Compensation of non-T_1-related artifacts in variable TR fMRI at 1.5T

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Introduction

Variable repetition time (TR) acquisitions have been utilized to mitigate physiologic confounds such as pulsatile brain-stem motion [1] and environmental confounds during fMRI acquisition such as acoustic imaging noise [2]. Associated with a variable TR acquisition is the need for an intensity correction due to differences in T_1 contrast, effected by scaling using a T_1 saturation model. Birn et al. investigated the efficacy of the T_1 saturation model for variable TR correction in cardiac gating by acquiring images of a phantom without and then with gating [3] and observed that the noise variance increased by a factor of three with gating (from 0.4% to 1.3%). T_1-based correction alone may not be sufficient for other, non-T_1-related confounds that arise in variable TR experiments. This study exploited a novel acquisition scheme to characterize and improve compensation for non-T_1-related confounds in variable TR experiments.

Methods and Procedure

Paradigm: Dummy image acquisitions (gradient readout sequences with radio-frequency excitation disabled) were applied at a series of variable post-offset sample times between actual image acquisitions occurring at a fixed TR. This simulates a variable TR without perturbing T_1 relaxation, facilitating study of non-T_1-related confounds. Three experiments were performed, in each of which a dummy volume acquisition, comprising 1-, 10-, or 15-slice dummy image acquisitions was effected via a clustered volume acquisition [4] scheme. These experiments were conducted on a DQA phantom over the course of three scanning sessions (over a period of three months) on a GE 1.5T Signa CVi using bilateral surface coils. Each session consisted of six experimental runs acquiring 12 trials of each post-offset sample time.

Percent Signal Change Calculation: To estimate signal change induced by non-T_1-related artifacts, a volumetric region of interest (324 voxels total) was constructed. Percent signal change was calculated with respect to the null acquisition for each voxel within the ROI, and averaged across voxels, runs, and sessions. The non-T_1-related artifact was modeled as the general solution of a second order equation modified by an offset: $F(t)=(A\cos(\omega t)+B\sin(\omega t))e^{-\lambda t}+C$.

Artifact Correction and Performance Assessment: The modeled second order signal change can be utilized to compensate for the observed non-T_1-related artifact. Voxel-based correction is effected on each voxel in a slice by a modified projection procedure in which the modeled fit for the given slice is scaled to the average signal level obtained for the voxel during the null acquisition condition, and subsequently subtracted. To assess the effectiveness of compensation, the contribution from the non-T_1-related signal to the phantom images was calculated prior to and after correction using a K-fold cross-validation methodology (17 runs as training data with remaining run as testing data). All 18 possible testing/training dataset combinations were evaluated. Fixed effects and random effects analyses were conducted in *AFNI* to assess the number of voxels in the phantom exhibiting "activation" (i.e., signal changes correlated with the estimated non-T_1-related artifact), before and after correction.

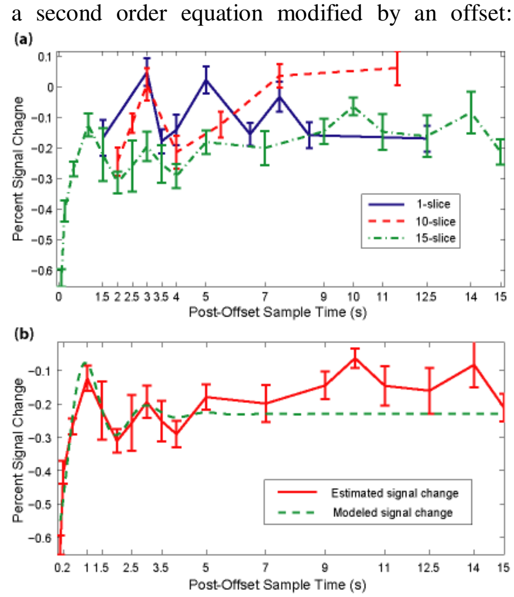

Figure 1. (a) Estimated signal fluctuations induced by non-T_1-related artifacts for 1-, 10-, and 15-slice dummy acquisitions. (b) Modeled signal change for 15-slice experiment.

Results

Figure 1a shows the estimated percent signal changes induced within the phantom ROI by the 1-, 10-, and 15-slice dummy volumes. Figure 1b depicts the second order solution fit obtained for constrained non-linear regression with the 15-slice experiment. Signal fluctuations are well-modeled by the second order process for offset sample times less than 5 s. Figure 2 shows the number of voxels exhibiting significant levels of the estimated artifact with and without correction. Correction reduced number of spurious detections at all *p*-value thresholds.

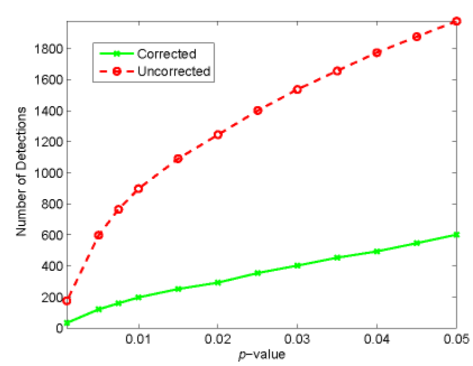

Figure 2. Number of spurious detections of phantom activity with respect to *p*-value.

Discussion and Conclusion

The non-T_1-related oscillatory signal fluctuation is likely due to eddy currents and vibrations of the gradient coil assemblies, brought about by interaction of rapidly switched gradient field-producing currents with the static magnetic field. Eddy currents cause intensity and phase distortions in the image and in the spectra [5] while vibrations produce temperature fluctuations in the gradient coils [6]. Differential heating of the gradient coils and transient fluctuations of eddy currents due to variable gradient activation times produce undesirable signal fluctuations in variable TR experiments. Non-T_1-related signal fluctuations represent an observable and potentially deleterious confound that can be modeled and corrected for using the procedure presented in this work.

References

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