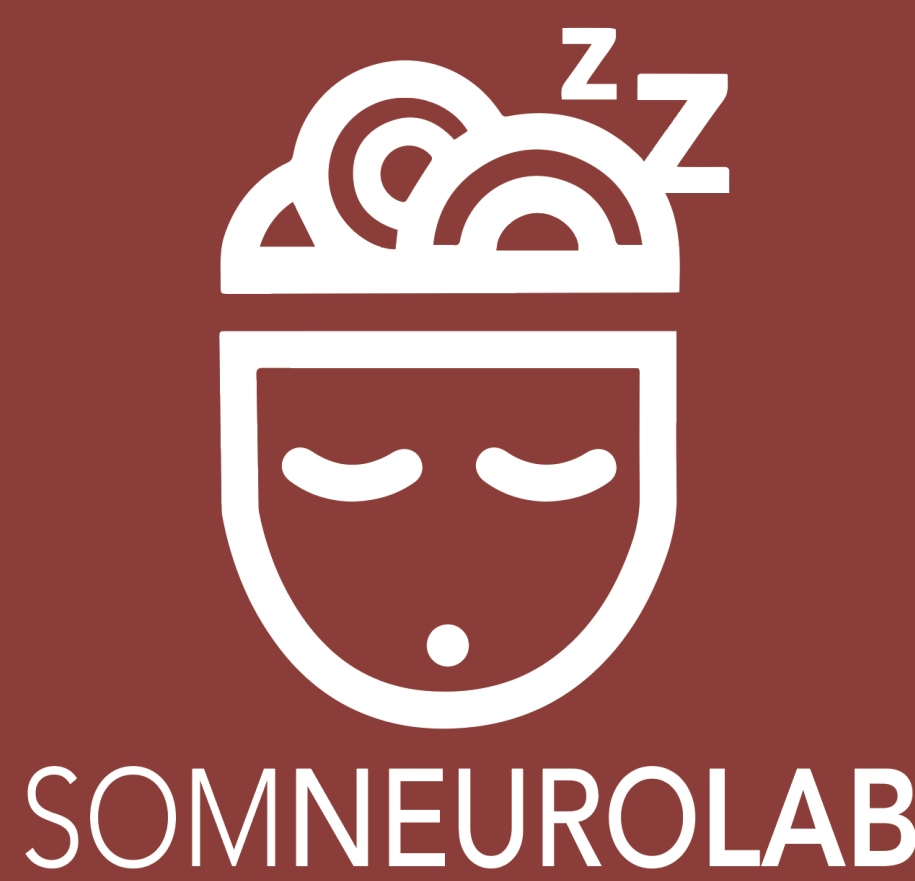




Corpus callosum white matter integrity and sleep EEG features are associated with young children’s current and later motor development

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Background

Sleep benefits motor learning, including in infants and children^{1,2}. In adolescents and adults, this benefit has been associated with sleep microstructures, such as spindles and slow oscillations in NREM sleep³⁻⁵.

Sleep has also been associated with motor development. Day and night sleep duration and nighttime wake episodes have been associated with fine and gross motor skills⁶⁻⁸. Sleep processes, such as twitching, support the development of motor cortical regions^{9,10}.

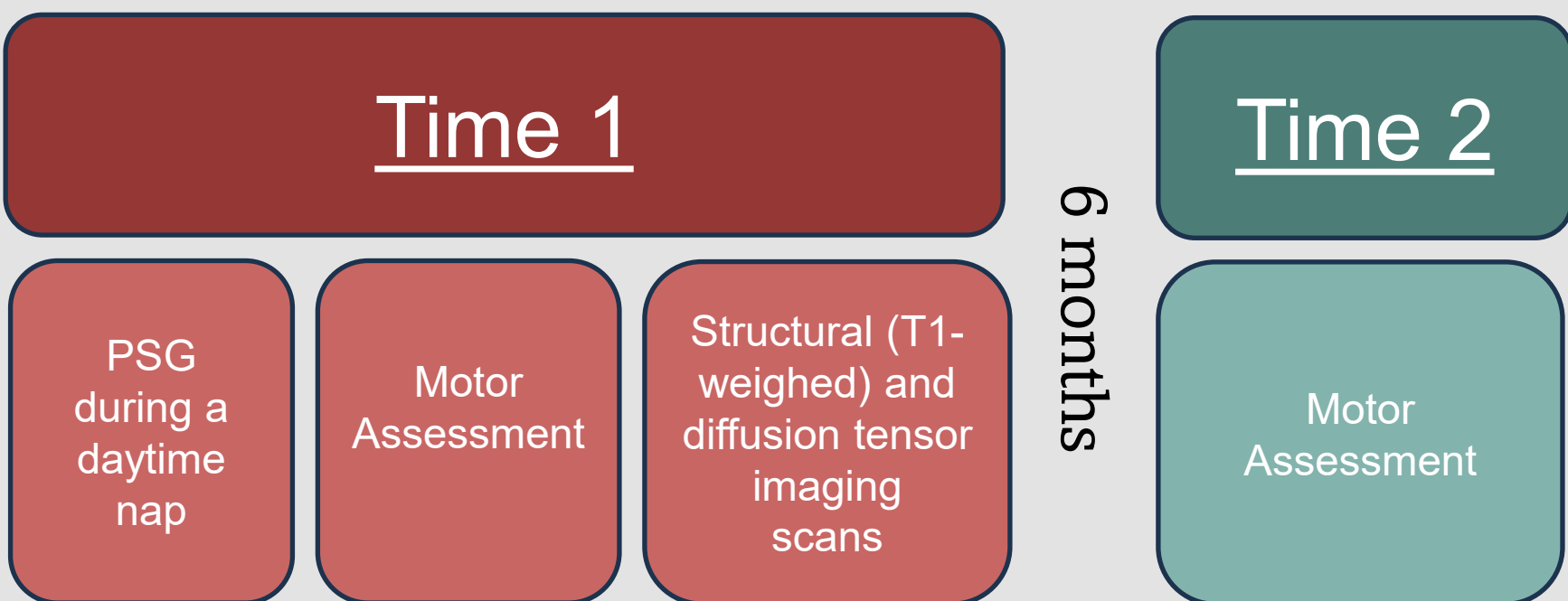
Sleep’s benefit on motor development may come from cumulative benefits of sleep microstructures on motor learning. Additionally or alternatively, sleep’s benefit on motor development may be the result of sleep-related development of brain regions critical to motor control.

Dissociating these roles requires longitudinal investigation of sleep, brain, and motor development. One longitudinal study found that spindle activity at 6-months is predictive of motor development when followed up at 1 and 2 years¹¹. Here we examined whether these relations held true in early childhood and whether they were dissociable from sleep-related brain development.

Methods

Data are from a larger ongoing study of sleep and memory. Participants were 51 children, 3-5 years (M age = 3.74 years; 29 F) who had useable polysomnography (n=35), structural (T1-weighted) and diffusion tensor imaging scans (n = 29), and motor assessments (n=49).

A subset of participants (n=24; 12 F) had follow-up motor assessments 6 months later.



Measures

Motor assessment: Movement Assessment Battery for Children (MABC-III) with Aiming & Catching, Balance & Locomotion, and Manual Dexterity subscales

Neuroimaging: Two regions of interest were included: the motor cortex and corpus callosum (CC) which each had 2 metrics (white matter volume and fractal anisotropy [FA]).

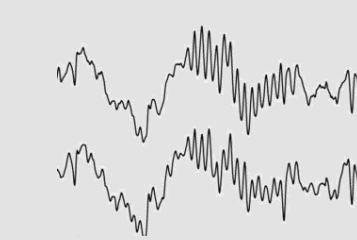
Polysomnography: Nap PSG included 14 or 32-channel EEG. Of interest was central spindle density (number per minute) and preferred coupling phase (alignment between coupled spindles and slow oscillations).

Analysis

We compared the fit of 2 linear models (sleep only vs. sleep + brain) to examine the amount of explained variance in concurrent and later MABC scores.

All predictors and outcomes were residualized to control for age and sex. Additionally, measures of brain volume control for total intracranial volume. MABC scores at Time 2 control for MABC scores at Time 1.

Sleep only model



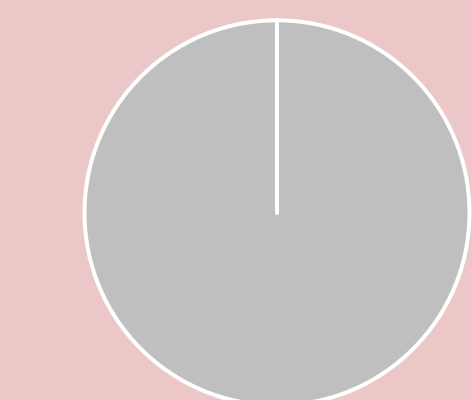
Sleep + brain model



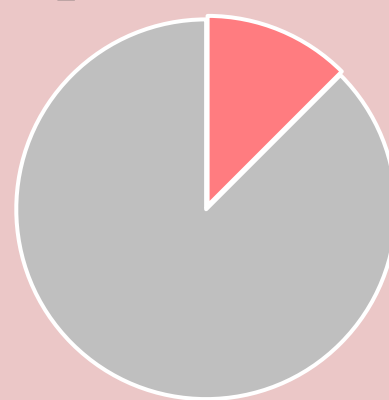
Results

The sleep and brain model was more predictive of concurrent motor scores with the impact of corpus callosum volume driving the effect.

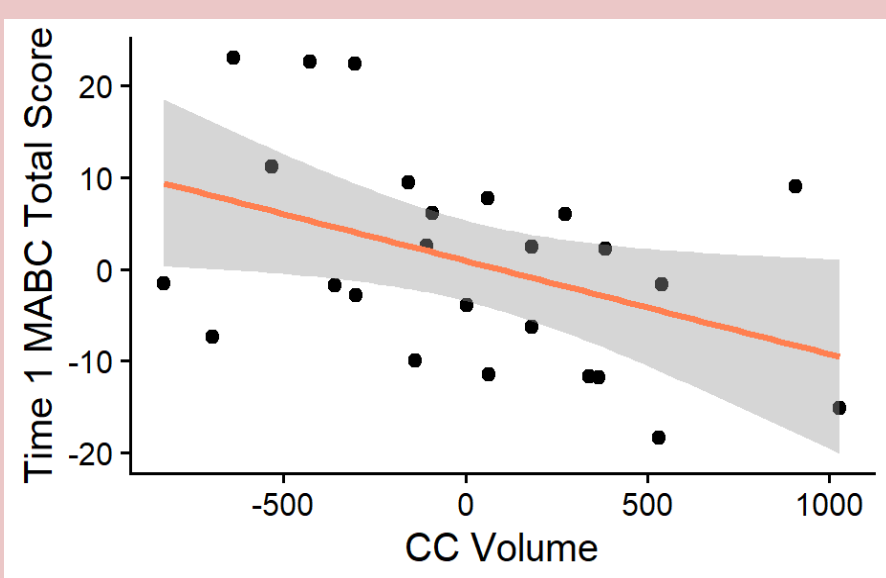
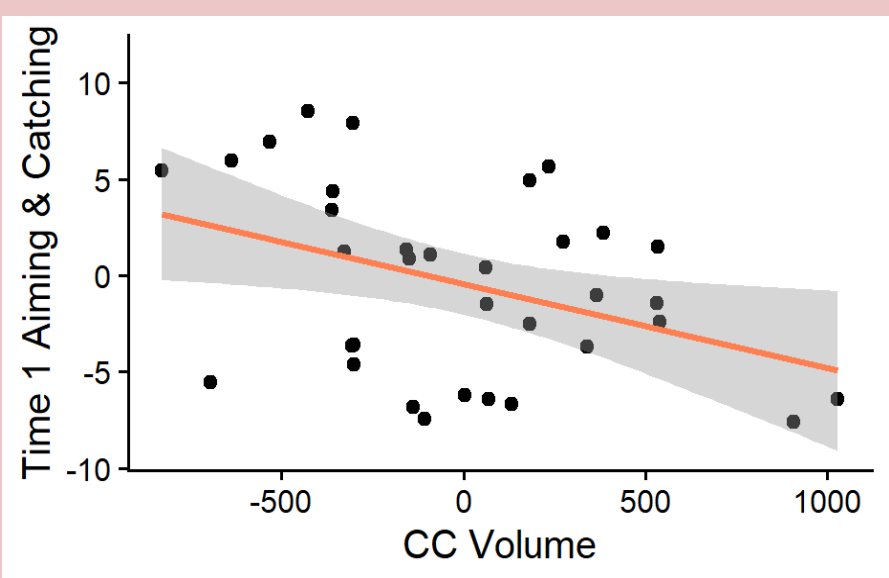
Sleep only model



Sleep + brain model



Explained variance
Unexplained variance

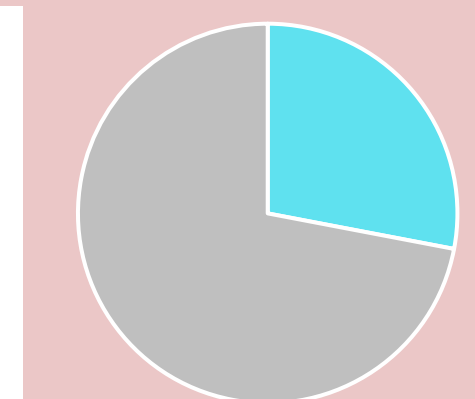


Time 1 MABC scores	Sleep only model (spindle density and preferred phase)	Sleep and brain model (spindle density, preferred phase, CC & motor volume and FA)
Aiming & Catching	Adj. R ² = -0.035, p = .6	Adj. R ² = 0.08, p = .3 Main effect of CC vol. (β = -.006, p = 0.03)
Balance & Locomotion	Adj. R ² = -0.08, p = .8	Adj. R ² = -0.06, p = .6
Manual Dexterity	Adj. R ² = -0.031, p = .6	Adj. R ² = -0.33, p = .9
Total MABC	Adj. R ² = -0.09, p = .8	Adj. R ² = 0.17, p = .2 Main effect of CC vol. (β = -.01, p = 0.04)

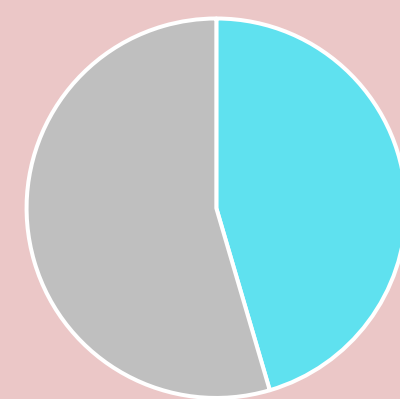
The sleep and brain model also accounted for more variance in later (+6 months) motor scores. Both corpus callosum volume and preferred phase of spindle-slow oscillation coupling had significant main effects.

Time 2 MABC scores	Sleep only model (spindle density and preferred phase)	Sleep and brain model (spindle density, preferred phase, CC & motor volume and FA)
Aiming & Catching	Adj. R ² = 0.02, p = .35	Adj. R ² = 0.44, p = .17 Main effect of CC vol. (β = -.005, p = 0.04)
Balance & Locomotion	Adj. R ² = 0.18, p = .3	Insufficient data
Manual Dexterity	Adj. R ² = 0.28, p = .056 Main effect of preferred phase (β = 1.84, p = 0.02)	Adj. R ² = 0.47, p = .11 Marginal effect of preferred phase (β = 0.007, p = 0.06) and CC vol. (β = 0.007, p = 0.06)
Total MABC	Adj. R ² = 0.16, p = .2	Insufficient data

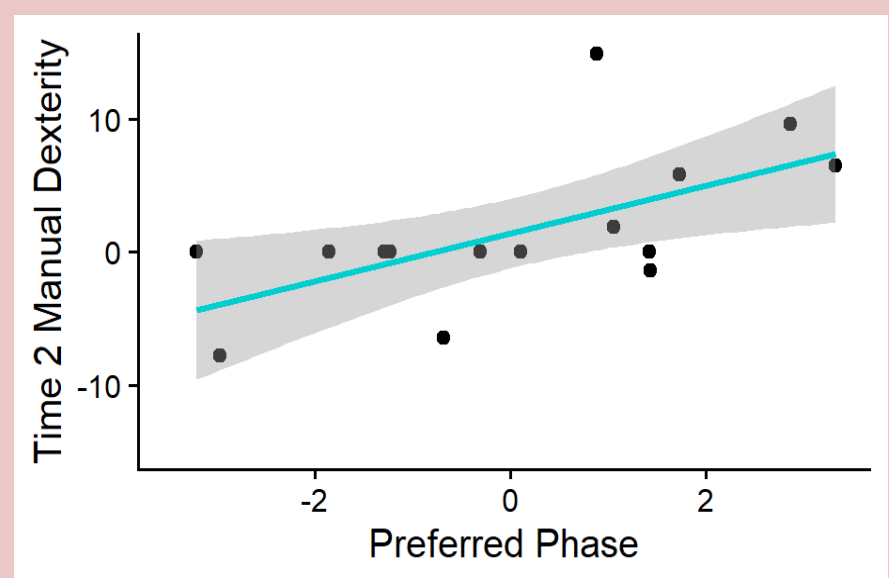
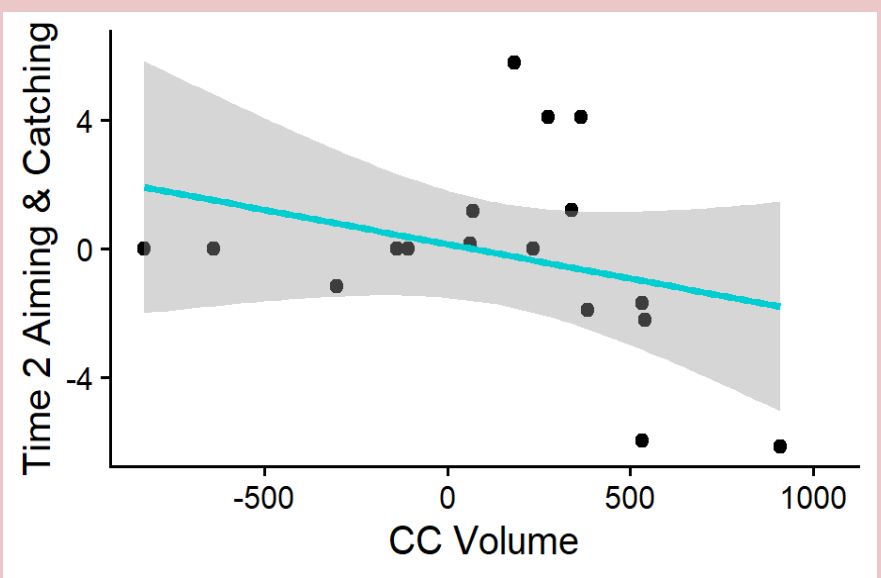
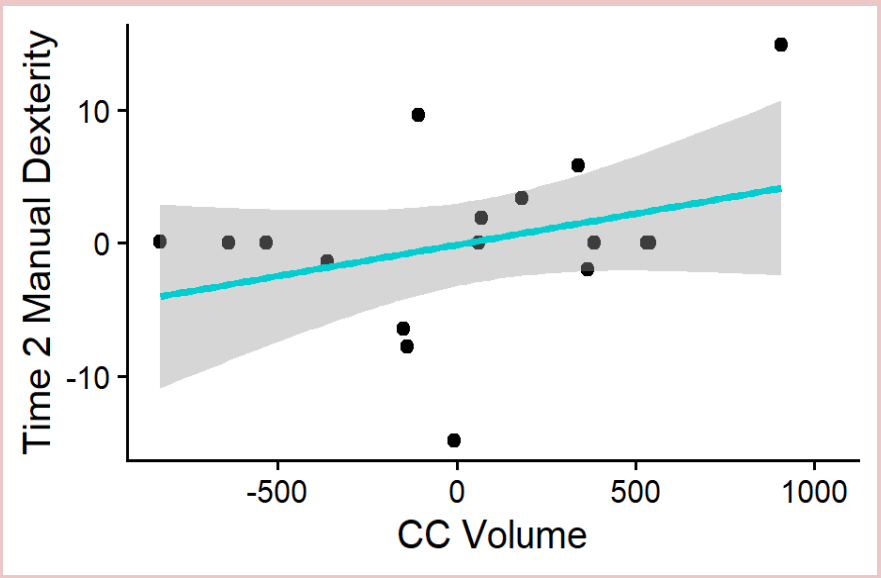
Sleep only model



Sleep + brain model



Explained variance
Unexplained variance



Conclusion

Results support the link between concurrent motor ability and neural maturation while sleep EEG features are more strongly related to later motor development.

Concurrent motor scores were negatively associated with CC white matter volume which may reflect neural pruning and more efficient interhemispheric connectivity.

Accounting for ability at Time 1, later motor scores were predicted by the sleep and brain model, specifically sleep microstructures (coupling of spindles and slow oscillations) and CC volume.

The unique relations between MABC subscales, sleep, and white matter suggest distinct mechanistic pathways for fine, gross, and visuomotor skills or nonlinear developmental trajectories.

Limitations include missingness and less Time 2 data which temper the generalizability of the data. Additionally, PSG was only collected from naps.

Taken together, these exploratory analyses posit that there is a cumulative impact of sleep on motor development which works in tandem with the development of brain regions critical to motor control.

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