Exploring the Gyral Bias on White Matter Tractography in Neonates

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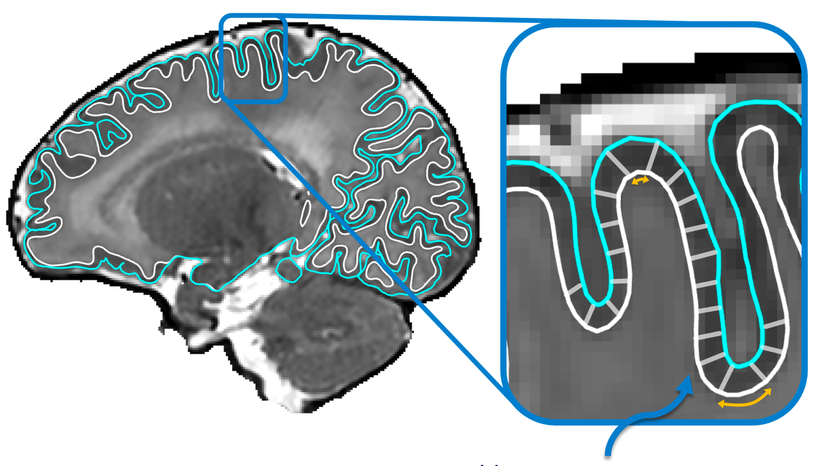
scan for abstract

What is the gyral bias in tractography?

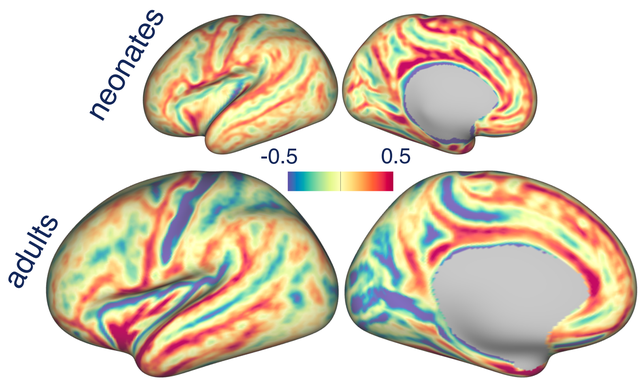
When tracking towards the cortex, tractography streamlines terminate preferentially at gyral crowns rather than the gyral walls or sulcal fundi [1,2]. This tendency is called the gyral bias. Some of the bias is neuroanatomically justifiable and can be predicted using cortical geometric features [3]. However, previous work has indicated that the gyral bias in tractography exceeds the predictions made from anatomy [1,3]. Here, we explore the effects of the gyral bias on tractography results in the neonatal brain, where gyrification is less developed. By comparing the results against adults, we also explore the impact of this effect on different tractography seeding strategies for generating connectomes.

Predicting the anatomical bias expected due to cortical folding



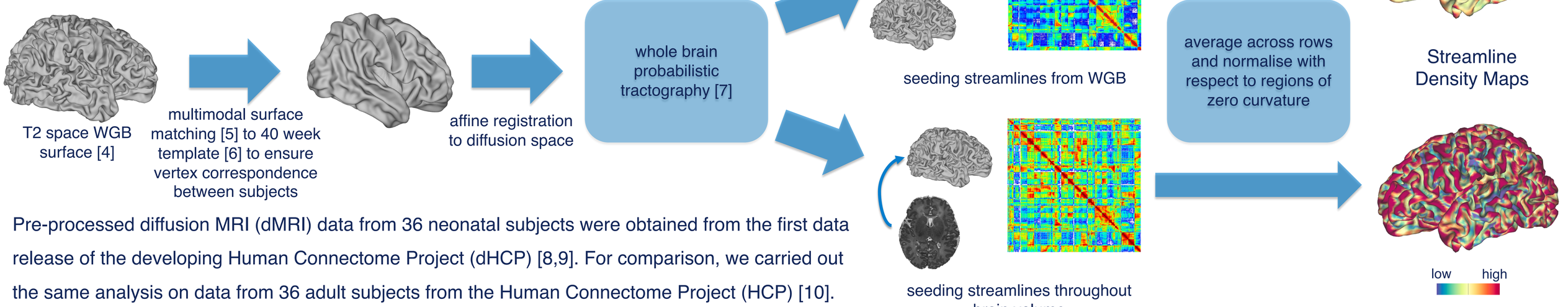
The cortex tends to be thicker along gyral crowns than sulcal fundi, and the curvature of the cortex means that a higher volume of cortical grey matter is subserved per unit area of the white matter-grey matter boundary (WGB) at the gyral crowns than at the sulcal fundi. Assuming a constant axonal density per unit cortical volume, we would therefore expect a higher density of axons terminating at the gyri than at the sulci [1]. We can empirically predict the fluctuations in axonal density due to this effect by calculating the cortical volume associated with each unit of surface area of the WGB [1,3]. Our results (right) show that we expect to see a greater contribution to streamline variability from this effect in adults, particularly in the sulci.

Log-scaled average predicted bias maps:



Generated using data from 36 neonates from the dHCP and 36 adults from the HCP. Maps have been normalised with respect to regions of zero curvature and log scaled.

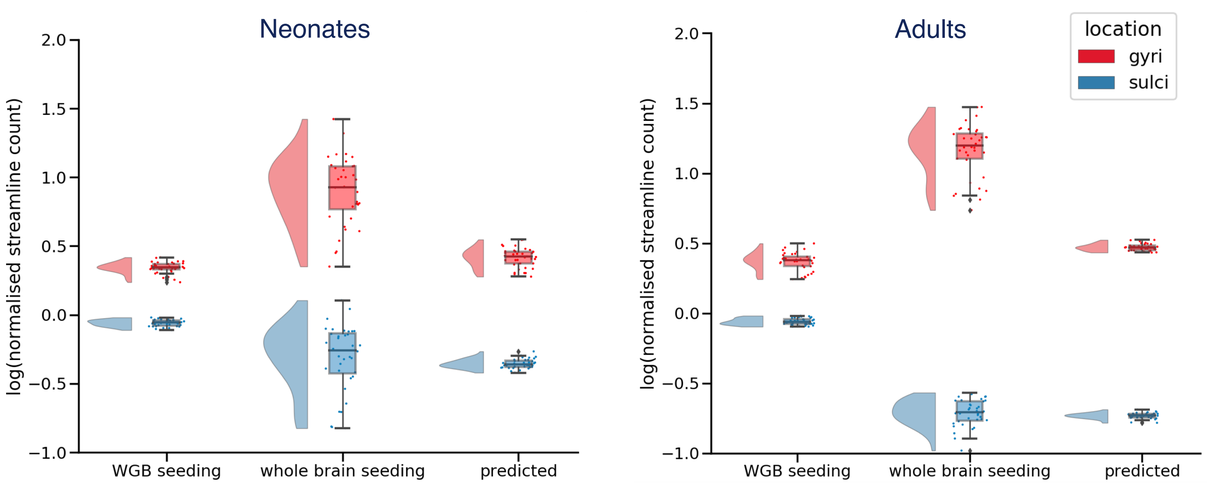
Measuring the tractography bias in neonates



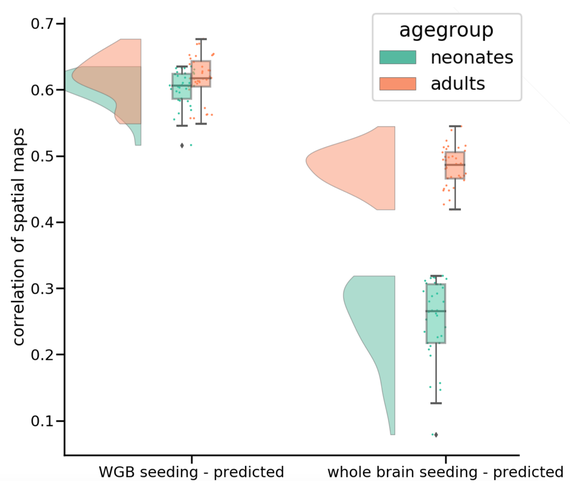
Pre-processed diffusion MRI (dMRI) data from 36 neonatal subjects were obtained from the first data release of the developing Human Connectome Project (dHCP) [8,9]. For comparison, we carried out the same analysis on data from 36 adult subjects from the Human Connectome Project (HCP) [10].

Results & Summary

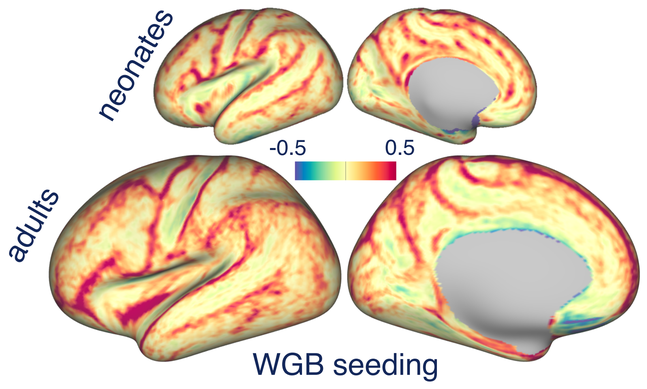
Comparison of streamline density between sulci and gyri

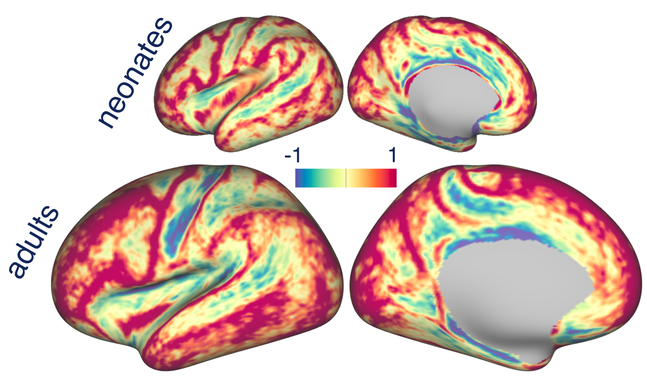


Spatial correlation between the predicted and tractography densities



Log-scaled average tractography streamline density maps:





- Whole-brain tractography seeding in neonates leads to an over-estimation of streamline terminations at the gyri, relative to predictions from anatomy. This is in agreement with previous work in adults [1,2].
- Seeding streamlines from the white – grey matter boundary leads to an overestimation of streamline terminations at the sulci
- The spatial patterns from WGB seeding were much more closely aligned with prediction than the maps from whole brain seeding.
- These effects are greater in adults, which is expected from their increased gyrification. Adults also have more developed superficial white matter systems, which have been shown to impede accurate detection of corticocortical connections with tractography [11].

Summary: the magnitude of the gyral bias in tractography is smaller in neonates than in adults. WGB seeding results in connectomes of the neonatal brain that have fewer confounds from the gyral bias than whole-brain seeding.

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References: **[1]** Van Essen et al. Diffusion MRI: From Quantitative Measurement to In vivo Neuroanatomy (2013). **[2]** Schilling et al. Human Brain Mapping (2017). **[3]** Donahue et al. Journal of Neuroscience (2016). **[4]** Makropoulos et al. Neuroimage (2018). **[5]** Robinson et al, Neuroimage (2018). **[6]** Božek et al. Neuroimage (2018). **[7]** Behrens et al. Neuroimage (2007). **[8]** Hughes et al, Magnetic Resonance in Medicine (2017). **[9]** Bastiani et al. Neuroimage (2018). **[10]** Van Essen et al. Neuroimage (2013). **[11]** Reveley et al. PNAS (2015)