Challenges in characterizing psychopathologies as unhealthy dynamic systems

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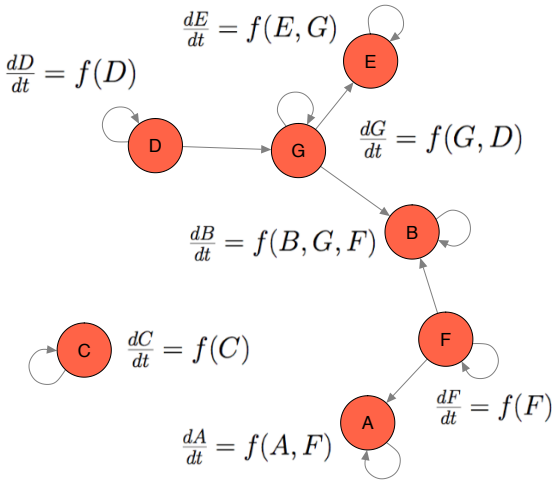
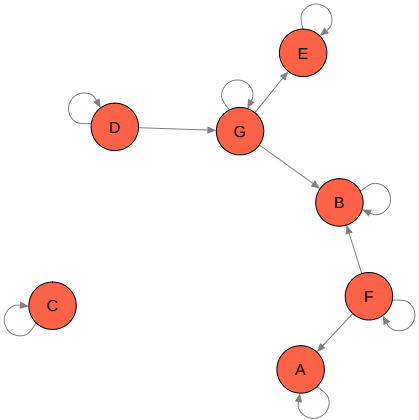
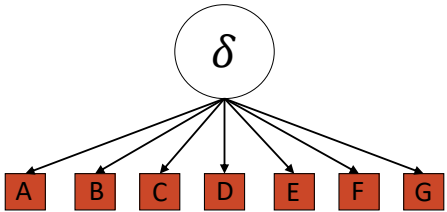
Psychological Disorders as Dynamic Systems



What's the appeal?





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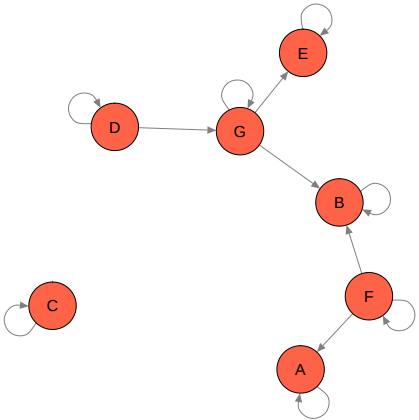


- Focus on causal interactions between variables/nodes
- Characterise structure of interactions that lead to pathology

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

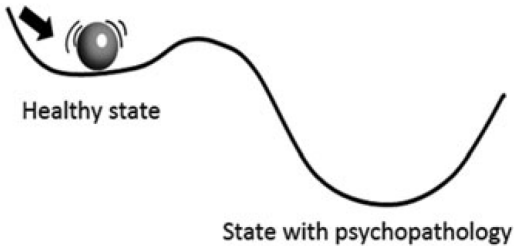


Figure: Wichers et al 2018

Theory: Symptom Networks

- Mental disorders arise from direct interactions betweeen **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

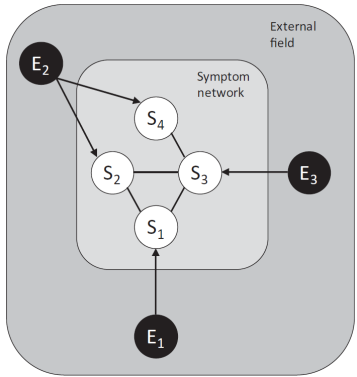
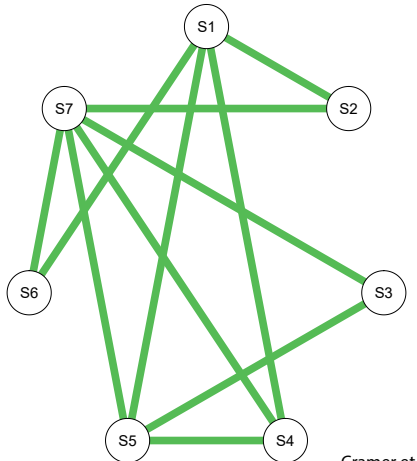


Figure: Borsboom 2017

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”

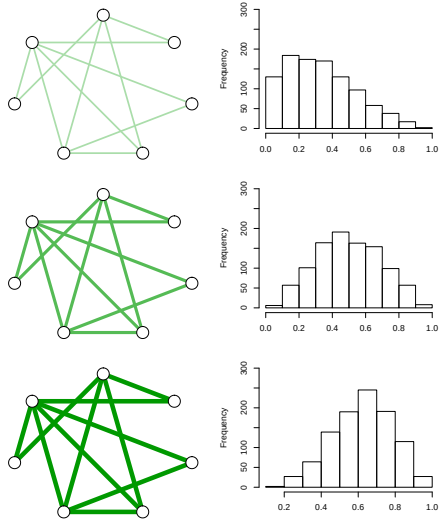


Cramer et al. (2016)

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* $\rightarrow$ 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

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

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

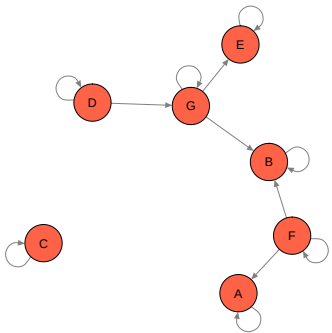
$$P(\boldsymbol{Y_j} = 1 | \boldsymbol{Y_{\setminus j}}) \Rightarrow \exp(\hat{\boldsymbol{\beta}} \boldsymbol{Y_{\setminus j}})$$

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

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

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?

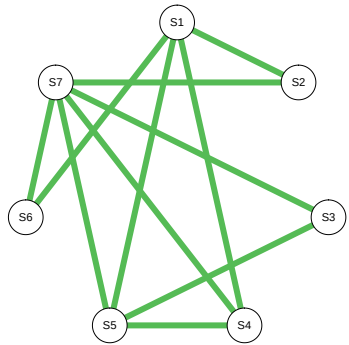
Empirical applications have outpaced theoretical contributions

	Theoretical	**Empirical**
Nodes	Symptoms	?
Dynamics	Bi-stable	?

Empirical Networks: Nodes

Empirical *symptom* networks

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



Empirical Networks: Nodes

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- Depression (van Borkulo et al 2015)
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Mix of symptoms and non-symptoms

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

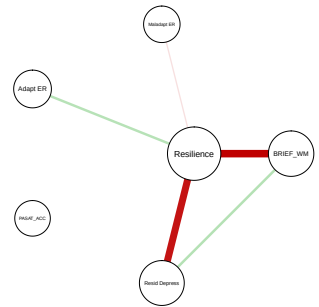

Figure: Hoorelebeke et al (2016)

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)

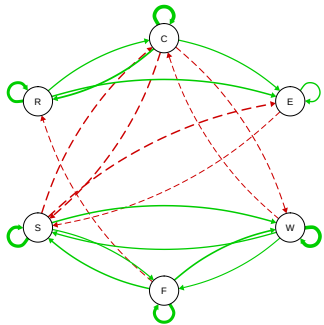
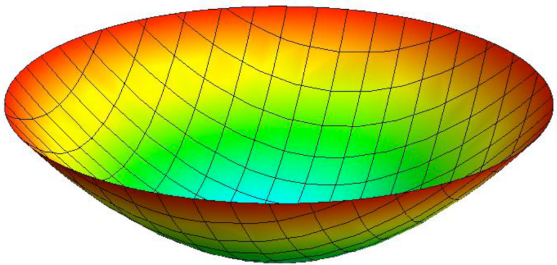


Figure: Bringmann et al. (2013)

Empirical Networks: Dynamics

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



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

- Stationarity assumed
- Uni-stable dynamics

Empirical $\rightarrow$ Theoretical?

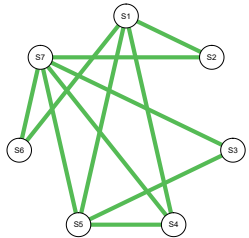
	Theoretical	**Empirical**
Nodes	Symptoms	Miscellaneous
Dynamics	Bi-stable	Uni-stable

Open Problem 1: Mapping from node to disorder

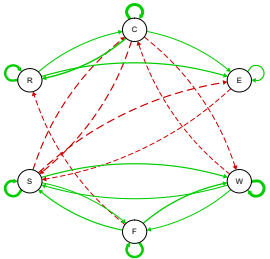
Meaningful characteristics of **symptom networks** not meaningful in other domains

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

Open Problem 1: Mapping from node to disorder



?



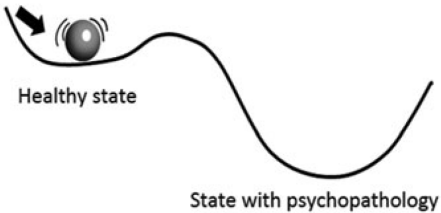
Symptoms

Emotions (Misc)

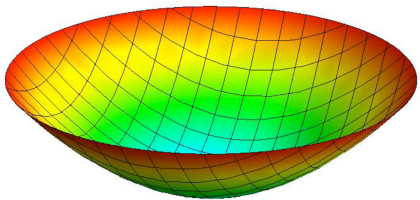
Defines

Disorder

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

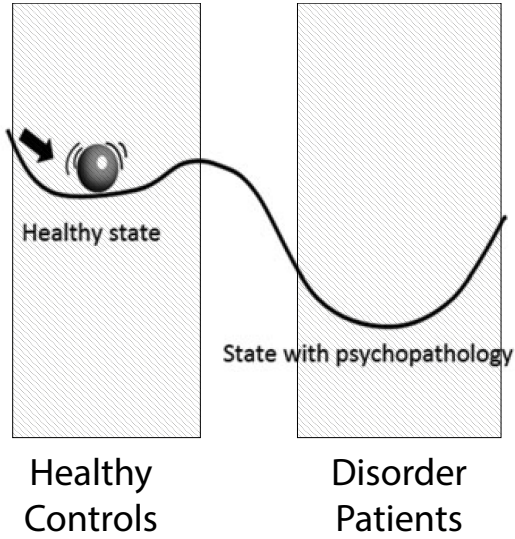


Theoretical

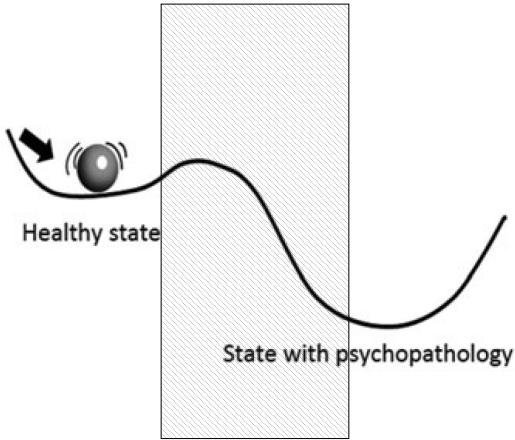


Empirical

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



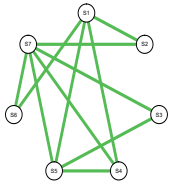
Open Problem 2: Bi-stable systems from Uni-stable models



Healthy to Disorder Transition

Wichers et al. (2015)

Summary



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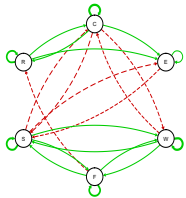
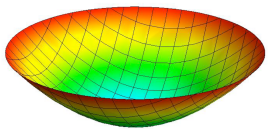


Symptom

Emotion (Misc)



Bi-stable

Uni-stable

Thanks for listening!

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