A quantitative comparison of PSIR and MP-RAGE at 7T using tissue classification

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Purpose. Phase Sensitive Inversion Recovery (PSIR) is showing great potential in neuroimaging [1] due to the increased contrast it provides with respect to other T1 weighted approaches, such as standard MP-RAGE. In a typical PSIR acquisition, two images are collected during a single inversion recovery and the phase images are used to restore the sign of the inversion recovery signal in the magnitude images, thereby doubling the dynamic range in the reconstructed image. In turn, this increase in range can be exploited by increasing image resolution, by reducing scanning time or, crucially, by increasing image contrast. While these offer intuitive advantages, the relative merits of MP-RAGE and PSIR have not been systematically assessed to date. Brain tissue classification, the partition of a brain image into disjoint regions corresponding to three or more tissue types (typically, white matter (WM), gray matter (GM), cerebro-spinal fluid (CSF) and "others" such as bone, skin, dura and the meninges) is the first step in many computational neuroscience studies and crucially depends on contrast. Consequently, it provides us with a realistic framework to compare performance. **Aim:** To quantitatively compare the performance of PSIR and MPRAGE by means of tissue classification.

Method. Six healthy volunteers (5 males, 1 female, mean age: 32yr±9yr) had their brain imaged on a Philips Achieva 7T scanner equipped with a NOVA 32 channel receive coil. First, three identical high-resolution 0.6mm isotropic MP-RAGE scans were acquired, to be later averaged together to improve SNR (TE/TR=6/15 ms, FA=8°, TI=1070ms, linear phase encoding, FOV of 200×180×140mm, Taq=12min20s). This was followed by a 0.6mm isotropic PSIR scan (SSi=5000ms, FA=8°, TE/TR=6/13ms, FOV= 200x180x140mm, Taq=11min55s) whereby 2 FFE images were simultaneously acquired at 2 different points during the inversion recovery: the first one at TI_1=780ms, half-way between the null points of GM and WM, to produce null signal for the partial volume voxels at the GM/WM boundary and the second one at TI_2=1600ms. The magnitude and phase information from the PSIR acquisition were then combined to produce a T1w image with double dynamic range. Finally, the TI_2 image, which shows low image contrast but reflects the variation in signal due to B1 inhomogeneity, was smoothed to reduce the effect of noise and then used to remove the effect of B1 field inhomogeneities from the PSIR image by simple division. For comparison, four of the volunteers were also scanned on a Philips Achieva 3T scanner equipped with a 32 channel receive coil, using a standard $1mm^3$ isotropic MP-RAGE sequence (TE/TR=4/8ms, FA=8º, TI=960ms, linear phase encoding, FOV=256x256x160mm, Taq=4min).

Each subject's scans were first registered to their PSIR scan using SPM [2]. To improve SNR, the registered MP-RAGE scans were then averaged into a single MPRAGE image, onto which FSL bet2 was run [3] to obtain a brain mask. This mask was used to remove non-brain tissues in all scans, to facilitate tissue classification. All masked scans (MP-RAGE at 3T and 7T, and PSIR) were then conjointly non-uniformity corrected and tissue classified in SPM using the New Segment approach. Finally, the transformations obtained from the SPM classification step were used to back-project the 48 labels of the Harvard-Oxford cortical atlas onto the scans in order to automatically define 48 cortical regions. We could then estimate, for each sequence, the volume of GM in each of the cortical regions defined by the atlas by integrating the tissue probability within those regions. We also computed the overall amount of WM on the probabilistic maps thresholded at 50%.

Results. We ran a series of two-tailed paired t-tests to compare the regional GM volume estimates obtained from the PSIR and MP-RAGE scans at 7T across all atlas regions, using a 5% false discovery rate to account for multiple comparisons. The superior frontal and precentral gyri were the only regions exhibiting significant differences, with strong trends in the middle and inferior parts of the frontal gyrus. Visual comparison between the sequences confirmed the loss of contrast exhibited by the 7T MP-RAGE scans in those regions, as a consequence of which the classification maps were incorrect. The 7T PSIR scans did not suffer from the issue and compared favorably with the 3T MP-RAGE scans (see Figure 1). We did not find any statistical difference in terms of overall WM volume.

Discussion. Qualitative and quantitative inspection of the probabilistic tissue maps indicate that the enhanced contrast afforded by PSIR translates into an easier, more confident classification process, which produces better defined maps, as evidenced by a much reduced transition area with intermediate probabilities between gray and white (blue regions in Figure 1). While we did not record statistically different volumes across most cortical regions, or indeed in terms of total WM volume, the MP-RAGE maps were rather degraded at the periphery of the cortex, and statistically significantly so in the superior regions. This is consistent with the studies of Bock et al., who showed in marmosets [4] that the T1 of high myelin content regions was up to 15% shorter than in regions with a low myelin content at 7T, with a similar pattern in human at 3T [5]. Variations in T1 across the cortex, together with B1 inhomogeneities, make it difficult for an MP-RAGE sequence optimised for the whole head to perform well in the superior part of the frontal lobe, even after SPM's non-uniformity correction. PSIR's relative immunity from this issue probably stems from both its increased dynamic range and its inherent bias field correction. Overall, it not only delivers superb contrast throughout the entire brain but it does so much faster; three times faster in this study.

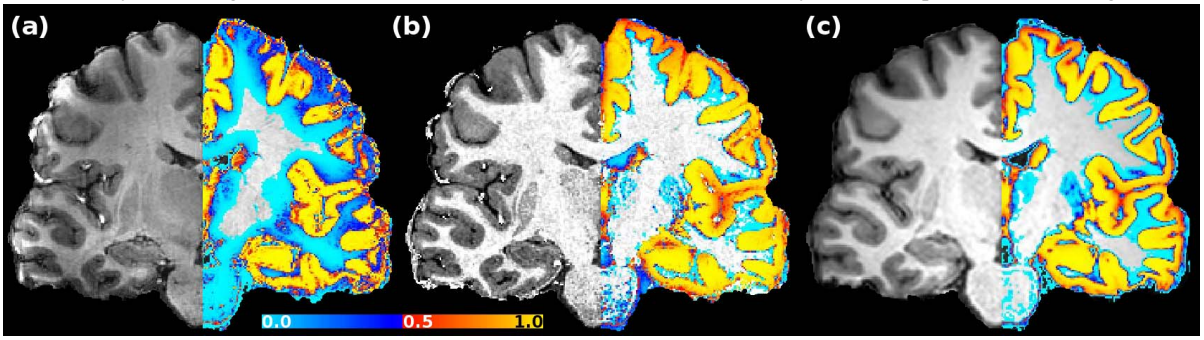

Figure 1: Magnitude image (left) and probabilistic GM map (right) for : (a) 7T MP-RAGE, (b) 7T PSIR, (c) 3T MP-RAGE. Slice chosen to highlight differences in superior frontal and precentral gyri.

References. [1] Sethi et al. J Neurol Neurosurg Psychiatry 2012. [3] Ashburner, Mag. Res. Imag. 2009. [4] Jenkinson et al., HBM'05. [5] Bock et al., J. Neuroscience Methods, 2009. [6] Bock et al., NeuroImage 2013, 65:1-12.