Mapping Changes in White Matter Microstructure throughout Development

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Introduction

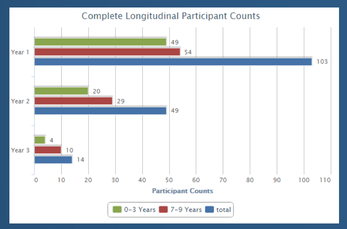
Developmental neuroimaging has shown that (1) cortical thickness decreases with age, due to pruning of unnecessary connections and (2) white matter integrity increases with age, as reflected by fractional anisotropy (FA). While these methods are sensitive to changes in structure, they are non-specific.

In this study, I am mapping the longitudinal development of infants, children, and adolescents using a combination of NODDI (neurite orientation dispersion and density imaging), a multi-shell diffusion imaging (dMRI) technique to model changes in tissue microstructural parameters with age.

Methods

Participants

- Imaging and behavioral data comes from the C-MIND (Cincinnati MRI Imaging of Neurodevelopment) study
- Participants range in age 0 through 18
- Longitudinal data – up to 3 time points



MRI Scan Parameters

- For multi-shell imaging, 2 dMRI acquisition protocols were performed. Voxel size: 2mm x 2mm x 2mm; 60 slices; 7 b0 images; 112x109 acquisition matrix; 61 directions
- Scan 1: b = 1000 s/mm^2
- Scan 2: b = 3000 s/mm^2

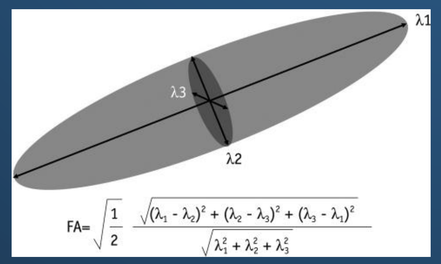
Modeling White Matter

Diffusion tensor imaging (DTI), which provides sensitivity to changes in white matter.

- Output parameter: fractional anisotropy (FA), which measures white matter integrity

NODDI, which provides specific information on neurite orientation and density.

- Output parameters: orientation dispersion index (ODI) and intracellular volume fraction (ICVF), which describes neurite density



Results

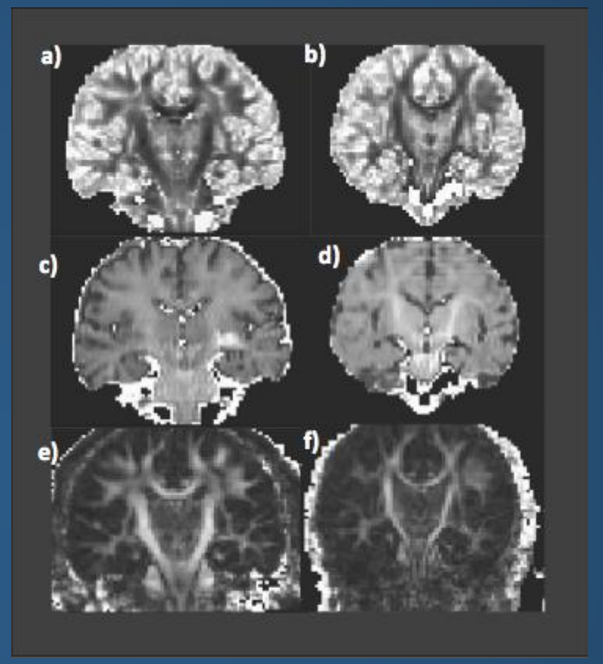


Figure 1. Image shows comparisons in structure between a 18-year old participant (a, c, e) and a 3-month old participant (b, d, f). Figures 1a and 1b show the ODI where brighter areas refer to more neurite dispersion. Note increased neurite dispersion in the gray matter and decreased dispersion in the white matter. Figures 1c and 1d show the ICVF. Figures 1e and 1f show FA values with bright areas corresponding to increased FA. Note the increased FA in the 18 year old (1e) compared with the 3-month year old (1f).

Future aims will attempt to characterize:

(1) Change of ODI, ICVF, and FA over time
(2) Relationship between FA, ODI, and ICVF
(3) How FA, ODI, and ICVF are different in developmental disabilities

Discussion

Experience-dependent specialization during critical developmental periods leads to structural remodeling of tissue through axonal and synaptic sprouting, synaptogenesis, and changes in myelin formation (Figure 2; Jacobs et al, 1997). Direct measurements of these features would provide much greater insight into mechanisms governing these developmental changes.

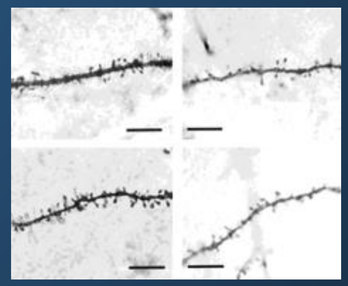


Figure 2. (Jacobs et al, 1997) shows changes in dendritic complexity are sensitive to age. Left shows more complex dendrites of an adolescent and right shows less complex dendrites with age.

References

1. Cincinnati MR Imaging of Neurodevelopment (C-MIND) 2014 https://research.cchmc.org/c-mind/
2. Jacobs B, Driscoll L & Schall M 1997 Life-span dendritic and spine changes in areas 10 and 18 of human cortex: a quantitative Golgi study. J Comp Neurol., 386(4):661-80.

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