

Sleep Disturbances Are Associated With Individual-Level Alterations in Structural Brain Networks in Preadolescence



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Beyond isolated brain regions: Are sleep disturbances reflected in how the developing brain is organized?



Background

- Sleep disturbances (SD) affect 30–40% of children and are associated with adverse developmental outcomes [1].
- Preadolescence is marked by reorganization of brain morphology, reflected in coordinated structural variation across distributed brain systems [2].
- Existing group-level evidence has linked SD to regional brain structural alterations; however, little is known about how SD relate to individual-specific deviations in brain structural covariance organization and their developmental course.

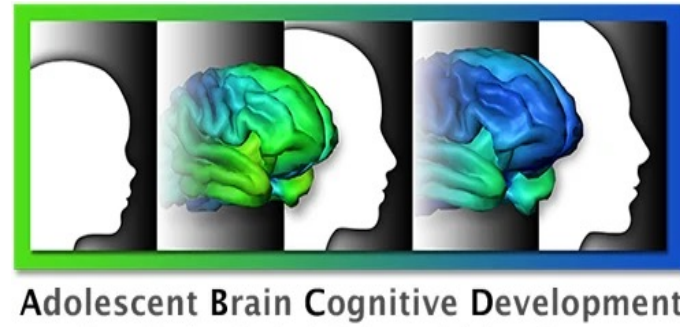
Research Aim

- Characterize individual-specific alterations in brain structural covariance organization in children with SD.
- Determine whether these individual-specific alterations form a shared pattern across children with SD.
- Examine the developmental course of the shared structural covariance pattern according to sleep-disturbance status.

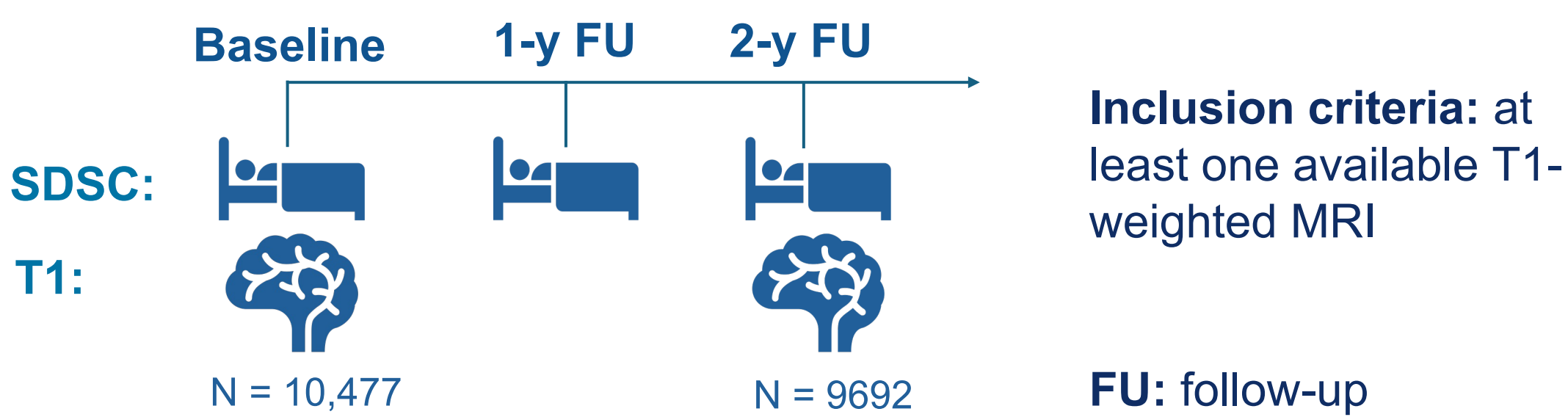
Sample Overview

ABCD

Subjects	10,447
Age	9–10 years old at baseline
Follow-up	2-year
Sleep	Sleep Disturbance Scale for Children (SDSC)
Imaging	T1-weighted MRI
Covariates	Age, Sex, BMI, Puberty Stage, Site, Total Intracranial Volume (TIV)



Data Preparation

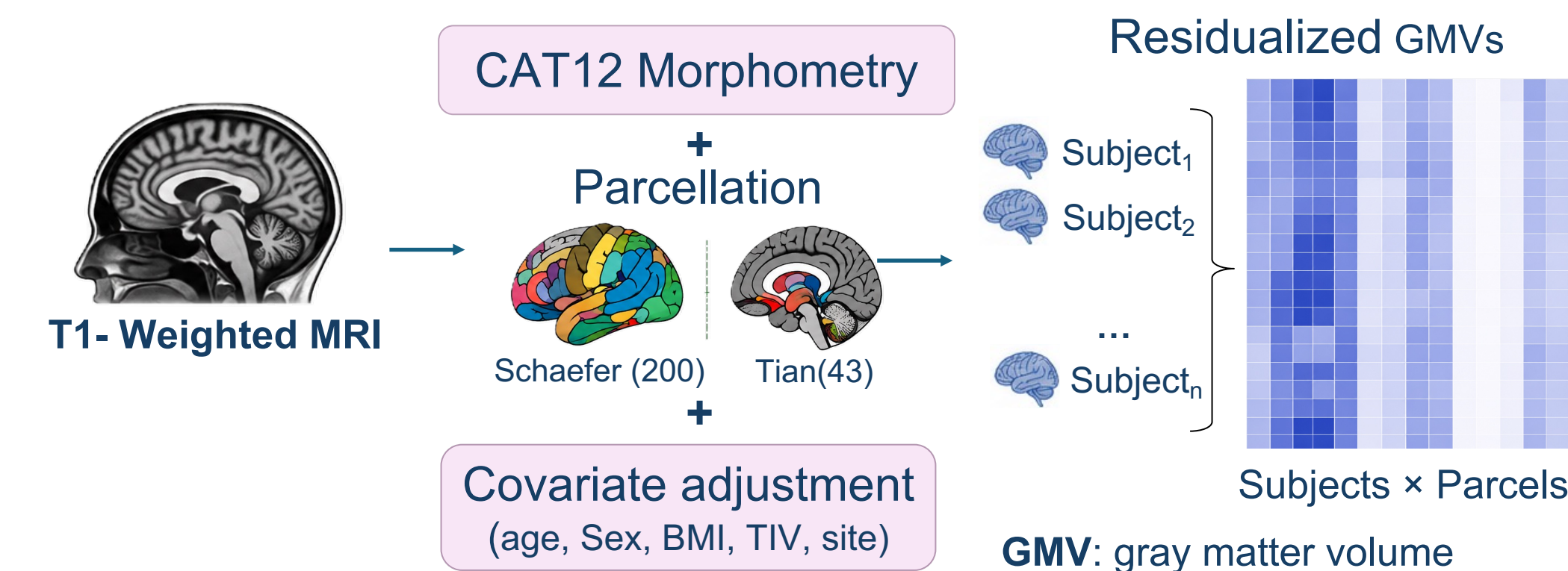


Sleep Phenotyping

Clinical cut-off: SDSC Total Score ≥ 39

Stable Good sleepers (Never SD)	SDSC Total Score < 39 at all available assessments	Baseline: n = 4420 2-y FU: n = 3995
With SD history	SDSC Total Score ≥ 39 at least at one time point	Baseline: n = 6057 2-y FU: n = 5697
Baseline	2-y FU	
Current SD n = 3182	Current non-SD n = 2875	Current SD n = 2850
		Current non-SD n = 2847

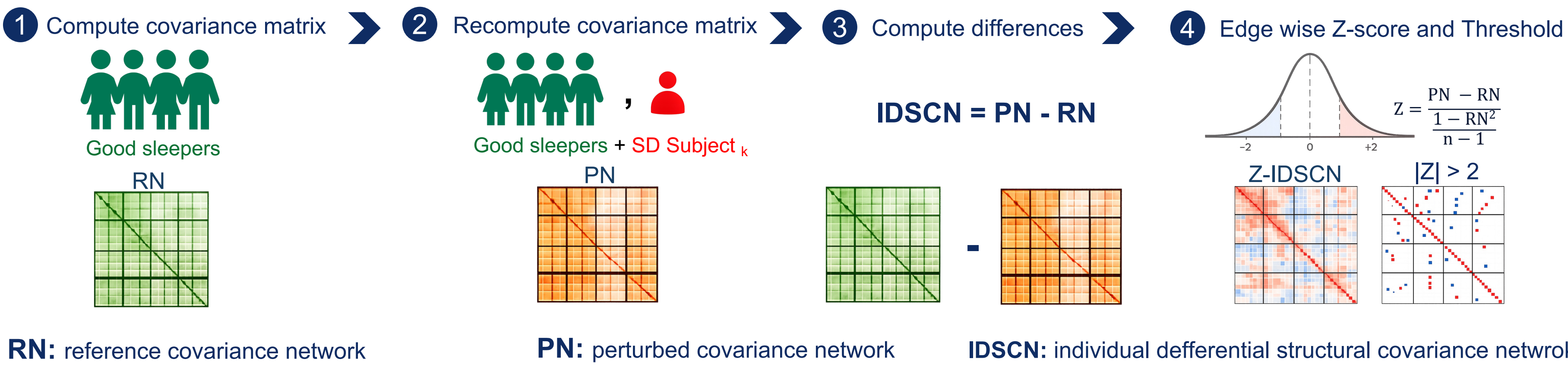
MRI Processing



Aim 1

Individual Differences in Structural Covariance Organization

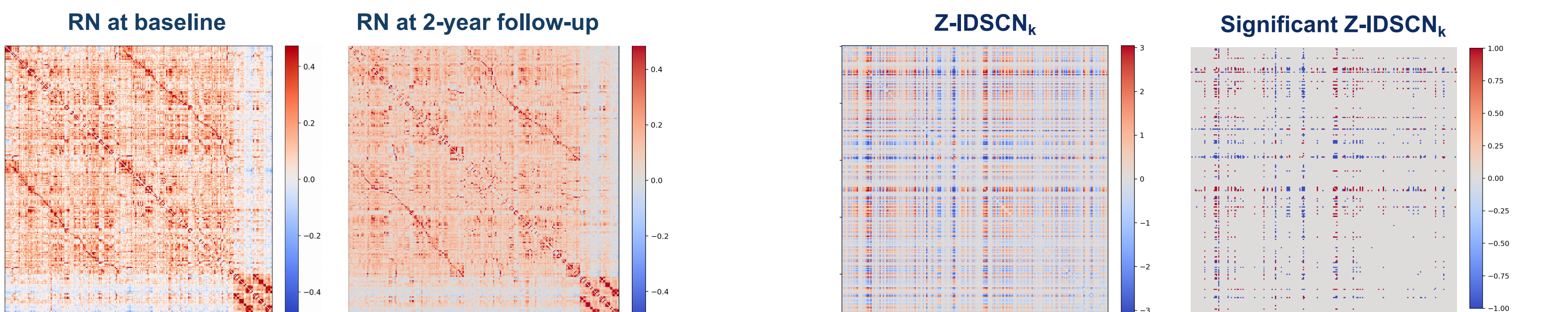
Approach



Key findings

- Reference networks showed high stability across resampling procedures

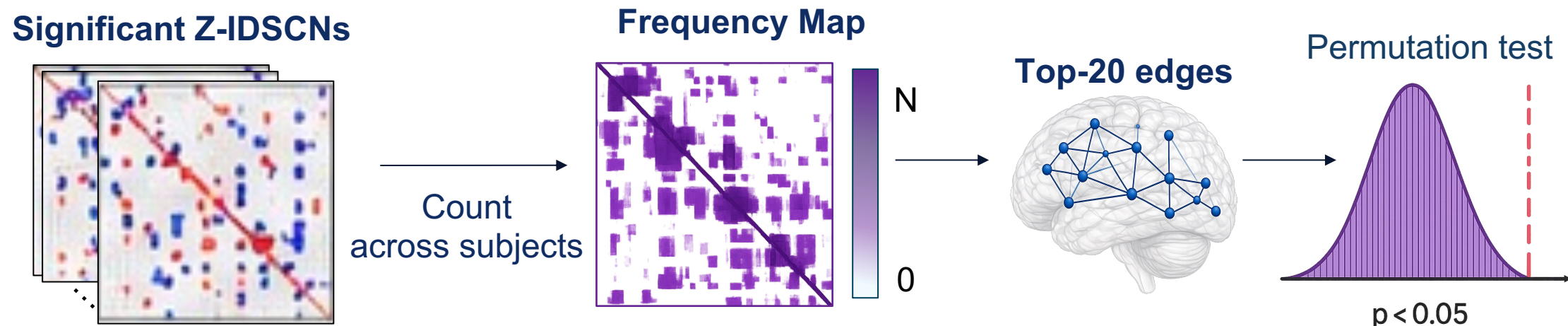
- Individual structural covariance deviations were reliably detectable beyond normative perturbation levels, demonstrating that IDSCN can capture inter/intra individual differences among children with SD.



Aim 2:

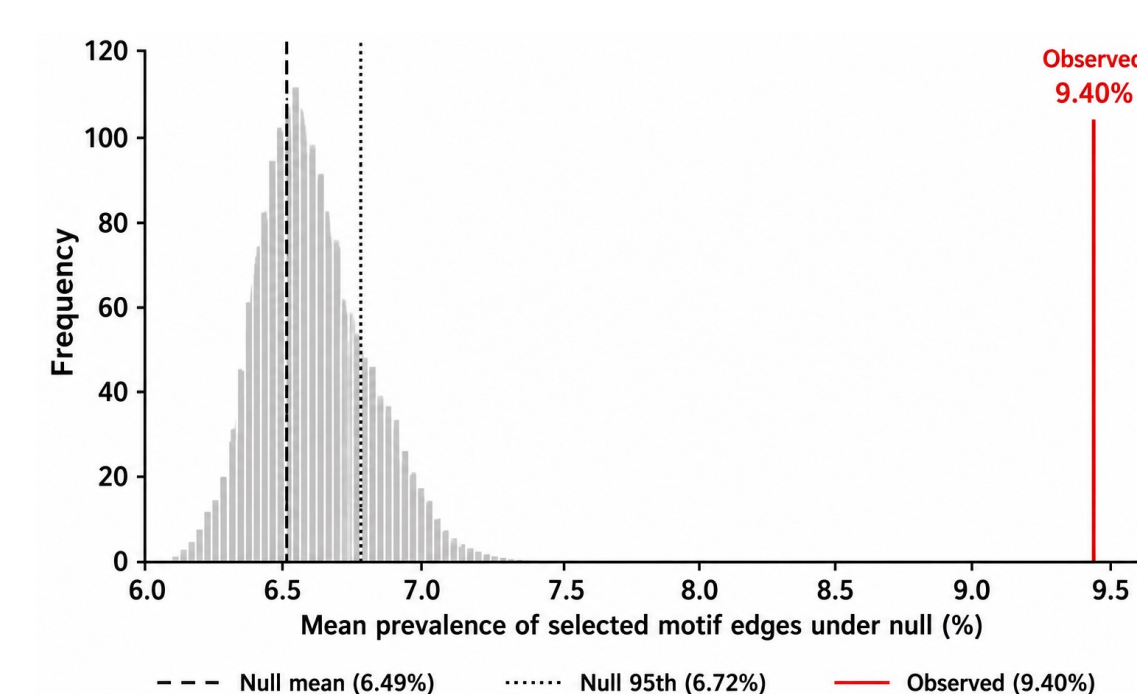
Shared Structural Covariance Alterations Across Children with SD

Approach

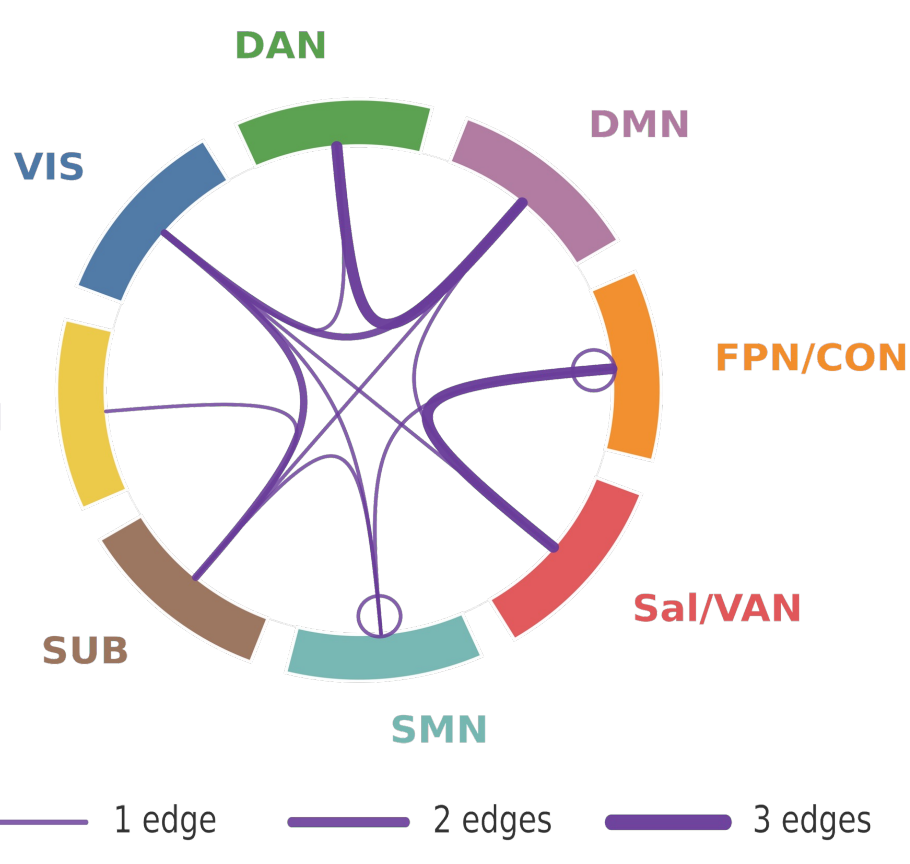


Key findings

- Despite substantial inter-individual variability, a shared pattern of structural covariance deviations emerged across children with SD. The pattern was defined by the 20 most prevalent deviation edges and was observed significantly more often than expected by chance.



Parcer i – Parcel j	Prevalence	Network Pair	Network Contribution
IDefaultB_PFCv_2 → ISalVentAttnB_IPL_1	10.01%	DMN – Sal/VAN	● VIS: Visual Network 7
IDefaultA_pCunPCC_1 → IVisPeri_StriCal_1	9.77%	DMN – VIS	● DMN: Default Mode Network 7
ISomMotB_Cent_2 → rSomMotA_9	9.53%	SMN – SMN	● FPN/CON: Frontoparietal / Control Network 6
ISomMotA_1 → IVisPeri_StriCal_1	9.53%	SMN – VIS	● Sal/VAN: Saliency / Ventral Attention Network 5
ISalVentAttnB_IPL_1 → rContA_IPS_2	9.53%	Sal/VAN – FPN/CON	● SMN: Somatomotor Network 5
IDefaultA_pCunPCC_1 → rDorsAttnB_TempOcc_1	9.45%	DMN – DAN	● SUB: Subcortical Network 5
rVisCent_ExStr_3 → subcort_THA-DP-rh	9.45%	VIS – SUB	● DAN: Dorsal Attention Network 4
IContA_PFCI_2 → ISalVentAttnB_IPL_1	9.45%	FPN/CON – Sal/VAN	● LIM: Limbic Network 1
rDefaultA_PFCm_1 → rDorsAttnB_PostC_4	9.45%	DMN – DAN	
IContA_pCun_2 → rContB_Temp_2	9.45%	FPN/CON – FPN/CON	
IContA_PFCI_2 → ISomMotB_S2_2	9.29%	FPN/CON – SMN	
rVisCent_ExStr_3 → subcort_aGP-rh	9.29%	VIS – SUB	
IDefaultC_IPL_1 → IVisPeri_StriCal_1	9.29%	DMN – VIS	
IContA_PFCI_2 → ISalVentAttnB_PFCI_1	9.29%	FPN/CON – Sal/VAN	
ISomMotA_4 → subcort_mAMY-rh	9.29%	SMN – SUB	
IVisPeri_StriCal_1 → rDorsAttnB_TempOcc_1	9.21%	VIS – DAN	
ISalVentAttnB_PFCI_1 → IVisCent_ExStr_5	9.21%	Sal/VAN – VIS	
IDefaultB_PFCd_3 → rDorsAttnB_PostC_4	9.21%	DMN – DAN	
ILimbicA_TempPole_2 → subcort_mAMY-rh	9.13%	LIM – SUB	
rDefaultA_PFCm_2 → subcort_pPUT-rh	9.13%	DMN – SUB	



Aim 3:

Longitudinal changes of the SD-related structural covariance pattern

Model : $|Z| \sim \text{Group} \times \text{Time} + \text{Pubertal stage} + (1|\text{subject}) + (1|\text{edge})$

Linear mixed-effect model with random intercepts for subject and edge

Longitudinal change in Z	β	p
Current SD (vs never SD)	-0.003	0.86
Current non- SD (vs never SD)	0.037	0.06
Current non- SD vs Current SD	-0.041	0.006
Pubertal stage	-0.027	<0.001

Never SD **Current non-SD** **Current SD**

No significant group-by-time effects for Signed Z (all p > 0.26)

The longitudinal changes of the shared deviation pattern differed according to current SD status

Conclusions

- Distributed alterations in brain structural covariance organization support a **network-level** rather than region-specific view of SD in preadolescence.
- SD history** may matter: longitudinal differences in structural covariance alteration were not fully captured by current symptom status alone.

Conflict of interest:

The authors declare no conflicts of interest.

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