

Structural brain correlates of subtraction and multiplication performance and their interaction with age in children

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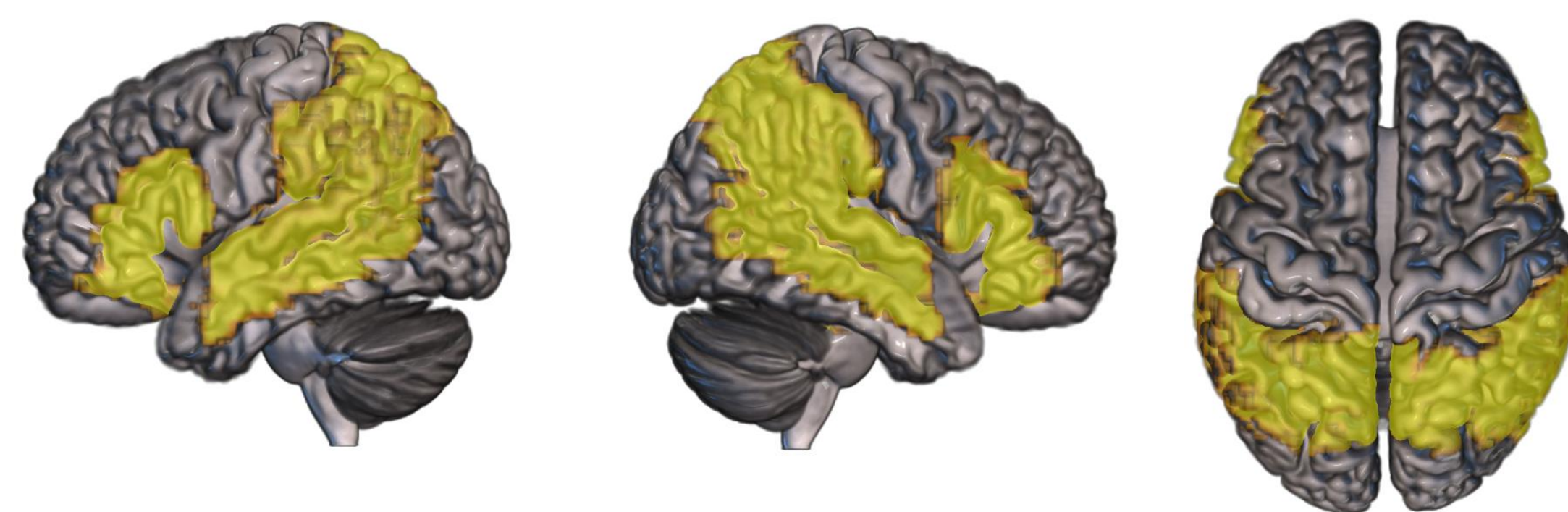
Introduction

Functional neuroimaging studies have revealed that children's arithmetic skills rely on widely dispersed brain networks that change and converge throughout development. While extensive research has focused on functional networks, there is a gap in understanding the structural correlates of arithmetic skills and their developmental trajectory. This study aims to bridge this gap by examining how changes in gray matter volume (GMV) and white matter volume (WMV) relate to multiplication performance in children from 3rd to 8th grade.

Methods

- 132 children (3rd to 8th grade) initially recruited; 62 returned for follow-up after two years.
- T1-W images obtained; measured gray matter volume (GMV) and white matter volume (WMV); arithmetic performance assessed using CMAT (1).
- Used previously established mask (2) for regions known to be related to mathematical cognition in GMV, including left MTG/STG, bilateral IPL/SPL, left IFG, and cerebellum.

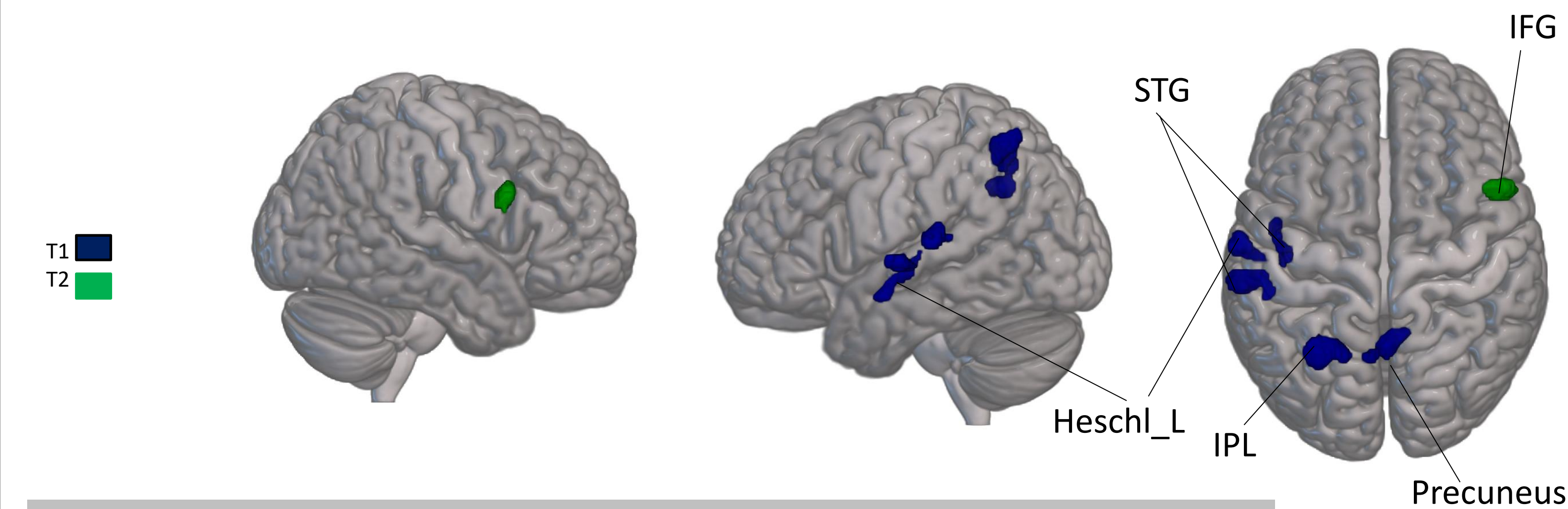
Mathematical Cognition Functional Mask (2)



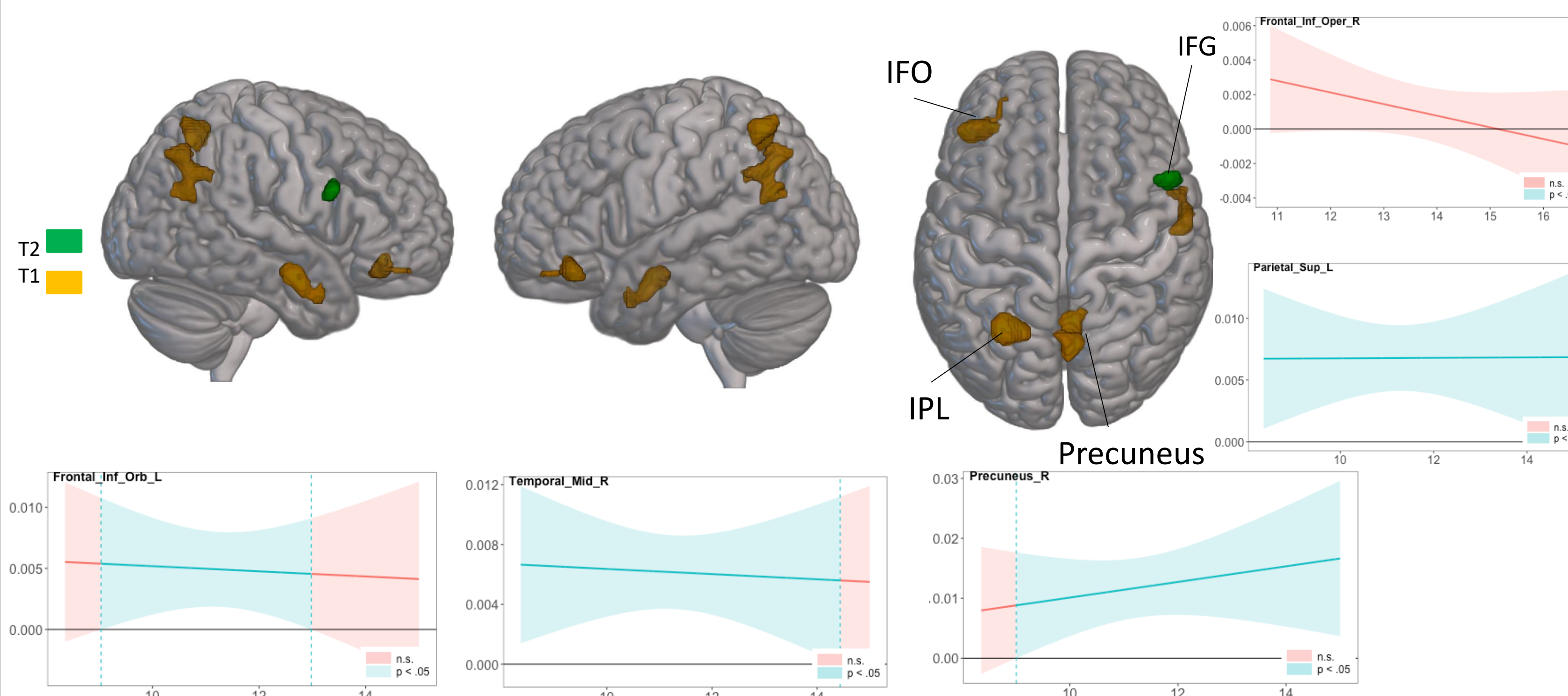
- Data analyzed with SPM12, Matlab toolboxes, and custom scripts; segmentation into GMV and WMV using CAT12; images normalized to MNI template and smoothed with 8 mm Gaussian kernel.
- Multiple regression models used for whole-brain GMV and WMV analyses with covariates.
- Johnson Neyman Analysis used for studying the association between age and multiplication performance.

Results

Negative Correlation Between GMV and Age



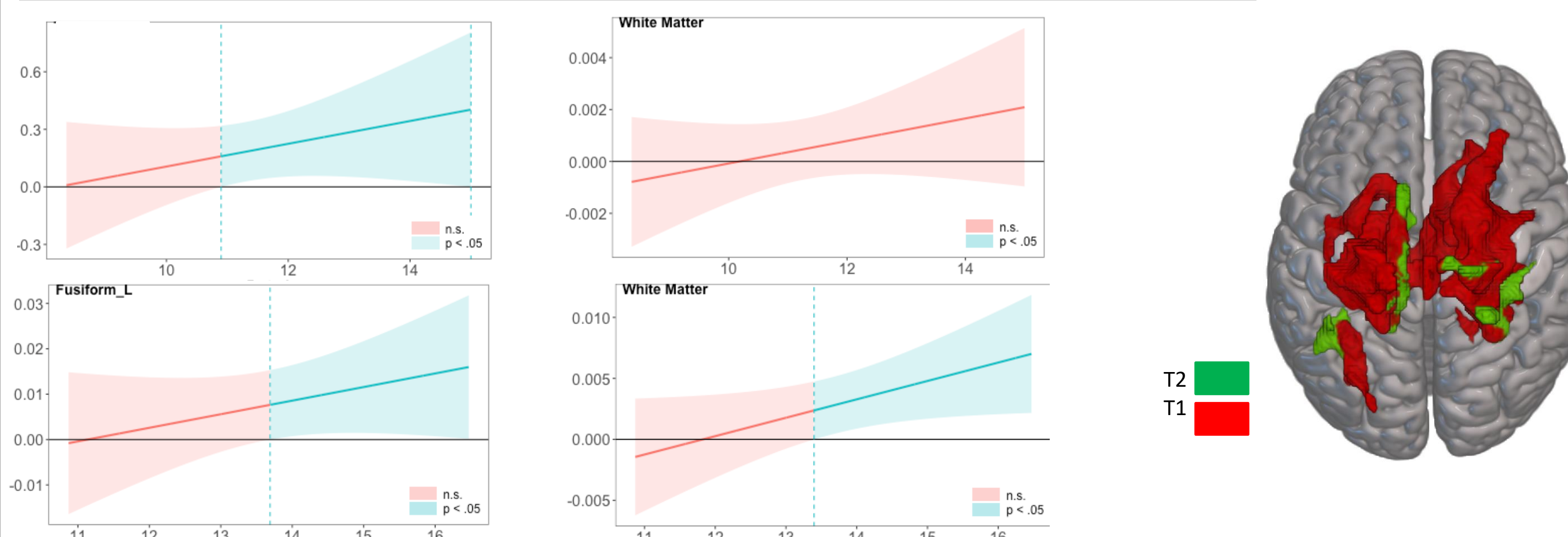
Interaction Between Age and Multiplication Performance



Positive Correlation Between WMV and Age



Interaction Between Age and Multiplication Performance



Key Findings

- Negative correlation between GMV and age in all ROIs
- IFO in GMV is correlated to multiplication performance from age 9 to 11.
- Positive correlation between WMV and age
- Interaction between multiplication performance and GMV reveals differential structural correlates across specific age intervals until 14 years old in multiple brain regions
- WMV continues to be associated to multiplication performance after age 14 and to later on

Conclusions

This study elucidates the structural brain correlates associated with arithmetic performance in children and demonstrates how these correlates evolve with age. The differential findings for multiplication reveal specialized arithmetic networks, with a negative correlation between GMV and age in all ROIs, and a positive correlation between WMV and age. Multiplication performance is linked to IFO in GMV from age 9 to 11 and shows differential structural correlates across specific age intervals until 14 years old. WMV remains associated with multiplication performance beyond age 14. Future research should further explore the functional significance of these structural changes and investigate how interventions targeting these brain regions can enhance arithmetic skills in children.

References

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- J  rome Prado, R. Mutreja, H. Zhang, R. Mehta, A.S. Desroches, Jennifer E. Minas, J.R. Booth (2011). Distinct representations of subtraction and multiplication in the neural systems for numerosity and language. Hum. Brain Mapp. 32 pp. 1932-1947. <https://doi.org/10.1002/hbm.21159>