Brain Fiber Architecture in the Blind

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Introduction:
Blind people compensate for the loss of vision with enhanced abilities in other sensory and cognitive areas. These behavioral adaptations are often, at least in part, the result of cross-modal recruitment of visual cortices. Consequently, differences in white matter fiber architecture between blind and sighted individuals are of interest as they may reflect the brain's capacity to adapt in response to chronic visual deprivation. Here we mapped the profile of differences in white matter fiber architecture between blind and sighted subjects using a new method that combines tensor-based morphometry and diffusion tensor imaging (DTI). Using a multivariate analysis of the full 6-dimensional tensor, group differences in fiber structure were more powerfully detected than with DTI-derived scalar statistics.

Methods:
We collected DTI data for 12 early blind but otherwise healthy subjects, and 14 age-matched sighted controls (mean age: 34.5+ 10.0 yrs) on Siemens (Avanto) 1.5 T scanner. T1-weighted and DTI images were linearly registered to the standardized Colin27 brain template using a 9-parameter registration (3 rotations, 3 translations and 3 scales), and nonlinearly aligned to a common space using fluid registration.

We mapped group differences for three scalar measures: the fractional and geodesic anisotropy (FA, GA), the mean diffusivity (MD), and 2 multivariate measures: the full tensor and the vector consisting of its 3 eigenvalues. GA is the anisotropy in the "Log-Euclidean" metric, $GA(S) = \sqrt{\frac{1}{6}\sum_{i<j}(\log S - \log S)^2}$ [2]. We applied permutation-based Student's *t-tests* to assess group differences. The warped multivariate tensors were rotated to preserve the coherence of the principal eigenvector field. A Riemannian manifold version of Hotelling's T^2 test was applied to the matrix logarithms of the tensors (see [1,2] for details).

Results and Discussion:
Figures f, l, and r are significance maps based on Hotelling's T^2 statistic computed at each voxel from the matrix logarithm of the full diffusion tensor. **Figures e, k, and q** show Hotelling's T^2 statistic computed on the logarithmically transformed diagonal matrix of the eigenvalues. Significance maps based on Student's *t-tests* on the scalar measures, FA, GA, tGA and MD are shown in **Figures a-d, g-j** and **m-p**.

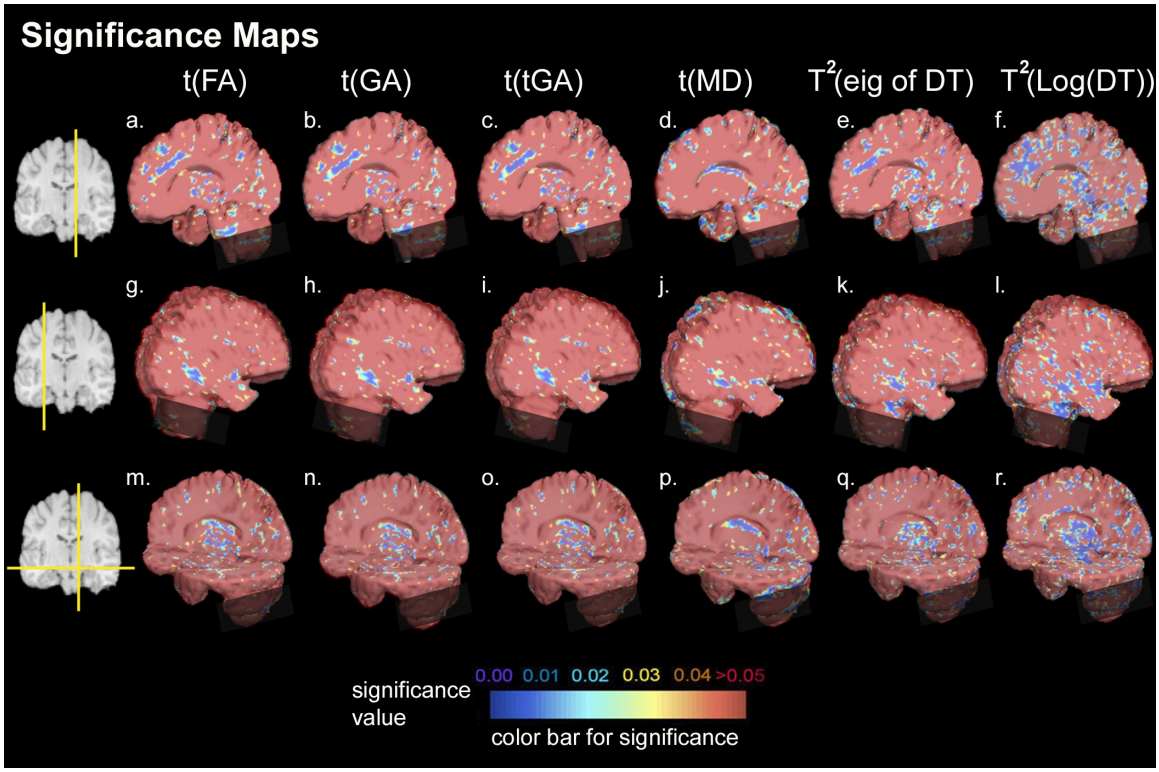
Group differences between blind and sighted subjects were apparent in broadly distributed brain regions. The full tensor statistic was most sensitive for detecting

differences between populations after a multiple comparisons correction (p=0.0005). For all measures, blind subjects exhibited deficits in occipital brain regions that house the primary and secondary visual cortices, in Meyer's loop and in the thalamostriate pathways fundamental to normal visual processing. These pathways are likely impaired in blind subjects, either due to developmental delay, or due to active dendritic pruning and myelin reduction in the absence of stimulation. All measures were significantly lower for blind subjects in the *rostrum* and the *splenium* of the corpus callosum, which carries fibers innervating occipital and parietal cortices. In maps based on the full diffusion tensor, in addition to the regions found in univariate statistics, white matter innervating classical language areas such as Wernicke's and Broca's areas, broad frontal lobe regions, and some temporal and limbic areas differed in the blind versus sighted subjects.

References:

[1] Leporé, N., Brun, C., Chou, Y., Chiang, M.C., Dutton, R.A., Hayashi, K.M., Luders. E., Lopez, O.L., Aizenstein, H.J., Toga, A.W., Becker, J.T., Thompson, P.M. (2007), *Generalized tensor-based morphometry of HIV/AIDS using multivariate statistics on deformation tensors*, IEEE Transactions on Medical Imaging **27**(1): 129-141.

[2] Lee, A.D., Leporé, N., Barysheva, M., Brun, C., Chou, Y-Y., Madsen, S., McMahon, K.L., Zubicaray, G.I., Wright. M.J., Toga. A.W., Thompson, P.M. (2008), *Comparison of Fractional and Geodesic Anisotropy in Monozygotic and Dizygotic Twins from Diffusion Tensor Imaging*. IEEE International Symposium on Biomedical Imaging (ISBI2008). Paris, France, April 12-15, 2008: 943-946.


Significance Maps
t(FA)
t(GA)
t(tGA)
t(MD)
T2(eig of DT)
T2(Log(DT))
a.
b.
c.
d.
e.
f.
g.
h.
i.
j.
k.
l.
m.
n.
o.
p.
q.
r.
significance value
0.00 0.01 0.02 0.03 0.04 >0.05
color bar for significance