Combining R2* Mapping and Slice Registration for fMRI Analysis of Moving Subjects

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Introduction: Multi echo fMRI has seen considerable new interest in adult imaging [1,2]. It makes use of data acquired at two or more echo times to allow the estimation of parametric MRI measurements. With these multi-echo techniques, parametric maps with high stability can be obtained and offer a route to dealing with distortions and motion artifacts [2,3]. One such measurement is the R2* map, which is a map of the signal relaxation rate [4]. This expresses, in units of 1/s, the signal relaxation that occurs during readout due to intra-voxel dephasing of magnetization. As a quantitative measure it can be related to cerebral hemodynamics such as cerebral blood flow and volume and CMRO2, which makes it attractive for looking at BOLD contrast in relation to the underlying mechanisms that drive it. Figure 1 shows a through plane view of an interleaved multi-slice EPI aquisition of a moving fetal head, where through plane motion is occurring. The R2* map on the right does not suffer from this artifact as the T2 weighted images on the left. In this work, we use this observation to investigate the application of dual echo R2* maps combined with volume and slice motion correction for detecting activation in the presence of large scale head motion in fMRI.

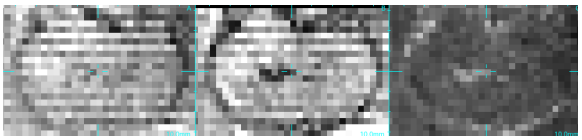

Figure 1: Fetal fMRI data. Left: First Echo, Middle: Second Echo, Right: R2* Map

Materials and Methods: Two dual-echo fMRI studies were acquired on Philips Achieva 3T scanner on an adult subject using a finger tapping paradigm. In the first study, the subject was stationary and in the second, the subject moved her head in a nodding motion during the middle third of the sequence. Both sequences were acquired with the following parameters: TR=3000ms, TE1 = 15.6ms, TE2 = 45ms, 3mm X 3mm X 3mm voxels. These images were used to generate R2* maps. The R2* value at each voxel x was computed as: $R2^*(x) = \ln(S1(x) - S2(x))/ (TE2-TE1)$, where S1 and S2 are the signal intensities in the first and second T2 weighted echoes respectively. Volume correction as well as slice motion correction [5,6] were then applied to align the T2 weighted and R2* sequences, and ICA was used to detect a cluster in the motor cortex corresponding to the finger tapping response, from the second echo of the standard T2 weighted stationary subject data. This was then used as an ROI (Figure 2 - cyan contour) to look at responses in motion corrupted data.

Results: Results of imaging using two echoes to calculate an estimate of R2* are shown in Figure 2. The first column shows results from the stationary subject and the second column shows results from the moving subject. The first row shows the head motion trajectory, and the second and third rows of graphs show the average mean subtracted percent signal change of the second T2 weighted echo and the R2* map, within the ROI selected in the motor cortex. The finger tapping signal changes can clearly be seen in both the T2 weighted as well as the R2* signal trajectories for the stationary subject as expected. For the moving subject, the T2 weighted signal trajectory suffers from severe artifacts, and the finger tapping signal cannot be observed. However, the R2* trajectory calculated using the same T2 weighted echo can eliminate some of the artifactual effects. Calculation of R2* from the two echoes thus provides a stable signal resulting in the extraction of a clear motor response component by ICA. We conclude that it is possible to reliably extract a finger tapping response from dual echo acquisitions with R2* mapping combined with volume and slice motion correction, in situations where conventional T2 weighted contrast would detect no activation due to slice to slice spin saturation. This can lead to some very interesting insights which can be applied to task based and possibly resting state fMRI analyses of moving subjects including young children and fetuses, where motion cannot be controlled.

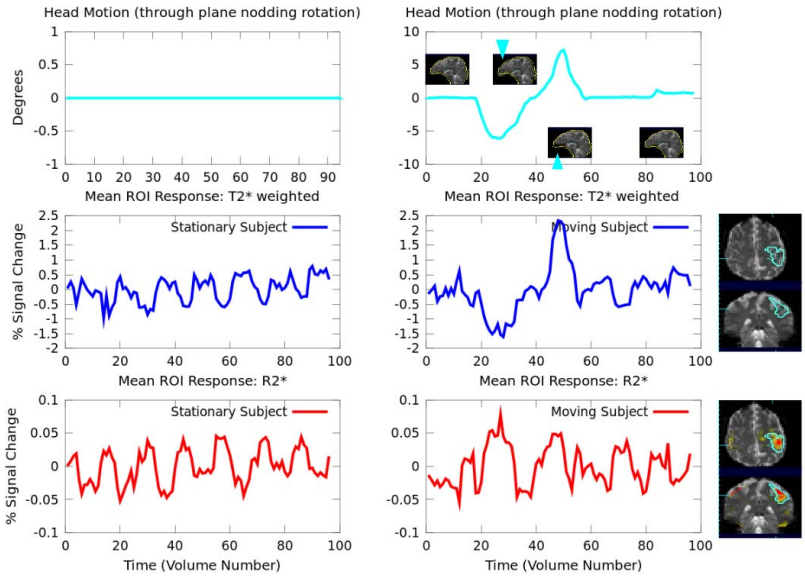

Figure 2: Detection of functional activation during head motion

References: [1] Kundu P., et al *NeuroImage*, (2011) [2] Schwarzbauer C., et al *NeuroImage*, 49(1):316-326 (2011) [3] Weiskopf N., et al *NeuroImage*, 24(4):1068-1079 (2005) [4] Ogawa, S, et al *Biophysical Journal*, 64(3):803-812 (1993) [5]Rousseau F et al, Acad Rad, 13:1072-1081 (2006) [6]Seshamani, S et al, ISMRM 2012