Measuring Effect of Embedded Navigators on MEMPRAGE Tissue Contrast

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Introduction Several prospective motion correction systems have been presented that are based on embedding very short navigator sub-sequences into neuroanatomical sequences [1,2]. While this process allows for significant reductions in motion-induced artifacts, it is also possible that the navigator sub-sequences affect the imaging contrast of the parent sequence. In sequences like multi-echo MPRAGE (MEMPRAGE) and SPGR, where the sequences' TI and TR are carefully selected for gray/white tissue contrast [3], it is important to ensure that the addition of navigators is not trading one source of error for another. We present some initial results using the new longitudinal data analysis stream in FreeSurfer to measure the contrast effect of using volumetric navigators (vNavs) [2] in MEMPRAGE.

Methods Two subjects were scanned with a 3T Tim Trio scanner (Siemens Medical Systems, Erlangen, Germany) using a 32-channel head coil. Both a standard 3D MEMPRAGE and a 3D MEMPRAGE with embedded vNavs (see Fig. 1) were collected – a total of four acquisitions. For both MEMPRAGE sequences, the imaging matrix was 256x256x176 mm with 1 mm isotropic voxels, and the contrast parameters were TR 2530 ms, TI 1350 with four echoes having TEs 1.6 ms, 3.5 ms, 5.4 ms, and 7.2 ms, a flip angle of 7 degrees, and a bandwidth of 651 Hz/pixel. The vNav was a 25-shot 3D-encoded EPI with a 256x256x256 mm imaging matrix and 8 mm isotropic voxels. The volume was acquired with TR 11 ms, TE 5.2 ms, bandwidth 4464 Hz/pixel, flip angle 2 degrees, and 6/8 partial Fourier with zero-padding, giving a total duration of 275 ms. We used 200 ms to reconstruct, register, and provide feedback to the scanner for coordinate re-alignment; thus the vNav-and-register block consumed the final 475 ms of the TI-gap immediately preceding the MEMPRAGE echo train. All inversion and excitation pulses were non-selective in both the MEMPRAGEs and the vNavs.

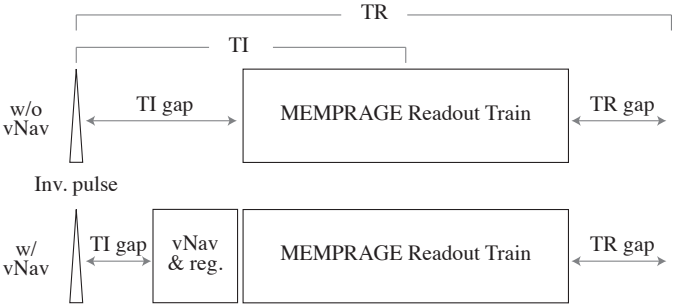

Fig 1. Timing diagram showing how the vNavs are inserted into the MEMPRAGE TRs.

All analysis was performed on the single volume produced by RMS-combination of the four echoes in each acquisition. These volumes were registered using the unbiased longitudinal analysis stream in the FreeSurfer 5.1 development version [4]. The registered with-nav volume for each subject was then subtracted from the registered without-nav volume to give a difference volume. Additionally, the longitudinal stream provides a single "average" parcellation. Using this shared voxel label map, we selected two ROIs: one containing the ribbon of cortical gray matter, and the other containing exclusively white matter except corpus callosum. These ROIs were then eroded to avoid partial-volume effects around the periphery. We note that this made for ROIs containing many small islands; however, the aggregate of the islands represents consistent anatomy across both subjects. We computed mean and variance of the difference in each of the gray and white matter "aggregate ROIs" for each subject.

	Mean	Std Dev
Subj. 1 WM	0.0010	0.019
Subj. 1 GM	0.0023	0.030
Subj. 2 WM	0.0021	0.016
Subj. 2 GM	0.0024	0.024

Table 1. Mean and standard deviation of the difference between paired with- and without-vNav MEMPRAGE. Image values were scaled from 0 to 1.

Results The mean and standard deviation of the difference between with- and with-out vNav MEMPRAGEs is presented for each subject and "aggregate ROI" in Table 1. We note that in all four conditions there is a very slight negative bias introduced by using vNavs; this is consistent with the vNavs consuming a very small amount of the available post-inversion magnetization before it is accessed by the MEMPRAGE pulse train. Our results seem to indicate that the scale of this effect is on the order of 0.25% of peak intensity.

Conclusions While informal observation of the images by non-specialists and radiologists have suggested there is no apparent contrast effect from introducing the vNavs, for much of the quantitative analysis performed with FreeSurfer even subtle contrast effects can be important. While our use of non-selective excitation for the vNavs should minimize spatially varying effects from navigator pulses, our analysis suggests that there is a very small global contrast effect from introducing the vNavs. This indicates that longitudinal studies should avoid introducing vNavs mid-study to avoid spurious segmentation changes. However, when applied at all time points in a longitudinal study, the contrast effects are unlikely to be relevant. Similarly, due to the negligible contrast change, vNav MEMPRAGE can be used clinically. Additionally, we suggest that studies such as this – making use of FreeSurfer's unbiased longitudinal stream – provide useful evaluations of the effect of embedded navigators.

References

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