White Matter Correlates of Executive Function in Early-Middle Childhood

Josh Litwin, Kelly Barry, M.A., Marguerite Knudtson, Haley Laughlin, M.A., Livia Merrill, Ph.D., Johanna Bick, Ph.D.
University of Houston

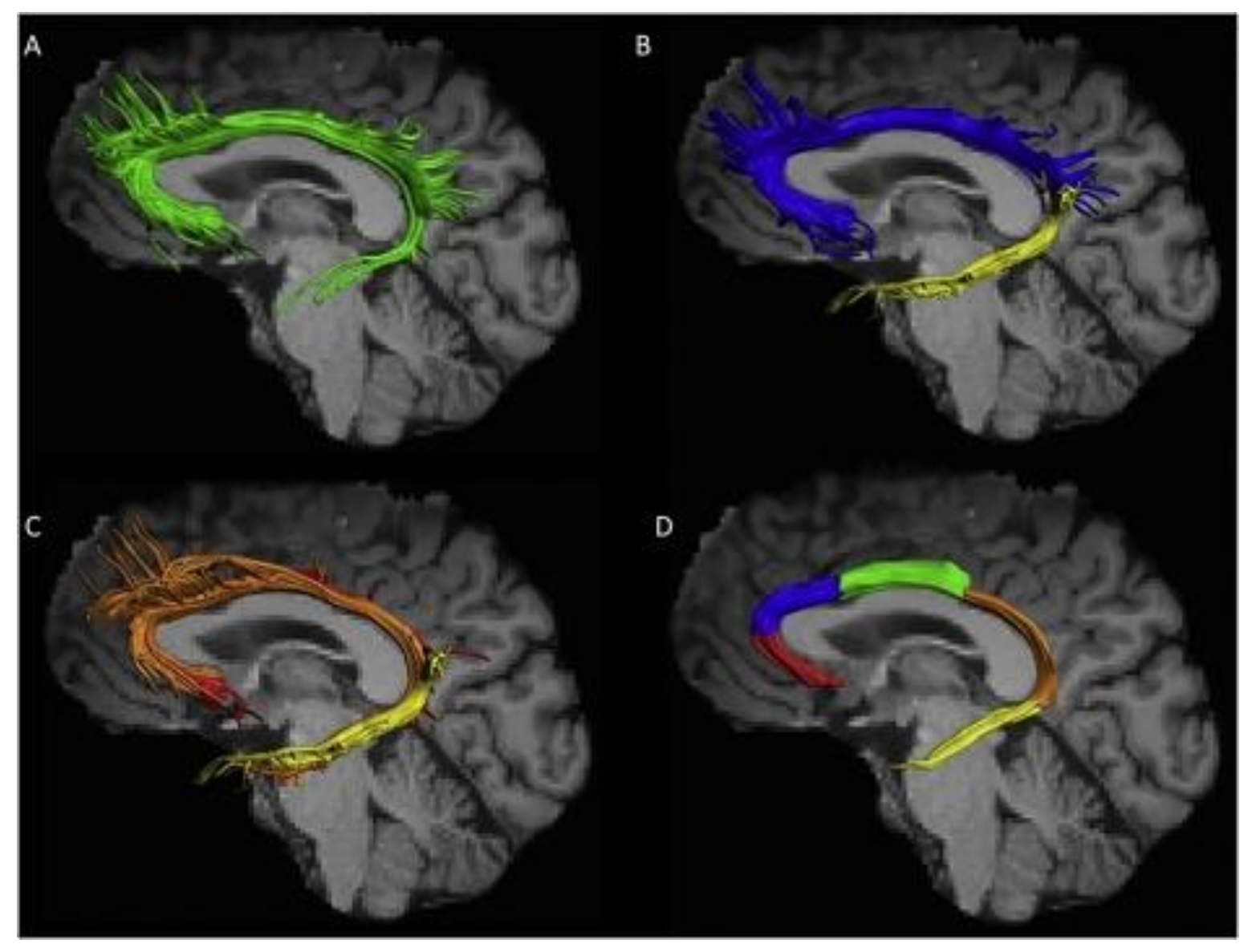
Introduction

Background

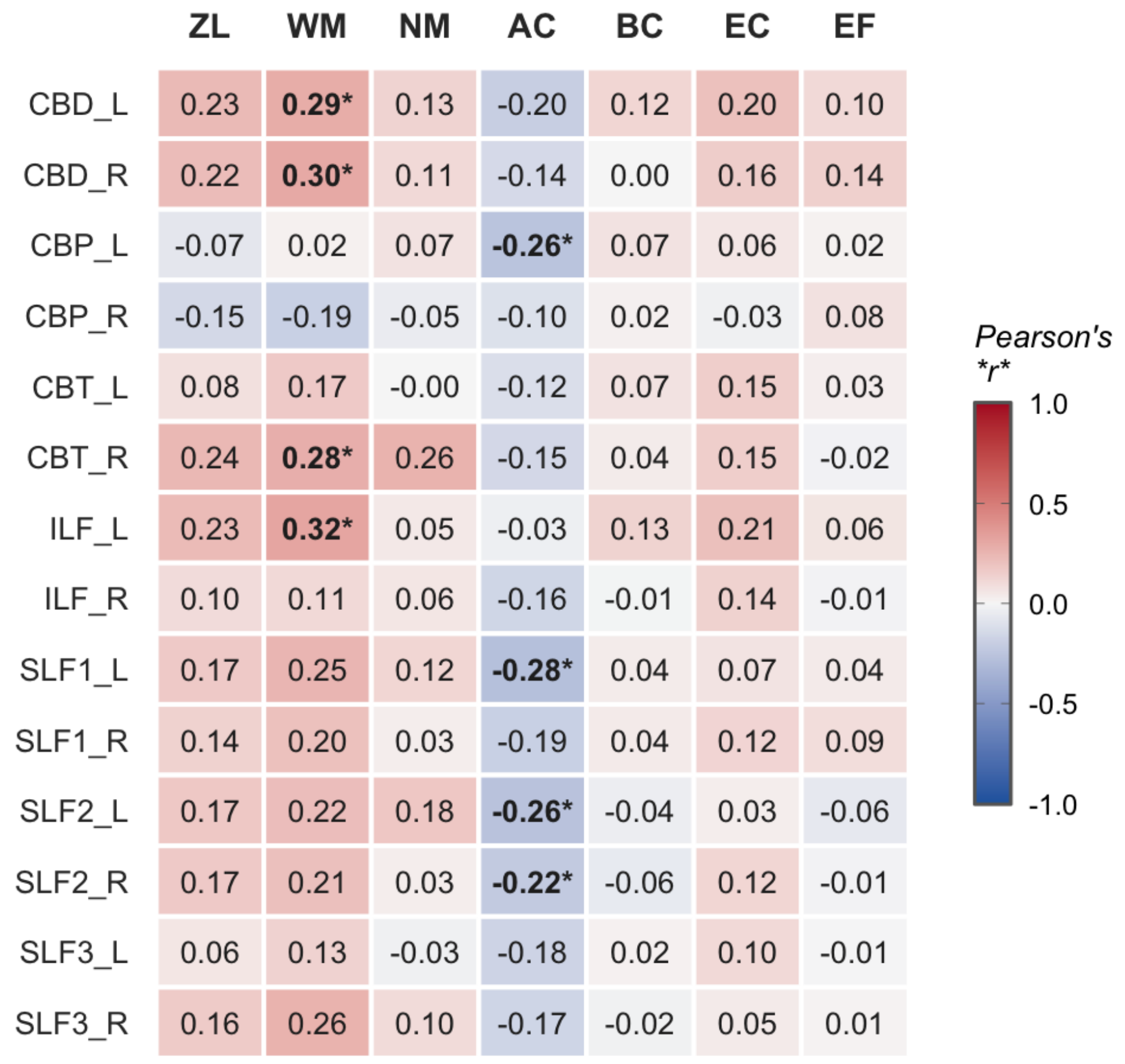
- Executive functioning (EF) refers to cognitive skills related to planning and goal-directed action, including domains such as selective attention, behavioral inhibition, and working memory
- White matter tracts such as the cingulum bundle (CB), inferior longitudinal fasciculus (ILF), and superior longitudinal fasciculus (SLF) have all been implicated in executive functioning skills such as working memory and inhibitory control.
- Alterations to the microstructure of these tracts has been associated with deficits in executive functioning across the lifespan.
- Studying individual differences in neural development during childhood allows us to identify early markers of both typical and atypical white matter growth, and to better understand mechanisms of risk for adverse cognitive and behavioral outcomes

Current Study

- We explored the link between white matter microstructure and executive functioning domains in 85 children (age range: 3.5-8.1, *M* = 5.25, *SD* = 1.02) in the Greater Houston area



Proposed subdivisions of the Cingulum Bundle (Bubb, Metzler-Baddeley, & Aggleton, 2018)



	ZL	WM	NM	AC	BC	EC	EF
CBD_L	0.23	**0.29***	0.13	-0.20	0.12	0.20	0.10
CBD_R	0.22	**0.30***	0.11	-0.14	0.00	0.16	0.14
CBP_L	-0.07	0.02	0.07	**-0.26***	0.07	0.06	0.02
CBP_R	-0.15	-0.19	-0.05	-0.10	0.02	-0.03	0.08
CBT_L	0.08	0.17	-0.00	-0.12	0.07	0.15	0.03
CBT_R	0.24	**0.28***	0.26	-0.15	0.04	0.15	-0.02
ILF_L	0.23	**0.32***	0.05	-0.03	0.13	0.21	0.06
ILF_R	0.10	0.11	0.06	-0.16	-0.01	0.14	-0.01
SLF1_L	0.17	0.25	0.12	**-0.28***	0.04	0.07	0.04
SLF1_R	0.14	0.20	0.03	-0.19	0.04	0.12	0.09
SLF2_L	0.17	0.22	0.18	**-0.26***	-0.04	0.03	-0.06
SLF2_R	0.17	0.21	0.03	**-0.22***	-0.06	0.12	-0.01
SLF3_L	0.06	0.13	-0.03	-0.18	0.02	0.10	-0.01
SLF3_R	0.16	0.26	0.10	-0.17	-0.02	0.05	0.01

Figure 1. Correlation Matrix of FA and EF measures

Methodology

Data Collection

- Data was collected as part of two broader studies on the relation between maternal mental health, brain development, and executive functioning
- Study visits occurred at the University of Houston campus and Baylor College of Medicine's Core for Advanced Magnetic Resonance Imaging (CAMRI)

White Matter Tracts of Interest

- Cingulum Bundle: Dorsal, peri-genual, and temporal subdivisions
- Inferior longitudinal fasciculus
- Superior longitudinal fasciculus: Branches I-III

Executive Functioning Measures

- WPPSI-IV: Zoo Locations subtest; Working Memory Index
- NEPSY-II: Narrative Recall subtest
- BASC-3: Attentional Control Index; Behavioral Control Index; Emotional Control Index; Overall Executive Function Index

Analyses

- Preliminary analyses involved simple correlations between mean FA in WM tracts of interest with all behavioral measures (Results shown in **Fig. 1**)
- FDR correction was used to control for multiple comparisons
- For secondary analyses, a multiple linear regression controlling for effects of age and sex was applied to all significant WM-behavior correlations (Correlations surviving significance shown in **Fig. 2**)

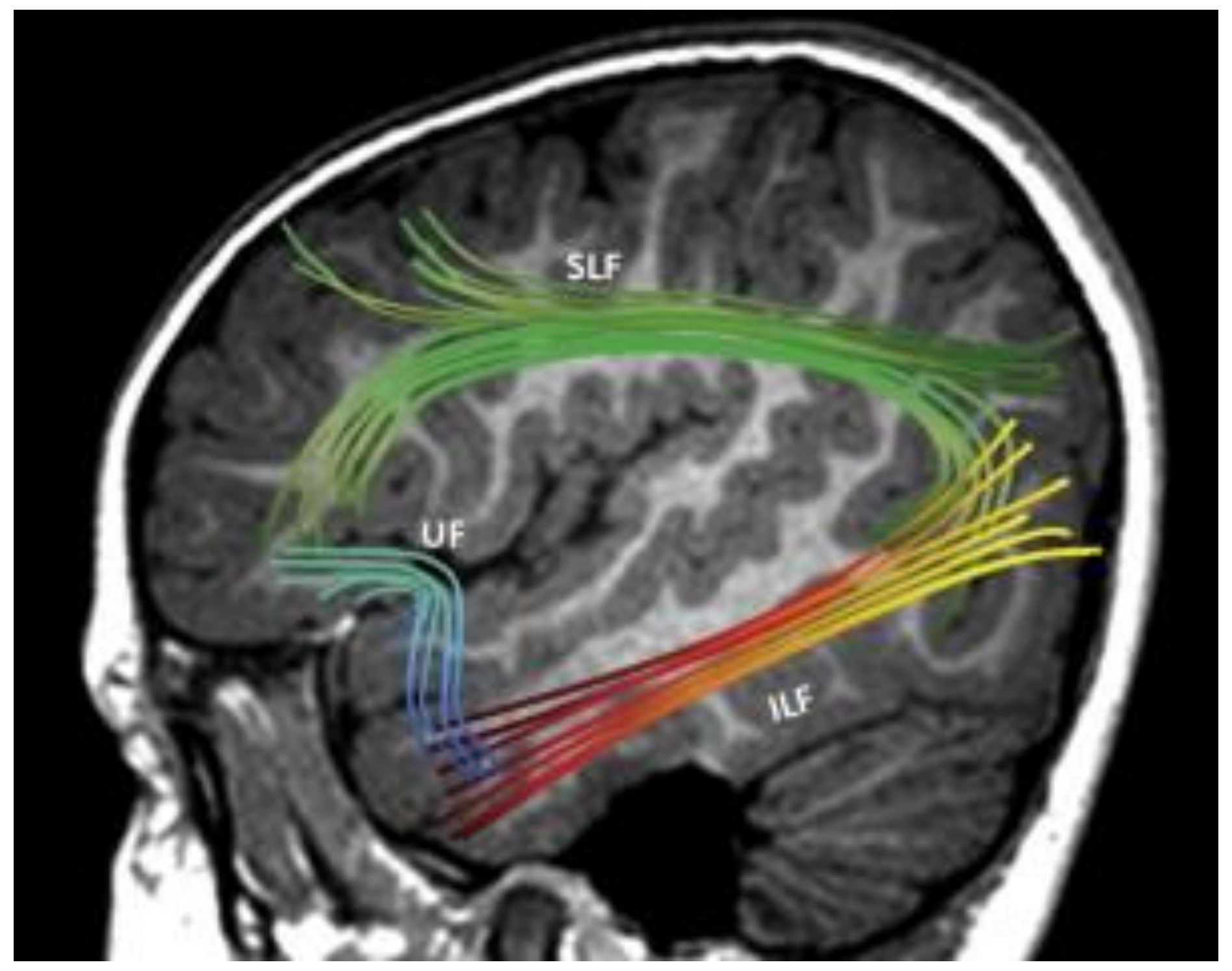
Results

Preliminary analyses

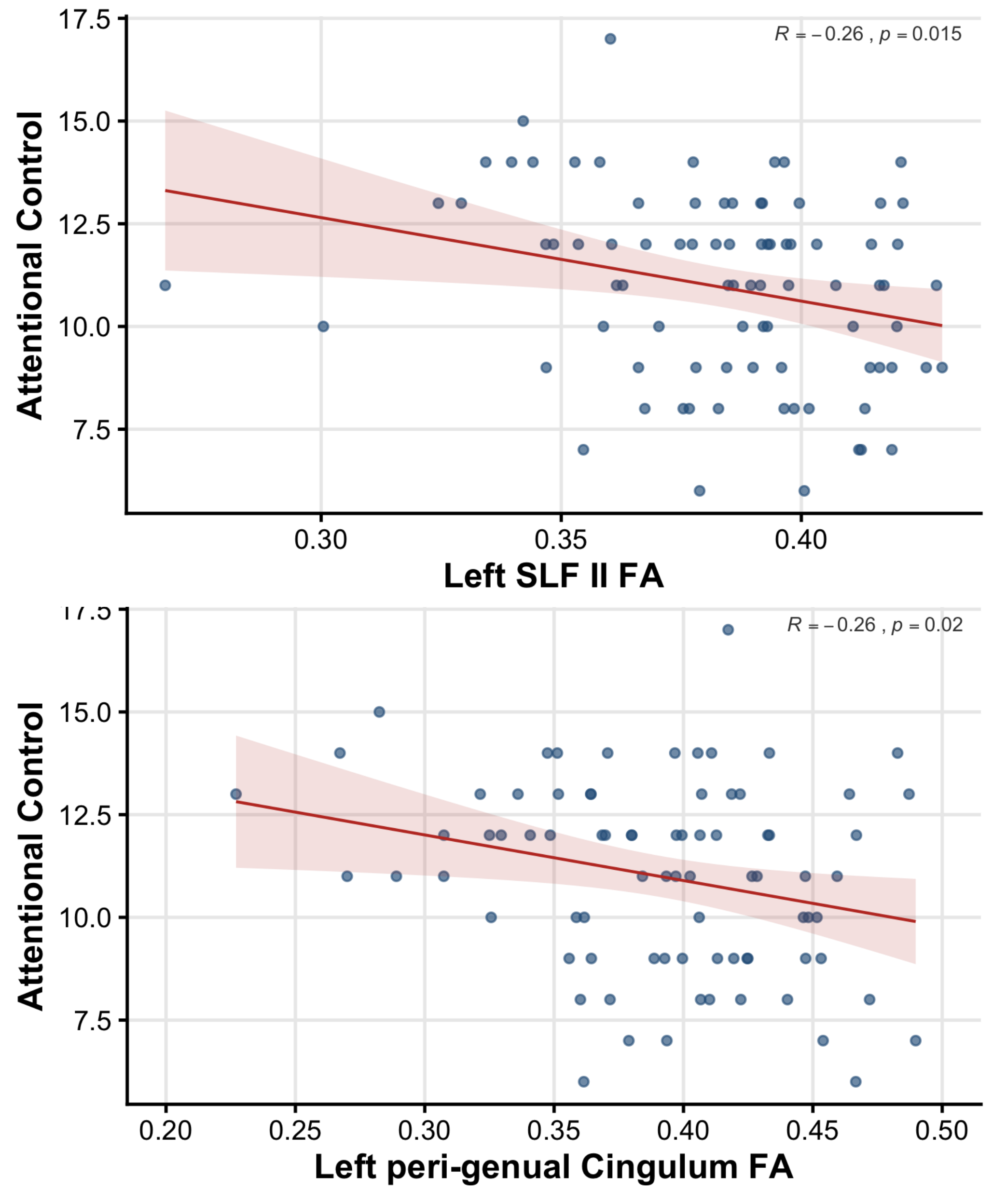
- A statistically significant correlation was found between working memory index scores and FA in the left ILF, right temporal CB, and bilateral dorsal CB
- The left peri-genual CB and multiple branches of the SLF were negatively correlated with attentional control deficits

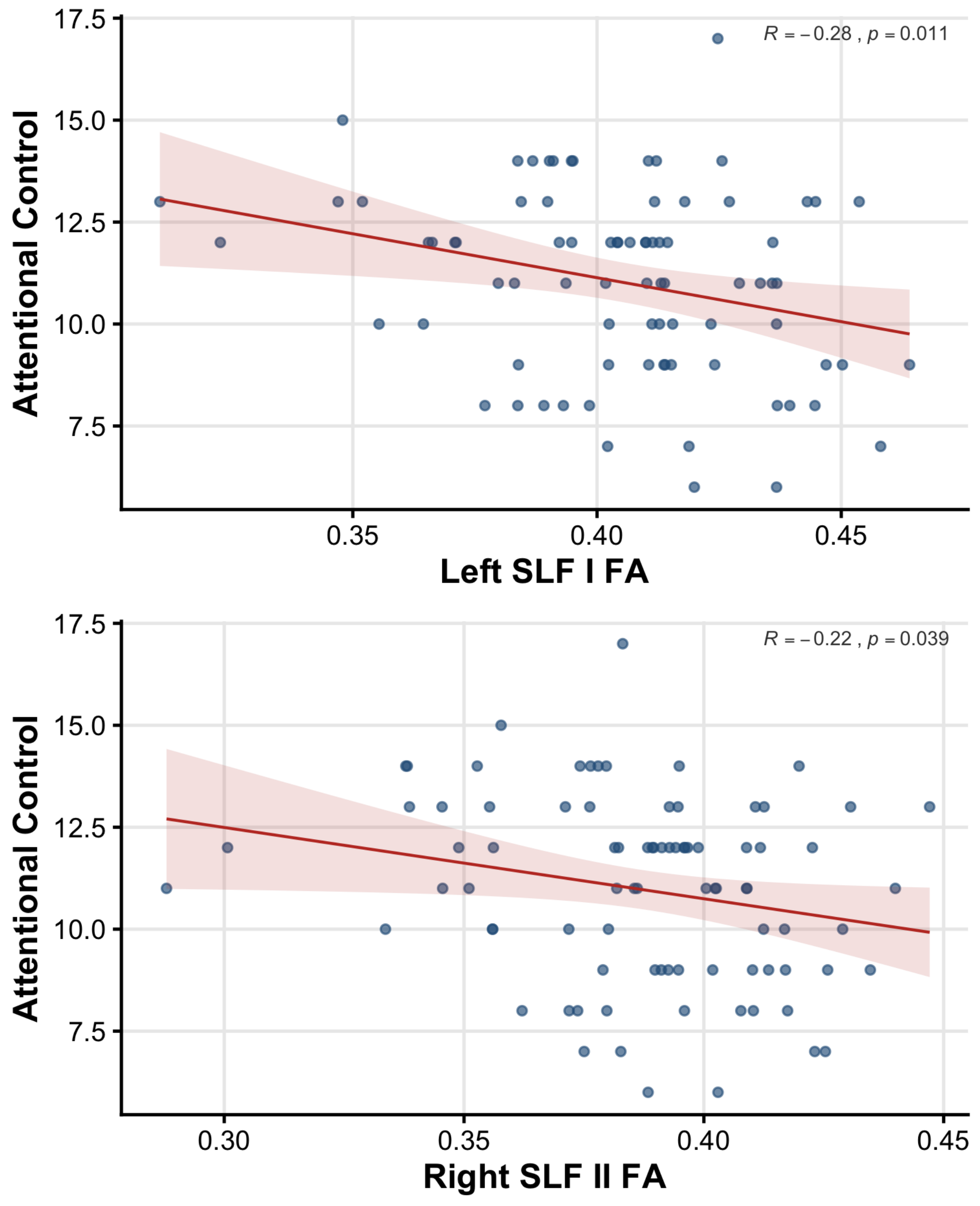
Secondary Analyses

- Among WM associations with working memory, the left ILF was the only tract to survive multiple linear regression
- All significant correlations between attentional control and WM microstructure remained significant after regressing out age and sex



The SLF, ILF, and UF in an adult brain (Wycoco et al., 2013)





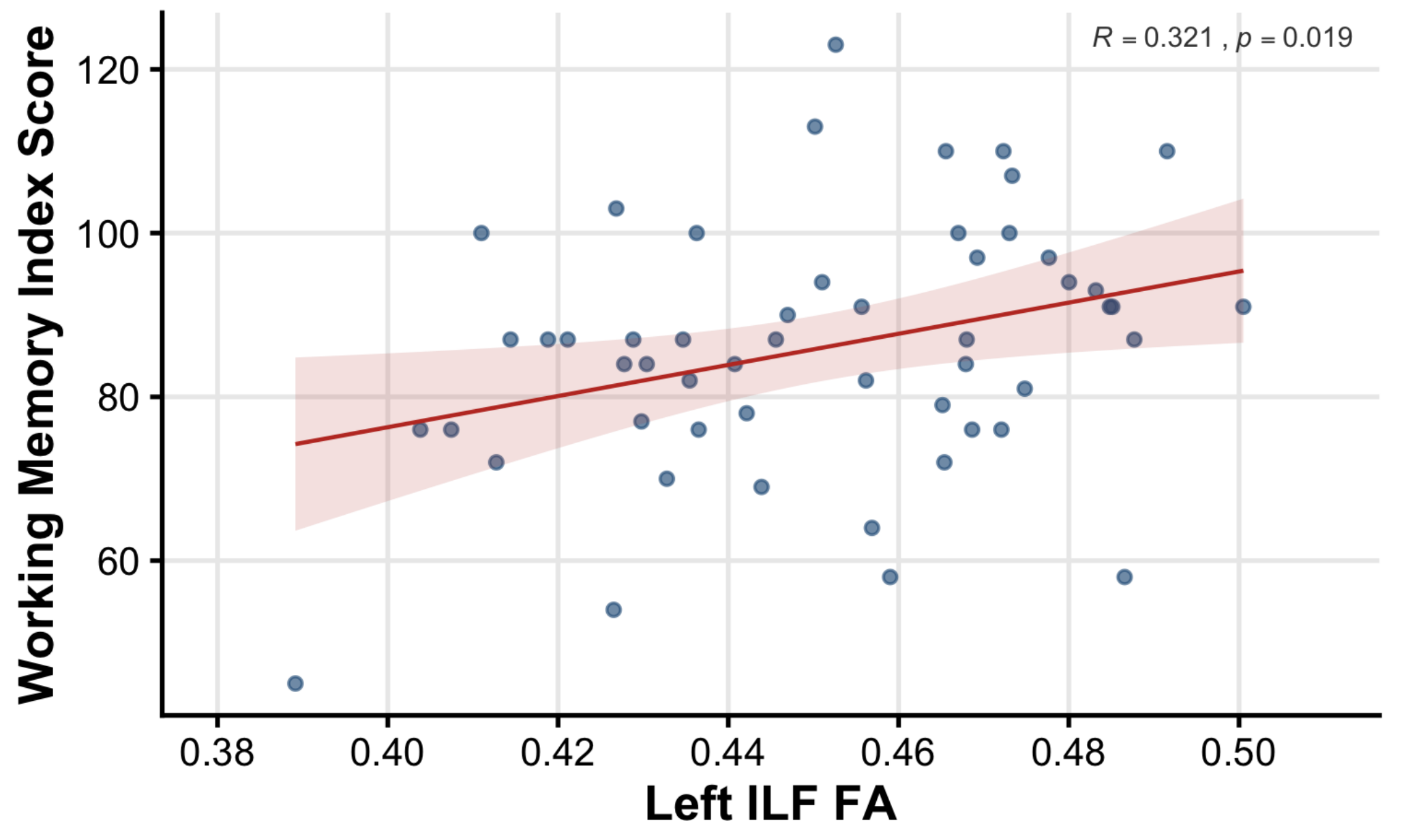


Figure 2. Significant WM and EF correlations after controlling for sex and age

Discussion

Attentional Control

- Mean FA in the SLF and CB was negatively associated with BASC-3 attentional control index scores, even after accounting for participant age
- Greater FA in these tracts was associated with fewer attentional concerns, supporting prior work linking fronto-limbic and fronto-parietal microstructure to attention in healthy and clinical populations across the lifespan

Working Memory

- Individual differences in ILF microstructure were significantly and positively correlated with WPPSI-IV working memory index scores
- Apart from the left ILF, participant age and sex accounted for all significant relations between white matter microstructure and working memory,
- No other measures of working memory were significantly correlated with FA
- These findings were somewhat unexpected given the robust literature supporting the link between working memory and WM integrity, particularly in the SLF

Other Executive Functioning Domains

- No other BASC-3 indices of executive functioning were significantly related to FA
- Participant age is an important consideration, as frontolimbic structures often experience a protracted development that extends into young adulthood

Limitations and Future Directions

- Data for this analysis was combined from two studies, resulting in large numbers of missing values on certain measures that were collected as part of one study and not the other
- Focusing on the role of socioeconomic and other demographic factors will be an important next step for understanding specific mechanisms underlying individual differences in white matter microstructure and associated cognitive and behavioral outcomes

Summary

- Taken together, these findings contribute to the growing literature on early neural mechanisms of cognition

Citations

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