Title
Quantifying the timecourse of recovery from mild traumatic brain injury using diffusion tensor imaging

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Introduction
Recent studies on mild traumatic brain injury (mTBI) by diffusion tensor imaging (DTI) [1] rely on quantitative comparison of diffusion scalar maps such as fractional anisotropy (FA) and mean diffusivity (MD) between groups, quantitative tractography [8,9] and tract-based spatial statistics (TBSS) [6]. However there is a lack of longitudinal DTI studies of mTBI and an effective approach to quantify temporal changes during recovery from mTBI. Furthermore, existing methods require large data samples which are not suitable for small sample case studies.

Methods
In this preliminary study four DTI datasets were gathered at Florida Atlantic University, one from a normal subject and three from an mTBI subject collected within 24 hours, one and two weeks post injury. All data were acquired by a 3T Signa scanner (GE Medical Systems, Milwauke, WI). Each volume contains 35 slices, each slice with dimension 256 x 256, field of view 24 cm, voxel size 0:973x0:973x3mm^3, echo time (TE) 60 ms and repetition time (TR) 2000 ms. Gradient direction was 25 and the b-value was 1000 s/mm^2.

We propose a group based independent component analysis (GICA) [2] to study the temporal change of diffusion patterns during recovery from mTBI. To date only a small number of studies have exploited ICA in DTI analysis [3,5,7,10]. In the proposed method (Fig. 1), a data array of FA and MD was constructed based on temporal concatenation. The GICA decomposes the group data into a number of spatially independent components (ICs). The desired component is the one that represents the common spatial pattern within the group data, which is separated from noise/artifacts and unknown spatial patterns. The timecourse (column of inverse of unmixing matrix) represents the distribution of the spatial IC in the group data, which also reveals the temporal changes of the diffusion patterns during recovery from mTBI.

Results
(1)Fig. 2 shows that the FA and MD maps are separated into four spatial ICs. The first IC in both maps represents the common spatial pattern. The other three ICs appear to be randomly distributed within the map and may be due to noise/artifacts and other unknown spatial changes during recovery.
(2)Timecourses of the selected component are given in Fig. 3. The *x* axis correspond to the time points of data collection. The *y* axis is the timecourse normalized by z-score. It can be seen that the timecourse of FA increases at the second time point (24 hours post injury), then decreases within the following two weeks. The timecourse of MD decreases after 24 hours, then increases after 1 week and remains at a similar level 2 weeks later. These results are in accordance with observations reported in [4].
(3) Quantitative comparison was based on the Euclidean distance between scalar maps of control (or desired IC after GICA) and mTBI at three time points. A mask was created based on the mean FA skeleton using FMRIB Software Library (FSL) software. From Fig. 4, no significant difference is apparent prior to the application of GICA, no matter whether a mask is employed or not. After applying GICA, results based on FA and MD show that Euclidean distance decreases two weeks after injury within the masked region. These results provide evidence of the evolution of diffusion patterns after injury. Their temporal course suggests a recovery process from mTBI, although the mechanisms are as yet unclear.

Conclusion
By applying group based ICA, the common spatial pattern within the grouped maps can be separated from noise and artifact, and the temporal information during recovery can be revealed by the corresponding timecourse. The results from quantitative comparison within a mask based on the mean FA skeleton further reveal the trend of recovery. The proposed method not only provides an effective solution to quantify temporal changes in longitudinal studies, but also has the potential to be applied to individual case studies in clinical applications.

References
[1] Basser, P.J. (1994), 'MR diffusion tensor spectroscopy and imaging', Journal of Biophys, vol. 66, pp. 259-267.

[2] Calhoun, V.D. (2001), 'A method for making group inferences from functional MRI data using independent component analysis', Human. Brain Mapping, vol. 14, no. 3, pp. 140-151.

[3] Franco, A.R.(2008), 'Multimodal and Multi-Tissue Measures of Connectivity Revealed by Joint Independent Component Analysis', IEEE Selected Topics in Signal Processing, vol. 2, no. 6, pp. 986-997.

[4] Hotiu, A. (2010). Diffusion Tensor Imaging in Mild traumatic nrain injuries. PhD Thesis, Florida Atlantic University.

[5] Jing, M. (2011), 'Enhancement of Fibre Orientation Distribution Reconstruction in Diffusion Weighted Imaging by Single Channel Blind Source Separation', IEEE Transactions on Biomedical Engineering, in press.

[6] Kinnunen, K. M. (2011), 'White matter damage and cognitive impairment after traumatic brain injury', Brain, vol. 134, pp. 449–463.

[7] O'Muircheartaigh, J. (2011), 'Clustering probabilistic tractograms using independent component analysis applied to the thalamus', Neuroimage, vol. 54, no. 3, pp. 2020-2032.

[8]Rutgers, D.R. (2008), 'Diffusion tensor imaging characteristics of the corpus callosum in mild, moderate, and severe traumatic brain injury', American Journal of Neuroradiology, vol. 29, no. 9, pp. 1730-1735.

[9] Singh, M. (2010), 'Novel diffusion tensor imaging methodology to detect and quantify injured regions and affected brain pathways in traumatic brain injury,' Magnetic Resonance Imaging, vol. 28, pp. 22-40.

[10]Singh, M. (2010).'Independent Component Analysis-Based Multifiber Streamline Tractography of the Human Brain', Magnetic Resonance in Medicine, vol. 64, pp. 1676-1684.

Figures

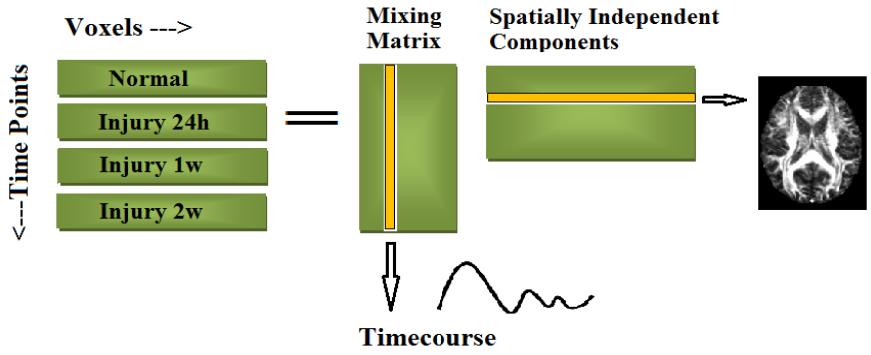

Fig. 1. Proposed method: a GICA model to study temporal change during recovery of mTBI.

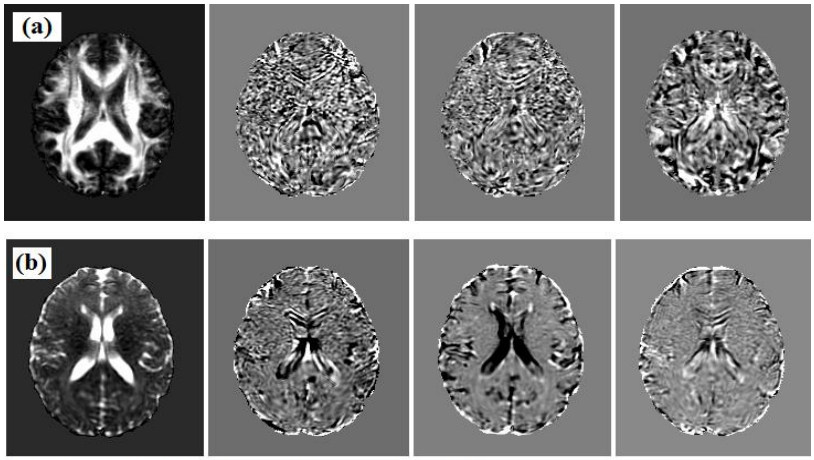

Fig. 2. Spatial ICs of (a) FA maps; (b) MD maps.

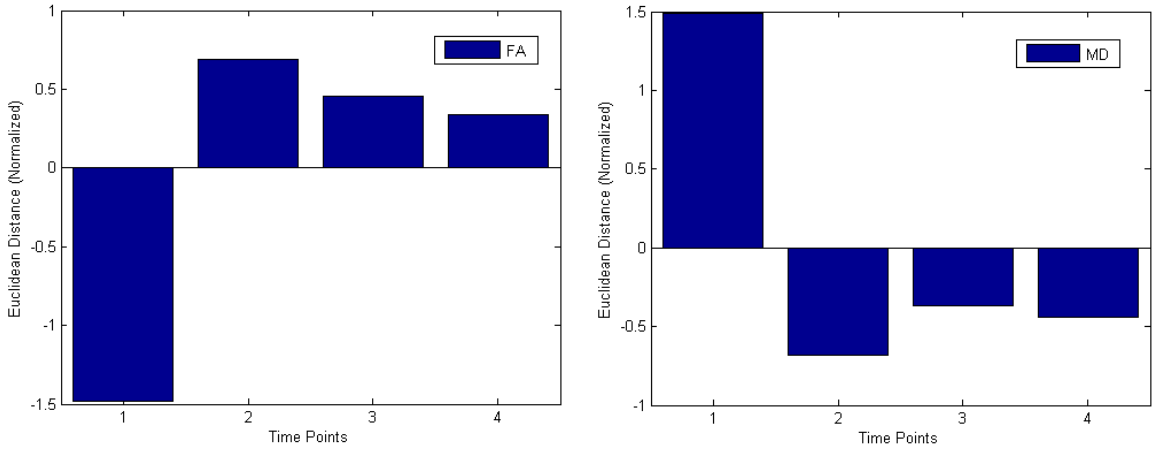

Fig. 3. The normalized timecourses of the selected IC of (L)FA and (R) MD after applying GICA.

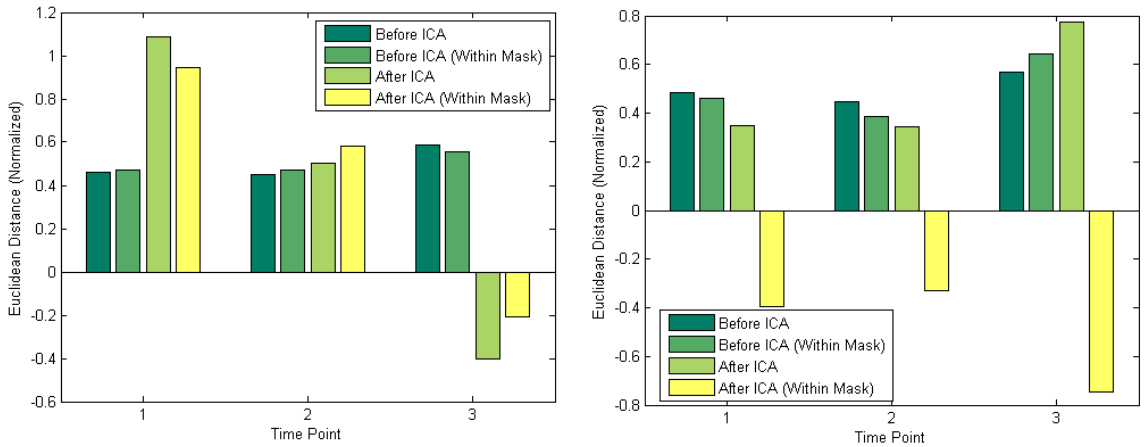

Fig. 4. The normalized Euclidean distances between the scalar maps of normal and mTIB subjects at three time points. (L) FA; (R) MD.