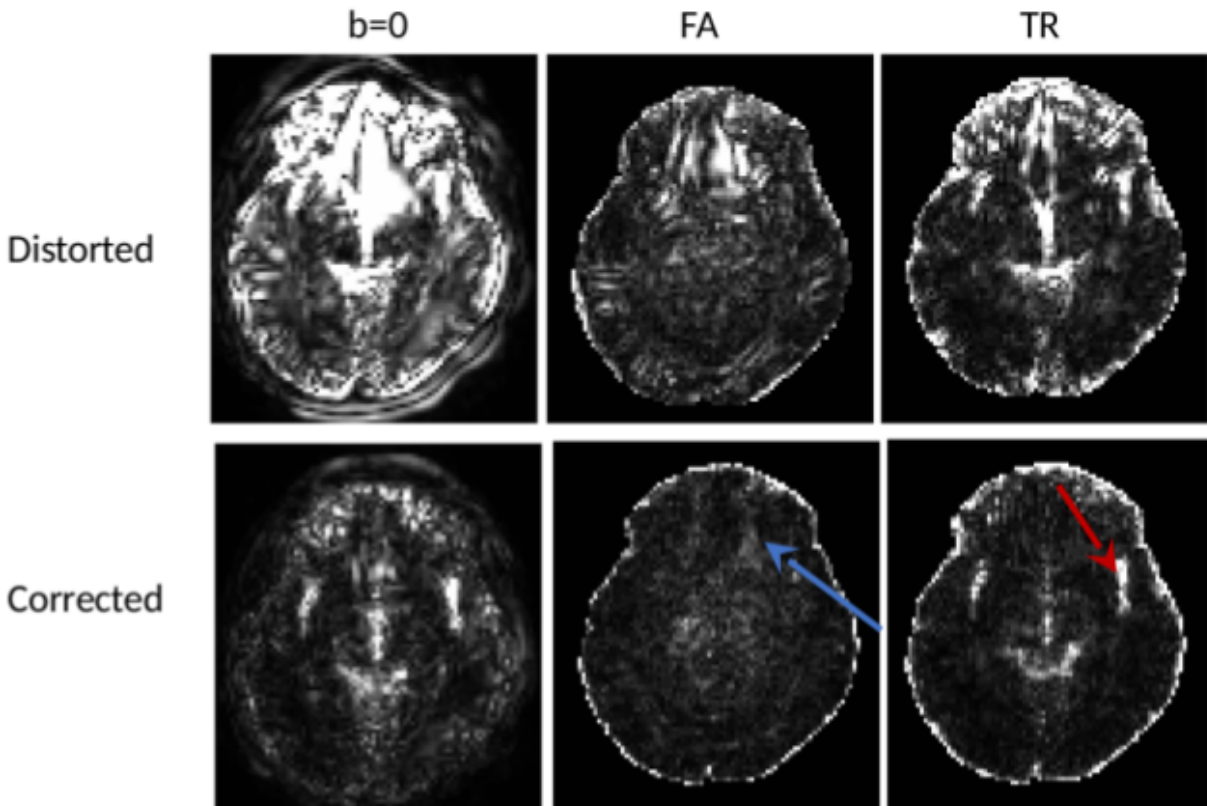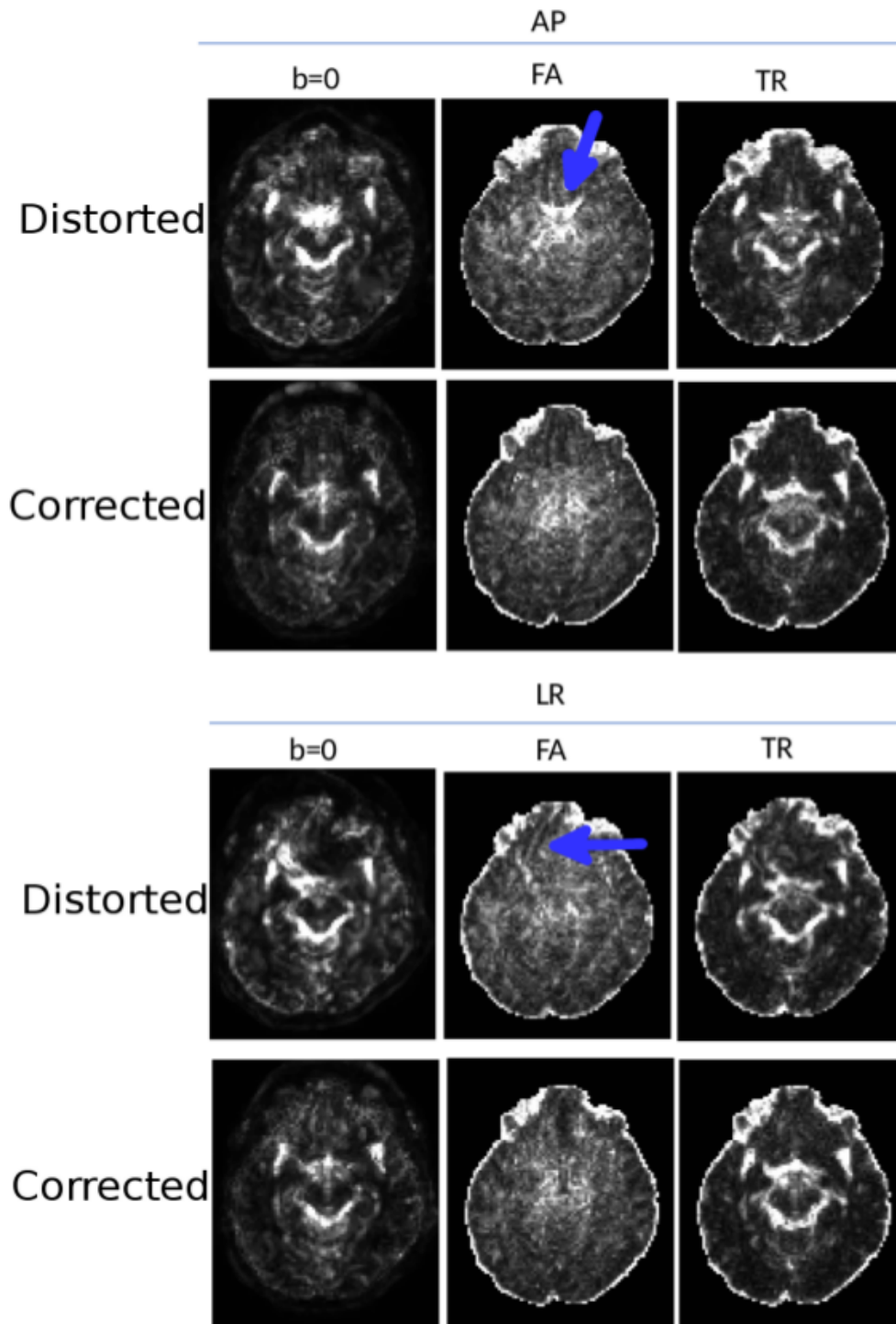**SUPPORTING INFORMATION FIGURE S1**. Sample distorted and distortion corrected images for the *AP* and *LR* encoded data for the additional test.

SUPPORTING INFORMATION FIGURE S2. *b=0 s/mm²*, FA and TR variability maps computed over the repetitions of the additional dataset computed with: $\sigma^2 = \frac{1}{9} \sum_{i=0}^{9} \left(I_i^{AP} - I_i^{RL} \right)^2$. As expected, the variability between the distorted *AP* and *RL* data is very large within the repetitions. Distortion correction significantly reduces this. A couple of interesting observations are indicated with the arrows. In the ventral frontal region which suffers from severe EPI distortions, the variance map reveals slight inconsistency between the *AP* and *RL* corrected data in this region for FA maps (blue arrow). Also, CSF-filled regions can contain flow-void artifacts, which are even visible on the *b=0* images above. The red arrow indicates that the variance maps are sensitive to such artifacts within the repetitions even after correction. These are two examples of residual variance that originate form imperfect correction of distortion (ventral frontal area) and other artifacts not possible to correct with image registration (CSF areas).

SUPPORTING INFORMATION FIGURE S3. Variance of the *AP* and *LR* data for *b=0*, FA and TR images before and after correction to test the reproducibility of the variance concept. This analysis was again repeated for both the corrected and uncorrected data. The variance was computed separately for *AP, PA, RL and LR*. For the *AP* set, it was computed as: $\sigma^2 = \frac{1}{9} \sum_{i=0}^{9} \left(I_i^{AP} - \overline{I}^{AP} \right)^2$ There are several sources of variability affecting both the distorted and corrected data. These include CSF flow voids, cardiac pulsations, etc... Several other sources only affect the distorted data, such as motion and eddy-currents distortions. The differences in EPI distortions among the repetitions due to motion is clearly visible in the uncorrected *AP* and *LR* maps (blue arrows). Distortion correction removed these sources of variability as can be seen in the bottom row. However, as expected, non-distortion related sources of variability still remain.