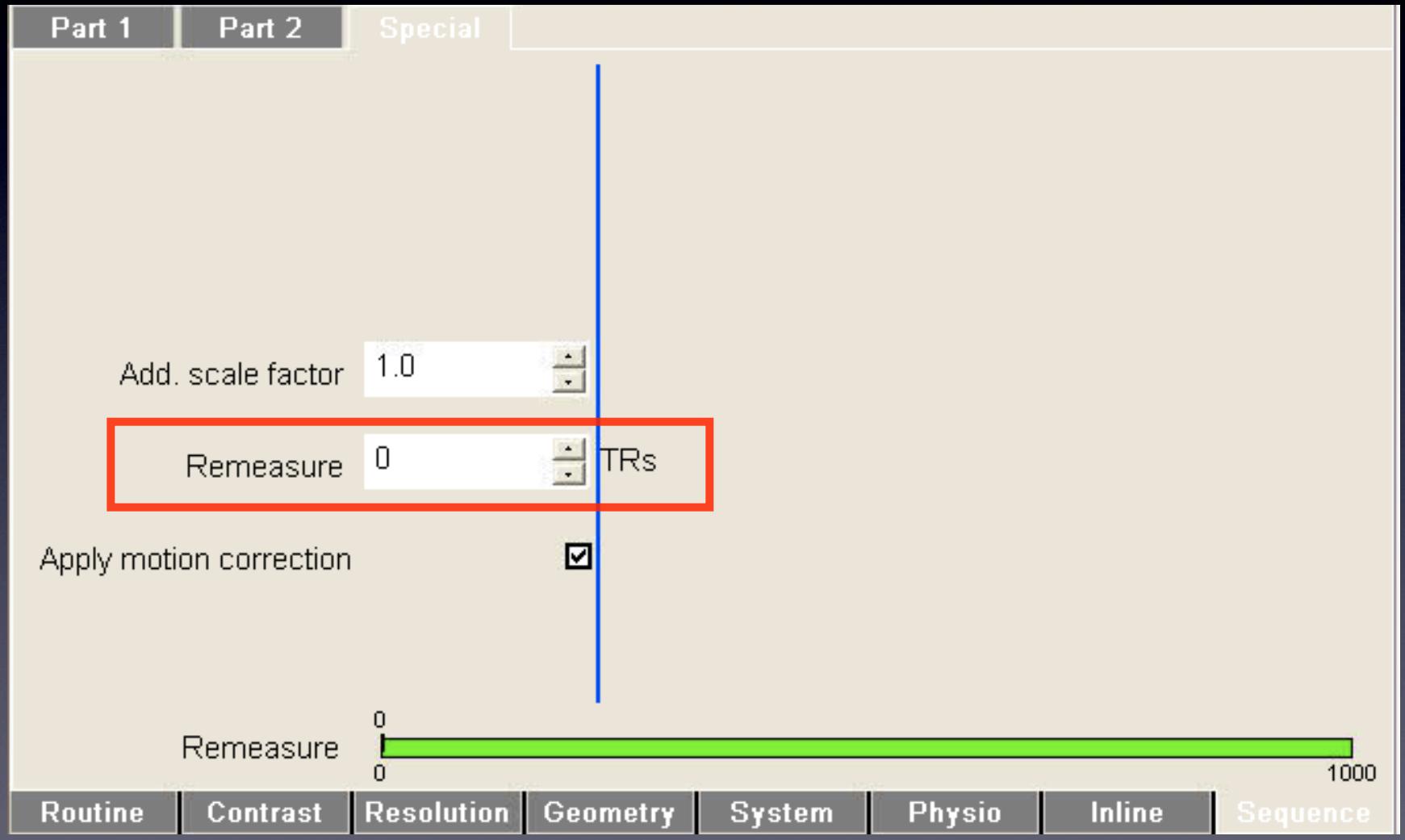

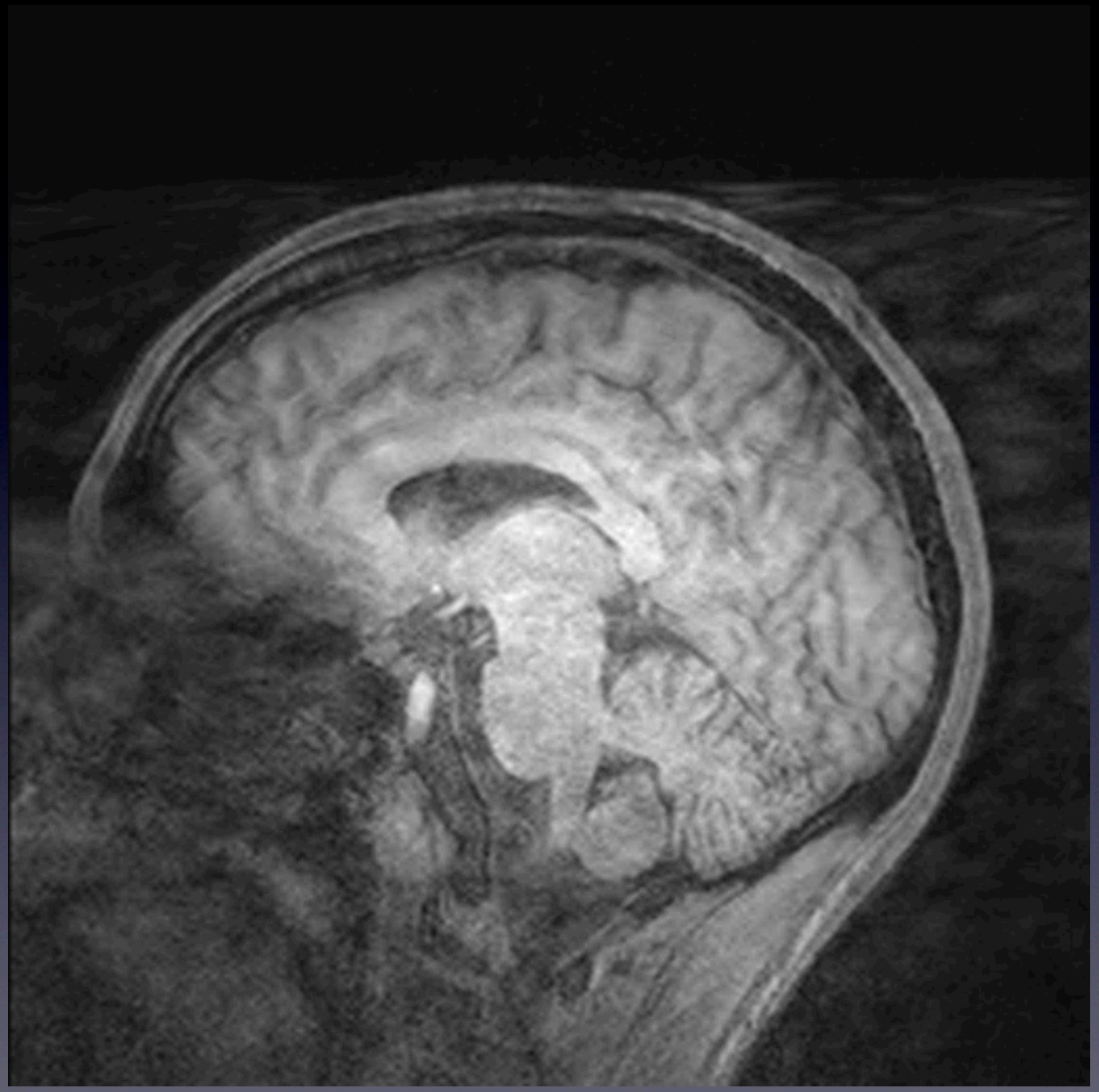

Overview

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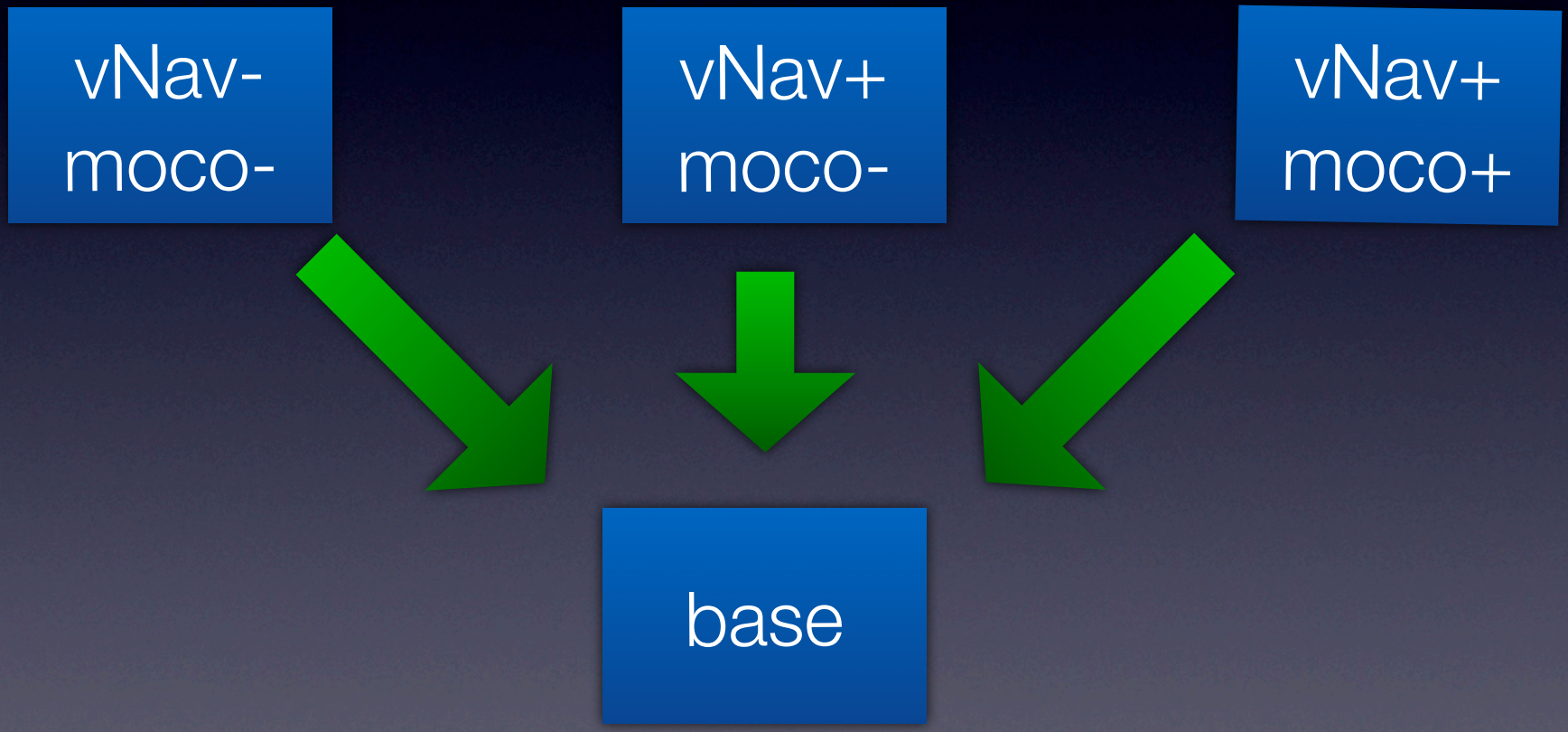
- **Using FreeSurfer for validation:**
  longitudinal, cross-contrast analysis

Three non-standard FreeSurfer uses

1. “Longitudinal” analysis of same-subject, same-day, motion-free T1 scans without navigators, with navigators but without motion-correction, and with navigators and motion-correction.
2. Registration of same-subject, same-day, with-motion T1 scans to a fully segmented same-subject, same-day, without-motion T1 scan.
3. Cross-contrast registration of same-subject, same-day, with- and without-motion T2 scans to a fully segmented same-subject, same day without motion T1 scan.

"Longitudinal" analysis of same-subject, same-day, motion-free T1 scans without navigators, with navigators but without motion-correction, and with navigators and motion-correction.



longitudinal stream

"Longitudinal" analysis of same-subject, same-day, motion-free T1 scans without navigators, with navigators but without motion-correction, and with navigators and motion-correction.

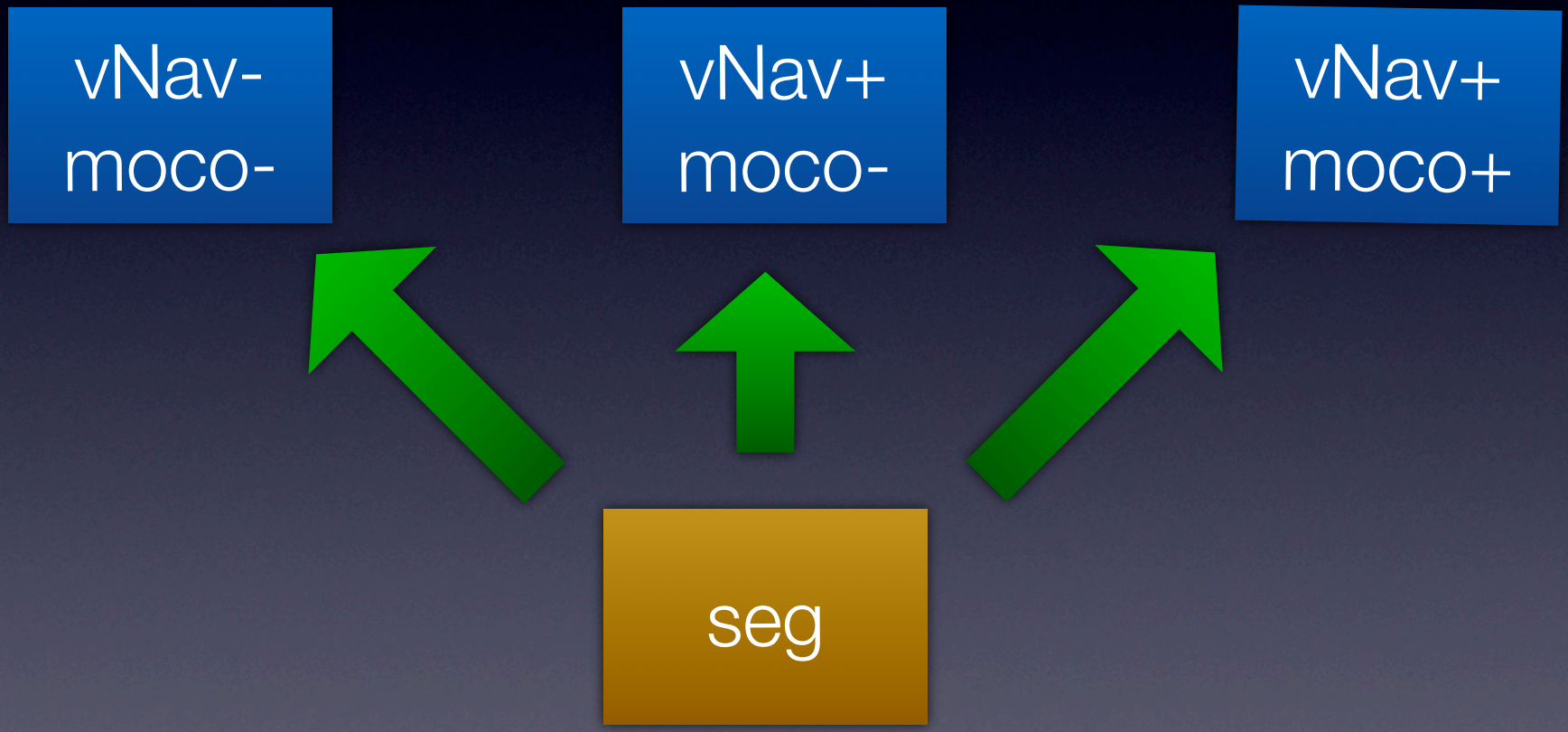
vNav-
moco-

vNav+
moco-

vNav+
moco+

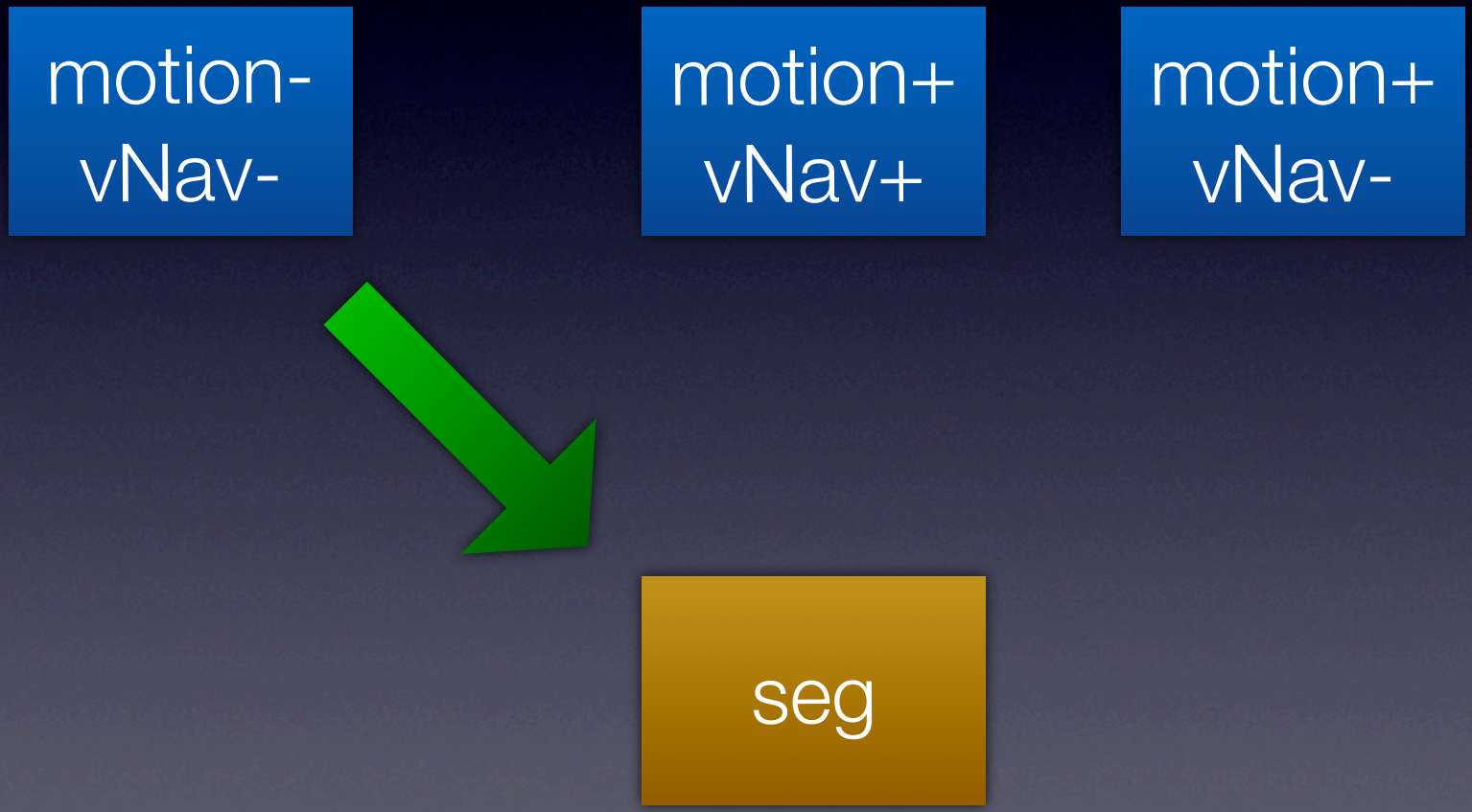
longitudinal stream

"Longitudinal" analysis of same-subject, same-day, motion-free T1 scans without navigators, with navigators but without motion-correction, and with navigators and motion-correction.



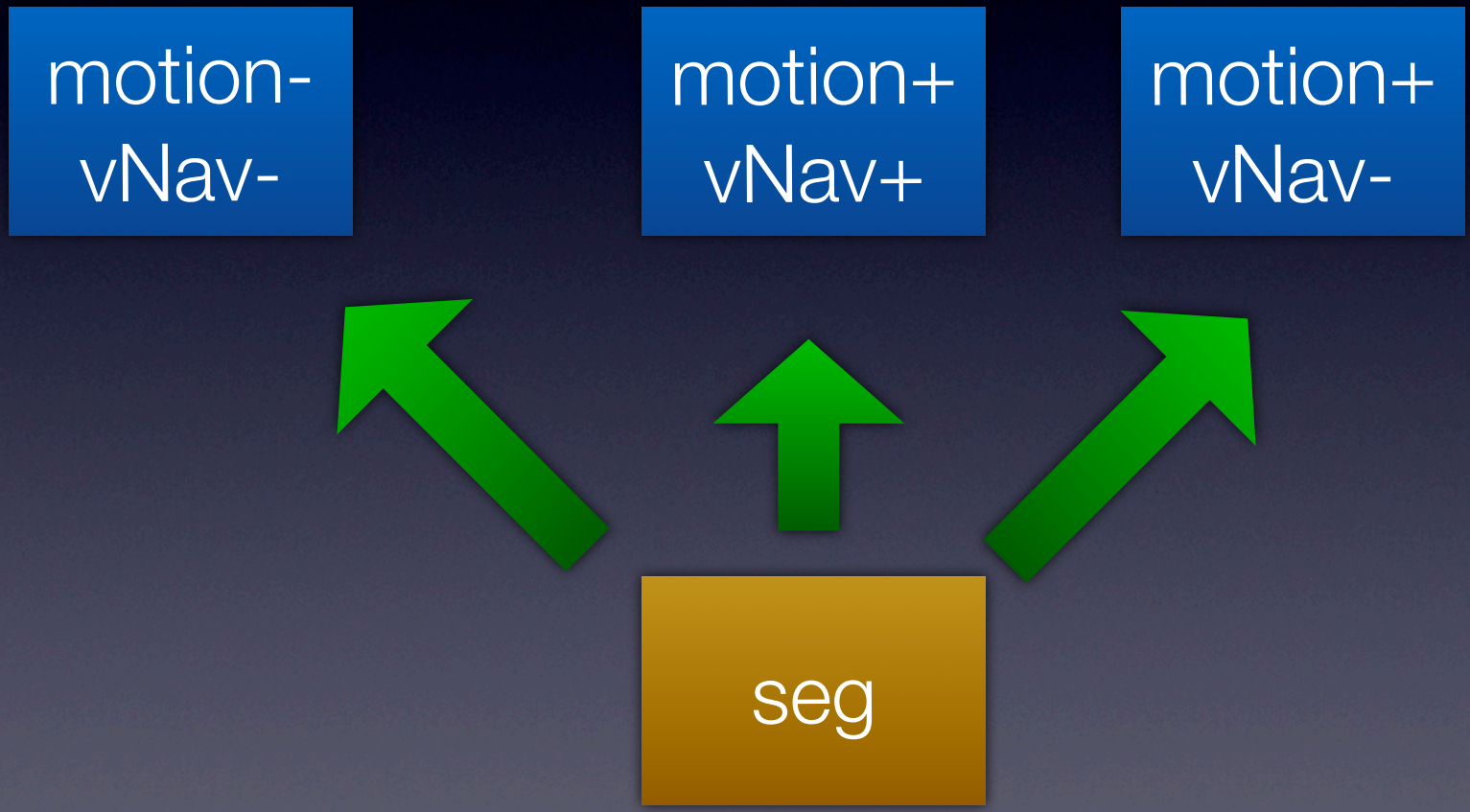
now we have voxel-wise equivalence

Registration of same-subject, same-day, with-motion T1 scans to a fully segmented same-subject, same-day, without-motion T1 scan.



cross-sectional stream

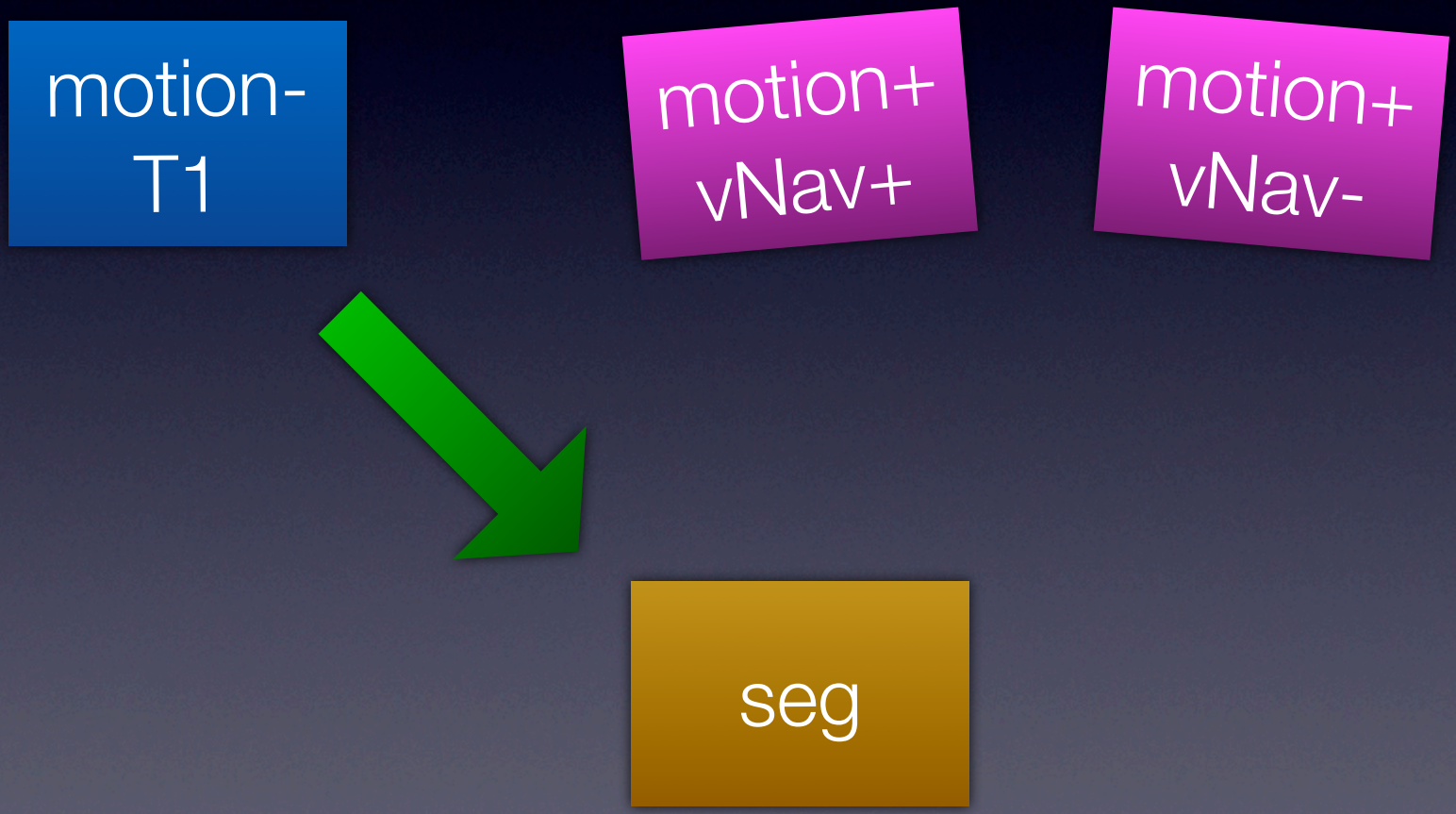
Registration of same-subject, same-day, with-motion T1 scans to a fully segmented same-subject, same-day, without-motion T1 scan.



now we have voxel-wise equivalence

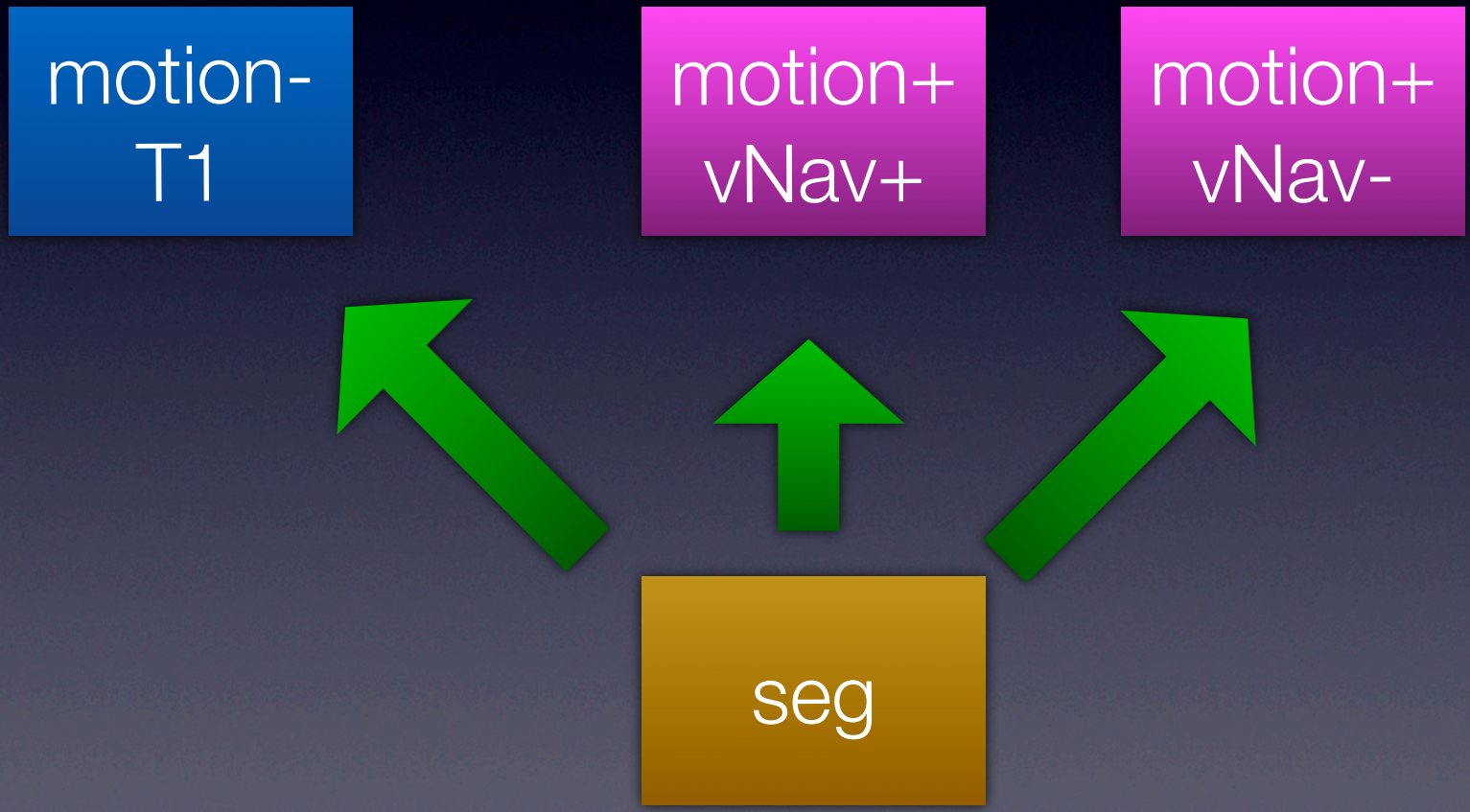
We can use mri_robust_register to **extrapolate a segmentation** to a subsequent acquisition.

Cross-contrast registration of same-subject, same-day, with- and without-motion T2 scans to a fully segmented same-subject, same day without motion T1 scan.



cross-sectional stream

Cross-contrast registration of same-subject, same-day, with- and without-motion T2 scans to a fully segmented same-subject, same day without motion T1 scan.



now we have voxel-wise equivalence

We can use bbregister to **extrapolate a segmentation** to a subsequent acquisition with a different contrast.

Acknowledgements:

- Aaron Hess
- André van der Kouwe
- Martin Reuter
- Himanshu Bhat
- Oliver Hinds
- Thomas Benner
- Michael Hamm
- NIH grants R21EB008547, R21AA017410, R21DA026104, R01NS055754, P41RR014075
- The Ellison Medical Foundation