

Motion-Compensated Neuroanatomical Imaging

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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:

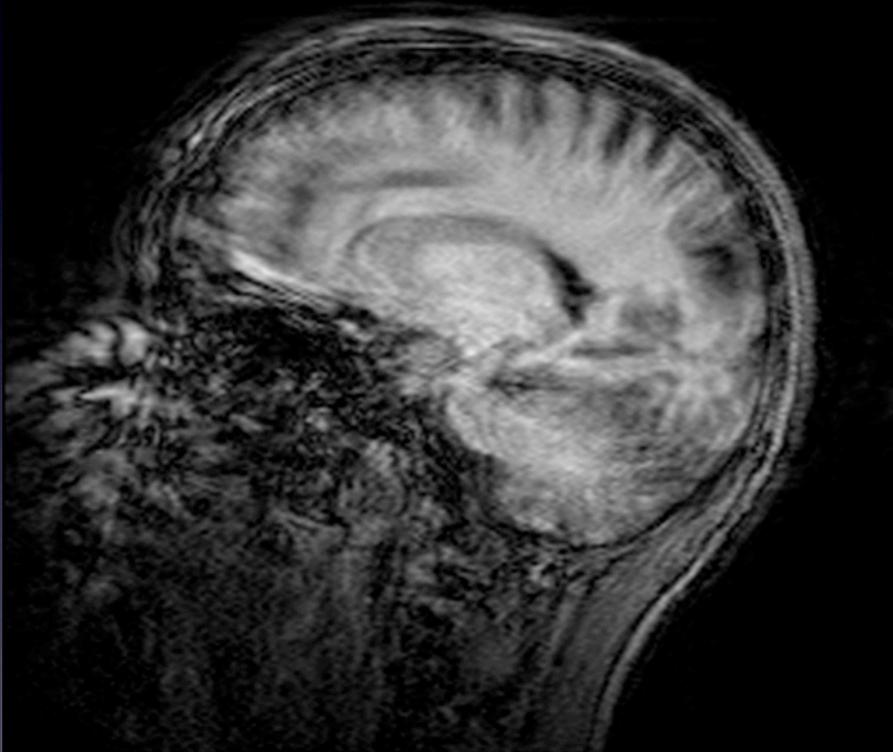
Retrospective

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

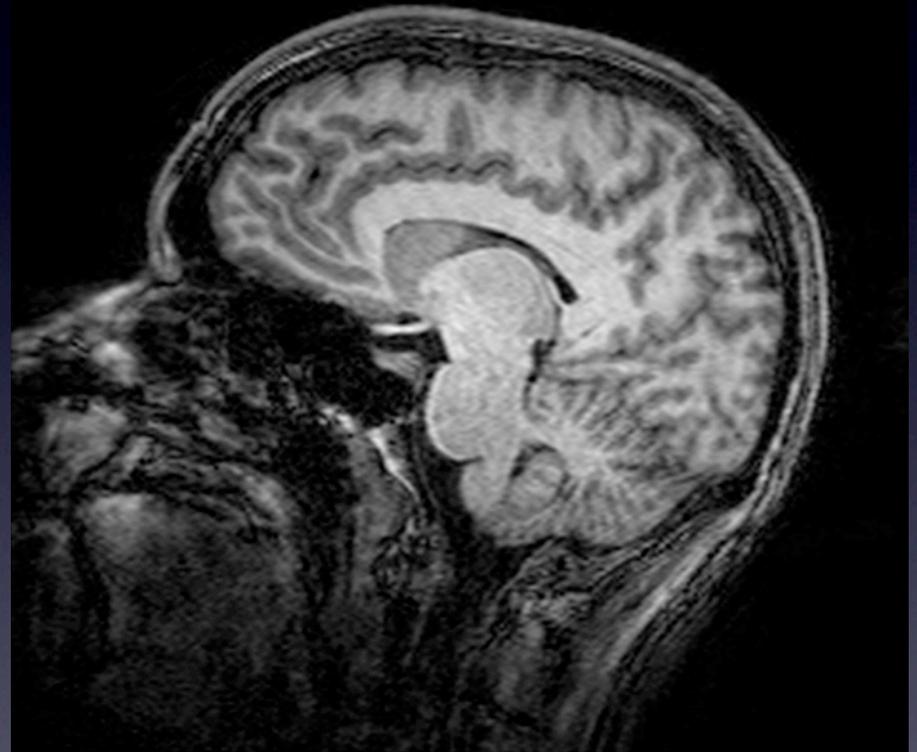
Prospective

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

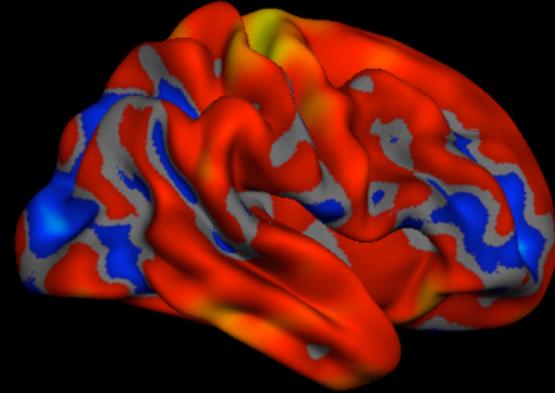
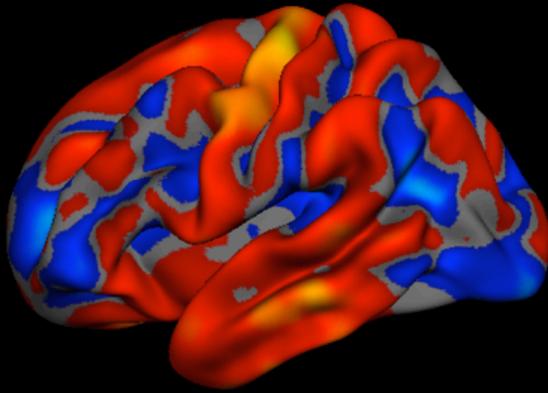
MPRAGE of subject prompted to
change position every 45 seconds



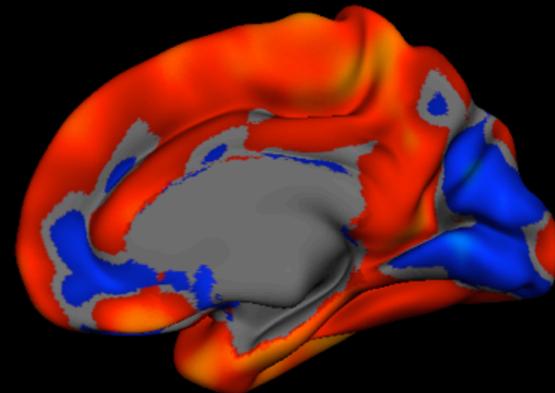
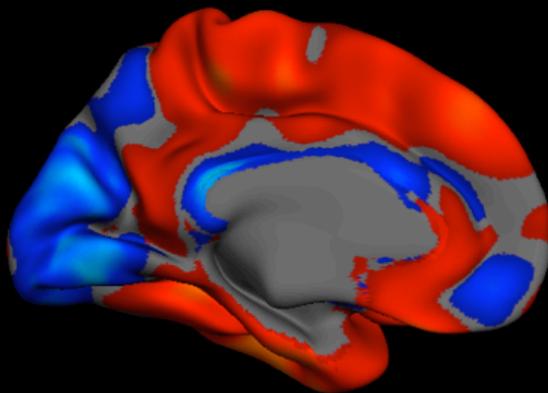
without prospective moco

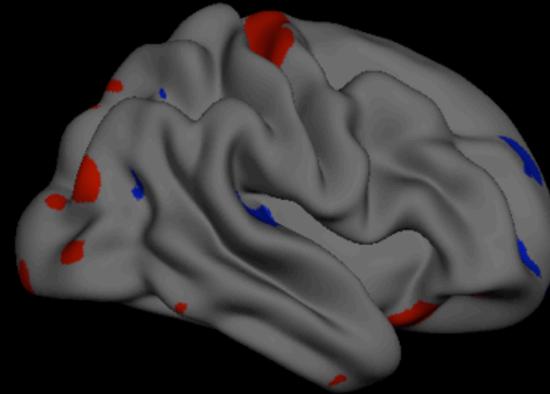
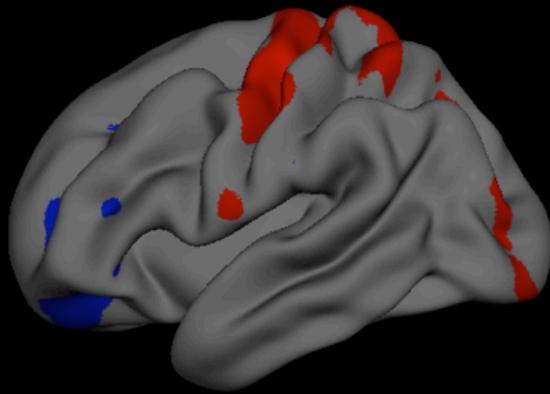


with prospective moco

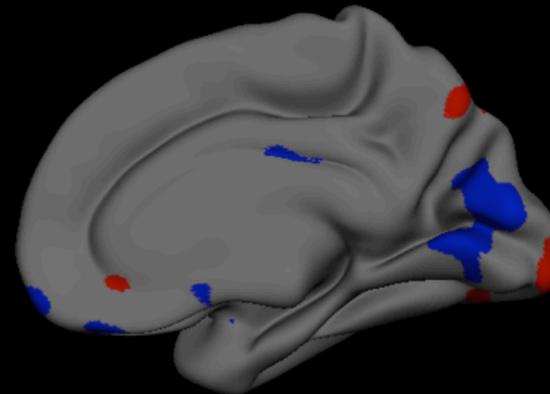
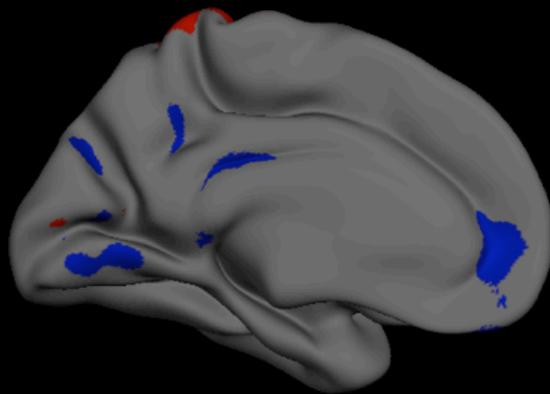


No Motion vs. Motion
Red/Yellow thinning, Blue thickening with motion
Yellow: 30% thinning





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



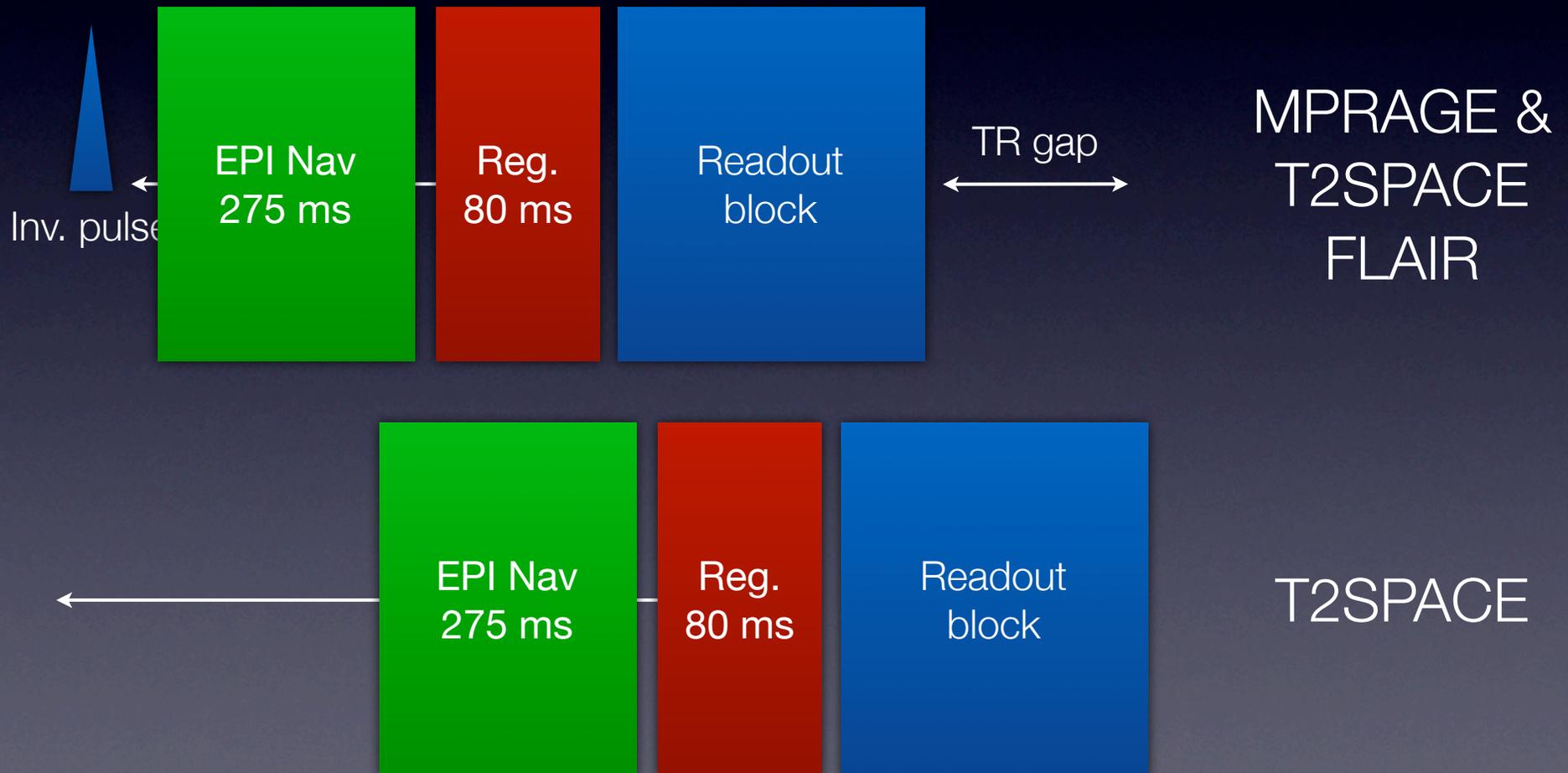
Who should use these sequences? Everyone!

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

Overview

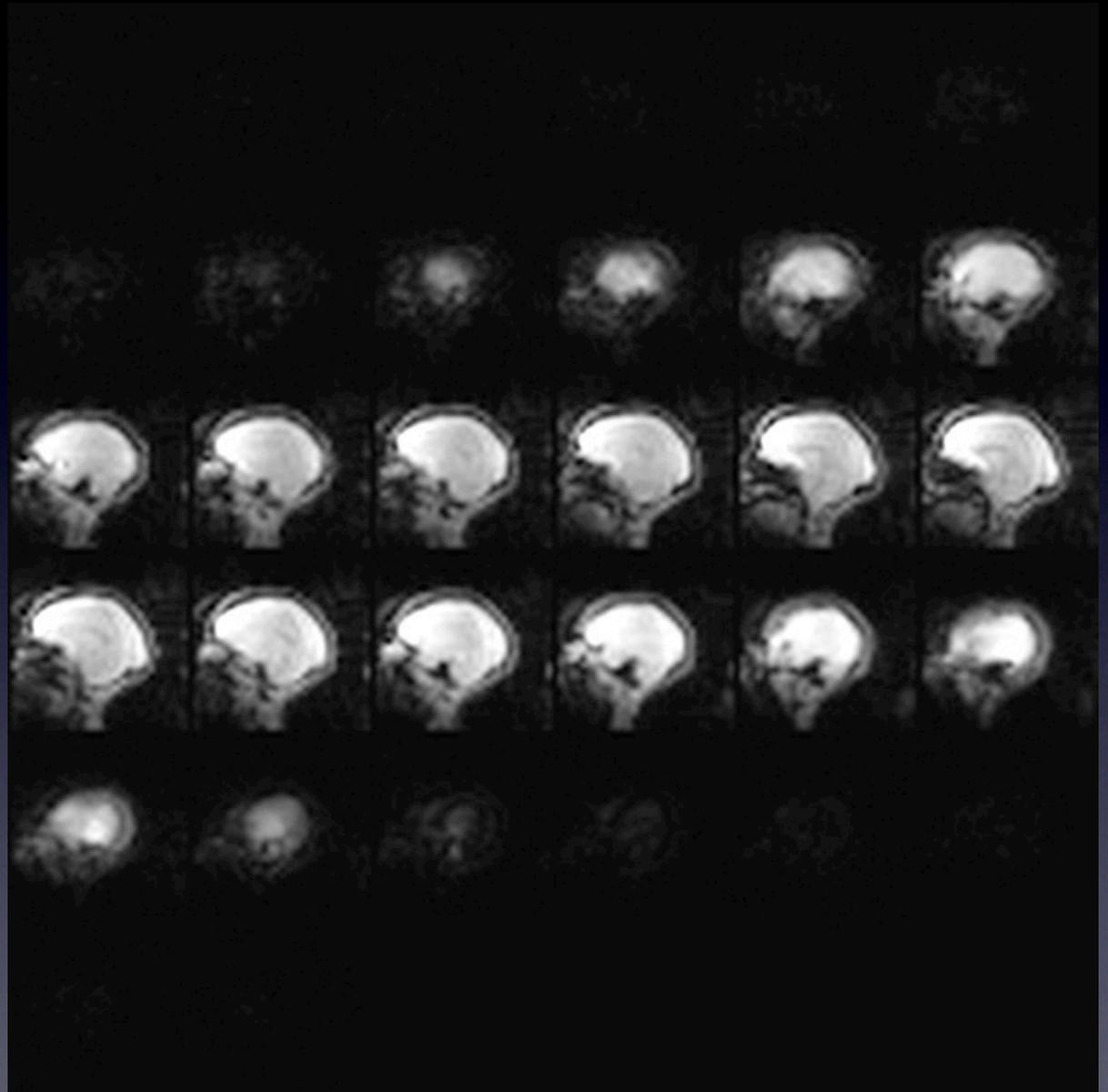
- **Following the subject:**
EPI-navigated prospective motion correction
- **More motion-resistance:**
automatic retrospective reacquisition
- **Using FreeSurfer for validation:**
longitudinal, cross-contrast analysis

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

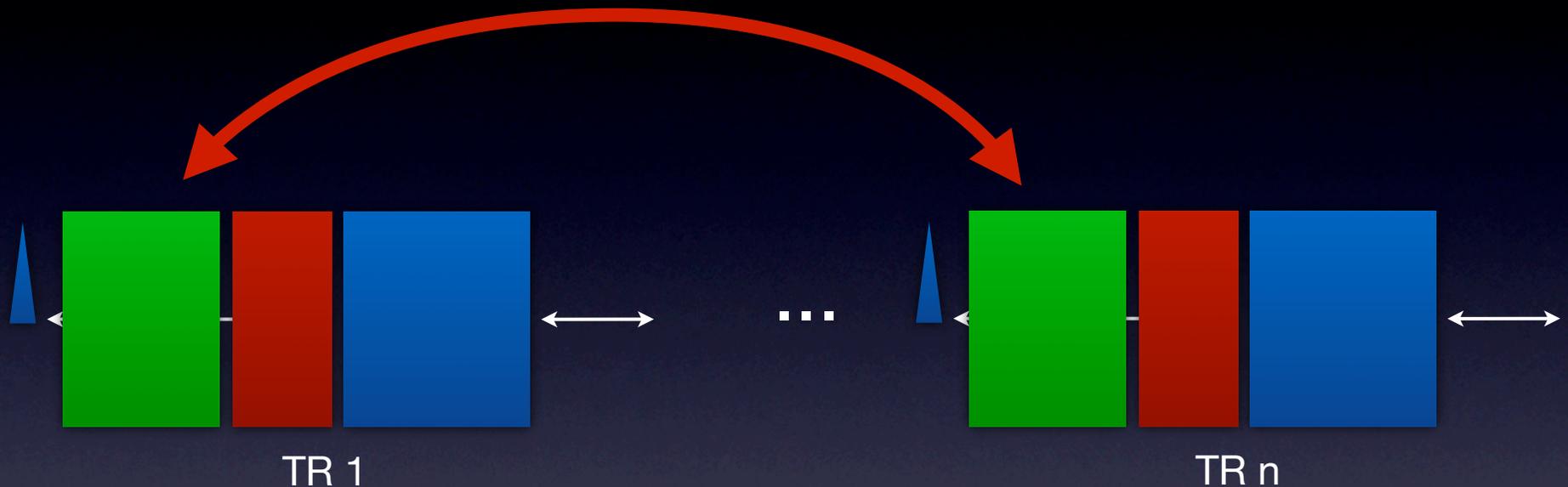


The Navigator

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



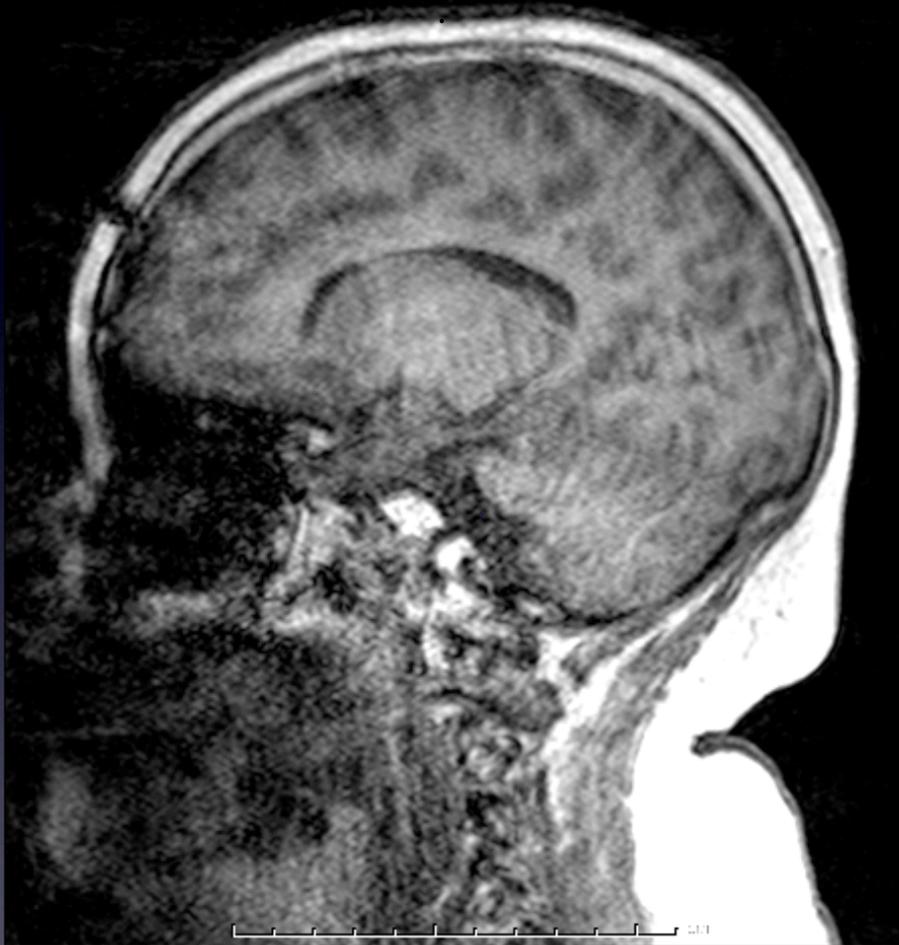
Register each EPI nav volume
back to first TR using Siemens'
PACE registration algorithm.



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



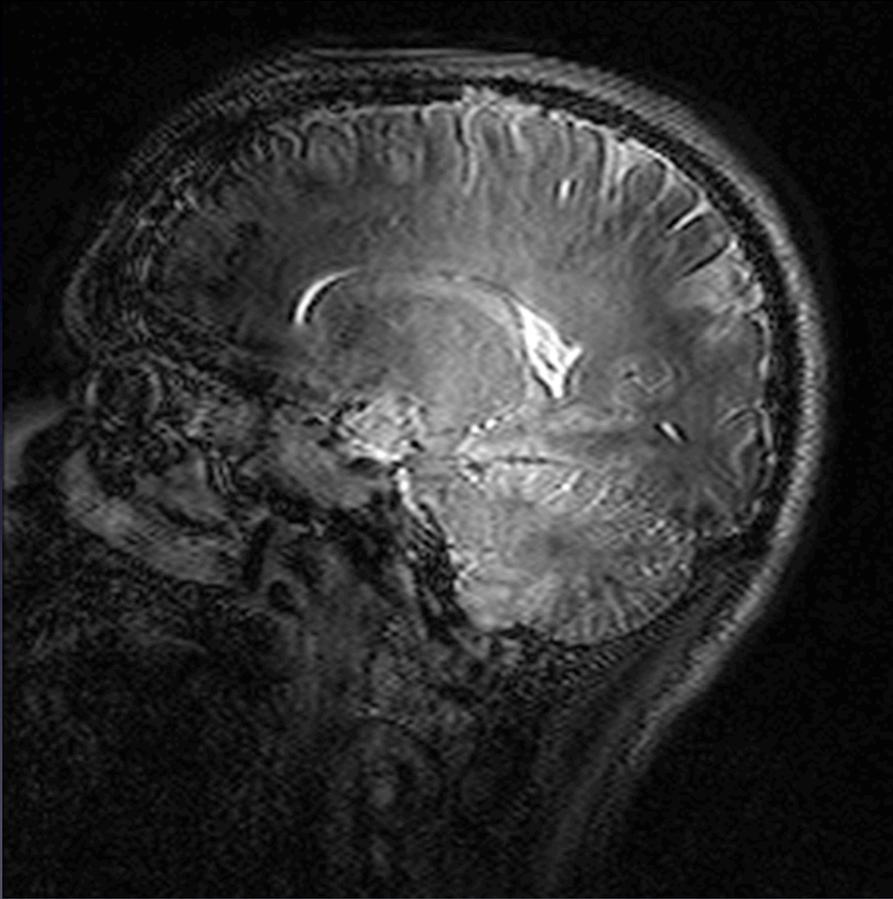
with navs and moco

Images courtesy of Ellen Grant, Children's Hospital Boston

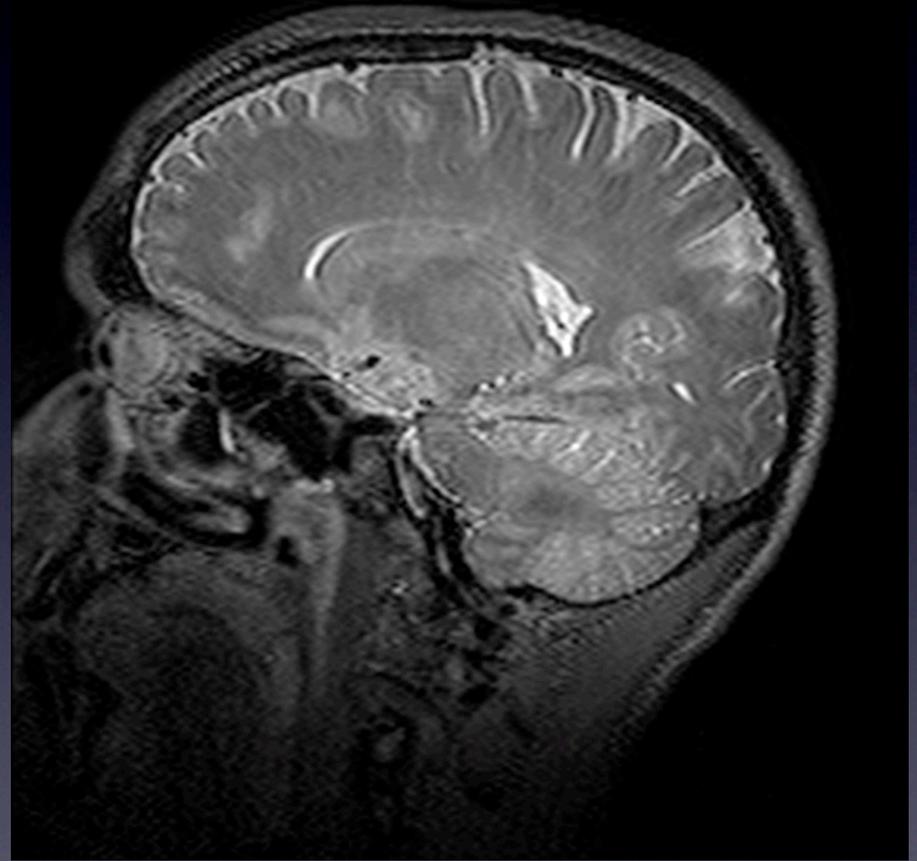
Overview

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

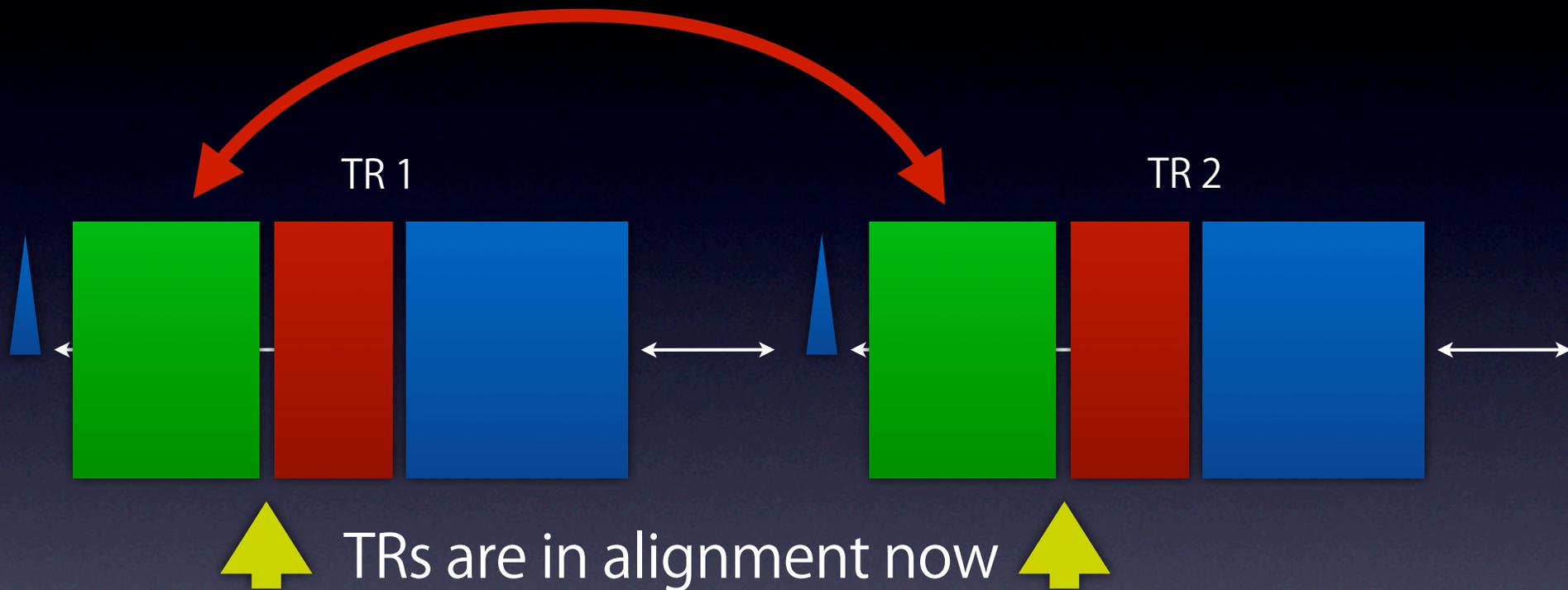


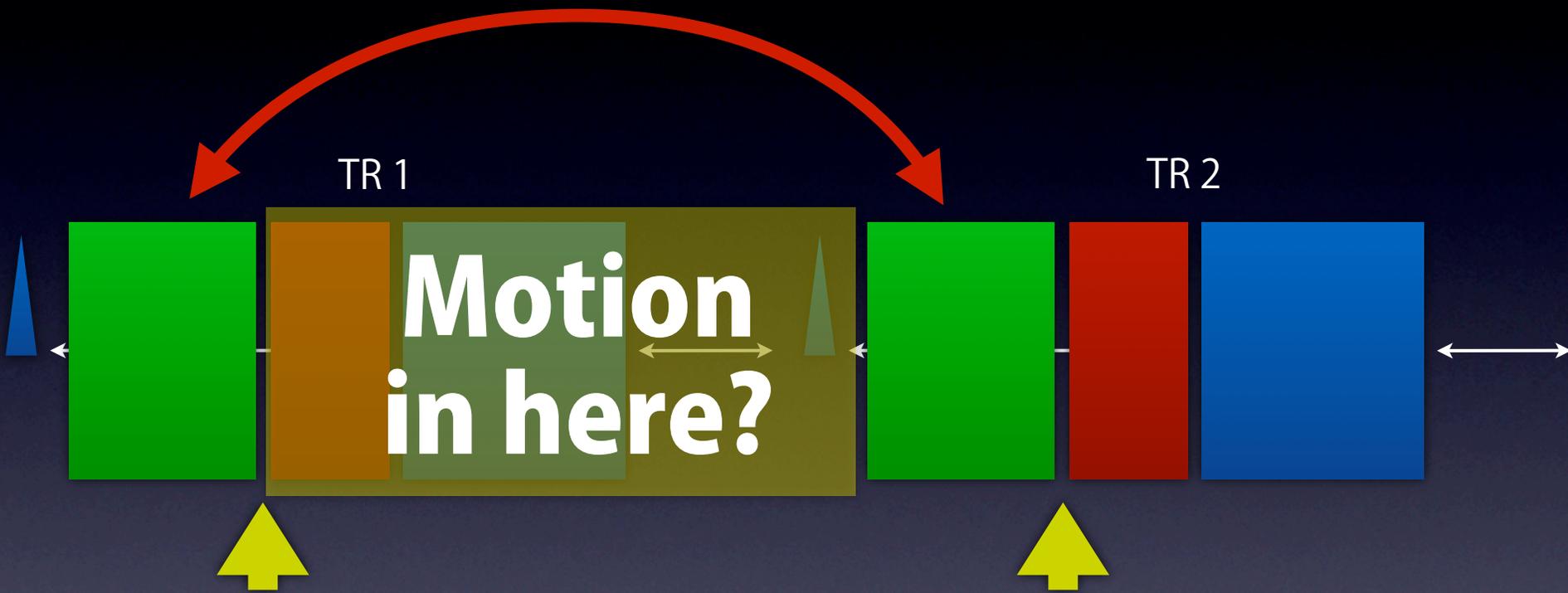
w/ moco
w/o reacquisition



w/ moco
w/ 10 TRs reacquired

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





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

Part 1 | Part 2 | **Special**

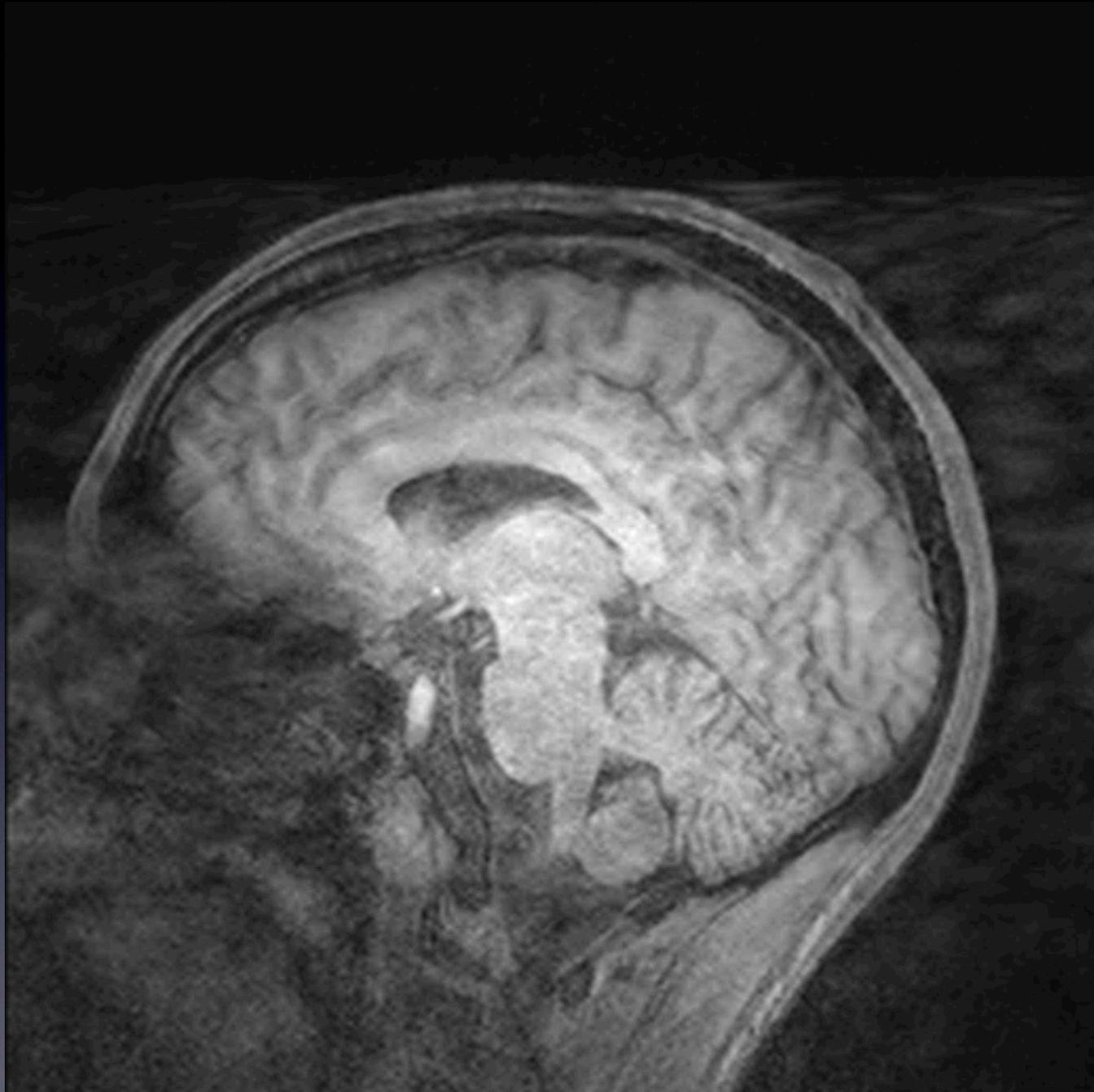
Add. scale factor 1.0

Remeasure 0 TRs

Apply motion correction

Remeasure 0 1000

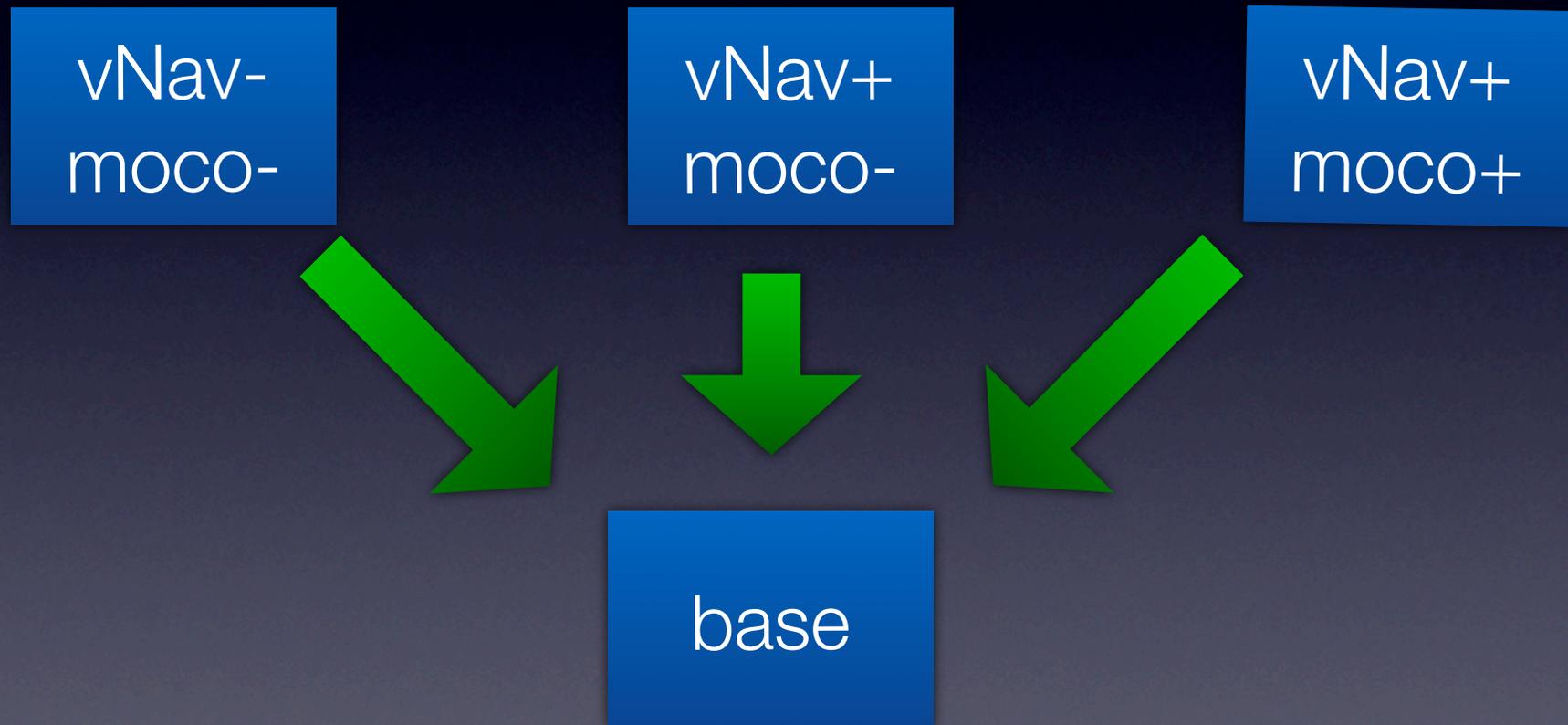
Routine | Contrast | Resolution | Geometry | System | Physio | Inline | Sequence



Overview

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

“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+

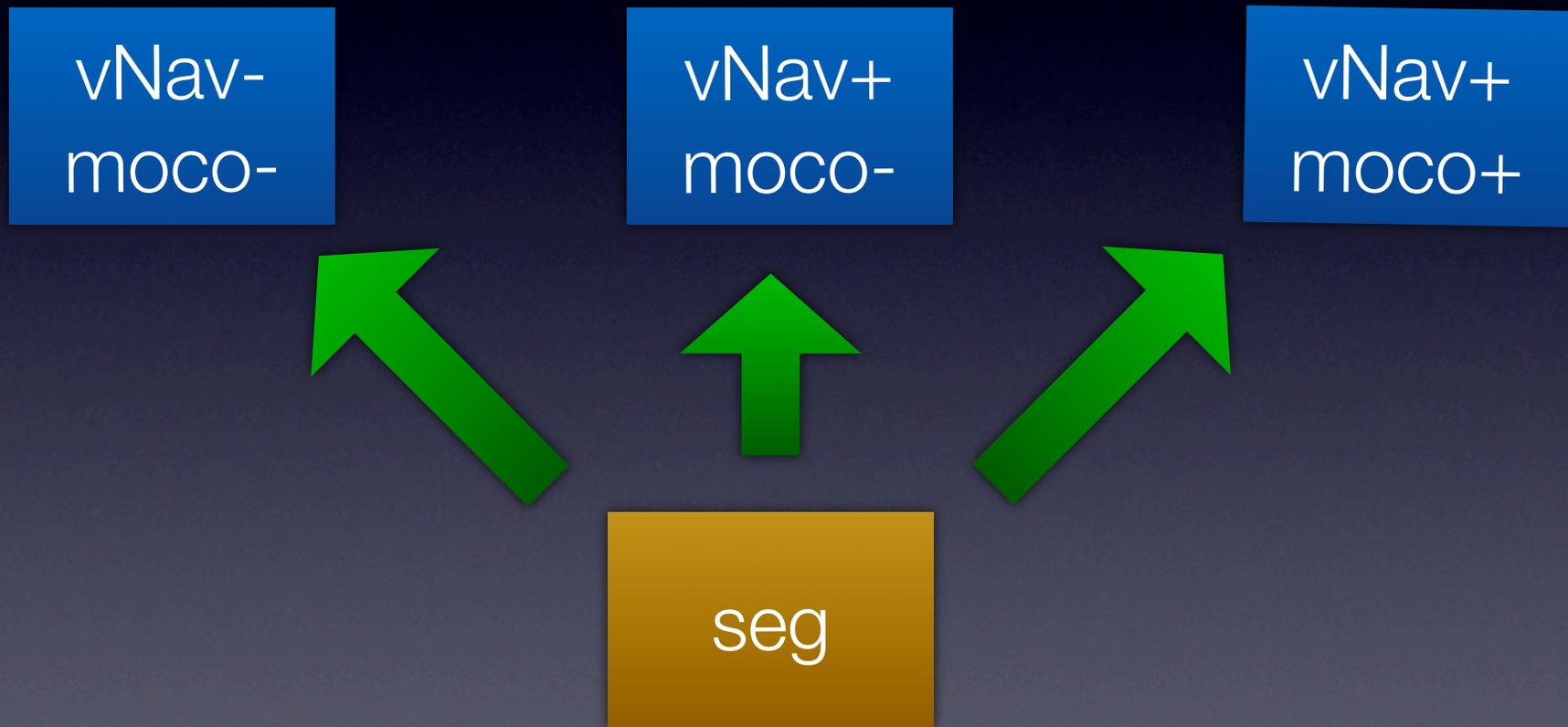
base



seg

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.

motion-
vNav-

motion+
vNav+

motion+
vNav-

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

motion-
vNav-

motion+
vNav+

motion+
vNav-

mri_robust_template

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

motion-
vNav-

motion+
vNav+

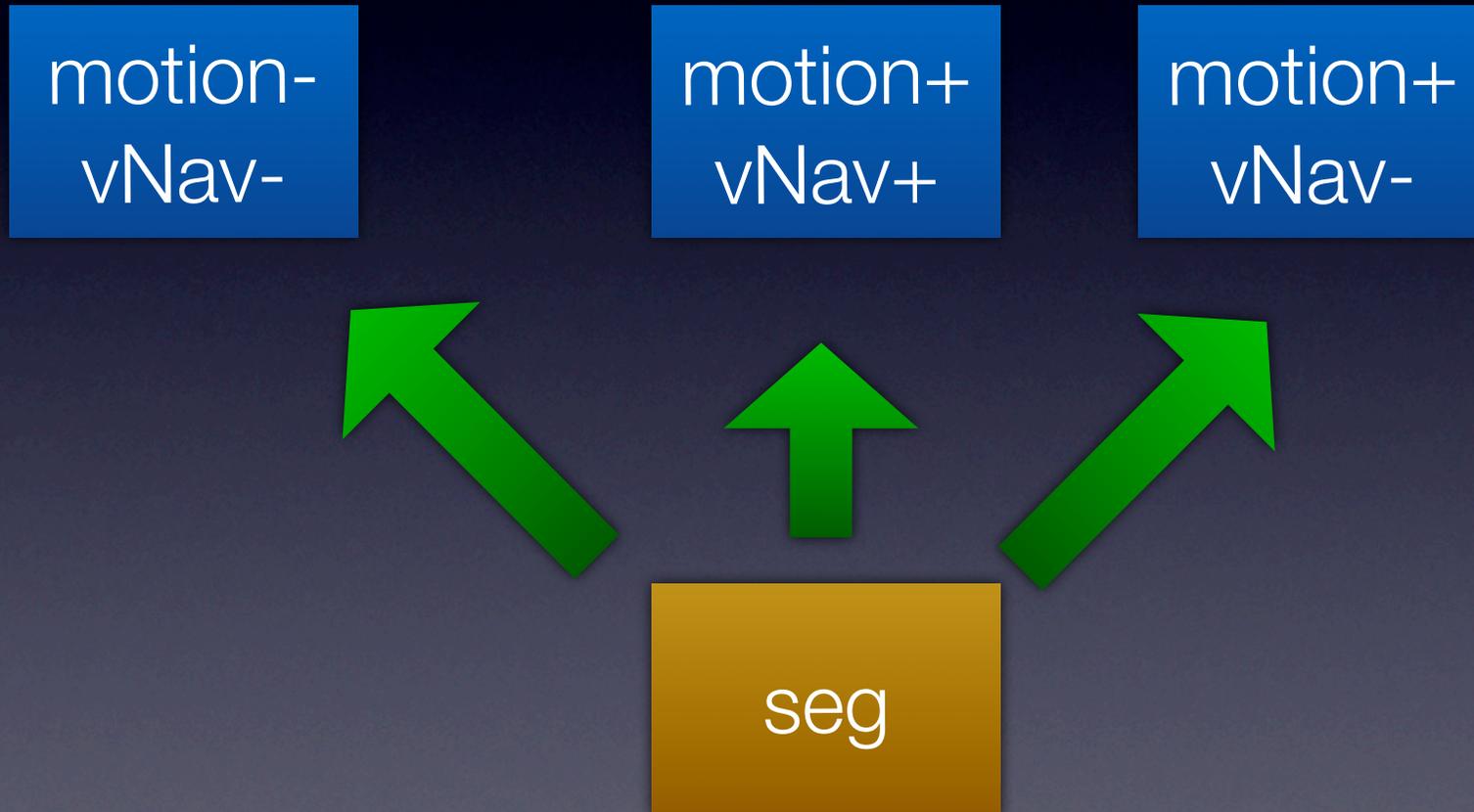
motion+
vNav-



seg

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.

motion-
T1

motion+
vNav+

motion+
vNav-



seg

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.

motion-
T1

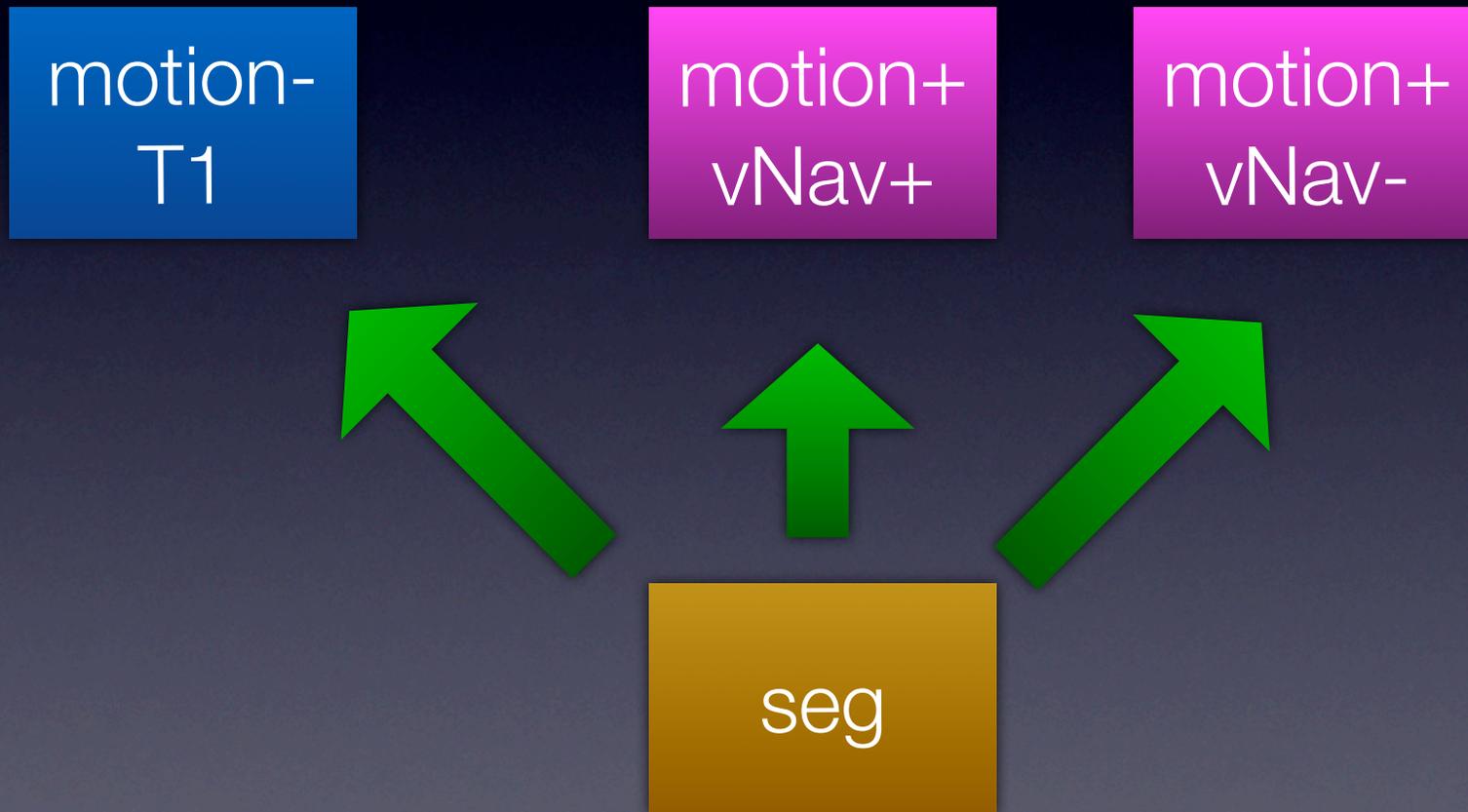
motion+
vNav+

motion+
vNav-

seg

bbregister

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
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