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

Inv. pulse

EPI Nav 275 ms

Readout block

TR gap

MPRAGE &
T2SPACE

FLAIR

EPI Nav 275 ms

Readout block

T2SPACE
A single TR
+ EPI Navigator
+ Registration and Feedback

Inv. pulse

EPI Nav
275 ms

Reg.
80 ms

Readout
block

TR gap

MPRAGE &
T2SPACE
FLAIR

EPI Nav
275 ms

Reg.
80 ms

Readout
block

T2SPACE
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

EPI Nav 275 ms
Reg. 80 ms
Readout block

TR gap

MPRAGE & T2SPACE FLAIR

T2SPACE

Inv. pulse
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
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• **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 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.
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Overview

• **Following the subject:**
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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.

vNav- moco-

vNav+ moco-

vNav+ moco+

base

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.
“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.

- 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.

now we have voxel-wise equivalence
We can use bbregister to **extrapolate a segmentation** to a subsequent acquisition with a different contrast.
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