

# **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:

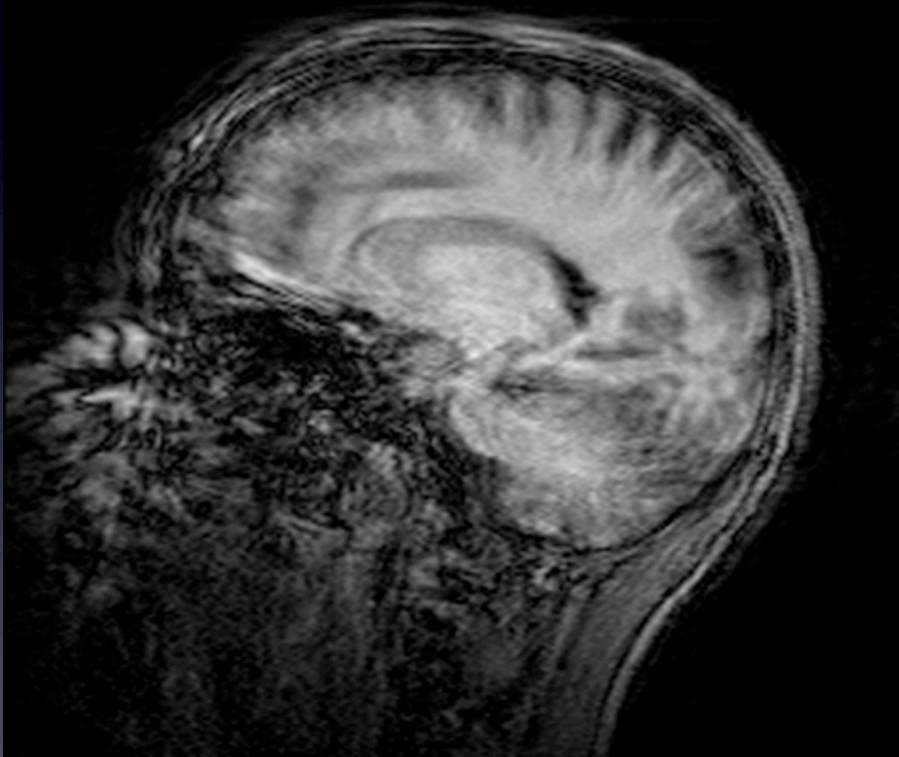
### **Retrospective**

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

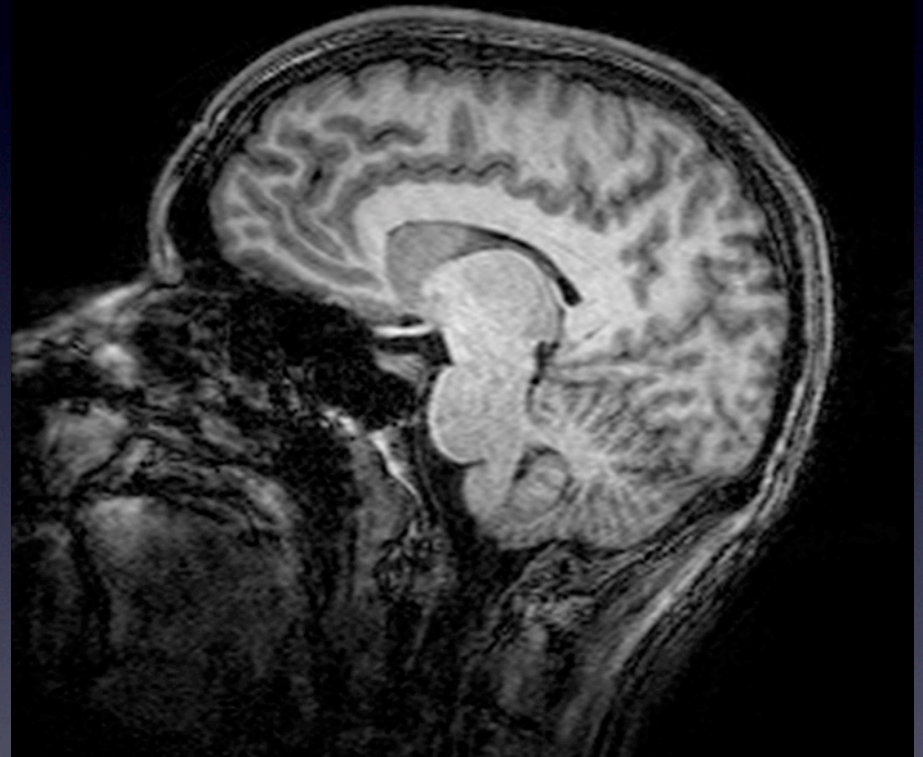
### **Prospective**

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

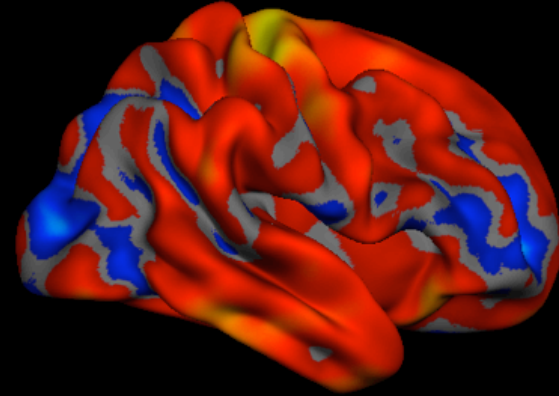
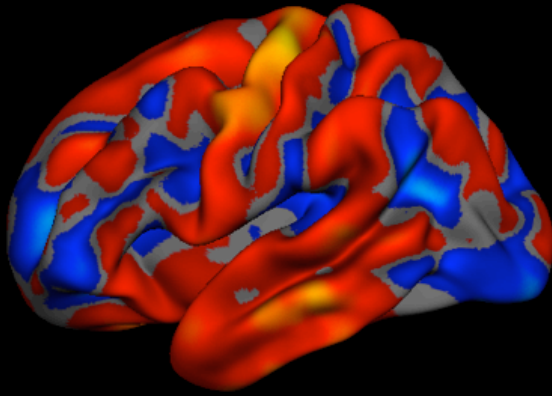
MPRAGE of subject prompted to change position every 45 seconds



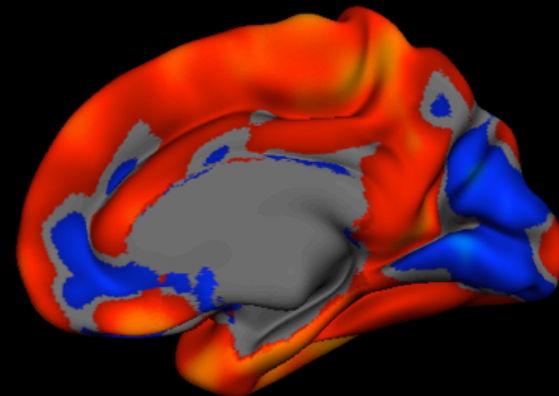
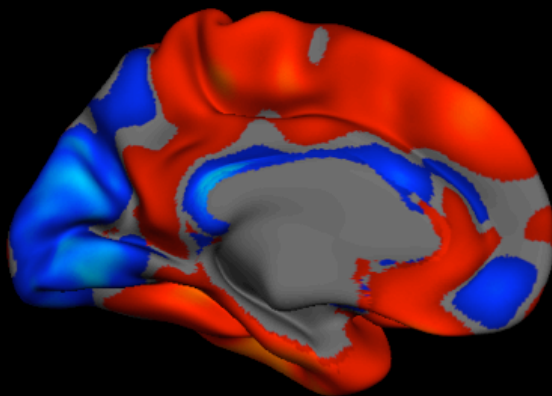
without prospective moco



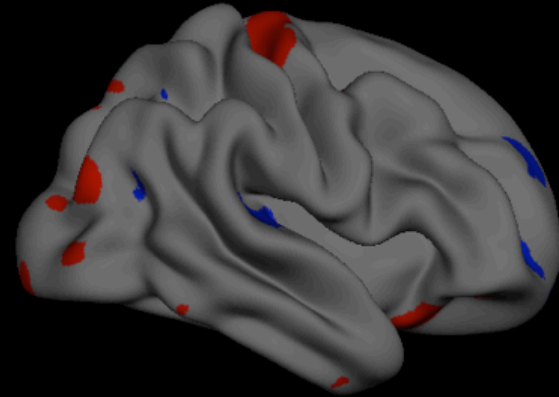
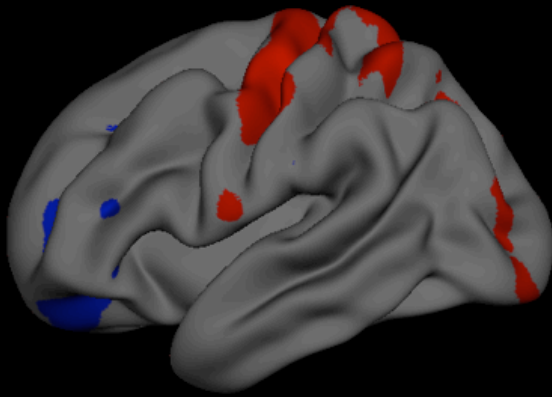
with prospective moco



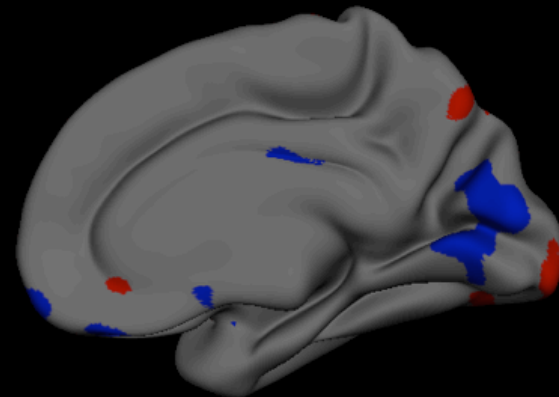
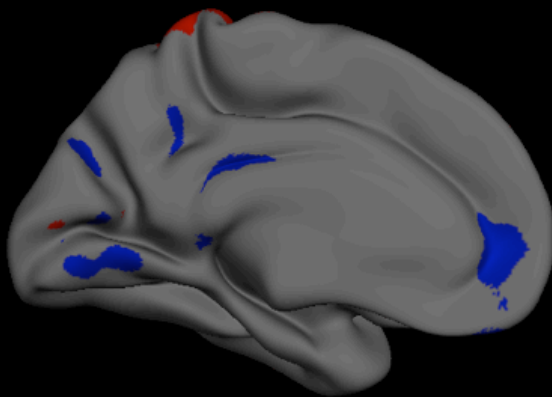
No Motion vs. Motion  
Red/Yellow thinning, Blue thickening with motion  
Yellow: 30% thinning







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



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

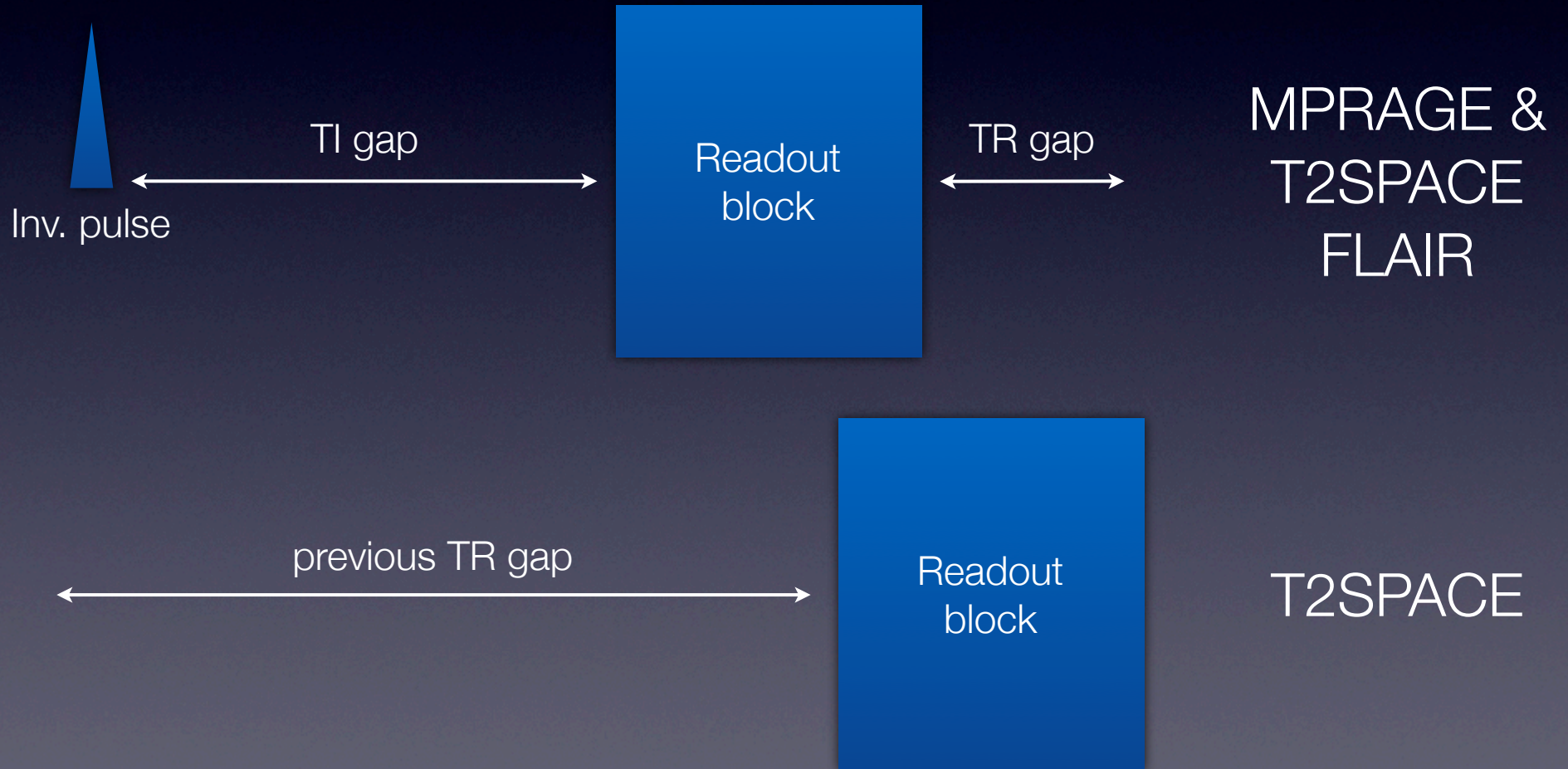
- Our vNav sequences are available now on Siemens scanners (WIP 711).
- Other groups are developing similar techniques on GE scanners (e.g., PROMO).

# Overview

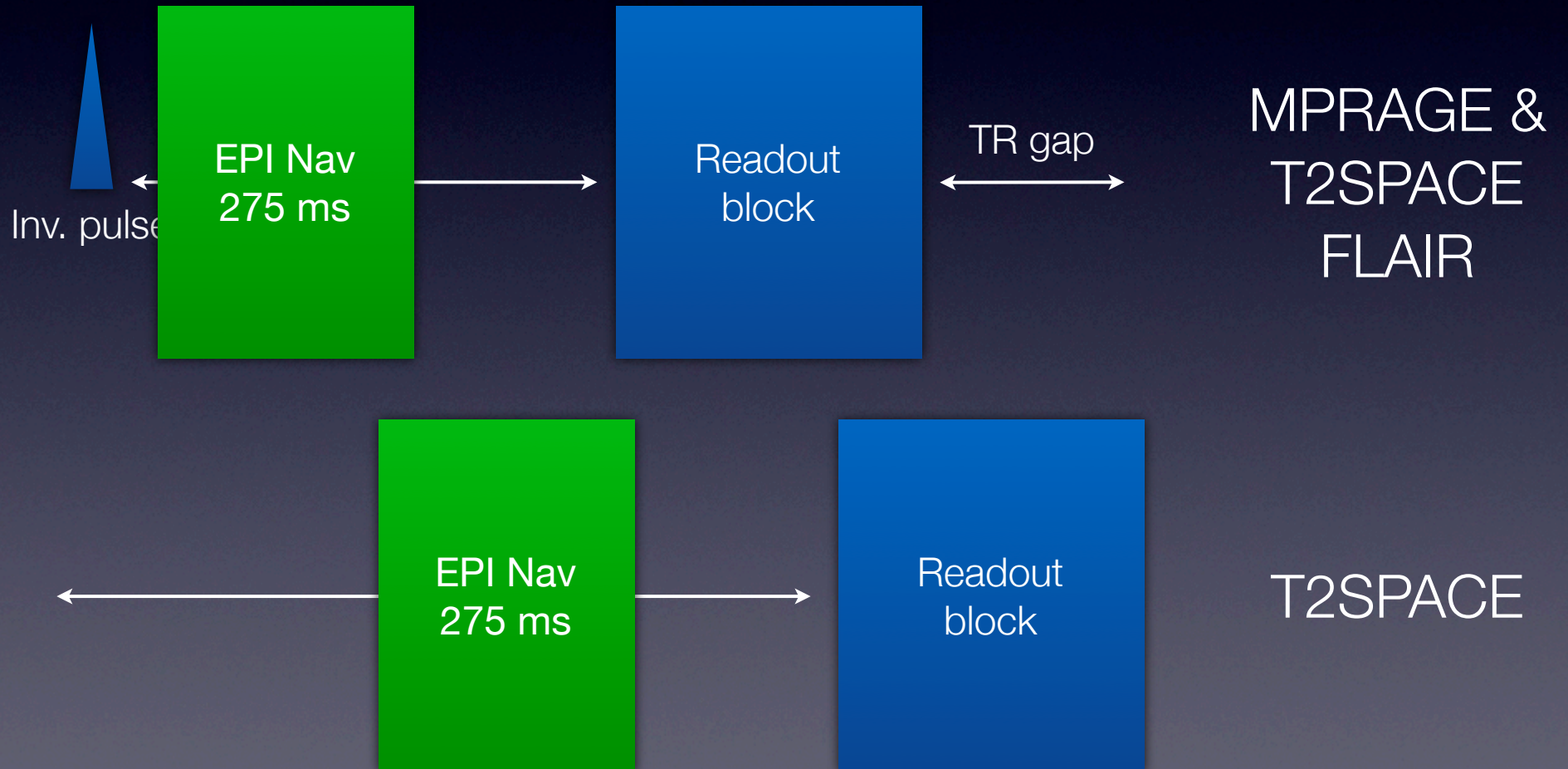
- **Following the subject:**  
EPI-navigated prospective motion correction
- **More motion-resistance:**  
automatic retrospective reacquisition
- **Using FreeSurfer for validation:**  
longitudinal, cross-contrast analysis



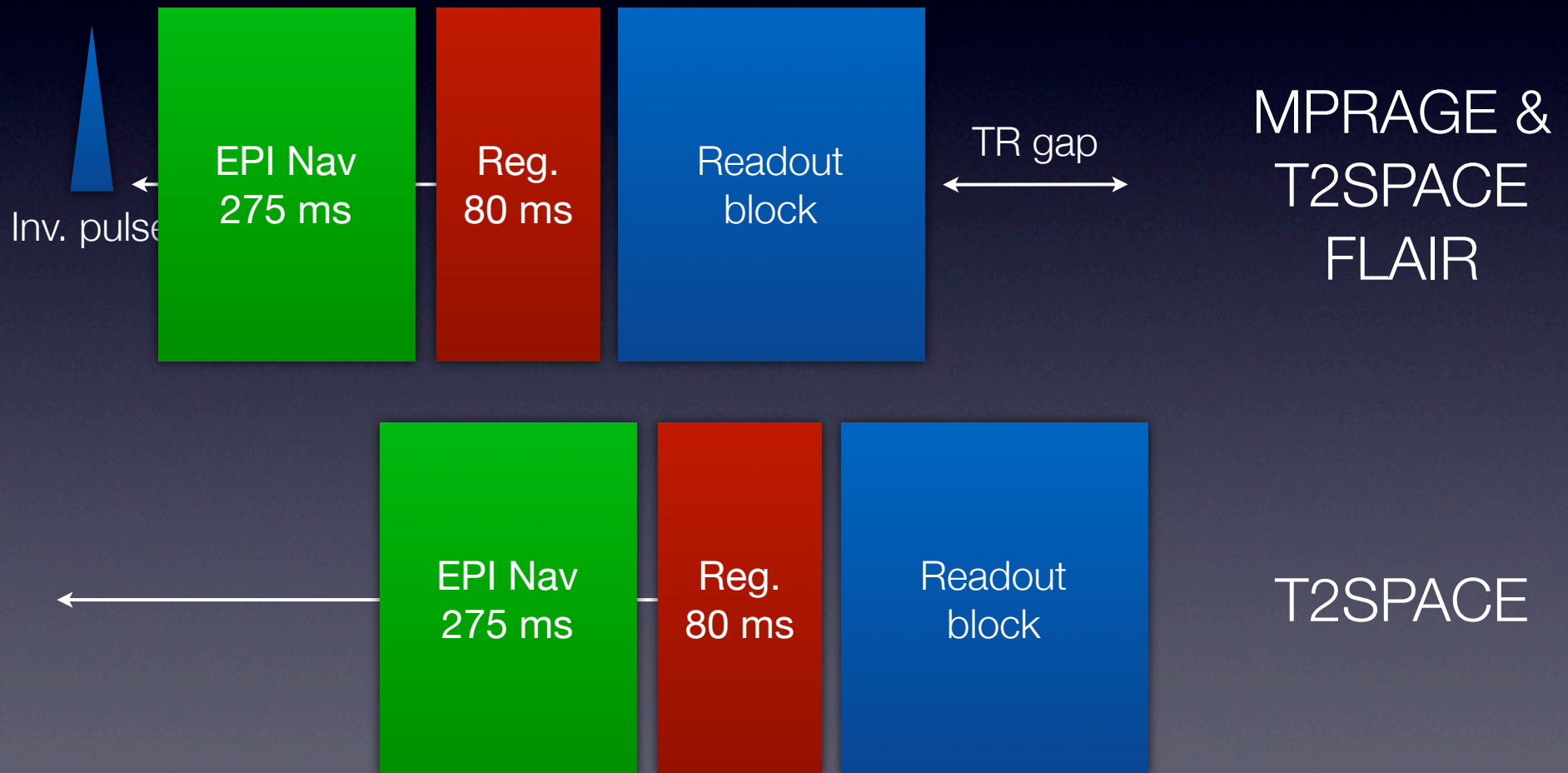
# A single TR



# A single TR + EPI Navigator

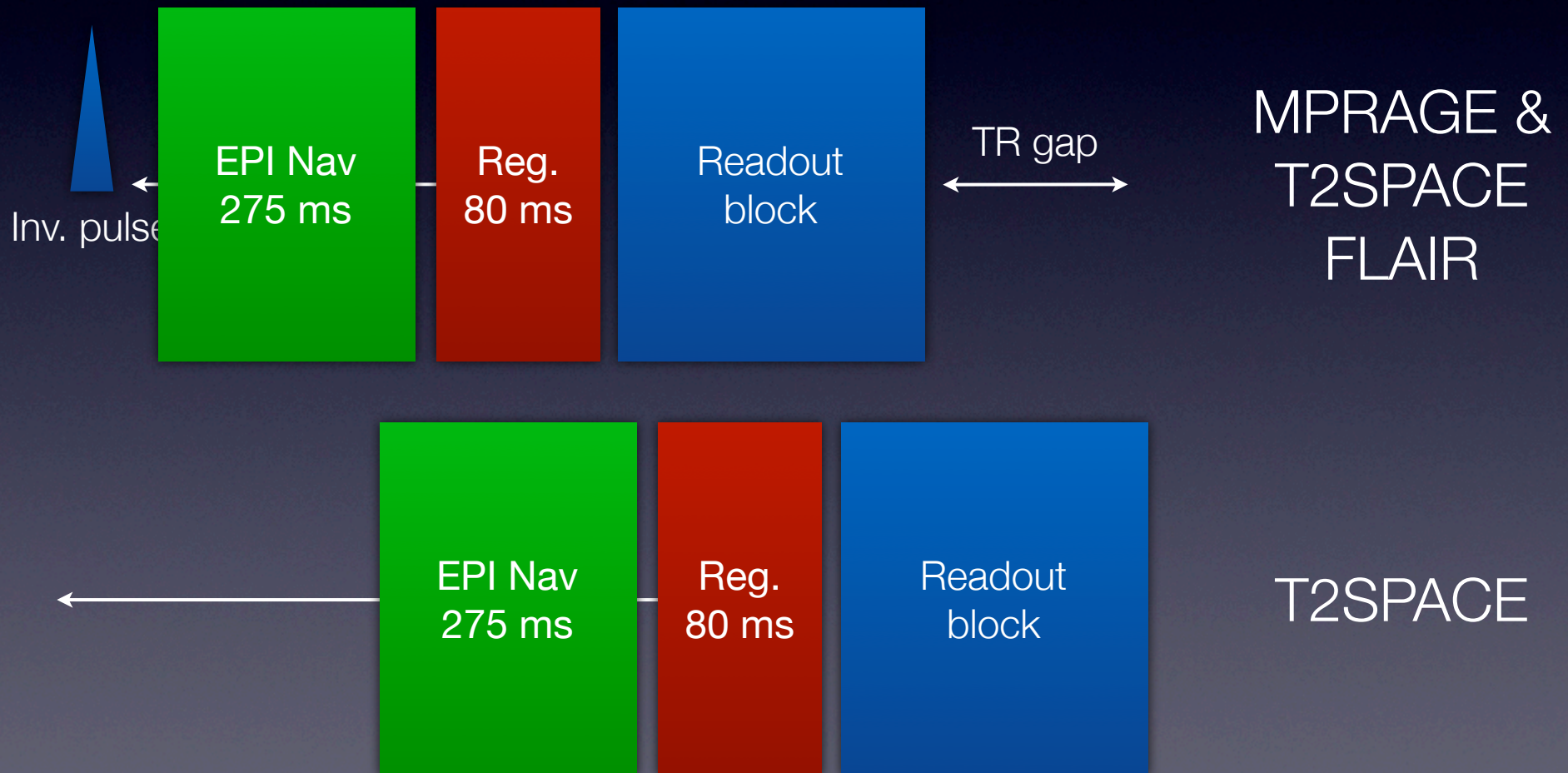


A single TR  
+ EPI Navigator  
+ Registration and Feedback



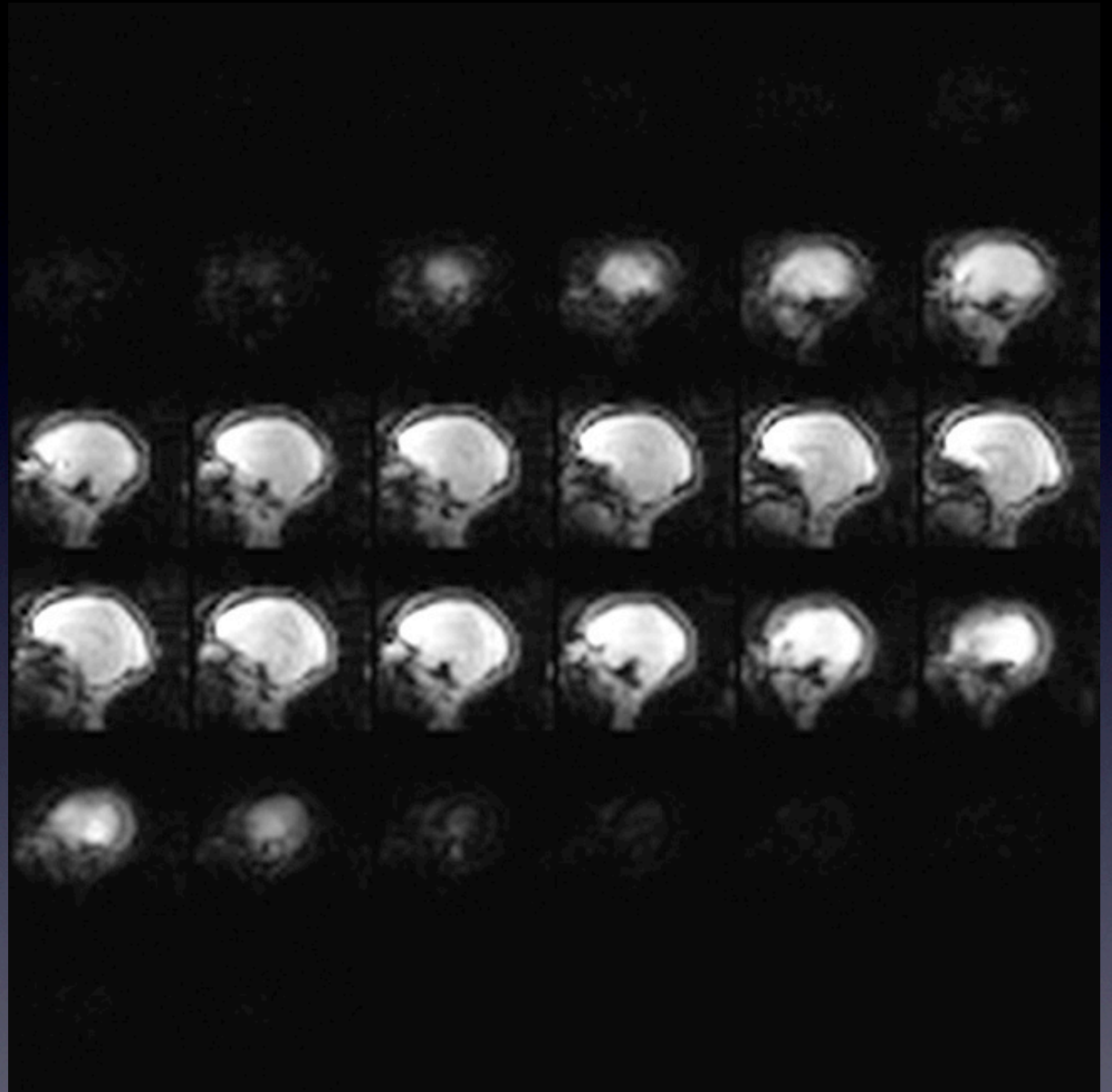


A single TR  
+ EPI Navigator  
+ Registration and Feedback  
= updated imaging coordinates

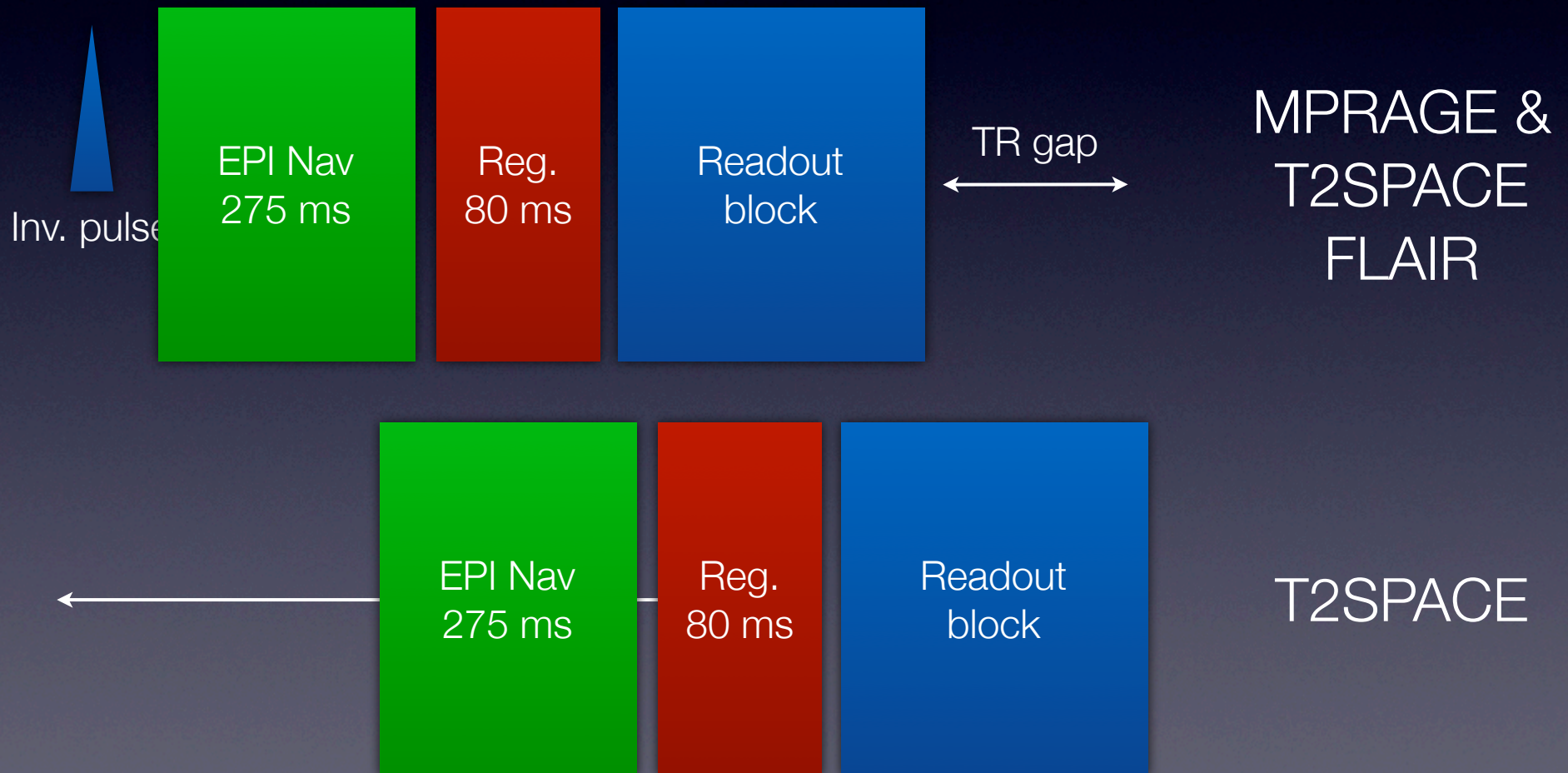


# The Navigator

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

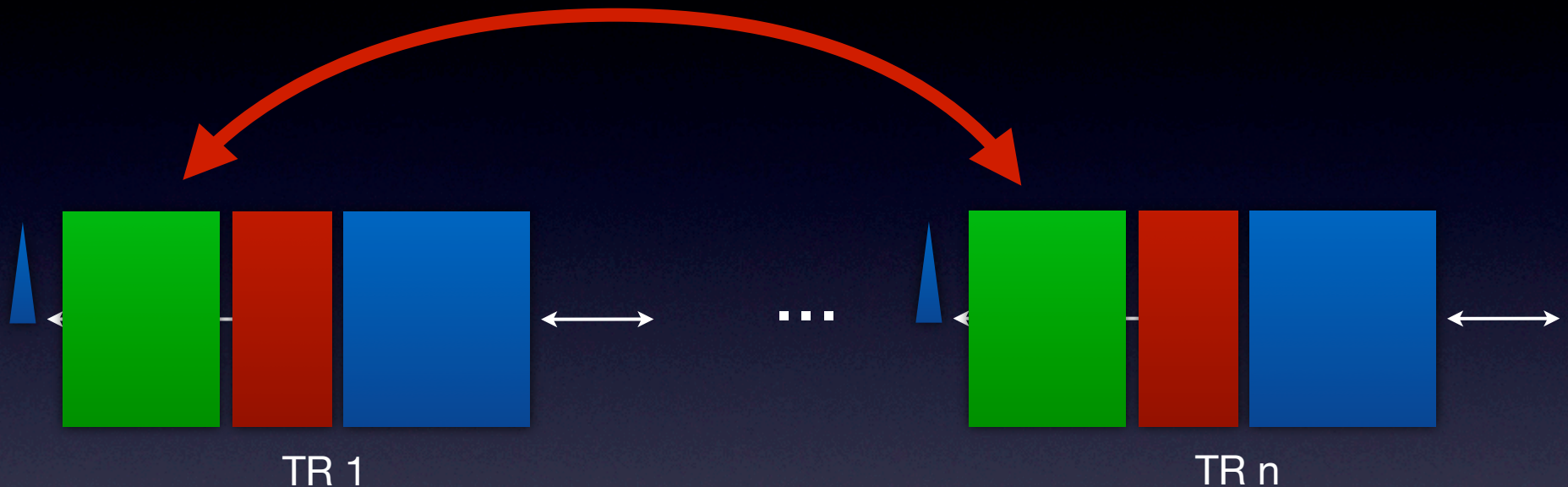


A single TR  
+ EPI Navigator  
+ Registration and Feedback  
= updated imaging coordinates





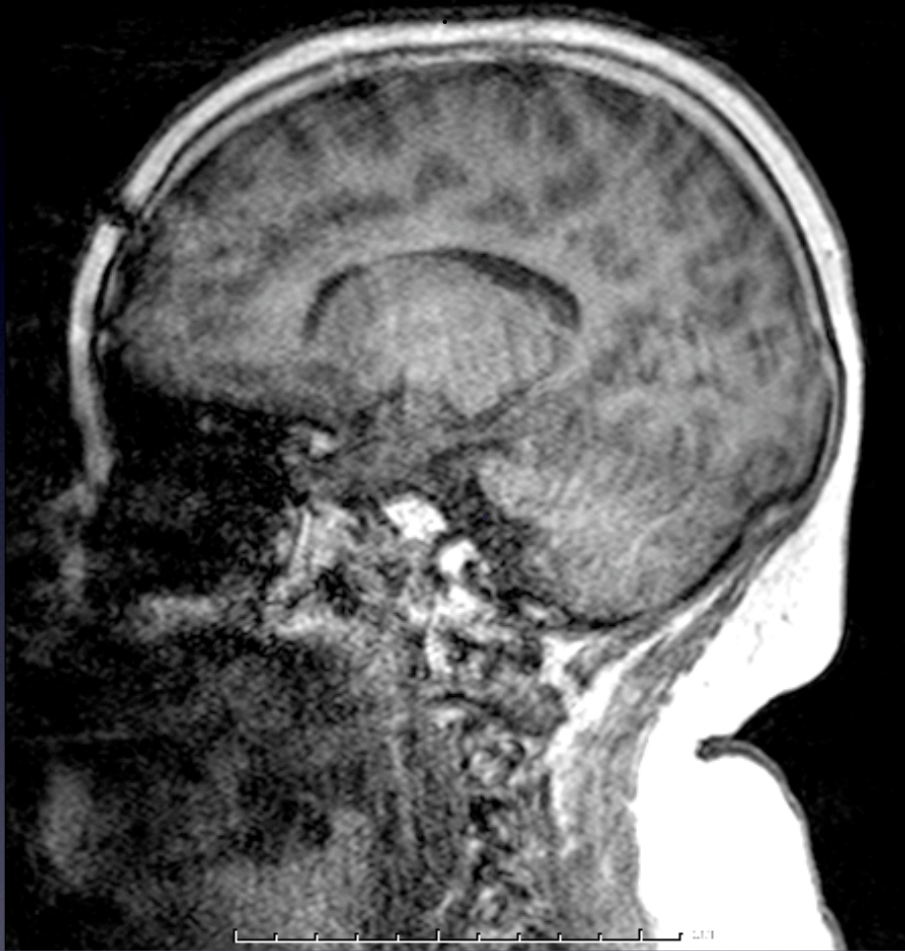
Register each EPI nav volume  
back to first TR using Siemens'  
**PACE** registration algorithm.



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

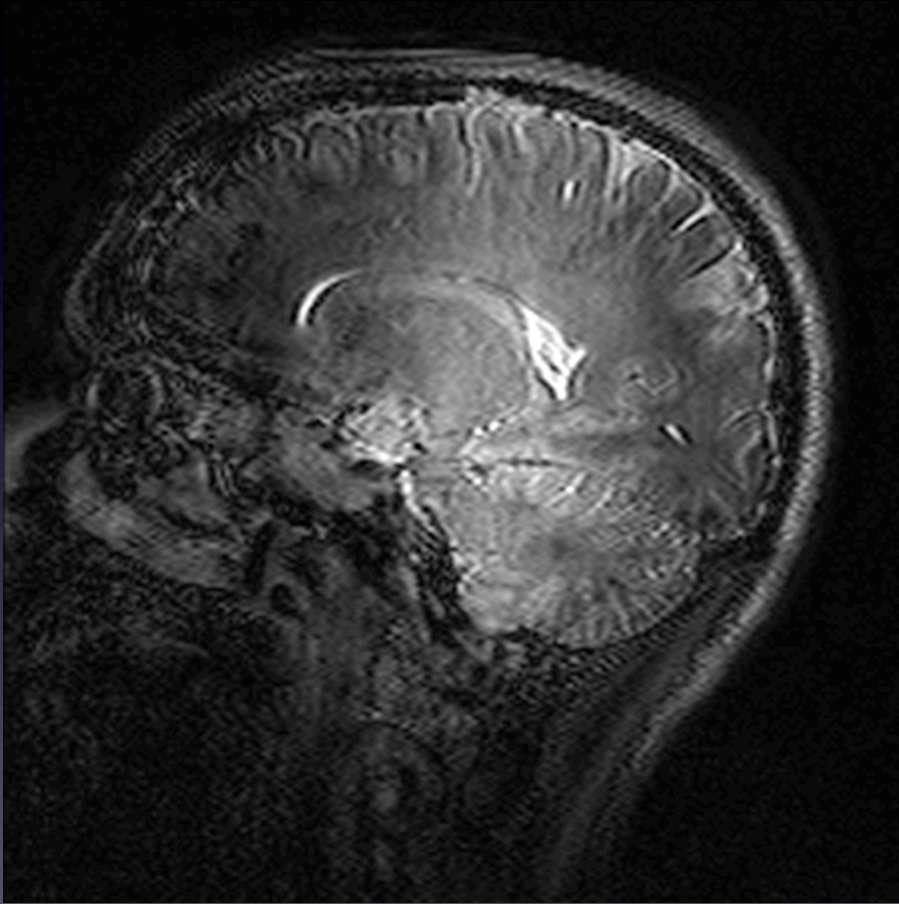


# Overview

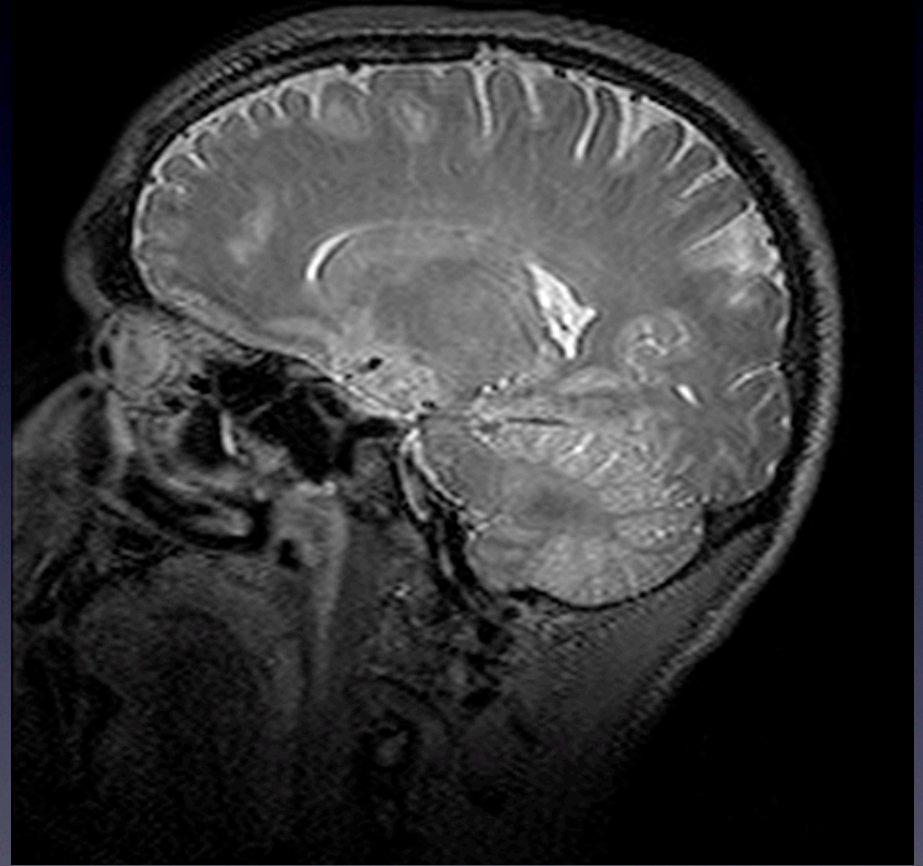
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T2SPACE corrupted by 20 seconds of free motion during acquisition of center of k-space

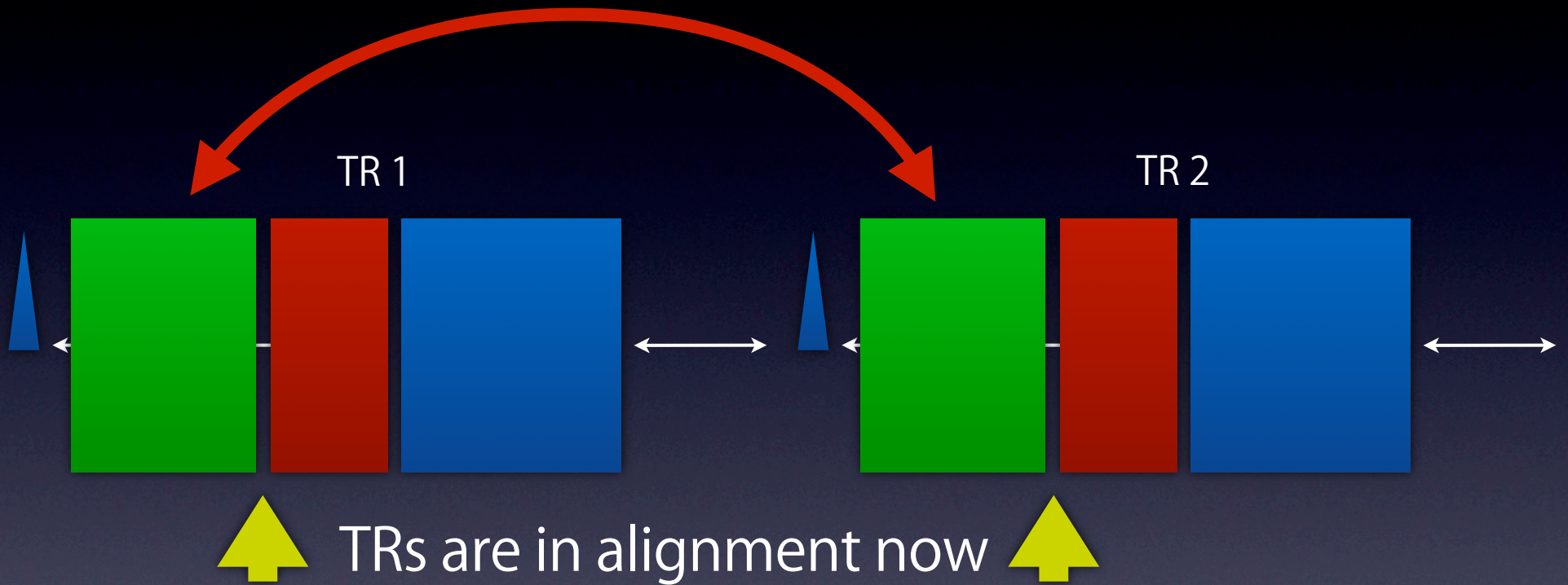


w/ moco  
w/o reacquisition



w/ moco  
w/ 10 TRs reacquired

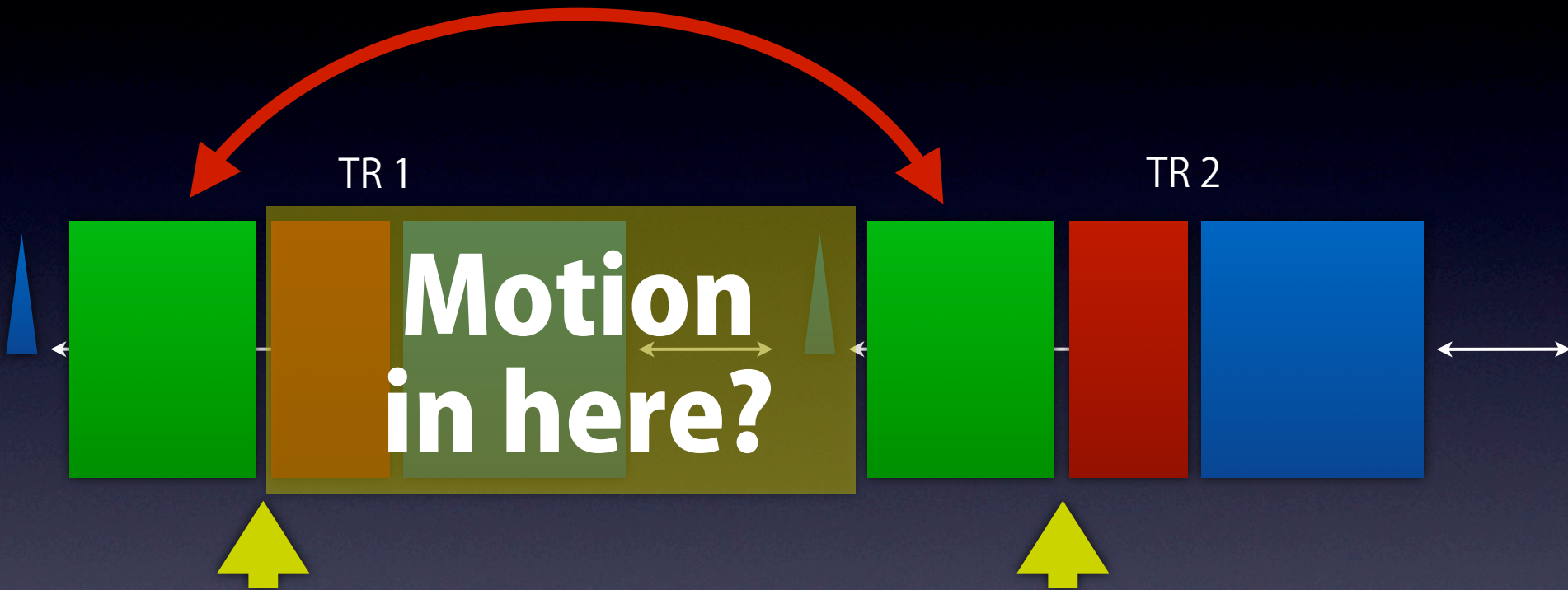
Register each EPI nav volume  
back to first TR using Siemens'  
**PACE registration algorithm.**



TR 1

TR 2

**Motion  
in here?**





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

The screenshot shows a software interface with a top navigation bar containing 'Part 1', 'Part 2', and 'Special'. The 'Special' tab is selected. Below the tabs, there are three main settings:

- 'Add. scale factor' is set to 1.0 with up and down arrow buttons.
- 'Remeasure' is set to 0 with up and down arrow buttons and the label 'TRs' to its right.
- 'Apply motion correction' is checked with a checkbox.

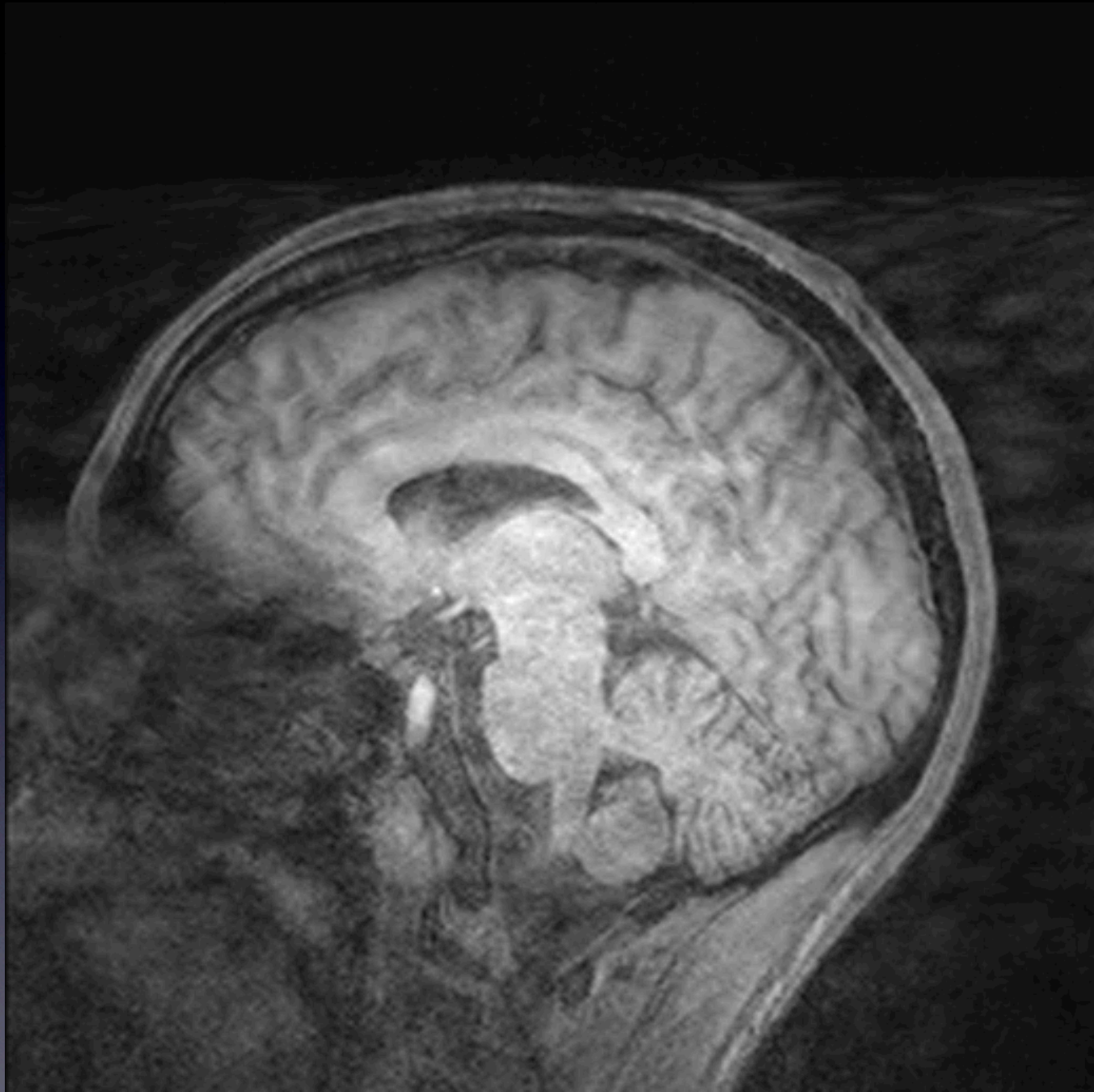
At the bottom of the settings area, there is a 'Remeasure' slider ranging from 0 to 1000, with a green bar indicating the current value at 0. A vertical blue line is positioned to the right of the 'Remeasure' input field.

The bottom navigation bar contains the following tabs: 'Routine', 'Contrast', 'Resolution', 'Geometry', 'System', 'Physio', 'Inline', and 'Sequence'.

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

The screenshot displays a software interface with the following elements:

- Navigation tabs: Part 1, Part 2, Special (selected), and an unlabeled tab.
- Parameter 'Add. scale factor': Value 1.0, with up/down arrow controls.
- Parameter 'Remeasure': Value 0, with up/down arrow controls and the label 'TRs'. This field is enclosed in a red rectangular box.
- Parameter 'Apply motion correction': A checked checkbox.
- Parameter 'Remeasure' (slider): A horizontal green slider bar ranging from 0 to 1000.
- Bottom navigation bar: Routine, Contrast, Resolution, Geometry, System, Physio, Inline, and Sequence.





# Overview

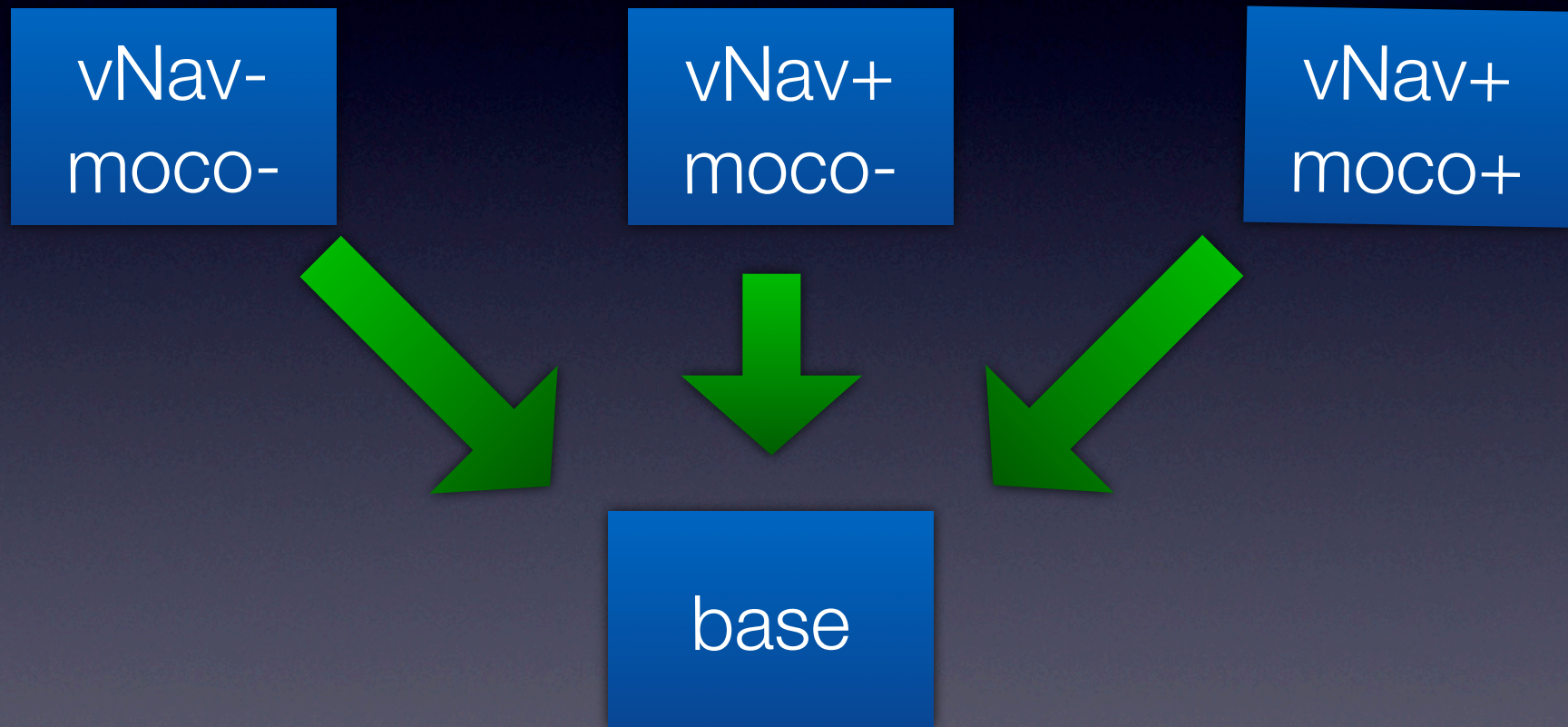
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longitudinal, cross-contrast analysis

## 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+

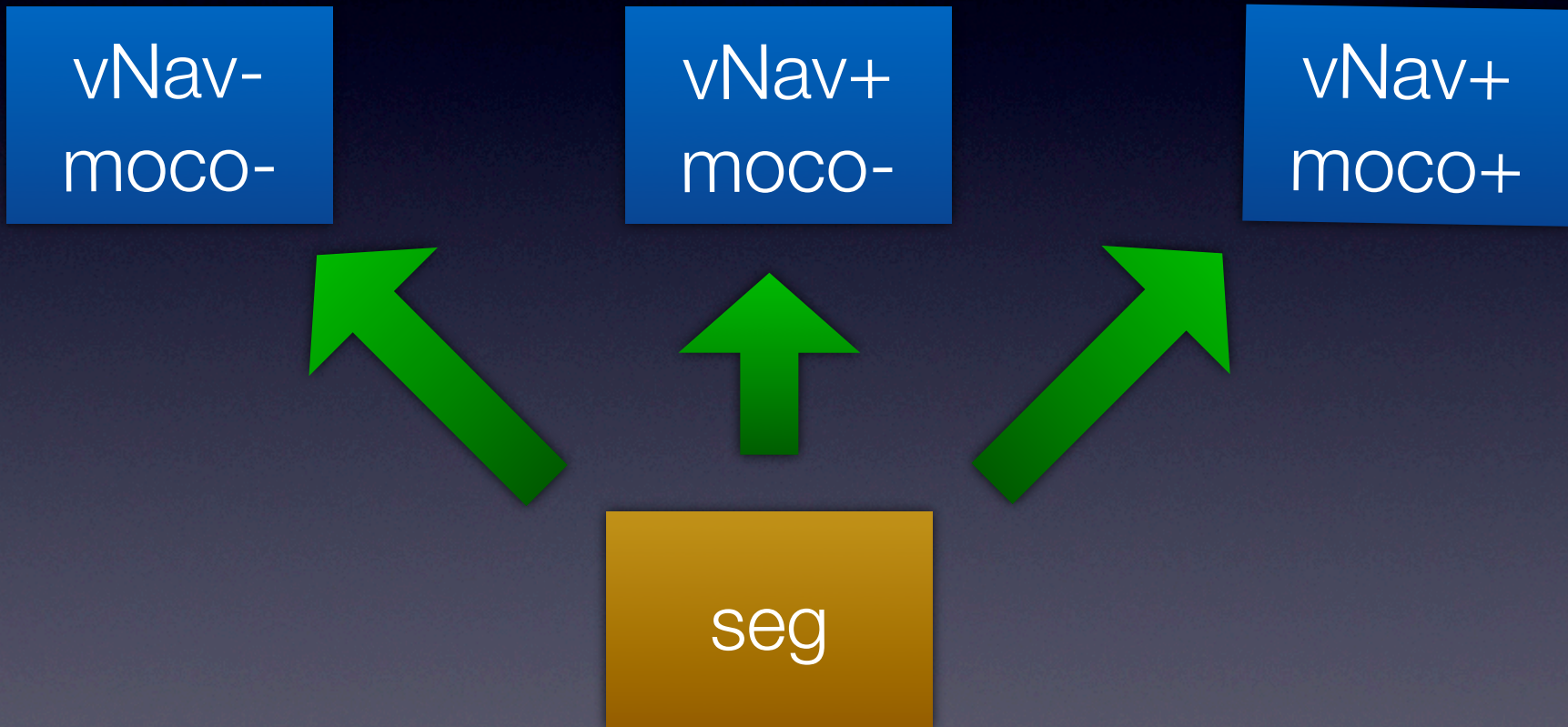
base



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-

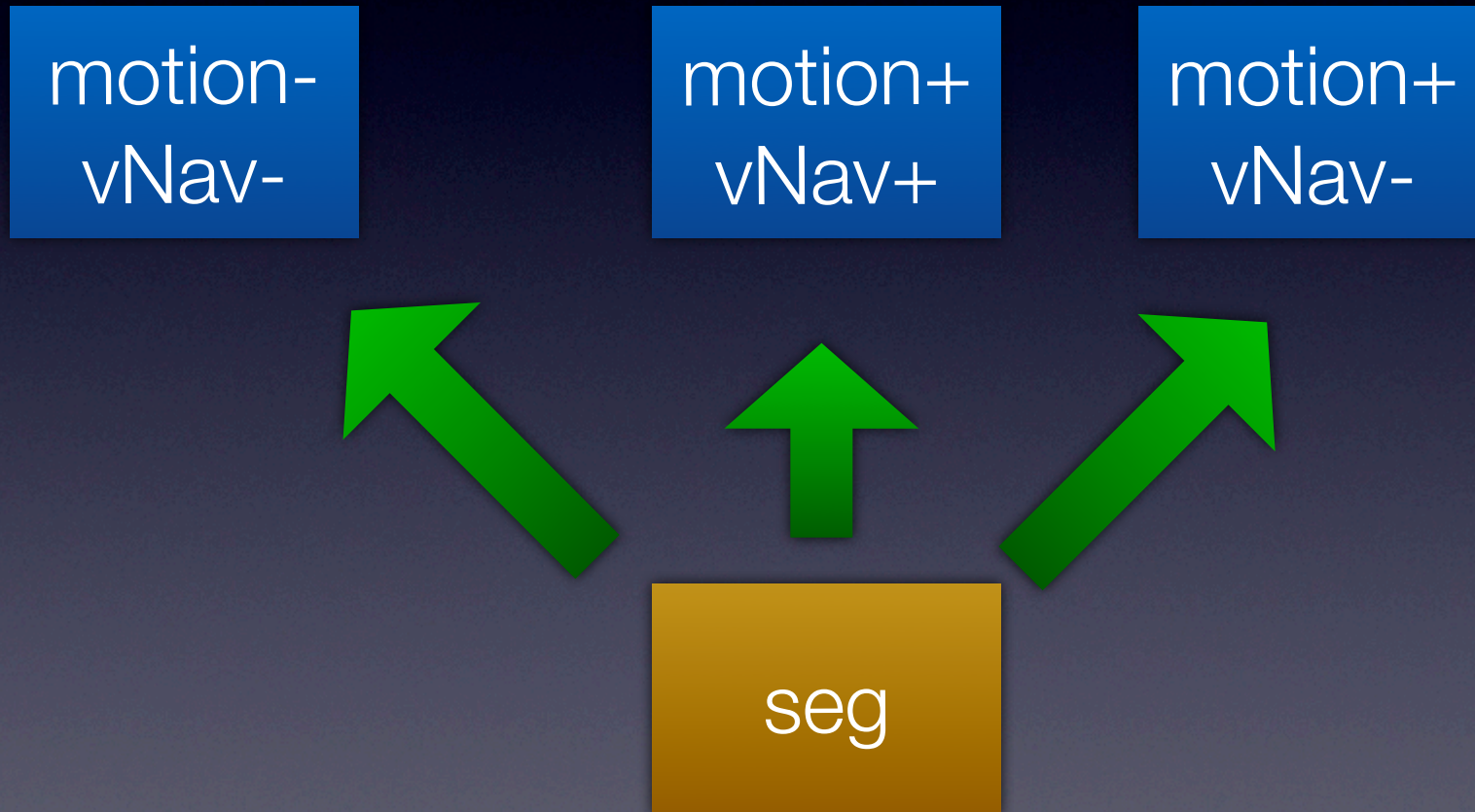


seg

**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.

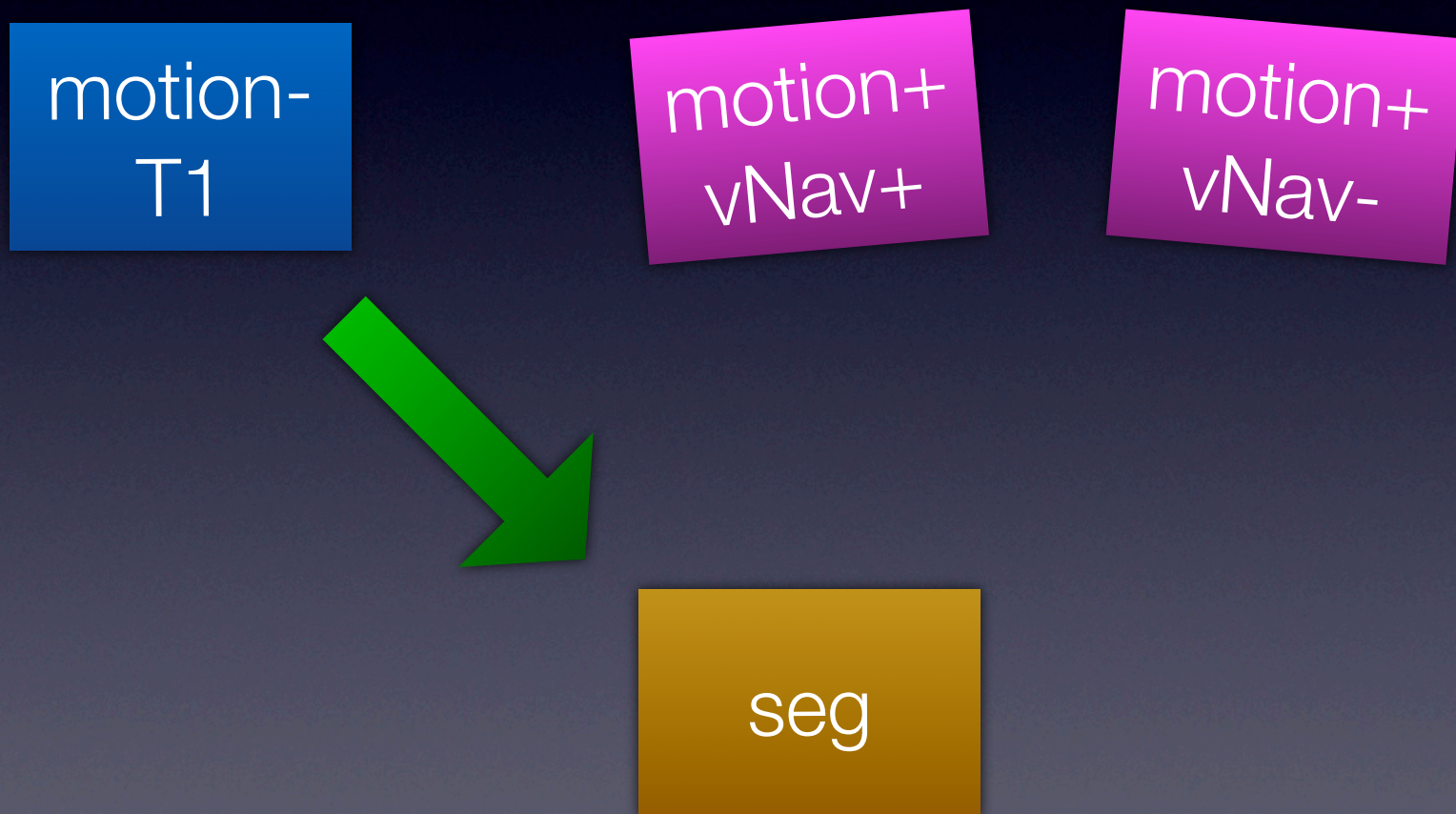


**now we have voxel-wise equivalence**

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



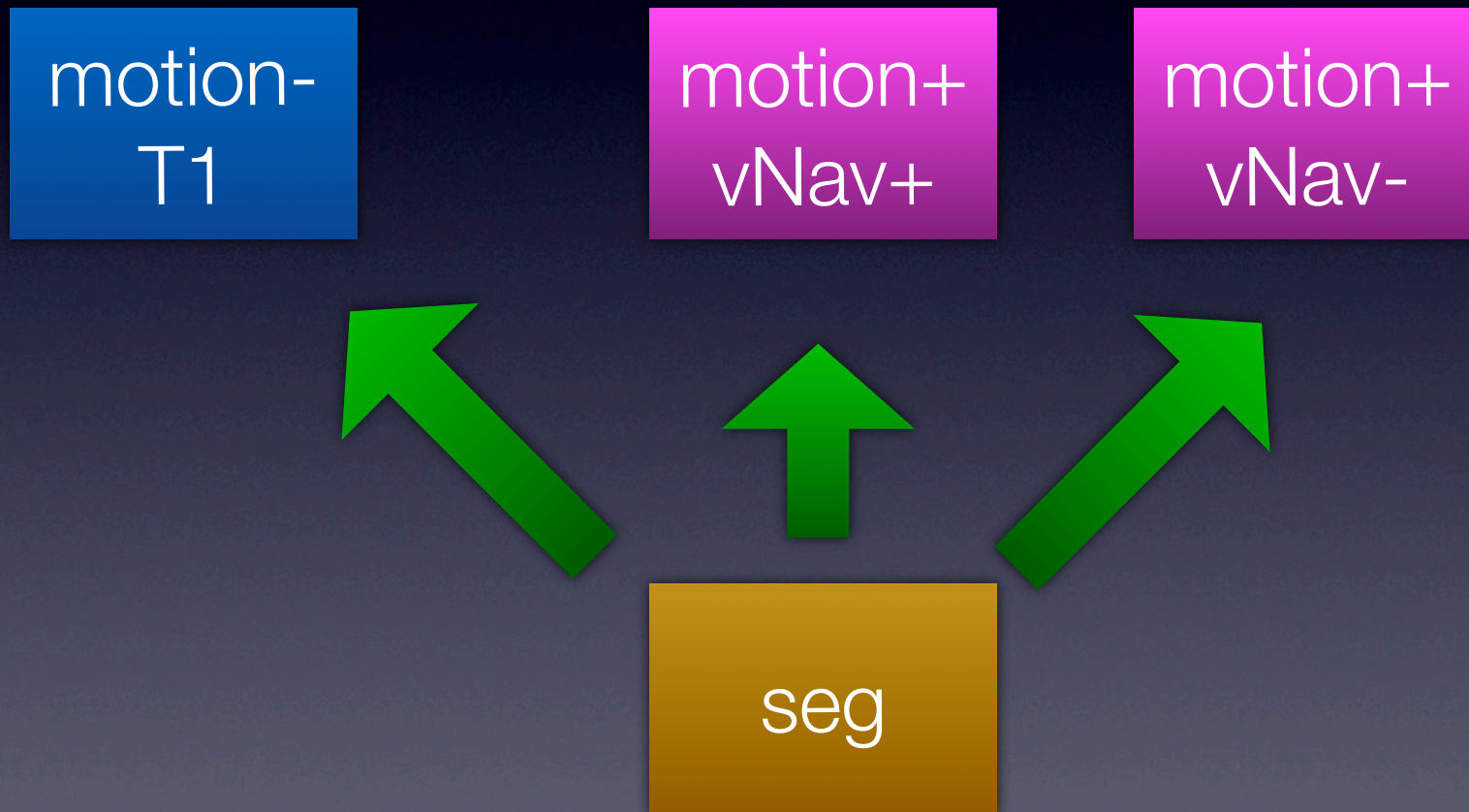
Cross-contrast registration of same-subject, same-day, with- and without-motion T2 scans to a fully segmented same-subject, same day without motion T1 scan.



**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.



**now we have voxel-wise equivalence**

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



## **Acknowledgements:**

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