The Psych Systems Project

Networks: Approaches, models, and theories

Denny Borsboom
University of Amsterdam

www.psychosystems.org

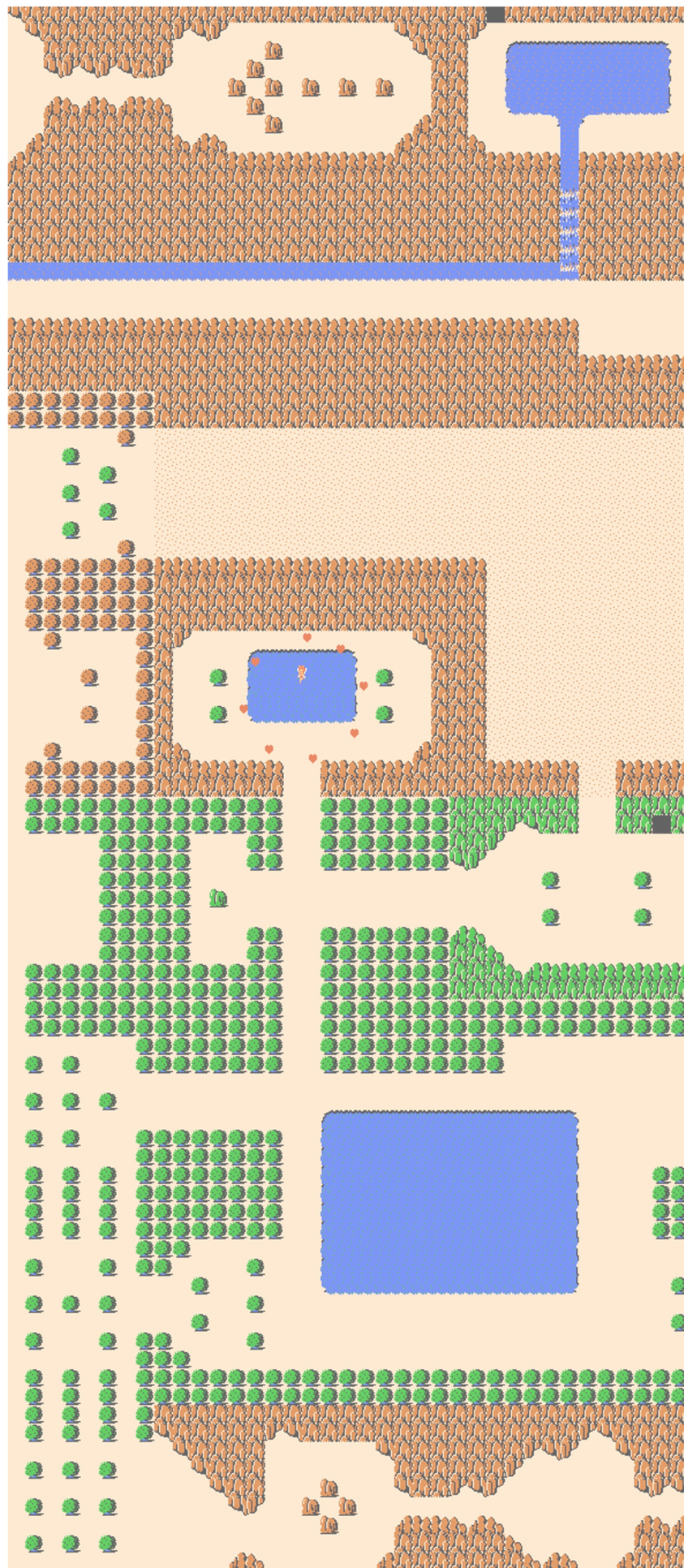
Roadmap

The network approach

Network models

Network theory

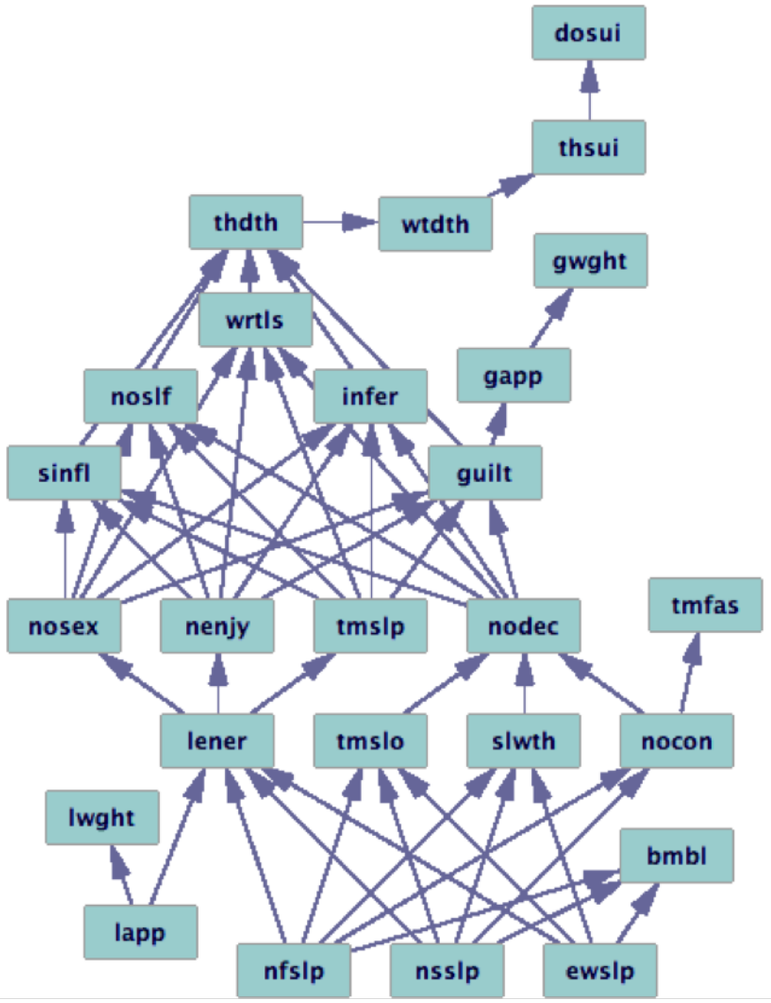
How does it al fit together?



Part I: The Network Approach

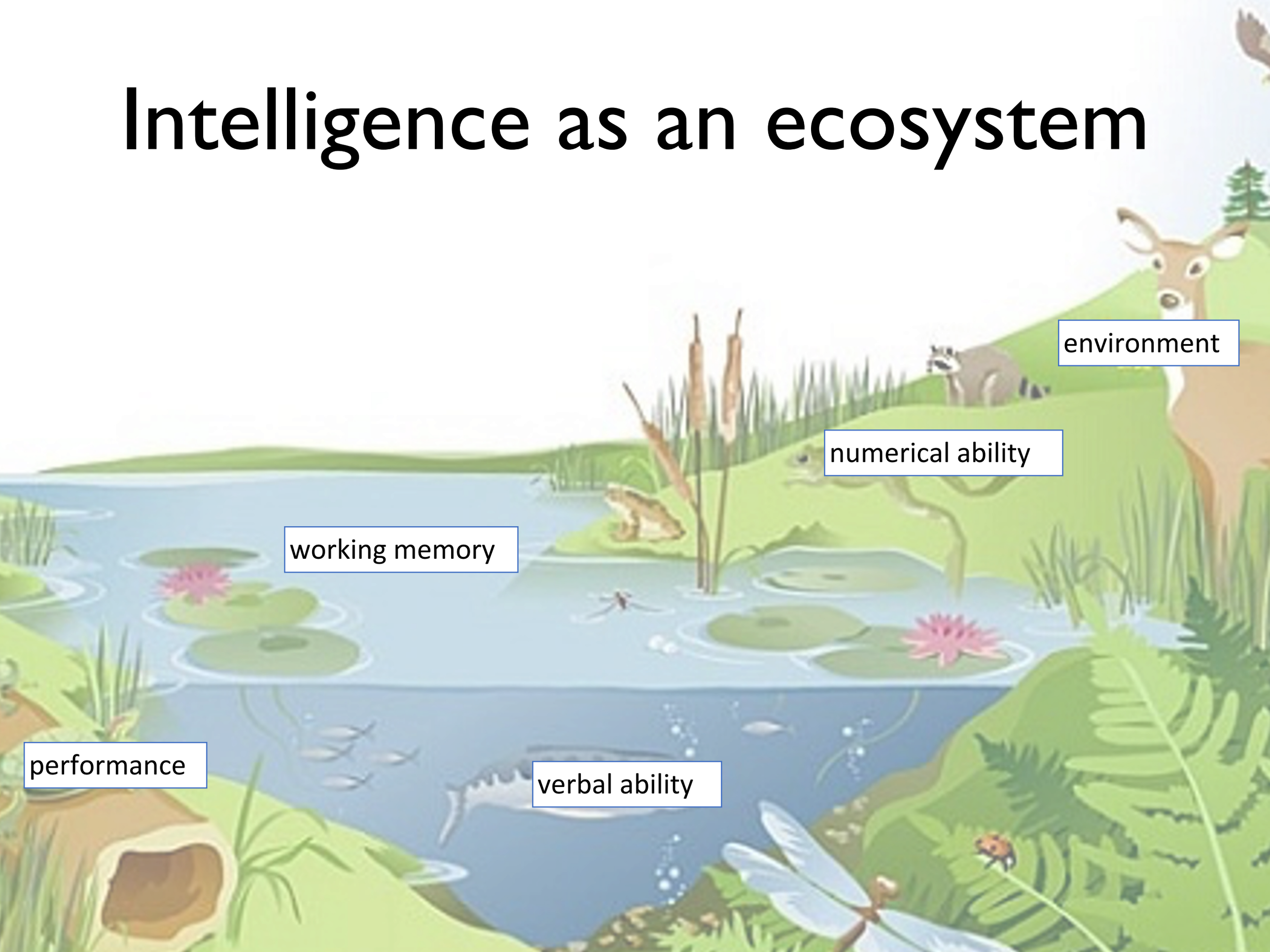
Psych Systems

- Psychological constructs (depression, intelligence, attitudes) are *systems*
- These systems consist of entities (symptoms, cognitive abilities, beliefs) that *interact*
- Studying these interactions is key to understanding psychology and behaviour



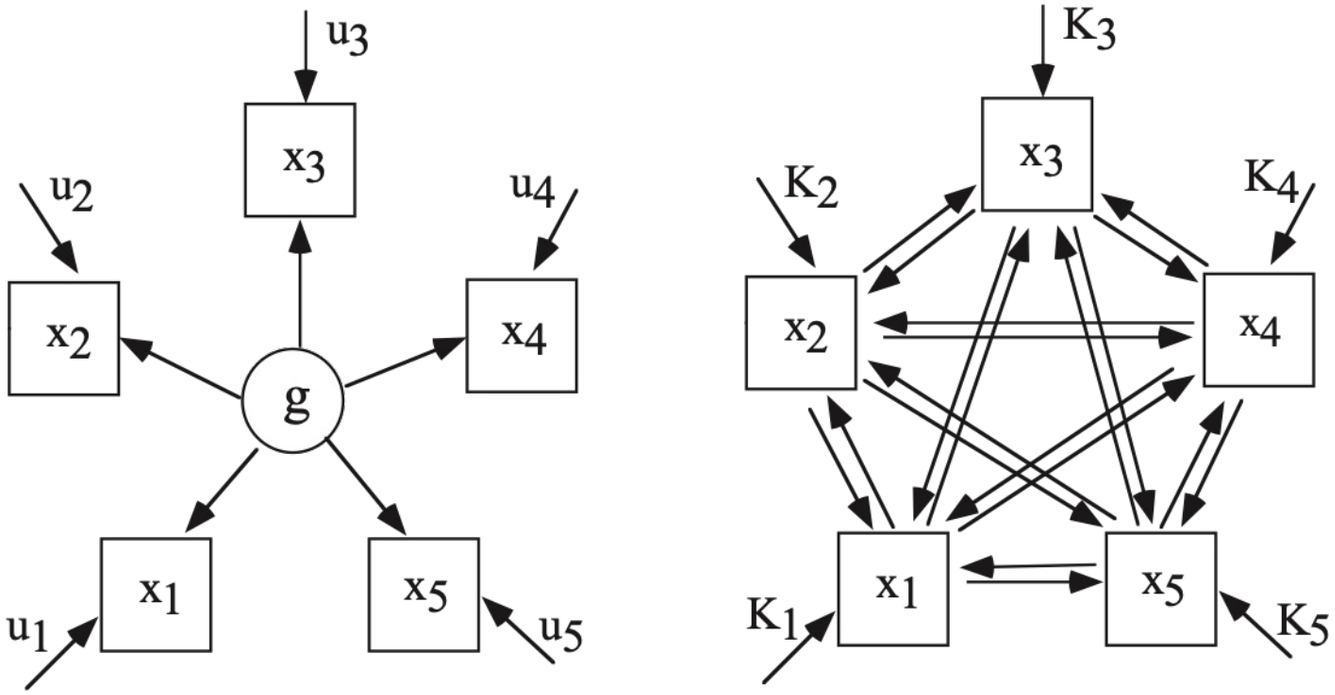
This is a causal network of DSM-symptoms, which I produced in 2007 using the Tetrad software of Clark Glymour et al.

Intelligence as an ecosystem



A Dynamical Model of General Intelligence: The Positive Manifold of Intelligence by Mutualism

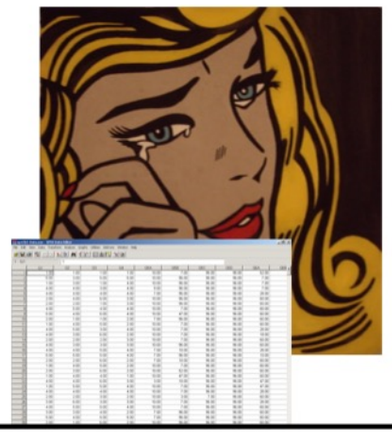
Han L. J. van der Maas, Conor V. Dolan, Raoul P. P. P. Grasman, Jelte M. Wicherts,
Hilde M. Huizenga, and Maartje E. J. Raijmakers
University of Amsterdam



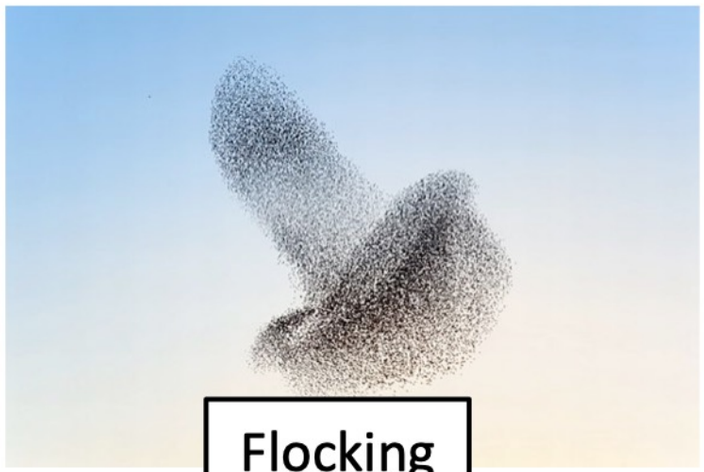
A final question is whether it is possible to apply this model, or at least this line of reasoning, to other areas in psychology, where correlational data play an important role, and the identification of latent variables is based strongly on the results of factor analyses. ... For instance, should we view depression as a true latent variable, which determines a variety of psychological behaviors, or is it actually the upshot of system of self-reinforced negative behaviors and feelings?

Latent disorders versus Networks

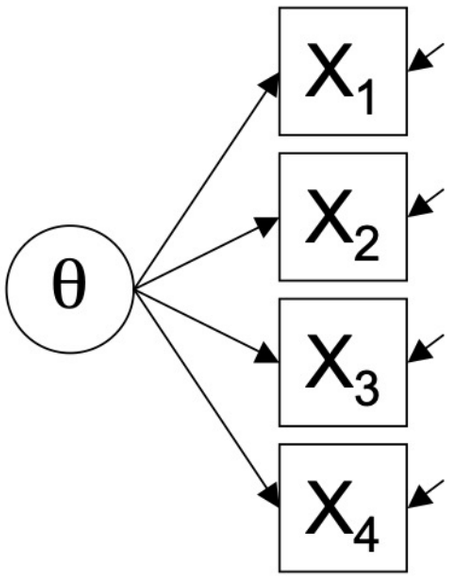
Disease analogy



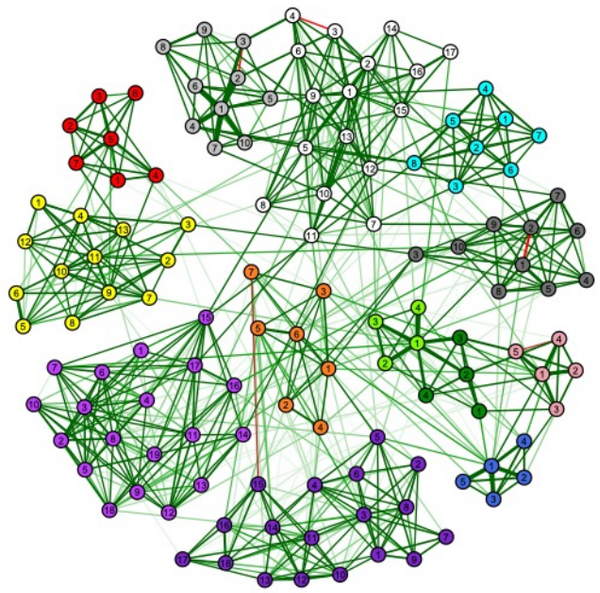
Psychopathology symptom data



Flocking analogy



Latent variable model



Network model

BEHAVIORAL AND BRAIN SCIENCES (2010) **33**, 137–193
doi:10.1017/S0140525X09991567

Comorbidity: A network perspective

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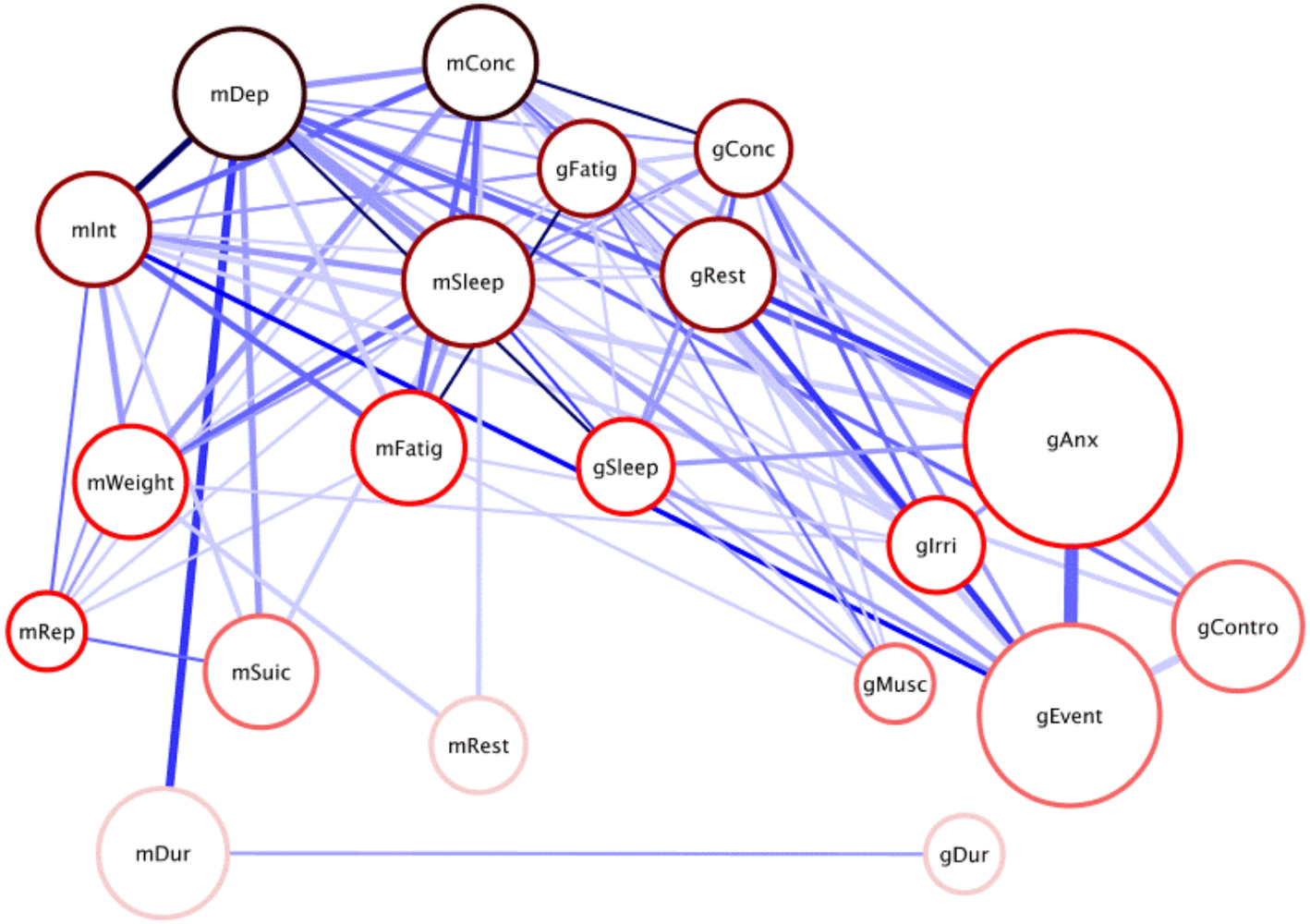
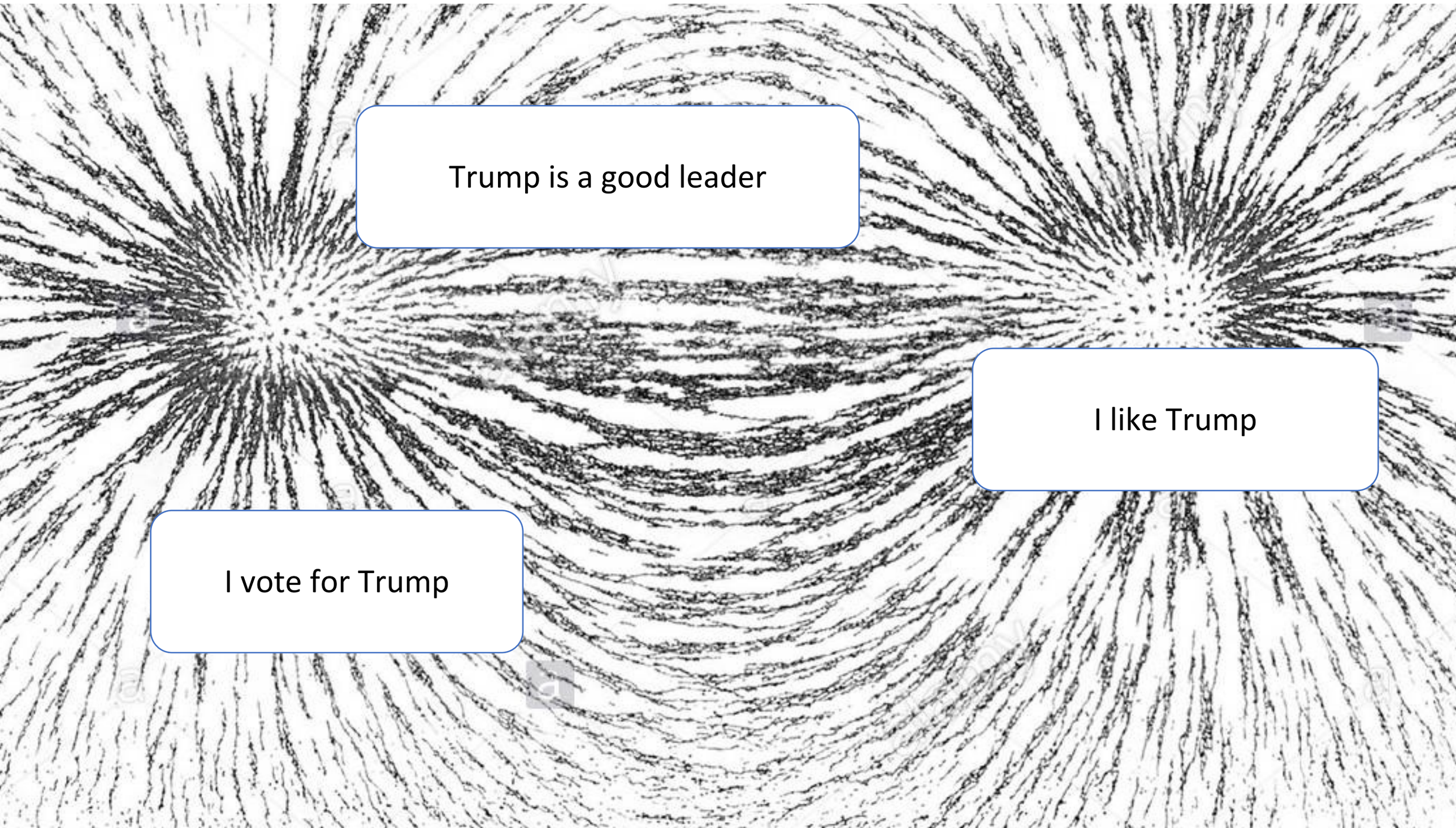


Attitudes and consistency



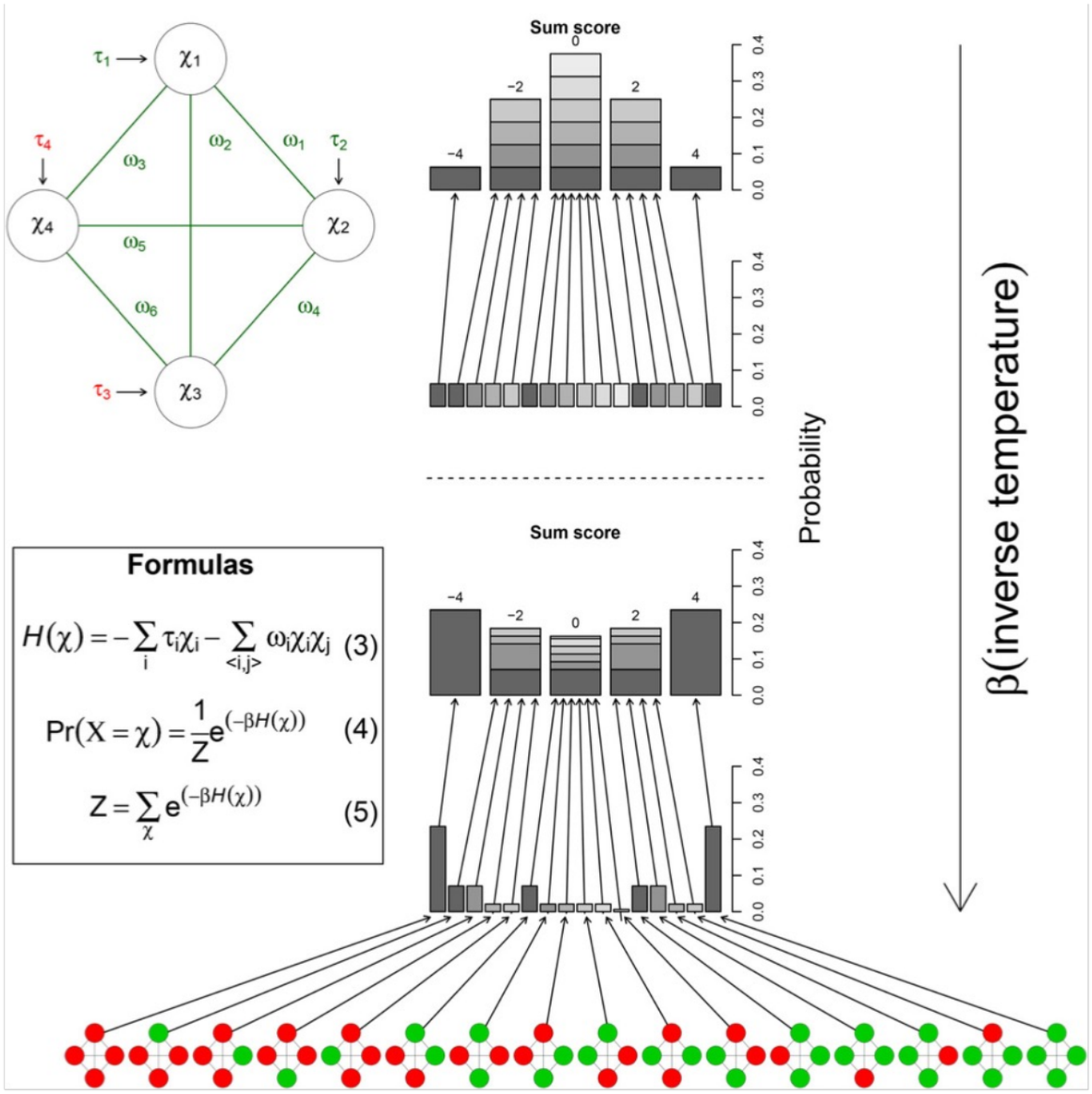
PSYCHOLOGICAL INQUIRY
2018, VOL. 29, NO. 4, 175–193
https://doi.org/10.1080/1047840X.2018.1537246

TARGET ARTICLE

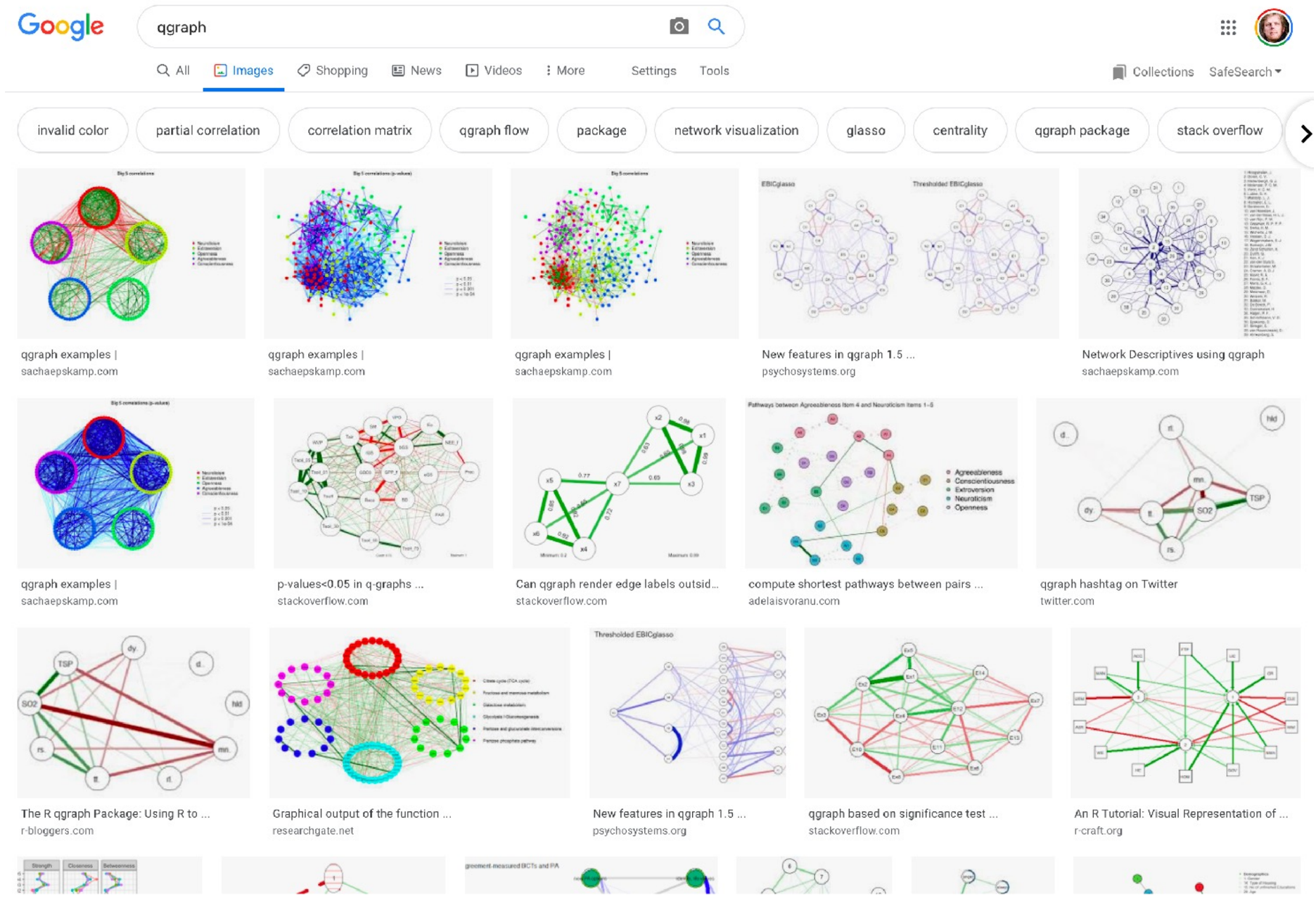
The Attitudinal Entropy (AE) Framework as a General Theory of Individual Attitudes

Jonas Dalege, Denny Borsboom, Frenk van Harreveld, and Han L. J. van der Maas

Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands

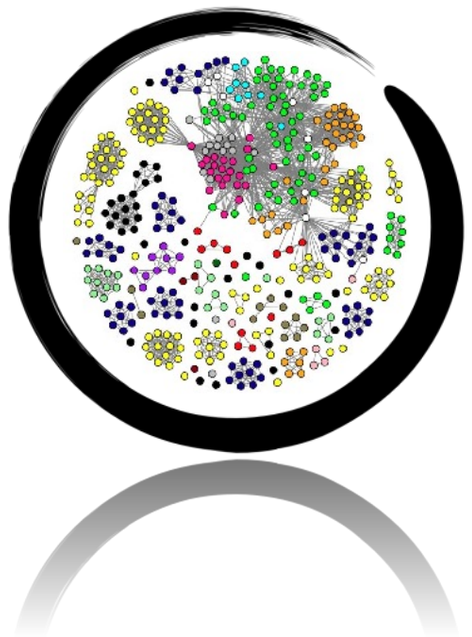


Variables and correlations



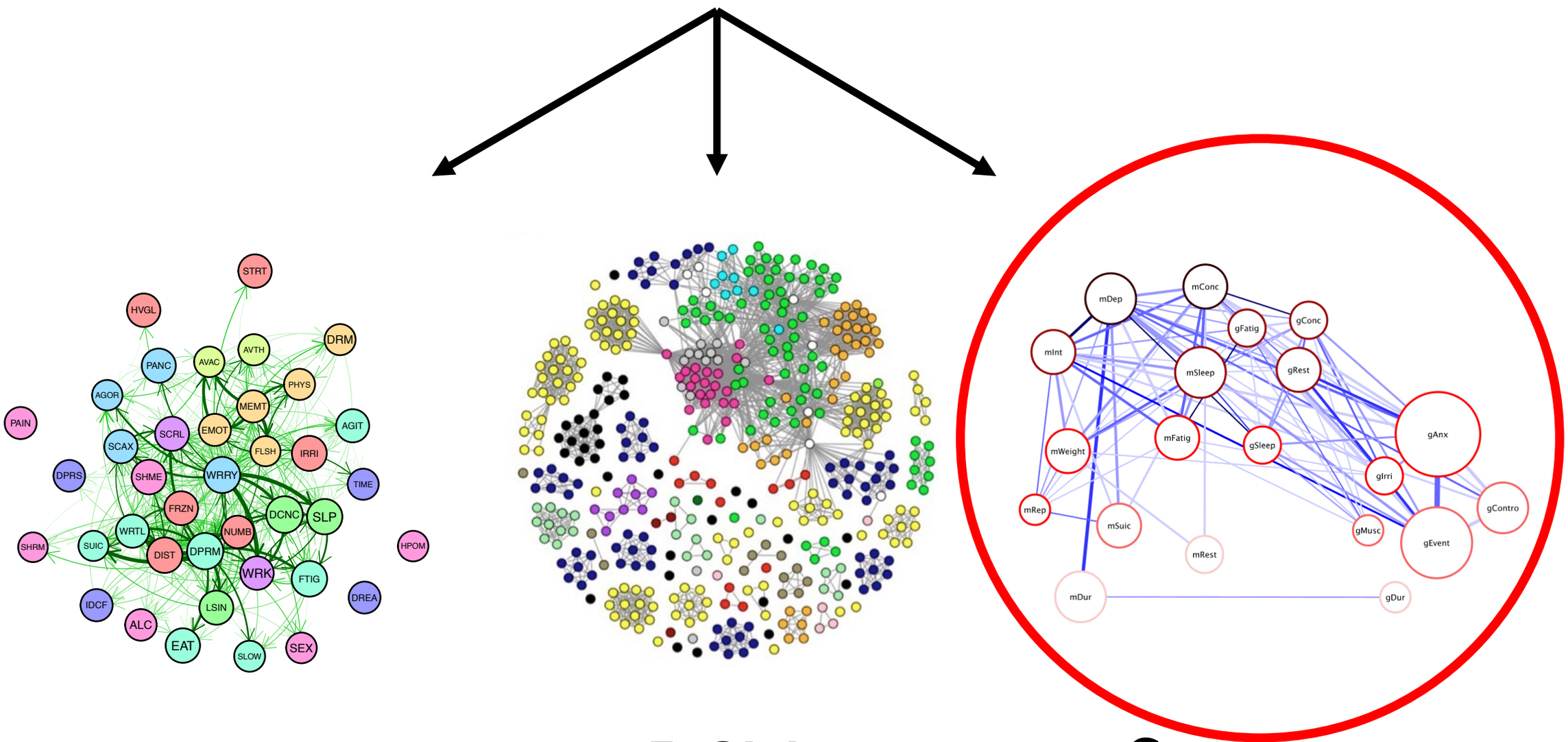
The Network Approach

- Themes
  - *Reciprocal interaction and feedback*
  - *Emergent order versus common causes*
- Techniques
  - *Assessing patterns of pairwise interactions*
  - *Analysis of system dynamics*
- Theoretical frameworks
  - *Network theory*
  - *Dynamical systems*



Part II: Network Models

The network approach: towards data analysis



Self report

DSM structure

Symptom data

Package ‘qgraph’

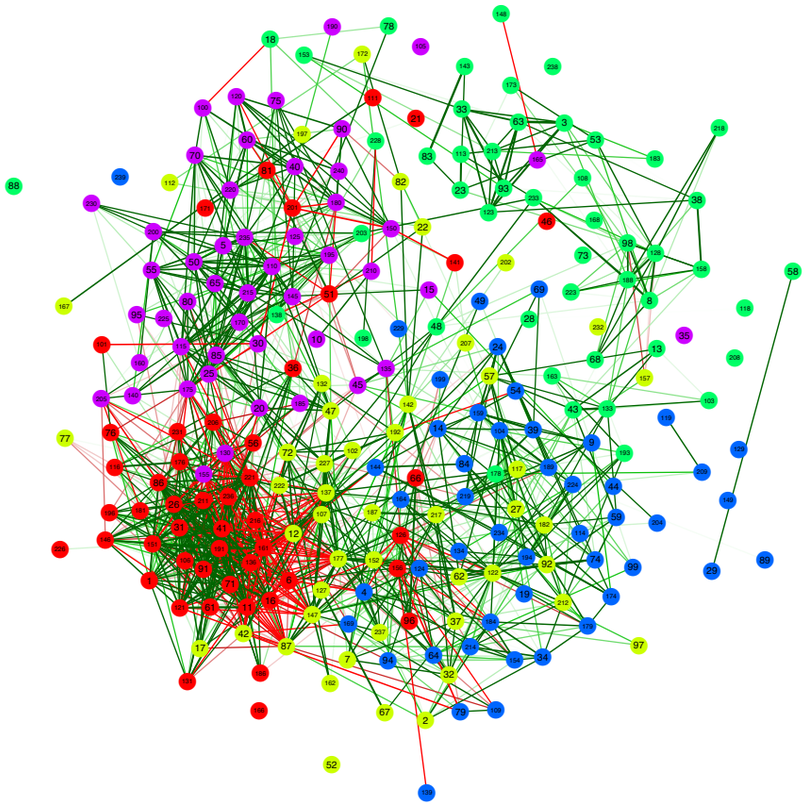
January 28, 2021

Type Package

Title Graph Plotting Methods, Psychometric Data Visualization and Graphical Model Estimation

Version 1.6.9

Maintainer Sacha Epskamp <mail@sachaepskamp.com>

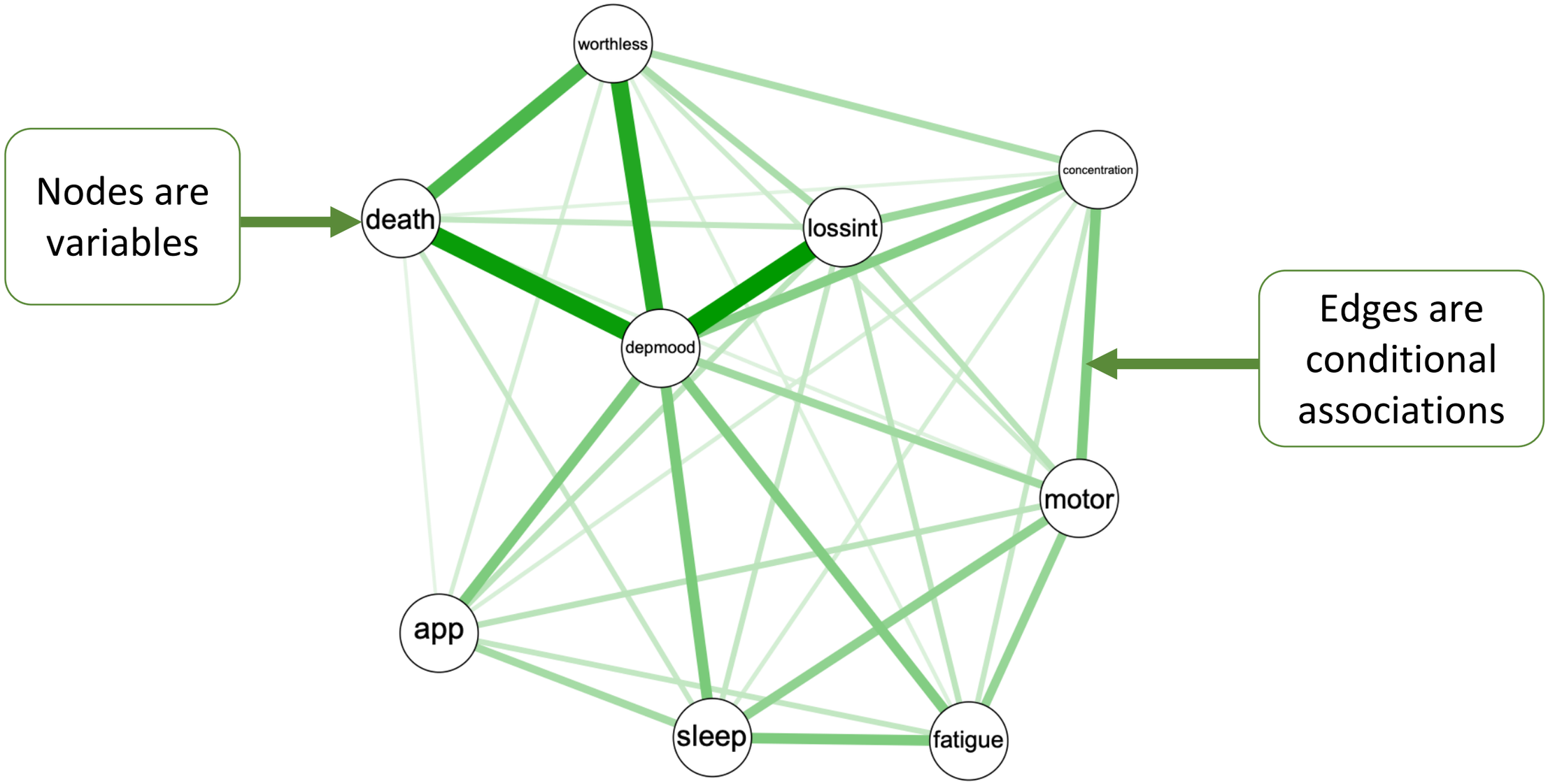


Statistical modeling

- The network approach almost immediately led to attempts to statistically estimate network structures from data
- At first, we just visualised correlations
- Lourens Waldorp came up with the idea of using regularised regression for neighbourhood selection
- On the basis of this idea, Claudia van Borkulo and Sacha Epskamp developed *IsingFit*: the first software designed to fit these networks for binary data
- Currently, we can fit networks to continuous, binary, and categorical data - and also to mixed sets of items using Jonas Haslbeck's mgm

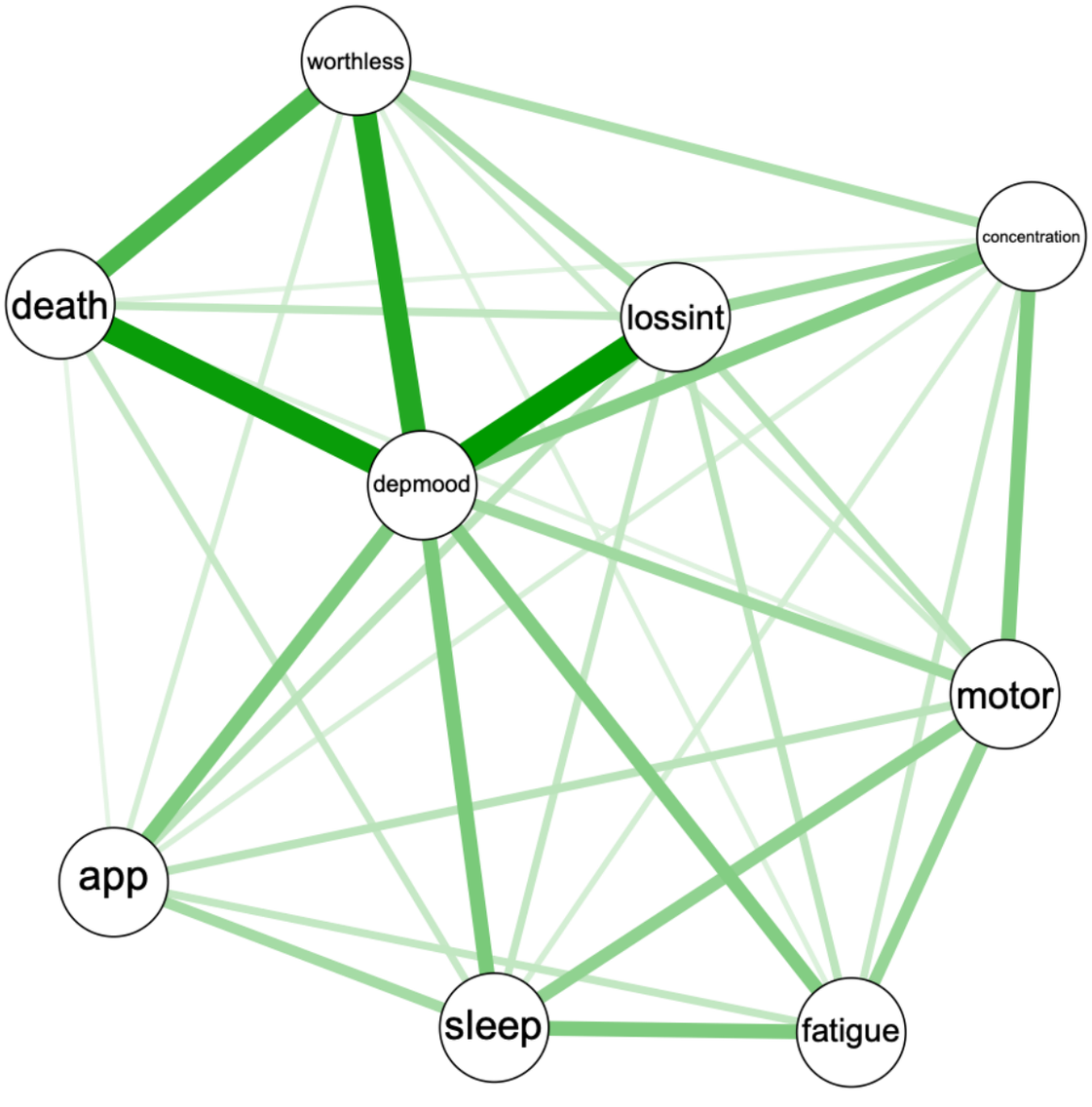
van Borkulo, C. D., Borsboom, D., Epskamp, S., Blanken, B. W., Bosschloo, L., Schoevers, R. A., & Waldorp, L. J. (2014). A new method for constructing networks from psychometric data. *Scientific Reports, 4*, 5918;

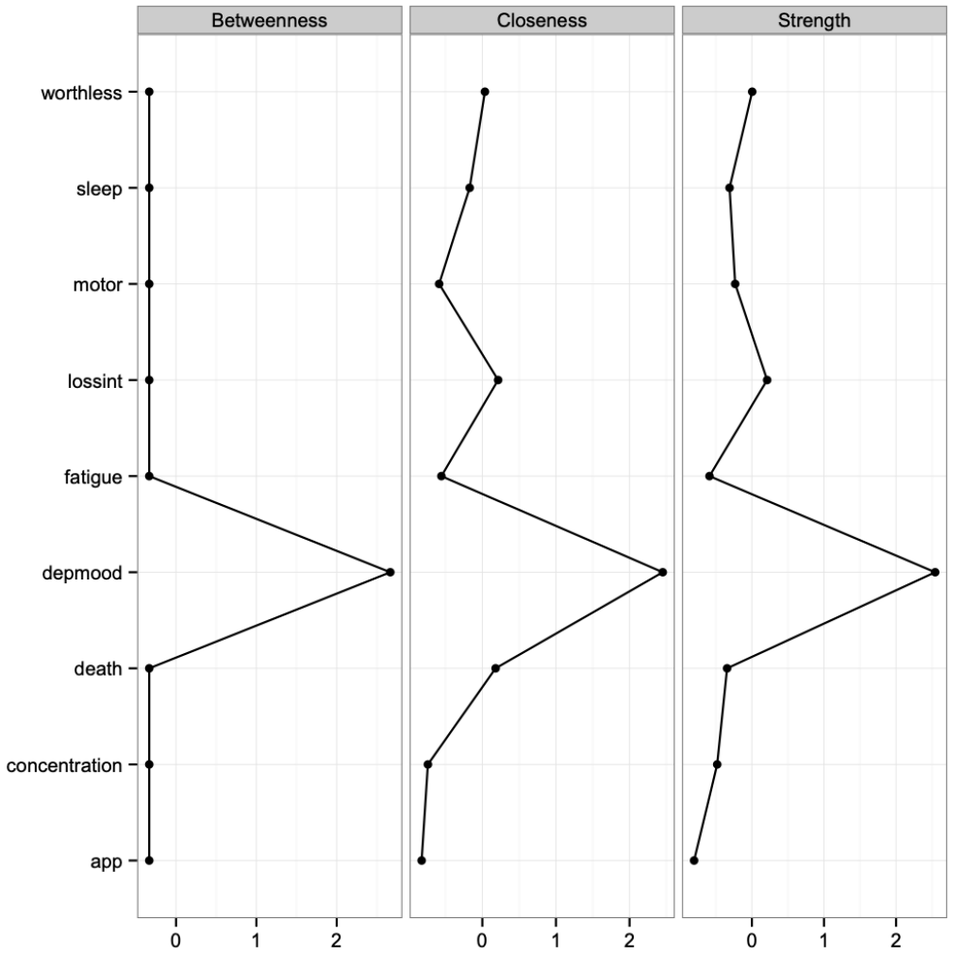
Network Models (graphical models as networks)



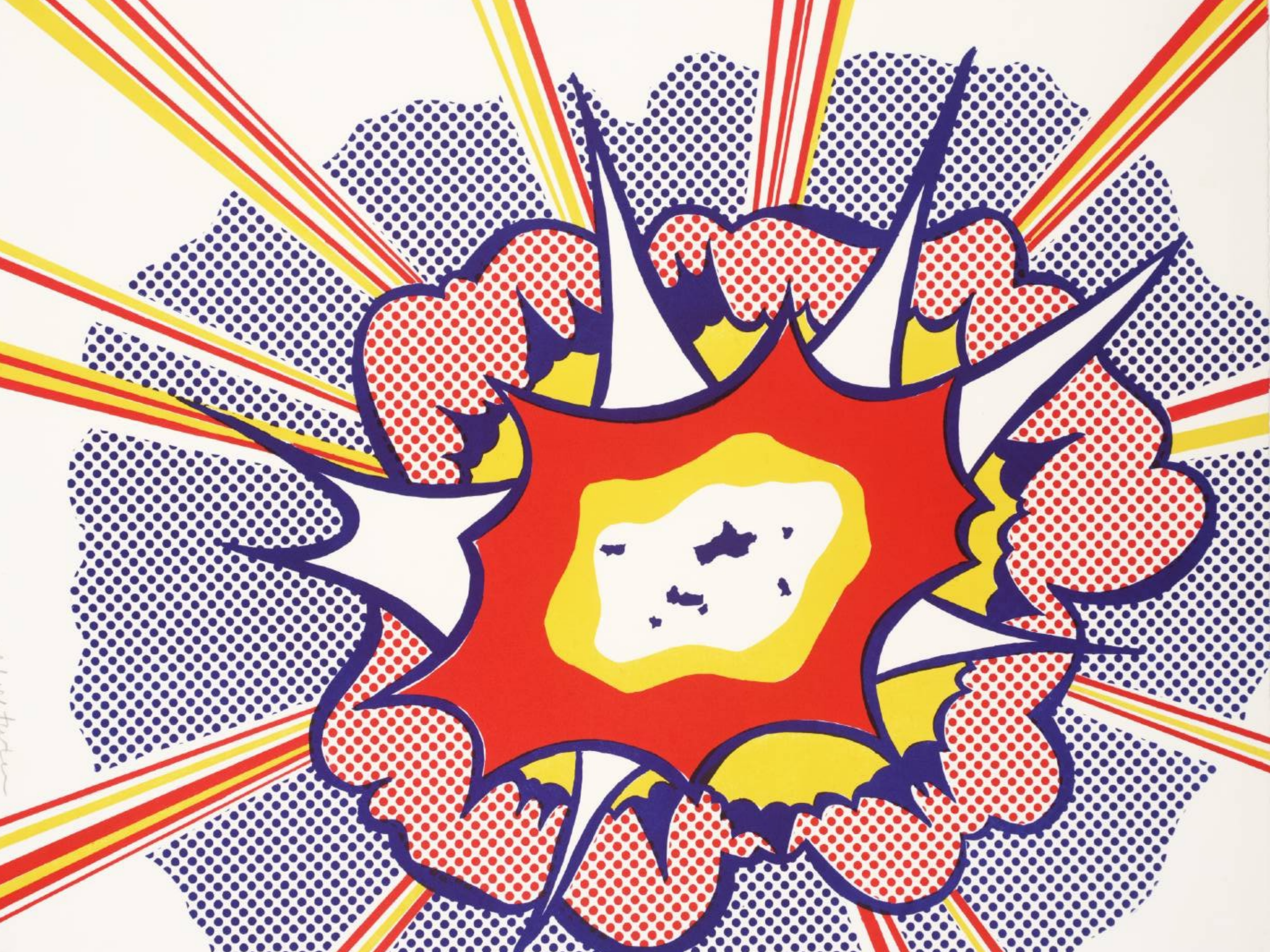
van Borkulo, C. D., Borsboom, D., Epskamp, S., Blanken, B. W., Bosschloo, L., Schoevers, R. A., & Waldorp, L. J. (2014). A new method for constructing networks from psychometric data. *Scientific Reports, 4*, 5918;

Centrality





centralityPlot(network)



Google qgraph

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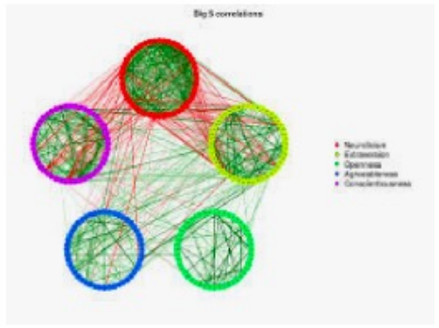
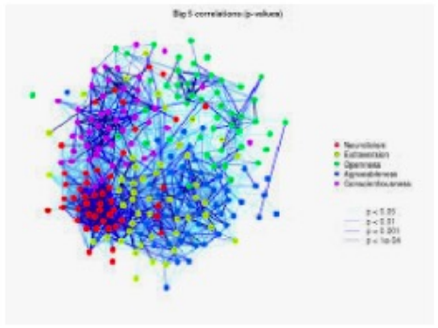
invalid color | partial correlation | correlation matrix | qgraph flow | package | network visualization | glasso | centrality | qgraph package | stack overflow



qgraph examples |
sachaepskamp.com



qgraph examples |
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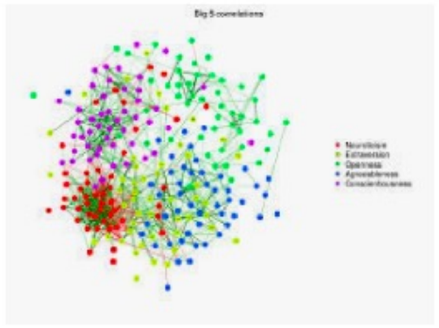
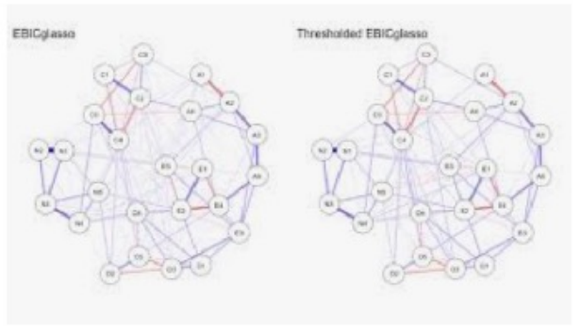
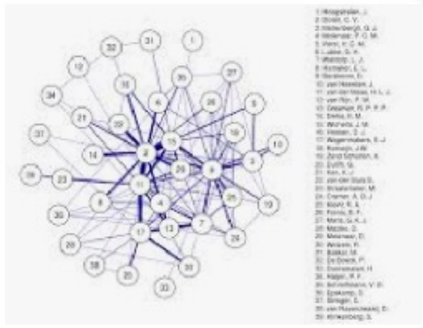


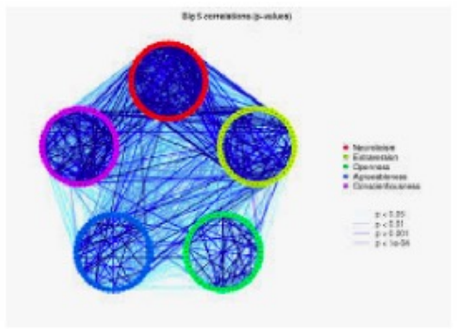
qgraph examples |
sachaepskamp.com



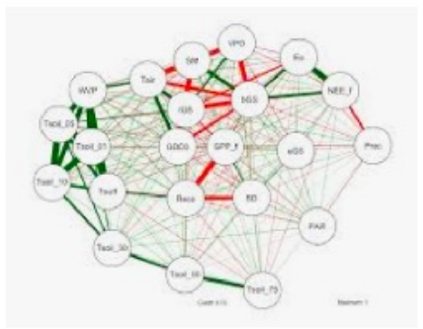
New features in qgraph 1.5 ...
psychosystems.org



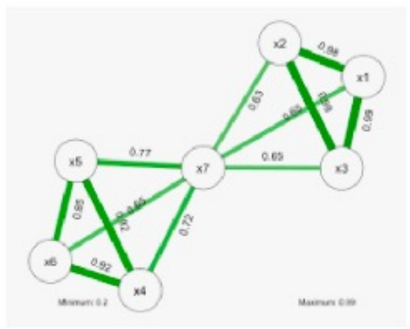
Network Descriptives using qgraph
sachaepskamp.com



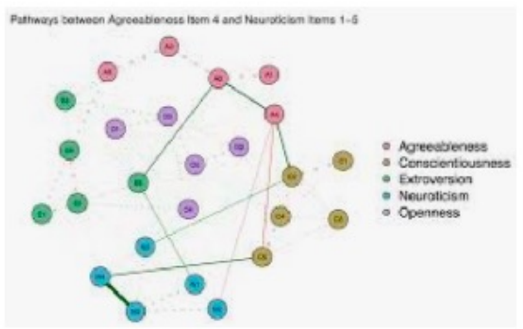
qgraph examples |
sachaepskamp.com



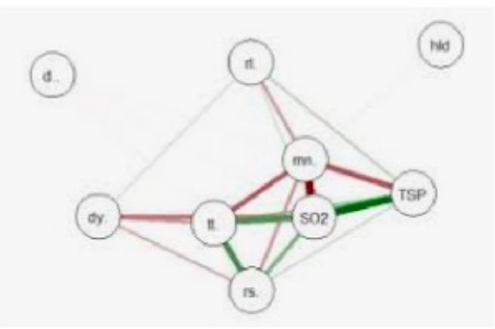
p-values<0.05 in q-graphs ...
stackoverflow.com



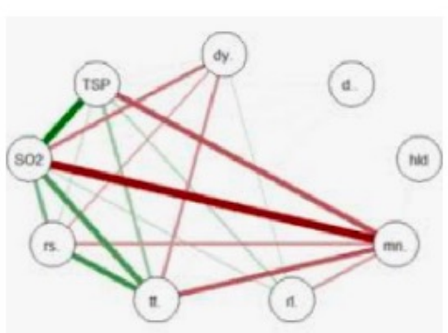
Can qgraph render edge labels outsid...
stackoverflow.com



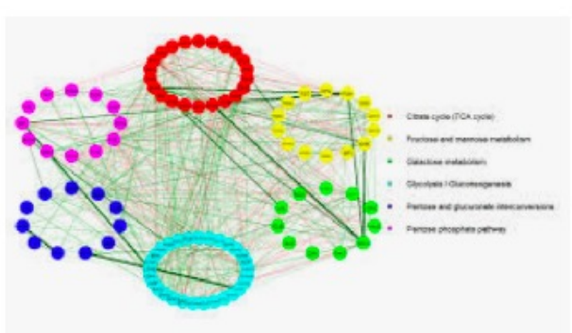
compute shortest pathways between pairs ...
adelaisvoranu.com



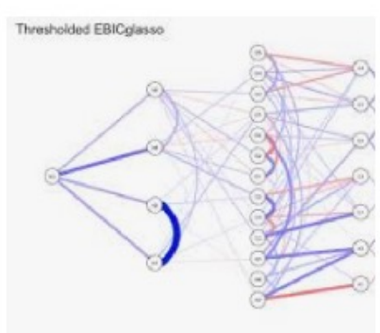
qgraph hashtag on Twitter
twitter.com



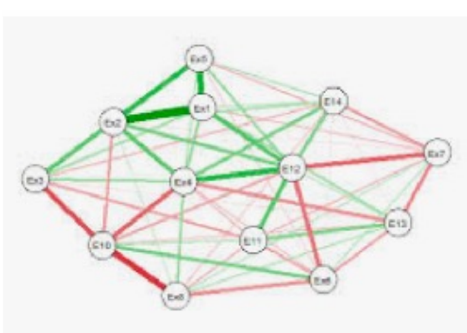
The R qgraph Package: Using R to ...
r-bloggers.com



Graphical output of the function ...
researchgate.net

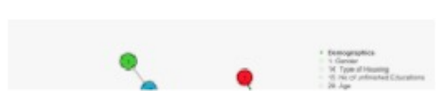


New features in qgraph 1.5 ...
psychosystems.org



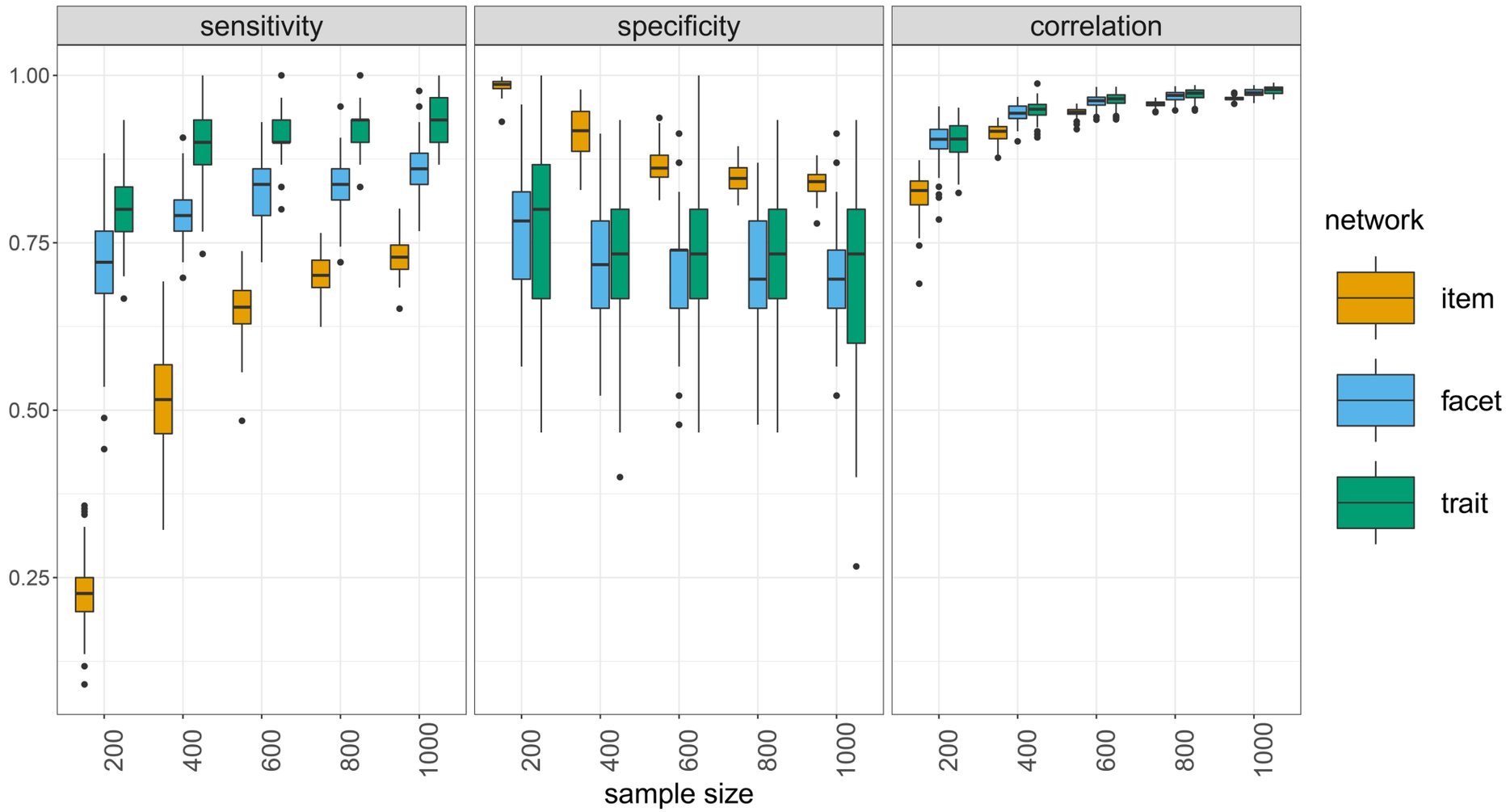
qgraph based on significance test ...
stackoverflow.com

An R Tutorial: Visual Representation of ...
r-craft.org




PANIC

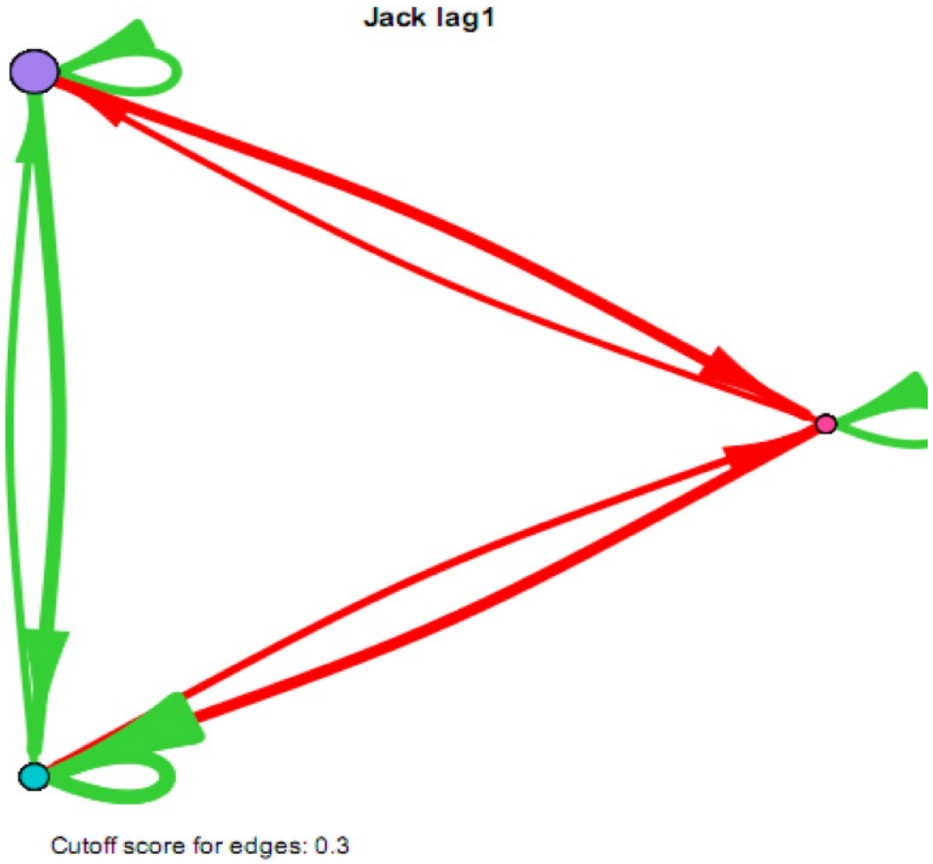
Bootnet

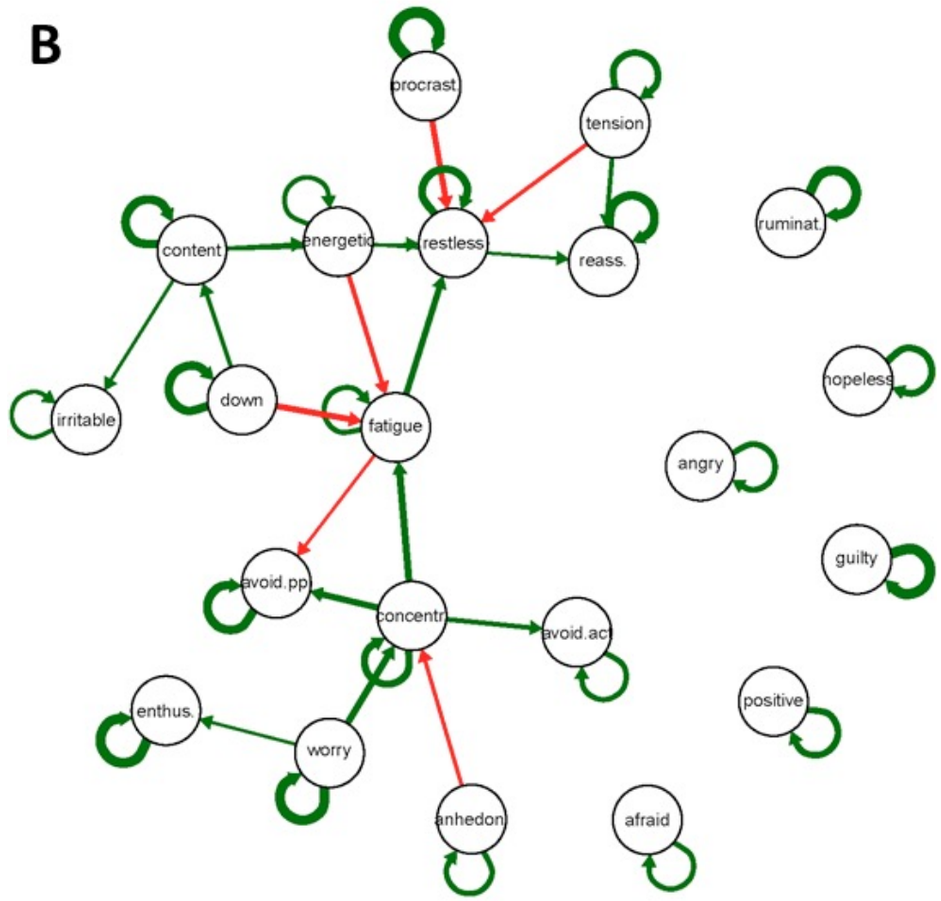


Epskamp, S., Borsboom, D. & Fried, E.I. Estimating psychological networks and their accuracy: A tutorial paper. *Behav Res* **50,** 195–212 (2018). https://doi.org/10.3758/s13428-017-0862-1

Improvements and extensions

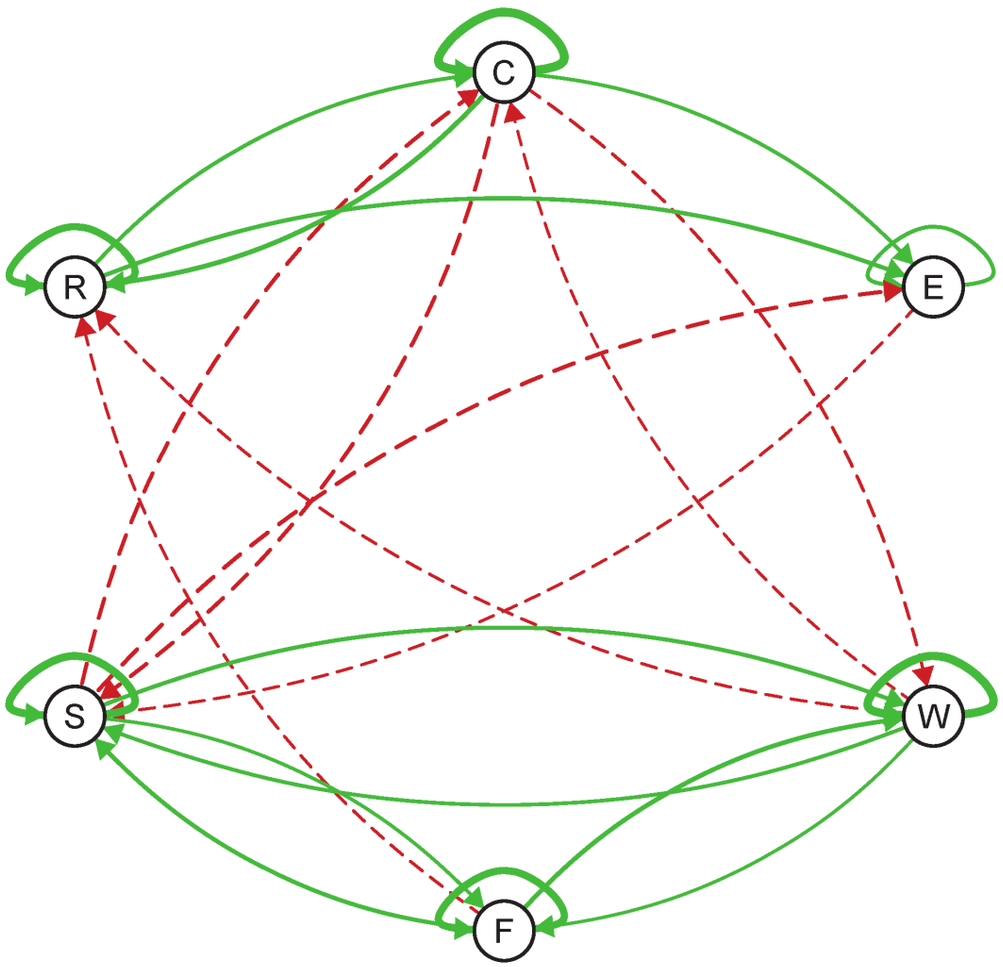
Modeling individuals

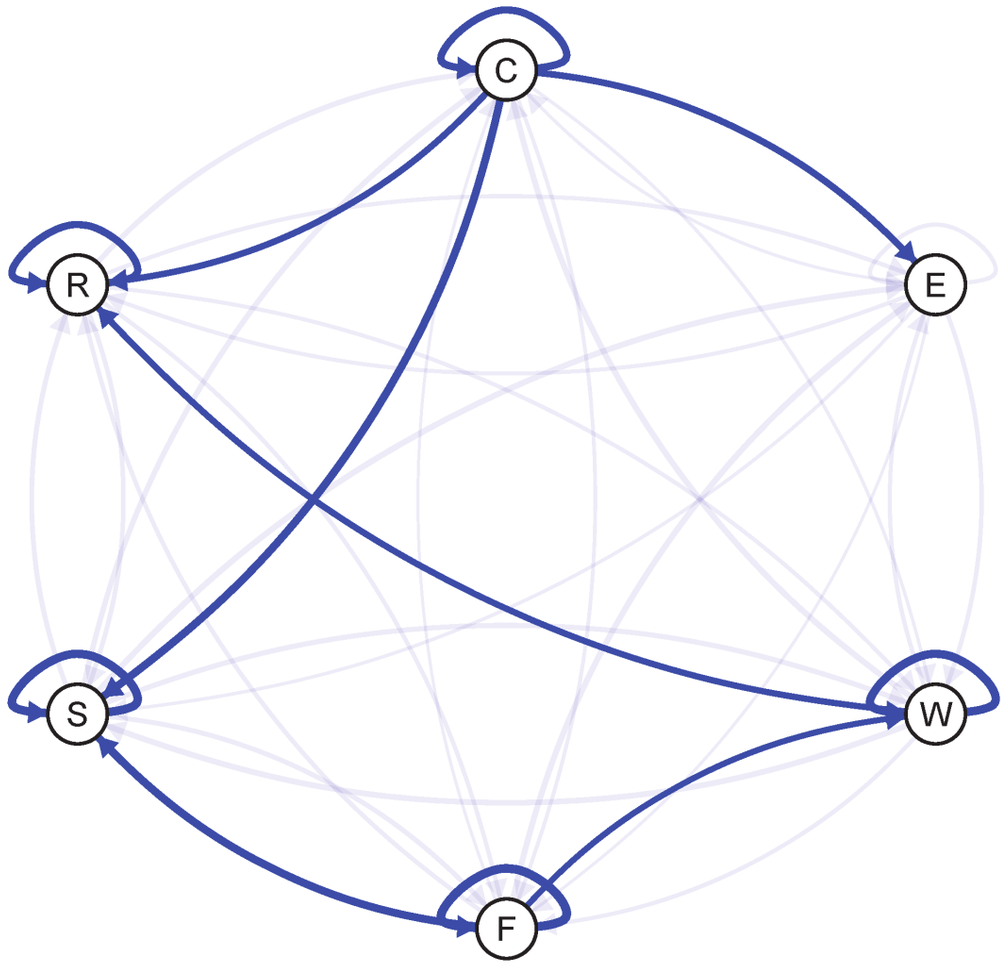




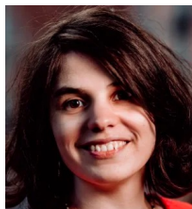
Schuurman, N. K. (2010). Exploratory time series modeling of individuals with burn-out. Unpublished internship report.

Multilevel networks

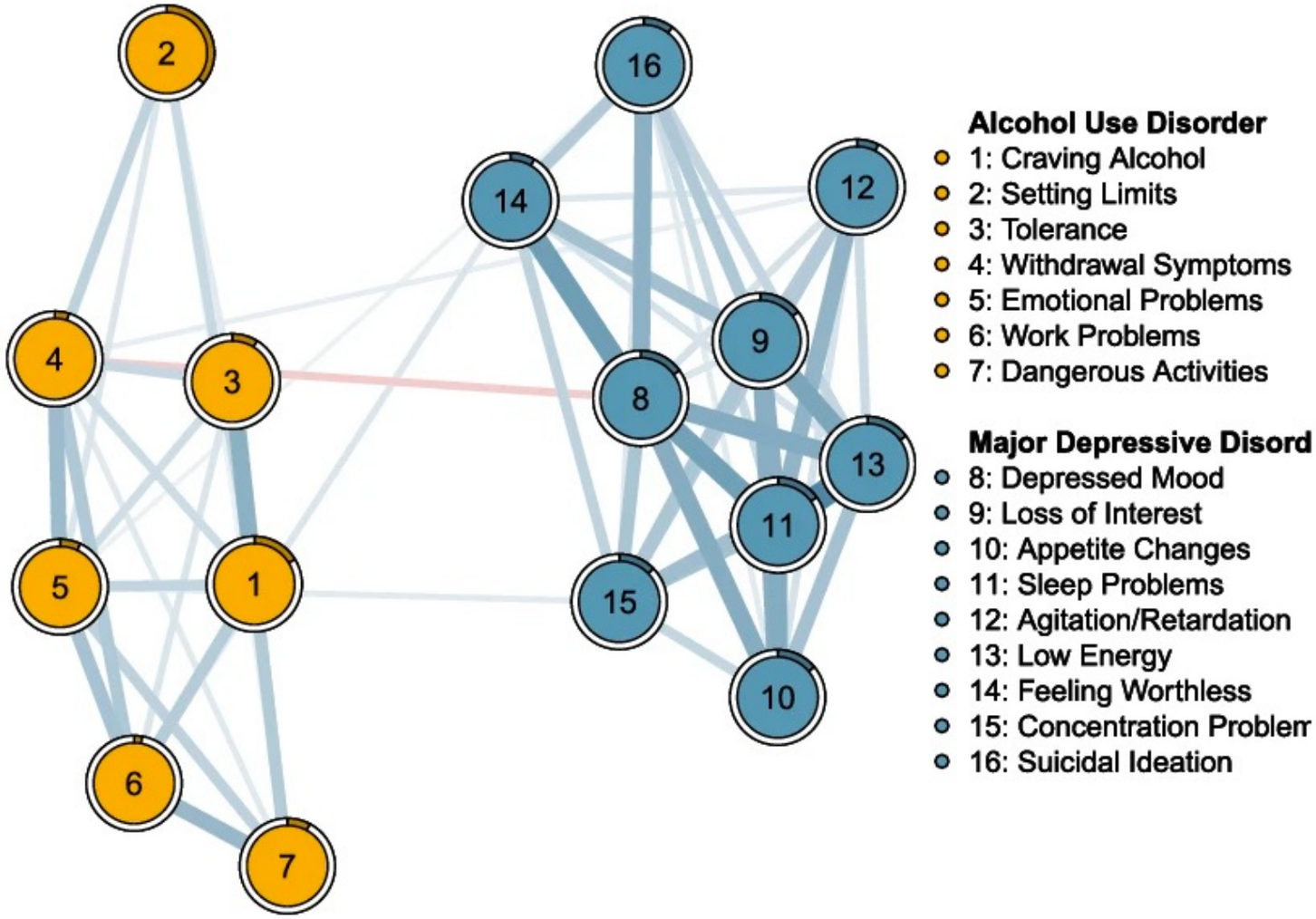




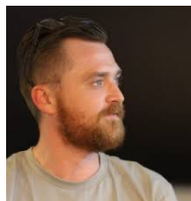
Bringmann LF, Vissers N, Wichers M, Geschwind N, Kuppens P, Peeters F, et al. (2013) A Network Approach to Psychopathology: New Insights into Clinical Longitudinal Data. PLoS ONE 8(4): e60188.



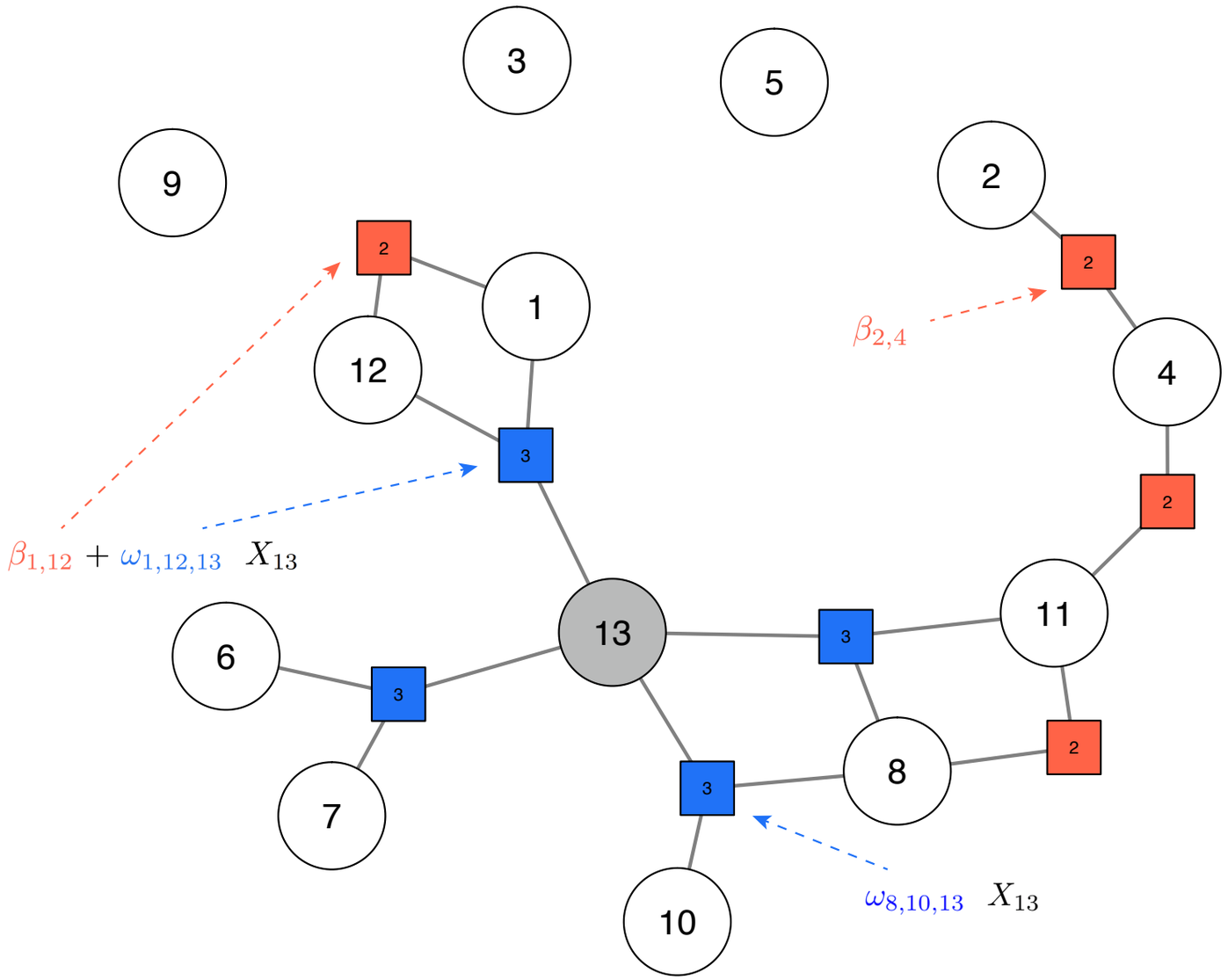
Bayesian approaches



Marsman, M., Huth, K., Waldorp, L.J. *et al.* Objective Bayesian Edge Screening and Structure Selection for Ising Networks. *Psychometrika* **87,** 47–82 (2022). https://doi.org/10.1007/s11336-022-09848-8. See today's session on Network Psychometrics

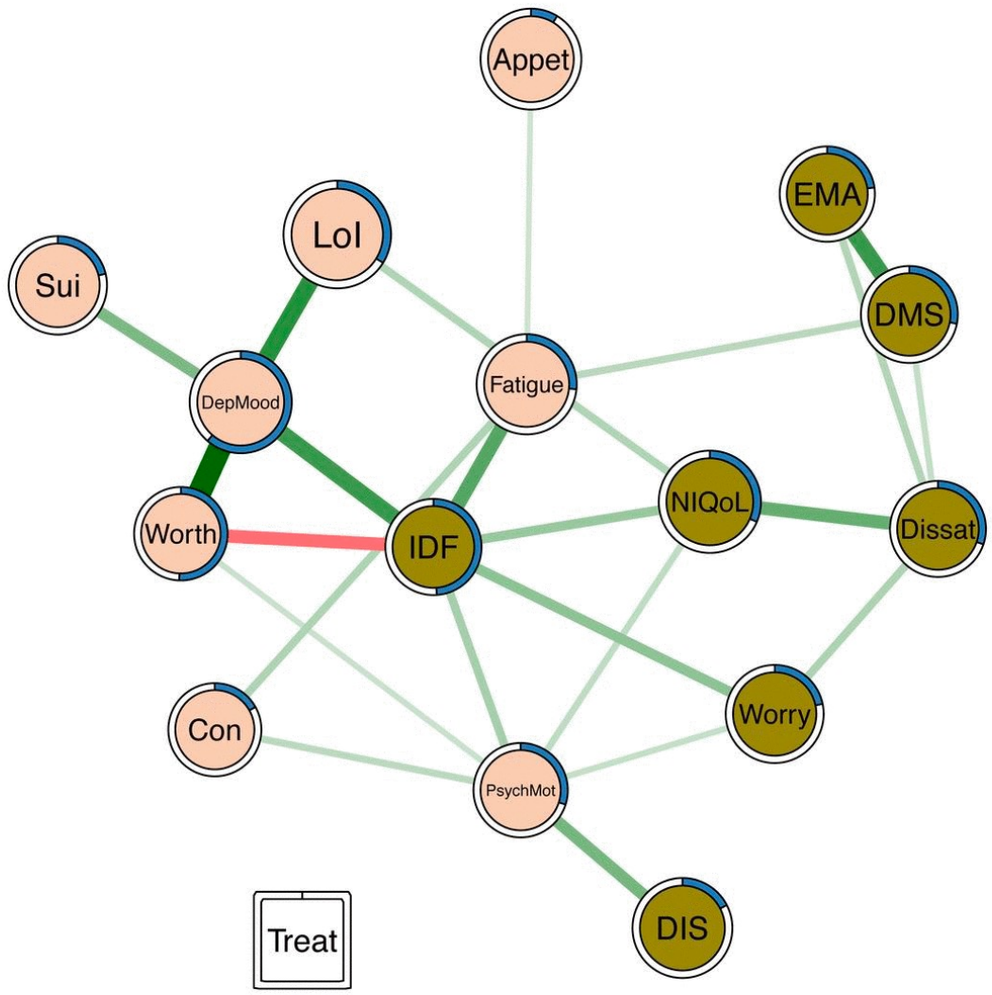


Moderated networks

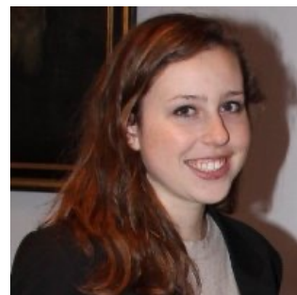


Jonas M. B. Haslbeck, Denny Borsboom & Lourens J. Waldorp (2021) Moderated Network Models, Multivariate Behavioral Research, 56:2, 256-287, DOI: 10.1080/00273171.2019.1677207

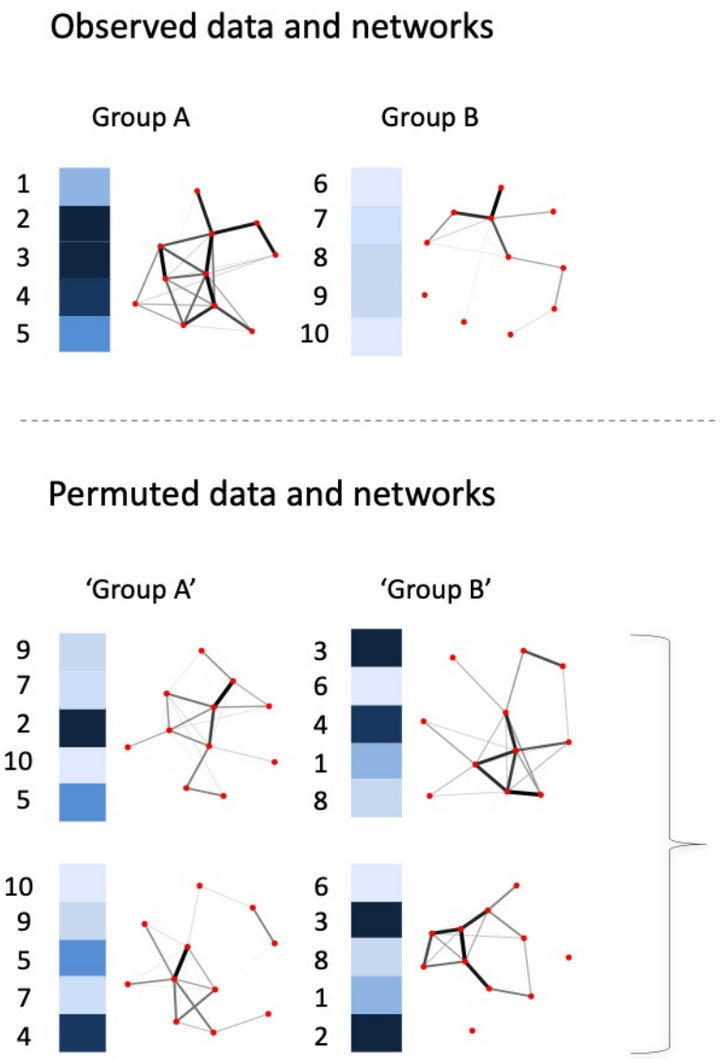
Network intervention analysis

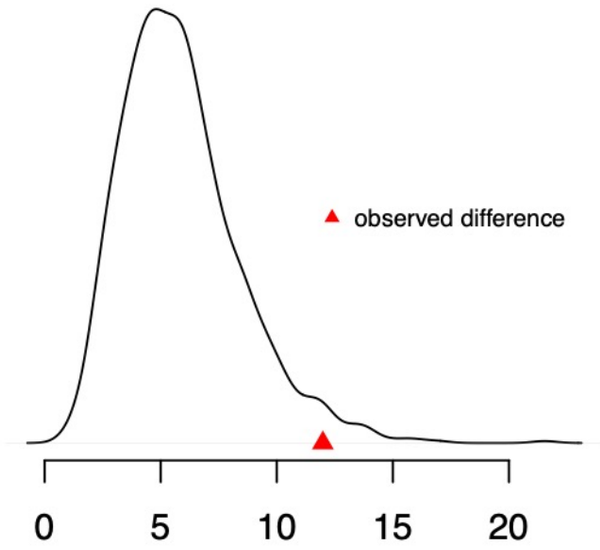


Blanken, T. F., Van Der Zweerde, T., Van Straten, A., Van Someren, E., Borsboom, D., & Lancee, J. (2019). Introducing Network Intervention Analysis to Investigate Sequential, Symptom-Specific Treatment Effects: A Demonstration in Co-Occurring Insomnia and Depression. *Psychotherapy and Psychosomatics*.



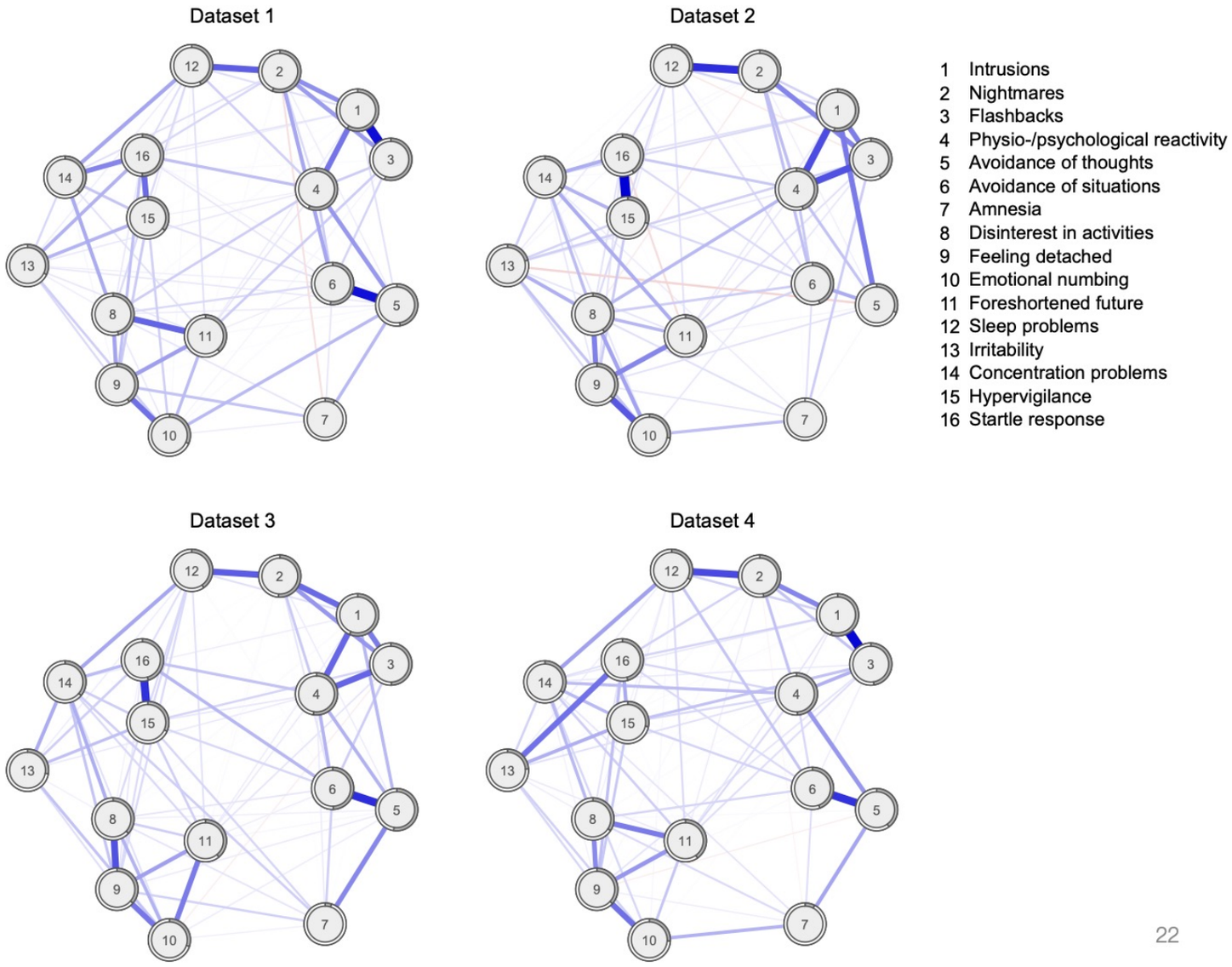
Network Comparison Test





van Borkulo, C. D., Waldorp, L. J., Boschloo, L., Kossakowski, J., Tio, P., L., Schoevers, R.A., & Borsboom, D. (2016). Comparing network structures on three aspects: A permutation test.

Generalizability and replication



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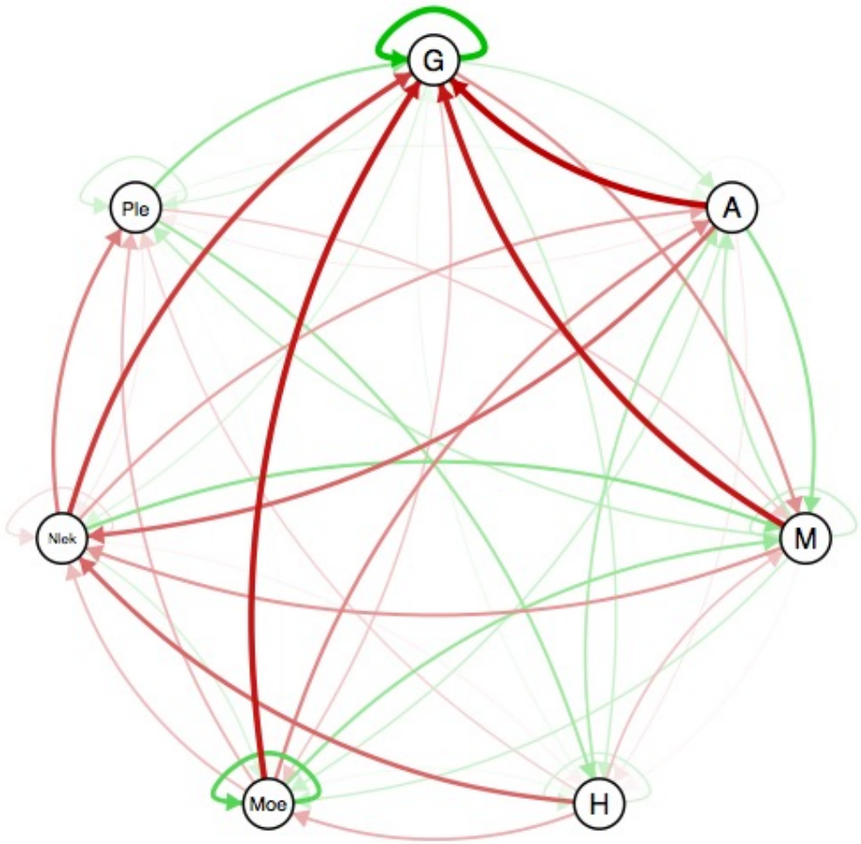
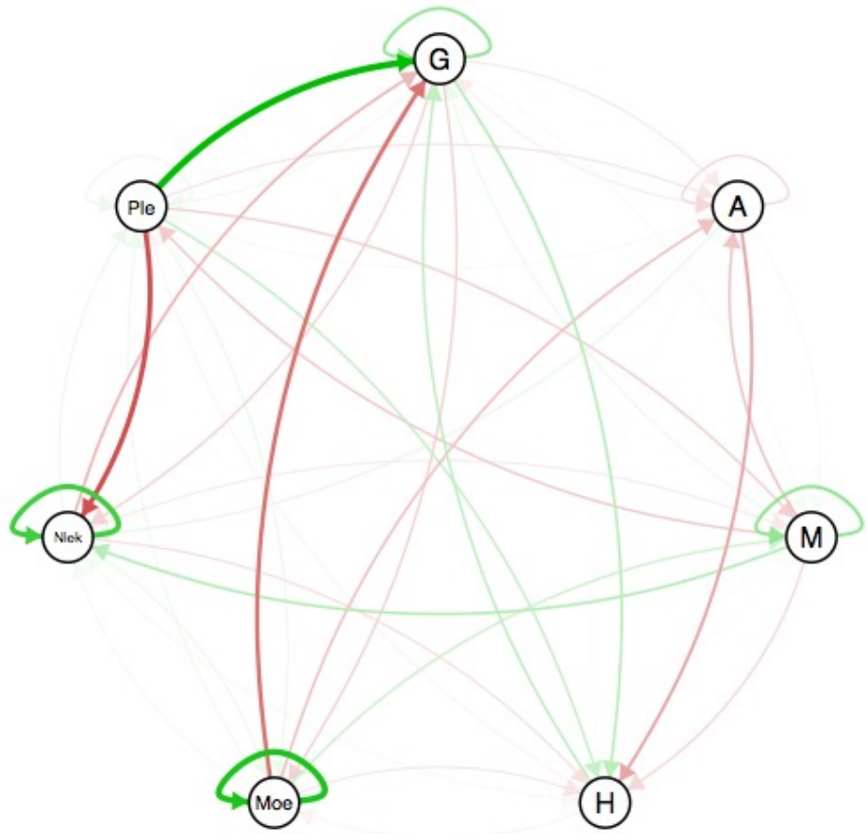
Testing for heterogeneity





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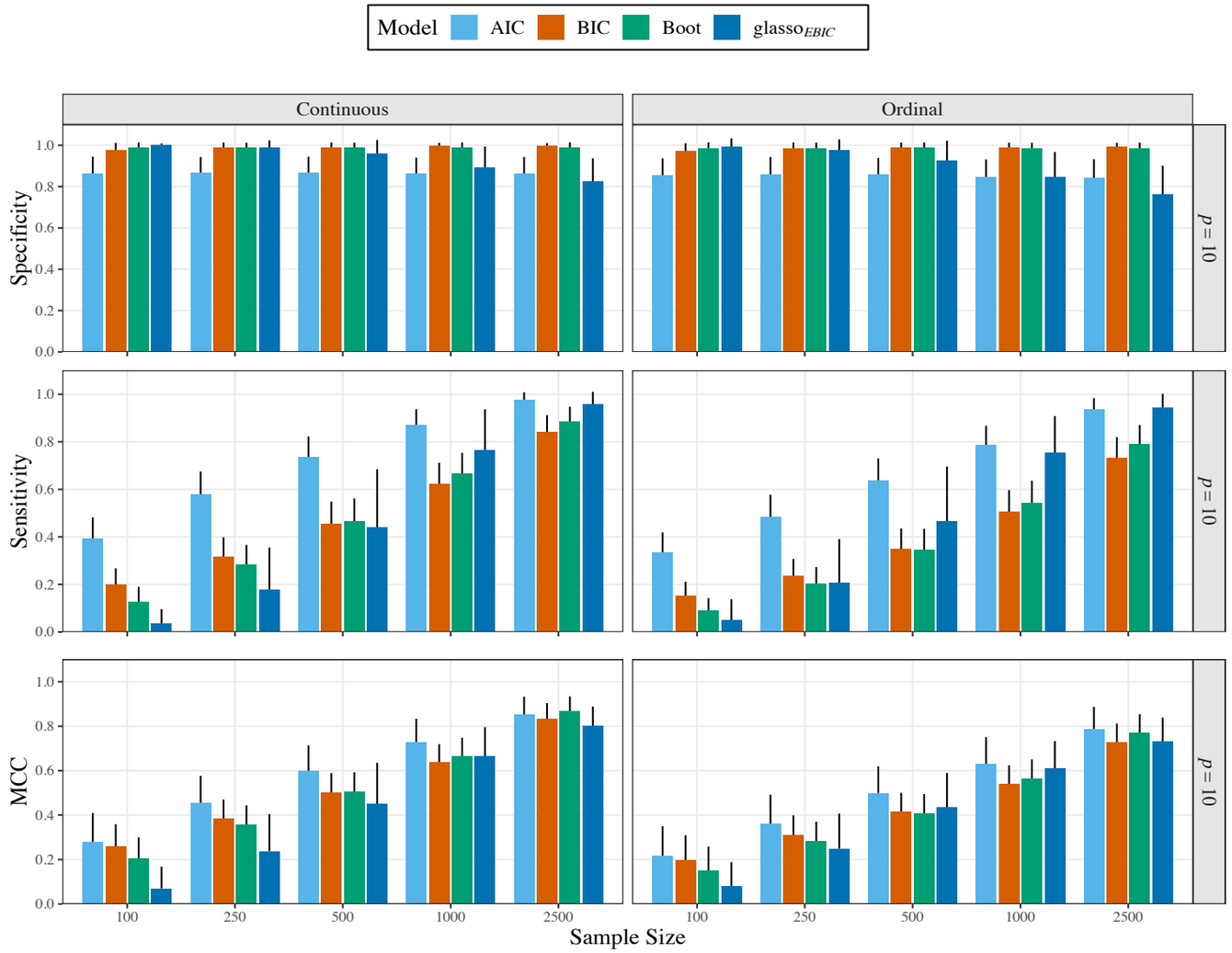
Nonregularized networks



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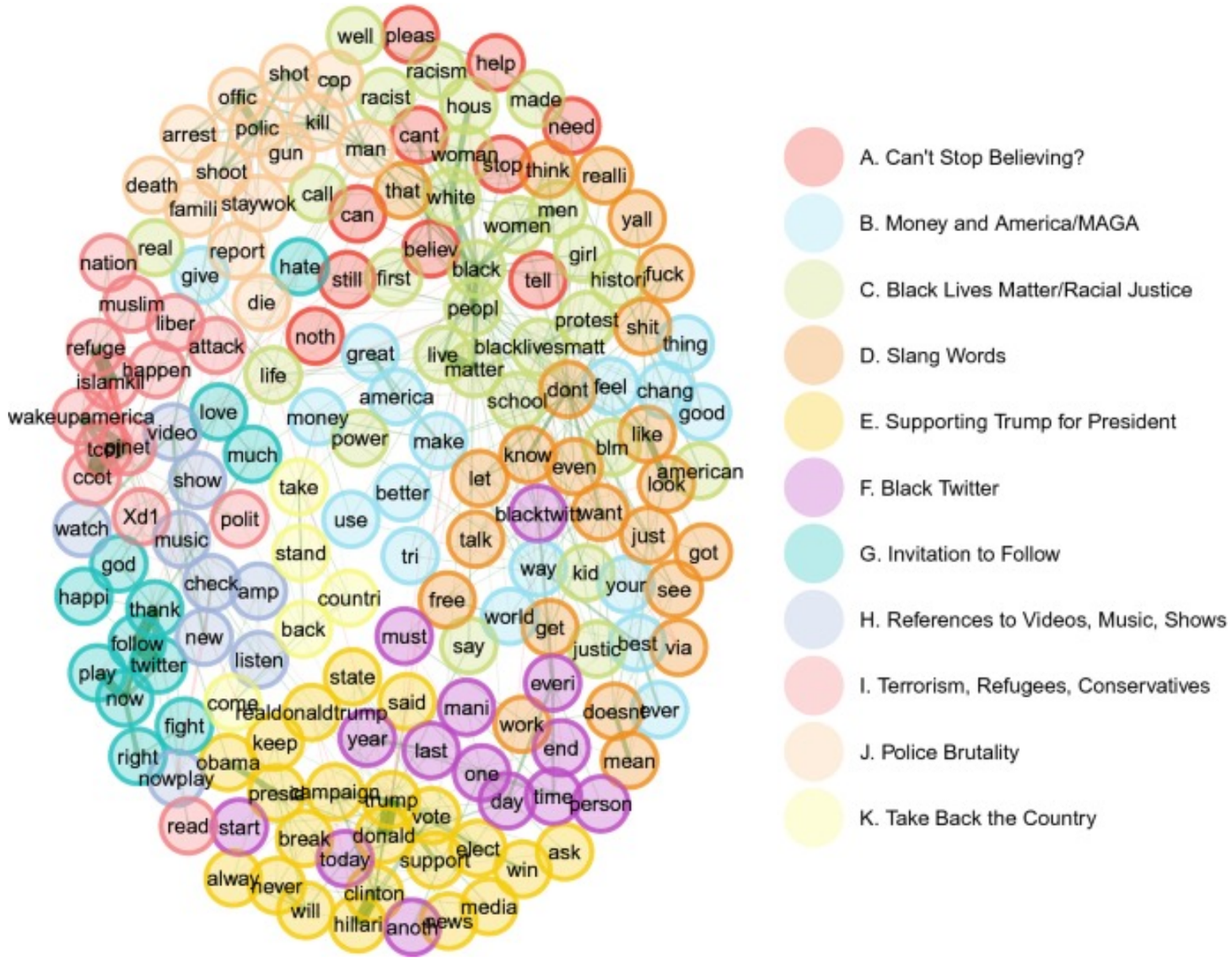
Exploratory Graph Analysis



Golino HF, Epskamp S (2017) Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. PLoS ONE 12(6): e0174035. https://doi.org/10.1371/journal.pone.0174035

psychonetrics

An R package for confirmatory network modeling

BGGM

Package 'networktools'

April 20, 2020

Title Tools for Identifying Important Nodes in Networks

Version 1.2.3

Date 2020-4-19

Description Includes assorted tools for network analysis. Bridge centrality; goldbricker; MDS, PCA, & eigenmodel network plotting.

PLOS | ONE

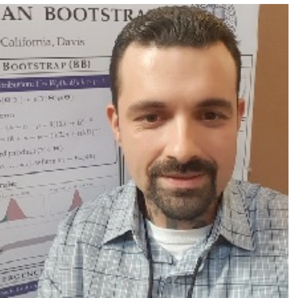
RESEARCH ARTICLE

Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research

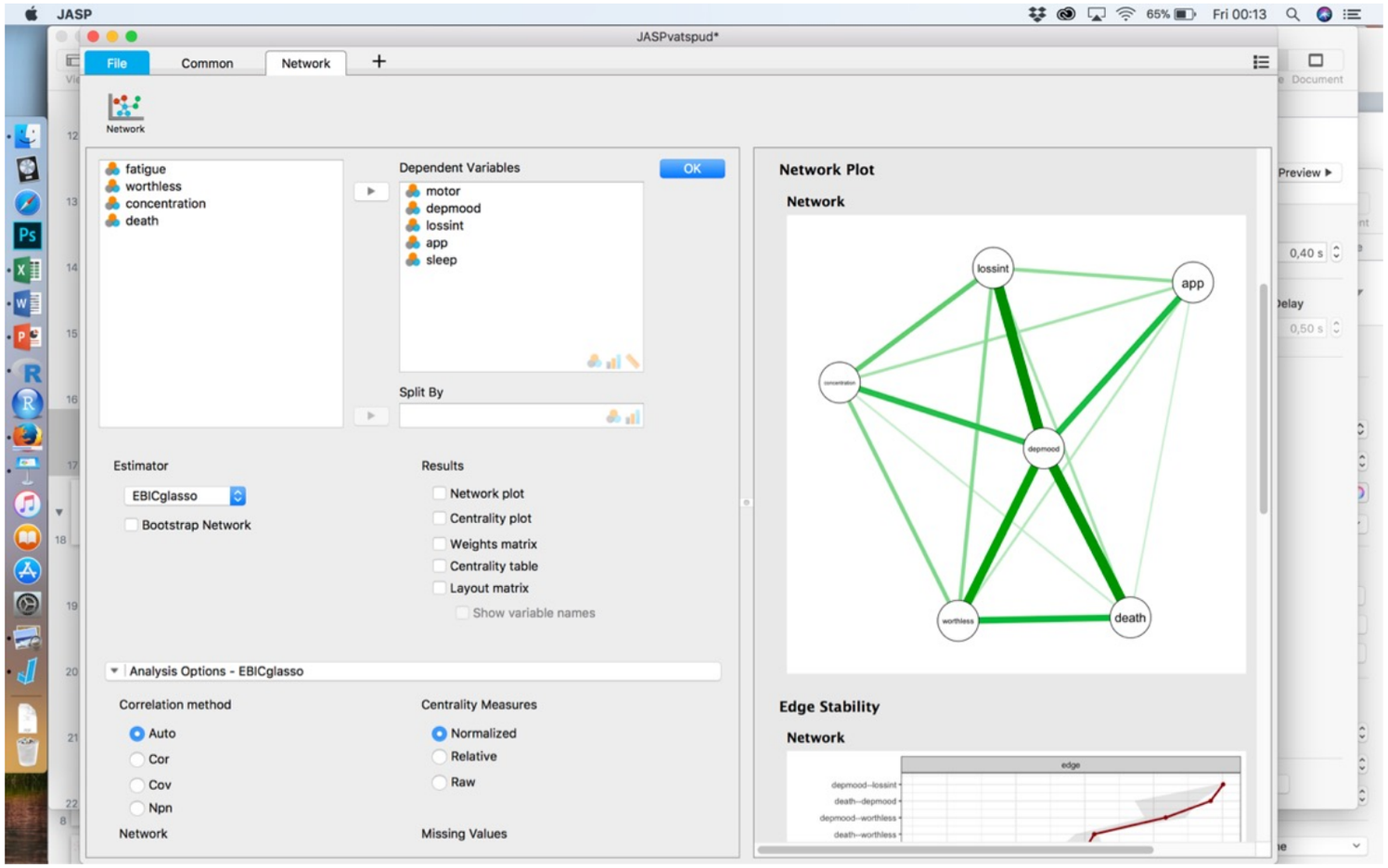
Hudson F. Golino[1,2]*, Sacha Epskamp[3]

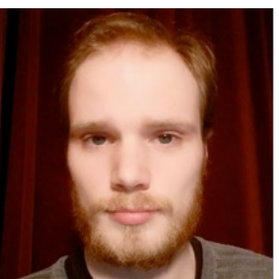
1 Department of Psychology, University of Virginia, Charlottesville, VA, United States of America, **2** Graduate School of Psychology, Universidade Salgado de Oliveira, Rio de Janeiro, Brasil, **3** University of Amsterdam, Amsterdam, Netherlands

* hfgolino@gmail.com



Networks in JASP





https://jasp-stats.org/

EDITED BY ADELA-MARIA ISVORANU, SACHA EPSKAMP, LOURENS WALDORP, AND DENNY BORSBOOM

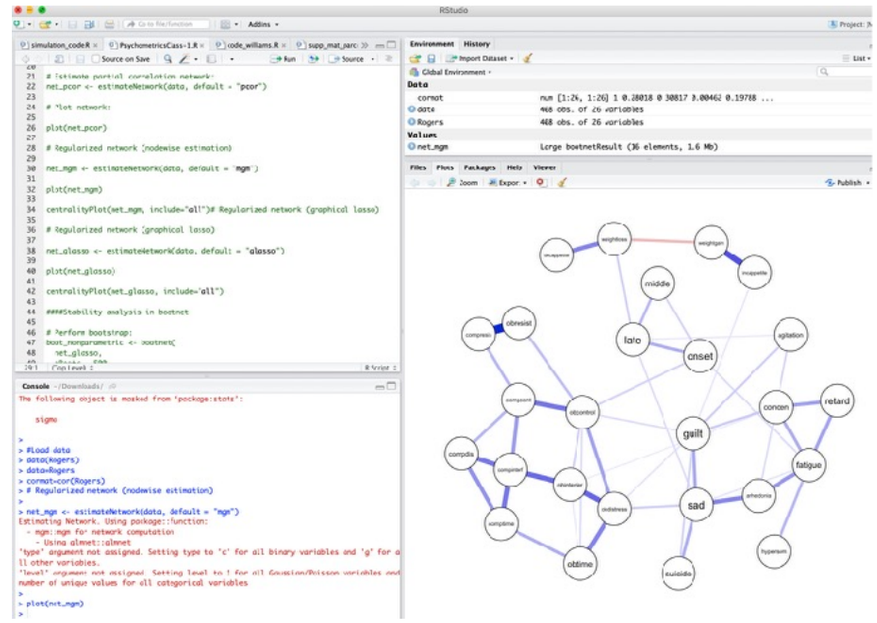
NETWORK PSYCHOMETRICS WITH R

A Guide for Behavioral and Social Scientists

ROUTLEDGE

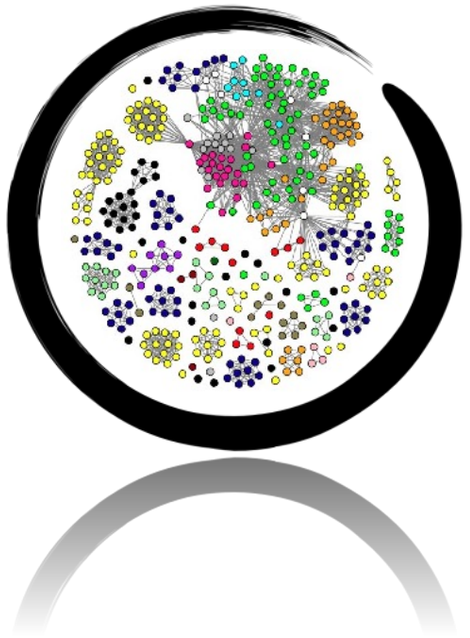
Network Models

- Network models are statistical structures designed to extract networks from data
- Uninterpreted: they are about Xs and Ys, not about psychological attributes
- Models are generic and "anonymous" (and that's why they are so useful)
- Can be understood as *families of probability distributions over data*
- Models are not usually true!



Network Models

- Network models have different uses:
  - exploratory analyses
  - visualisation
  - detecting structure
  - hypothesis generation
- Like all statistical models, results should be interpreted carefully (correlation≠causation)
- Many new techniques are being developed at a high pace



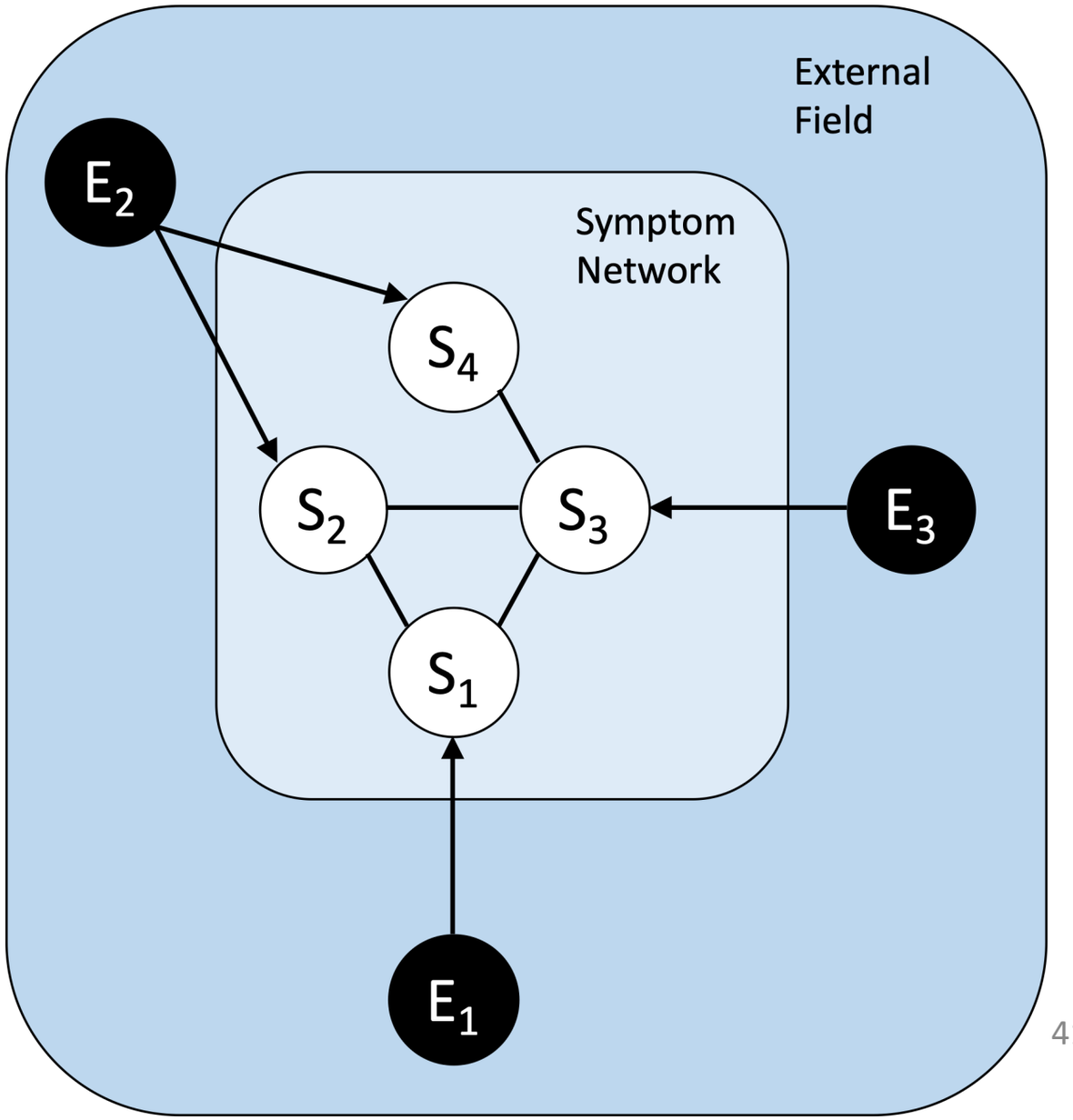
Part III: Network Theory

Network Theory

- A network theory is a putative system of relations (e.g., between psychological attributes) that explains empirical phenomena
- Typically these relations have a dynamic or causal interpretation
- The question whether theories are true or false is important (not so for statistical data models)
- Network theories can be highly detailed or quite schematic

Symptom networks

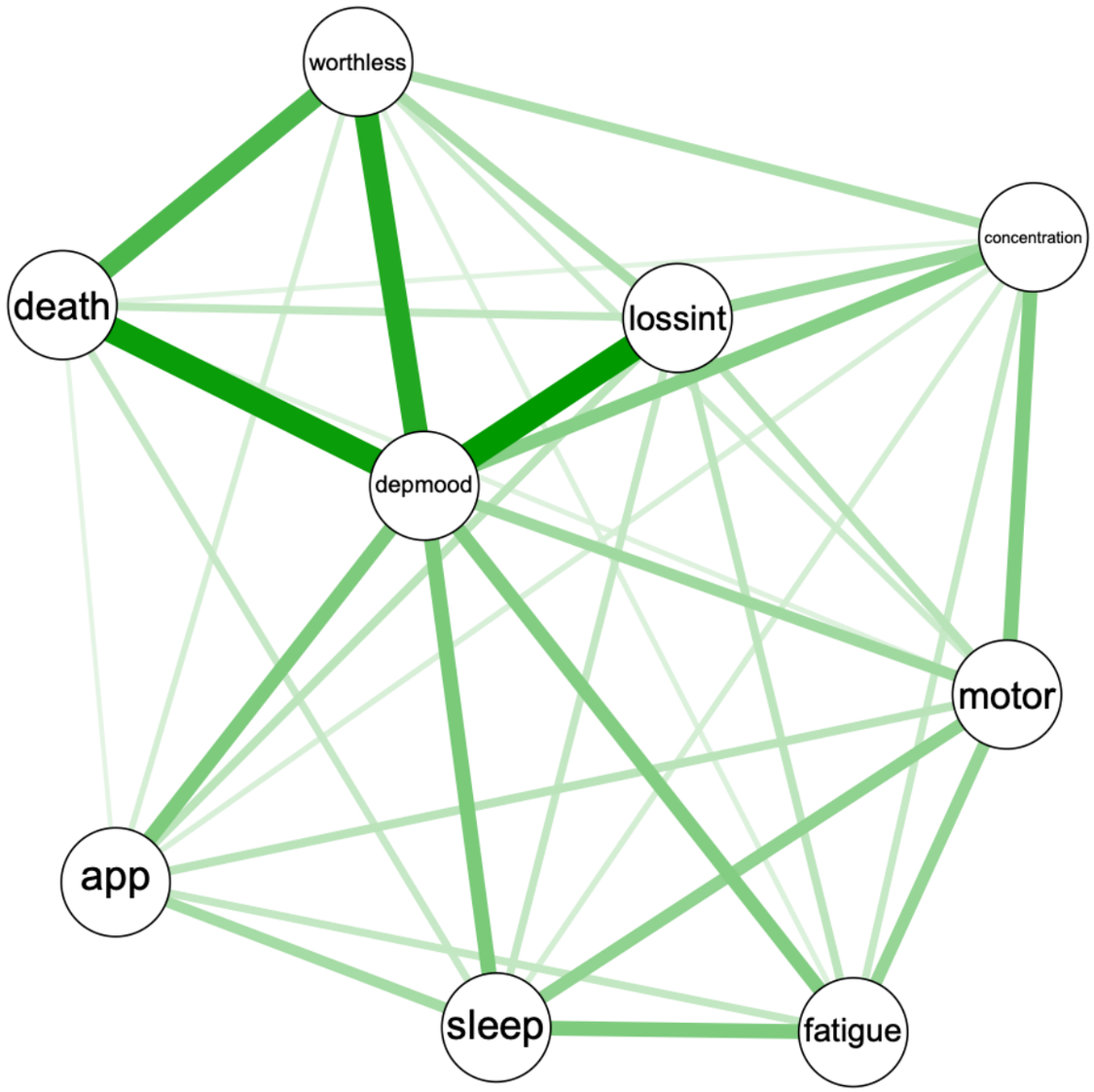
- The simplest nontrivial network model consists of
  - *node thresholds* (how easily is a symptom activated)
  - *connections* (how easily does activation spread)
  - *external factors* (outside influences that activate symptoms)



Borsboom, D. (2017). A network theory of mental disorders. World Psychiatry.

Ising network for depression (Ken Kendler's VATSPSUD data)

- The simplest nontrivial network model consists of
  - *node thresholds* (how easily is a symptom activated)
  - *connections* (how easily does activation spread)
  - *external factors* (outside influences that activate symptoms)




```
IsingDep=IsingFit(data)
```

NetLogo — Hysteresis Model_DBEdits {/Users/dennyborsboom/Dropbox/PsychoNetw...

Interface | Information | Procedures

Edit | Delete | Add | Button | normal speed | view updates | continuous | Settings...

setup | go

connection-strength 1.00

external-activation -1.0

ticks: 0 | 3D

Depmood
Death
Lossint
Conc
Wloss
Worthless
Wgain
Fatigue
Dapp
Pretar
Iapp
Pagit
Hypersom
Insom

Network Status

14
umber of node
0
0
time
0

symptom-present
cut-off

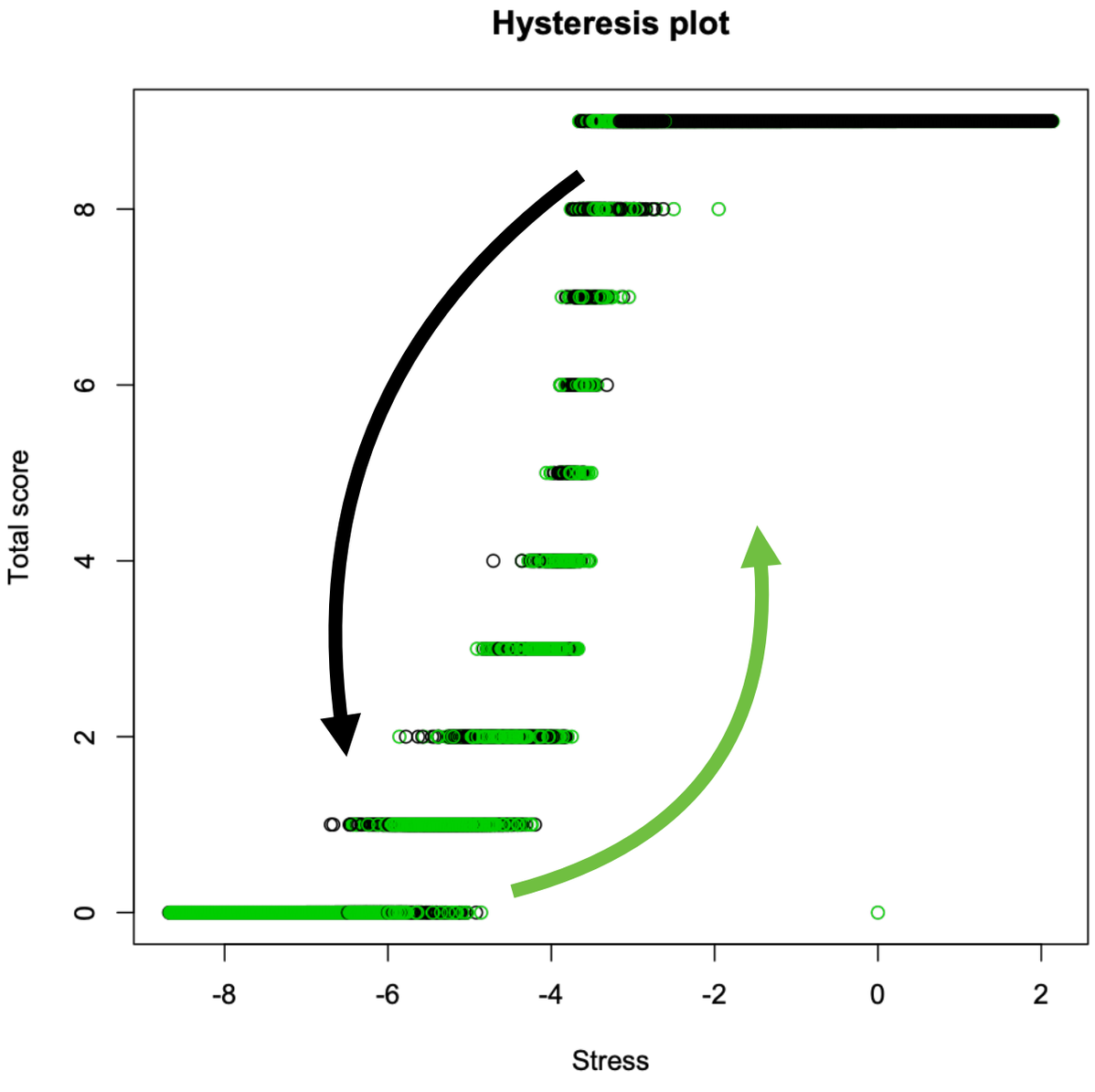
Command Center | Clear

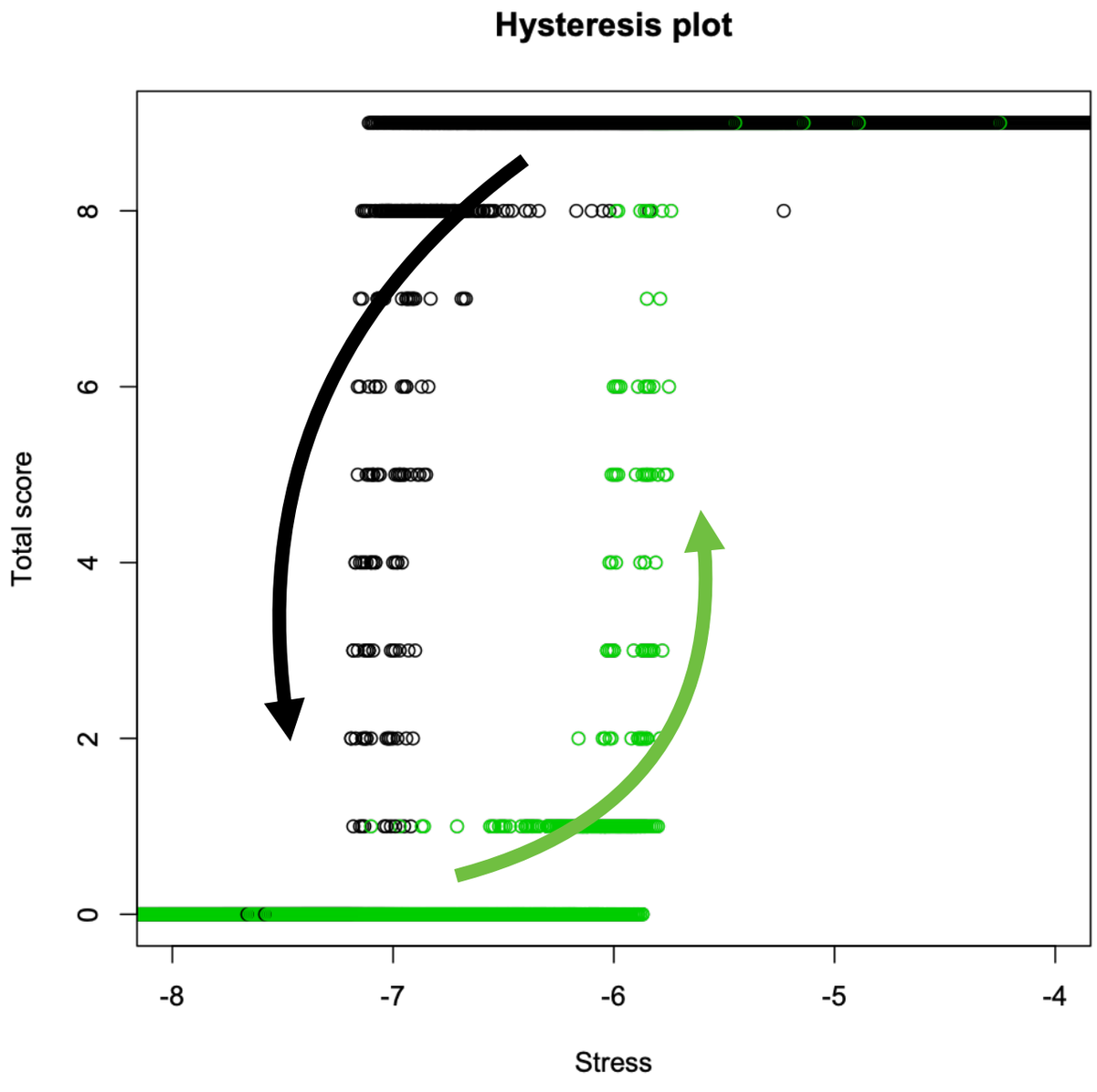
observer>

LOW Connectivity

HIGH Connectivity

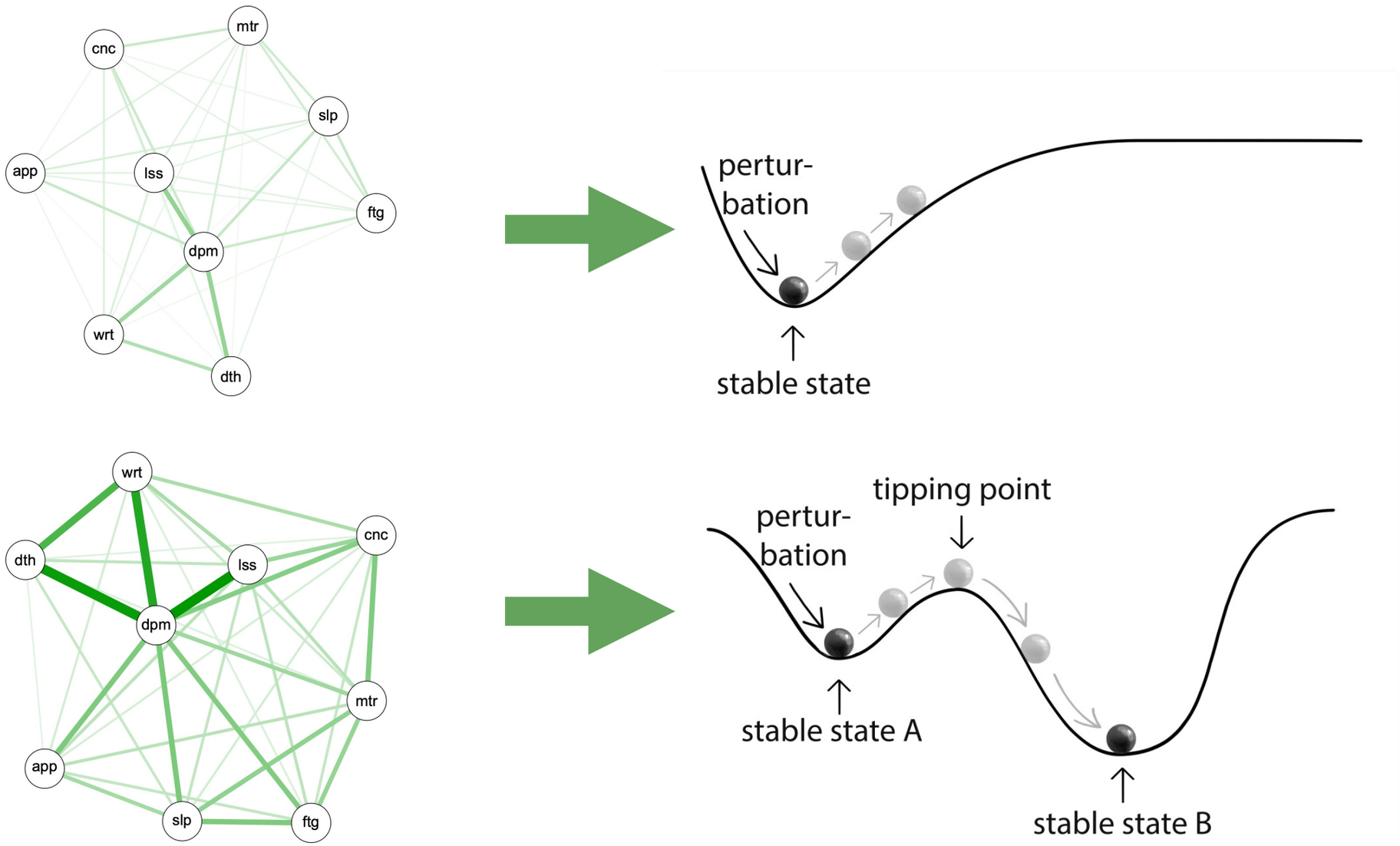
Weakly versus strongly connected networks





Cramer, A. O. J., van Borkulo, C. D., Giltay, E. J., van der Maas, H. L. J., Kendler, K. S., Scheffer, M., & Borsboom, D. (2016). Major depression as a comp

Strong connectivity yields sudden transitions



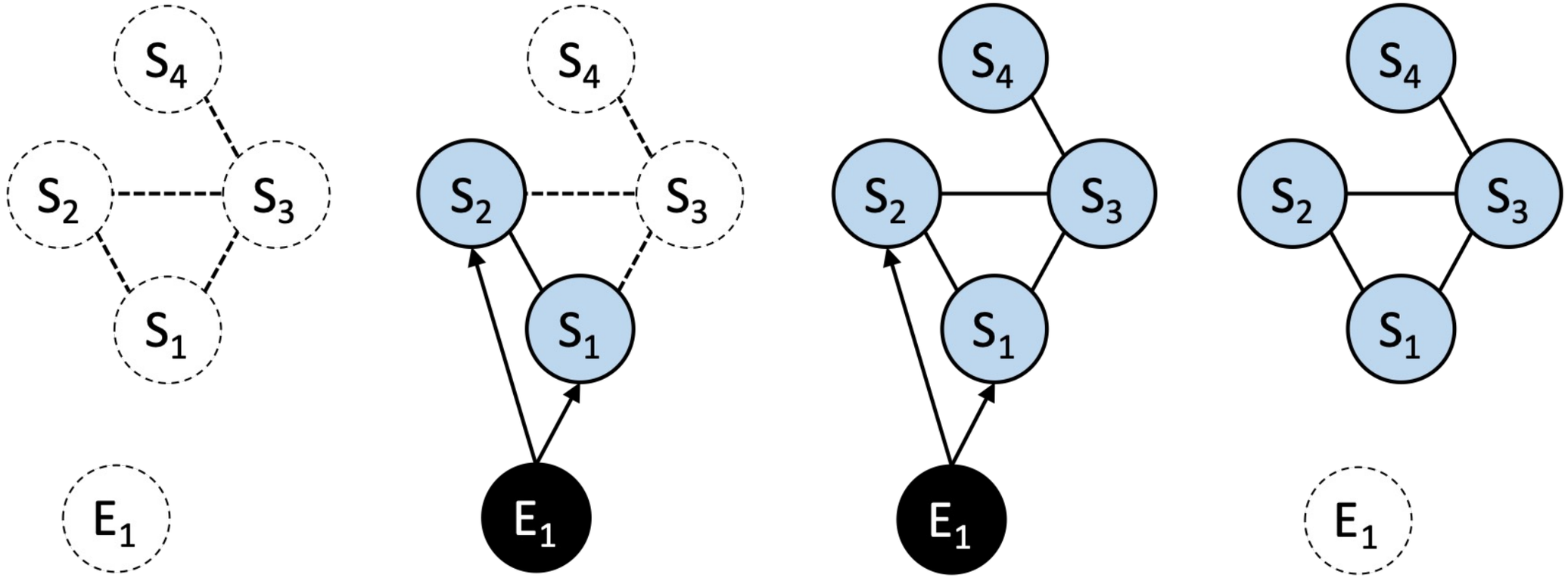
Mental disorders: Getting stuck in the wrong stable state

Phase 1.
Dormant network
in stable state

Phase 2.
Network activation

Phase 3.
Symptom spread

Phase 4.
Active network
in stable state



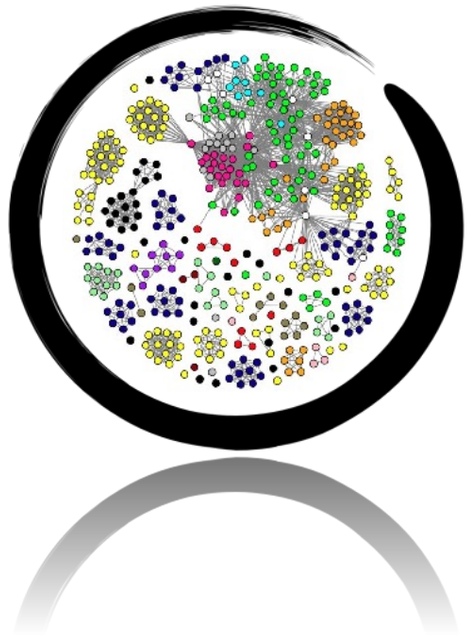
Borsboom, D. (2017). A network theory of mental disorders. World Psychiatry.

Mental disorders as alternative stable states in networks

- Theory: *Mental disorders are alternative stable states in a symptom network*
- Mental disorders are due to (local) hyper-connectivity of the symptom network in combination with (possibly random) perturbations
- This leads the network to get "stuck" in its disordered state
- Whether this shift is permanent depends on the size of the hysteresis effect

Network Theory

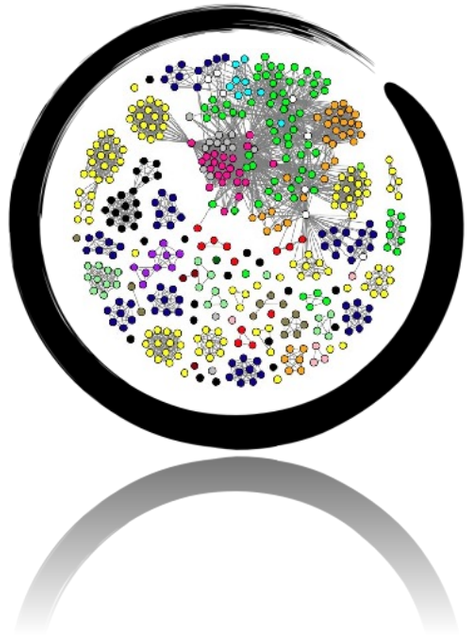
- Most network theories have typical explanatory schemes:
  - Emergence (e.g. positive manifold without latent variable)
  - Phase transitions (e.g., high connectivity leads to sudden jumps)
  - Fuzziness (e.g., cross-disorder connections lead to comorbidity)
- These schemes are generic and broadly useful
- You can use them to construct your own network theory



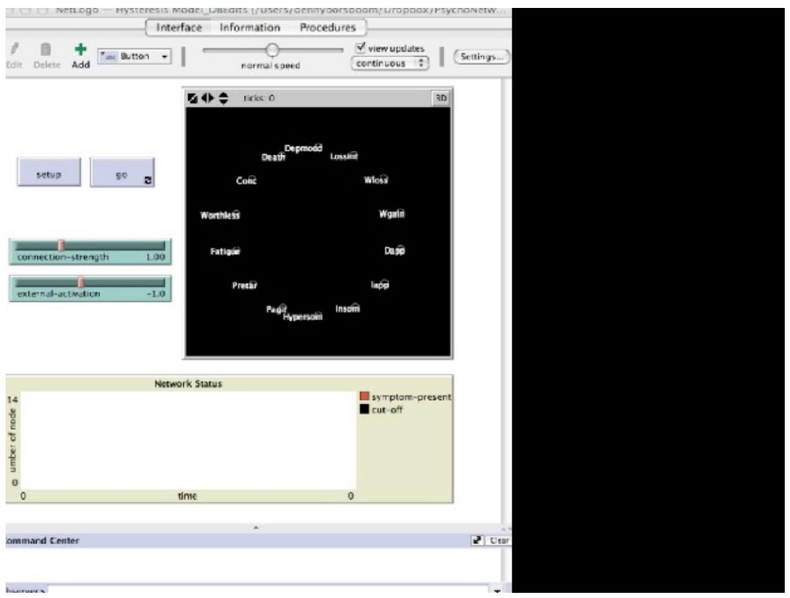
Part IV: Relations between network approaches, network theories and network models

Approaches, theories, models…

- The network approach is literally an *approach*, and does not dictate specific models or theories
- Network theories can (but need not) be investigated with network models
- Network models can stand on their own, and do not "assume" the validity of network theories



Network models and network theories

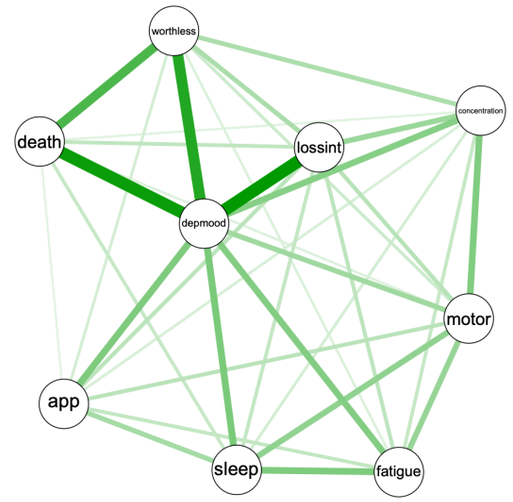


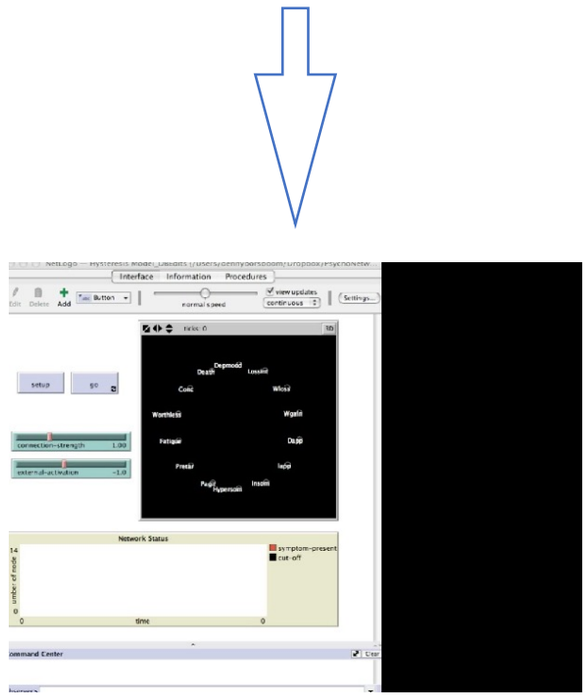
A network *theory* represents causal interactions between elements in a target system

A *network model* represents statistical relations between variables in a set of data

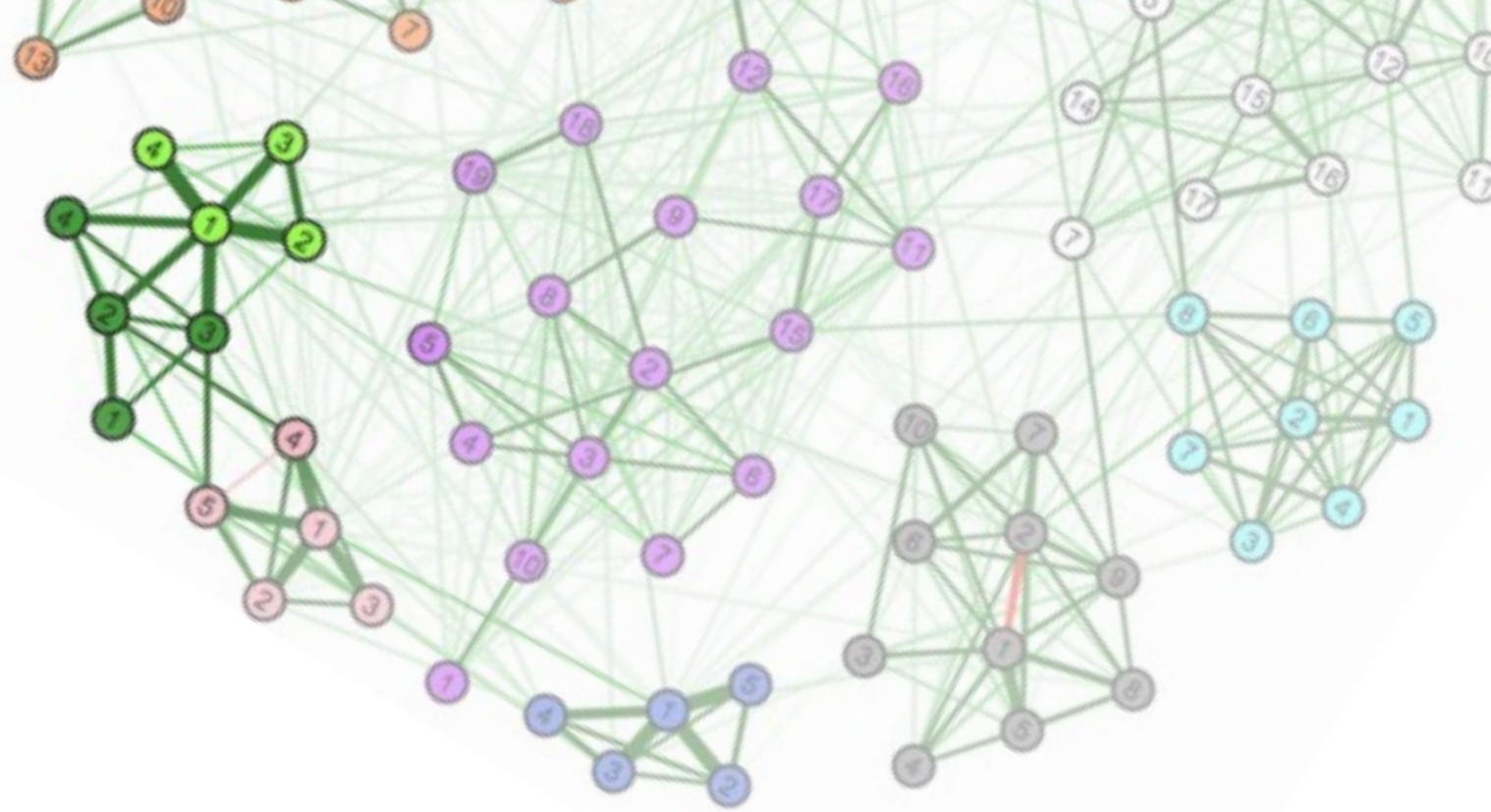
From model to theory: Direct route

- One strategy is to just assume an estimated structure to be accurate
- Put a dynamical model on top and you're off to the races
- Validity issues:
  - data pecularities need not be theoretically accurate
  - dynamical model is rarely empirically informed

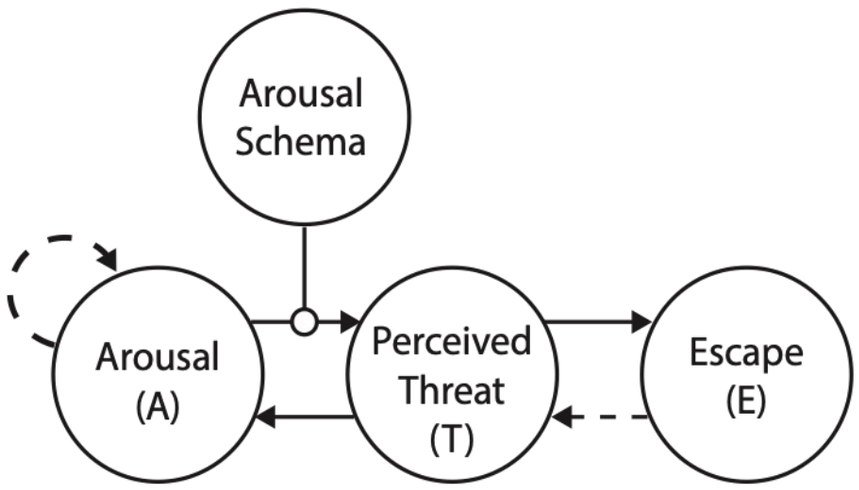




From model to theory: Indirect route



Causal Diagram



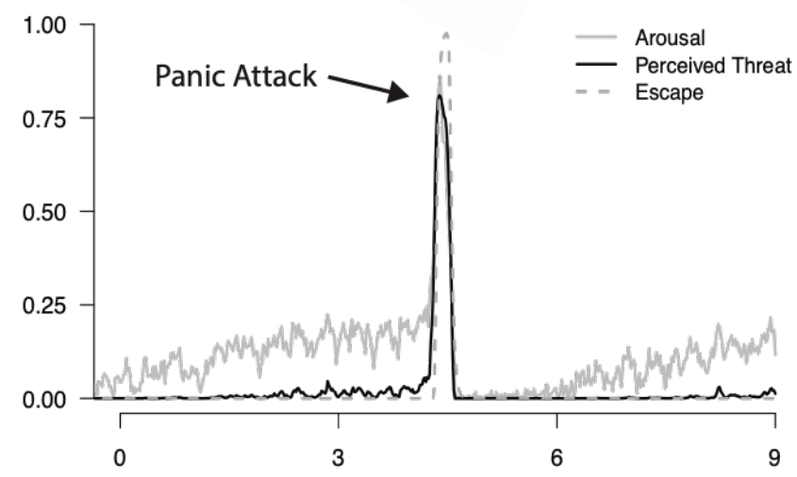
Formal Theory

$$\frac{dA}{dt} = \alpha((\nu T - A) - \kappa H + N)$$

$$\frac{dT}{dt} = \gamma\left(\left(\frac{A^{\mu}}{A^{\mu} + \lambda^{\mu}} - T\right) - \tau E\right)$$

$$\frac{dE}{dt} = \varepsilon\left(\frac{T^{\sigma}}{T^{\sigma} + \rho^{\sigma}} - E\right)$$

Simulated Data



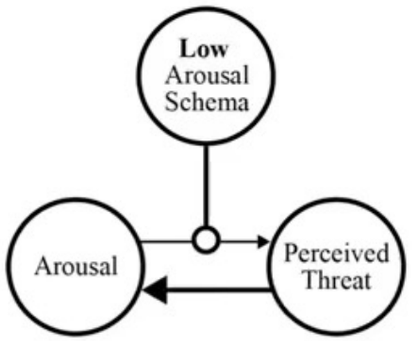
A network *theory* of panic disorder

Theory Construction Methodology

Step 1	Identify a set of phenomena that you want to explain
Step 2	Come up with a proto-theory
Step 3	Formalize both the proto-theory and the phenomena
Step 4	Evaluate how well the resulting formal theory actually explains the phenomena
Step 5	Overall evaluation of the theory

The Panic model

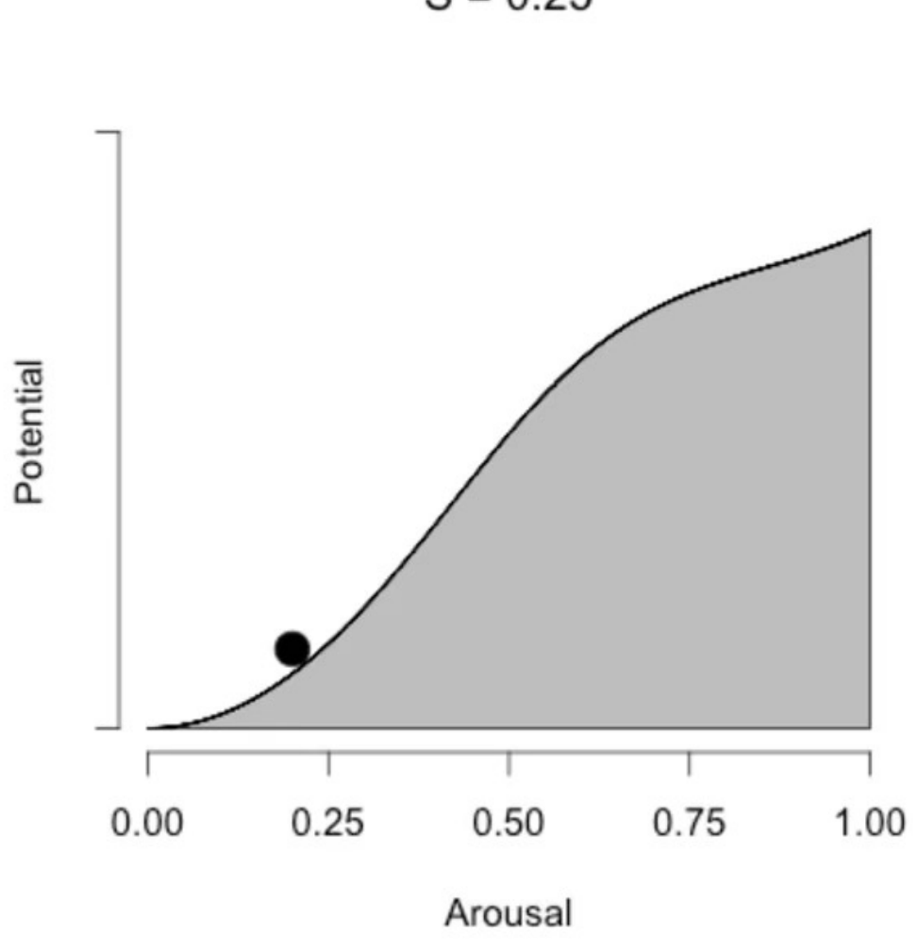
A

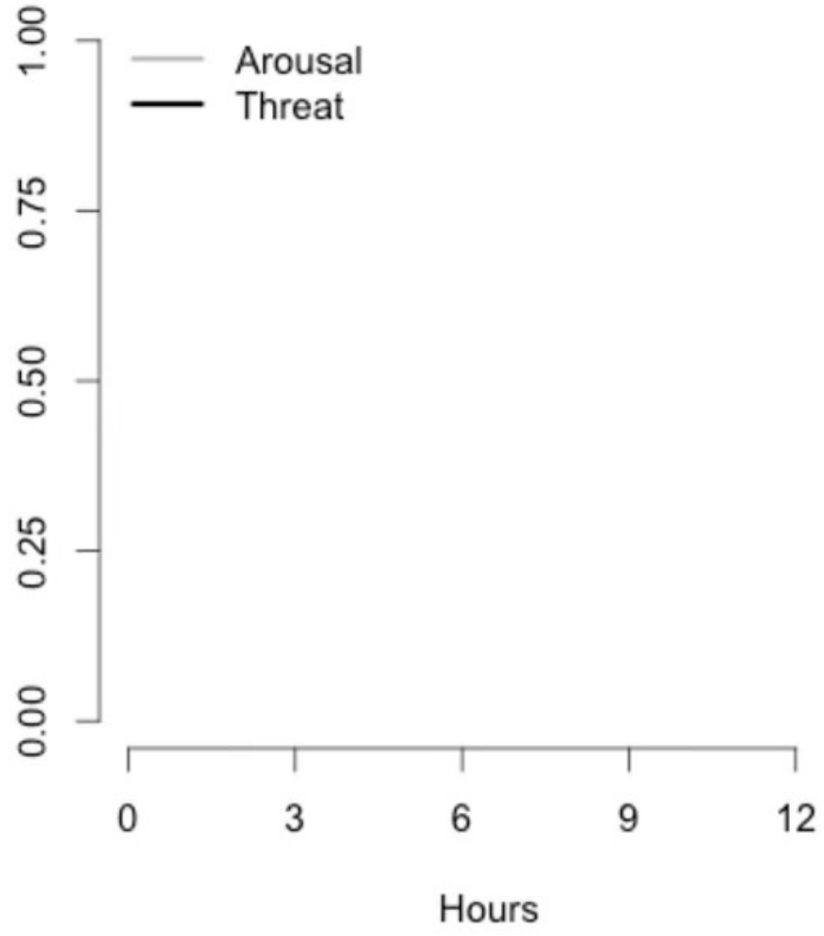


B

With low feedback between arousal and perceived threat, the system is stable

S = 0.25





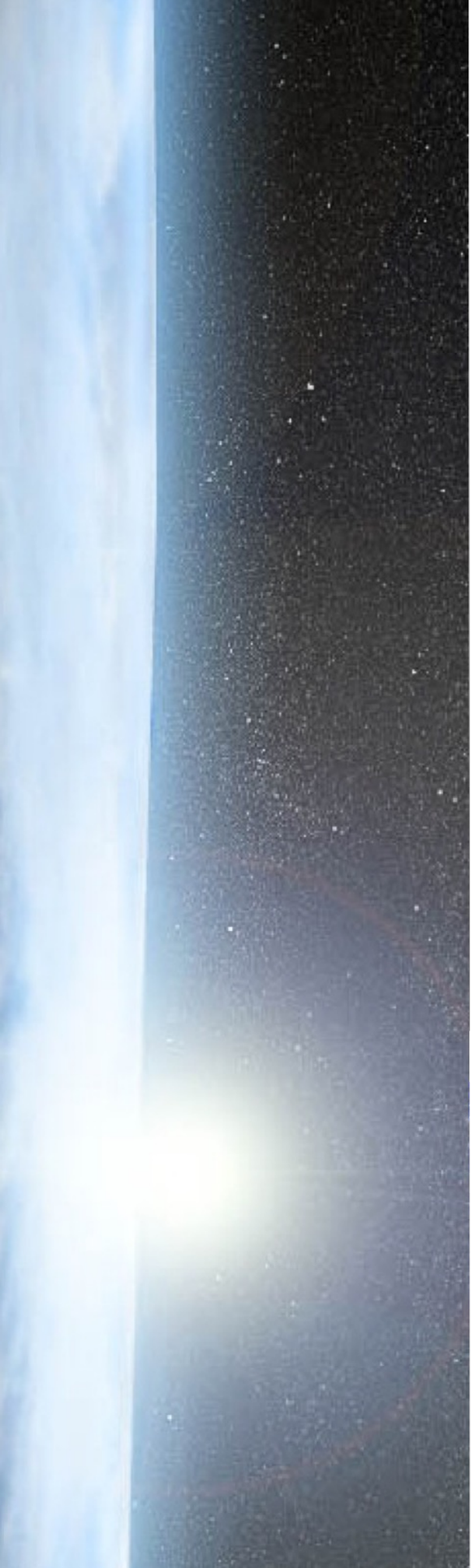
From model to theory: Indirect route

- The indirect route considers statistical models as *data models*
- These encode *empirical phenomena*
- These phenomena are used to construct a theory
- No direct correspondence between theory and data model!
- Threats: lots of assumptions, little validation

$$\frac{dA}{dt} = \alpha((\nu T - A) - \kappa H + N)$$

$$\frac{dT}{dt} = \gamma\left(\left(\frac{A^{\mu}}{A^{\mu} + \lambda^{\mu}} - T\right) - \tau E\right)$$

$$\frac{dE}{dt} = \varepsilon\left(\frac{T^{\sigma}}{T^{\sigma} + \rho^{\sigma}} - E\right)$$



Discussion

- The network approach is a general perspective; it has no truth conditions
- Network models are statistical representations of relations between variables: data models
- Network theory is an interpreted formal model: it has empirical truth conditions and can be falsified by data (in principle)
- The scientific challenge is how to appropriately connect theory to data

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