# Prospective Motion Correction (PROMO) enabled MP2RAGE for multi-contrast high-resolution brain imaging

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**Target Audience:** MR scientists and neuroscientists interested in high-resolution anatomical brain imaging in moving subjects

**Introduction**: 3D MP2RAGE (1) is derived from the standard MPRAGE pulse sequence (2) and acquires within the same repetition time (TR) two images with different inversion times (TI) that can be used for B1-field intensity correction (1), or for improved clinical visualization of healthy and pathological tissues based on multiple contrasts (3). While the two images in MP2RAGE are inherently co-registered, they can suffer from imaging artifacts due to subject motion especially in studies involving non-compliant subjects such as pediatric or elderly patient populations, or in high resolution studies requiring longer scan durations or multiple averages. The PROMO prospective motion correction uses navigator data to estimate and correct for subject motion in every TR (4) and, when combined with the standard MPRAGE, has been shown to significantly improve cortical surface reconstruction in moving subjects (5) with little scan time penalty. In this study we implement a PROMO-enabled 3D MP2RAGE pulse sequence, evaluate its ability to correct for subject motion, and illustrate how it can be used to obtain multi-contrast high-resolution images at 3T.

**Methods**: Two healthy volunteers were scanned on a 3T MRI with a 32 channel RF head coil using a PROMO-enabled 3D MP2RAGE pulse sequence. Inversion times were chosen to obtain preferentially white matter (WM) and fluid suppression (3), respectively. To test the ability of PROMO to correct for subject motion in the 3D MP2RAGE scan we acquired images at 1x1x1mm$^3$ isotropic resolution in three scan conditions: 1. PROMO turned on, patient asked to lay still, 2. PROMO turned on, patient asked to move (Figure-8 head motions every 60sec), and 3. PROMO turned off, patient asked to move (same as in 2.). The imaging parameters were: field-of-view (FOV) 220x220mm$^2$, 160 slices, TE/TR/TI1/TI2 = 2.1/3520/450/1820ms, bandwidth 62.5kHz, flip angles $\theta_1/\theta_2$=5°/5°, and parallel imaging acceleration of 2, with total scan duration of 5 minutes. In addition we conducted a high-resolution isotropic 0.75x0.75x0.75mm$^3$ scan with the same imaging parameters and PROMO turned on across 6 averages, for a total scan time of 39 minutes. The MP2RAGE images with white matter and fluid suppression (**WMs** and **FLs**, respectively) were combined to obtain MPRAGE-like brain tissue contrast **C1**=**FLs**-**WMs**, and primarily gray matter (GM) contrast **C2**=min(**WMs**,**FLs)**.

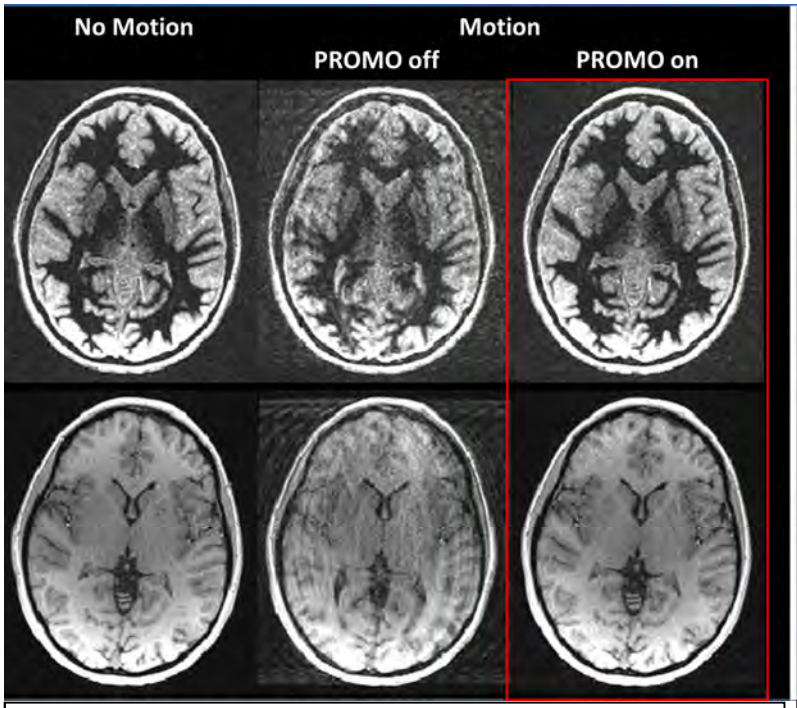


**Figure 1:** PROMO-enabled MP2RAGE successfully corrects for subject motion in both **WMs** (**top row**) and **FLs** (**bottom row**) images (red box). Without PROMO, subject motion generates significant motion artifacts degrading spatial accuracy and tissue contrasts.

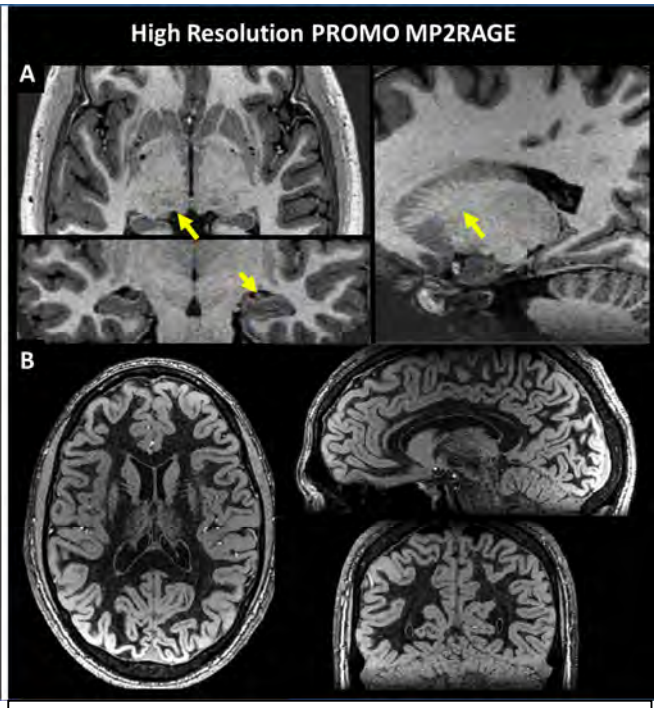


**Figure 2:** High-resolution images with contrasts **C1**=**FLs**-**WMs** (**A: top panel**) and **C2**=min(**FLs**,**WMs**) (**B: bottom panel**) computed from the two PROMO MP2RAGE images (**WMs**, and **FLs**), show high spatial fidelity, excellent tissue contrast and sensitivity.

**Results and Discussion**: As expected, 3D MP2RAGE images (**WMs** and **FLs**) acquired without PROMO, although co-registered, are significantly degraded by subject motion (**Fig. 1** middle column) resulting in loss of spatial accuracy and tissue contrast. Conversely, images obtained with PROMO-enabled MP2RAGE show almost no artifacts even in the presence of significant subject motion (**Fig. 1** red box). The use of prospective motion correction complements the inherent co-registration between different contrasts in MP2RAGE to provide artifact-free high-resolution images ideal for multi-contrast tissue visualization and characterization. This synergy between motion tracking ability of PROMO and the inherent multi-contrast co-registration of MP2RAGE is best illustrated in the 0.75mm scan for which PROMO was applied across all 6 averages. In **Fig. 2A**, the MPRAGE-like contrast **C1** reveals fine neuroanatomical features such as the subthalamic nuclei, the hippocampal cortex, or the internal capsule (**Fig. 2A** yellow arrows); while the high resolution **C2** contrast in **Fig. 2B** enables clear visualization of the cortical ribbon.

**Conclusion**: PROMO-enabled 3D MP2RAGE presented here has the ability to provide co-registered, artifact-free images with multiple contrasts in moving subjects. It may have a significant clinical impact, enabling multi-contrast structural imaging in studies with pediatric or elderly patient populations. In addition, the ability of PROMO to track subject motion across multiple averages provides submillimiter resolution with suitable SNR, and could allow ultra-high-resolution clinical investigations of specific brain regions using reduced-FOV on conventional 3T scanners.

**References**: 1. Marques et. al., Neuroimage 2010 49:1271-1281; 2. Mugler & Brookeman, MRM 1990 15:152-157; 3. Tanner et. al., JMRI 2010 35:1063-1070; 4. White et. al., MRM 2010 63:91-105; 5. Brown et. al., Neuroimage 2010 53:139-145;