Cumulative Impacts of Smartphone Use on Cognitive Control and Human Brain White Matter Connectivity

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Introduction

Background:
- Smartphone and social media use (SSMU) has been found to be linked to weaker cognitive control (CC), including deficits in inhibitory control, working memory, and sustained attention among heavy users[1].
- Neuroimaging studies in adults show decreased white matter (WM) integrity in neural pathways linked to cognitive control (e.g., PFC, cingulum bundle) among heavier smartphone users[2].
- There is limited and mixed evidence surrounding how these relationships might emerge over the course of development.

Research Question:
- How do SSMU and CC interact across developmental stages, including adolescence and young adulthood?
- How does white matter microstructure change with cumulative SSMU?

Methods

- **Participants.** 129 adolescents (13–17 years; 73 females) and 158 young adults (18–21 years; 99 females).
- **SSMU Measures.** Mobile Technology Engagement Scale (MTES) and Smartphone Addiction Scale (SAS). Objective screen time and checking frequency were obtained from the usage–tracking functions on participants' smartphones.
- **CC Measures.** Two scales: Barratt Impulsiveness Scale (BIS-Brief) and the Teenager Executive Functioning Inventory (TEXI), and two performance-based tasks: the Flanker Inhibitory Control Task and the Planet Go/No-Go task.
- **Diffusion-Weighted MRI.** Tract profiles with fractional anisotropy (FA) values generated by pyAFQ.
- **Statistical Analysis.** Node-wise correlations and linear regressions.

Conclusion

- SSMU is negatively associated with cognitive control, but the association varies with age and based on specific measures.
- SSMU shows meaningful associations with FA in white-matter pathways, including the cingulum cingulate, corticospinal and several other tracts.
- SSMU moderates the maturation of cingulum bundles, which may be coupled with its effect on the development of CC.

Behavioral Results

Figure 1. CC and SSMU habits change by age.

SSMU marginally ($p = 0.08$) moderated the relationship between CC and age.
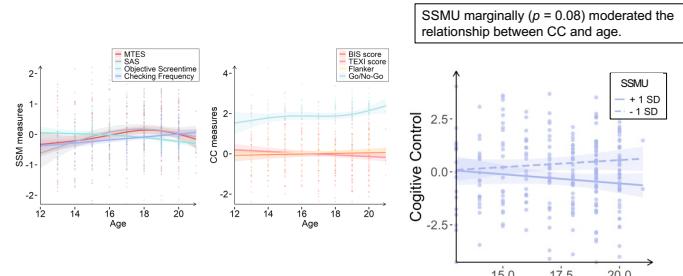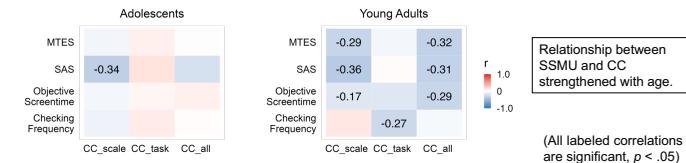
Table 1. Correlations between SSMU and CC.

Adolescents

	CC_scale	CC_task	CC_all
MTES			
SAS	-0.34		
Objective Screentime			
Checking Frequency			

Young Adults

	CC_scale	CC_task	CC_all
MTES	-0.29		-0.32
SAS	-0.36		-0.31
Objective Screentime	-0.17		-0.29
Checking Frequency		-0.27	

Relationship between SSMU and CC strengthened with age.

(All labeled correlations are significant, $p < .05$)

White Matter Integrity

Figure 2. Relationship between FA and age.

Left Cingulum Cingulate

All of the key tracts showed a positive association between age and white matter integrity (FA values).
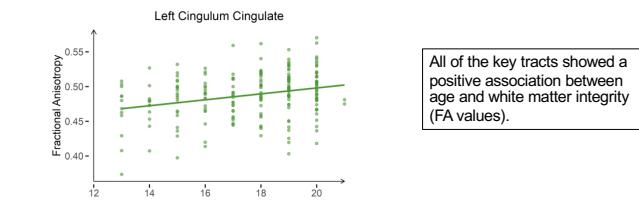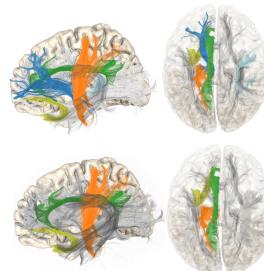
Table 2. Node-wise association between fractional anisotropy (FA) and CC/SSMU

Adolescents:

Tracts	Hem.	Sig. Nodes	Variable	Direction of Association
Cingulum Cingulate	Left	50–73	CC_scale	-
Uncinate	Left	66–82		+
Anterior Thalamic	Left	52–74	SAS	+
Corticospinal	Left	40–62		+
Arcuate	Right	30–45	Screentime	-
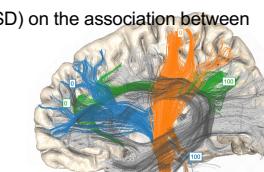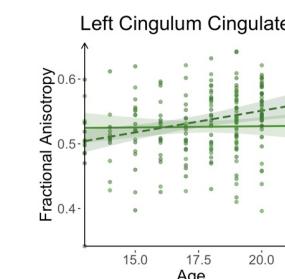
Young adults:

Tracts	Hem.	Sig. Nodes	Variable	Direction of Association
Cingulum Cingulate	Left	14–36	MTES	-
Uncinate	Left	52–71		-
SLF	Right	13–27	Screentime	+
Corticospinal	Left	22–33	CC_scale	-
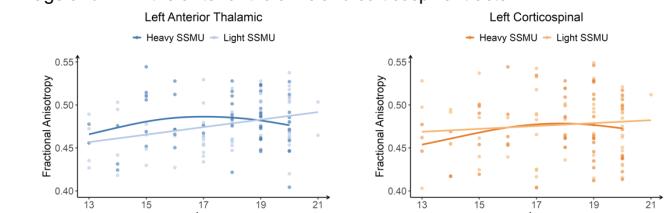
Moderation of WM Integrity by SSMU

Figure 3. Moderating effect of SSMU (±1 SD) on the association between age and FA in the left cingulum cingulate.

Left Cingulum Cingulate
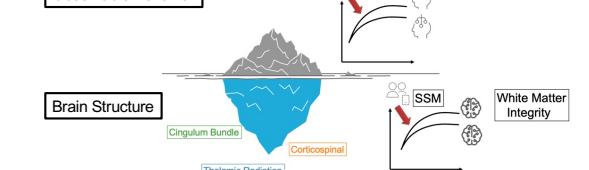
SSMU
+ 1 SD
- 1 SD

The moderation effect was significant, $t(206) = -2.29$, $p = .023$, $R^2 = 0.18$, indicating that the positive effect of age on FA became weaker at higher levels of SSMU.

Figure 4. No moderating effect of SSMU group on the association between age and FA in the anterior thalamic and corticospinal tracts.

Left Anterior Thalamic
Left Corticospinal

Heavy SSMU   Light SSMU

Cumulative Impacts of SSMU on Cognitive Control

Observable Behavior

Brain Structure

Cingulum Bundle   Corticospinal

Thalamic Radiation

SSM → Cognitive Control

SSM → White Matter Integrity

References

[1]Chiu, M., & Chein, J. (2022). Digital media and the developing brain. *Handbook of adolescent digital media use and mental health*, 104-134.
[2]Hu, Y., Long, X., Lyu, H., Zhou, Y., & Chen, J. (2017). Alterations in white matter integrity in young adults with smartphone dependence. *Frontiers in human neuroscience*, 11, 532.

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