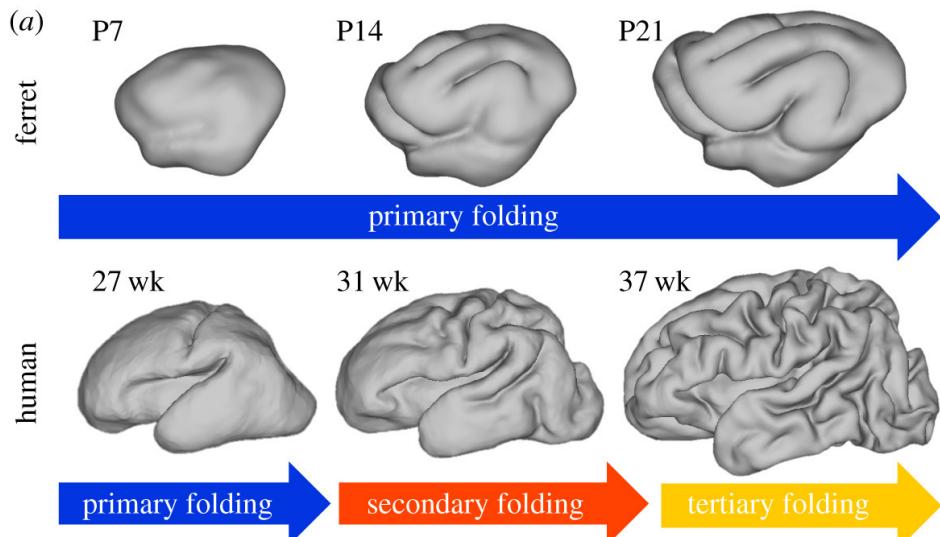
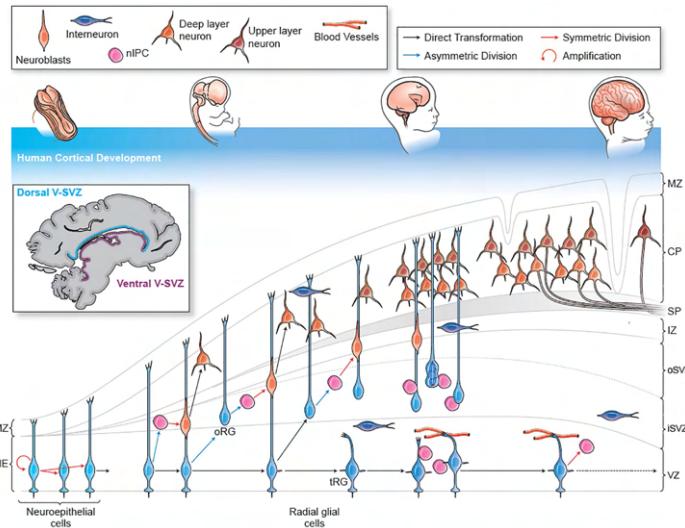


Differential Patterns of Cortical Expansion in Fetal and Preterm Brain Development



CORTICAL FOLDING

- Cortical folding is a critical process in brain development. In normal human fetal development, it occurs between the 15th and 40th weeks of gestation.

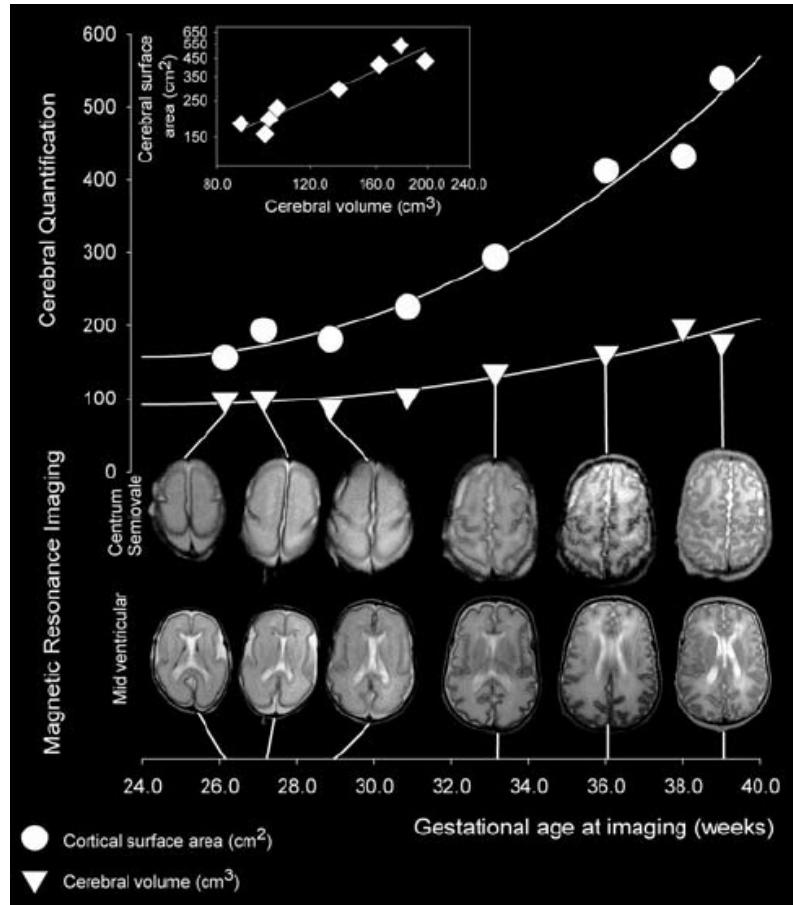


Subramanian, L., Calcagnotto, M.E., Paredes, M.F., 2020. Cortical Malformations: Lessons in Human Brain Development. *Frontiers in Cellular Neuroscience* 13.

Garcia, K.E. et al, 2018. Dynamic patterns of cortical expansion during folding of the preterm human brain. *Proceedings of the National Academy of Sciences* 115, 3156–3161.

CORTICAL FOLDING

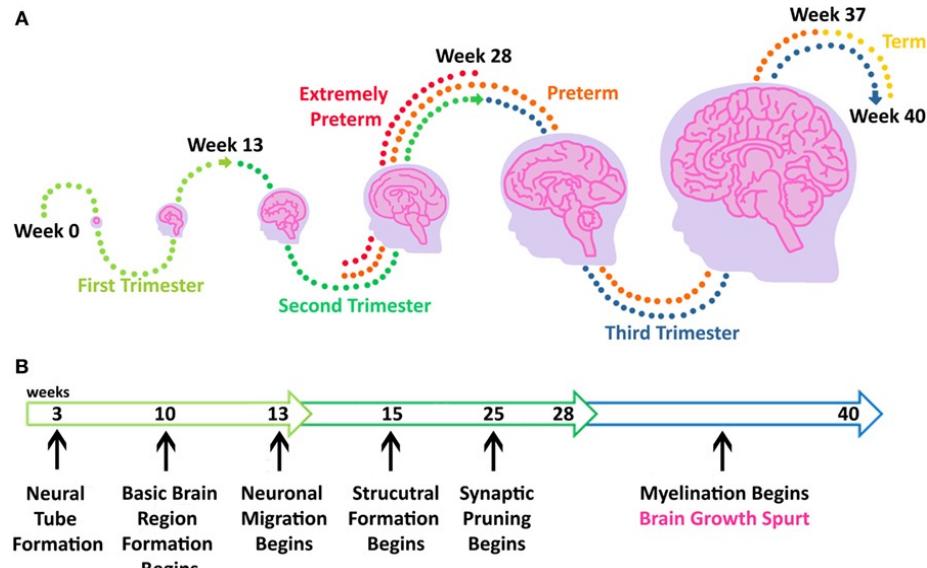
- The folded shape of the human brain allows the cerebral cortex to attain a large surface area relative to brain volume.
- From around the 25th week, the cortical surface area begins to grow much faster than the total brain volume, as the gyration process occurs.



Kapellou, O., et al, 2006. Abnormal Cortical Development after Premature Birth Shown by Altered Allometric Scaling of Brain Growth. PLOS Medicine 3, e265.

PRETERM BIRTH

- Preterm birth is defined as being born before 37 weeks gestational age (GA).
- Magnetic Resonance Imaging (MRI) studies have shown that preterm infants have altered cortical growth, expansion, folding and microstructure at term-equivalent age.
- The truncation of gestation due to preterm birth is associated with widespread alterations in cortical morphometry.



Newville J, Ortega M and Maxwell J (2018) Babies Born Early Can Have Brain Injury. *Front. Young Minds.* 6:20. doi: 10.3389/frym.2018.00020

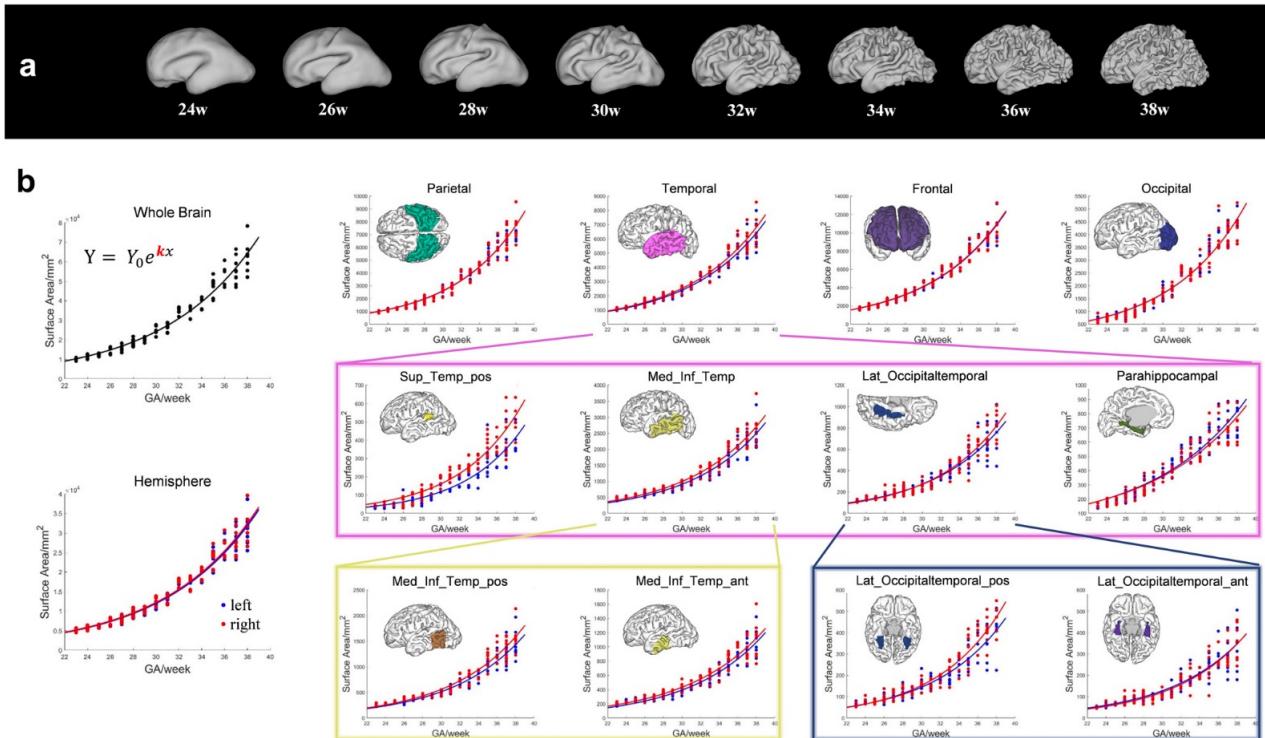
STUDIES ON FETAL CORTICAL EXPANSION

Preterm Data

Cross-sectional Fetal Data

Longitudinal Fetal Data

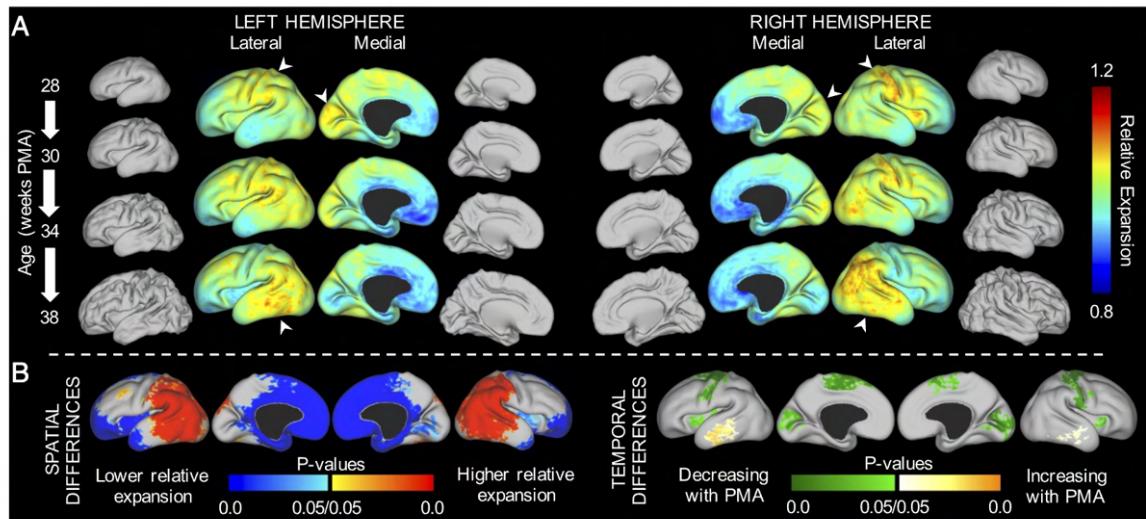
STUDIES ON FETAL CORTICAL EXPANSION



Xu, X., Sun, C., Sun, J., Shi, W., Shen, Y., Zhao, R., Luo, W., Li, M., Wang, G., Wu, D., 2022. Spatiotemporal Atlas of the Fetal Brain Depicts Cortical Developmental Gradient. *J. Neurosci.* 42, 9435–9449. <https://doi.org/10.1523/JNEUROSCI.1285-22.2022>

DYNAMIC PATTERNS OF CORTICAL EXPANSION DURING FOLDING OF THE PRETERM HUMAN BRAIN (GARCIA ET AL, 2018)

- Continuous patterns of surface expansion following preterm birth were computed using longitudinal surface registration with biomechanical constraints.
- Patterns were shown to differ to some ROI-based analysis, due to the use of very large regions in previous studies.
- In ROI analysis, finer differential patterns can be incorrectly averaged-out.



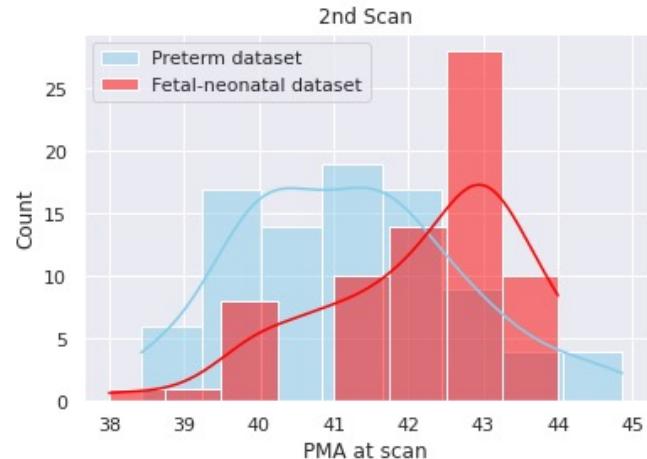
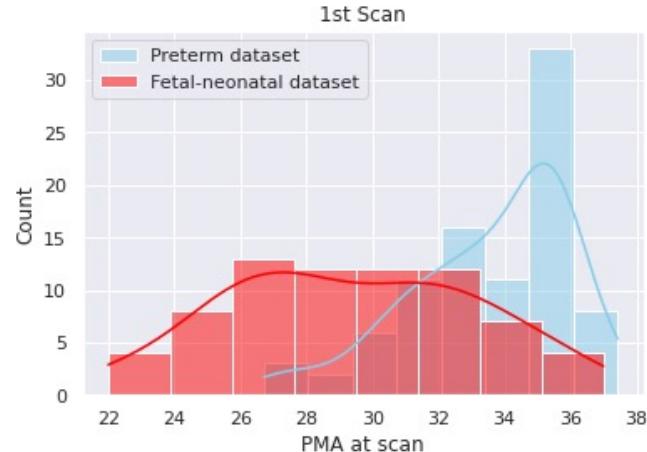
DATASET - dHCP

- 72 subjects born at term (38 to 42 weeks)

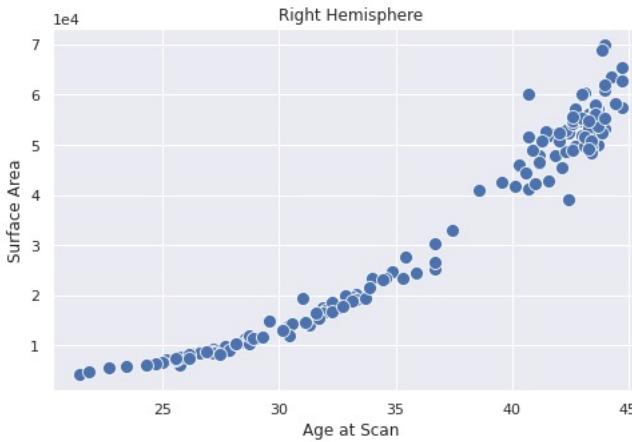
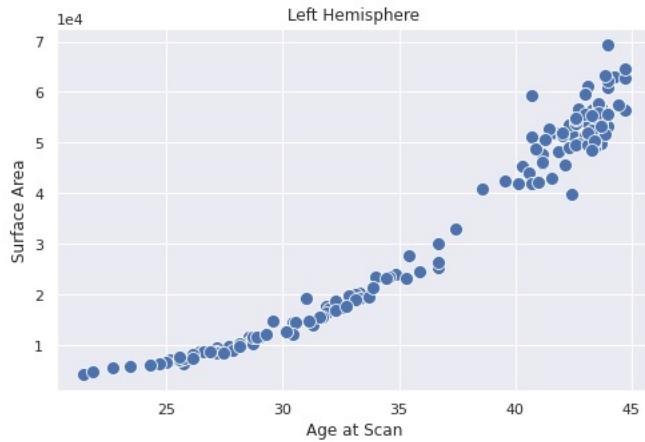
1. scanned in utero
2. and shortly after birth

- 90 subjects born preterm (26 to 37 weeks)

1. scanned shortly after birth
2. and at term-equivalent age

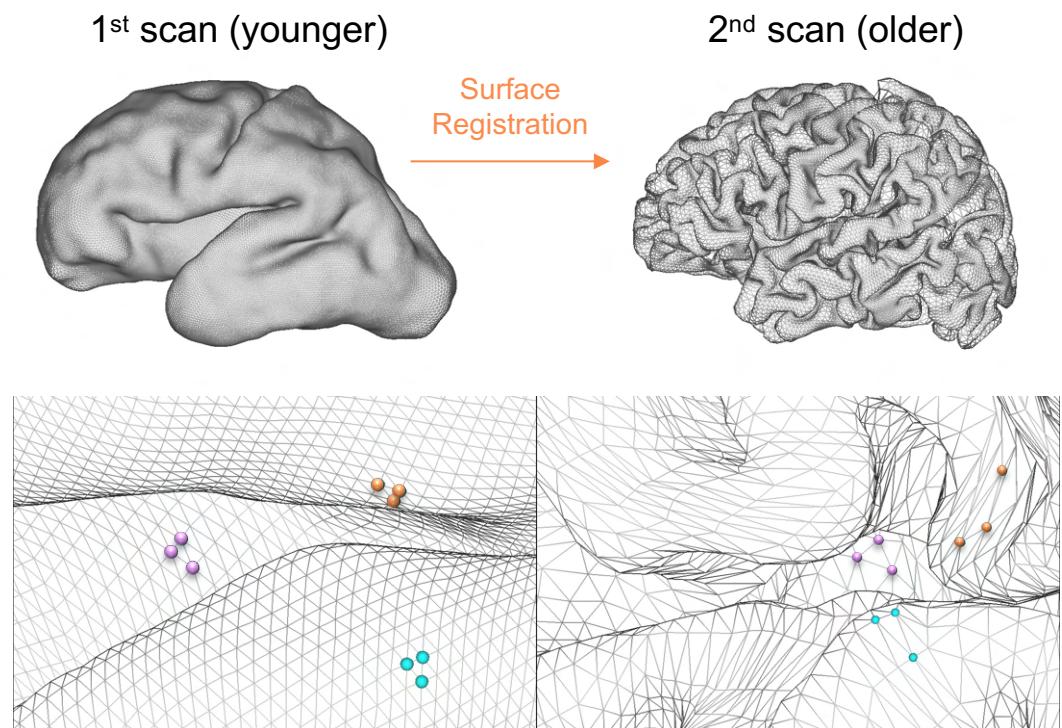


INITIAL ANALYSIS: SURFACE AREA

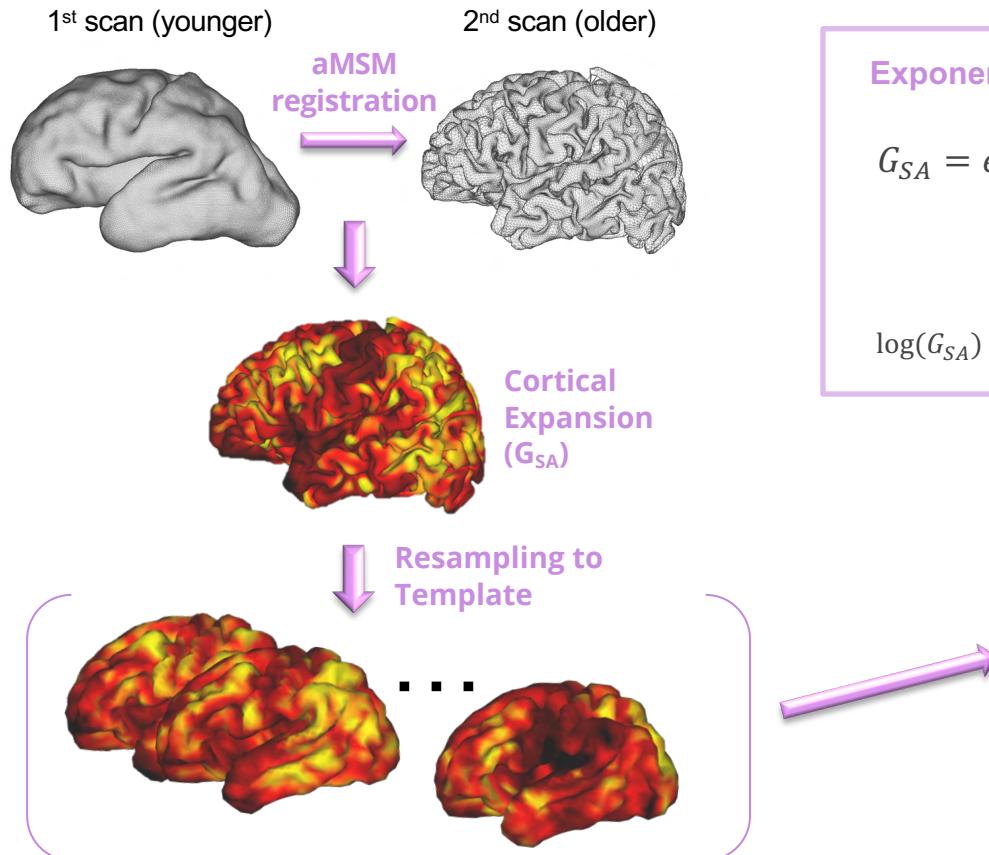


SURFACE REGISTRATION WITH aMSM

- Longitudinal registration of the 1st to 2nd scan was performed using anatomically Constrained Multimodal Surface Matching
- Cortical expansion corresponds to J between input surface and registered surface, i.e. local area difference for each mesh element, between input and registered scan



ESTIMATION AND ANALYSIS OF CORTICAL EXPANSION

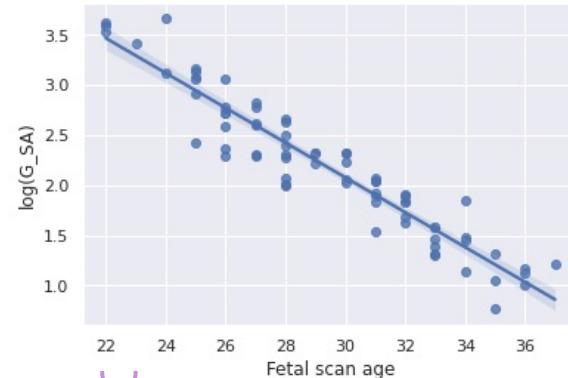


Exponential model of growth

$$G_{SA} = e^{k_0 - k_1 age_{fetal} + k_2 age_{neonatal}}$$

Rate of growth Fixed age_{neonatal}

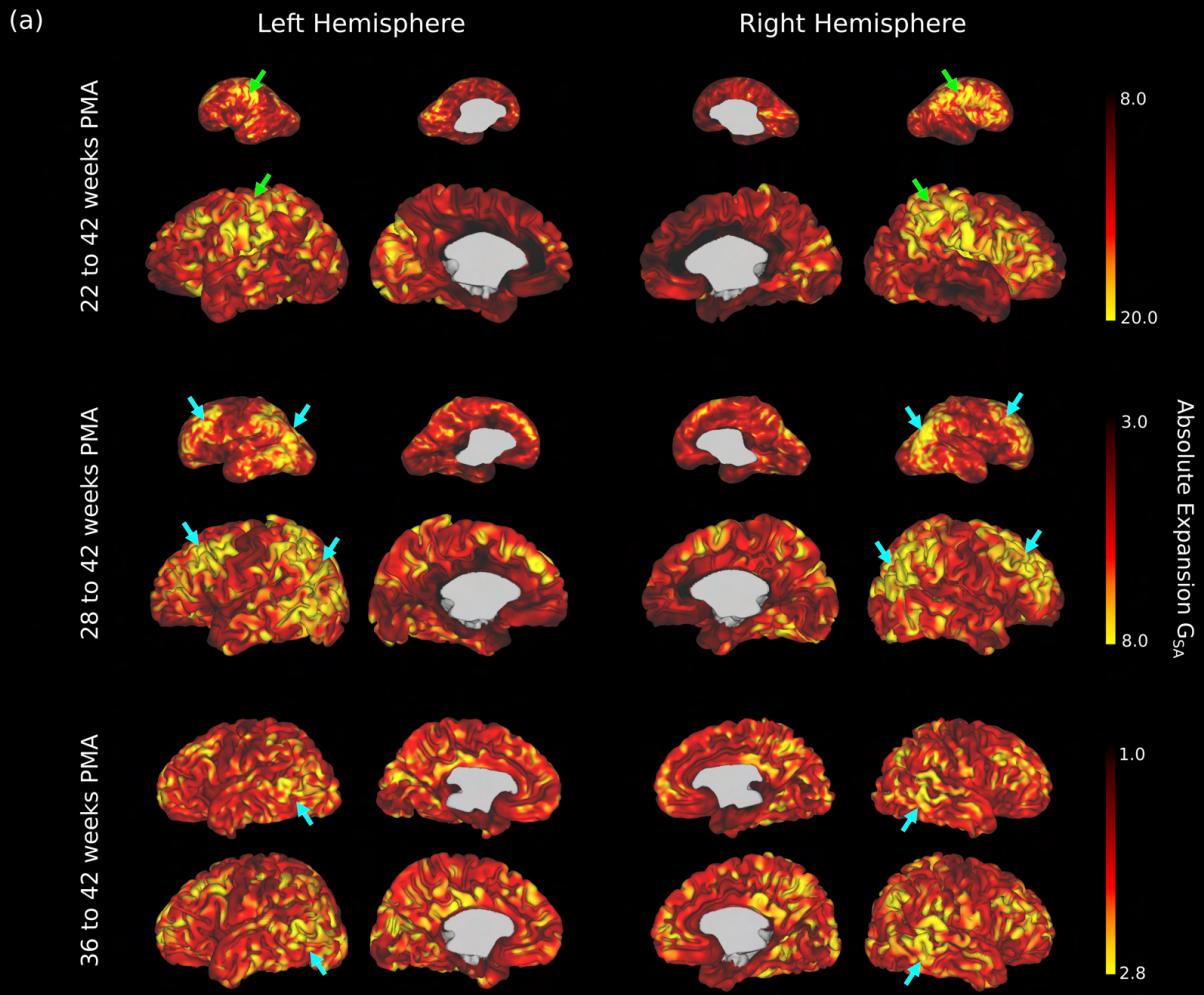
$$\log(G_{SA}) = \log(k_0) - k_1 age_{fetal} + k_2 age_{neonatal}$$



$$\log(G_{SA} 22 \rightarrow 23) = \log(G_{SA} 22 \rightarrow 40) - \log(G_{SA} 23 \rightarrow 40)$$

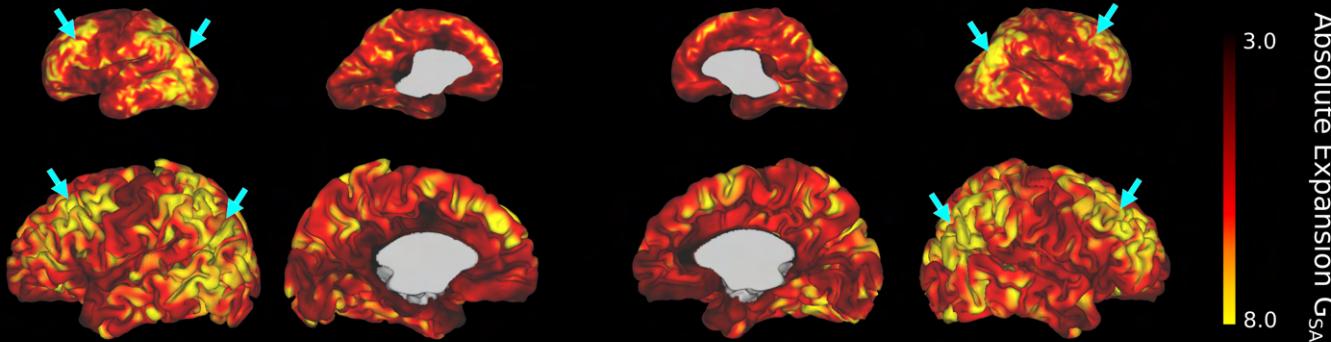
RESULTS

- Absolute cortical surface expansion maps (G_{SA}) for 3 individual pairs of surfaces, visualized in both the first and second scan.



Fetal-neonatal

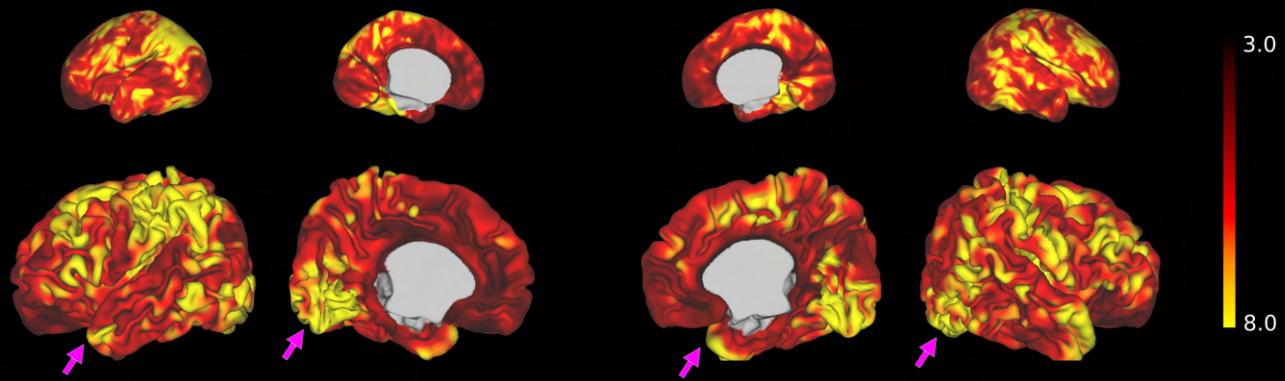
28 to 42 weeks PMA



Absolute Expansion G_{SA}

Preterm

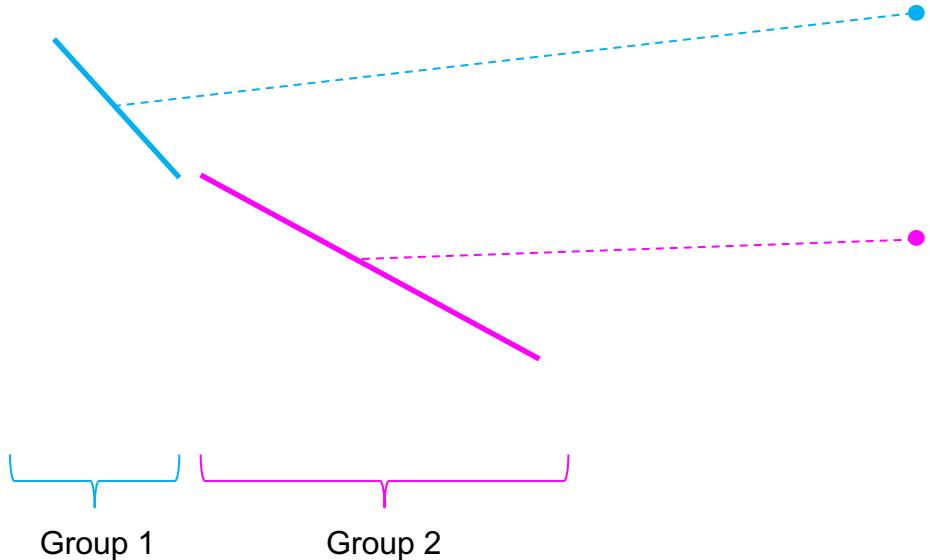
28 to 42 weeks PMA



Absolute Expansion G_{SA}

CORTICAL EXPANSION RATES

$$\log(G_{SA}) = \log(k_0) - k_1 age_{fetal}$$



t-test: k_1 Group 1 > k_1 Group 2

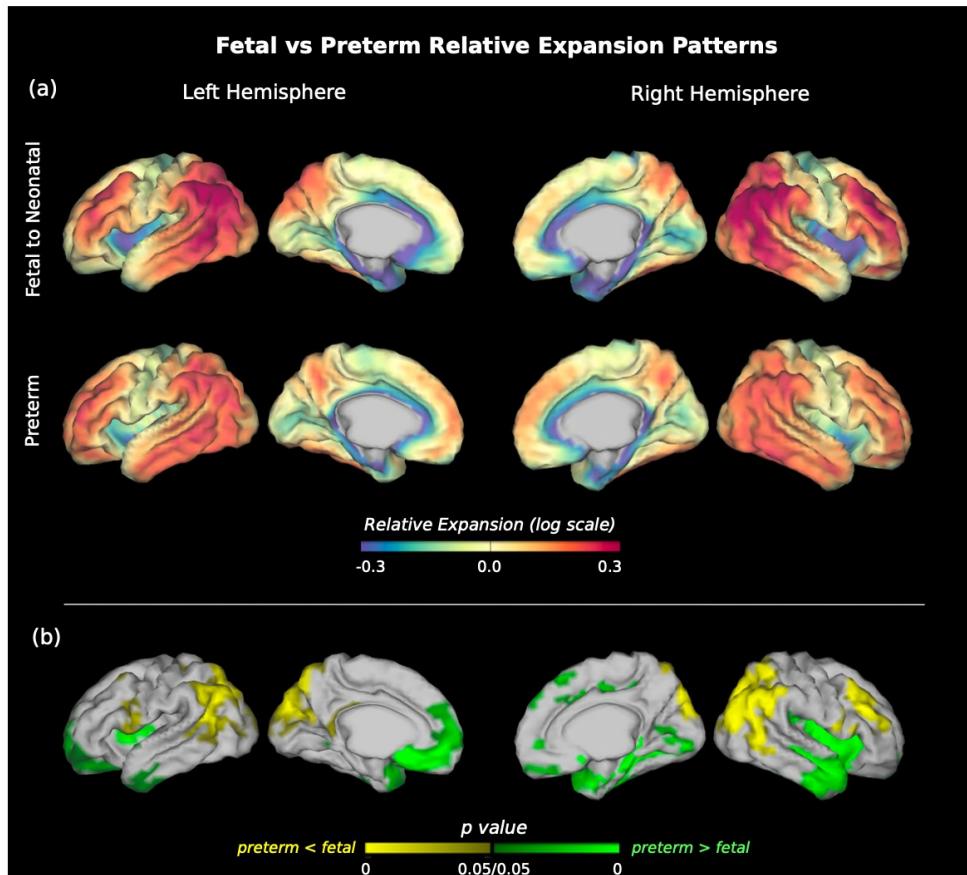
COMPARISON WITH PRETERM DATASET

- Relative expansion maps (normalised by global growth) reveal different regional patterns between fetal and preterm development, for the same scan ages.
- Preterm neonates exhibit higher relative expansion in the temporal and frontal poles and insula, while fetal relative expansion was higher for the posterolateral parietal cortex.



t-test: Relative G_{SA} Preterm > Relative G_{SA} Fetal

t-test: Relative G_{SA} Preterm < Relative G_{SA} Fetal

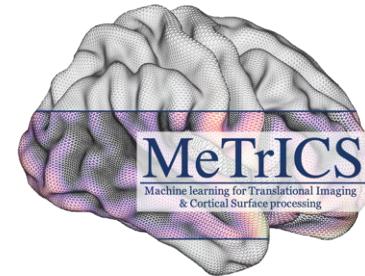


ACKNOWLEDGEMENTS

- Emma Robinson, King's College London, UK
- Jorge Cardoso, King's College London, UK
- Kara Garcia, Indiana University, USA
- Logan Williams, King's College London, UK
- Vanessa Kyriakopoulou, King's College London, UK
- Anderson M. Winkler, National Institute of Mental Health, Maryland, USA



Engineering and
Physical Sciences
Research Council



...and the entire MeTrICS Lab!

