Analysis of Growth Trajectory through Multi-modal Longitudinal MR Imaging

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Introduction

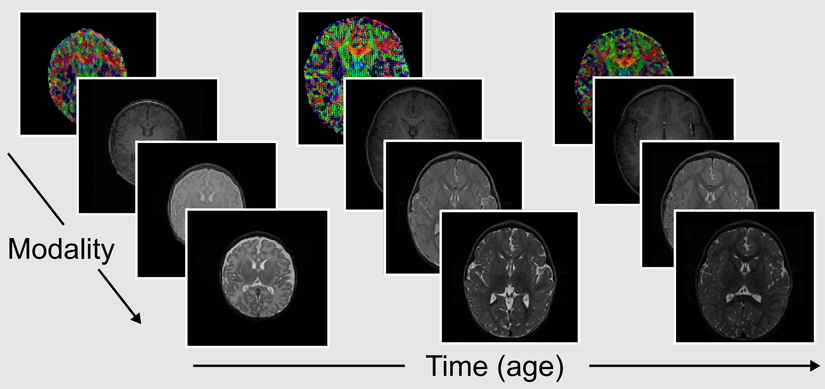
The human brain undergoes significant changes in the first few yeas after birth, but knowledge about this critical period is quite limited. Brain growth analysis can be described by volume, size measurements, and by contrast changes as is reflected in patterns observed in multi-modal structural MRI and DTI. In this study we focus on longitudinal tissue property changes as is reflected in structural MRI and DTI. Our preliminary study includes eight healthy pediatric subjects with repeated scans at the age of two weeks, one year, and two years with T1, T2, PD, and DT MRI.

The objective is to gain a better understanding of neurodevelopment through longitudinal multi-modal analysis of DTI and MRI as is observed in neonates, 1-year, and 2-year olds.

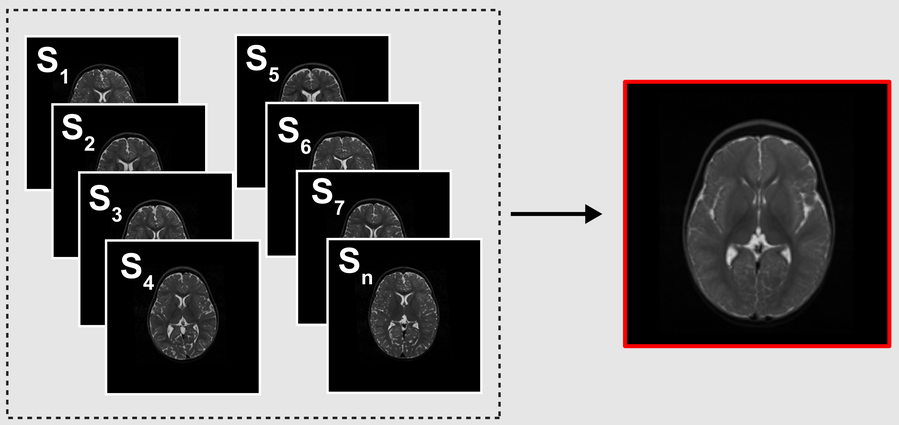
Methods

Image analysis of this dataset and this age group presents multiple challenges including scale of developmental changes involved, contrast changes attributed to myelination, multiple modalities, multiple time points, and variability among subjects. The following figure shows longitudinal images of one subject as is reflected in different modalities.

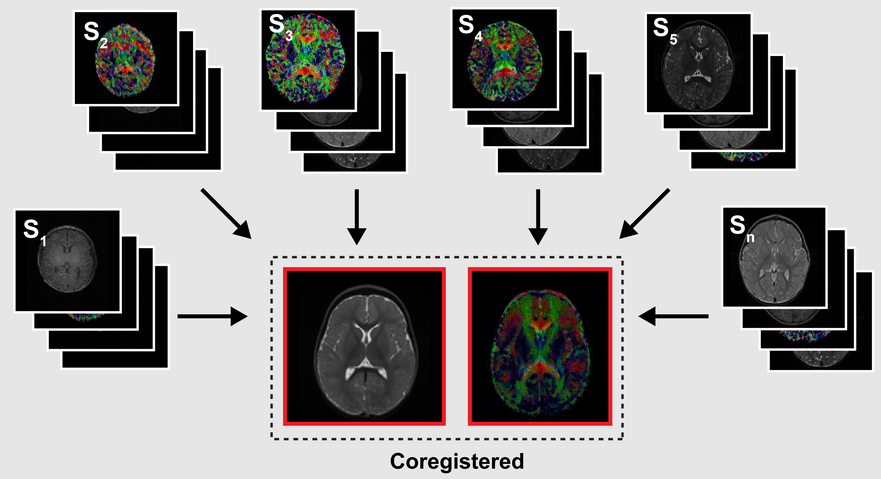
Multi-modal longitudinal images of ***one*** subject (s_1)



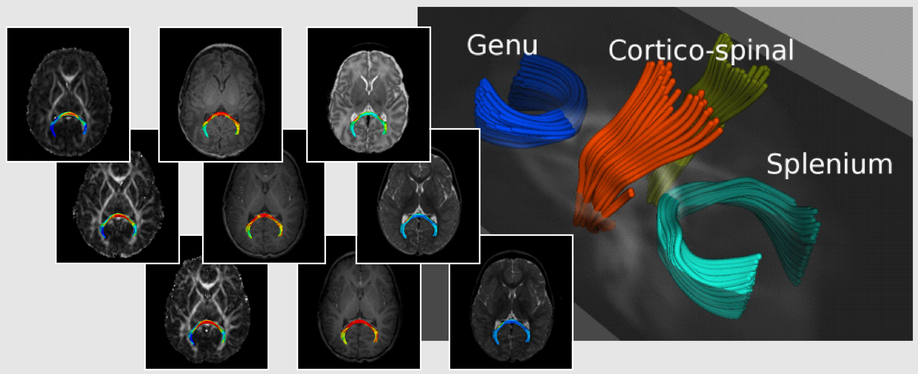
Population analysis of ***several*** subjects ($s_{1...n}$)



Coregistration of modalities, time (age), and subjects



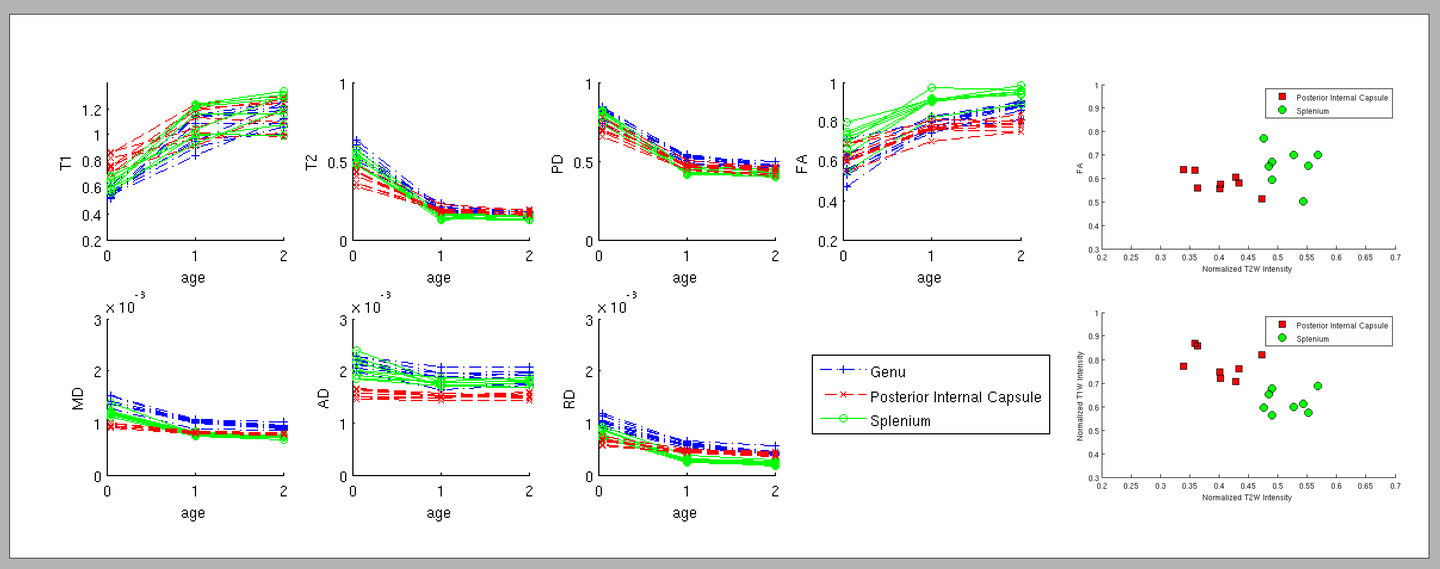
Quantitative Analysis of Fiber Tracts



Results

We analyzed changes of central regions of splenium and genu which are unmyelinated at birth, and posterior region of internal capsule which is myelinated at birth. The following figure shows growth trajectories of specific locations along the fiber tracts for the subjects in the study. Different locations show different growth trajectories. Also, each modality has a different discriminative power. We observed changes related to age such as decrease in MD, T2, PD, AD, RD, and increase in T1 and FA as is shown in the left figure below.

The right figure below shows an interesting finding obtained through quantitative analysis of regions of interest of specific tracts extracted through tractography where increased FA isn't always correlated with increased myelination. It is known that the splenium at birth is not myelinated, but the posterior internal capsule shows a high degree of myelination. The FA values appear to be more related to the structure and organization of fiber tracts than to the amount of myelin, and as a result studying FA alone can have misleading results. Multivariate analysis separates tracts with different degree of myelination.



Conclusion

Our results suggest that we need a multi-modal framework with both structural imaging and diffusion imaging to better understand parameters related to tissue properties such as myelination, axon density changes and water density. Such a description will complement a characterization of brain morphometry changes and will potentially lead to an improved understanding of the trajectory of early brain maturation. Our proposed registration and analysis framework for multi-modal MRI also includes spatial mappings that encode growth as spatial changes, and this information can be integrated in our framework for future work. We are also currently working on using data reduction techniques such as principal component analysis to reduce the dimensionality of the data, and look for patterns of growth that may repeat through out time and different regions of brain.

References

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