Brain differences in early- and late- blind subjects mapped using tensor-based morphometry

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INTRODUCTION: The central nervous system is remarkably adaptive to environmental demands. In blind subjects, in particular, the brain is functionally reorganized in the absence of visual input. However, few studies have examined anatomical correlates of blindness. Here we present fully 3D maps of brain anatomical differences in early- and late-blind subjects versus sighted subjects, detected using tensor-based morphometry. We hypothesized that non-visual structures would be expanded in the blind, with a greater relative expansion in those who were blind from an early age of onset.

METHOD: T1-weighted 3D MRI scans were obtained for 3 groups of subjects, consisting of: 16 early-onset blind individuals (EB; loss of vision < 5 years old; median age 36.0 years; 10 men, 6 women), and 16 late-onset blind subjects (LB; loss of vision > 14 years of age; median age 36.5 years; 10 men, 6 women), and healthy matched sighted controls. Brain images were linearly aligned (3 translations, 3 rotations and 3 scales) to the ICBM-53 brain template, and extracerebral tissues were removed. Each 3D whole brain image was non-linearly aligned to an anatomical template using a 3D fluid registration [1]. The determinant of the local Jacobian matrix J expresses the local volume differences between each subject and the target image. To adjust for age and sex effects, we first covaried the logarithms of the determinants at each voxel with these variables, using the general linear model:

$$Log(J) = \beta_0 + \beta_1 * age + \beta_2 * sex + \beta_3 * diagnosis + error, \qquad (1)$$

where the β_i are estimated regression coefficients at that specific voxel. Sex and diagnosis were coded as binary dummy variables (0 or 1). A Student's t-test was then performed at each voxel, and permutation statistics were obtained at each voxel to assess the significance of the differences in each blind subject group versus controls.

RESULTS AND DISCUSSION: The left column shows structural differences (both excesses and deficits). Occipital brain regions show highly significant volumetric deficits associated with blindness for the EB (top row) and LB (bottom row) groups, after adjusting for individual differences in brain scale. The

middle and rightmost columns show the significance of volume excesses for the EB versus sighted subjects (top row) and for the LB versus sighted subjects (bottom row) for the unscaled data (i.e., in data not adjusted for inter-individual differences in overall brain scale). Anatomical differences between groups reveal profound deficits of up to 30% in primary and secondary visual cortices for both blind groups. Regions outside the occipital lobe showed significant hypertrophy, particularly in the frontal lobes and the cerebellum, suggesting widespread compensatory adaptations. We used the same voxelwise statistical method to compare the EB group to the LBs. The differences between the two blind groups were not statistically significant.

References

1. N. Leporé, Y-Y. Chou, O.L. Lopez, H.J. Aizenstein, J.T. Becker, A.W. Toga, P.M. Thompson, *Fast 3D Fluid Registration of Brain Magnetic Resonance Images*, Proceedings, SPIE conference on Physiology, Function and Structure from Medical Images, San Diego, CA, February 16 - 21 (2008).