Using quantitative methods to support novel research hypotheses

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Quantitative Cognitive Neuroscience

- Intersection of methodological development in cognitive neuroscience and applied psychometrics
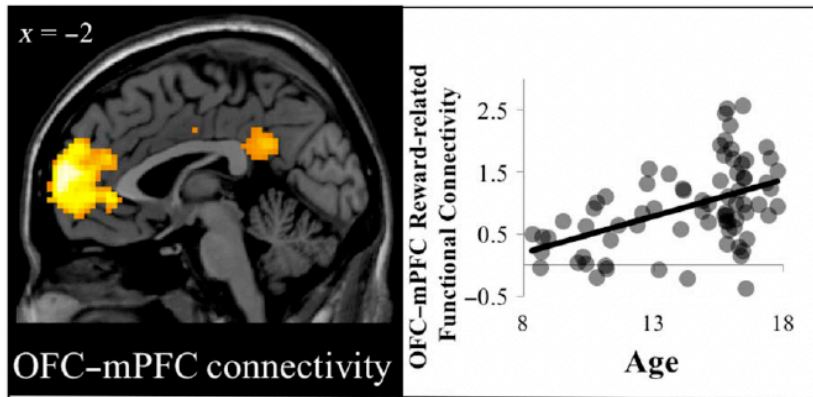
Quantitative Cognitive Neuroscience

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- Motivated from substantive research but foundationally interested in quantitative methods
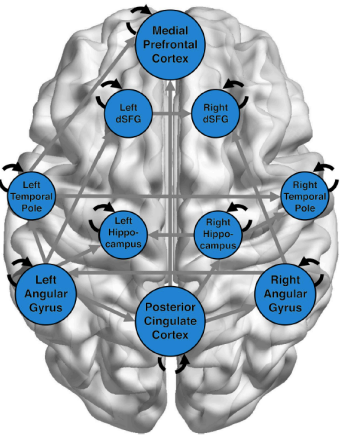 - Measurement and modeling of change over time

Quantitative Cognitive Neuroscience

- Intersection of methodological development in cognitive neuroscience and applied psychometrics

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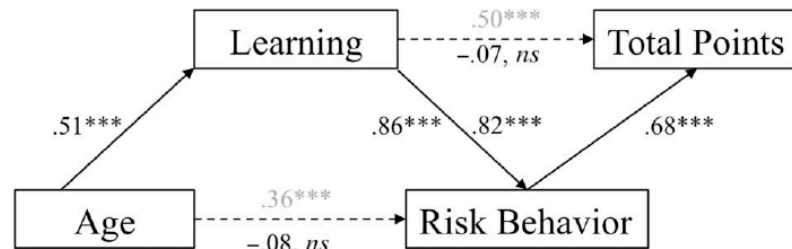- Structure of the talk: motivation, two examples, and future plans

Motivating Quantitative Cognitive Neuroscience

Longitudinal/Psychometric are methods still rare in cognitive neuroscience

Early projects using longitudinal models of learning (McCormick & Telzer, 2017a; b; 2018a; b) sparked an interest in quantitative methods

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Established collaborations with top quantitative methods researchers in the field
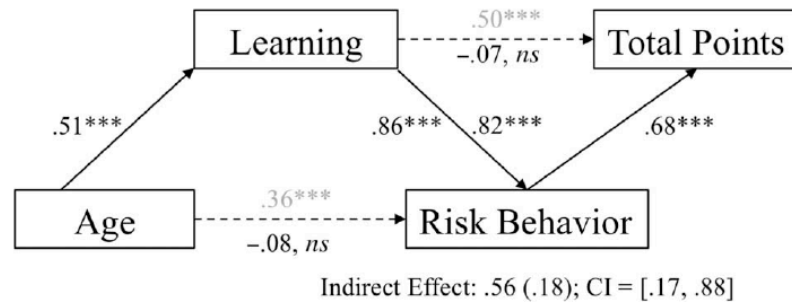
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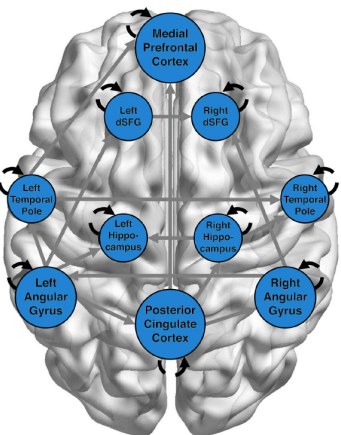
Established collaborations with top quantitative methods researchers in the field
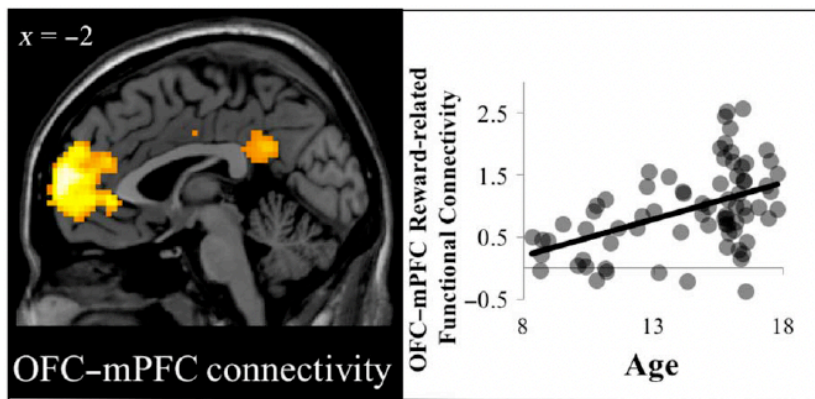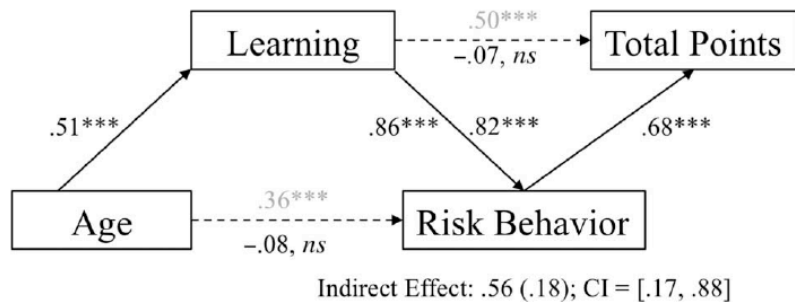

Use methods development to enable more theoretically-driven applied research (2 examples)
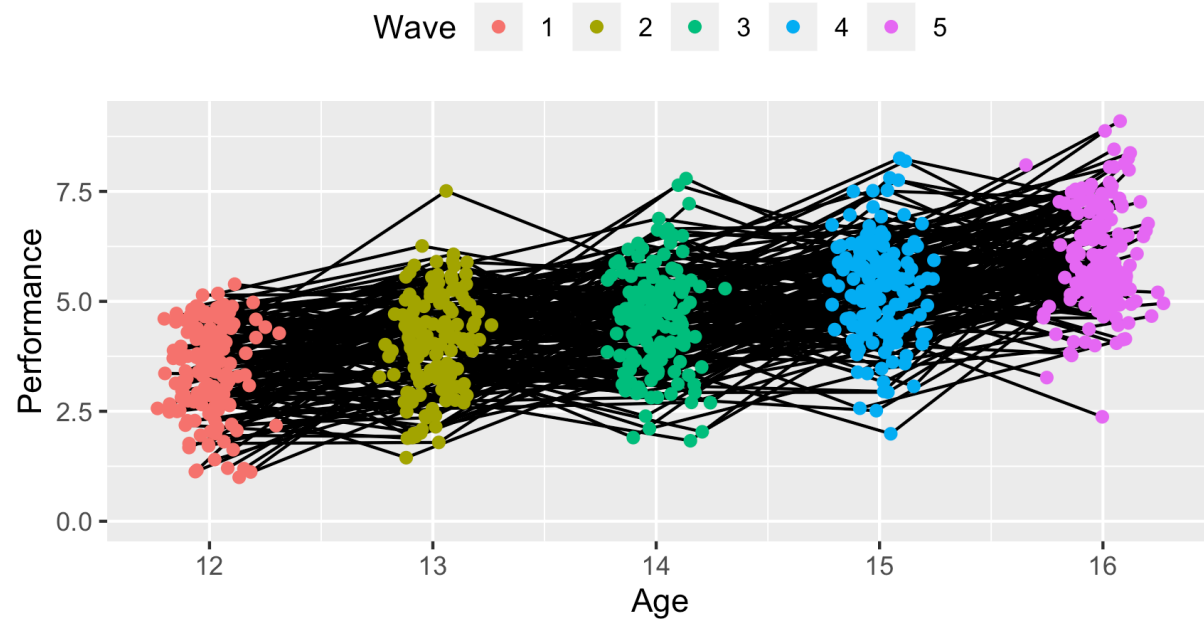
Example #1: Modeling Simultaneous Growth Processes

McCormick, E.M. (2021). Multi-Level Multi-Growth Models: New opportunities for addressing developmental theory using advanced longitudinal designs with planned missingness. *Developmental Cognitive Neuroscience, 51*, 101001.
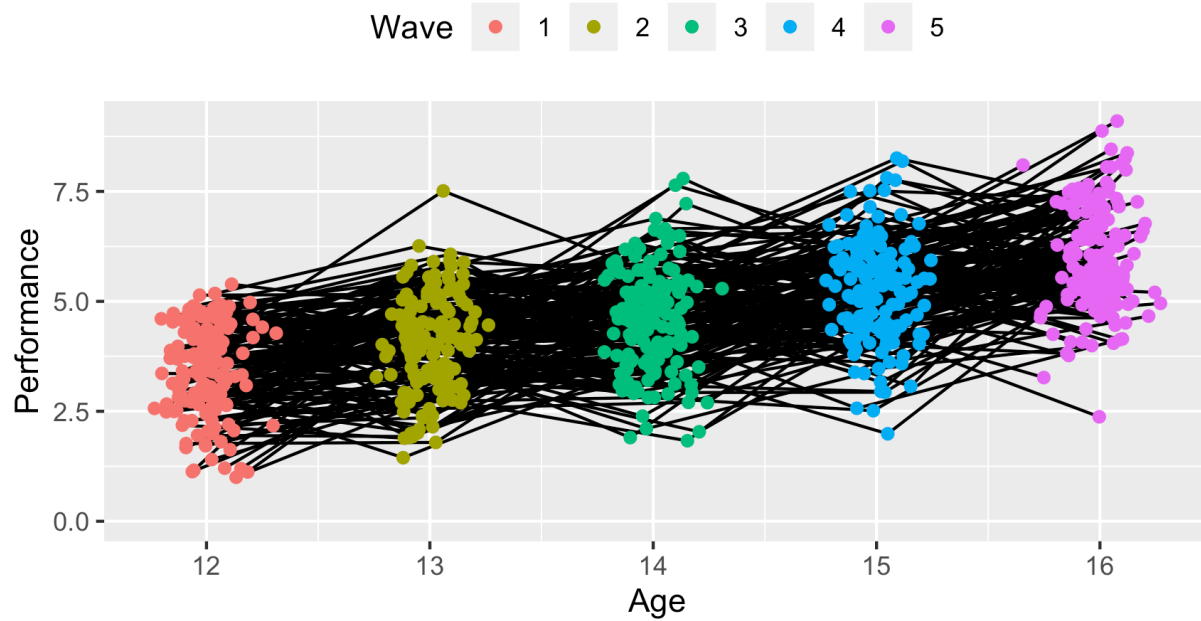
Multiple reasons individuals show change over time

A.

McCormick, 2021

Cohort Studies make it impossible to simultaneously model age + retest

A.

Estimated Effects for Growth Models from Scenario Set 1: Additive Effects.

	Cohort Design					
	Mean Est.	Std. Err.	Min	Max	Std. Bias	Prop. Sig.(adj.)
Additive Effects						
ρ_{growth}	.998	.000	.997	.998		
VIF	202.2	10.7	169.2	238.8		

14.2x larger SEs

McCormick, 2021

Parameter instability in cohort designs make sample estimates unreliable

A.
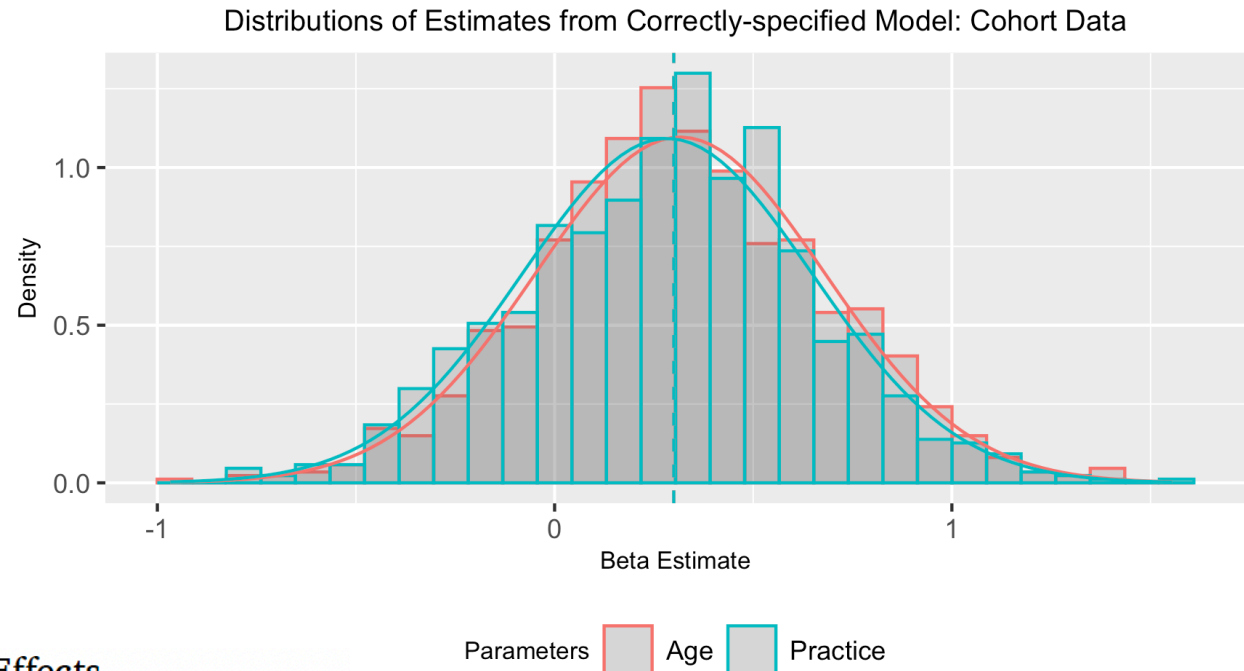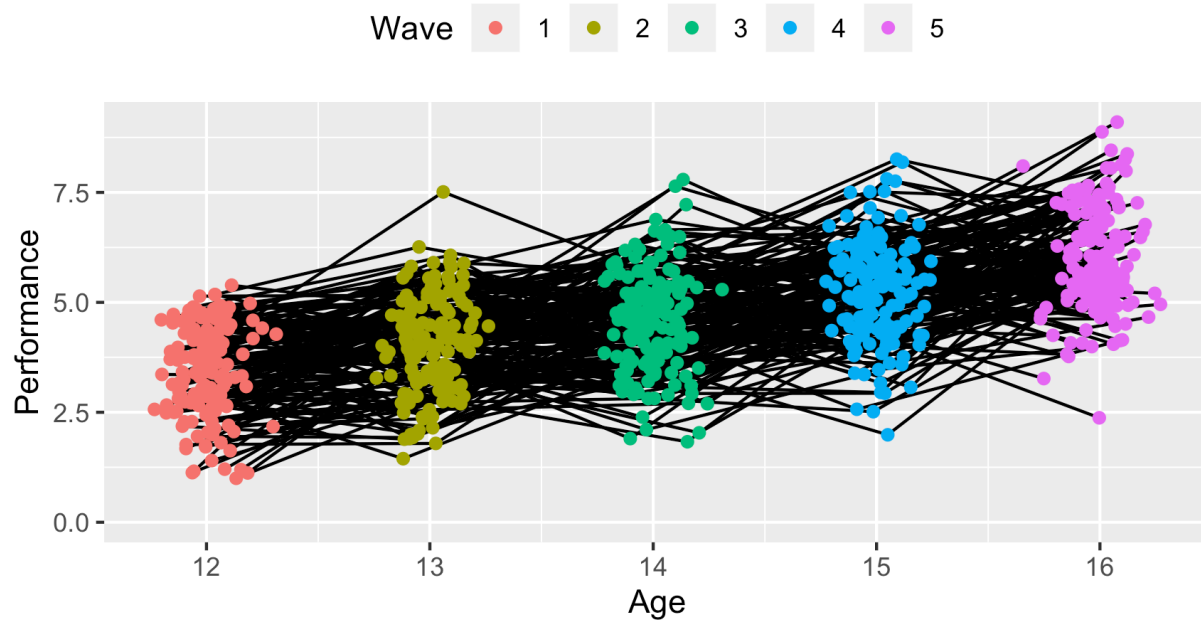
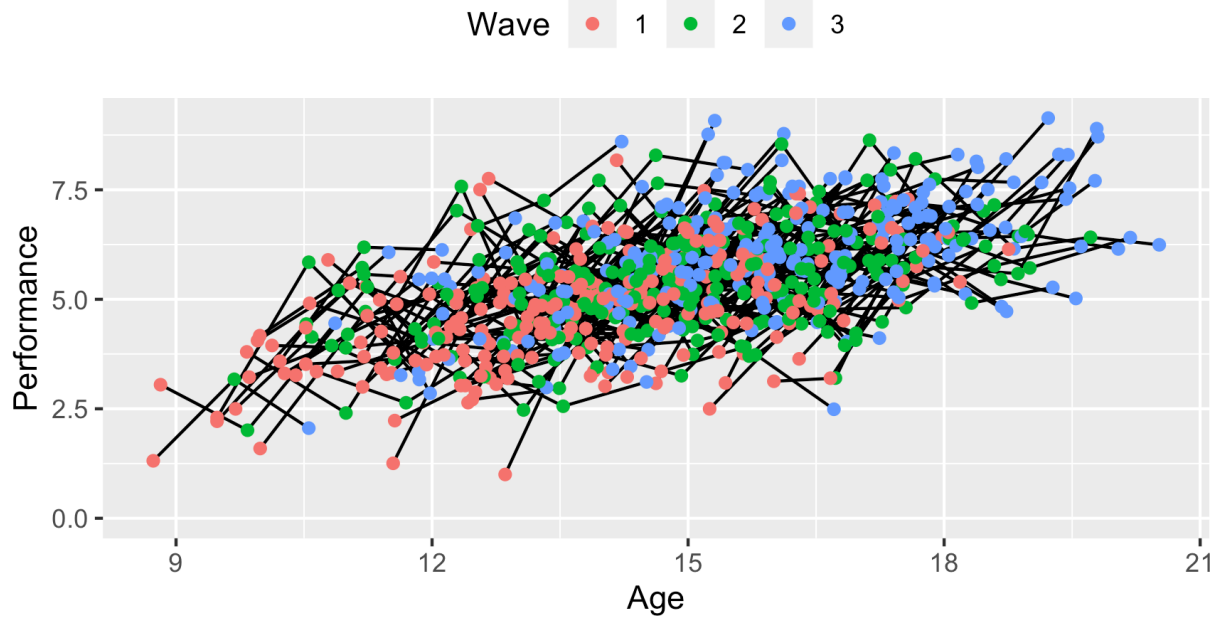Estimated Effects for Growth Models from Scenario Set 1: Additive Effects.

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True Effect = 0.3
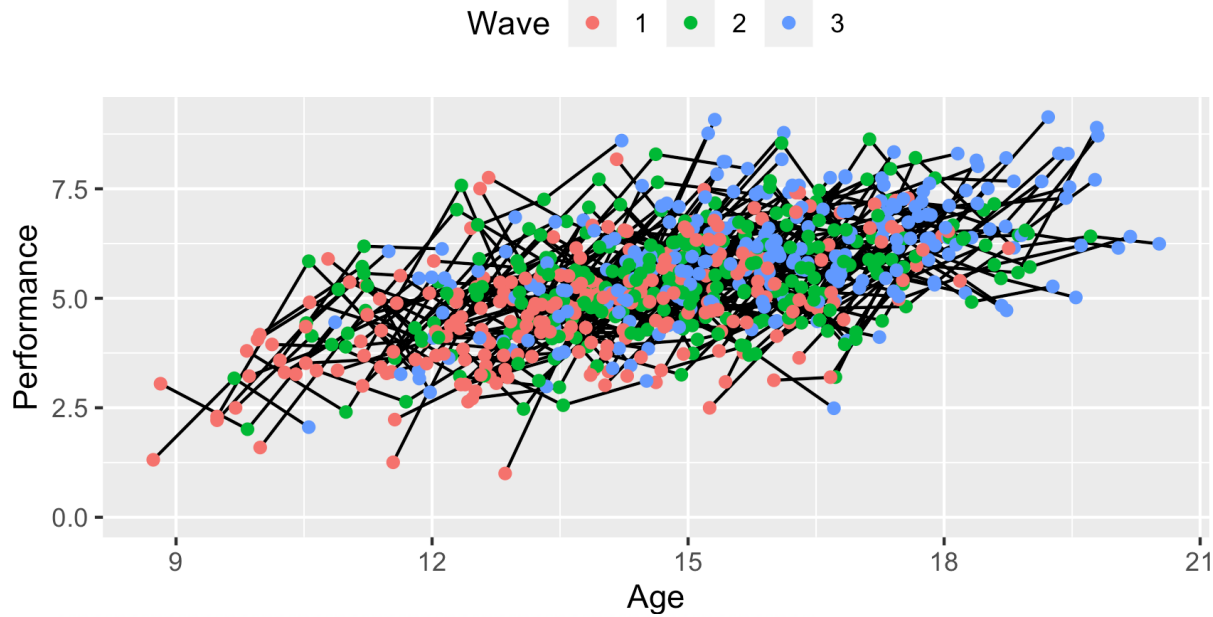Effect Estimate Range: -1 to +1.5

McCormick, 2021

I distinguished maturation and practice using missing data designs

B.

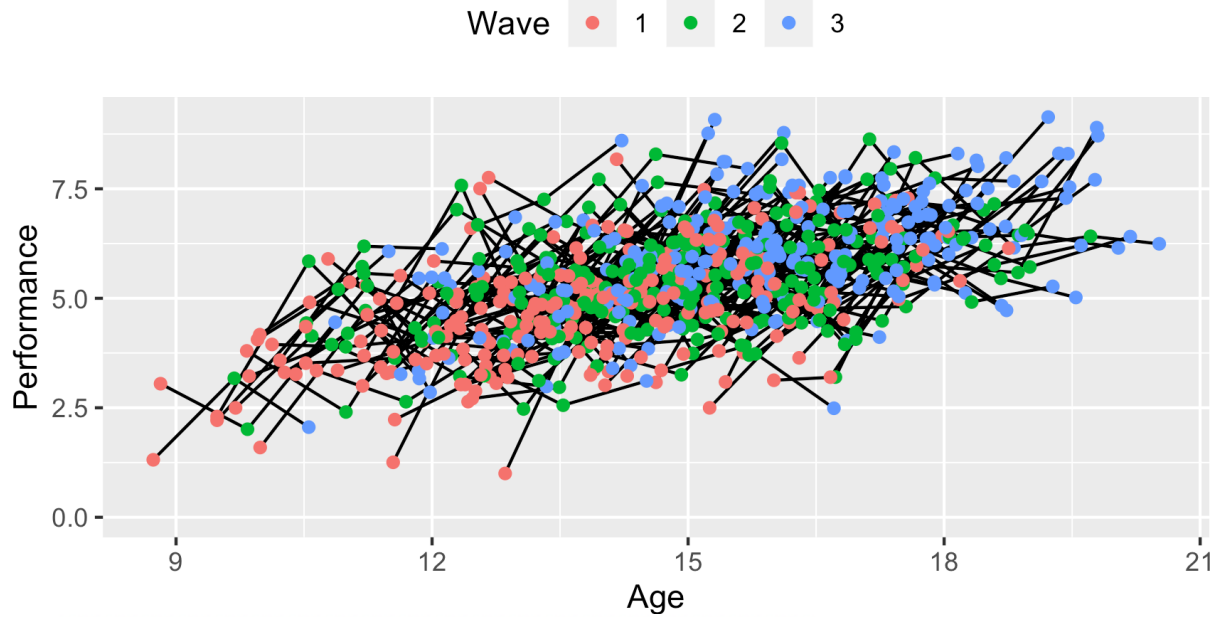# I distinguished maturation and practice using missing data designs

B.

Accelerated Design			
Mean Est.	Std. Err.	Min	Max
.379	.015	.338	.434
1.17	.016	1.13	1.23

1.03x larger SEs

McCormick, 2021

I distinguished maturation and practice using missing data designs

B.

Wave ● 1 ● 2 ● 3

Accelerated Design

Mean Est.	Std. Err.	Min	Max
.379	.015	.338	.434
1.17	.016	1.13	1.23

1.03x larger SEs

Distributions of Estimates from Correctly-specified Model: Accelerated Data
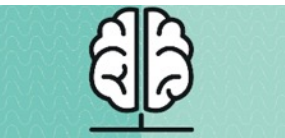
Parameters ▢ Age ▢ Practice
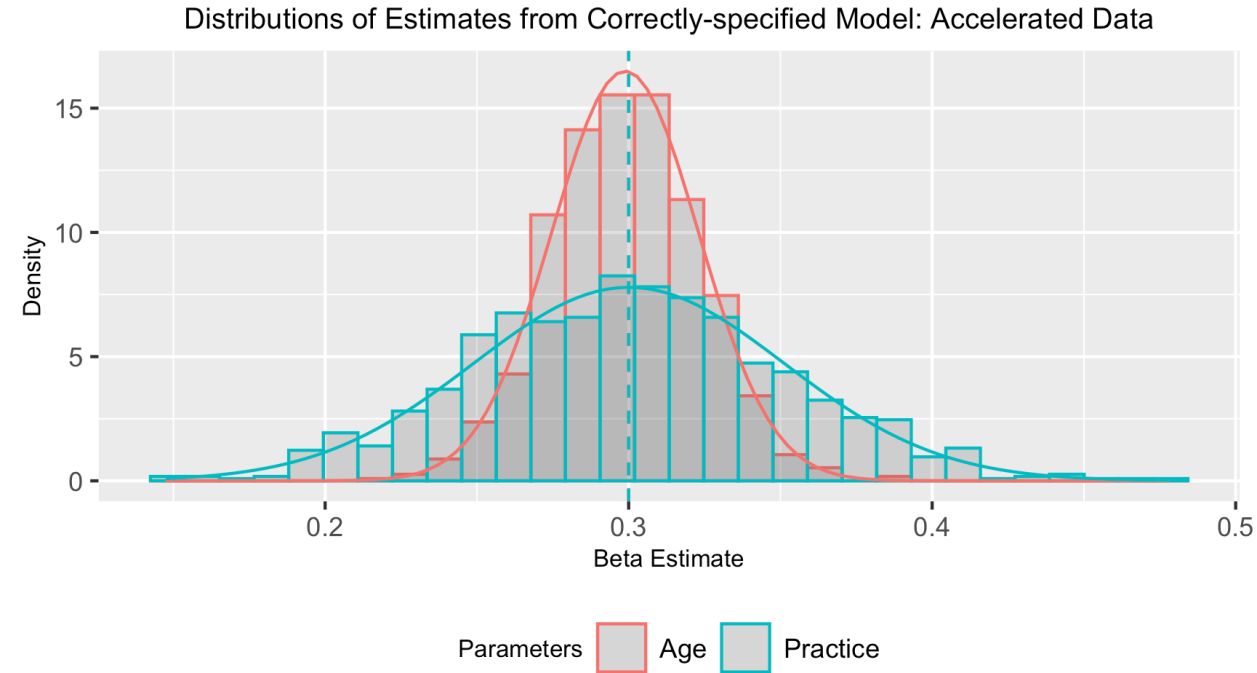
Effect Estimate Range: 0.15 to 0.45

Using missing data designs should be used to investigate multiple causal factors in longitudinal studies and their interactions
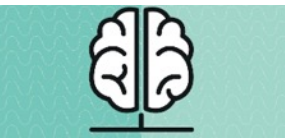
$$Learning\ Rate_{ij}$$
$$= \gamma_{00} + \gamma_{30} Wave_{ij} + \gamma_{40} Age_{ij} + \gamma_{50} Age_j^2 + \gamma_{120} Wave_{ij}$$
$$* Age_{ij} + \gamma_{130} Wave_{ij} * Age_{ij}^2 + u_{0j} + r_{ij}$$

McCormick, Peters, Crone, & Telzer, 2021

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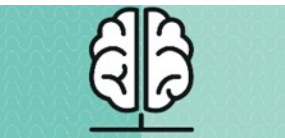
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McCormick, Peters, Crone, & Telzer, 2021

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Additional exposure to the task boosted performance relative to naïve participants, especially following adolescence
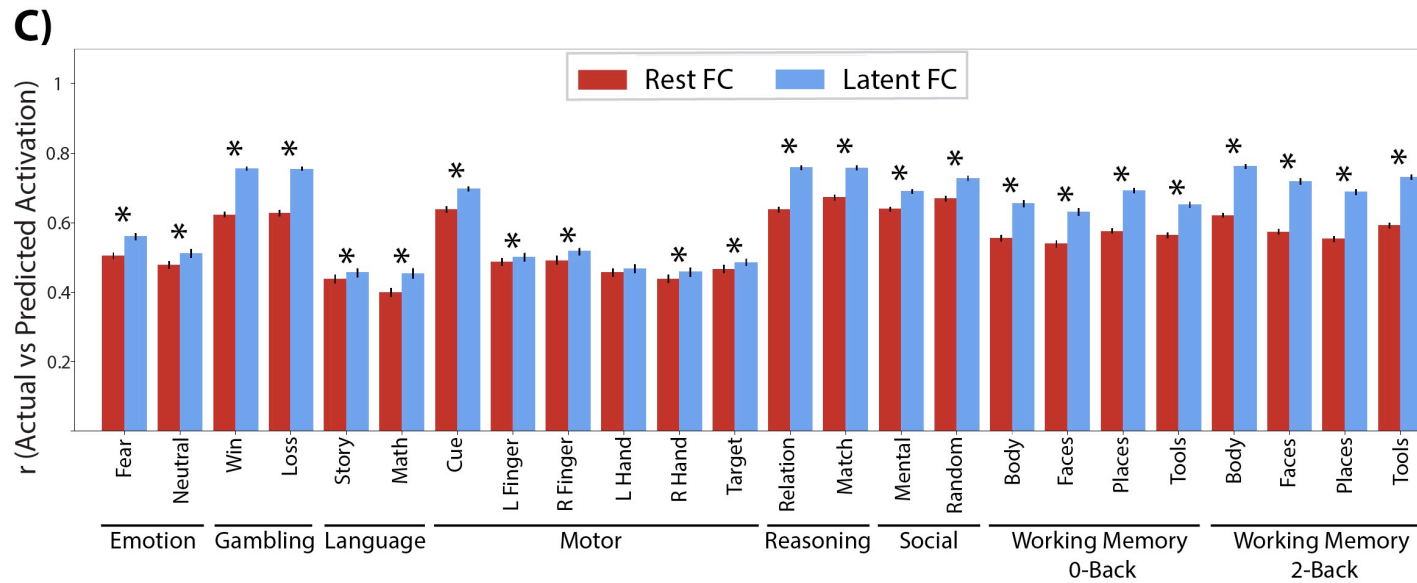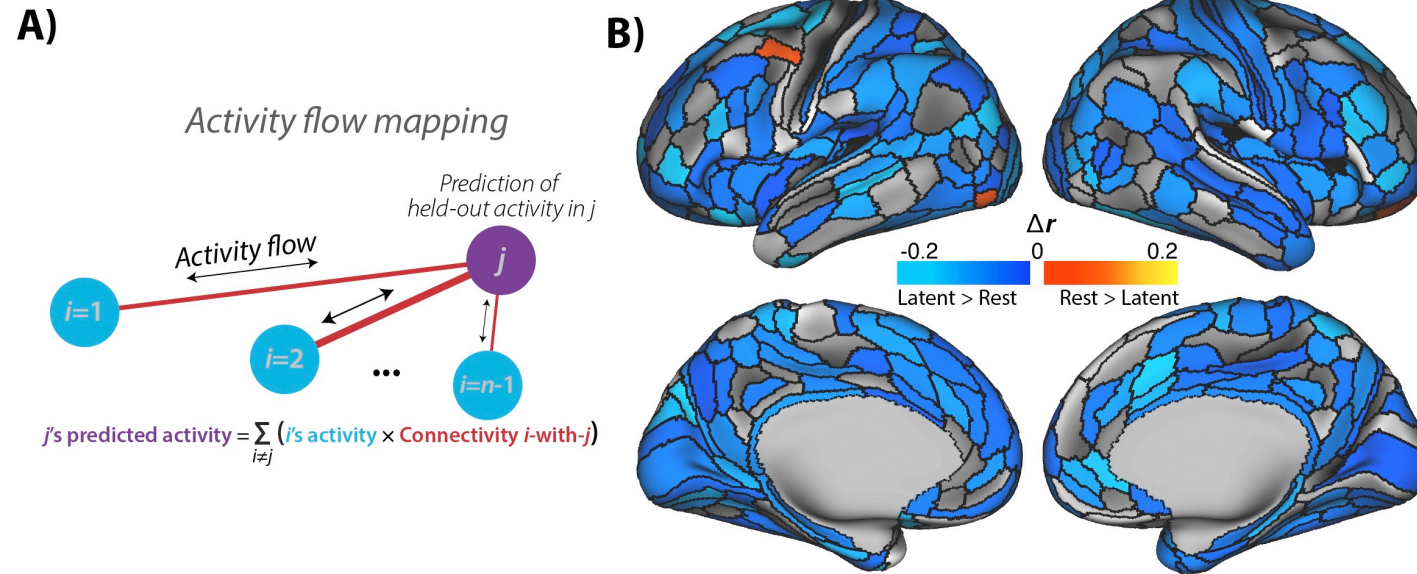
Age * Experience Model

Experience Moderates the Effects of Age on Learning Performance
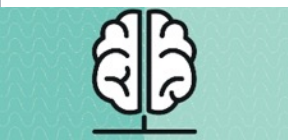
These effects are invisible unless we combine the right study design with new modeling approaches!

McCormick, Peters, Crone, & Telzer, 2021

Example #2: Psychometric Approach to "Intrinsic" Functional Connectivity

Psychometric approaches can model common variance across many brain states
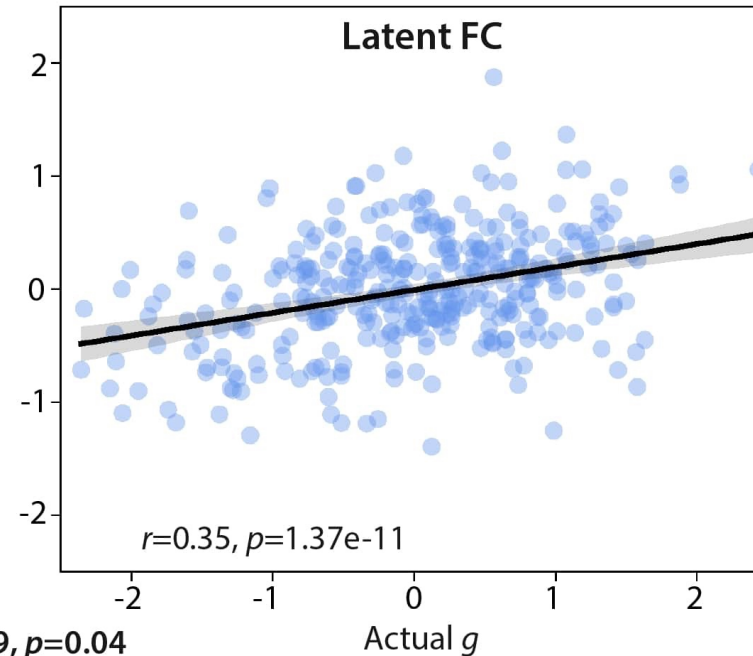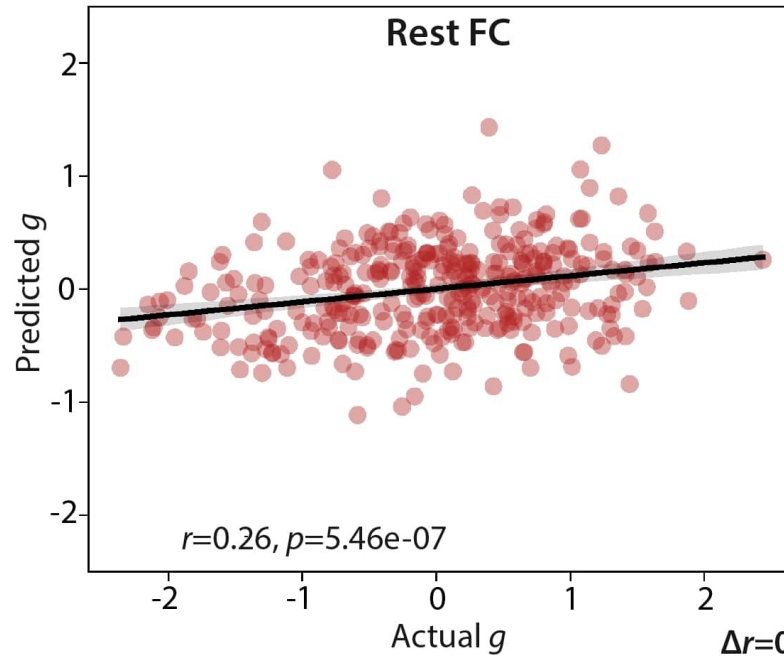

Latent FC

McCormick, Arnemann, Ito, Hanson, & Cole, 2022
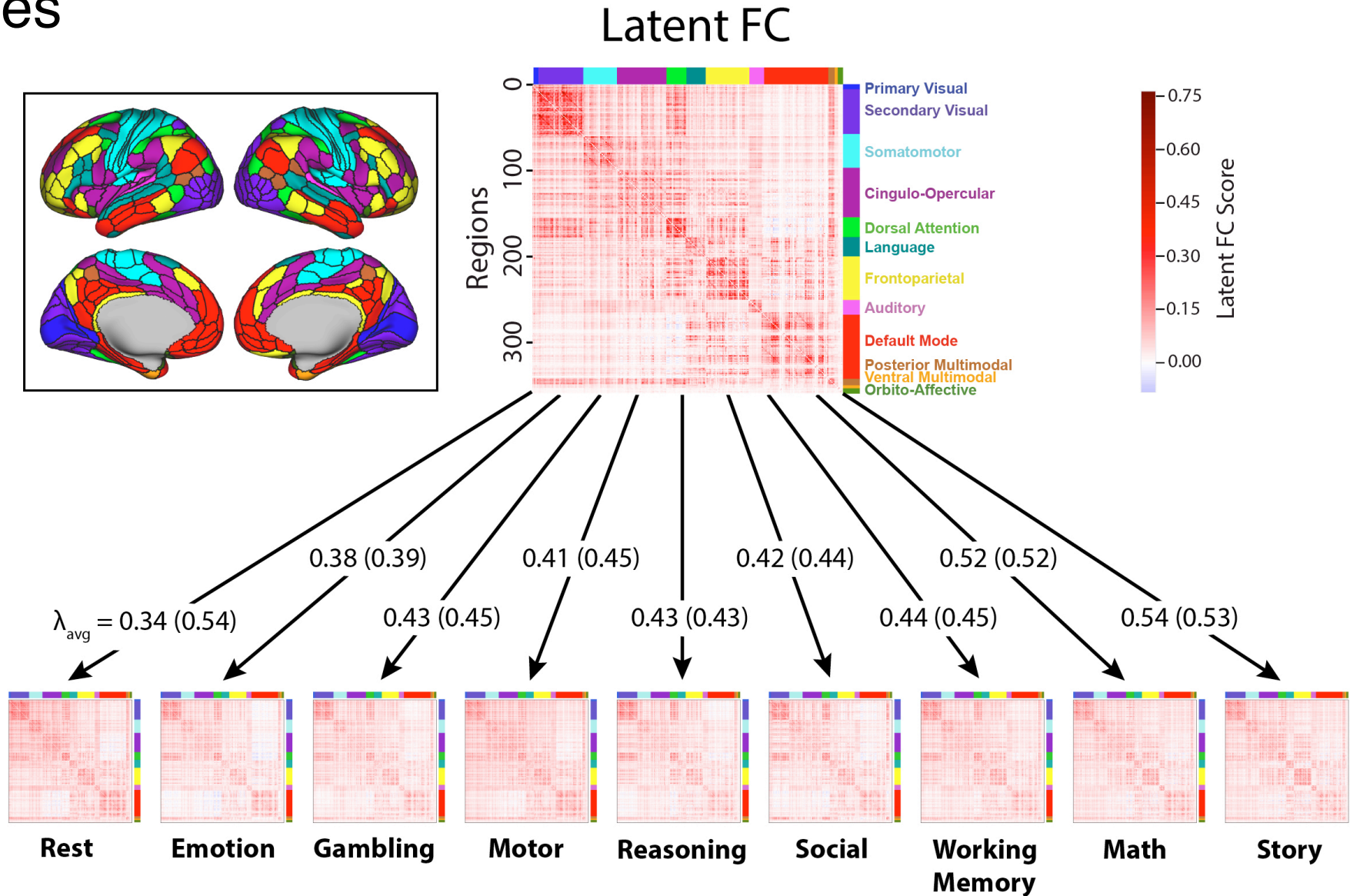
Latent FC predicts held out brain regions better than resting state FC

McCormick, Arnemann, Ito, Hanson, & Cole, 2022

Latent FC also better predicts an external measure of generalized intelligence (which is itself a factor model)

A) Full Sample

Rest FC: $r=0.26$, $p=5.46e{-}07$, $R^2= 0.067$

Latent FC: $r=0.35$, $p=1.37e{-}11$, $R^2= 0.123$

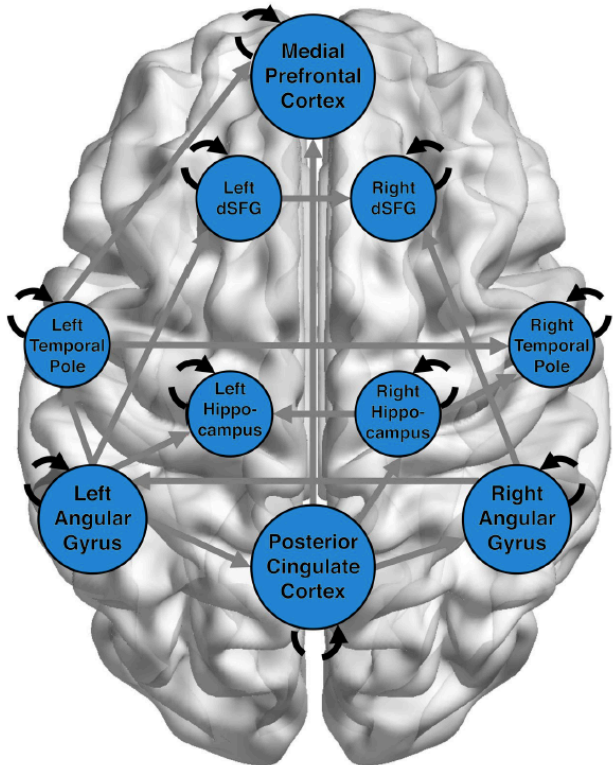$\Delta r=0.09$, $p=0.04$

McCormick, Arnemann, Ito, Hanson, & Cole, 2022
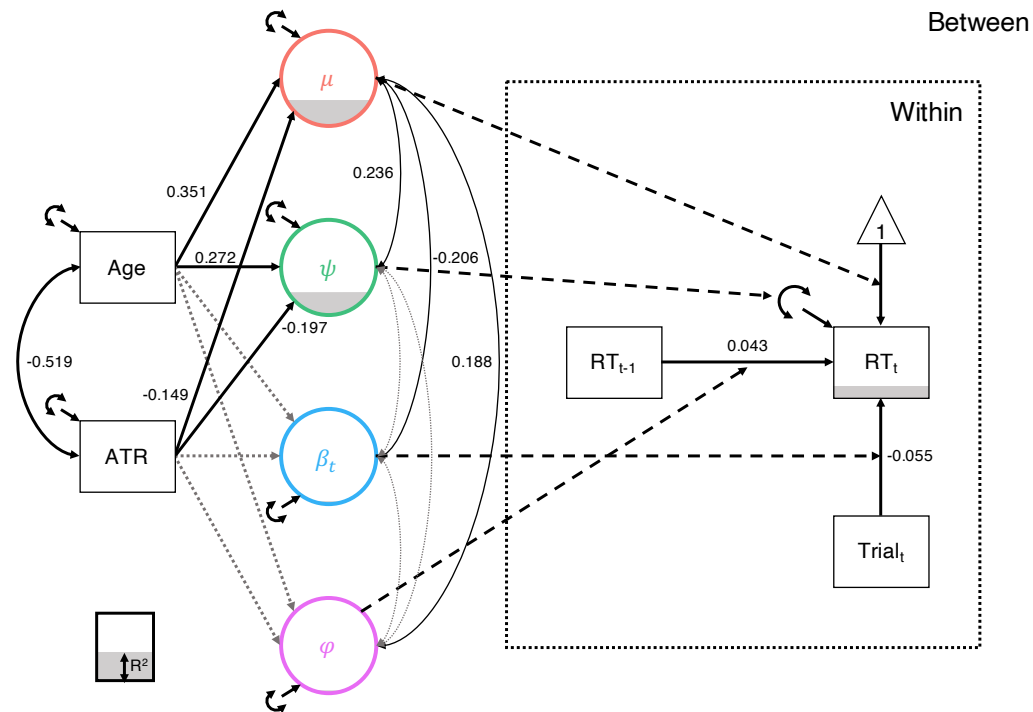
Additional Examples

Autoregression, not activation, predicts risky behavior
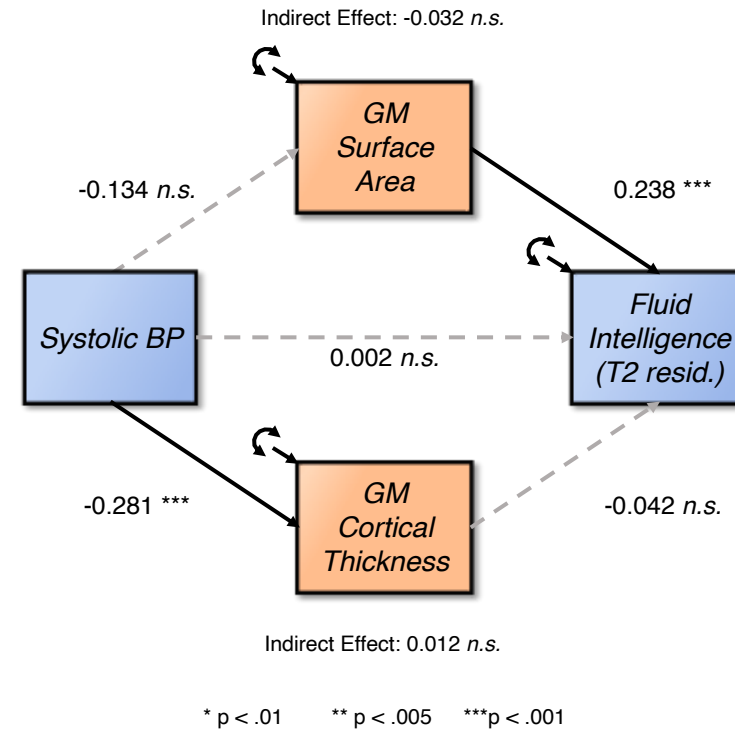
McCormick & Telzer, 2018b

Separating mean performance and variability using DSEM

McCormick & Kievit, *preprint*

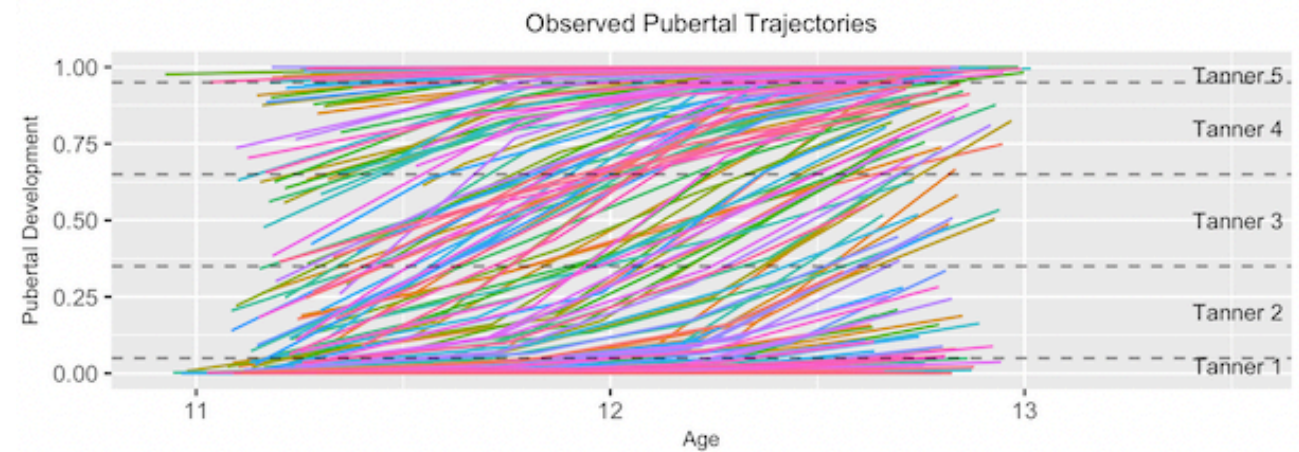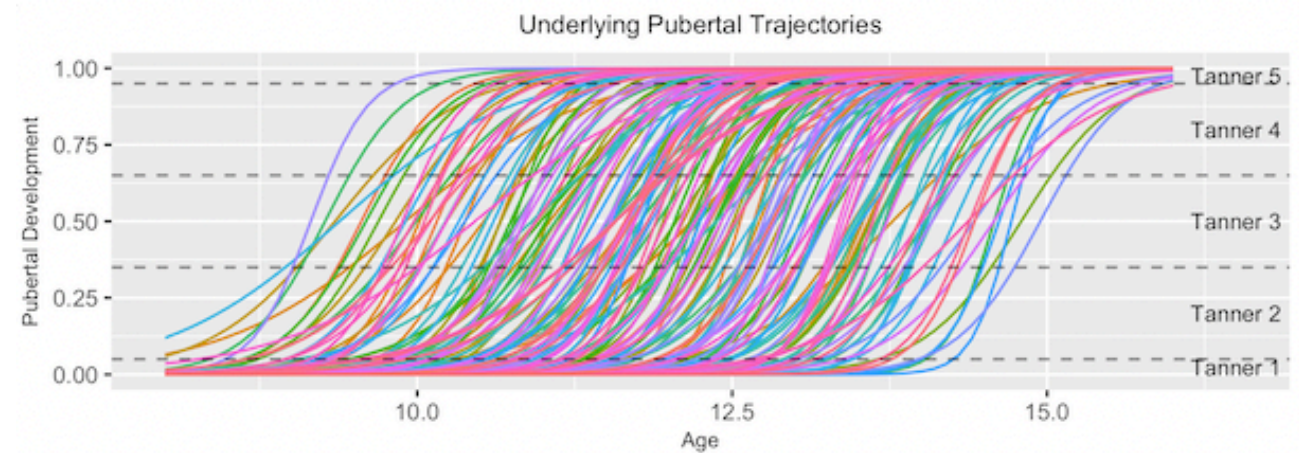Diagnosing interrupted causal structures in mediation

McCormick, Borgeest, Rhemtulla, & Kievit, *in prep*
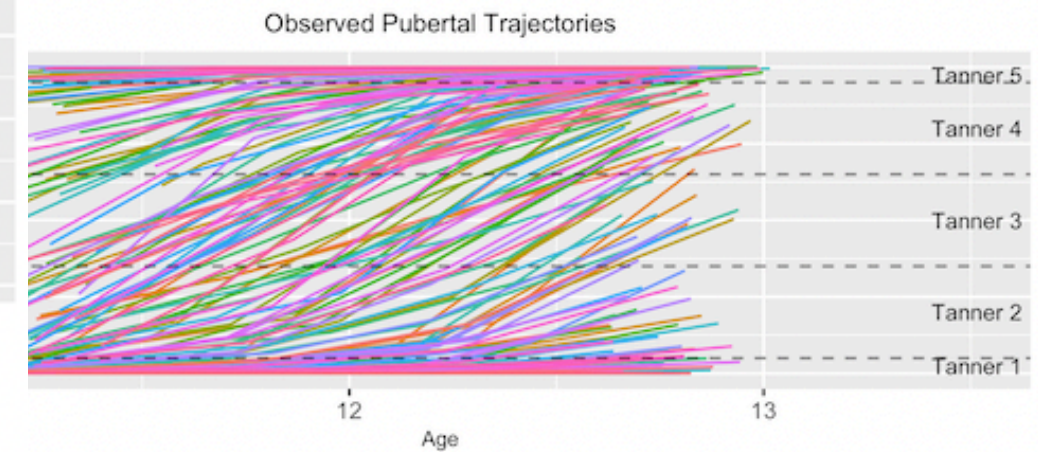
Ongoing and Future Research Plans

I showed that we can model puberty and age separately

- Age is the primary metric used in longitudinal modeling
  - Usually least theoretically interesting
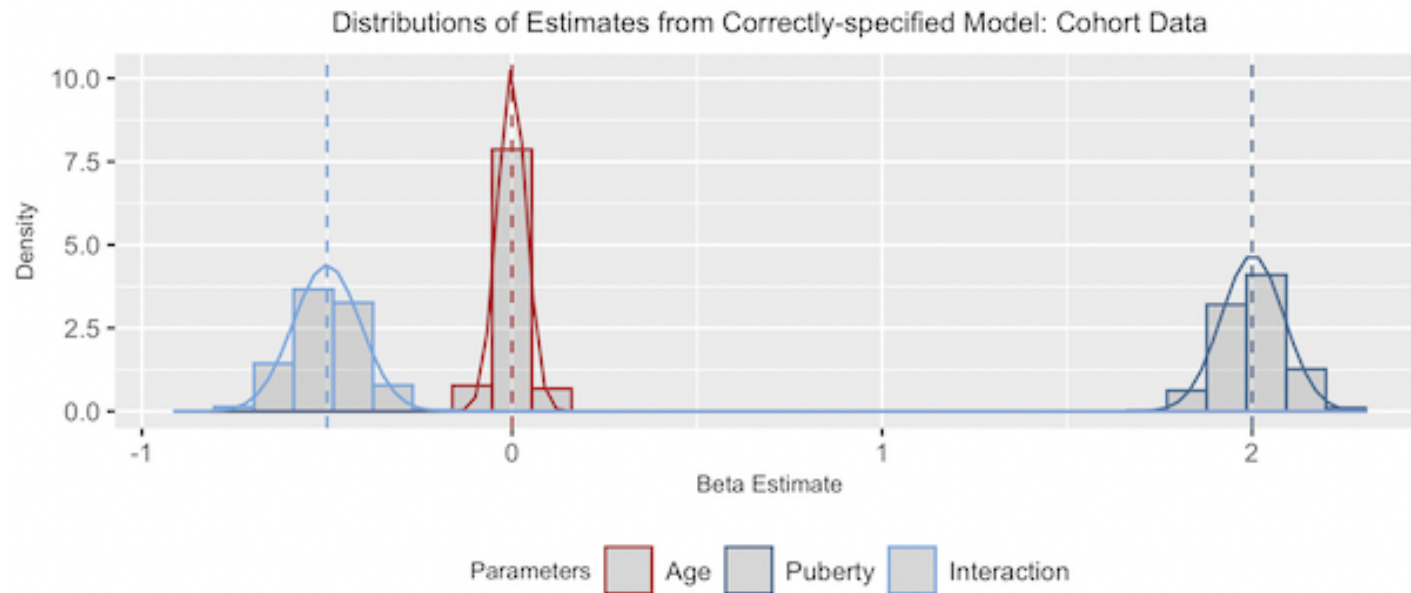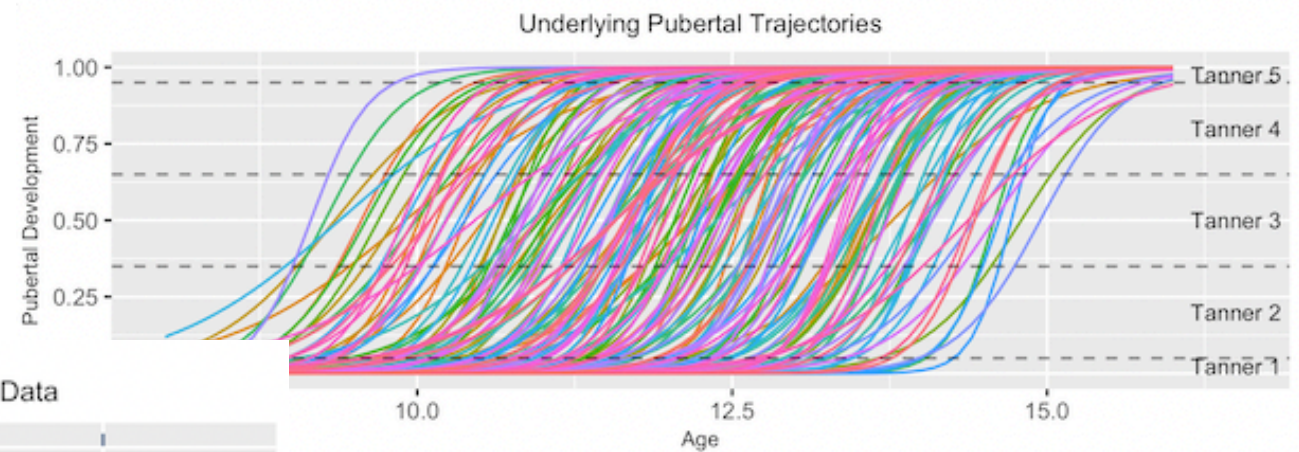
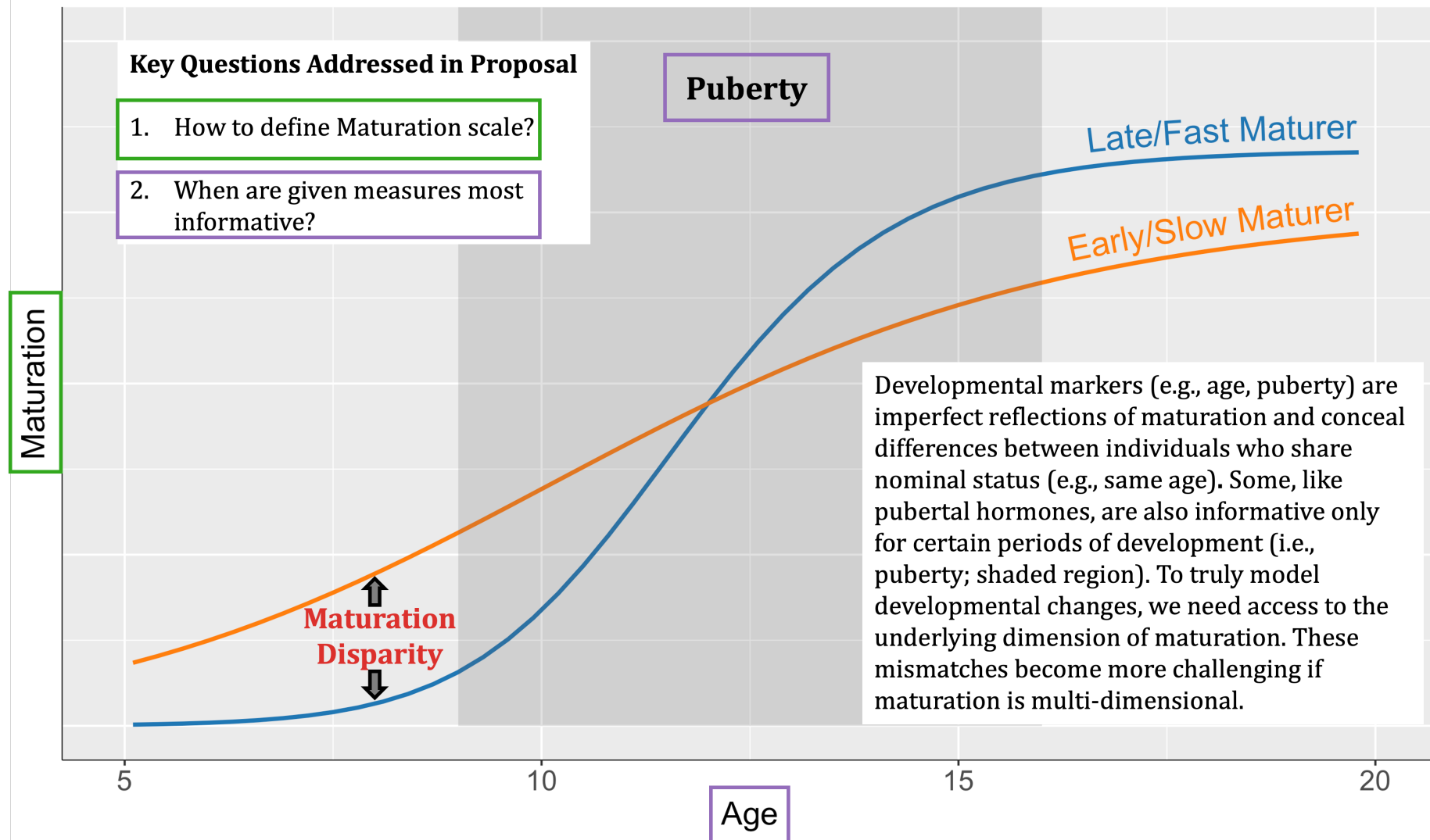# I showed that we can model puberty and age separately

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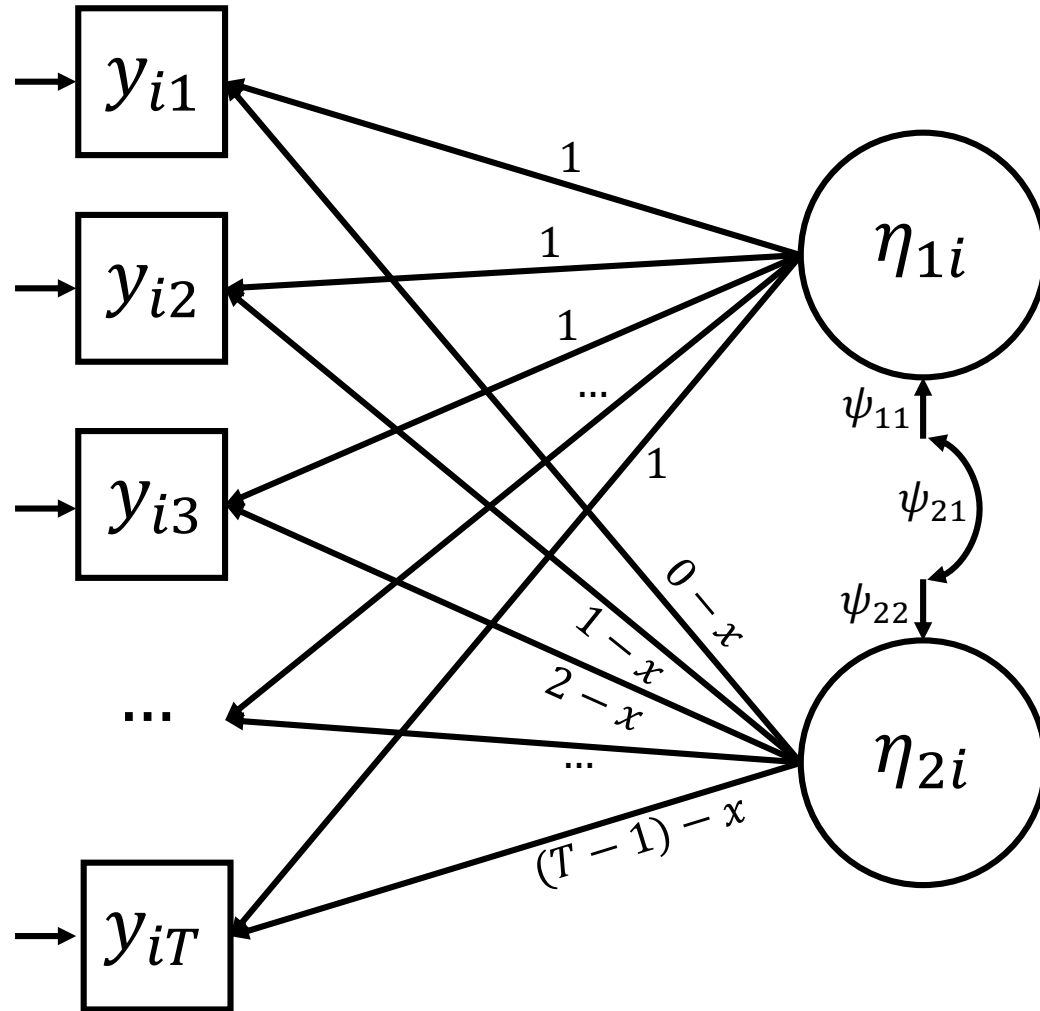 - Usually least theoretically interesting

Next step is to **combine** information from age and puberty (and other measures) into dimension(s) of maturation
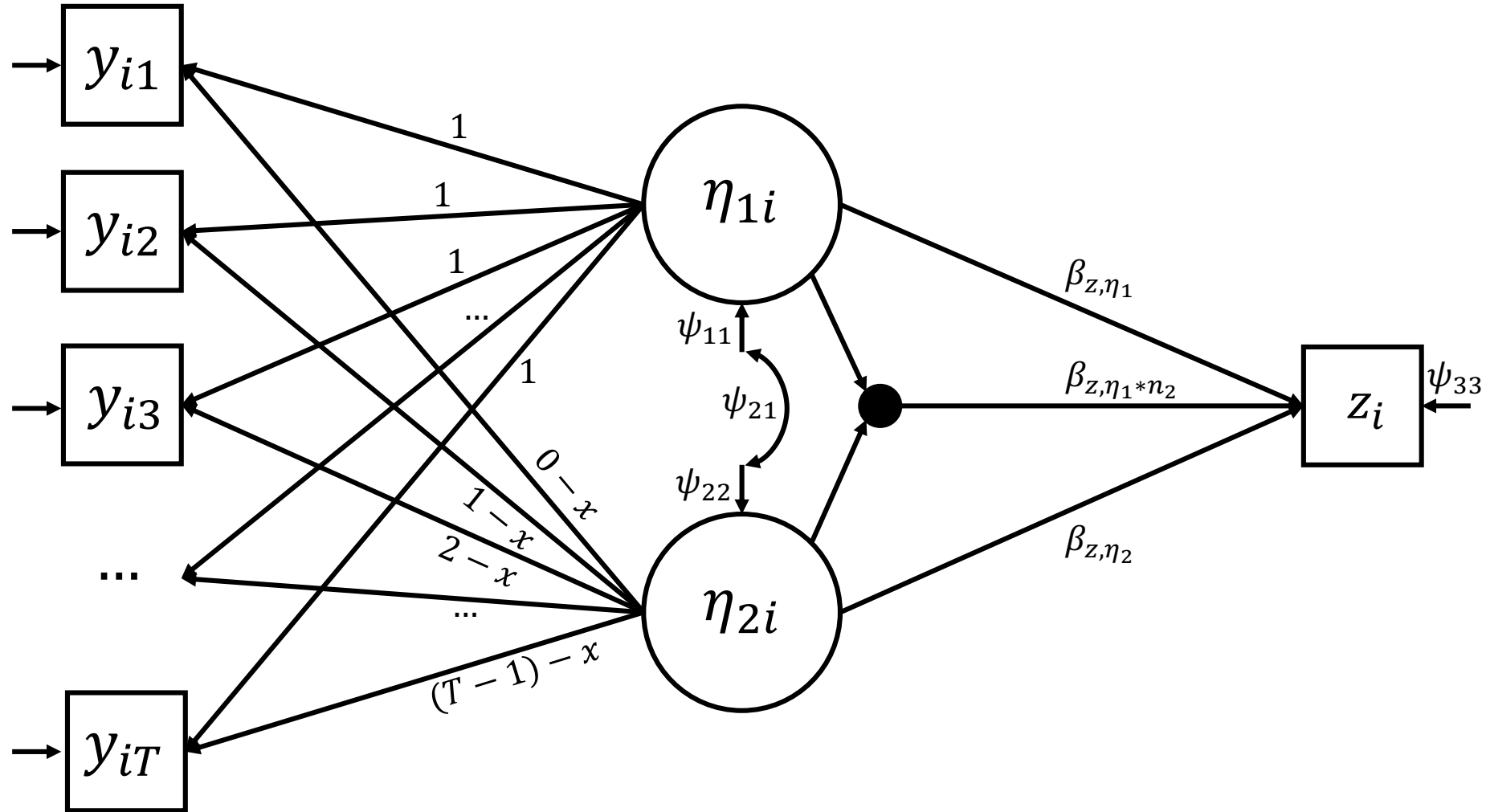

Modeling Challenges when Maturation and Developmental Measures Diverge

We have well developed tools for charting developmental trajectories

McCormick, Curran, & Hancock, *in prep*

# Little work has considered how to predict long-term consequences of individual differences in developmental trajectories

Seemingly simple decisions about time coding can fundamentally change the inferences about the effect of the slope

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McCormick, Curran, & Hancock, *in prep*
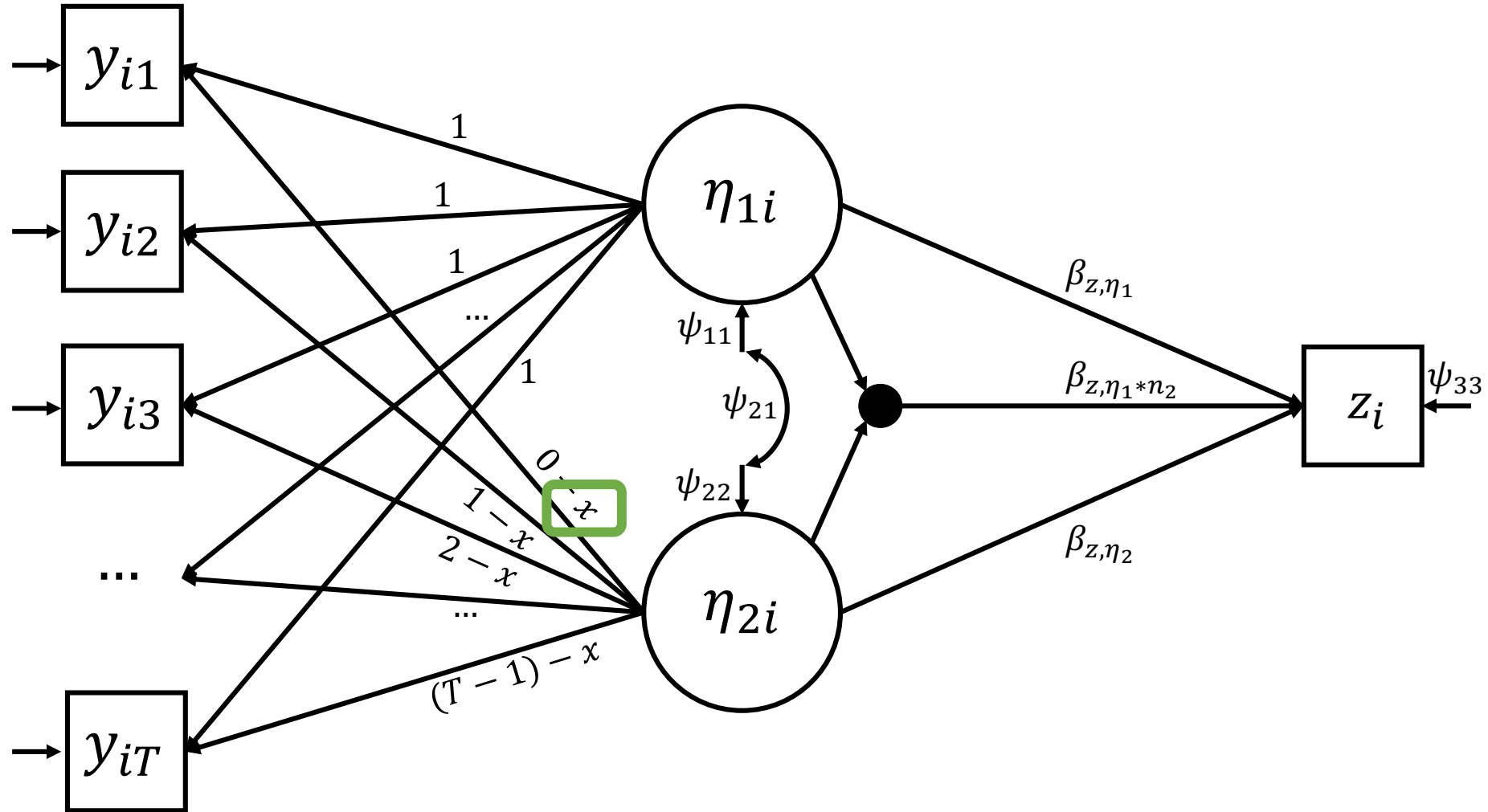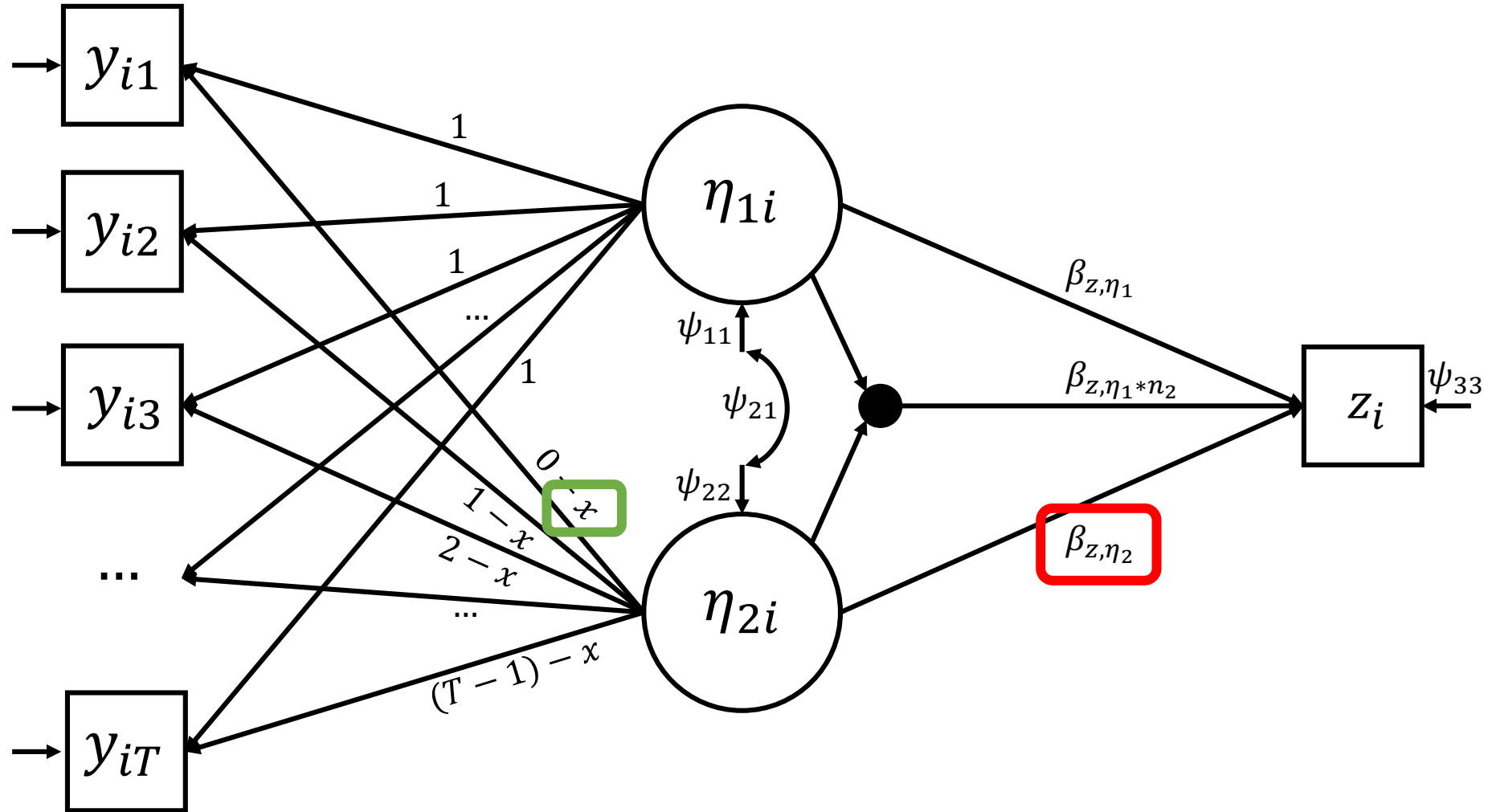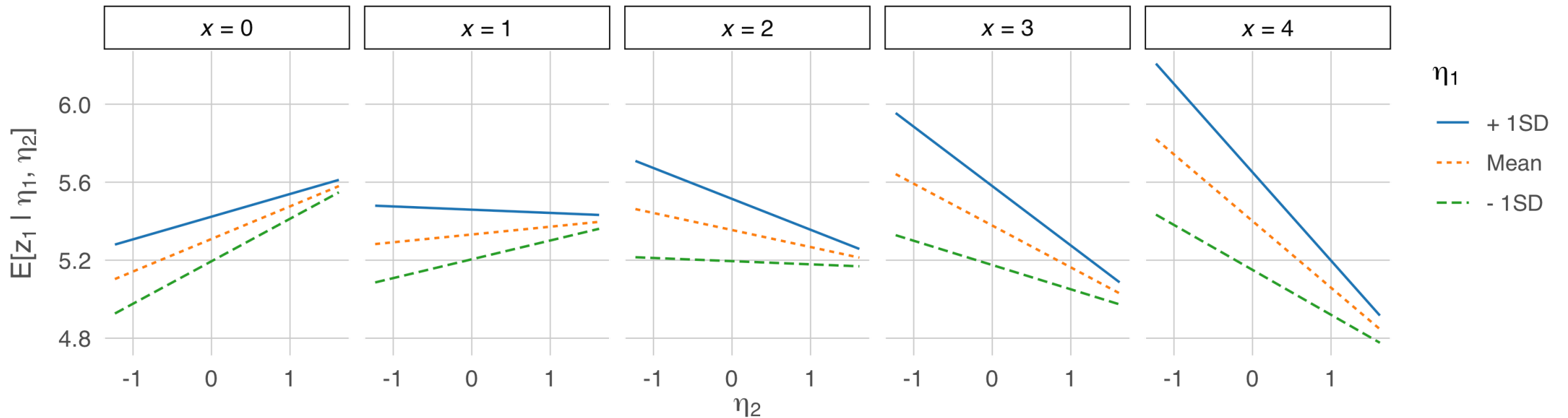
The effect of the slope changes significance and sign across different time-coding approaches

A

Probing Simple Slopes for z_1 on η_2

McCormick, Curran, & Hancock, *in prep*

An overview of my research approach to quantitative methods

- Quantitative methods can better enable our ability to do interesting and novel applied research
  - Often need to combine methods with creative study designs

  - Measurement and modeling change over time with a focus on cognitive neuroscience
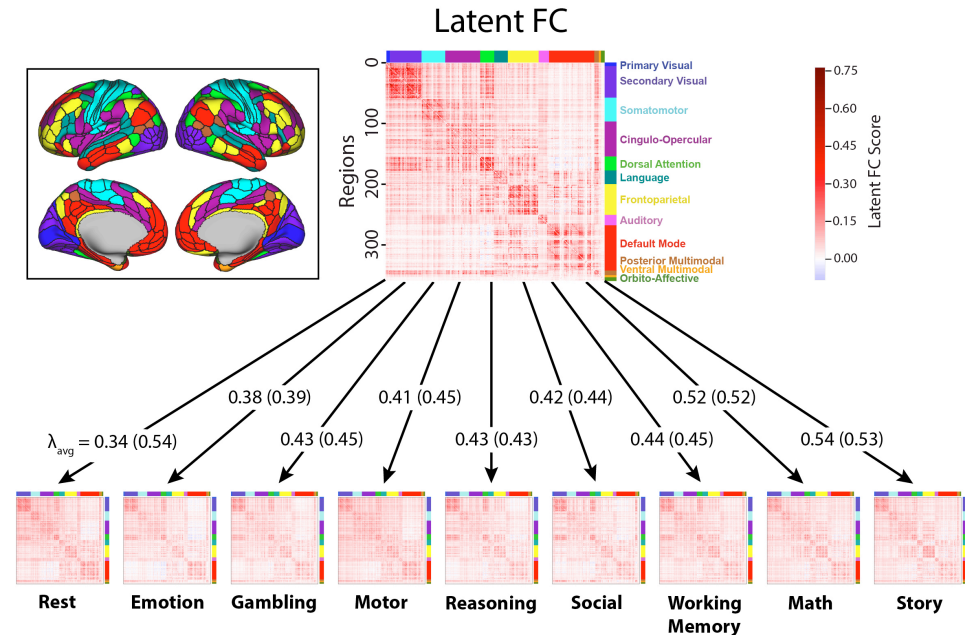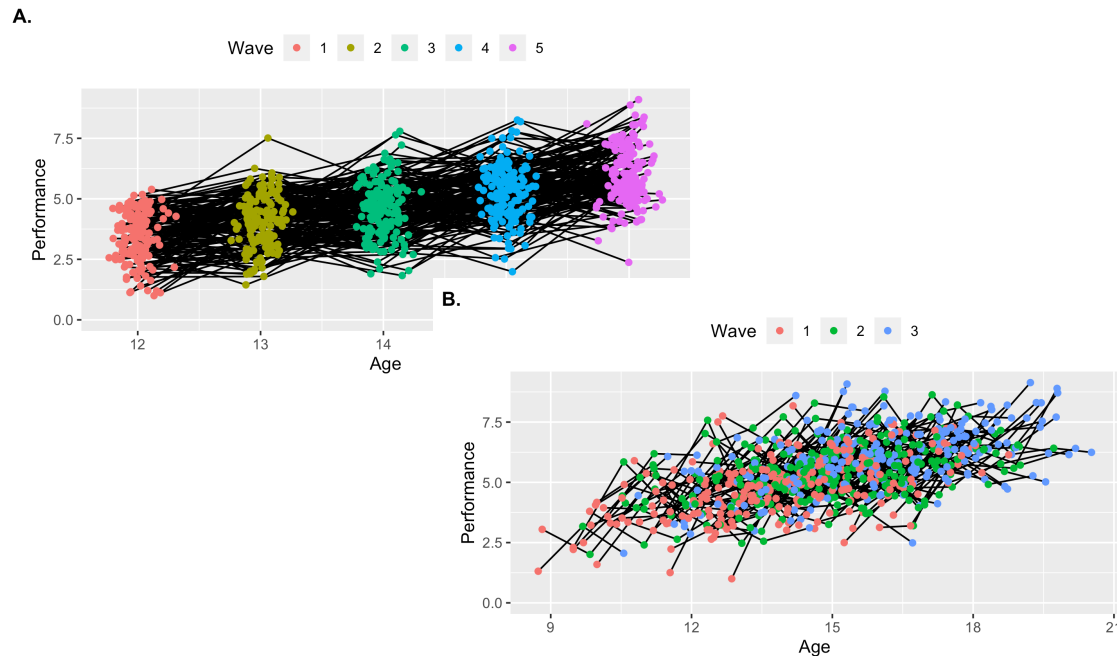
I can make unique and value contributions to the department

- Quantitative methods can better enable our ability to do interesting and novel applied research
  - Often need to combine methods with creative study designs

  - Two areas: longitudinal models & psychometric models

- Fit within the department
  - Intersection of fMRI Methodology and Statistics and Applied Psychometrics

  - Open and Reproducible Science

  - Collaborations with the larger Institute of Psychology

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Brains, Psychology and Psychometrics

NIH National Institute of Mental Health

NIH National Institute on Drug Abuse

NSF

erc European Research Council

NIH National Institute of Mental Health

Questions?

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