Prospective correction of large simple through-plane motion

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Objectives

When head motion occurs through-plane during fMRI, the steady-state magnetization of the imaged slice can be disrupted. For a single slice, through-plane motion introduces tissue that has not been excited previously into the imaging plane. This leads to signal increases which can be comparable in amplitude to, and therefore difficult to separate from, the BOLD response. The amplitude of the signal change due to through-plane motion increases with velocity and T1. Separation of motion artifact from BOLD response is made more challenging by the fact that motion frequently increases during the task portion of the fMRI experiment.

As an alternative to developing post-processing techniques to correct this problem, a prospective correction technique to prevent artifact during acquisition is under investigation. Ideally, an adaptive imaging plane adjusts in response to head motion such that the same tissue is imaged with each excitation, the magnetization remains at steady-state, and signal changes can be assumed to arise primarily from the BOLD response.

A preliminary experiment focuses on theoretical and instrumental issues surrounding prospective correction for simple through-plane motions, investigating the effect of linear, back-and-forth motion on spiral imaging of a single slice within a phantom with known T1. This allows comparison of theory and experiment, as well as testing of the limits of prospective correction.

Simulation Methods

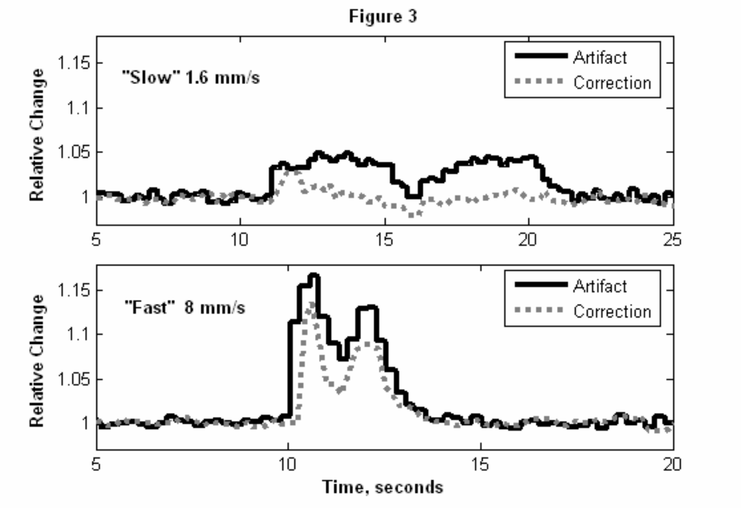
Matlab was used to predict signal change within a 5mm slice resulting from back-and-forth through-plane motion. The MR signal was calculated as a function of slice velocity, T1, TR, and flip angle, assuming instantaneous, ideal, slice-selective excitation. The slice was divided into segments of thickness corresponding to the displacement during TR. The signals from each segment, each with individual excitation history, were summed to yield the total signal for the slice. Previously unexcited segments had the largest signal, and those at steady-state had the least. See Figure 1.

Experimental Methods

A gadolinium-doped agar ball phantom (radius 15cm, T1=1436ms) was mounted to an acrylic plate that was moved within the magnet bore by a stepper motor at the foot of the patient table. Displacements of 8mm into and out of the magnet bore were achieved at 1.6mm/s and 8mm/s. Imaging was performed on a longbore GE 3T system and occurred before, during, and after motion to compare with simulation results. A real time imaging interface [1] controlled the imaging plane, data acquisition, and reconstruction. Imaging parameters were typical of a single-slice fMRI experiment (TE=30ms, TR=250ms, 30 degree flip angle, 5mm slice, 3668 point spiral readout, 30cm FOV, 50x50 image). An fMRI-compatible optical tracking device [2], mounted at the back of the magnet room, tracked the position and orientation of a tool mounted to the phantom. The tracking data were calibrated and sent to the real time imaging interface to en able prospective correction by adjusting the frequency of the excitation pulse for the net phantom displacement each TR.

Simulation Results

As shown in Figure 2, the start of motion (b) creates increased signal that reaches a plateau (c) after several excitations. The time to plateau is inversely related to the velocity. At this point, each image has the same composition of segments with different excitation histories. When the motion is reversed, the entire slice is one excitation closer to steady-state, and the signal drops, then returns to the previous plateau.



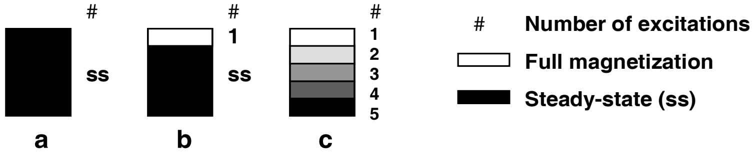
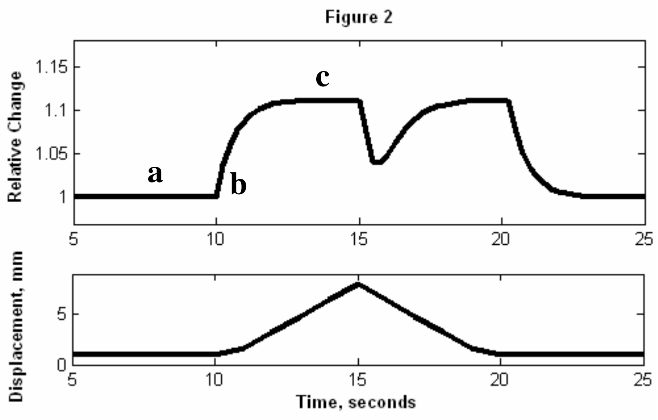


Figure 1. Net signal from a slice in the presence of motion
a) At rest, the entire slice is at steady-state (10+ excitations). b) When motion begins, one segment has received only one excitation while the rest remains at steady-state. c) After 5+ excitations during constant velocity, the total slice has received less excitations than previous cases, thus there is a net signal increases.



Experimental Results

Figure 3 shows the signal change from through-plane motion as well as the corrected signal change for both slow and fast motions. The signal change in the slower case was consistent with simulation results and was effectively suppressed by prospective correction. The fast motion also showed the anticipated signal changes but was not well corrected with this prospective technique. The artifact that remains represents the displacement of the slice during system lag.

Conclusions

Further study into correction quality with a range of velocities and improved tracking will be used to evaluate the correction of complicated, patient-like through-plane motions. Such work will contribute to a better understanding of through-plane motion artifact as well as the limits of prospective motion correction technique**.**

References

[1] Stainsby 2004 *Proc. ISMRM* #537
[2] Tremblay, Tam, Graham 2005 *MRM* **53**(1):141-9