

# Modeling Psychopathology: From Data Models to Formal Theories

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*University of Amsterdam*

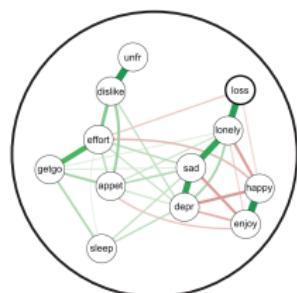
IMPS 2021

# Thanks to my Collaborators

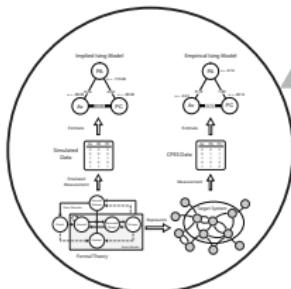
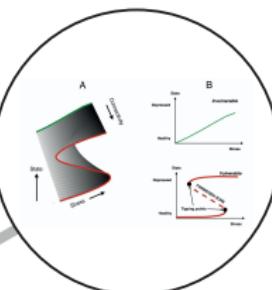


# Overview of Talk

## Extending Network Models



## Psychopathology & Dynamical Systems

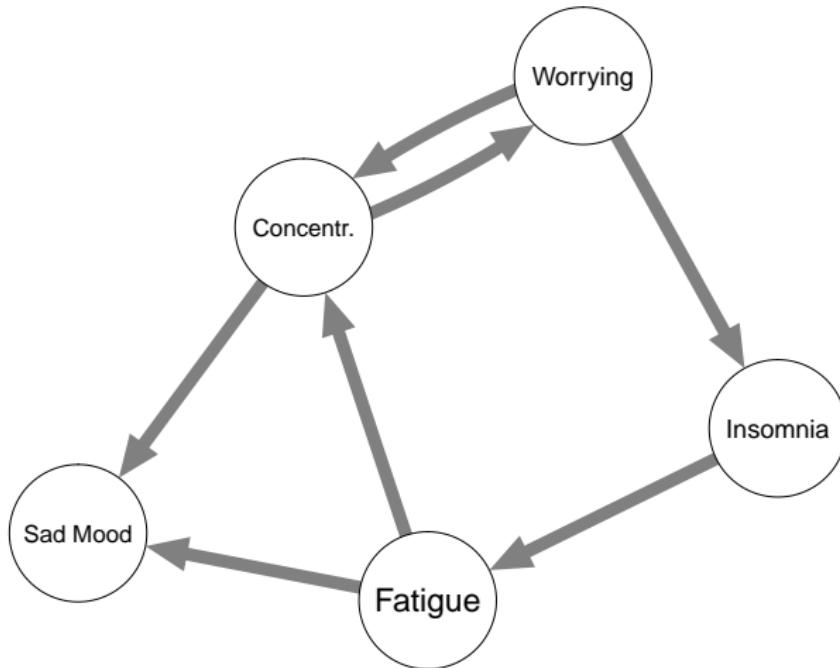


## Theory Construction

?

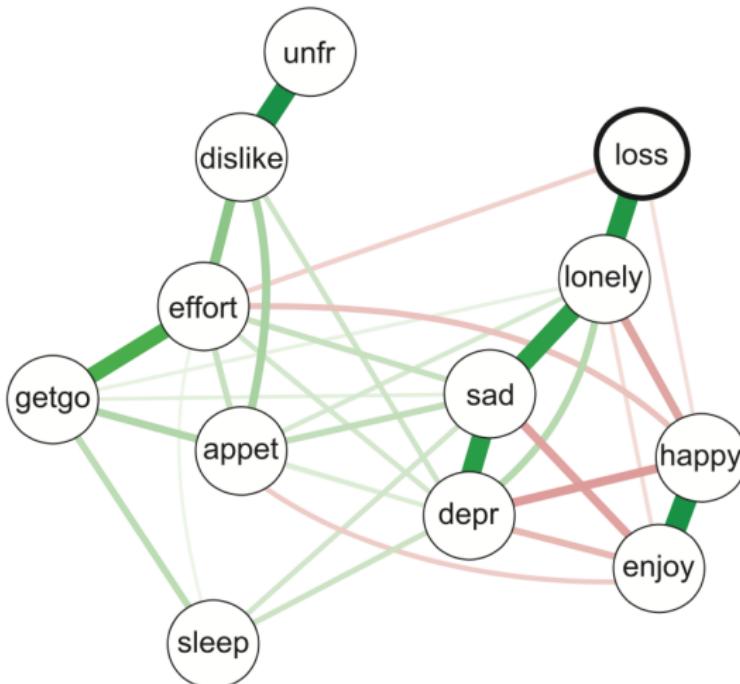
## Open Questions

# Network Approach to Psychopathology



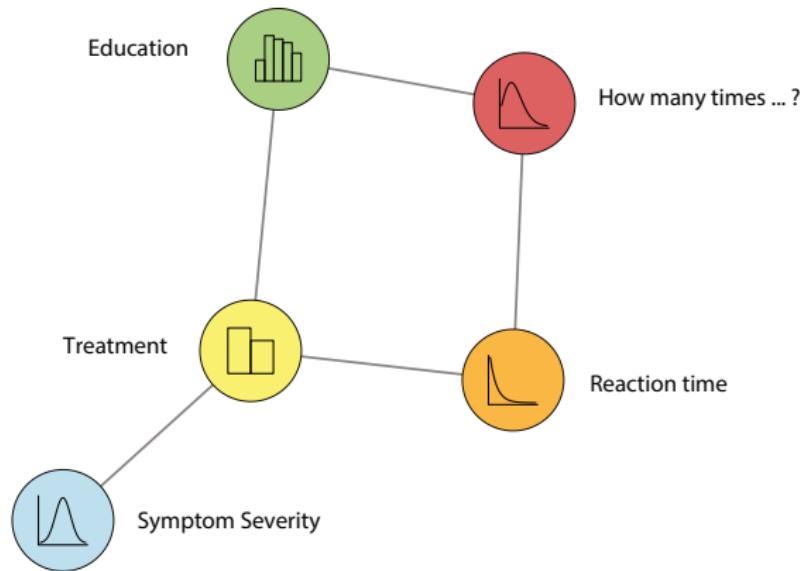
(Cramer et al, 2010; Borsboom et al. 2013; Schmittman et al, 2013; Borsboom, 2017)

# Statistical Network Models



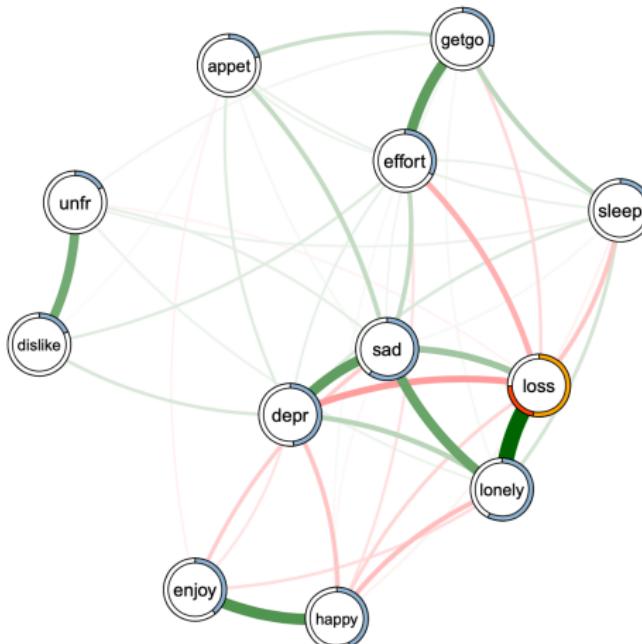
(Epskamp et al., 2014; van Borkulo et al., 2014; Figure from Fried et al., 2015)

# Mixed Graphical Models



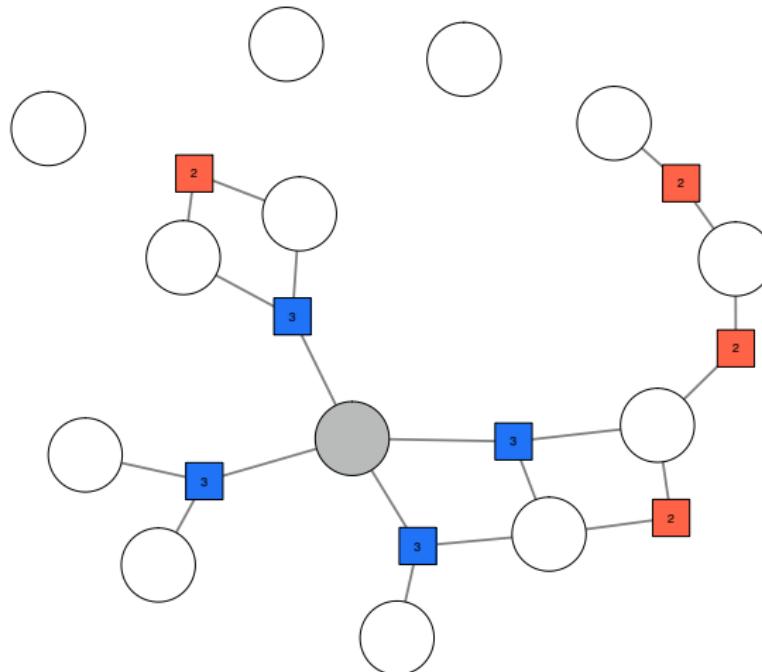
(Yang et al., 2014; Haslbeck & Waldorp, 2020)

# Node Predictability



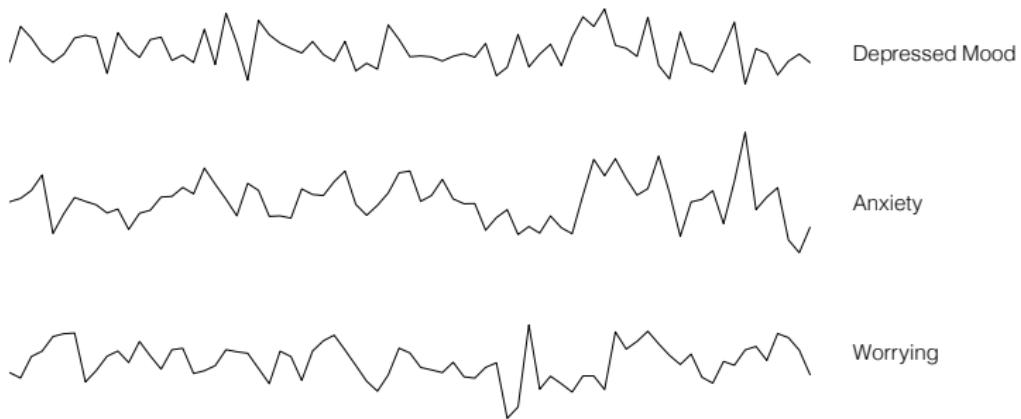
(Haslbeck & Waldorp, 2017; Haslbeck & Fried, 2018)

# Moderated Network Models



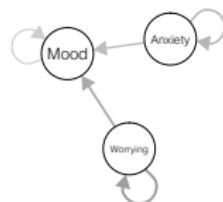
(Haslbeck, Waldorp & Borsboom, 2019; Haslbeck, 2021)

# Time-varying Network Models

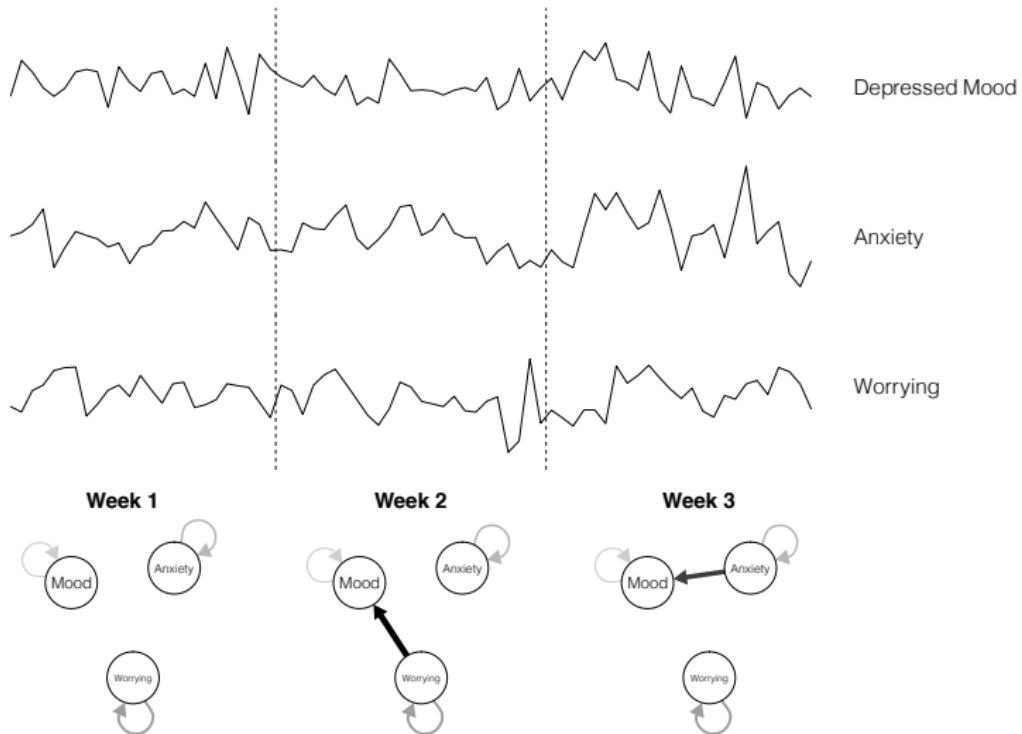


(Haslbeck, Bringmann & Waldorp, 2020)

# Time-varying Network Models



# Time-varying Network Models

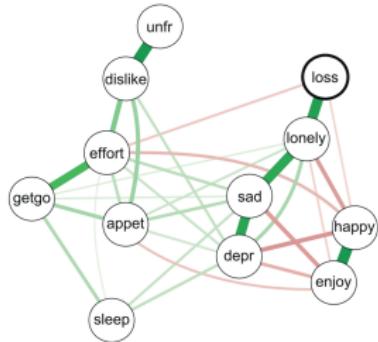


(Haslbeck & Waldorp, 2020; Haslbeck, Bringmann & Waldorp, 2020)

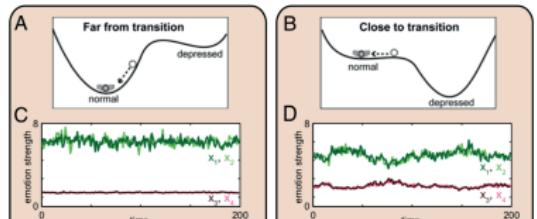
# Network Models

vs.

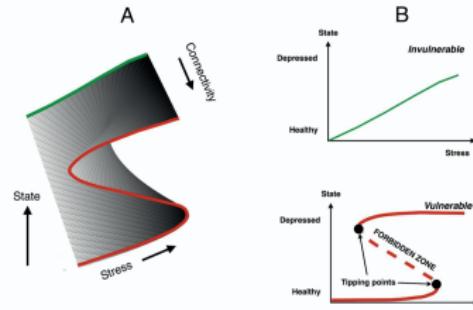
# Theoretical Ideas



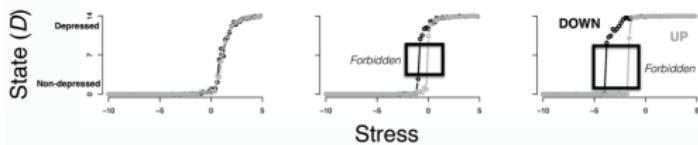
$$\begin{matrix} & X_1 & X_2 & X_3 \\ X_1 & \left[ \begin{matrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{matrix} \right] \\ X_2 \\ X_3 \end{matrix}$$



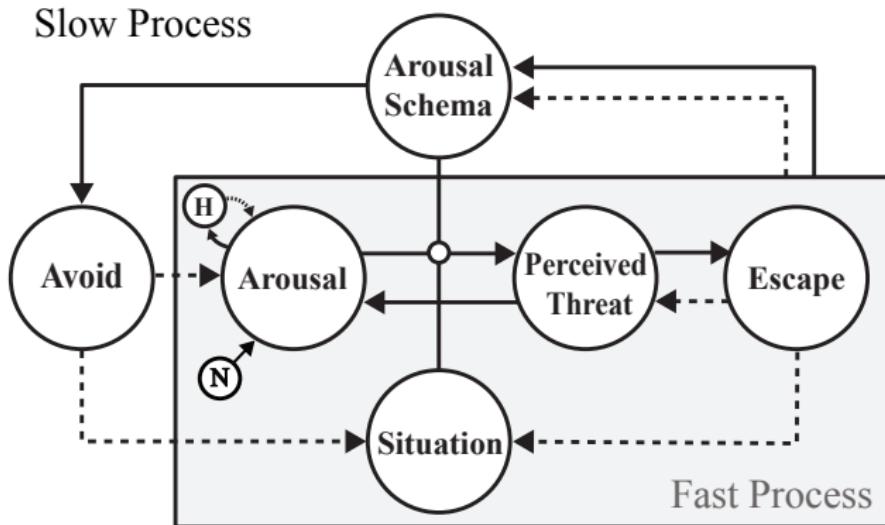
(van Leemput et al., 2014)



(Cramer et al., 2016)

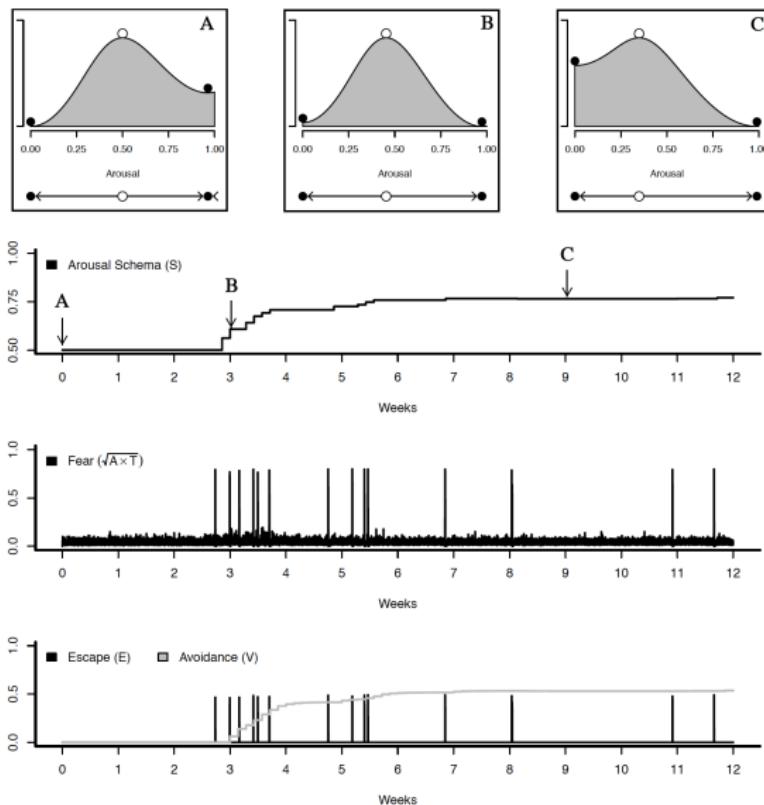


# A Dynamical Systems Model for Panic Disorder



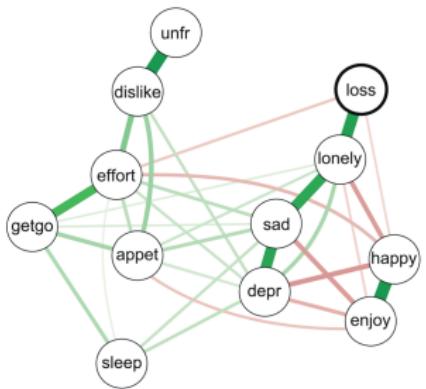
(Robinaugh et al., 2019)

# A Dynamical Systems Model for Panic Disorder

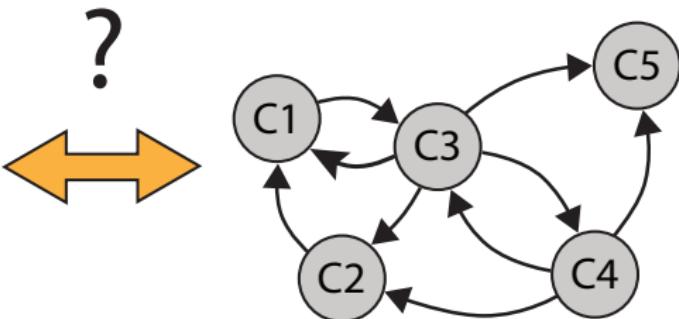


(Robinaugh et al., 2019)

## How to use network models for theory construction?



## Network Models

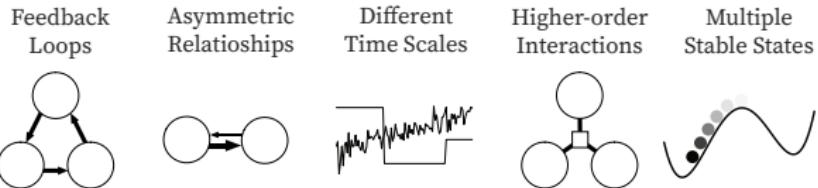


## Formal Theory

(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Statistical Network Models as Theories?

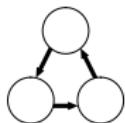
# Statistical Network Models as Theories?



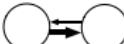
(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Statistical Network Models as Theories?

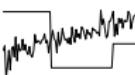
Feedback Loops



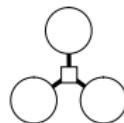
Asymmetric Relationships



Different Time Scales



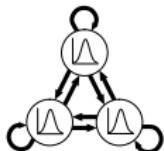
Higher-order Interactions



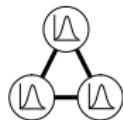
Multiple Stable States



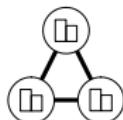
VAR  
Model



GGM



Ising  
Model



(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

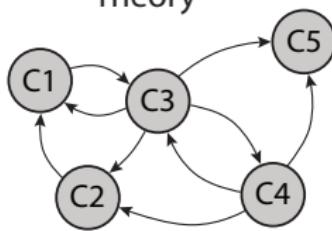
# Statistical Network Models as Theories?

	Feedback Loops	Asymmetric Relationships	Different Time Scales	Higher-order Interactions	Multiple Stable States
VAR Model		✓	✓	✗	✗
GGM		✓	✗	✗	✗
Ising Model		✓	✗	✗	✗

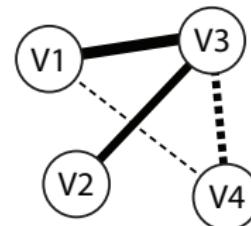
(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Target systems, Theories, Data and Data Models

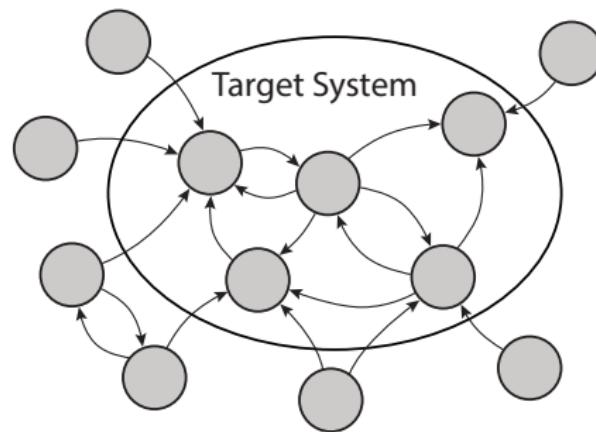
Theory



Data Model



Target System

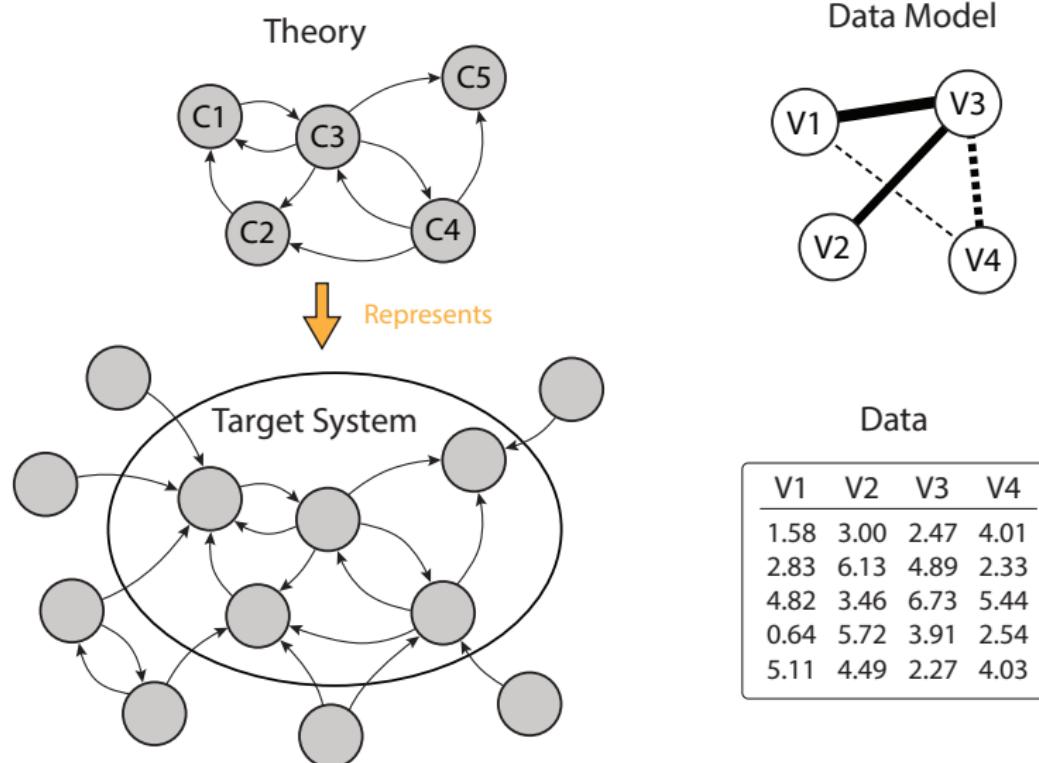


Data

V1	V2	V3	V4
1.58	3.00	2.47	4.01
2.83	6.13	4.89	2.33
4.82	3.46	6.73	5.44
0.64	5.72	3.91	2.54
5.11	4.49	2.27	4.03

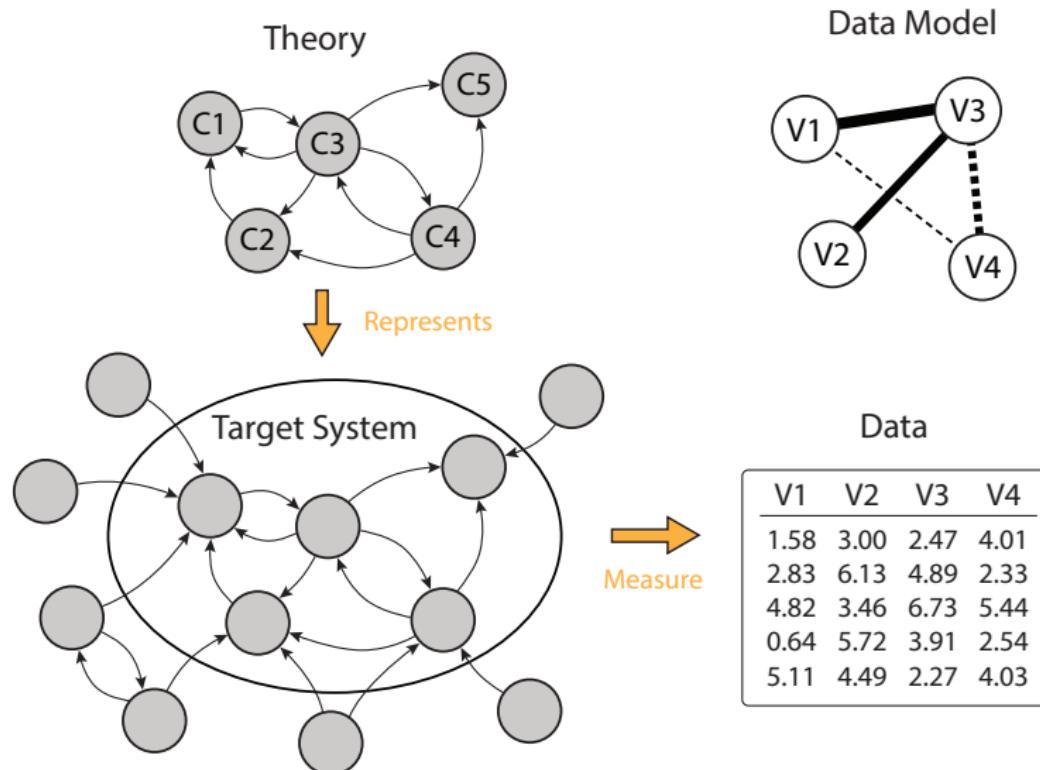
(Suárez & Pero, 2019; Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Target systems, Theories, Data and Data Models



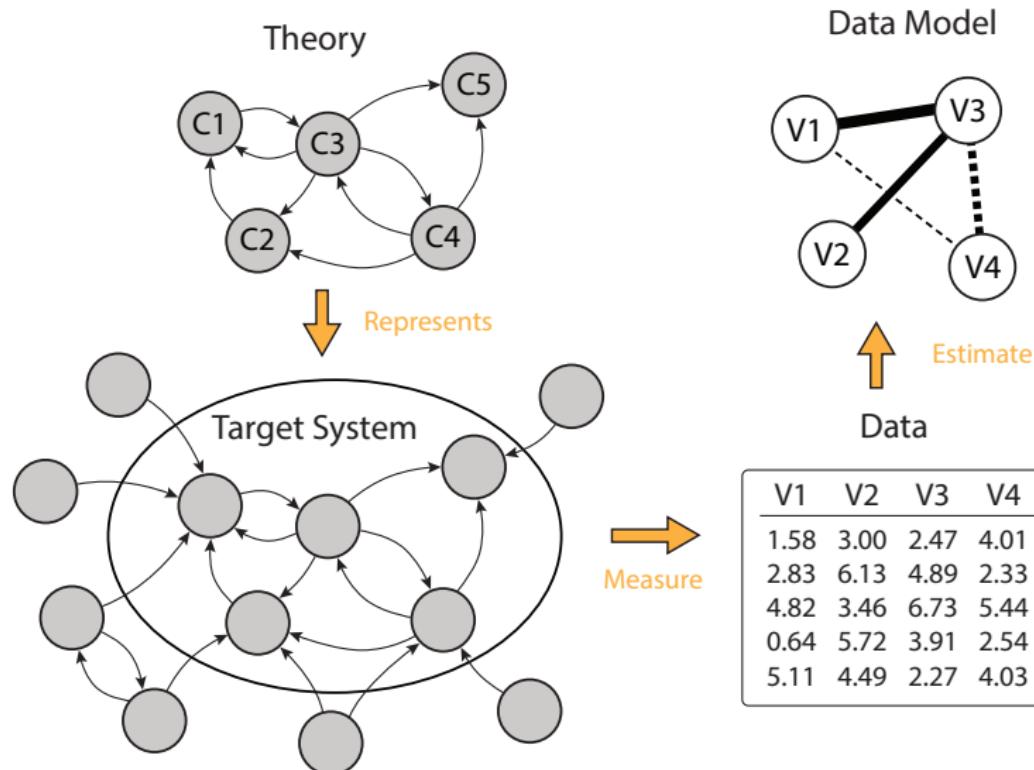
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# Target systems, Theories, Data and Data Models



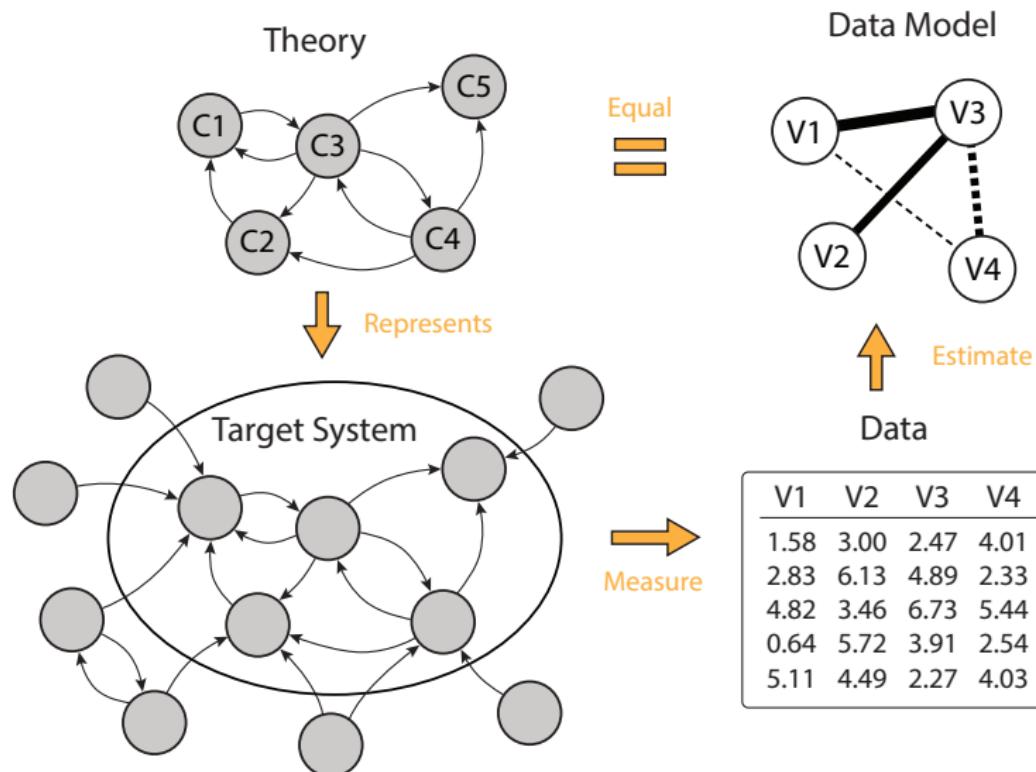
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# Target systems, Theories, Data and Data Models



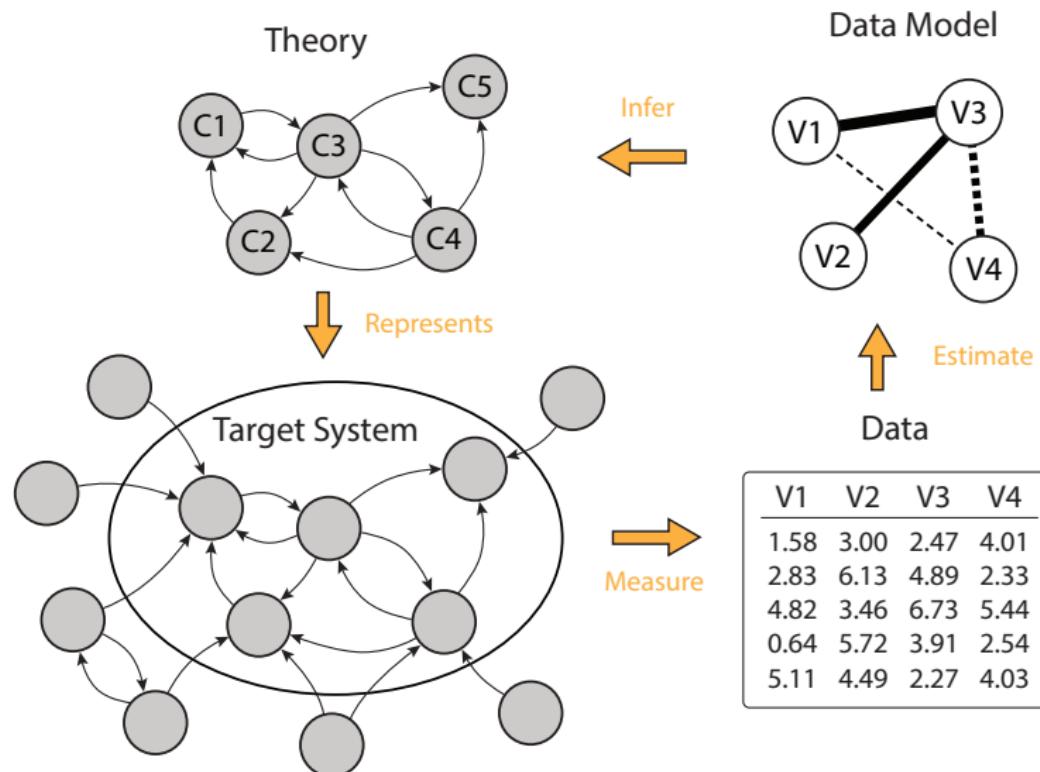
(Suárez & Pero, 2019; Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Target systems, Theories, Data and Data Models



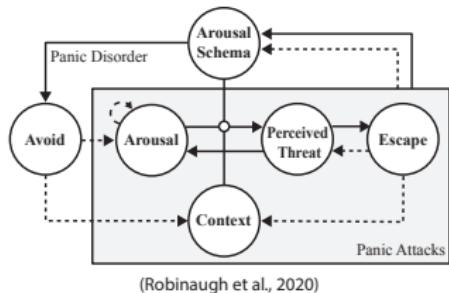
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# Target systems, Theories, Data and Data Models

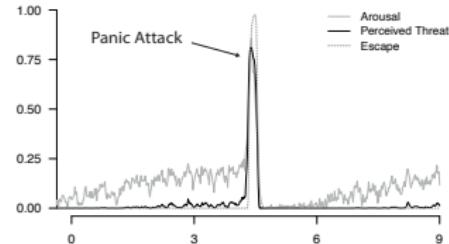


(Suárez & Pero, 2019; Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

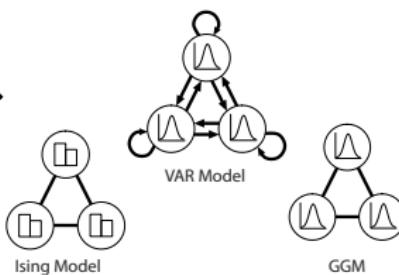
# Infer Theories from Data Models?



Generate



Try to infer  
true formal theory

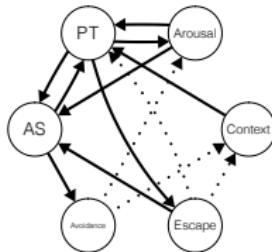


Estimate

(Robinaugh et al., 2020; Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Infer Theories from Data Models?

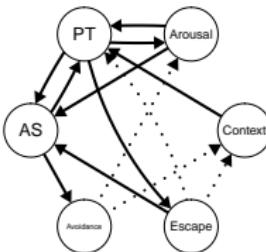
(a) True Local Dependence



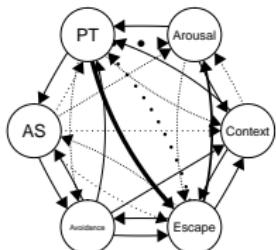
(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Infer Theories from Data Models?

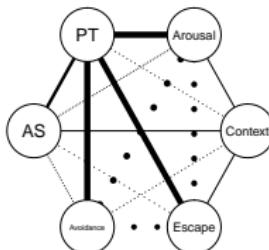
(a) True Local Dependence



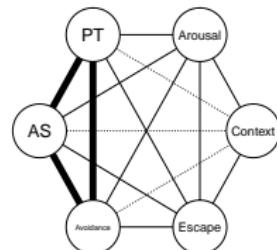
(b) VAR Model



(c) Gaussian Graphical Model

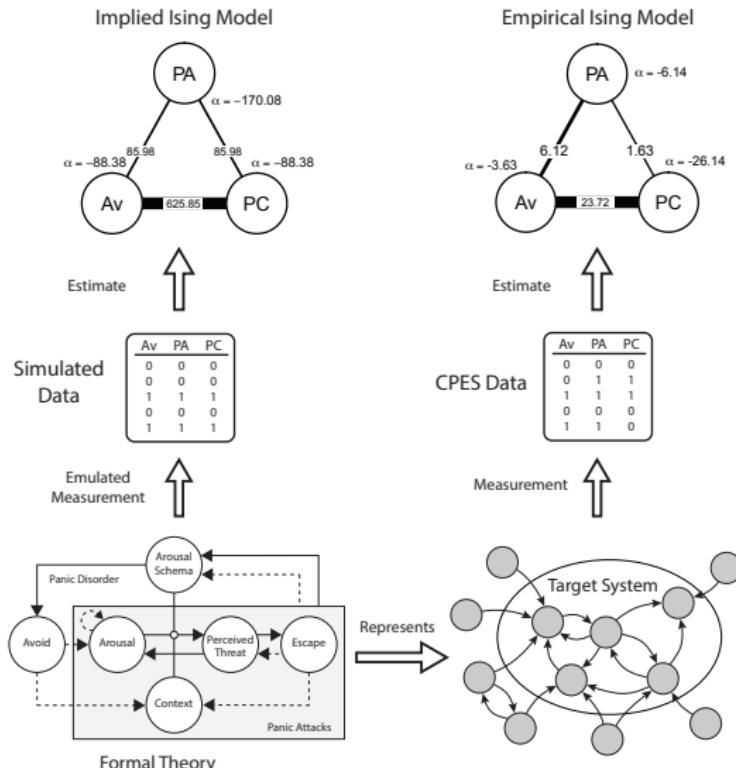


(d) Ising Model



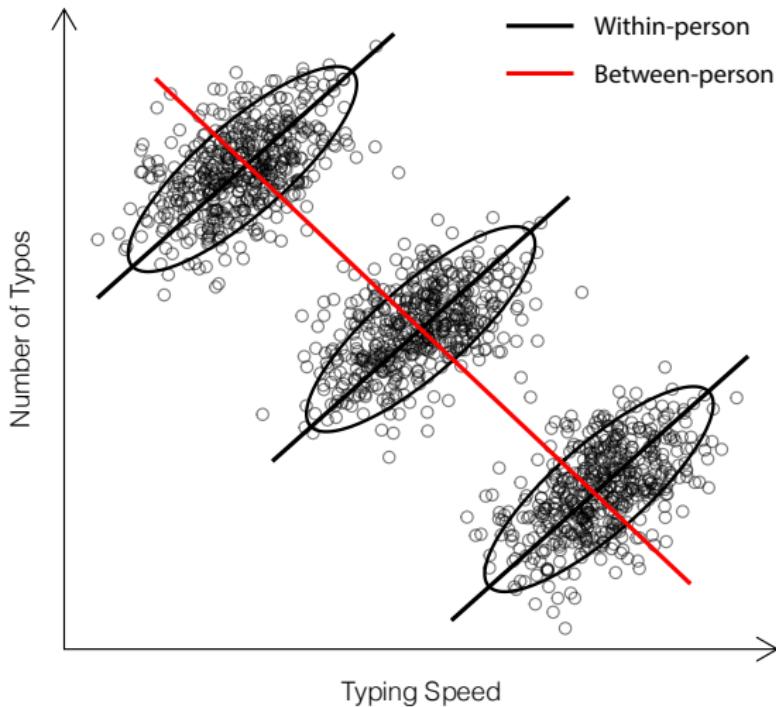
(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Alternative: Abductive Theory Construction

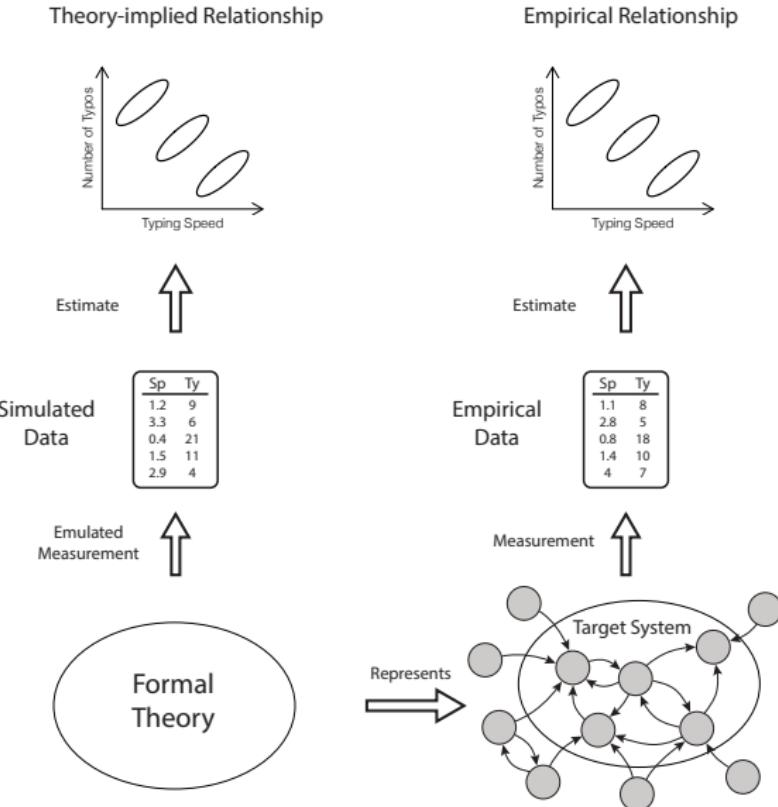


(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Abduction vs. “Direct Inference”

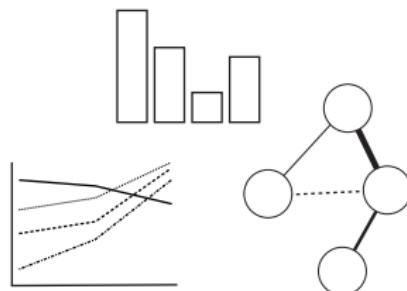


# Abduction vs. “Direct Inference”

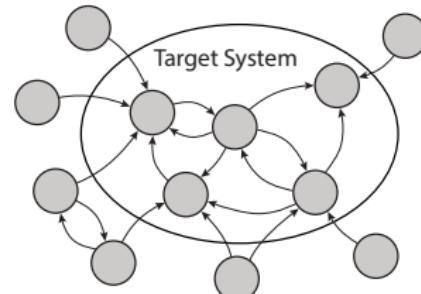


# How to generate an initial theory?

**Step 1:** Specify phenomenon to be explained

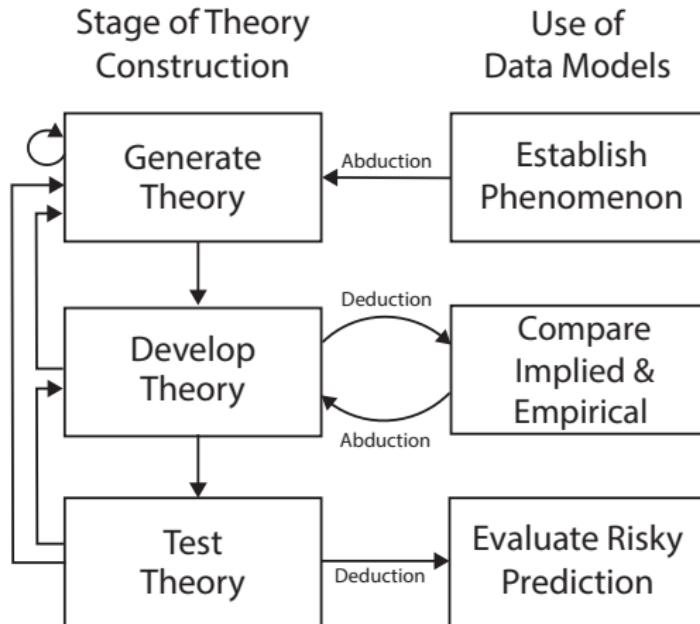


**Step 2:** Specify components and relations of target system



(Wimsat, 1987; Smaldino, 2017; Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Three Stages of Theory Construction



(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

# Open Questions in Theory Construction Process

1. How do I know whether I have an appropriate measurement model?
2. How to develop the theory with several different data sets and data models?
3. When should a theory be developed and when should it be abandoned?

(Haslbeck\*, Ryan\*, Robinaugh\*, et al., 2021)

## How to make theory construction more approachable?



- ▶ Applied researchers are not trained in formal modeling
- ▶ However: Researchers have a lot of ideas they would like to formalize & there is a lot of enthusiasm

# How to make theory construction more approachable?

Applied  
Research



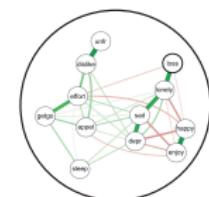
Formal  
Theories

Way forward?

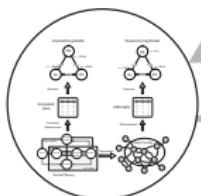
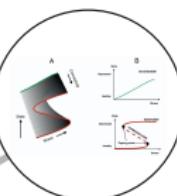
- ▶ Include formal modeling in education
- ▶ Collaboration between applied researchers and modelers
- ▶ Lowering threshold to engage with formal theories

# From Data Models to Formal Theories

Extending Network Models



Psychopathology & Dynamical Systems



Open Questions

## Open Questions:

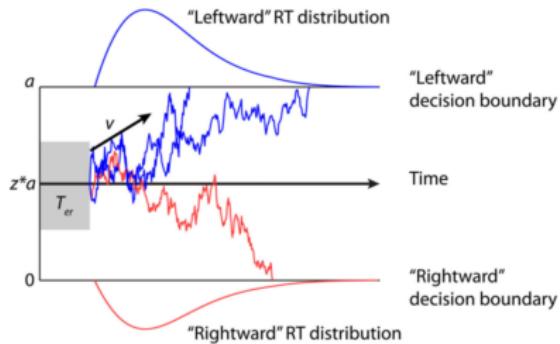
- ▶ Measurement?
- ▶ Multiple data sets/models?
- ▶ Develop vs. Abandon?
- ▶ **How to make theory construction more approachable?**

Theory Construction

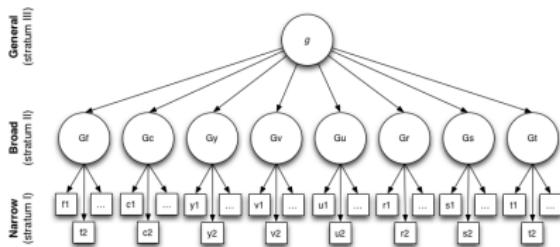
# Extra Stuff

# Data Models $\neq$ Formal Theories: Really?

# Data Models $\neq$ Formal Theories: Really?



**Drift diffusion model** for  
two-alternative forced choice  
tasks



**g-factor model** for general  
intelligence

Some theoretically motivated models can be estimated from data

# Data Models $\neq$ Formal Theories: Really?

