Modeling Ongoing Acts-in-context

A Network Analytic Approach

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Review Article

Contextual Behavioral Science: Creating a science more adequate to the challenge of the human condition

Steven C. Hayes [a,*], Dermot Barnes-Holmes [b], Kelly G. Wilson [c]

As a functional contextualist sees it, the ultimate purpose of behavioral science is to change the world in a positive and intentional way. Science is taken to be an empirical strategy of interacting in and with the world so as to learn how to be more effective in organizing it, speaking about it, measuring it, and changing it. This distinctively pragmatic perspective derives from a focus on the functions of actions in a historical and situational context

From a functional and contextual perspective, scientific analysis is a social enterprise that seeks the development of increasingly organized statements of relations among events that allow analytic goals to be accomplished with precision, scope, and depth, based on verifiable experience.

Precision: only a limited number of analytic concepts apply to a given case

Scope: a given analytic concept applies to a range of cases

Depth: analytic concepts cohere across well-established scientific domains

2. Definition of Contextual Behavioral Science

It is worth beginning with the ending. Contextual Behavioral Science (CBS) *is a principle-focused, communitarian strategy of reticulated scientific and practical development. Grounded in contextualistic philosophical assumptions, and nested within multi-dimensional, multi-level evolution science as a contextual view of life, it seeks the development of basic and applied scientific concepts and methods that are useful in predicting-and-influencing the contextually embedded actions of whole organisms, individually and in groups, with precision, scope, and depth; and extends that approach into knowledge development itself so as to create a behavioral science more adequate to the challenges of the human condition.*

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The *goal of functional contextualism is to predict-and-influence, with precision, scope, and depth, whole organisms interacting in and with a context considered historically and situationally.*

The hyphenation of the term "prediction-and-influence" is to indicate that the goal of functional contextualism is unified; for that reason, *causal analysis in a functional contextual approach ultimately must extend to the manipulable context of action*

Network analysis…

- Offers analysis with precision, scope, and depth
- Advances both basic and applied levels of scientific inquiry
- Can incorporate current and historical contextual variables
- Is consonant with the value of prediction-and-influence

The plan:

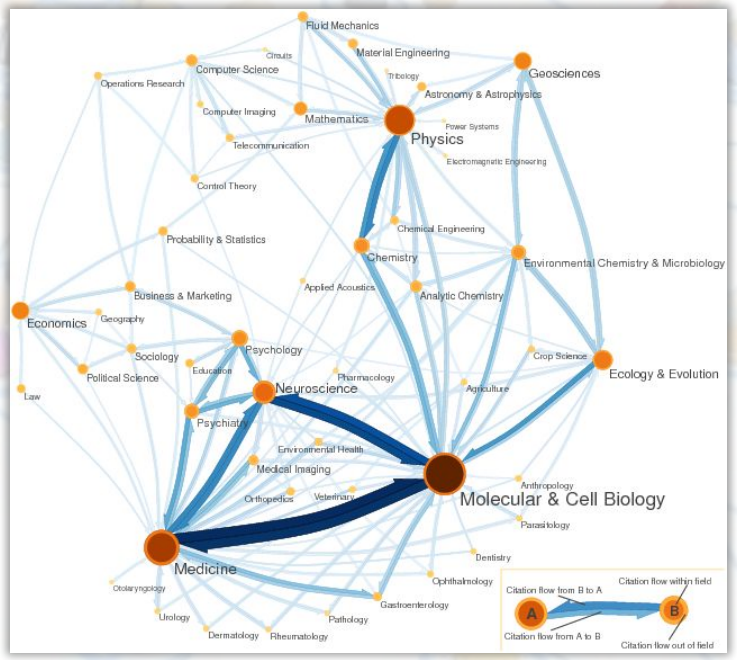
- Describe network analysis
- Discuss different network analytic modeling techniques and their applications
- Examine these methods within the framework of contextual behavioral science
- Take a look at some cool research

Some words of caution

- This talk is meant to be a brief overview of these methods
- It is *not* a technical description
- I am not an expert in network analysis, but I think the application is promising

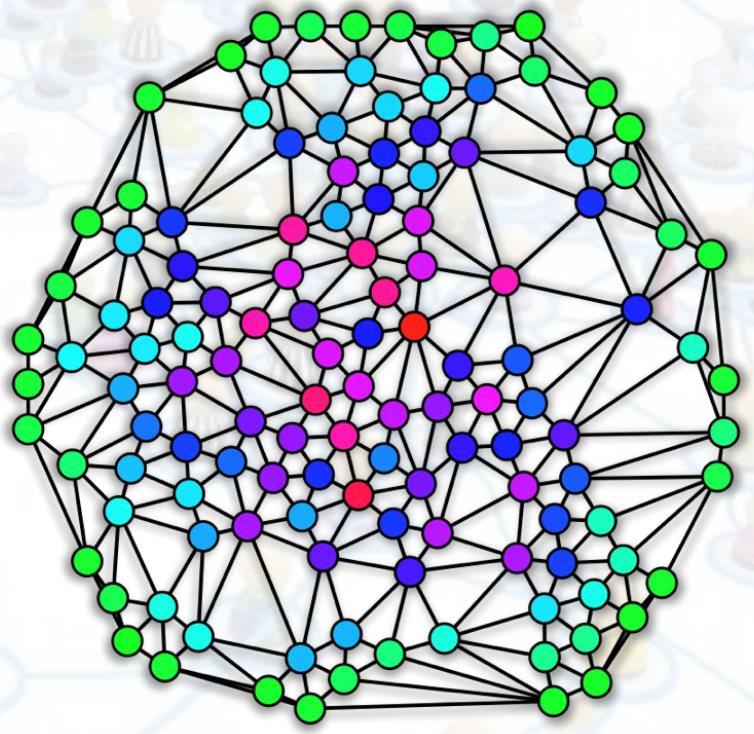
What is network analysis?

- An array of multivariate statistical methodologies that model complex, dynamic systems of variables
- What kinds of variables?
  - People (e.g., social networks)
  - Epidemiology (e.g., disease transmission)
  - Business (e.g., airport connections)
  - Scientific process (e.g., citation networks)
  - Psychology (more to be said here!)
  - Basically anything else



Some terminology

- Nodes: Individual variables of interest in the network
  - For example: An individual person, scientific fields, psychological variables
  - Directed or Undirected
- Edges: The connections between nodes
  - For example: relationships, citation flow, behavior-behavior relations
  - Weighted or Unweighted
  - Positive or Negative (directionality)



Gaussian Graphical Model (GGM)

- Used to model continuous, multivariate normal, cross-sectional data
- Edges represent partial correlation coefficients
  - i.e., edge weights are conditionally dependent on all other associations in the network
  - Absent edges represent conditional independence given all other variables
- Edges represent possible causal relationships
- Methods to model networks of binary and mixed variables exist

Vector Autoregression (VAR)

- Autoregression (AR): Single-subject, univariate prediction of a future time point given previous observations
- Vector autoregression (VAR): A multivariate extension of AR
  - Future time points a function of previous (a) observations of itself and (b) of other variables
- For example, a VAR model with two variables (for simplicity):
  - $y_{1,t}=\beta_{01}+\beta_{11}y_{1,t-1}+\beta_{12}y_{2,t-1}+e_{1,t}$
  - $y_{2,t}=\beta_{02}+\beta_{21}y_{1,t-1}+\beta_{22}y_{2,t-1}+e_{1,t}$

This model has important clinical applications!

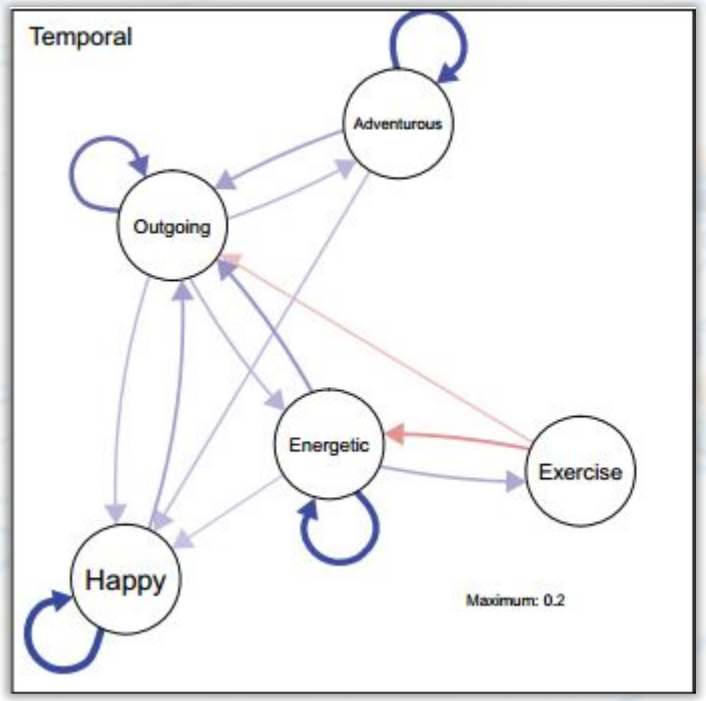
Clinical Applications

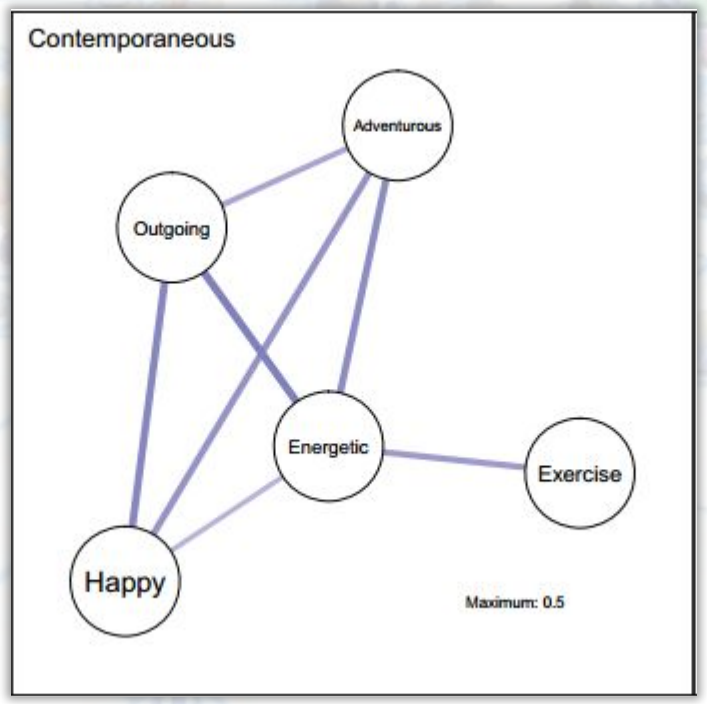
- VAR network models are very useful for assessment
- Can be done with N_{obs} = 70 (e.g., 5 prompts per day, 14 days)
- Can accompany first couple of sessions, or be done before scheduling
  - Informs and speeds up behavioral analyses
- Can be used as a tool to predict changes
  - E.g., increasing autocorrelation predicts changes in depressed states (van de Leemput et al., 2014)

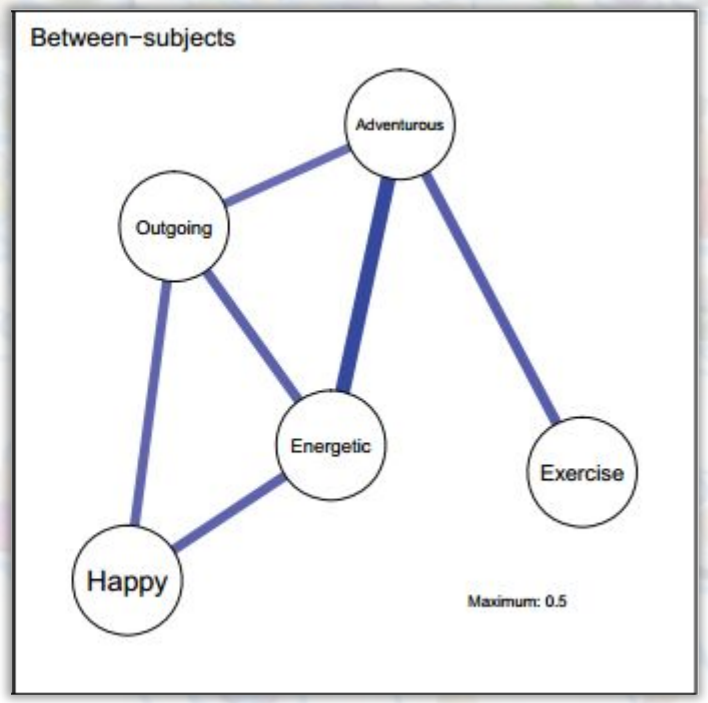
Multi-level Vector Autoregression (mlVAR)

- If VAR and multi-level modeling had a kid → mlVAR
- Extension of VAR to $N > 1$
- Estimate fixed and random effects for each variable in the network
  - Thus, essentially estimating group- and individual-level effects
- Three components:
  - Within-subjects network
  - Between-subjects network
  - Contemporaneous network
    - GGM of variables within the same measurement occasion
    - Conditioned on temporal prediction (i.e., network of residuals)

Multi-level Vector Autoregression (mlVAR)





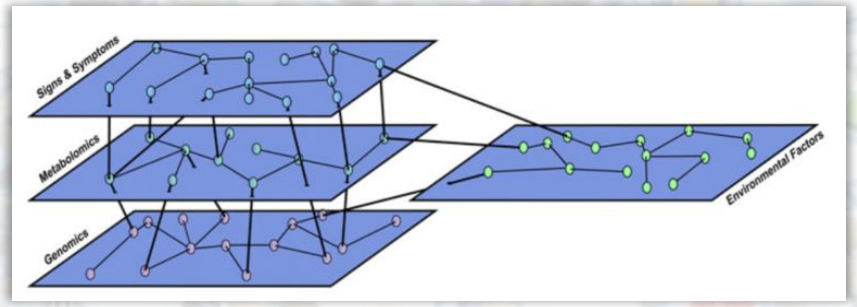


Epskamp, Waldorp, Mottus, & Borsboom (2018)

Node Centrality

- Several types of centrality measures
- Betweenness centrality: the number of times a node lies on the shortest path between two other nodes
  - Changes in a node with high betweenness centrality likely to cause changes throughout the entire network
- Strength centrality: the sum of absolute edge weights connected to a given node (in- and out-strength)
  - Likelihood that changes in one node will lead to changes in other nodes

Examination within a CBS Framework



I said earlier…

- Offers analysis with precision, scope,and depth
  - Examine scope in mlVAR models
    - Fixed effect estimation
    - Random effects variance (how much do people differ on these effects?)
    - Network comparison tests
  - Examine depth by including variables across domains and see how they cohere together in a network
- Advances both basic and applied levels of scientific inquiry
  - VAR models can be a very useful clinical tool
  - GGM, VAR, and mlVAR models all inform hypotheses and experimental research

Examination within a CBS Framework

I said earlier…

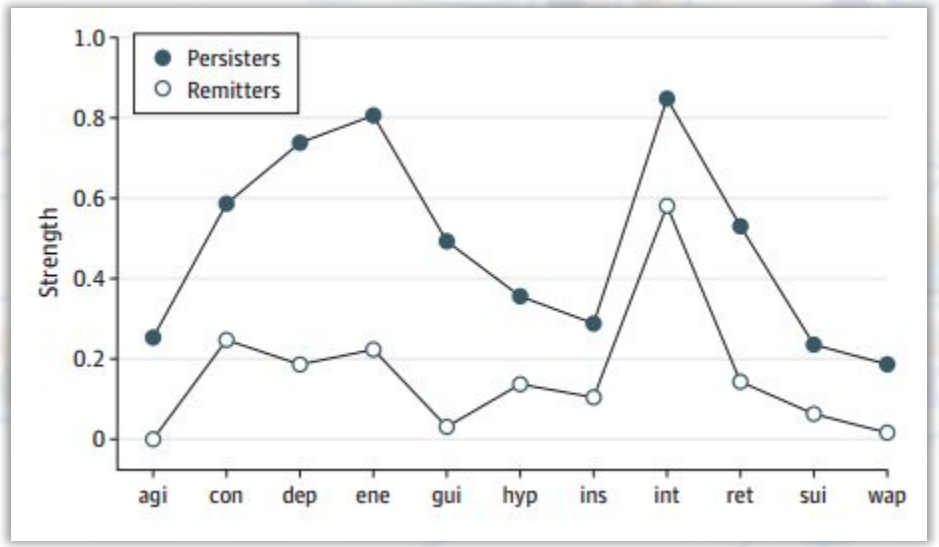
- Can incorporate current and historical contextual variables
  - Including variables with varying distributions!
  - Both current and historical contextual variables are represented simply as nodes
- Is consonant with the value of prediction-and-influence
  - Nodes in the network can be examined as IVs, DVs
    - Choose nodes that you can directly influence
    - Prediction entails examination of centrality measures and bivariate associations in the network

Some cool research

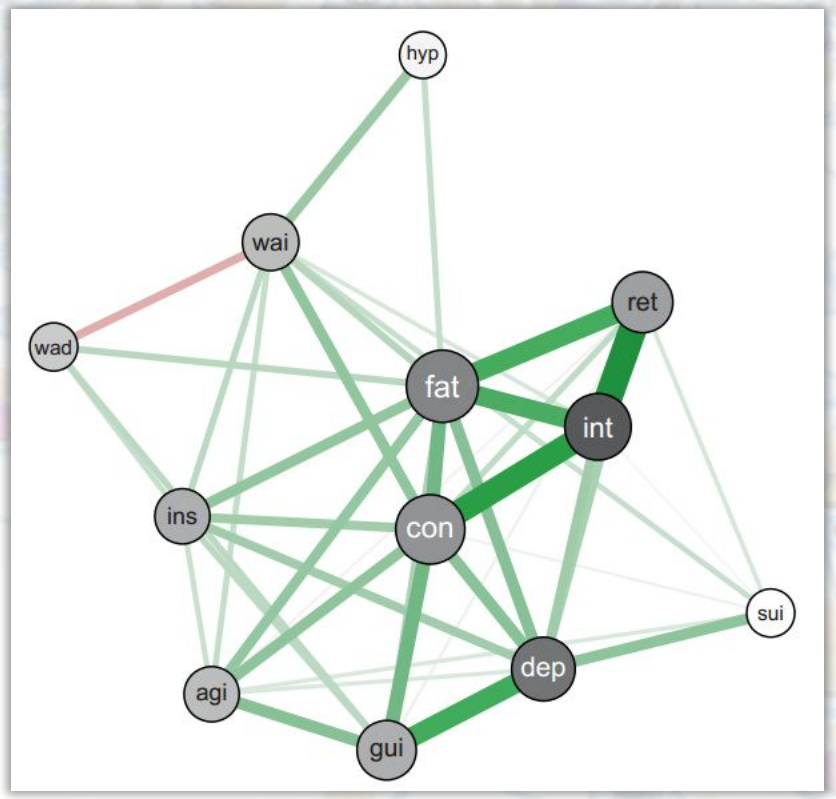
- Much recent literature examines the structure of psychopathology
- DSM/ICD “common cause” model
- Network approach: symptoms in a complex network of causal associations

Some cool research

- Networks predict course of MDD

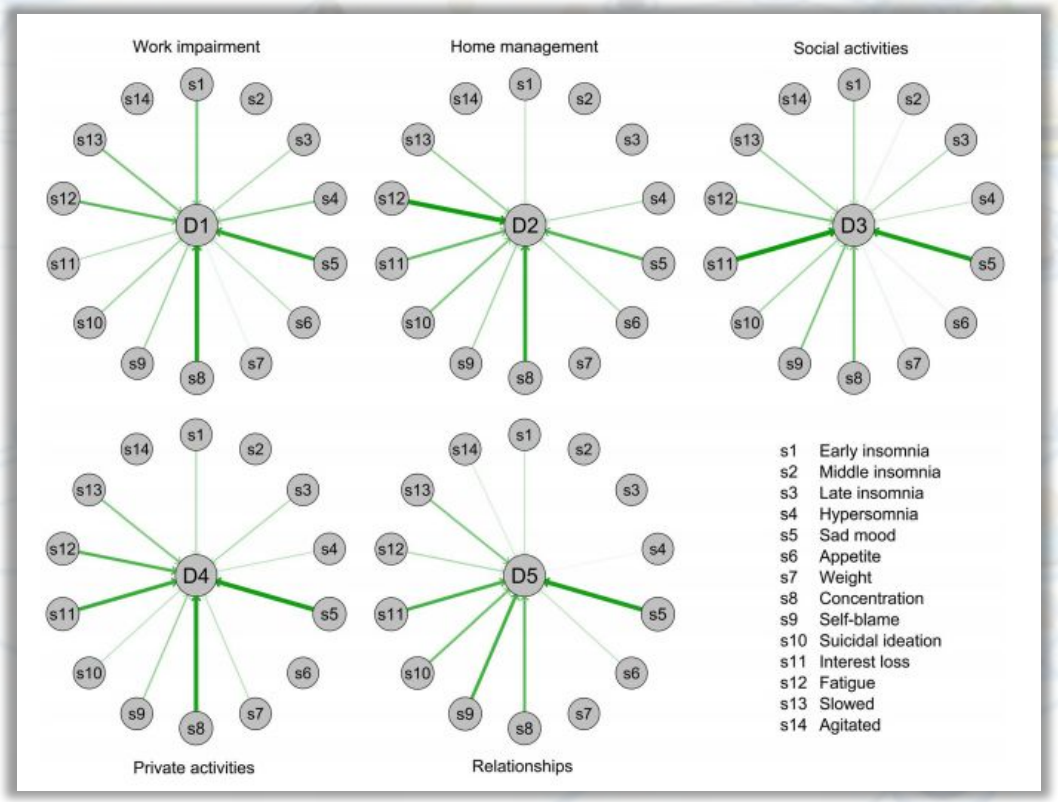


Van Borkulo et al. (2015)

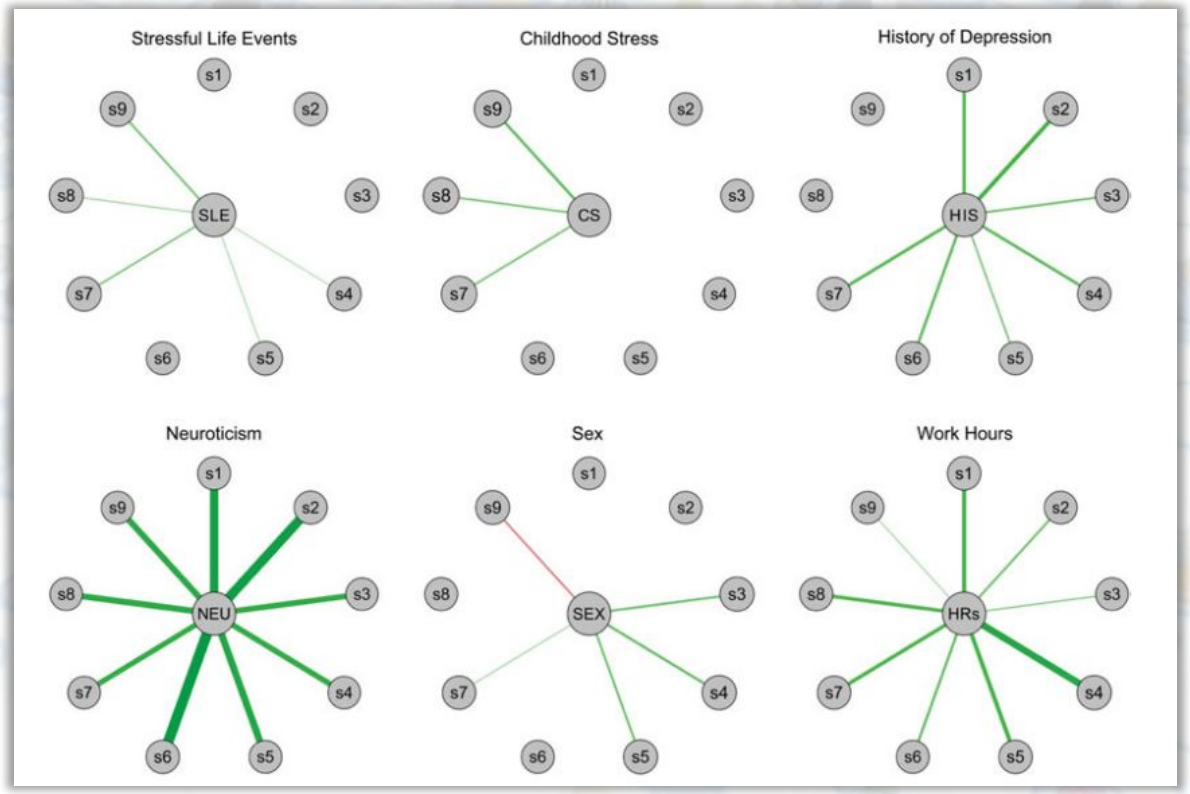


Boschloo, van Borkulo, Borsboom, & Schoevers (2016)

Some cool research

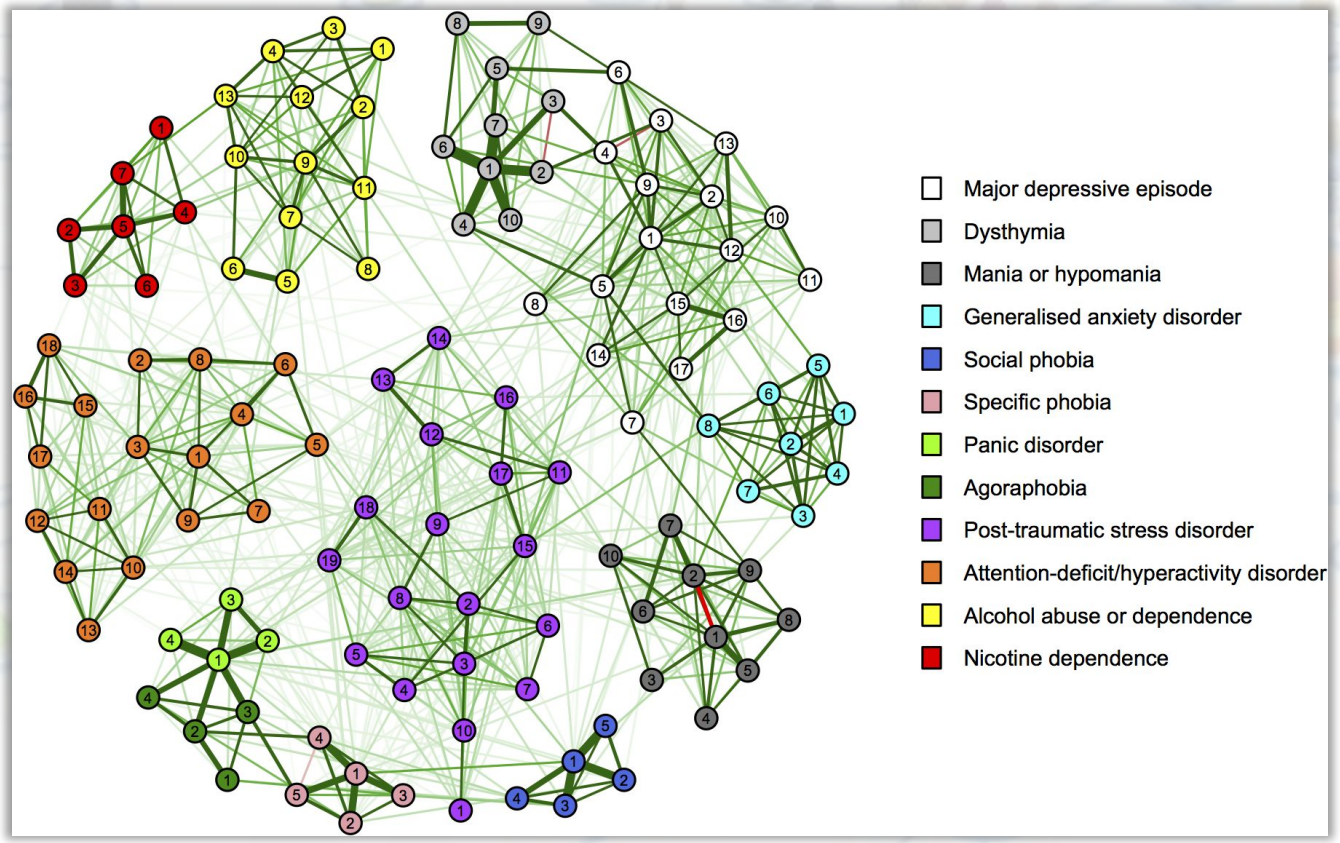


Fried & Nesse (2014)

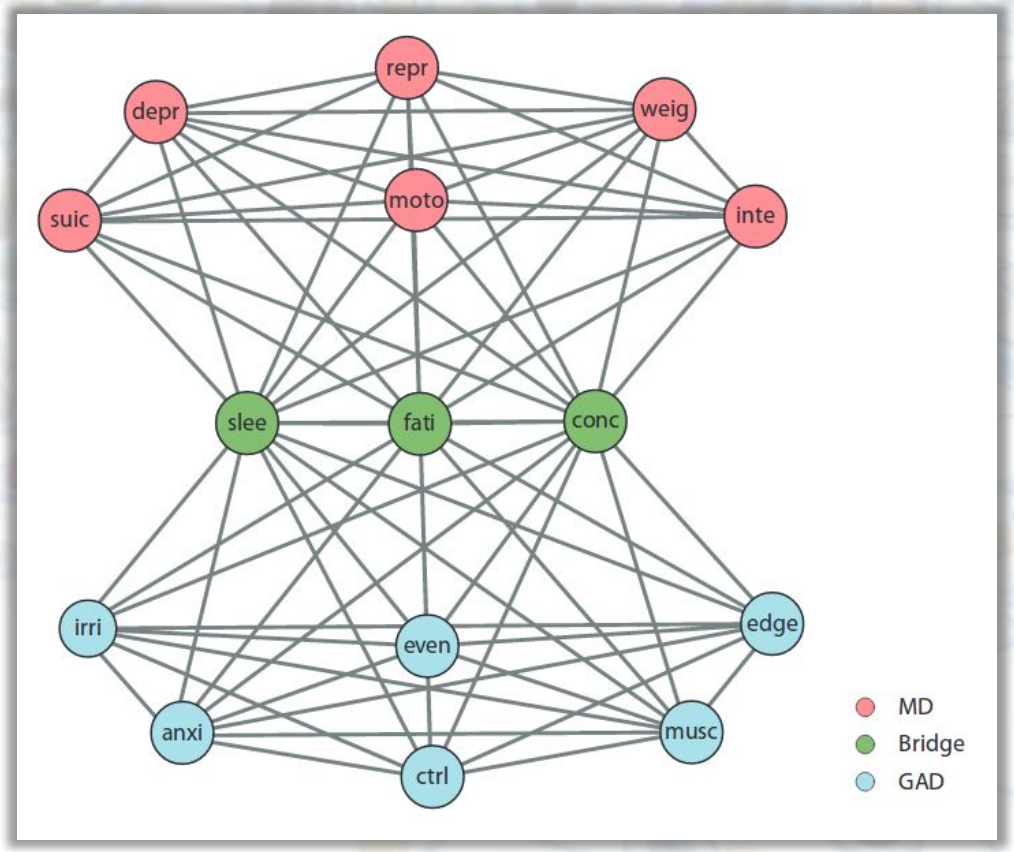


Fried, Nesse, Zivin, Guille, & Sen (2014)

Some cool research



Boschloo et al. (2015)



Borsboom & Cramer (2013)

Putting it into practice

Cross-sectional data

- `qgraph`: estimate GGMs in cross-sectional data
- `IsingFit`: estimate Ising Models in cross-sectional data (networks with binary variables)
- `mgm`: estimate mixed graphical models in cross-sectional data (network models with different types of variables)
- `bootnet`: estimate accuracy and stability of cross-sectional network models
- `NetworkComparisonTest`: test the difference of network structures across different samples

Time-series data

- `graphicalVAR`: estimate time-series network models for $N = 1$
- `mlVAR`: estimate time-series network models (mlVAR models) for $N > 1$
- `mgm`: estimate time-series network models (i.e., network models that change over time)

Thank you

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