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Brain Structure-Function Coupling in Female Roller Derby Athletes

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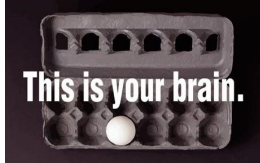
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This is your brain.

Contact & collision sports ↑ risk of concussion

Mechanical loading of the head accelerates brain aging independent of concussion

This is your aging brain on contact & collision sports


???

Neuroimaging studies characterize the natural history of concussion in collegiate athletes

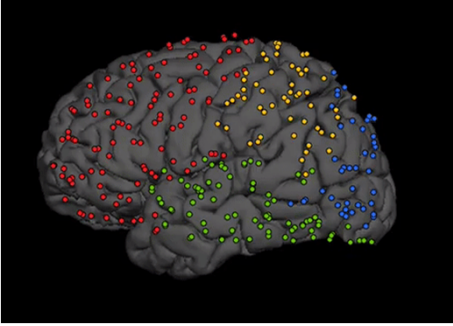
Neuroimaging studies of (sub)concussion do not include female athletes

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The Human Brain is a Complex Network



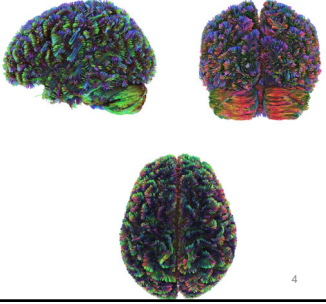
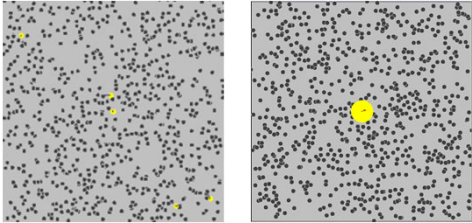
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Brain Structure

White matter pathways can be inferred from water diffusion

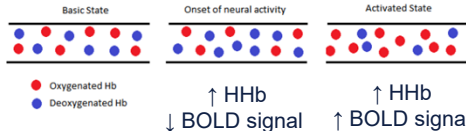
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Brain Function

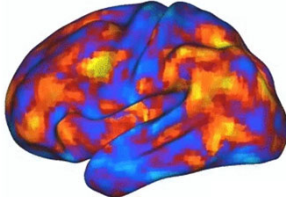
Blood Oxygen Level Dependent (BOLD) Signal is a surrogate measure of neuronal activity

Basic State Onset of neural activity Activated State



● Oxygenated Hb
● Deoxygenated Hb

↓ BOLD signal ↑ BOLD signal

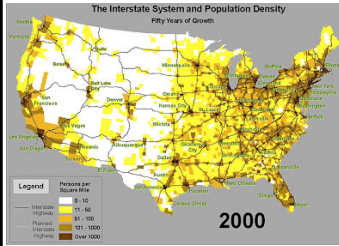


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Structure-Function Coupling



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Functional connectivity is only partially supported and constrained by the underlying white matter structure

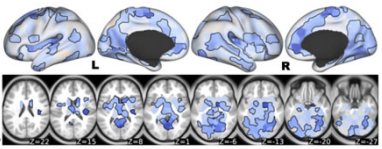
Structure-function coupling may be more sensitive to effects of aging than constituent parts Zimmerman 2016 *Human Brain Mapping*

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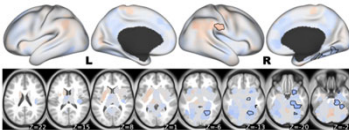
Structure-Function Coupling in Aging



Aging = ↓ Structure-Function coupling
Blue indicates decreased coupling

Sex-specific trajectories

Blue indicates ↑ structure-function coupling in females
Red indicates ↑ structure-function coupling in males



Gu (2020). Regional structural-functional connectome coupling is heritable and associated with age, sex and cognition in adults. *bioRxiv*.

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Participants

Roller Derby		Controls	
Age (Years)	Age (Years)	Sport History (Current Participation*)	
23	19	Track, Soccer, Volleyball	
24	20	Volleyball, Track	
24	21	Gymnastics	
26	21	Badminton, Swimming, Tennis	
26	21	Tennis, Taekwondo, Soccer	
27	22	Soccer	
28	22	Volleyball*, Tennis	
29	22	Track, Volleyball*	
30	23	Cheerleading, Volleyball, Track	
31	25	Dance, Competitive Cheer	
32	25	No	
32	26	Basketball	
35	29	Tennis, Lacrosse, Softball, Cheerleading	
35	49	Soccer, Field Hockey, Basketball, Lacrosse, Softball	
36			
40			
41			
41			
45			

Roller derby (RD) athletes
n = 19
23-45 y.o. (M = 32.1 y.o.)
No mTBI during brain imaging

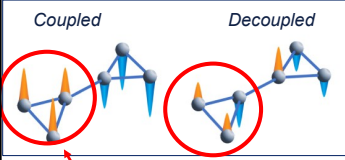
Control Participants
n = 14
20-49 y.o. (M = 24.6 y.o.)
Not currently engaged in contact or collision sports
No mTBI in previous 3 yrs

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Methods: Graph Signal Processing



Consider each grey ball as a Twitter user
 'Followers' are designated by a blue line
 Consider their signal (+/-) as a tweet in favor of or against
 Taco Tuesday as a National Holiday

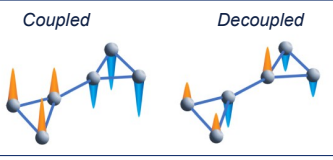
Opinions are coupled to the underlying social network structure | Opinions are decoupled from the underlying social network structure

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Methods: Graph Signal Processing



Each grey ball is a cortical area
 Blue lines represent monosynaptic, white matter pathways
 The BOLD signal fluctuates (+/-) and is thus coupled to or decoupled from the underlying structure at each time

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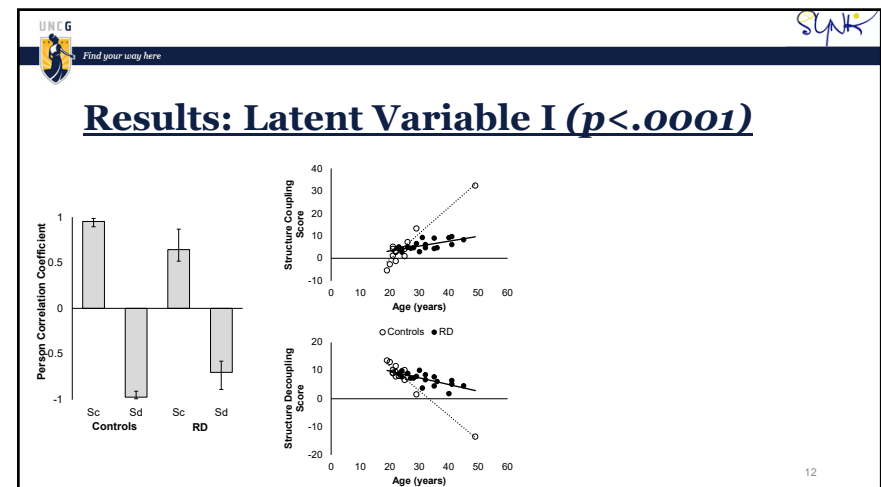
Research Questions

1. Are there patterns of structure coupling/decoupling that predict age differently between RD & controls?
2. What are the brain areas (& networks) that contribute to these patterns?

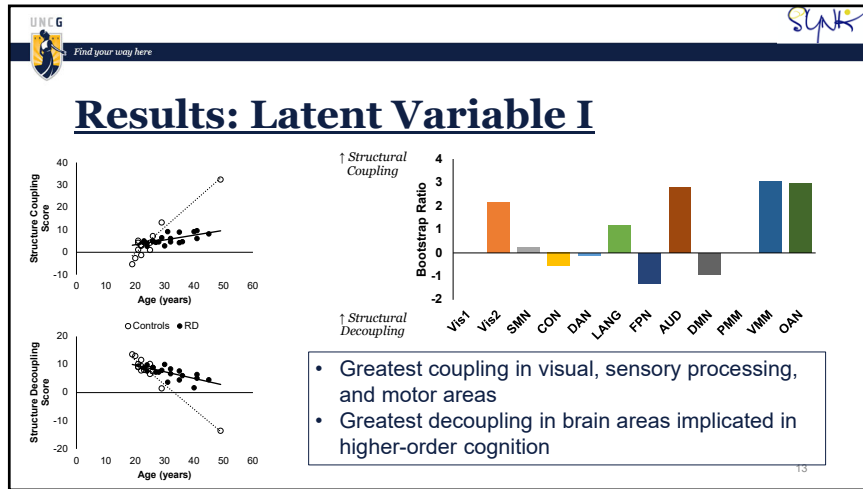
Partial Least Squares Correlation
 Non-parametric: Permutations & bootstrap resampling
 Like Principal Component Analysis or Canonical Correlation

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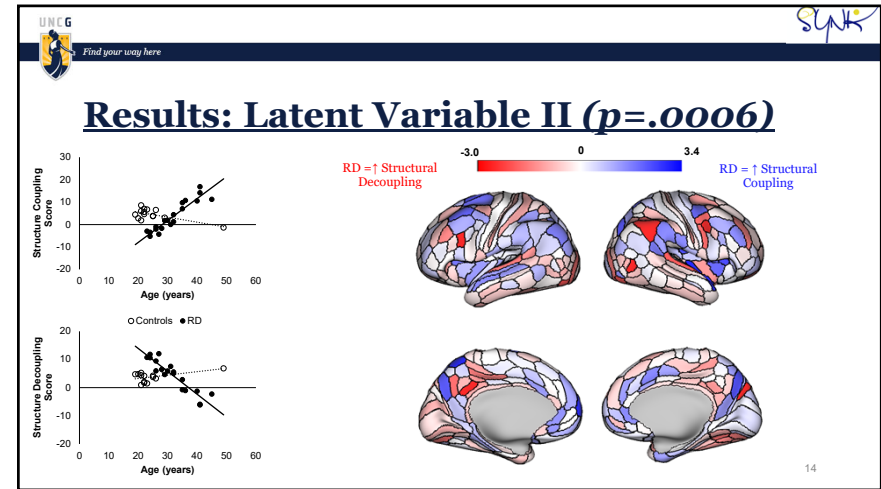
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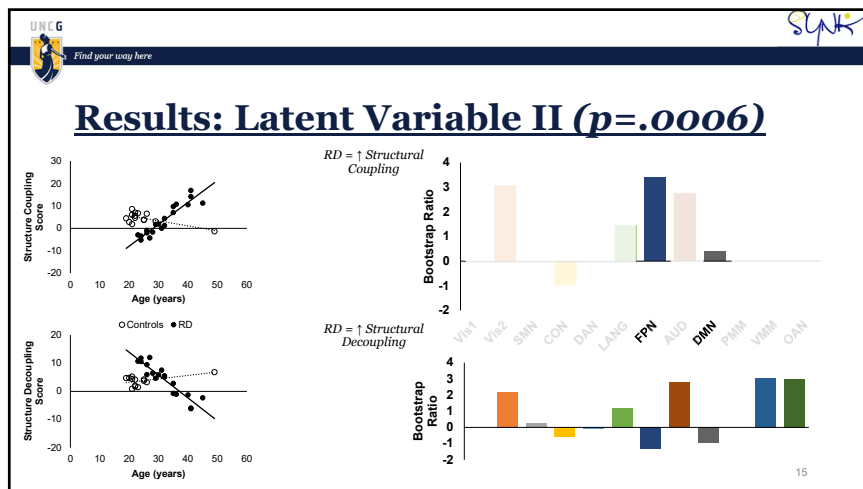
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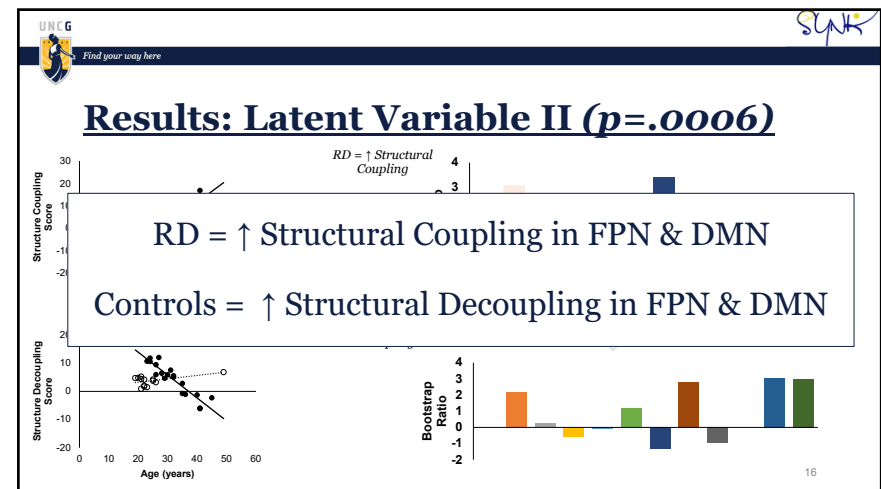
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Increased Structure Coupling in the FPN & DMN

Structural Coupling in FPN & DMN: RD > Controls

Decreased BOLD variability related to declining cognition (n = 422, 43-89 y.o.) Millar 2020, Cerebral Cortex

Desegregation of brain networks is common in aging SXXX

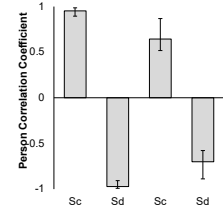
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Increased Structure Coupling in the FPN & DMN

Structural Decoupling in FPN & DMN: RD ~ Controls (LV1)



LV1 = **aCC**, **mOFC**, **SgCC**, and **DLPFC** appear throughout the exercise literature

LV2 = **iPC** and **IOFC** exhibit faster rates of thinning in those with a history of mTBI Santhanam 2019 Brain & Behavior

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Questions?

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Methods: PLS-Correlation

Structure-Function Coupling in Each Brain Area (66 x 360 Matrix)

Age (66 x 1 Vector)

360 Brain Areas (180 per Hemisphere)

Controls (n = 14)	BRAIN _{SC}	X	AGE	→	Brain x Age Correlation (2 x 360 Matrix) BRAIN _{SC} x AGE CORRELATION BRAIN _{SD} x AGE CORRELATION
RD (n = 19)	BRAIN _{SC}				
Controls (n = 14)	BRAIN _{SD}				
RD (n = 19)	BRAIN _{SD}				

↓

SVD decomposes this matrix to latent variables

Treated as a different 'Task' or a Repeated Measure
Data permuted within task across groups

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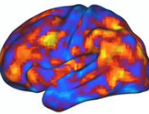
'Resting-State' Brain Function

Most of the brain's energy consumption is used at rest

Spatiotemporal patterns in spontaneous fluctuations of the BOLD signal can be decomposed into networks

These networks represent the brain's functional organization

Finger Tapping

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There are s/g behavior differences

Can we find areas/circuits that are different to explain behavioral differences?

Total brain volume is different between males and females (Cohen's $d = .80$) and most structural/functional differences do not survive correction for TBV

"If 'real', then they like sex differences in gene-phenotype interactions: very small, thus only revealed through studies of large samples, and explaining very little variance"

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Dump the "dimorphism": Comprehensive synthesis of human brain studies reveals few male-female differences beyond size

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