PNAS

Supplementary Information for
Adolescent development of multiscale structural wiring and functional interactions in the human connectome.

Bo-yong Park, Casey Paquola, Richard A. I. Bethlehem, Oualid Benkarim, Neuroscience in Psychiatry Network (NSPN) Consortium, Bratislav Mišić, Jonathan Smallwood, Edward T. Bullmore, Boris C. Bernhardt

[†]*A complete list of investigators from the Neuroscience in Psychiatry Network (NSPN) Consortium can be found in the Supporting Information.*

Bo-yong Park
Email: boyong.park@inha.ac.kr
Boris C. Bernhardt
Email: boris.bernhardt@mcgill.ca

This PDF file includes:

Figures S1 to S12

Other supplementary materials for this manuscript include the following:

Neuroscience in Psychiatry Network (NSPN) Consortium author list

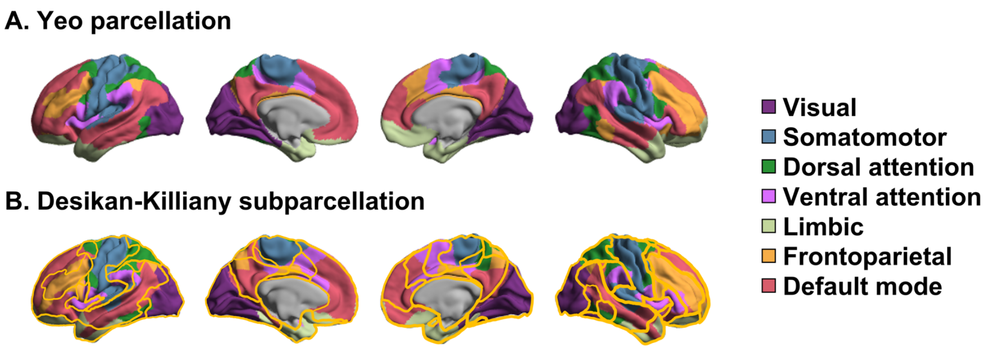

Fig. S1. Remapping of the Yeo-7 parcellation to the subparcellation of the Desikan-Killiany atlas used for this study. (A) Intrinsic functional networks based on Yeo, Krienen, et al. (1). **(B)** Parcels of the 200 node Desikan-Killiany subparcellation were assigned to each of these networks, and the boundaries of the Yeo 7-networks are shown with lines.

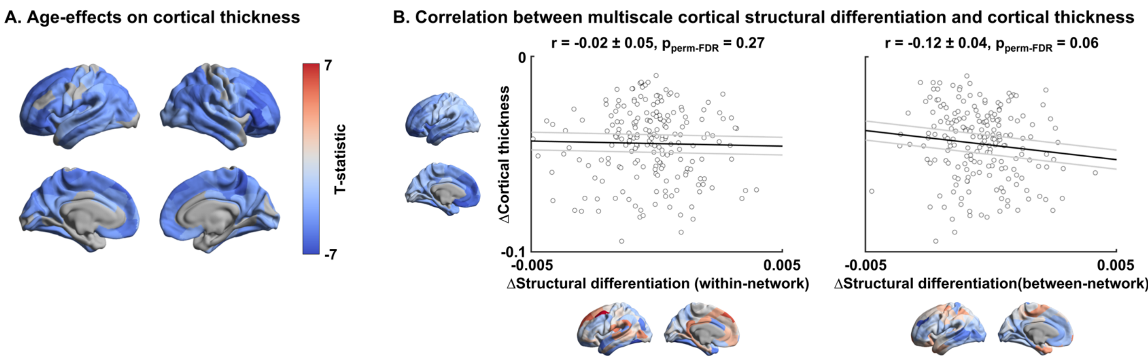

Fig. S2. Cortical thickness effects. (A) The t-statistics of the identified regions that showed significant age-related changes in cortical thickness. **(B)** Linear correlations between time-related changes in cortical thickness and within/between-network structural differentiation.

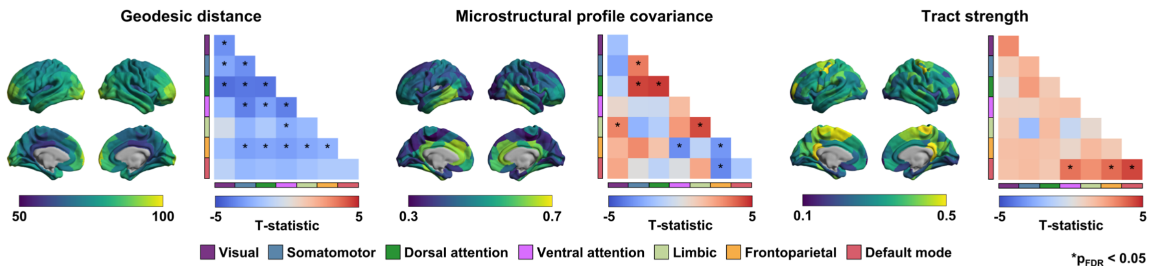

Fig. S3. Age-effects on each cortical wiring feature. The spatial maps of geodesic distance, microstructural profile covariance, and tract strength are shown on the brain surface. The t-statistics of age-related changes on each cortical feature within- and between-networks, with significant ($p_{FDR} < 0.05$) results marked with asterisks. *Abbreviation:* FDR, false discovery rate.

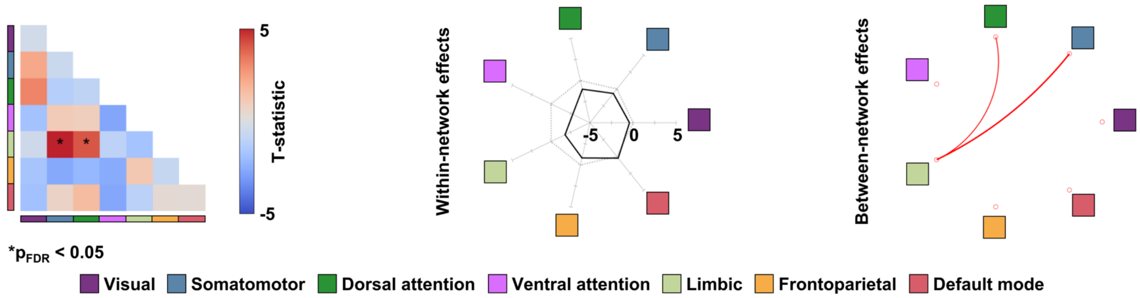

Fig. S4. Age-effects on multiscale cortical structural differentiation after controlling for mean structural differentiation. The t-statistics of age-effects are reported in the matrix, and within- and between-network effects are represented with radar and circular plots, respectively. For details, see *Fig. 1*.

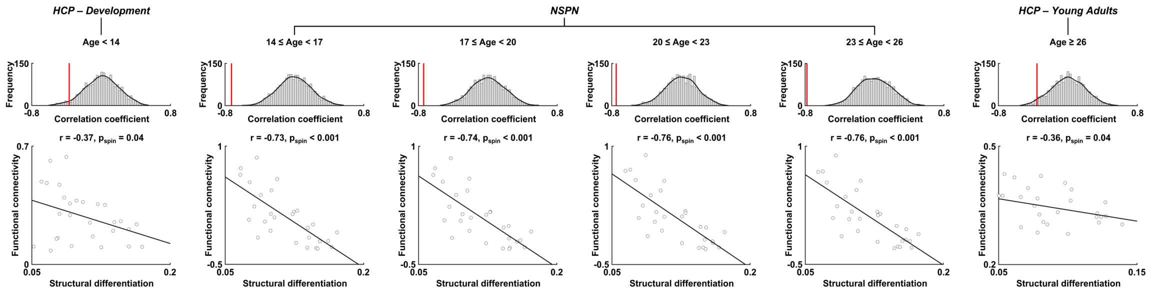

Fig. S5. Association between functional connectivity and structural differentiation during development. Cross-sectional structure-function coupling between functional connectivity and structural differentiation at different age bins. The histogram indicates a null distribution of correlation coefficients generated based on 1,000 spin tests, and the actual r-value is represented with a red bar.

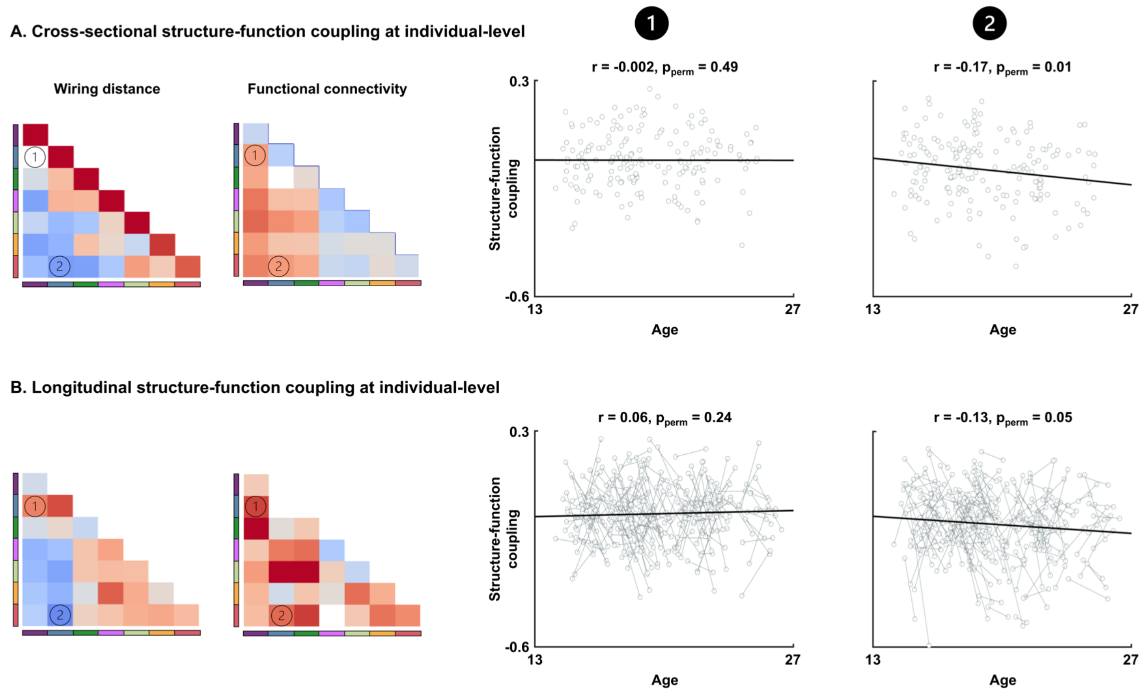

Fig. S6. Inter-individual differences in structure-function coupling. (A) The scatter plots show cross-sectional structure-function coupling between the connections that showed significant age-effects on both structural differentiation and functional connectivity, which are marked with 1 and 2. **(B)** We reported the results of longitudinal structure-function coupling.

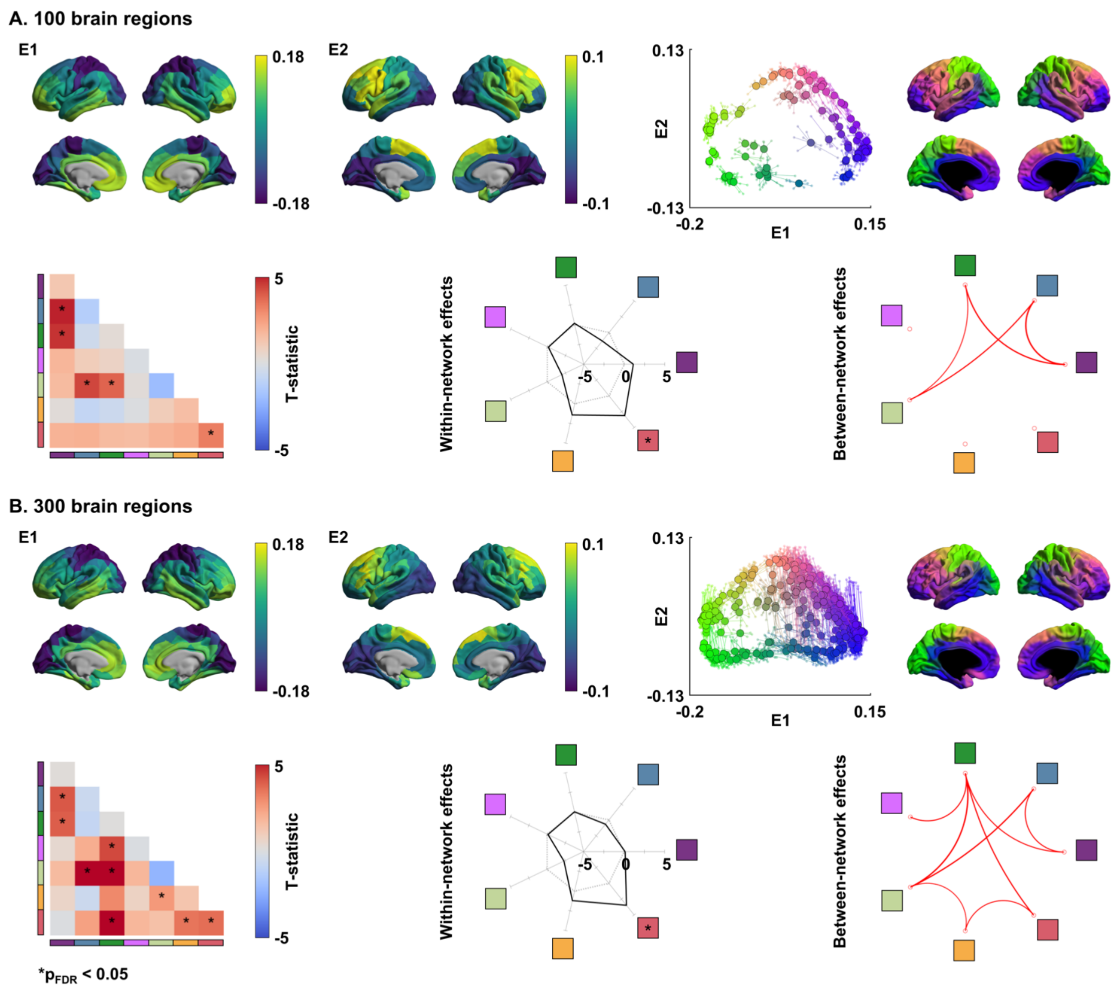

Fig. S7. Structural eigenvectors and age-effects on multiscale cortical structural differentiation using different parcellation scales. (A) Results using 100 and **(B)** 300 parcellations. Two eigenvectors (E1, E2) estimated from the cortical wiring features (top) and t-statistics of age-effects within- and between-networks (bottom) are reported. For details, see *Fig. 1*.

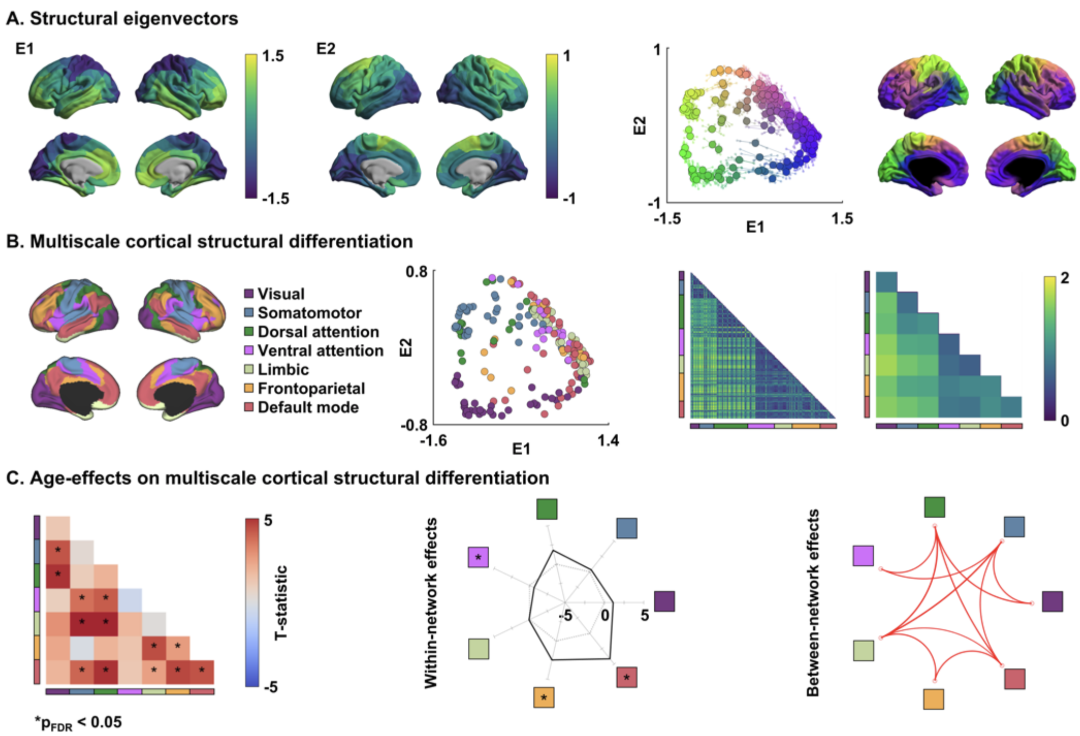

Fig. S8. Structural eigenvectors derived using principal component analysis and age-effects on multiscale cortical structural differentiation. (A) Two eigenvectors (E1, E2) estimated from the cortical wiring features. **(B)** The structural differentiation summarized based on functional communities. **(C)** The t-statistics of age-effects on structural differentiation within- and between-networks. For details, see *Fig. 1*.

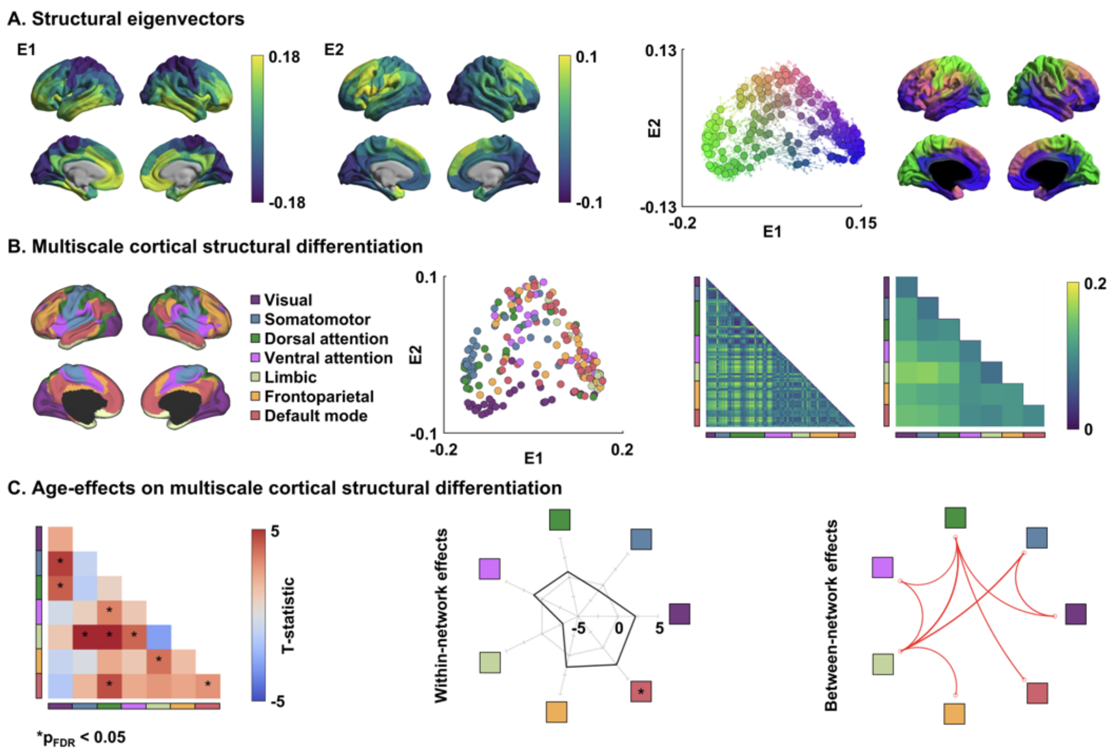

Fig. S9. Structural eigenvectors and age-effects on multiscale cortical structural differentiation using Schaefer 200 parcellation. (A) Two eigenvectors (E1, E2) estimated from the cortical wiring features. **(B)** The structural differentiation summarized based on functional communities. **(C)** The t-statistics of age-effects on structural differentiation within- and between-networks. For details, see *Fig. 1*.

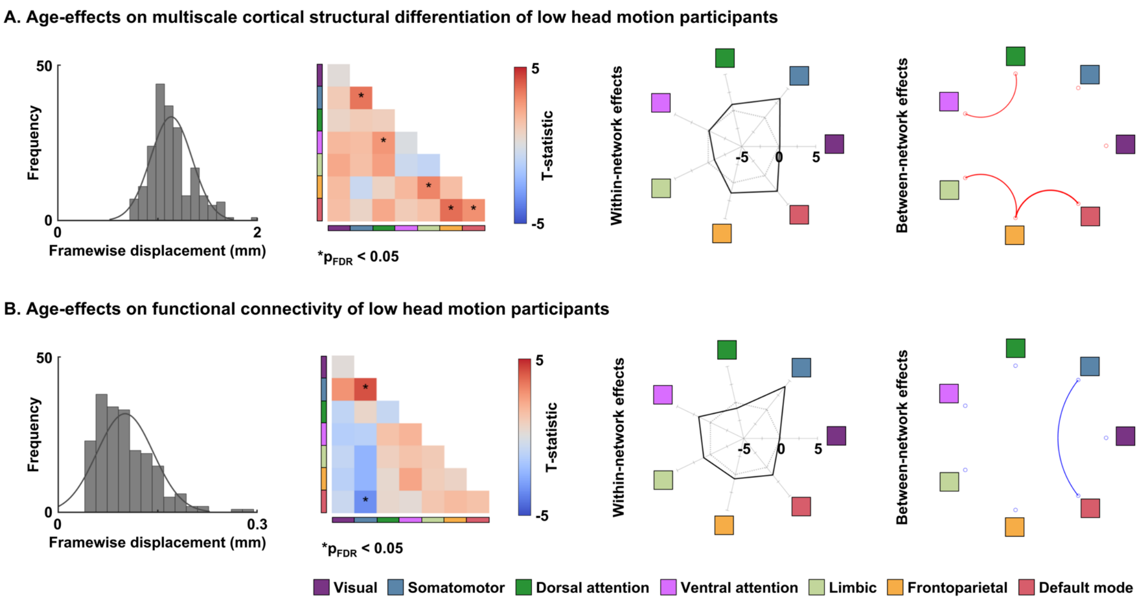

Fig. S10. Age-effects on structural and functional measures based on participants with low head motion. (A) Age-effects on structural differentiation and **(B)** functional connectivity. The histograms indicate frequency of framewise displacement. For details, see *Fig. 1* and *2*.

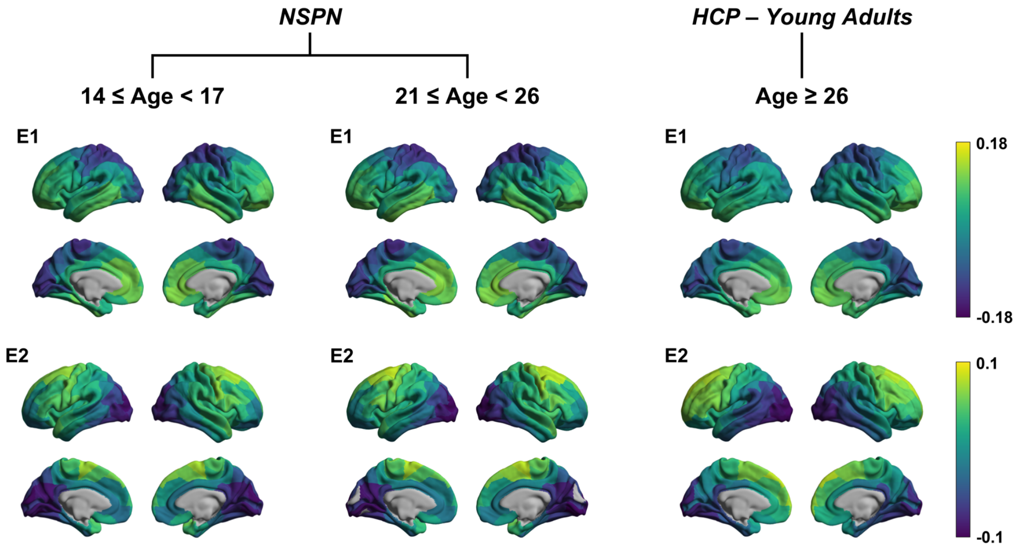

Fig. S11. Structural eigenvectors of different age bins. We estimated two eigenvectors (E1, E2) from cortical wiring features using (A) younger (age < 17) and **(B)** older (age ≥ 21) adolescence from the *NSPN* dataset, and **(C)** those using the *HCP – Young Adults* dataset. *Abbreviations:* NSPN, the Neuroscience in Psychiatry Network; HCP, Human Connectome Project.

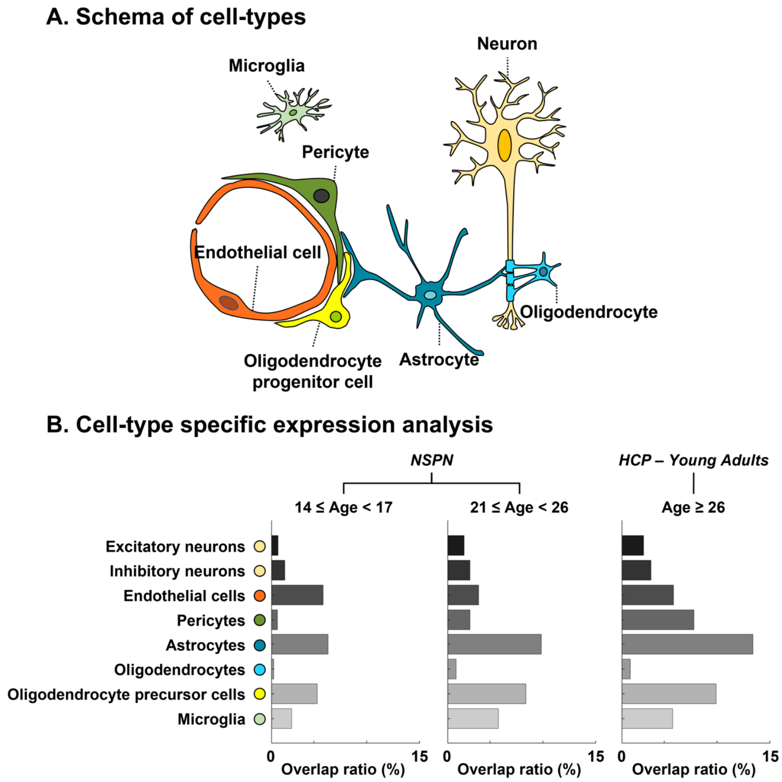

Fig. S12. Transcriptomic analysis. (A) Schema of different cell types and **(B)** overlap ratio between cell-type specific genes and the genes associated with multiscale cortical wiring of younger (age < 17) and older (age ≥ 21) adolescence from the *NSPN* dataset, and young healthy adults from the *HCP – Young Adults* database. *Abbreviations:* NSPN, the Neuroscience in Psychiatry Network; HCP, Human Connectome Project.

Neuroscience in Psychiatry Network (NSPN) Consortium author list

Principal investigators:
Edward Bullmore (CI from 01/01/2017)[1,2,3]; Raymond Dolan[4,5]; Ian Goodyer (CI until 01/01/2017)[1]; Peter Fonagy[6]; Peter Jones[1]

NSPN (funded) staff:
Michael Moutoussis[4,5]; Tobias Hauser[4,5]; Sharon Neufeld[1]; Rafael Romero-Garcia[1,2]; Michelle St Clair[1]; Petra Vértes[1,2]; Kirstie Whitaker[1,2]; Becky Inkster[1]; Gita Prabhu[4,5]; Cinly Ooi[1]; Umar Toseeb[1]; Barry Widmer[1]; Junaid Bhatti[1]; Laura Villis[1]; Ayesha Alrumaithi[1]; Sarah Birt[1]; Aislinn Bowler[5]; Kalia Cleridou[5]; Hina Dadabhoy[5]; Emma Davies[1]; Ashlyn Firkins[1]; Sian Granville[5]; Elizabeth Harding[5]; Alexandra Hopkins[4,5]; Daniel Isaacs[5]; Janchai King[5]; Danae Kokorikou[5,6]; Christina Maurice[1]; Cleo McIntosh[1]; Jessica Memarzia[1]; Harriet Mills[5]; Ciara O'Donnell[1]; Sara Pantaleone[5]; Jenny Scott[1]; Beatrice Kiddle[1]; Ela Polek[1]

Affiliated scientists:
Pasco Fearon[6]; John Suckling[1]; Anne-Laura van Harmelen[1]; Rogier Kievit[4,7]; Sam Chamberlain[1]

[1]Department of Psychiatry, University of Cambridge, United Kingdom
[2]Behavioural and Clinical Neuroscience Institute, University of Cambridge, United Kingdom
[3]ImmunoPsychiatry, GlaxoSmithKline Research and Development, United Kingdom
[4]Max Planck University College London Centre for Computational Psychiatry and Ageing Research,
University College London, UK
[5]Wellcome Centre for Human Neuroimaging, University College London, United Kingdom
[6]Research Department of Clinical, Educational and Health Psychology, University College London,
United Kingdom
[7]Medical Research Council Cognition and Brain Sciences Unit, University of Cambridge, United Kingdom

SI References

1. B. T. T. Yeo, *et al.*, The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *J. Neurophysiol.* **106**, 1125–1165 (2011).