The impact of robust tensor estimation on voxel-wise analysis of DTI data

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Motivation: Despite the sensitivity of DTI to subject motion and susceptibility artifacts, robust methods of tensor estimation [1][2] are rarely used, even among studies of vulnerable populations. Robust Estimation of Tensors by Outlier Rejection (RESTORE) [3] has been shown to reduce the effect of artifacts and corrupted data on the tensor fit and the resulting scalar contrasts, but only in the context of a single subject. The purpose of this study is to evaluate RESTORE in the context of a voxel-wise group analysis, and to determine 1) if using RESTORE results in a benefit for the group comparisons and 2) if RESTORE introduces confounding factors into the statistical analysis. Cerebellar Ataxia, a condition involving the cerebellum, was used as a sample condition, as the cerebellum is a region that is especially prone to artifacts in DTI.

Background: The RESTORE method is algorithm aimed at identifying and rejecting aberrant data points from the tensor fit. In brief, RESTORE iteratively re-weights the data points to maximize a goodness-of-fit metric, and then rejects points lying three standard deviations of the noise outside the best fit found. The final tensor is then estimated as a nonlinear equally-weighted fit to the remaining data points. This procedure is done independently at each voxel.

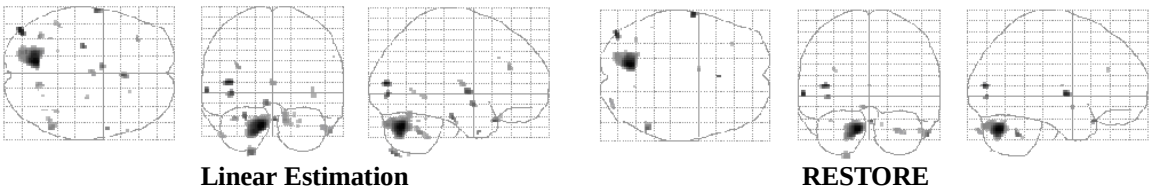

Fig 1: $FA_{Control} > FA_{Ataxia}$: T-test for regions of decreased FA in cerebellar ataxia ($p \leq 0.001$ uncorr.).

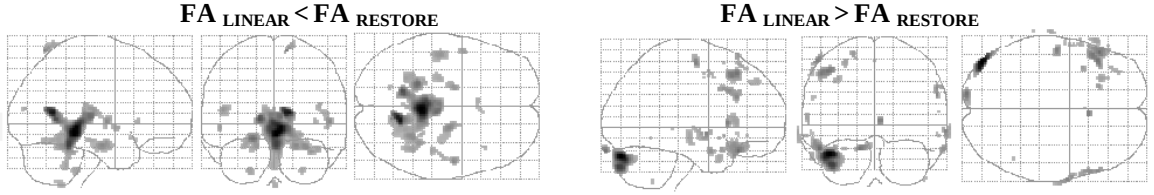

Fig 2: Statistical maps of a paired t-test for FA differences with the two methods ($p \leq 0.05$ FWE)

Methods: Data was collected on 36 subjects (17 atax/19 ctrl, 17 M/ 19F, 29-82 y/o) with 3 repetitions of a Jones30 acqusition on a Philips Achieva 3T System. DTI data was processed using CATNAP.[4] The implementation of RESTORE as part of the Camino[5] processing package was integrated into CATNAP. The noise level for RESTORE calculations was estimated by a robust in house method.[6] Spatial normalization was done by affine transformation of the b0 image to the T2 MNI152 template. Statistical analysis was done with SPM2.[7]

Results and Discussion: While it is difficult to say which one is more representative of the underlying neurobiology, the significance map processed with RESTORE (Fig 1) resulted in qualitatively cleaner results. While applying a more stringent p-threshold would leave only the large area of significance in the cerebellum, the threshold shown serves to highlight the difference between the techniques. For studies with pediatric populations and/or of conditions with more subtle or unknown neurobiological correlates, reducing the effects of artifacts is a major consideration. **Fig 2** shows the difference in FA of the two processing methods. FA was found to be elevated with RESTORE in regions surrounding the cerebral peduncles.

Fig 3 shows the spatial distribution of outliers identified by the RESTORE method over all subjects. Outlier density was high in regions prone to susceptibility artifacts. Statistical analysis of the number of outliers identified in patients vs. controls did not reach significance in any part of the brain, suggesting that there was not an outlier rejection bias towards any group. There was no increase in outlier count in known regions of fiber-crossing, so RESTORE did not systematically exclude data where crossing fibers are evident (**Fig 1**). The authors recommend using RESTORE in studies that are likely to be impacted by motion artifacts, but with caution since RESTORE significantly alters the FA contrast in a spatially heterogeneous manner (**Fig 2**).

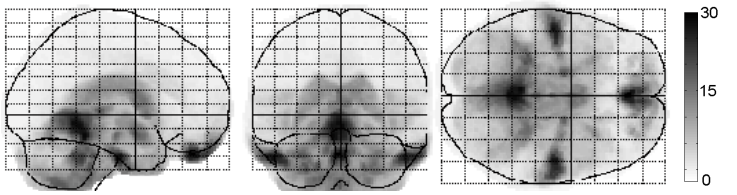

Fig 3. Mean Number of Outliers identified by RESTORE

References: [1] Koay et al *Magn Reson Med*. 2006 55(4):930. [2] Koay et al *J Magn Reson*. 2006 182(1):115-[3] Chang et al *Magn. Reson. Med* 2005 53(5):1088- [4] Landman et al. NeuroImage 2007 36(4):1123 [5](http://www.cs.ucl.ac.uk/research/medic/camino/) [6] Landman et al. ICCV/MMBIA 2007 [7](http://www.fil.ion.ucl.ac.uk/spm/) [8] Snook et al *NeuroImage* 2007 *34(1):243-*

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