Densely Mapping Cortical Micro-architecture Properties of the Developing Brain

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Summary

- Problem:
  - Dynamic and heterogeneous brain structural changes during the first two years of life [1].
  - Knowledge on cortical changes is scarce.
- Approach: Using **SMSI** [2] on longitudinal baby brain data to probe tissue microstructure:
  - Intra-cellular volume fraction (ICVF)
  - Microscopic anisotropy index (MAI)
  - Orientation coherence index (OCI)
  - Intra-soma volume fraction (ISVF)
- Results: During brain maturation
  - MAI and ICVF **increase globally** but in **spatially heterogeneous patterns**.
  - ISVF shows **distinct** developmental trend with spatial patterns resembling the adult brain at 2 years of age.
  - Spatially, OCI **varies more** than MAI and ICVF, indicating **heterogeneity** in axonal configurations in the cortex.

Experiments

- Structural and diffusional MRI data of 126 healthy subjects [3]
  - Age at scan ranging from 20 to 751 days; 52 males, 74 females.
  - Structural data: T1w and T2w, 0.8 mm isotropic resolution.
  - Diffusion data: 6 b-shells of 500, 1000, 1500, 2500, 3000 s/mm^2, 1.5 mm isotropic resolution.
- Individual and common template surfaces were generated from T1w/T2w.
- Tissue diffusion indices were mapped to individual surfaces then transferred to a common template [4].
- For each vertex, the developmental trajectories of the indices were determined using a General Additive Mixed Model (GAMM).

Results

- Figure 1 and Figure 2 show the cortical ICVF, ISVF, MAI, and OCI every month during the first year and every three months during the second year.
- MAI and ICVF:
  - Increase globally but in spatially heterogeneous patterns.
  - Somatosensory, auditory, and visual cortices, which correspond to primary functions, mature earlier.
  - Frontal cortex, which correspond to higher cognitive functions, develop later.
- ISVF:
  - Distinct developmental trend.
  - Higher values in the posterior and the premotor areas, language comprehension area, and ventral attention network.
  - Resembling the adult brain at two years of age.
- OCI:
  - Mostly increases with age.
  - Affected by the relative amounts of axons in tangential directions to axons in radial directions.
  - Indicates heterogeneity of axonal configurations in the cortex.

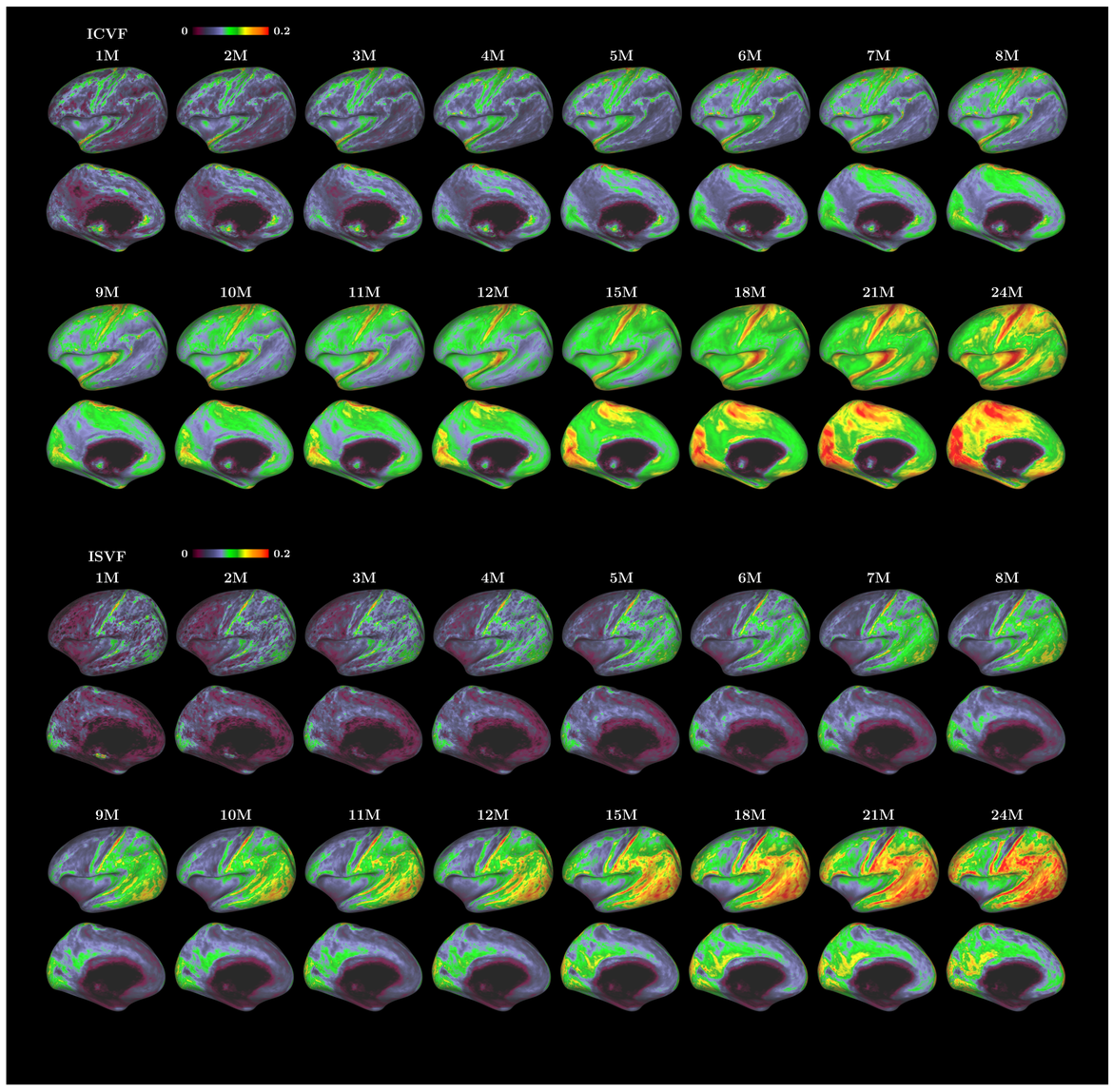

Figure 1: Lateral and medial views of cortical ICVF and ISVF every month during the first year and every three months during the second year.

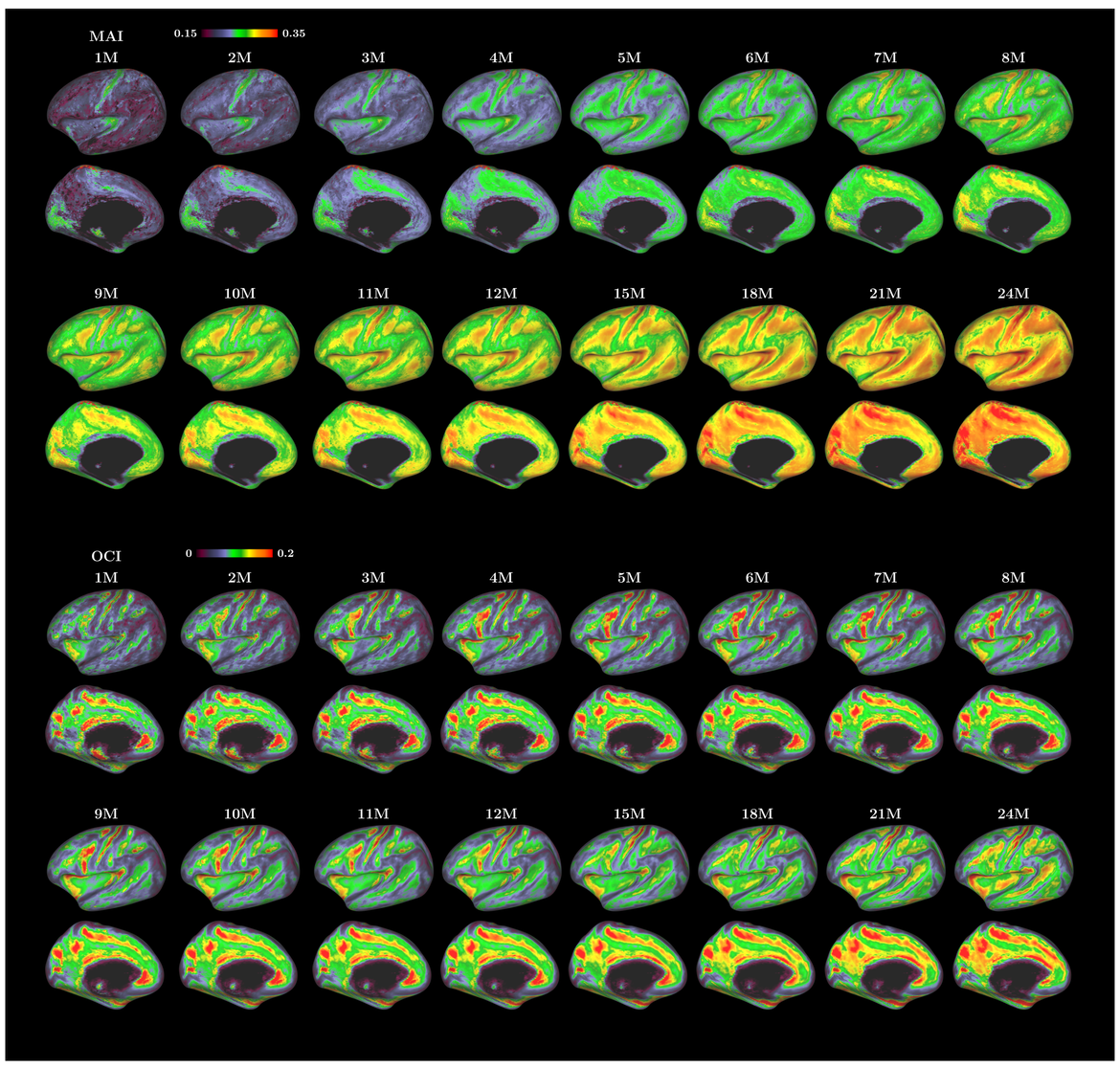

Figure 2: Lateral and medial views of cortical MAI and OCI every month during the first year and every three months during the second year.

Conclusions

- We have presented a dense temporal mapping of brain cortical microstructure from birth to two years of age.
- Although the results suggest that myelination increases globally with time, the spatial patterns are significantly heterogeneous, revealing complex developments in myeloarchitecture and cytoarchitecture.

Acknowledgments

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