

# 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.

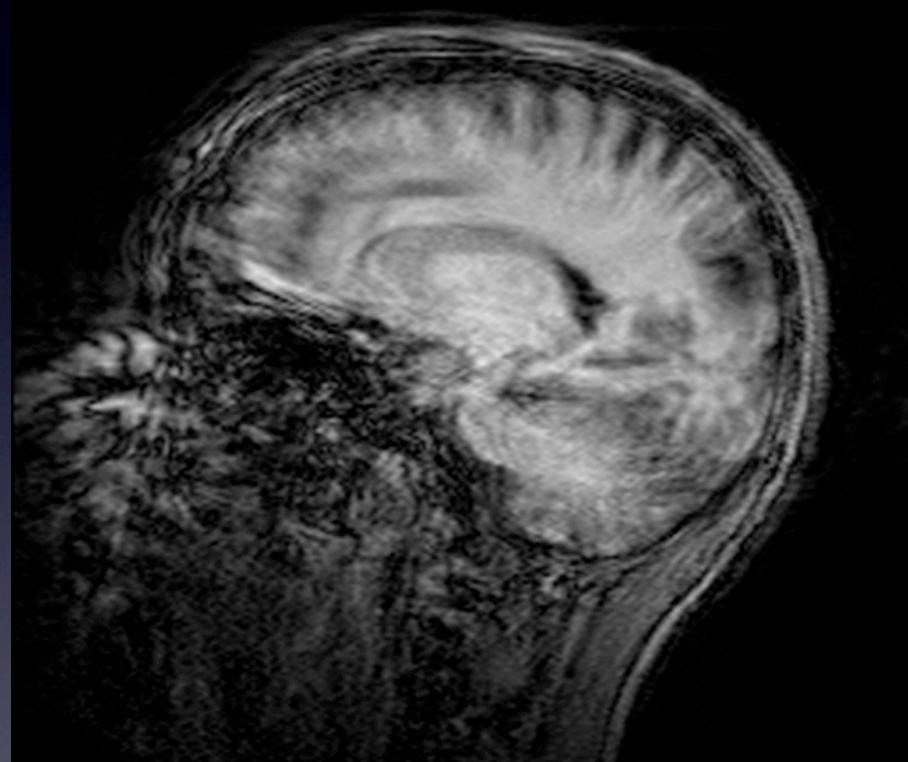
Examples: PROPELLER, SNAILS

## **Prospective**

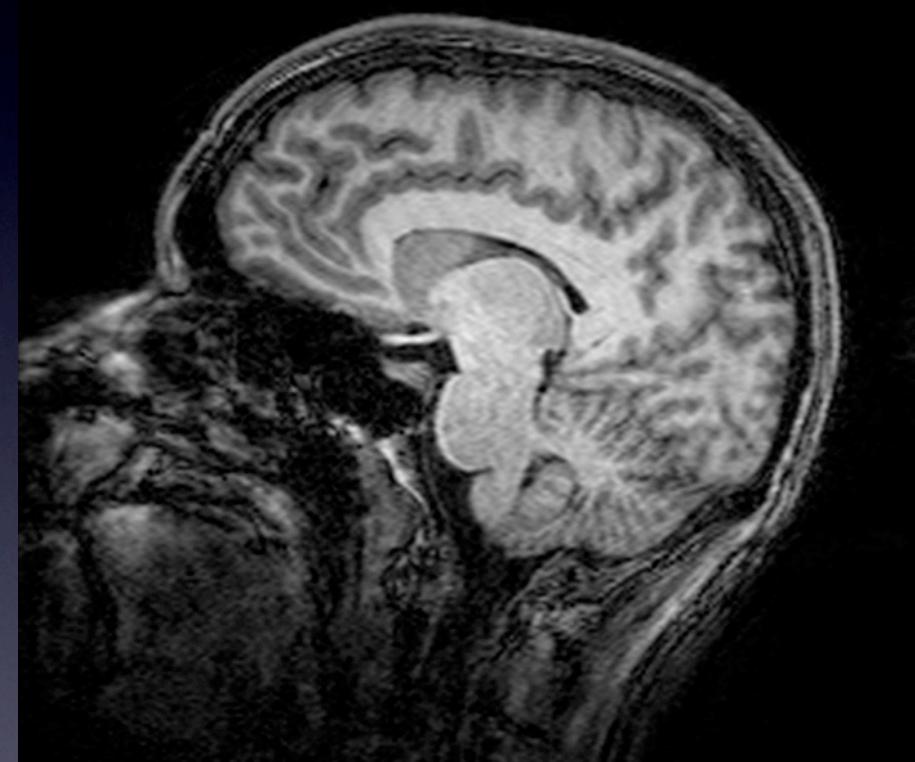
Track the subject and alter the acquisition “on-the-fly” to account for subject motion.

Examples: PACE, vNavs, PROMO

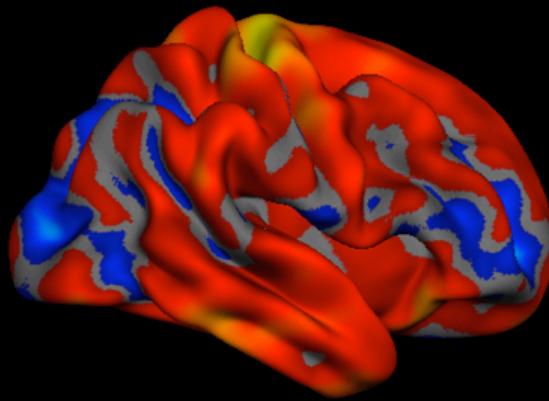
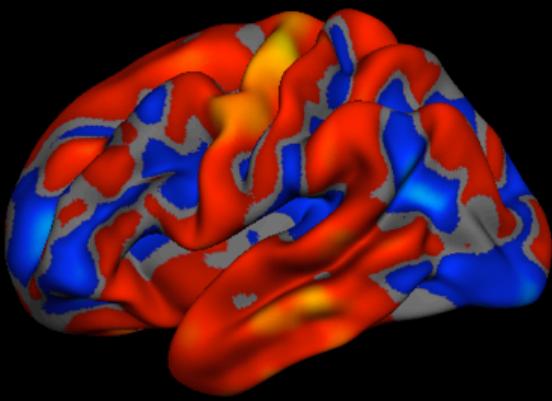
MPRAGE of subject prompted to change position every 45 seconds



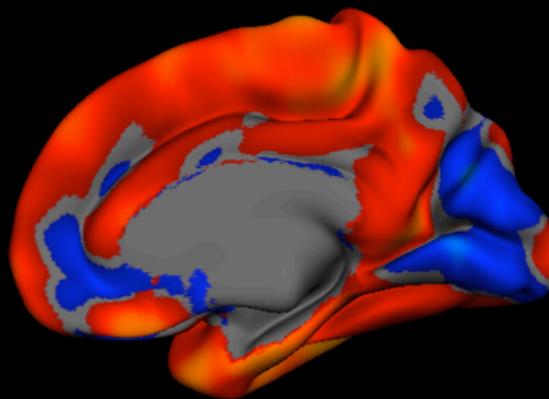
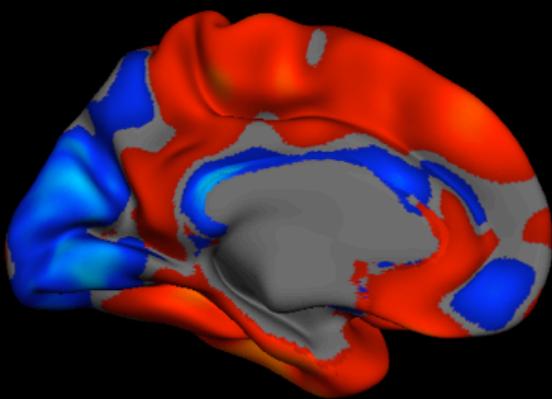
without prospective moco

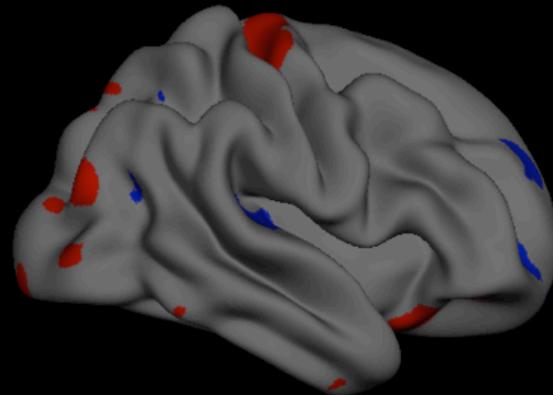
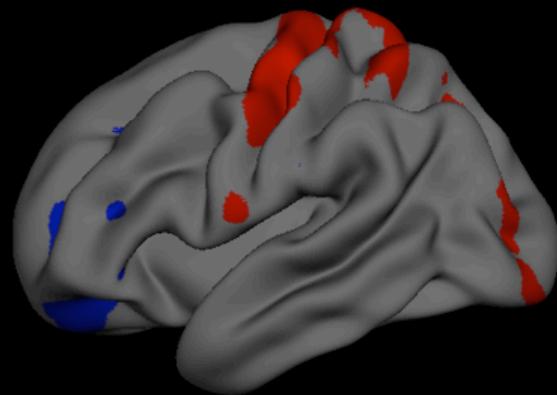


with prospective moco

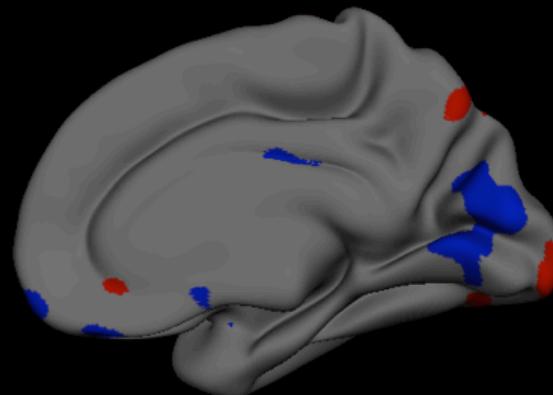
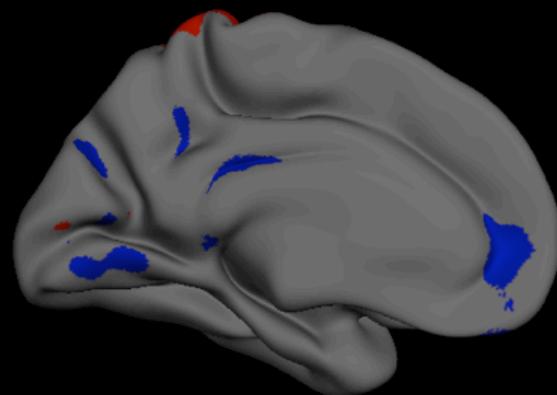


No Motion vs. Motion  
Red/Yellow thinning, Blue thickening with motion  
Yellow: 30% thinning





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



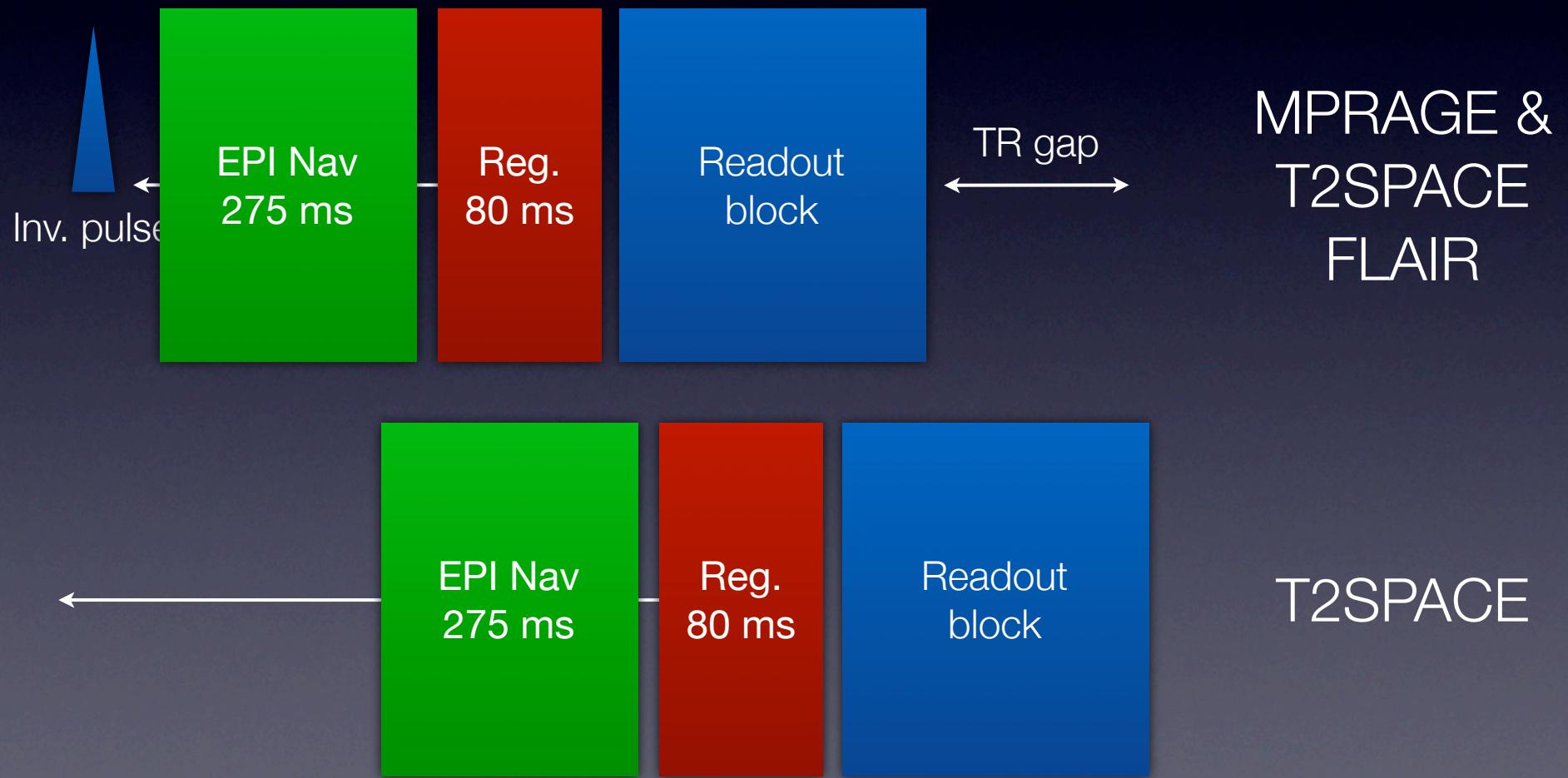
## **Who should use these sequences? Everyone!**

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

# Overview

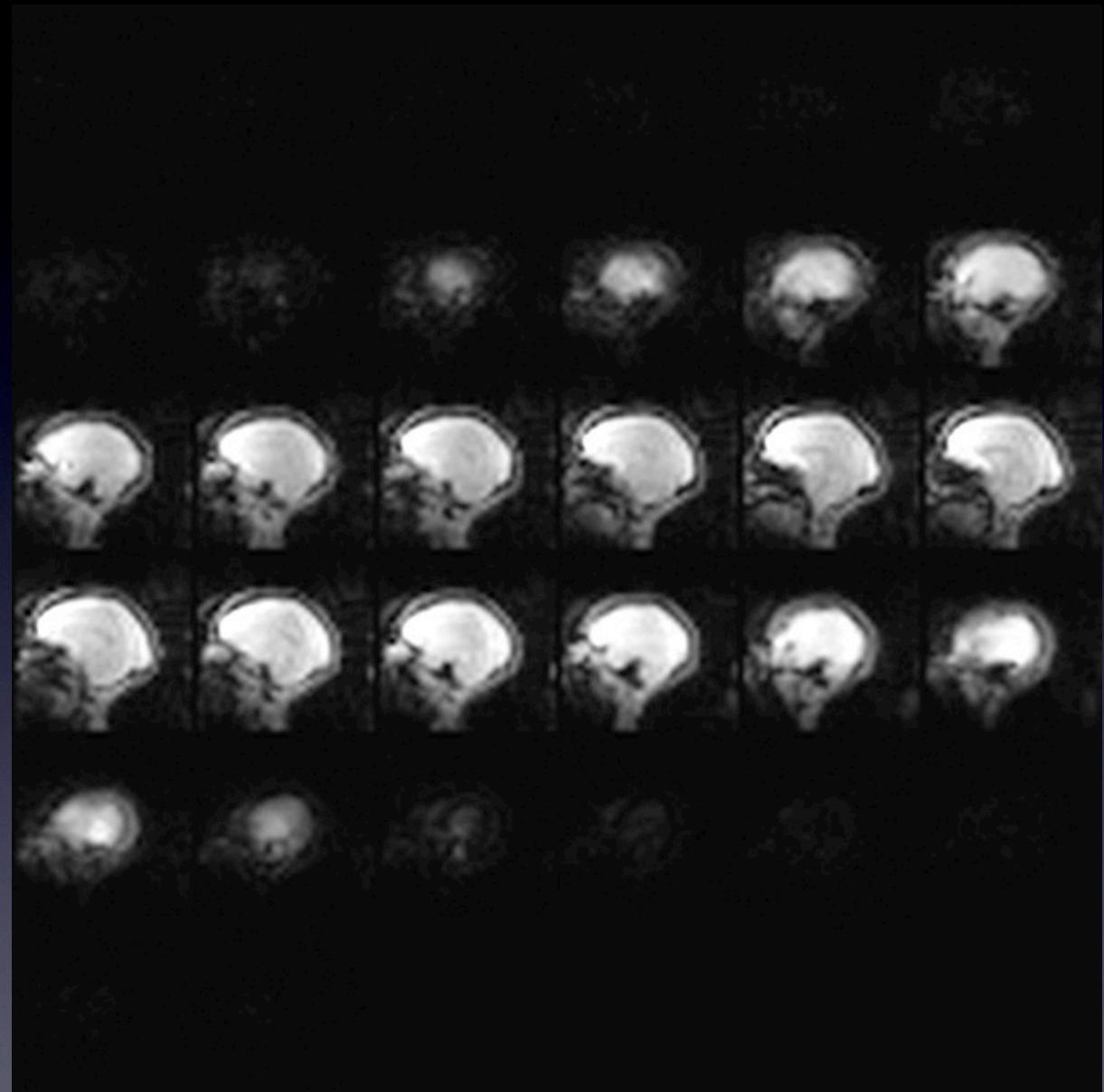
- **Following the subject:**  
EPI-navigated prospective motion correction
- **More motion-resistance:**  
automatic retrospective reacquisition
- **Using FreeSurfer for validation:**  
longitudinal, cross-contrast analysis

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

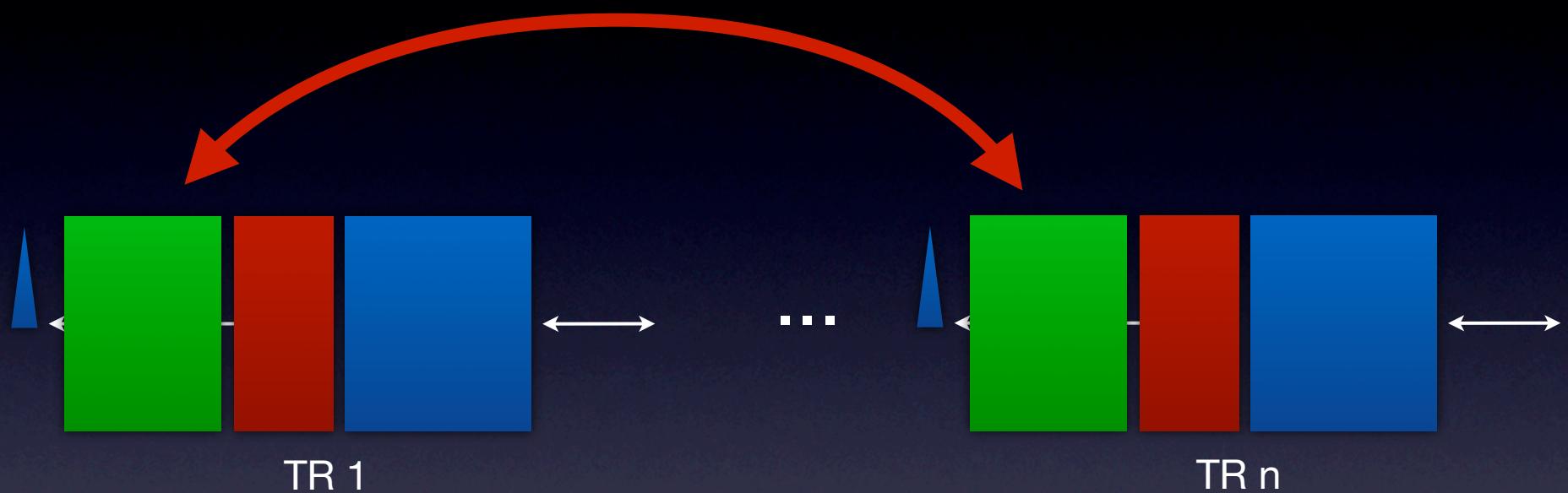


# The Navigator

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



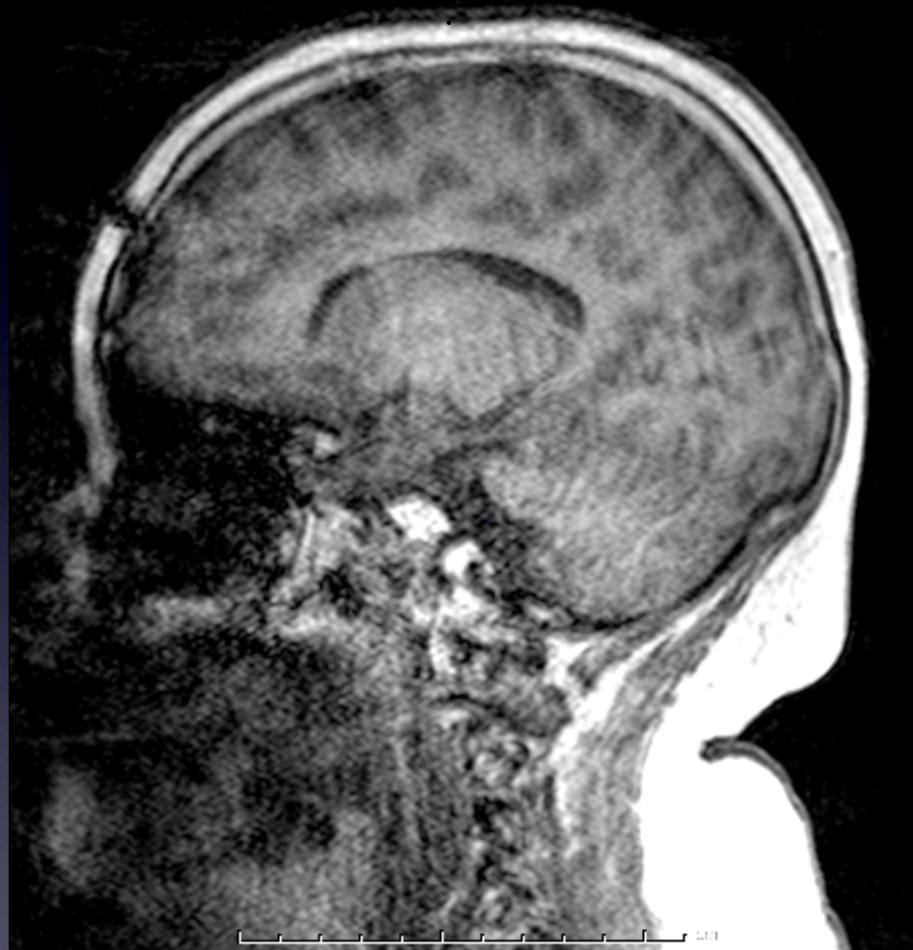
Register each EPI nav volume back to first TR using Siemens' **PACE** registration algorithm.



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



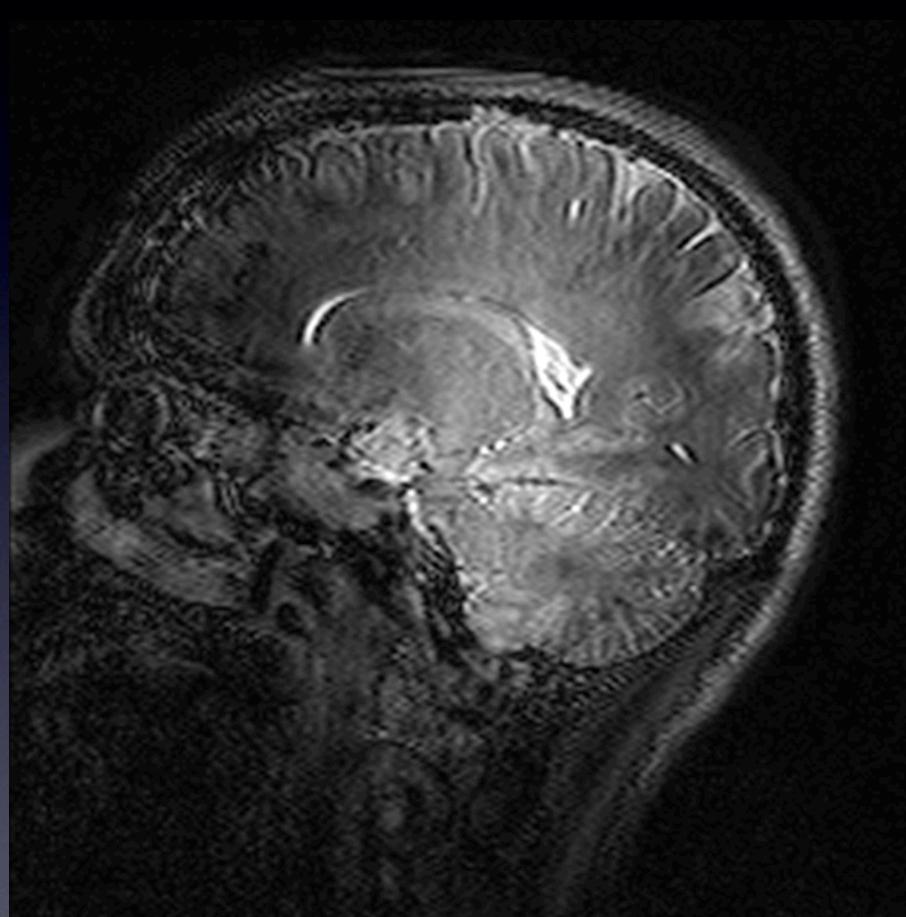
with navs and moco

Images courtesy of Ellen Grant, Children's Hospital Boston

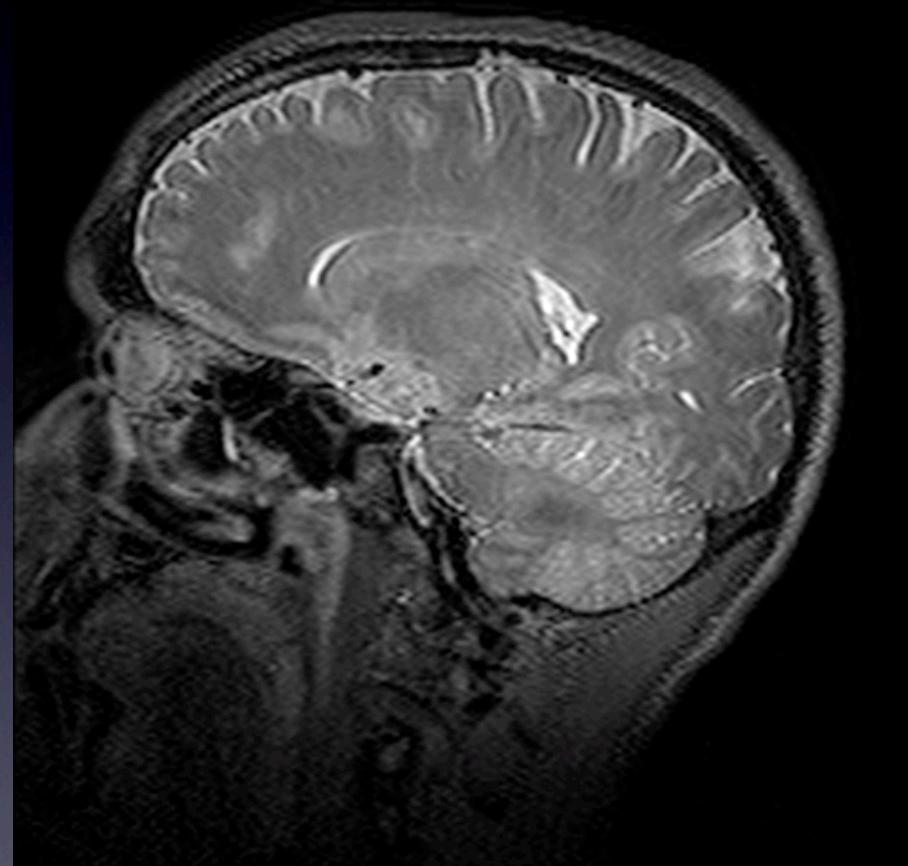
# Overview

- **Following the subject:**  
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T2SPACE corrupted by 20 seconds of free motion during acquisition of center of k-space

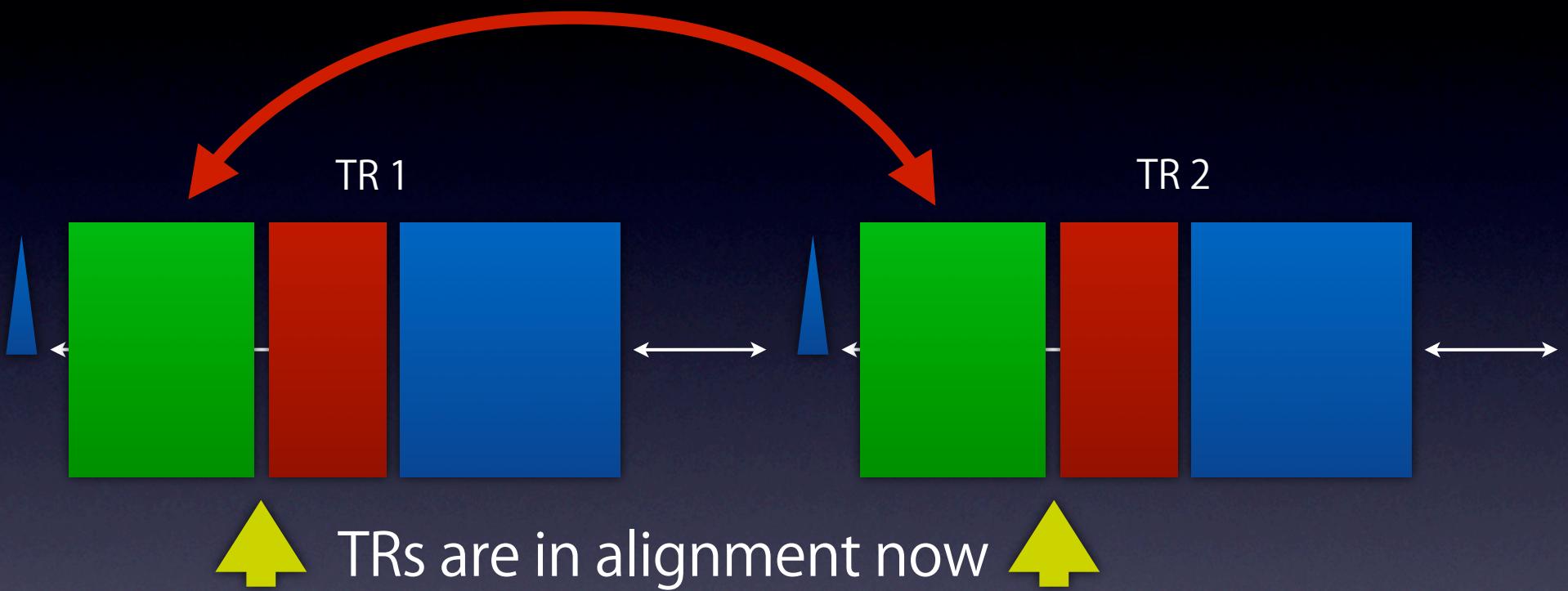


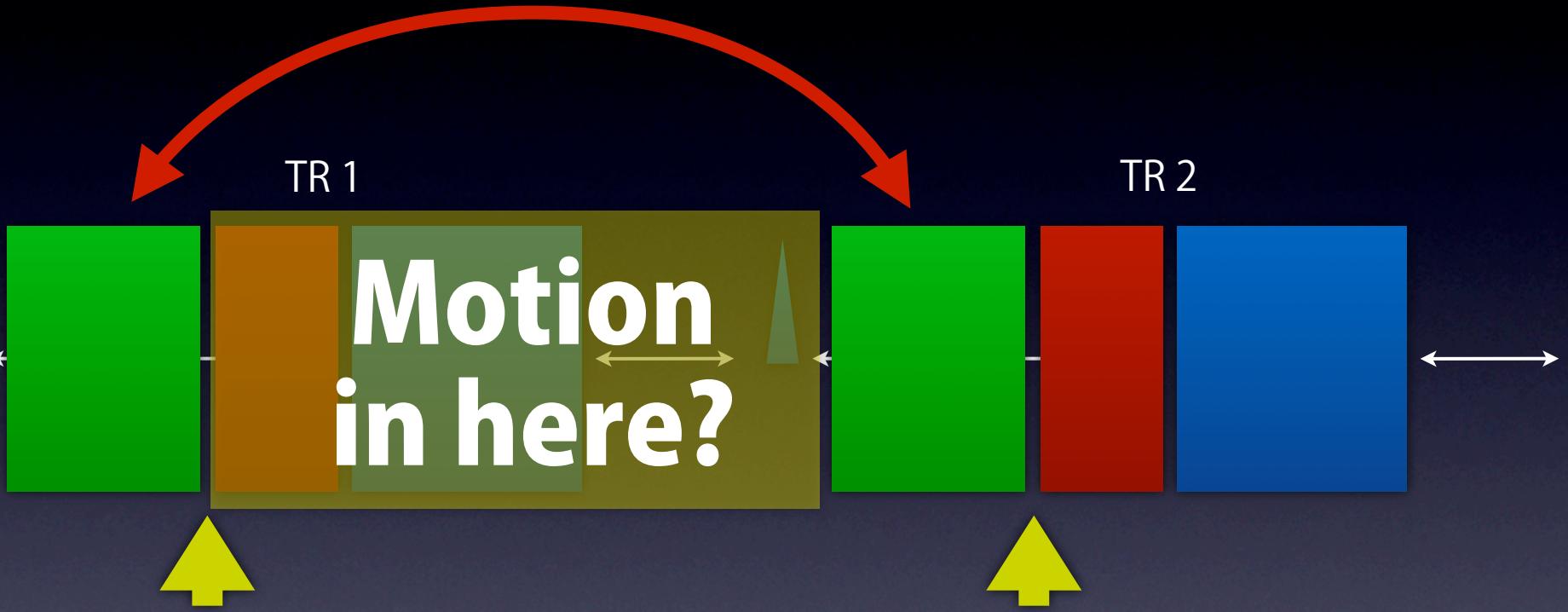
w/ moco  
w/o reacquisition



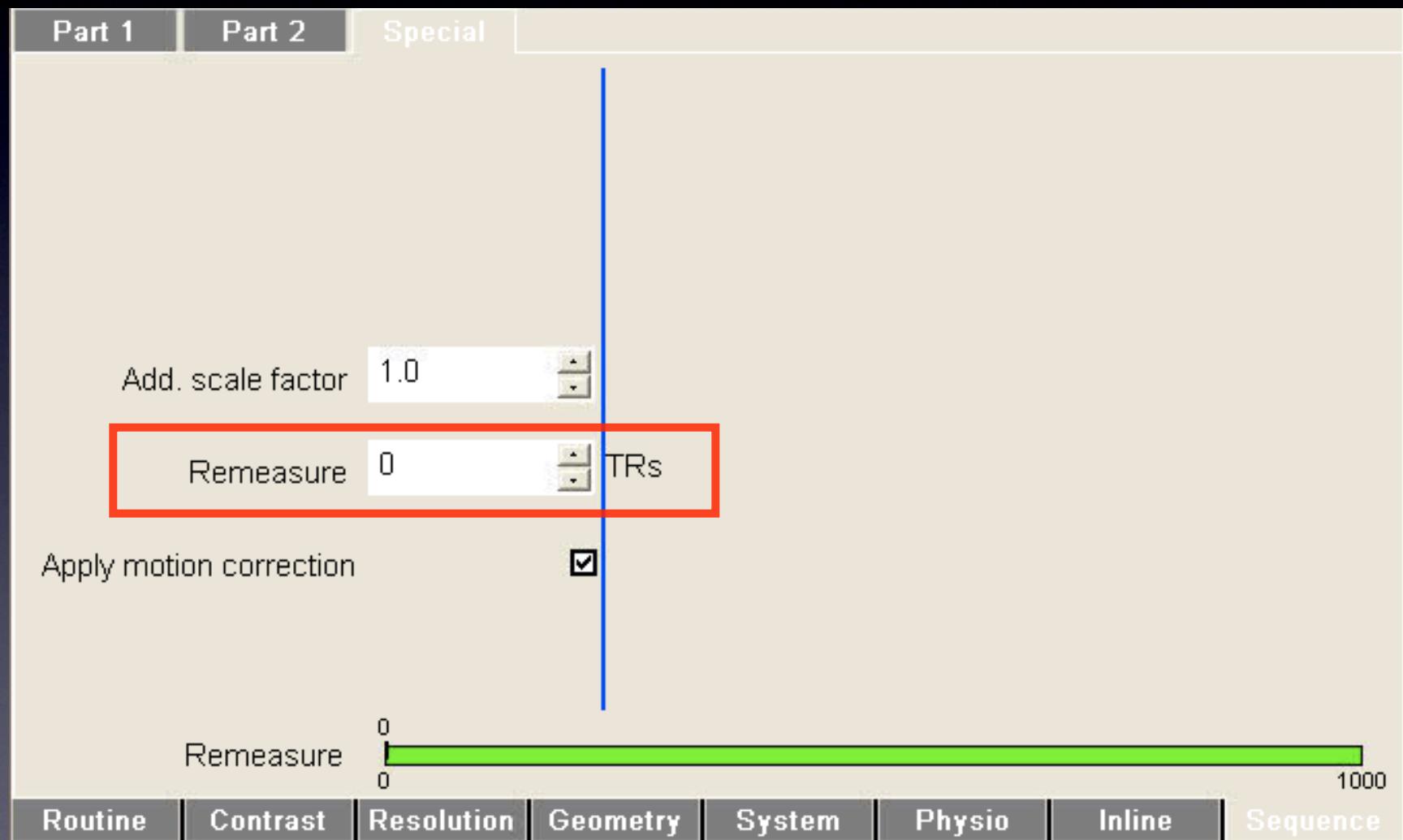
w/ moco  
w/ 10 TRs reacquired

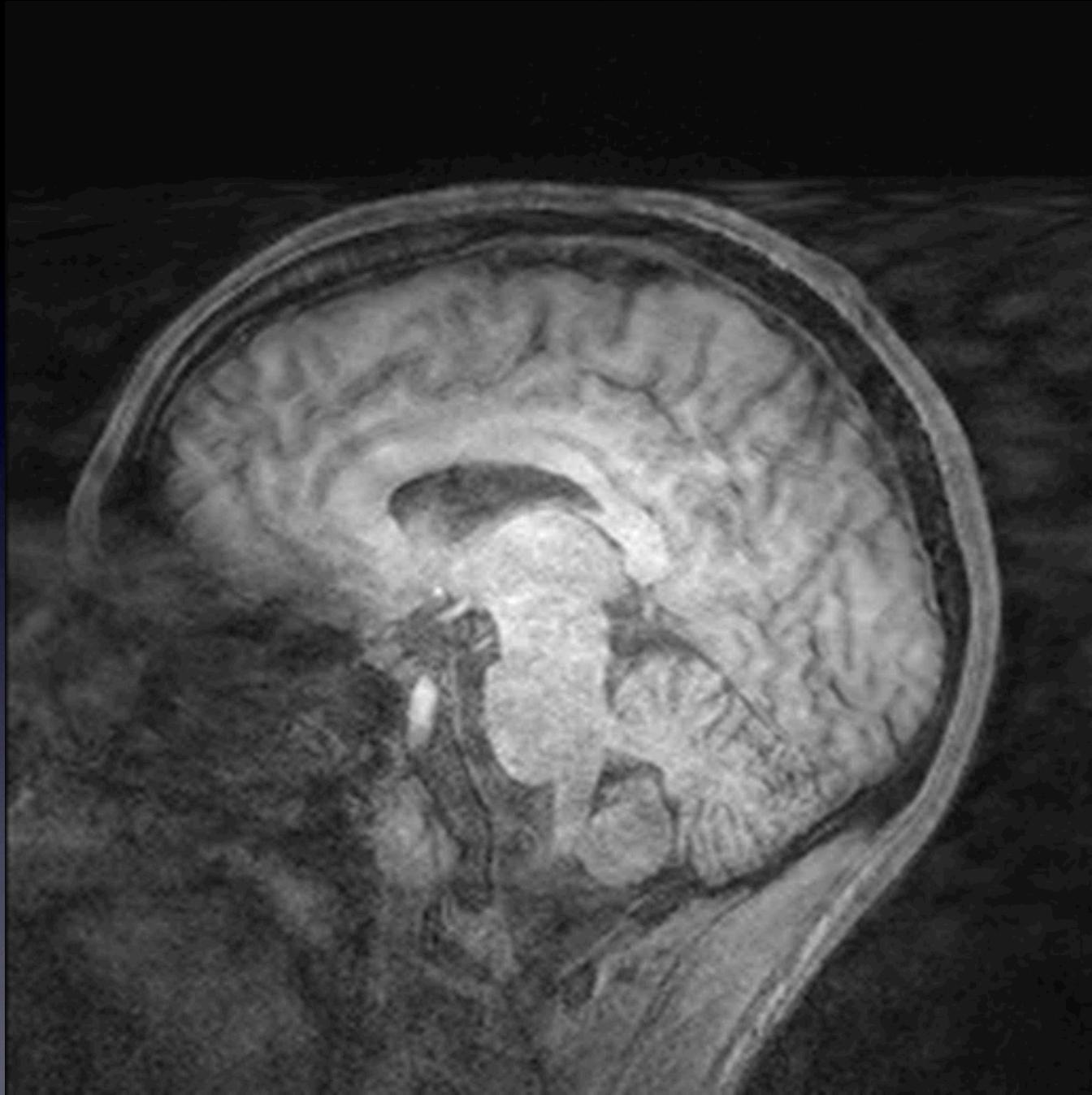
Register each EPI nav volume  
back to first TR using Siemens'  
**PACE registration algorithm.**





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

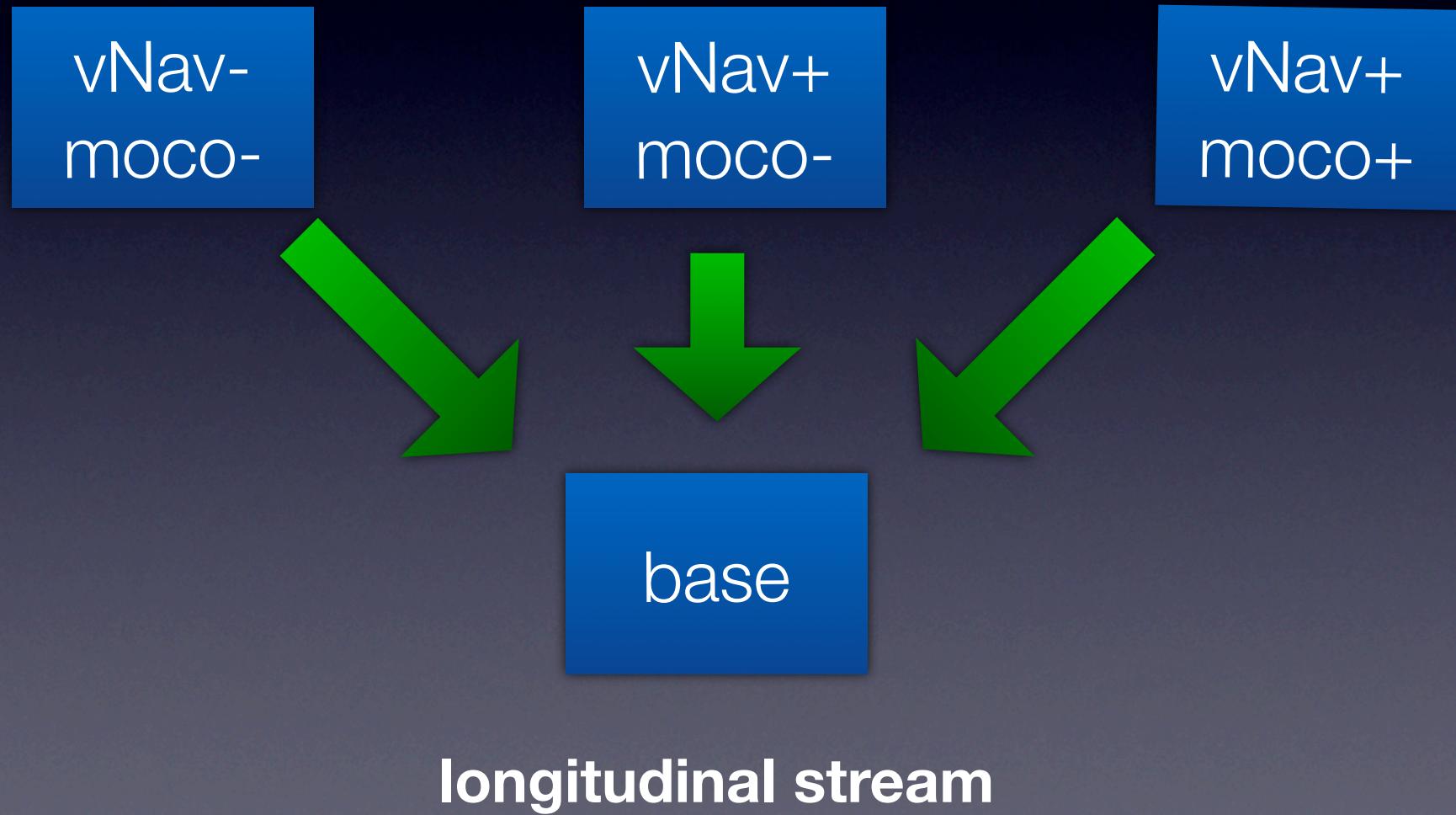




# Overview

- **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” 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-

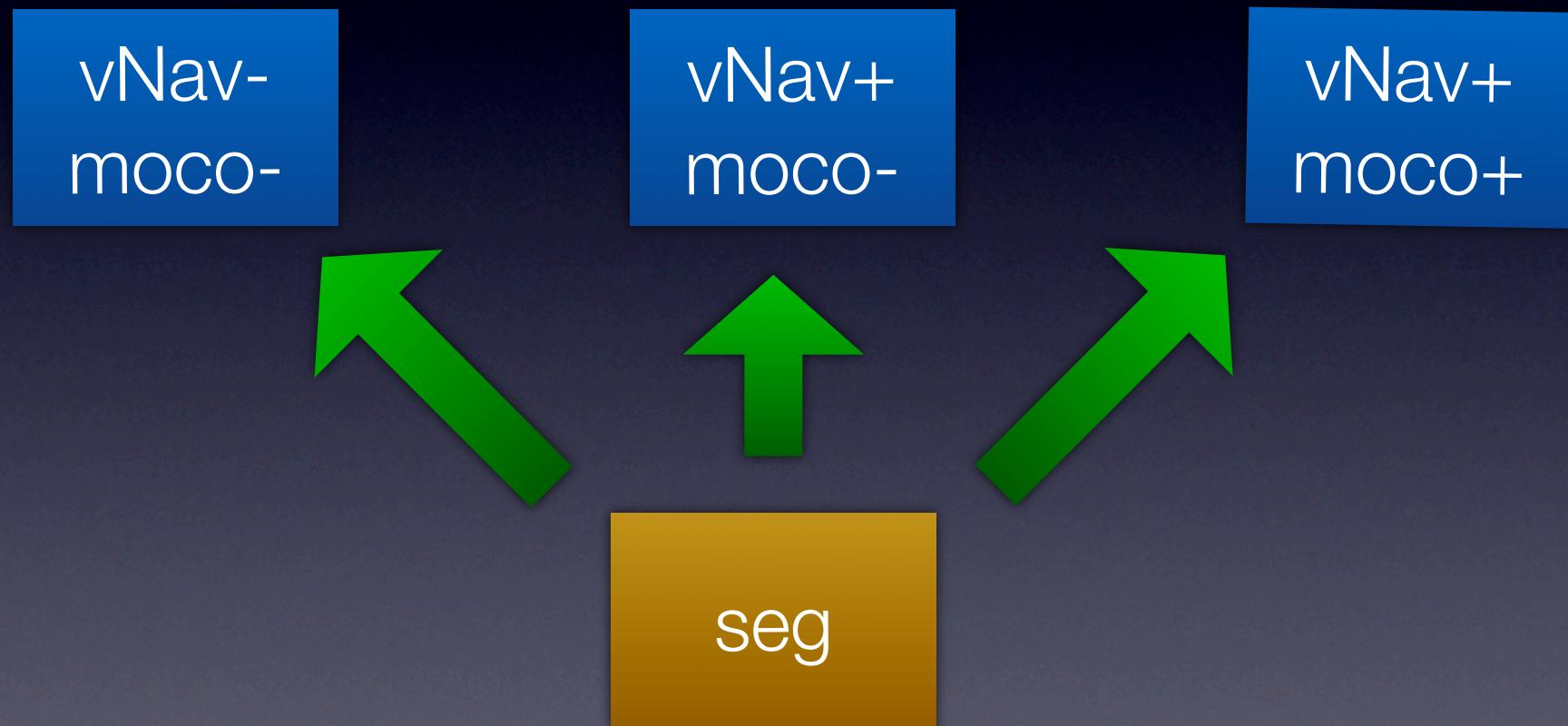
vNav+  
moco+

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+

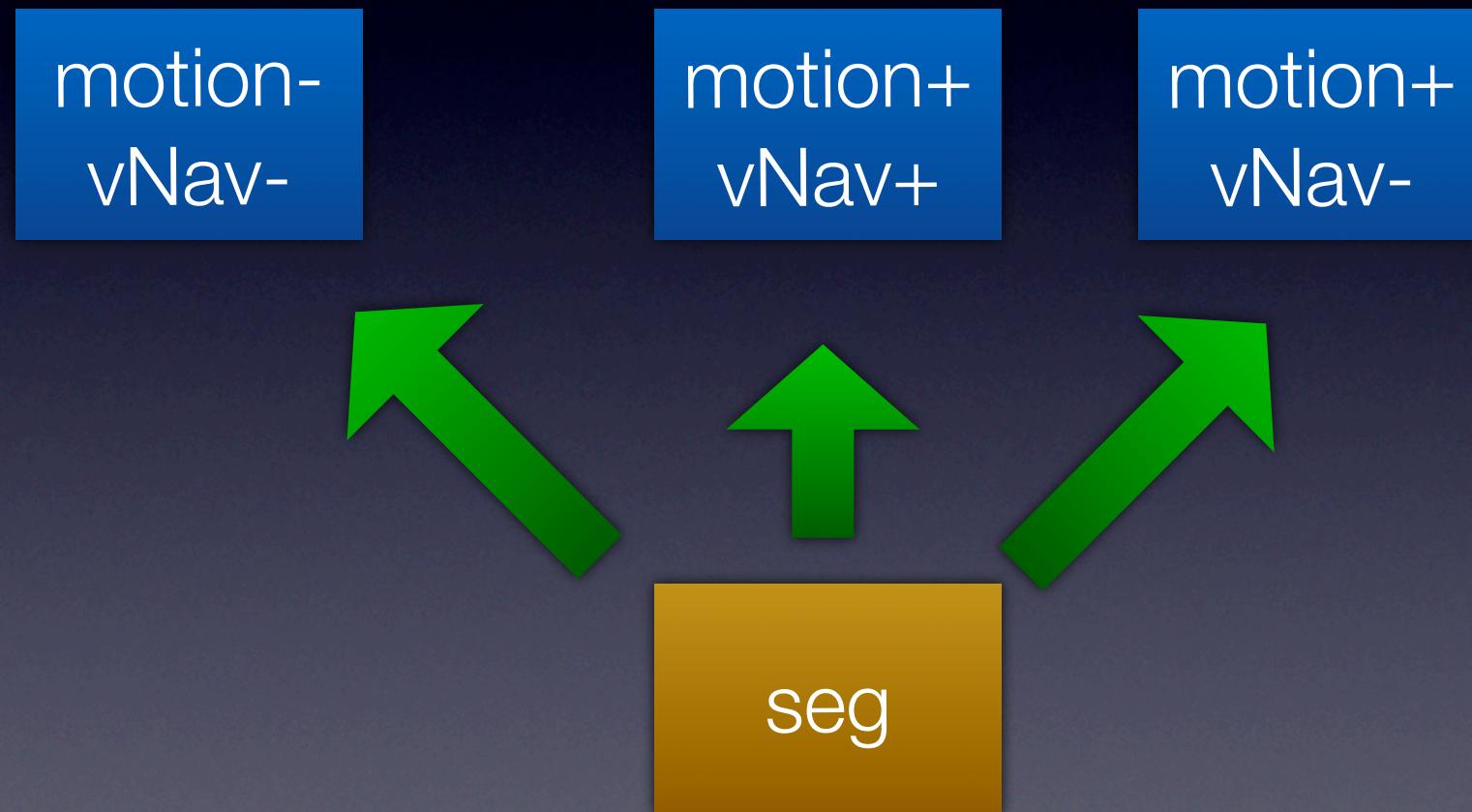
motion+  
vNav-



seg

**cross-sectional stream**

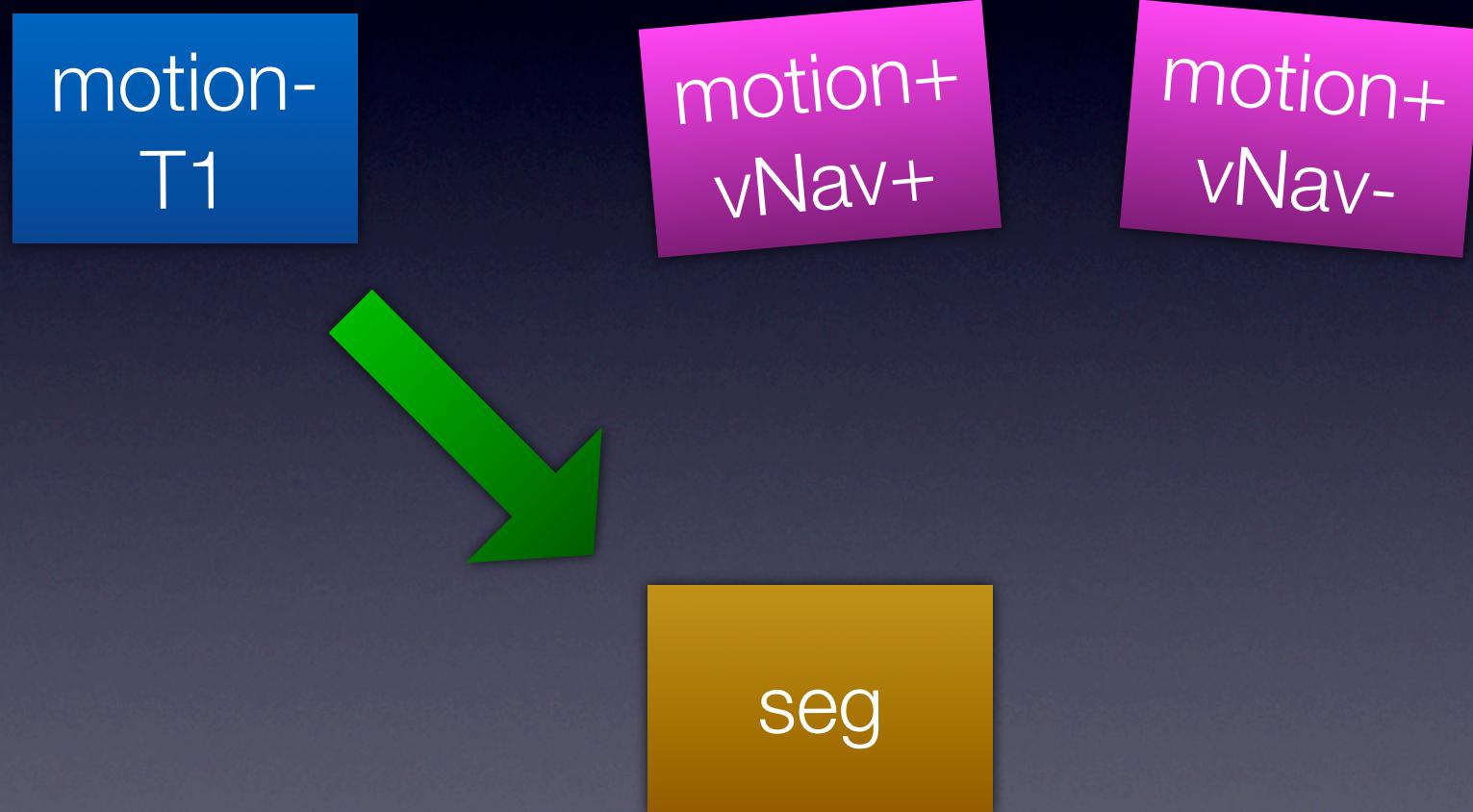
Registration of same-subject, same-day, with-motion T1 scans to a fully segmented same-subject, same-day, without-motion T1 scan.



**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.



**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

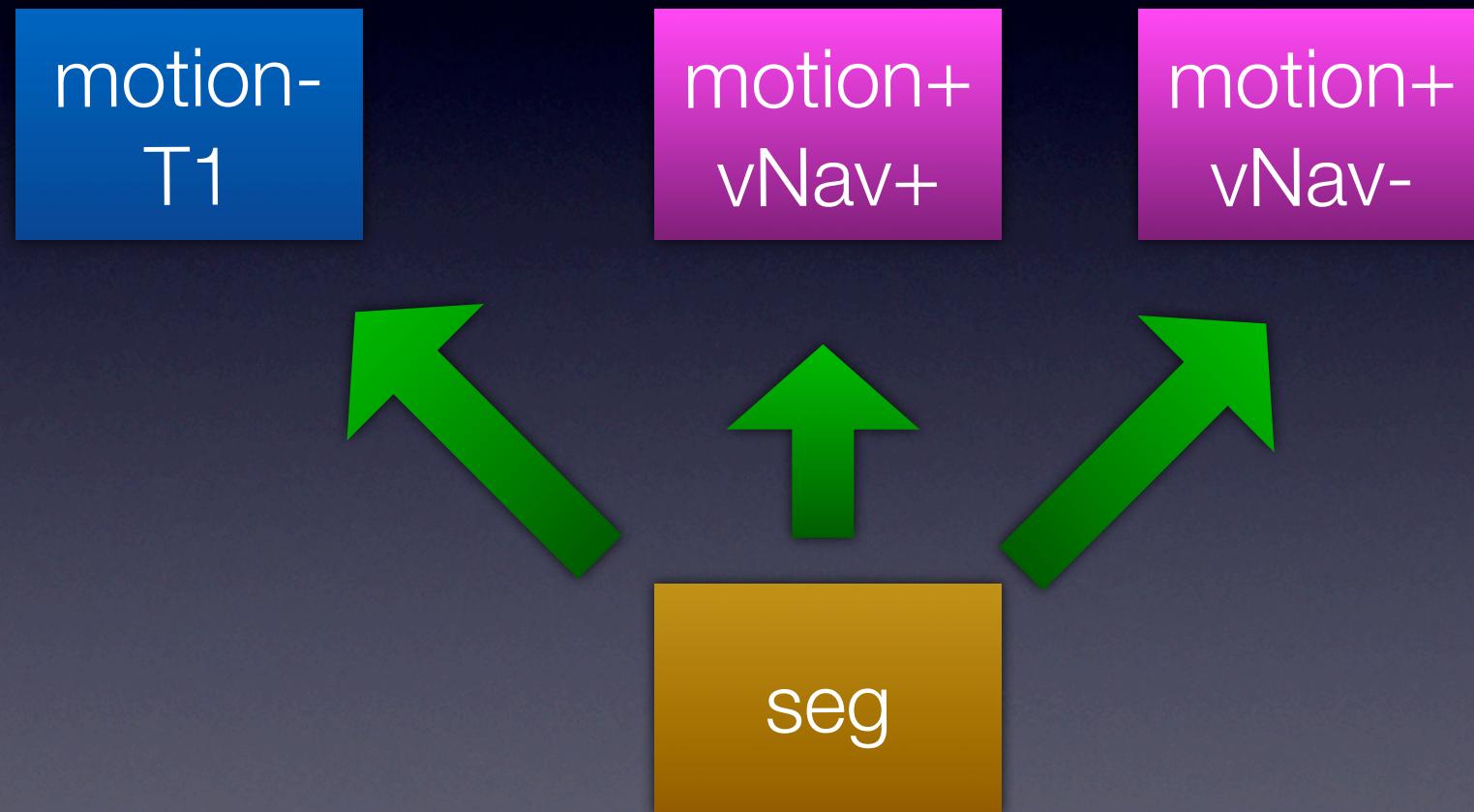
motion+  
vNav+

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
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