Slice-timing correction affects functional MRI noise, model fit, activation maps, and physiologic noise correction

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Introduction: Slice-timing correction (STC), correction for the different acquisition times of individual slices in a TR interval, is frequently employed in FMRI data processing. This involves interpolation of the time series data for each slice, based on its acquisition time. The effect of STC on FMRI noise and task activation is expected to be positive but its benefit has not been clearly demonstrated. Furthermore, the interaction between STC and commonly applied slice-wise physiologic noise correction, which also modifies the FMRI data, has only recently been explored in resting-state FMRI data [1]. This study examined STC and slice-wise respiratory correction (RC) in FMRI of pain, where significant task-induced increases in respiratory rate and depth occur [2].

Methods: Seven subjects (4 male, mean age=31±6) volunteered for this painful electrical nerve stimulation FMRI study. Block stimulus design was used with four 30 second pain epochs in a 4.5 minute scan. A General Electric 1.5T scanner was used with parameters: GRE EPI, TR=3s, TE=50ms, 90º flip, FOV=24cm, and voxel size=3.75x3.75x5mm. Full-brain coverage was accomplished with 28 contiguous interleaved axial slices. During scanning, respiratory depth was monitored with a strain gauge belt sampled at 200 Hz. Image data were processed with FSL [3], with or without STC in preprocessing. Respiratory data were reordered to account for the interleaved acquisition before voxel-wise regression was performed and significant respiratory-correlated ($p<0.05$) signal fluctuations were subtracted. The adjusted coefficient of multiple determination (R^2_a) was calculated for the fit of the stimulus paradigm to each voxel timecourse [4], with the application of STC, RC, or both. Average temporal standard deviation and mean R^2_a values were averaged across the whole brain. Activated voxel counts were totaled in each subject and averaged across all subjects.

Results: The effects of STC and respiratory noise correction are shown by the summary statistics listed in Table 1. Both RC and STC reduced the average temporal standard deviation of the signal timecourse (σ), with the largest, synergistic reduction seen when both were applied (Both vs. neither). The quality of model fit, indicated by mean R^2_a [4], improved with both RC and STC in any combination. However, the 67.6% R^2_a increase from RC without STC (RC vs. no corr.) was reduced to 49.2% with prior STC applied (Both vs. STC alone). This is shown graphically in Fig. 1; when RC followed STC, fewer voxels on average (5199 vs. 5537) were correlated to the respiratory regressor. Strikingly small was the 2.1% impact on R^2_a from STC in the context of RC (Both vs. RC alone). The number of activated voxels was affected by STC (increased), RC (decreased), and both together (increased).

% Changes in All-Subject Average Summary Values			
Analysis Comparison	σ	Mean R^2_a	Active Voxels
STC vs. no correction	-6.8 %	14.7 %	39.4 %
RC vs. no correction	-1.9 %	67.6 %	-5.7 %
Both (RC & STC) vs. neither	-44.5 %	71.0 %	25.6 %
Both (RC & STC) vs. STC alone	-19.1 %	49.2 %	-9.9 %
Both (RC & STC) vs. RC alone	-15.7 %	2.1 %	33.2 %

Table 1 - Percent changes in all-subject average summary values (described in Methods) comparing effects of slice-wise respiratory correction (RC) and slice-timing correction (STC).

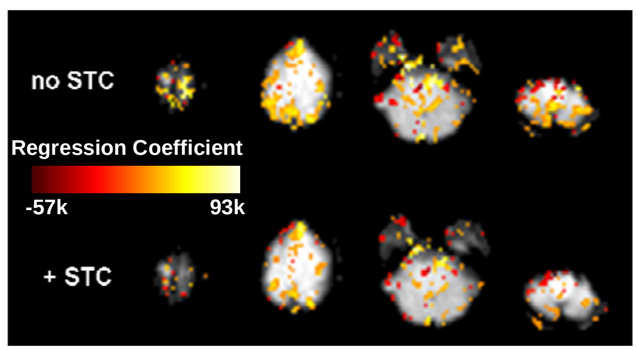

Fig. 1 – Voxels in the brain significantly correlated to the respiratory noise regressor without (top row) and with (bottom row) slice-timing correction (STC) applied for 4 selected slices of one subject's dataset.

Discussion: The results of this study show that using slice-timing correction in the analysis of a block-design functional MRI study can influence all aspects of the results, including temporal noise (σ), model fit (R^2_a), and activation. These effects likely result from propagation of small errors from interpolation used to temporally shift slices within the (undersampled) TR interval. Jones et al. [1] recently showed that the percent reduction in σ depended on the order in which slice-timing and physiologic noise corrections were applied, suggesting an interaction between the two. Such an interaction is demonstrated here for three measures of task-related FMRI study outcome. STC and RC caused synergistic decreases in σ , but had mixed and competing effects on R^2_a and voxel count. Specifically, the 14.7% (without RC) or 2.1% (with RC) increases in R^2_a from applying STC in this block-design study were overshadowed by the 67.6% (without STC) or 49.2% (with STC) increases from slice-wise RC, suggesting that **RC may be more important than STC for the accurate detection of task activation**. Furthermore, the amounts of σ reduction and R^2_a increase due to RC depended on whether or not STC was also employed. Thus, the typical measures [4, 5, 6] used in quantifying the effects of physiologic noise correction algorithms, **temporal noise, model fit, and activation, are all influenced by STC**. Based on these findings, FMRI investigators should specify in their methods description whether or not STC was used in data processing.

References: [1] Jones, et al., 2008. NIMG 42:582-590. [2] Ibinson and Small, 2004. *Anesthesiology* 101:A-1059. [3] Smith et al., 2004. NIMG 23:S208-19. [4] Razavi et al., 2003. HBM 20:227-38. [5] Vogt et al., 2007. *Proc* ISMRM 15:1825. [6] Glover et al., 2000. MRM 44:162-167.