

# Challenges in characterizing psychopathologies as unhealthy dynamic systems

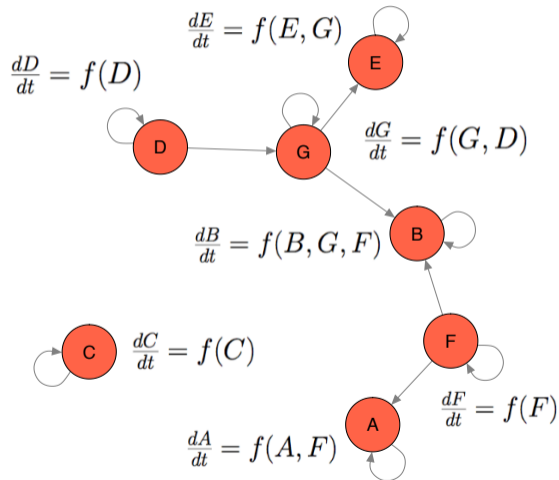
Conference on Complex Systems 2018 Thessaloniki

Oisín Ryan<sup>1</sup> & Jonas Haslbeck<sup>2</sup>

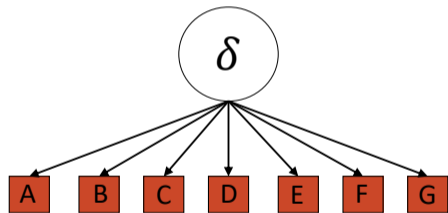
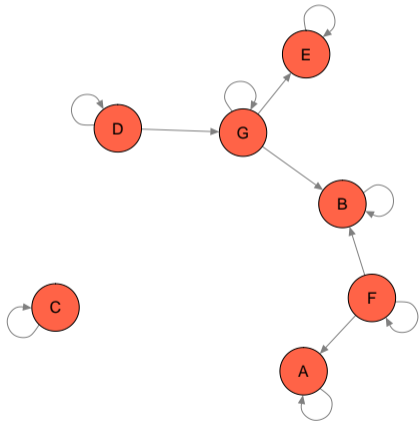
<sup>1</sup>*Department of Methodology and Statistics, Utrecht University*

<sup>2</sup>*Psychological Methods, University of Amsterdam*

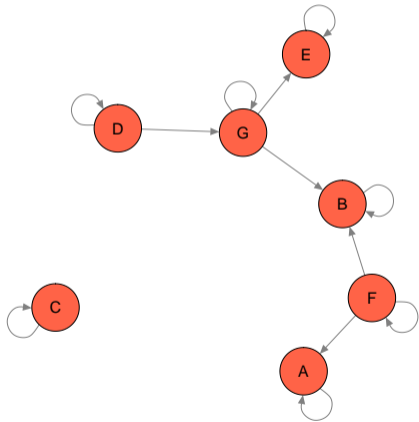
# Psychological Disorders as Dynamic Systems



What's the appeal?



## What's the appeal?



- ▶ Focus on causal interactions between variables/nodes
- ▶ Characterise structure of interactions that lead to pathology

# Why a complex dynamical system?

Potentially promising mapping between complex systems concepts and psychological theories

- ▶ Bi-stable system
  - ▶ Disorder vs no-disorder
- ▶ Hysteresis
  - ▶ Disorder triggered by adverse life-events

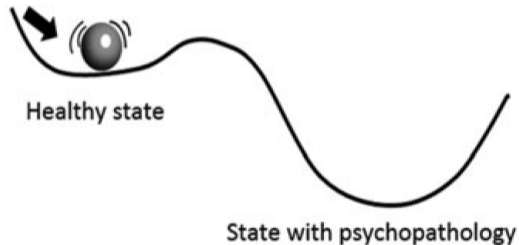


Figure: Wichers et al 2018

# Theory: Symptom Networks

- ▶ Mental disorders arise from direct interactions between **symptoms**
- ▶ Unhealthy state: symptoms activated
  - ▶ Consistent with medical diagnosis
- ▶ People prone to disorder have different network structures
  - ▶ Move more easily/frequently from healthy to unhealthy state

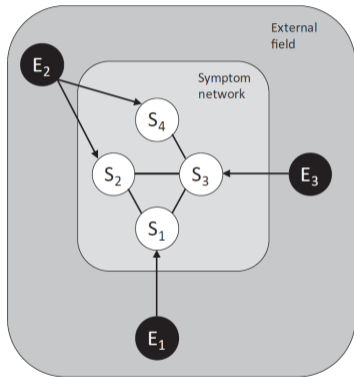
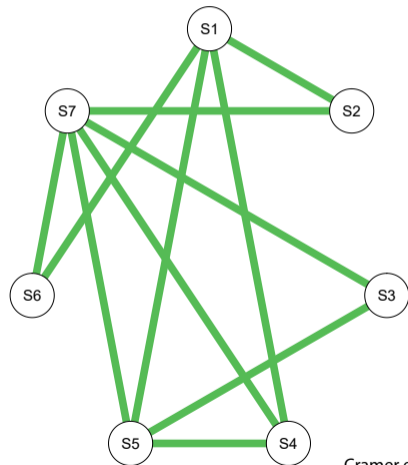


Figure: Borsboom 2017

# Computational Model for Symptom Networks

## Ising Model

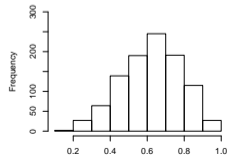
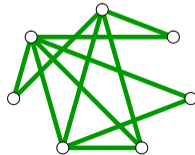
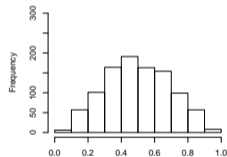
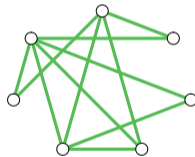
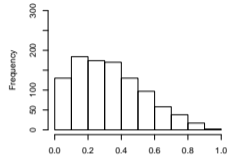
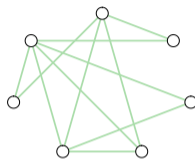
- ▶ Simple proxy model of pairwise interactions
- ▶ Positive Manifold
  - ▶ Symptoms “mutually activating”
  - ▶ (0,1) coding: symptoms not “mutually disactivating”



# Computational Model for Symptom Networks

## Ising Model

- ▶ Simple proxy model of pairwise interactions
- ▶ Positive Manifold
  - ▶ Symptoms “mutually activating”
  - ▶ (0,1) coding: symptoms not “mutually disactivating”
- ▶ *Density* → marginal probability of “unhealthy” state
- ▶ Pathology as a function of network topology





# Empirical Network Models

- ▶ Dataset on psychological constructs related to some pathology
  - ▶ Self-report questionnaire
  - ▶ Cross-sectional / time-series
  - ▶ Unhealthy vs healthy controls

$$\begin{array}{c} 1 \\ 2 \\ 3 \\ \vdots \\ N-2 \\ N-1 \\ N \end{array} \begin{pmatrix} A & B & C & D & E & F & G \\ 3.45 & 1.11 & -0.91 & 3.18 & -0.88 & 2.28 & 2.12 \\ 1.72 & 2.14 & 0.78 & 0.82 & 0.36 & 1.03 & 1.28 \\ 0.11 & -3.12 & 1.21 & 1.80 & 0.57 & 0.99 & 1.32 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ -1.29 & 1.65 & 4.62 & 1.74 & -0.44 & -2.80 & 3.13 \\ -0.02 & 1.54 & 5.21 & 1.71 & 0.04 & -0.02 & 3.00 \\ 1.18 & 0.82 & 1.05 & 8.77 & -0.82 & 0.05 & 2.01 \end{pmatrix}$$

# Empirical Network Models

- ▶ Dataset on psychological constructs related to some pathology
  - ▶ Self-report questionnaire
  - ▶ Cross-sectional / time-series
  - ▶ Unhealthy vs healthy controls
- ▶ Fit a linear model to the data
  - ▶ PMRF or VAR

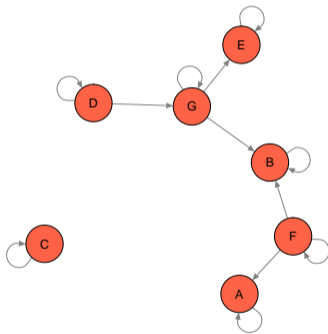
$$P(\mathbf{Y}_j = 1 | \mathbf{Y}_{\setminus j}) \Rightarrow \exp(\hat{\beta} \mathbf{Y}_{\setminus j})$$

$$\mathbf{Y} \sim N(\boldsymbol{\mu}, \boldsymbol{\Sigma}) \Rightarrow \hat{\boldsymbol{\Sigma}}^{-1}$$

$$\mathbf{Y}_t = \hat{\boldsymbol{\Phi}} \mathbf{Y}_{t-1} + \mathbf{e}_t$$

# Empirical Network Models

- ▶ Dataset on psychological constructs related to some pathology
  - ▶ Self-report questionnaire
  - ▶ Cross-sectional / time-series
  - ▶ Unhealthy vs healthy controls
- ▶ Fit a linear model to the data
  - ▶ PMRF or VAR
- ▶ Use estimated parameters to construct a network
  - ▶ Compute network metrics
  - ▶ Node centrality and *Density*
  - ▶ Look for individual/group differences



## What's the problem?

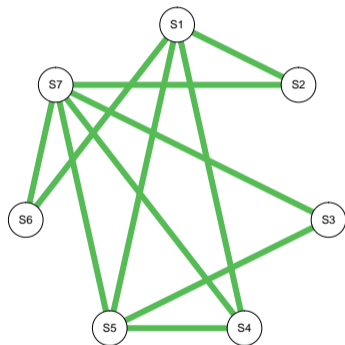
Empirical applications have outpaced theoretical contributions

	<b>Theoretical</b>	<b>Empirical</b>
<b>Nodes</b>	Symptoms	?
<b>Dynamics</b>	Bi-stable	?

## Empirical Networks: Nodes

Empirical *symptom* networks

- ▶ Depression (van Borkulo et al 2015)
- ▶ Schizophrenia (van Rooijen et al 2018)



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## Mix of symptoms and non-symptoms

- ▶ Self-efficacy (Santos et al 2018)
- ▶ Working memory (Hoorelebeke et al 2016)

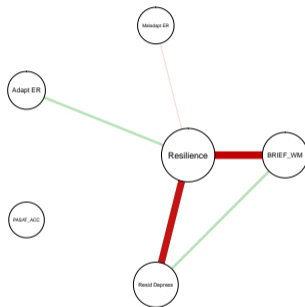


Figure: Hoorelebeke et al (2016)

## Empirical Networks: Nodes

### Empirical *symptom* networks

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### Mix of symptoms and non-symptoms

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### Pathology networks with *no symptoms*

- ▶ Personality traits (Fonseca Pedrero et al 2018)
- ▶ **Emotions** or mood states (Bringmann et al 2013; Pe et al 2015)

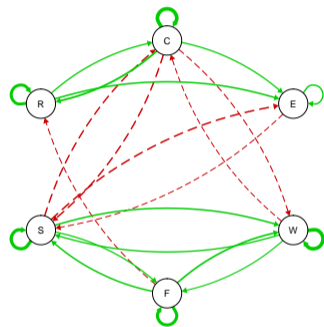
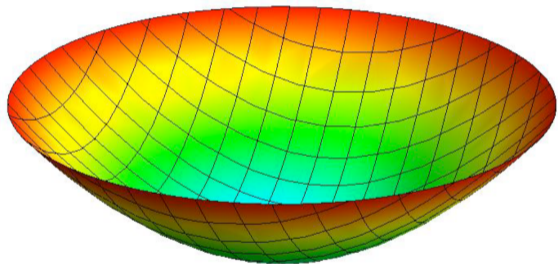


Figure: Bringmann et al. (2013)

## Empirical Networks: Dynamics

Time-series data typically fitted using VAR(1) models



$$Y_t = \Phi Y_{t-1} + e_t$$

- ▶ Stationarity assumed
- ▶ Uni-stable dynamics



Empirical  $\rightarrow$  Theoretical?

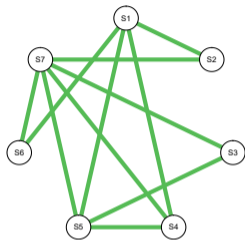
	<b>Theoretical</b>	<b>Empirical</b>
<b>Nodes</b>	Symptoms	Miscellaneous
<b>Dynamics</b>	Bi-stable	Uni-stable

## Open Problem 1: Mapping from node to disorder

Meaningful characteristics of **symptom networks** not meaningful in other domains

- ▶ **Symptoms:** Density  $\rightarrow$   $P(\text{Symptom}=\text{On}) \rightarrow$  Disorder present
- ▶ **Emotion:** Density  $\rightarrow$  ?

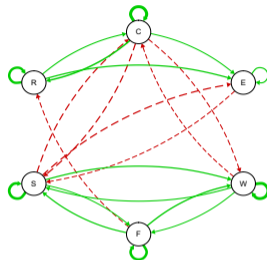
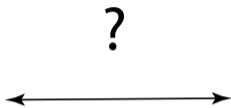
## Open Problem 1: Mapping from node to disorder



Symptoms

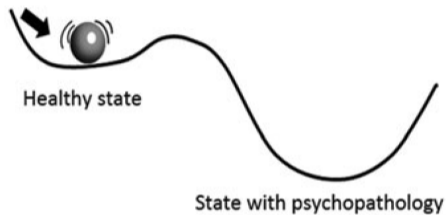
*Defines*

Disorder

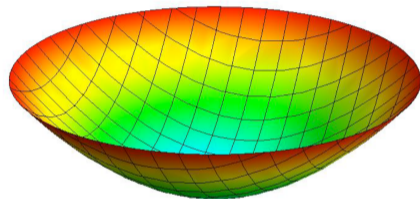


Emotions (Misc)

## Open Problem 2: Bi-stable systems from Uni-stable models

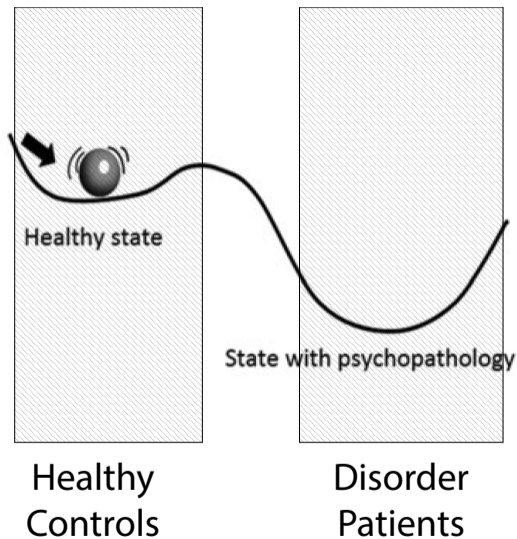


Theoretical

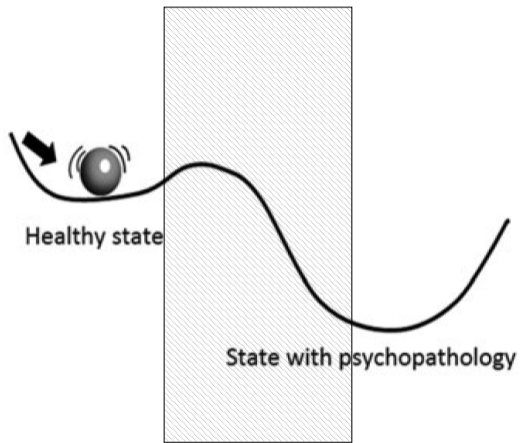


Empirical

## Open Problem 2: Bi-stable systems from Uni-stable models



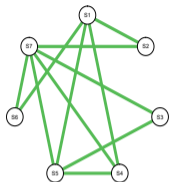
## Open Problem 2: Bi-stable systems from Uni-stable models



*Healthy to Disorder  
Transition*

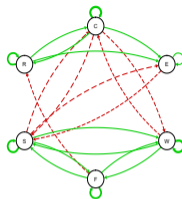
Wichers et al. (2015)

# Summary



Symptom

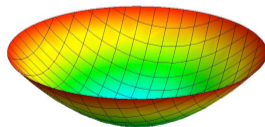
?



Emotion (Misc)



Bi-stable



Uni-stable

Thanks for listening!

`o.ryan@uu.nl`

`ryanoisin.github.io`

