

Time to spread the nets?

Network models in Psychology
Psychometrics, autumn 2021

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I will tell you a story...







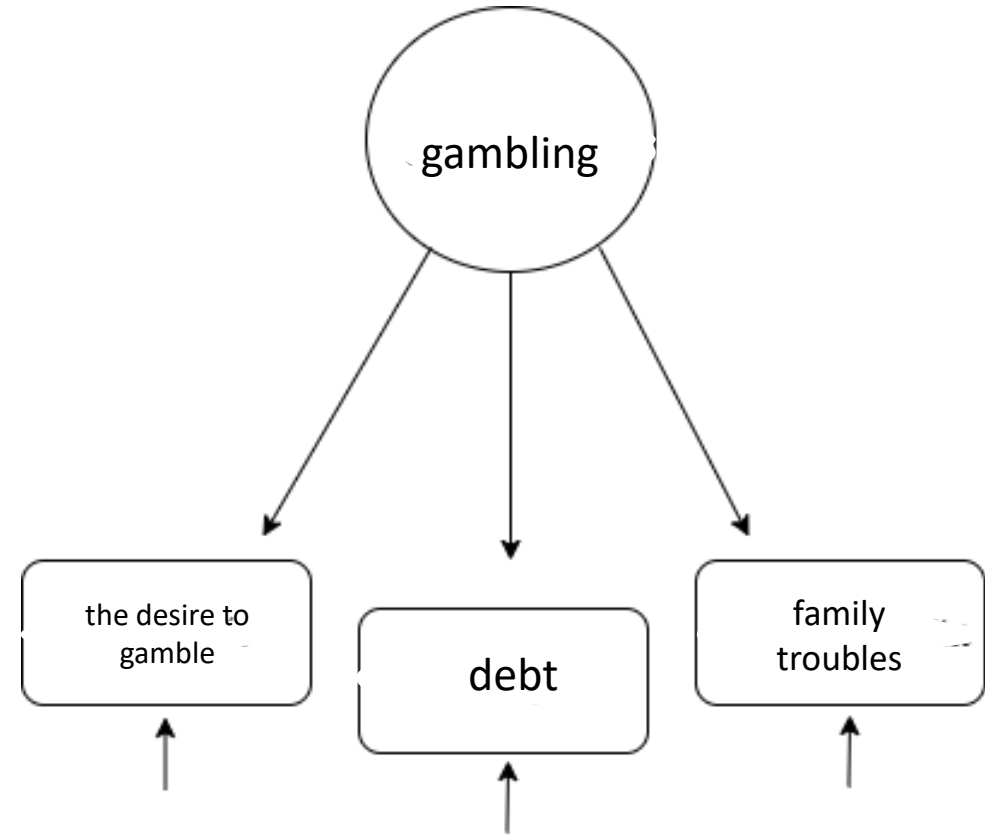










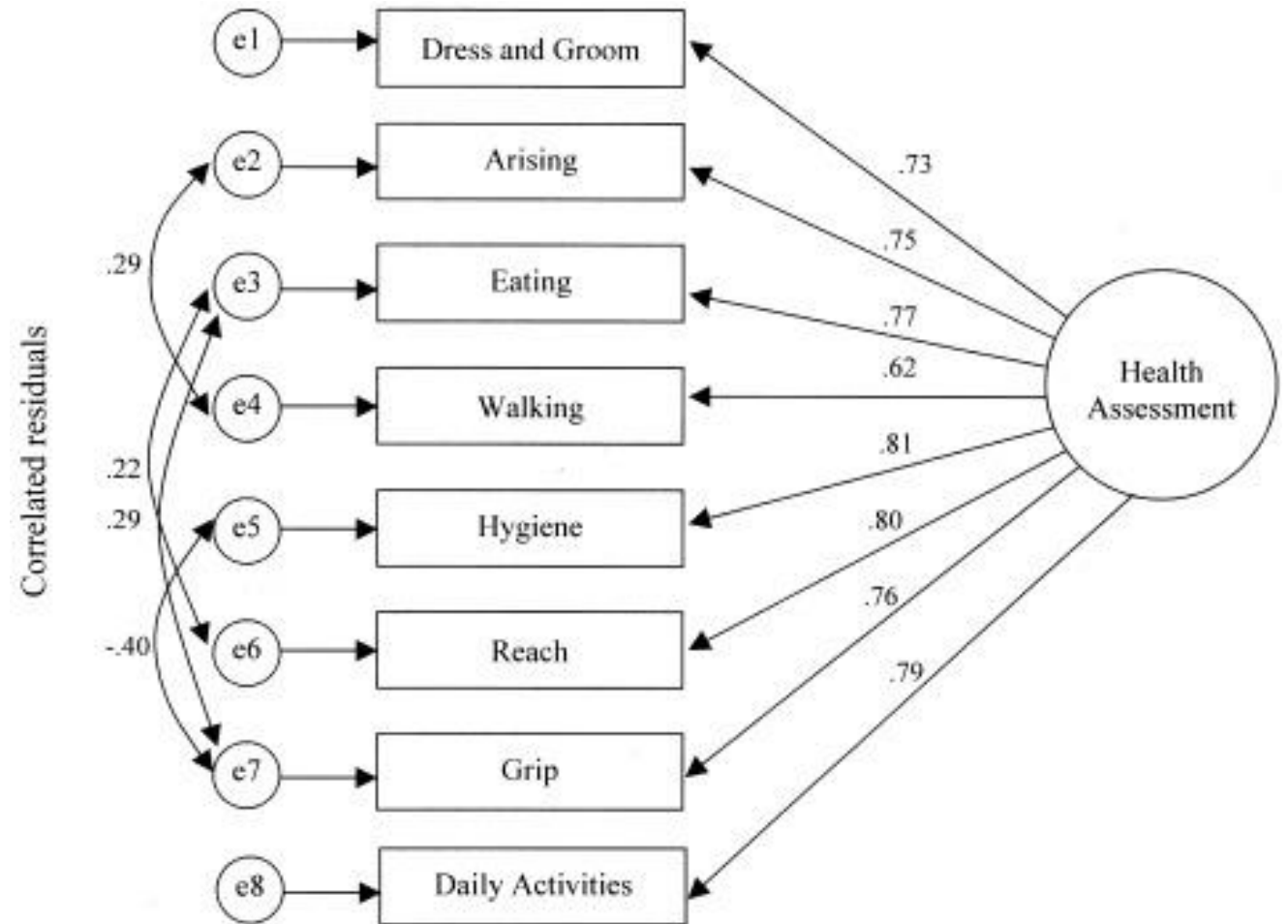


- the scale was published and everyone was happy
- What do you think about the CFM?

The causal interpretation of CFM

assumption:

- local independence





Consequences of Network Theory (by Sacha, 2020)

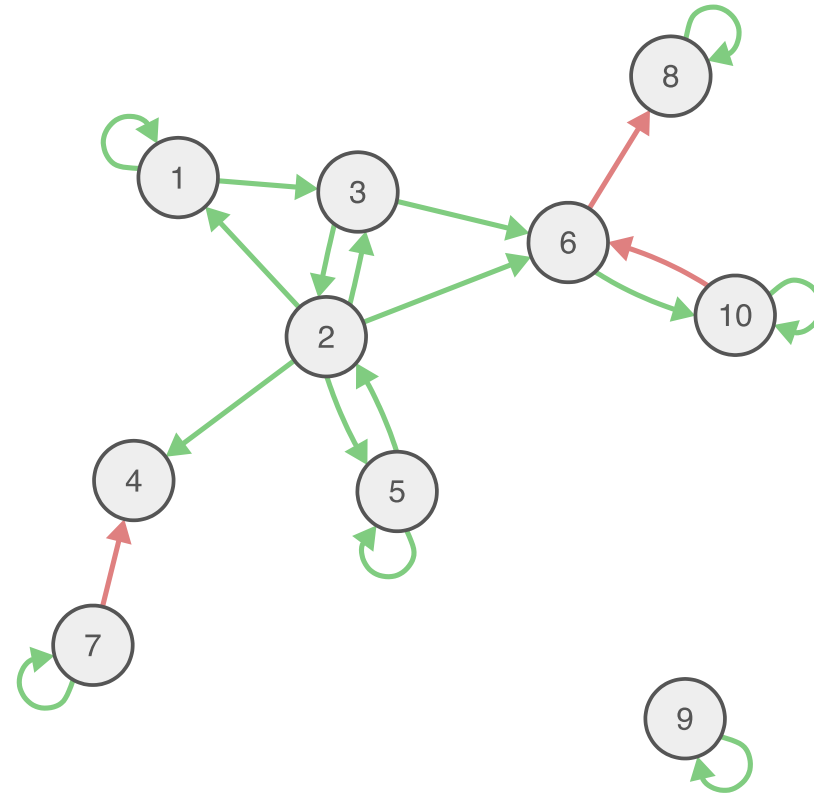
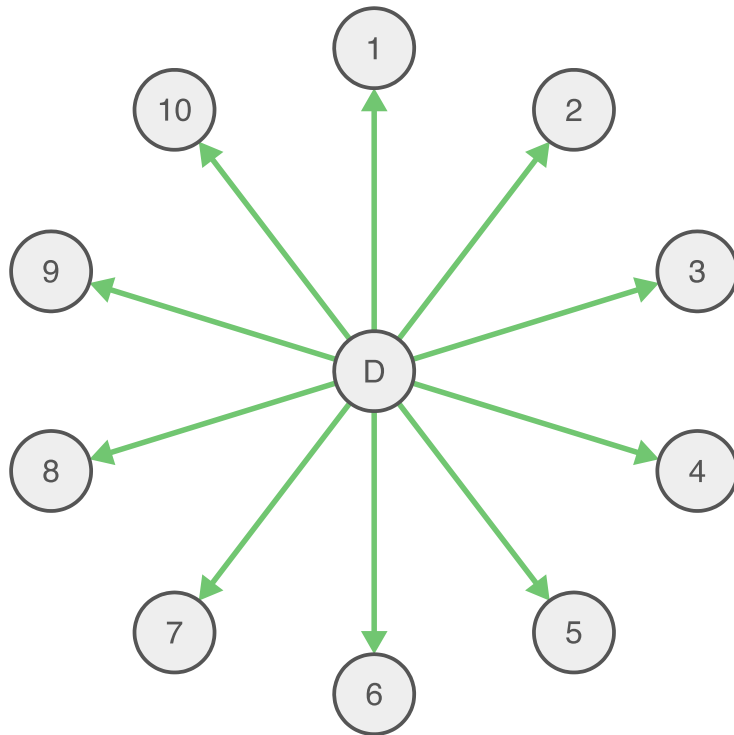
- Co-occurrence of symptoms, moods, personality aspects understood as emergent behavior
 - Implication: symptom-based interventions possible
- Every person is a different system
 - Implication: personalized modeling and treatment
- Possible to think in terms of attractor states with smooth or critical transitions
 - Implication: dynamical models may lead to insight in optimal intervention
- Analogies possible to many fields

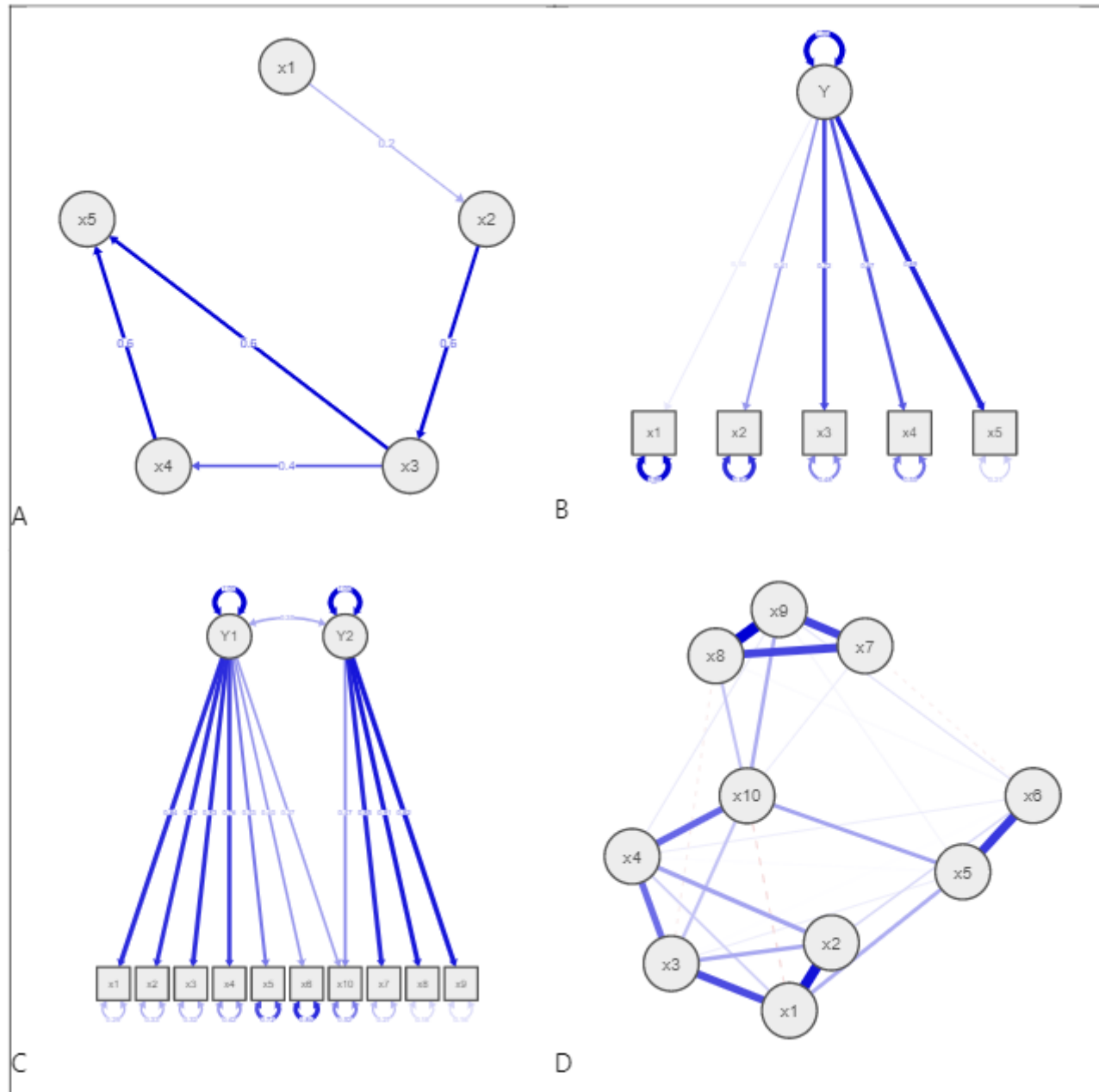
Pros & cons?

- the goal of the CFM is to find a common cause
 - parallel to e.g. medicine
- the goal of the psychologist is to prevent and/or intervene
 - dynamic psychological assessment
- do I know whether the latent variable exists?
- can I intervene on something which does not exist?
- **disclaimer**

Network Theory

- Traditional: symptoms cluster because of a shared origin
- Network: symptoms cluster because they influence each other





Two most prevalent types of data

Population data

Assumption:

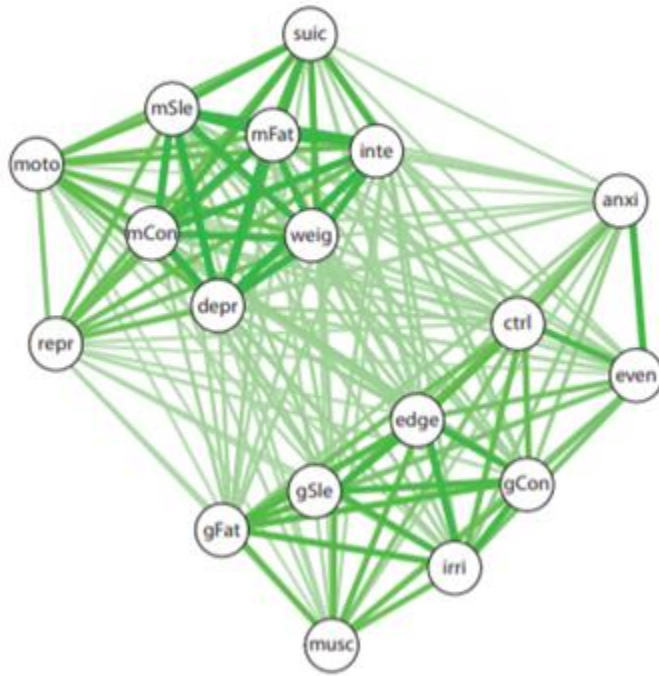
people are more or less
interchangeable

Time series

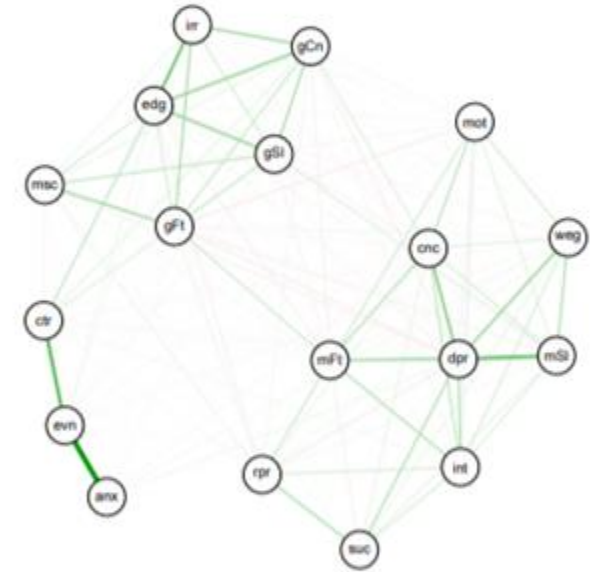
Assumption:

The right time on the
right scale

Population data

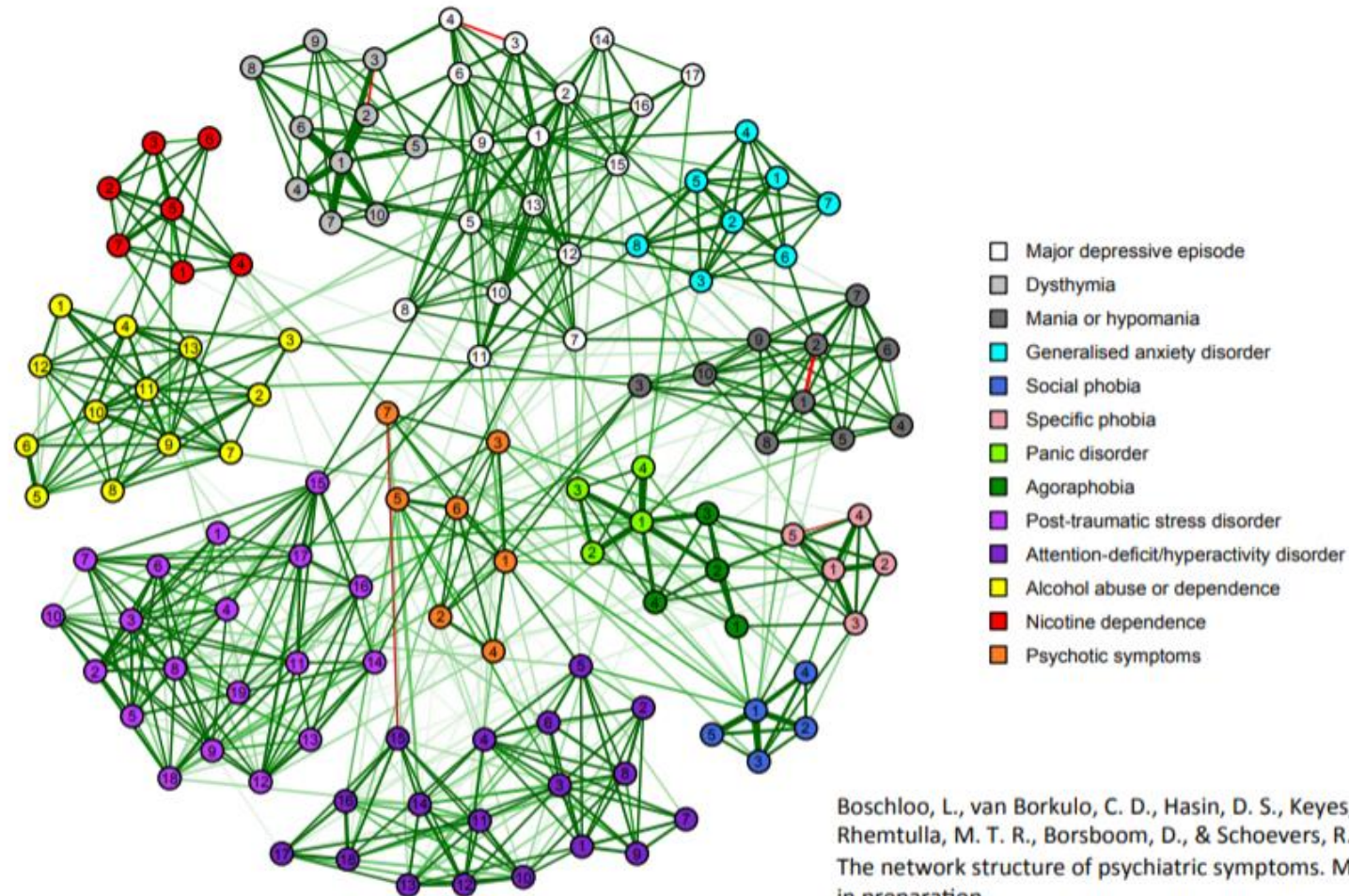


Correlation graph
of MDE-GAD



Partial correlation graph
of MDE-GAD

Ising model for the entire DSM-IV



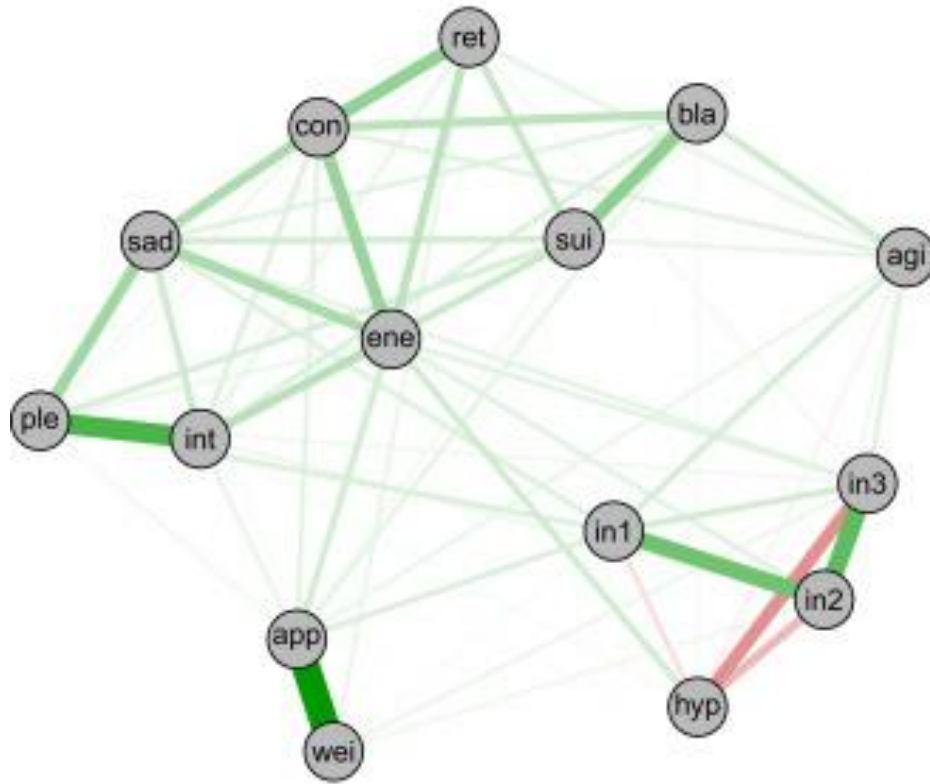
Depression DSM-5 Diagnostic Criteria

The DSM-5 outlines the following criterion to make a diagnosis of depression. The individual must be experiencing five or more symptoms during the same 2-week period and at least one of the symptoms should be either (1) depressed mood or (2) loss of interest or pleasure.

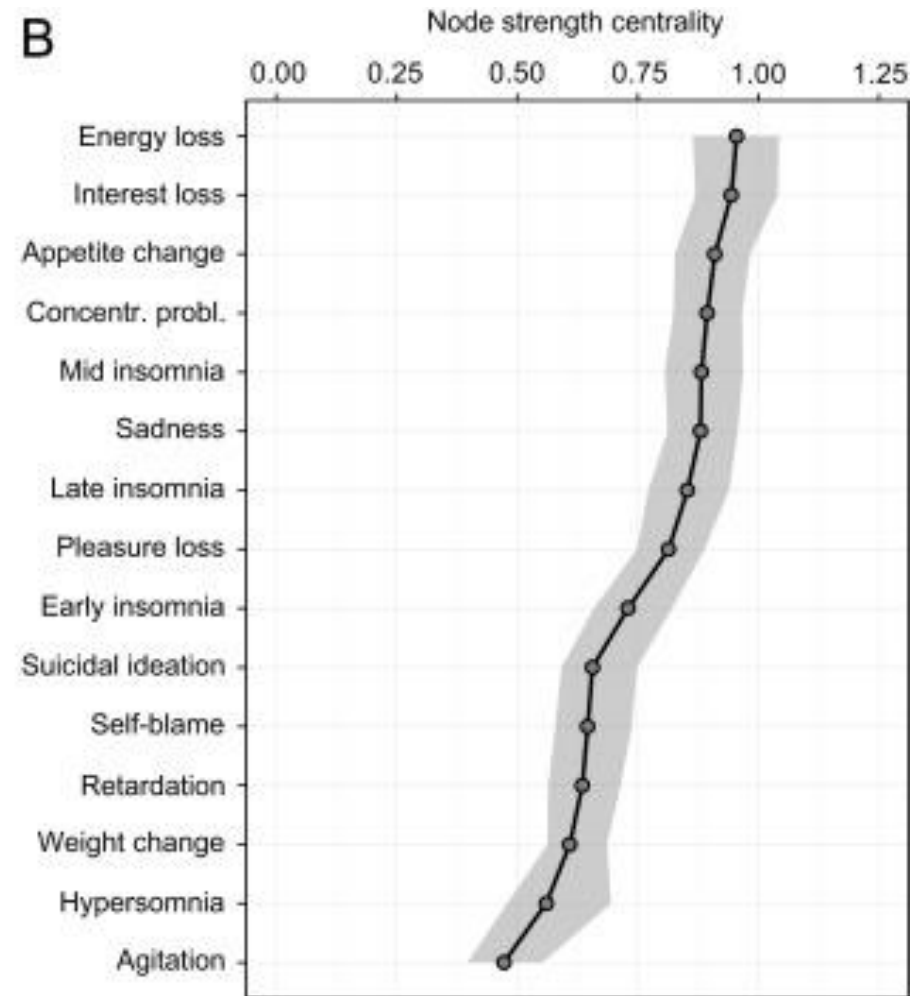
1. Depressed mood most of the day, nearly every day.
2. Markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day.
3. Significant weight loss when not dieting or weight gain, or decrease or increase in appetite nearly every day.
4. A slowing down of thought and a reduction of physical movement (observable by others, not merely subjective feelings of restlessness or being slowed down).
5. Fatigue or loss of energy nearly every day.
6. Feelings of worthlessness or excessive or inappropriate guilt nearly every day.
7. Diminished ability to think or concentrate, or indecisiveness, nearly every day.
8. Recurrent thoughts of death, [recurrent suicidal ideation](#) without a specific plan, or a suicide attempt or a specific plan for committing suicide.

Network of depression symptoms - DSM

A

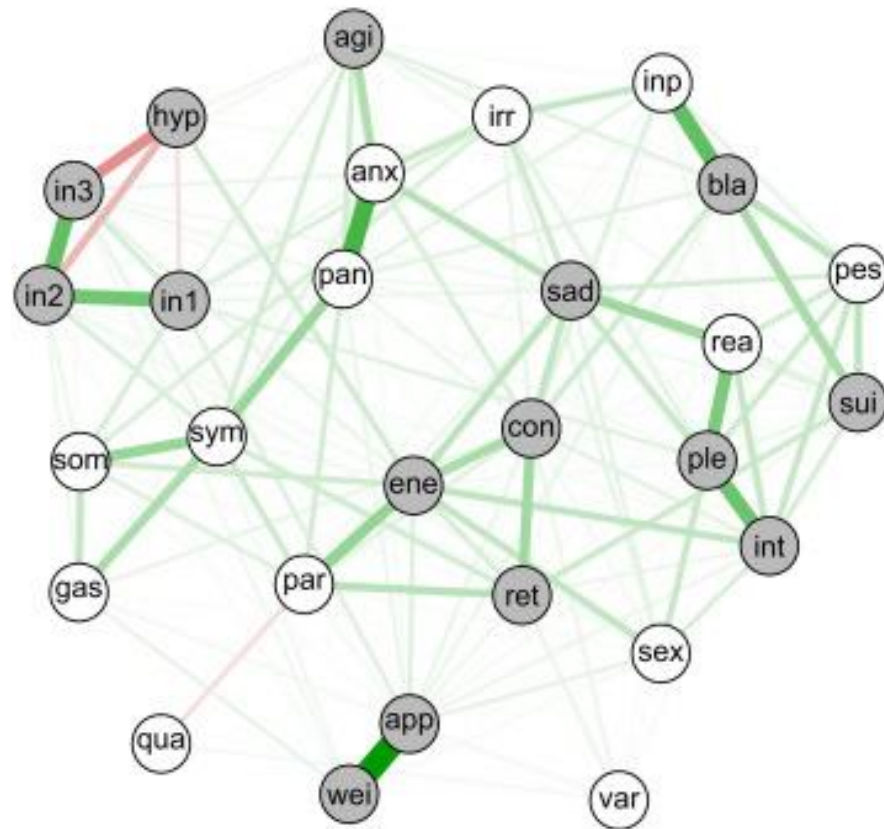


B



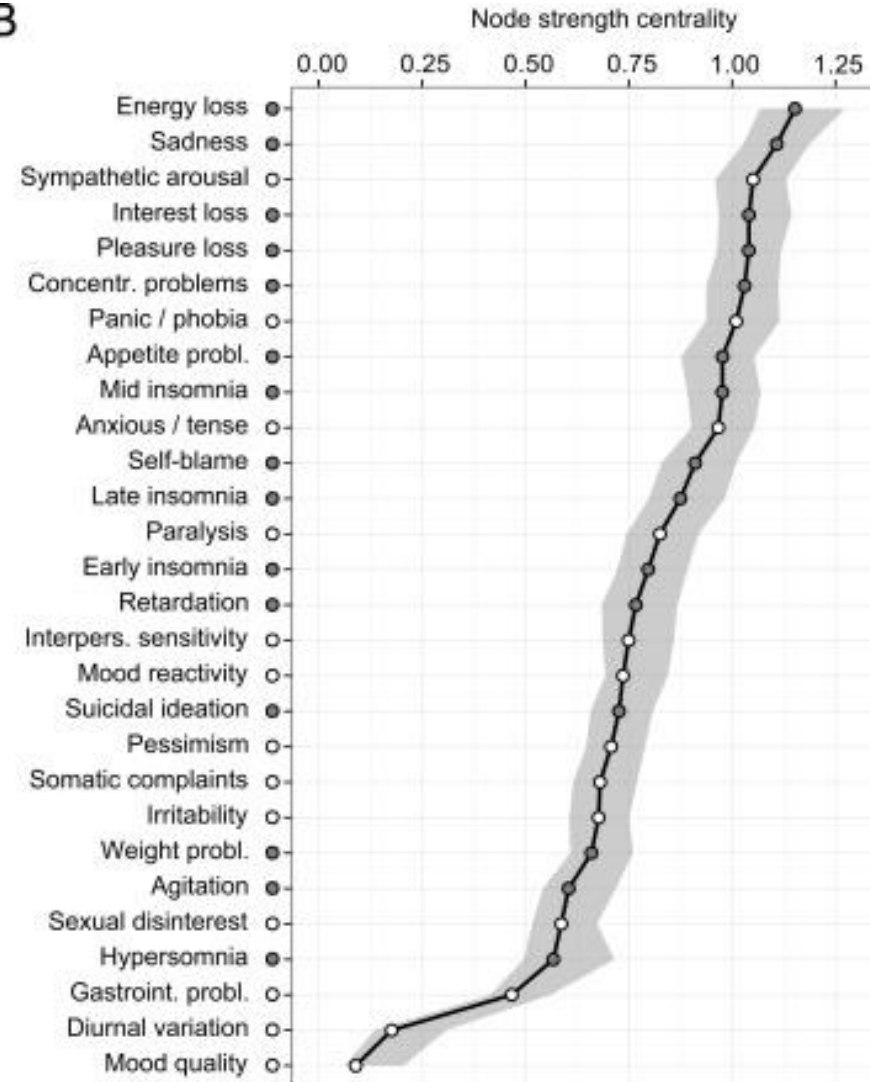
Network of depression symptoms - extended

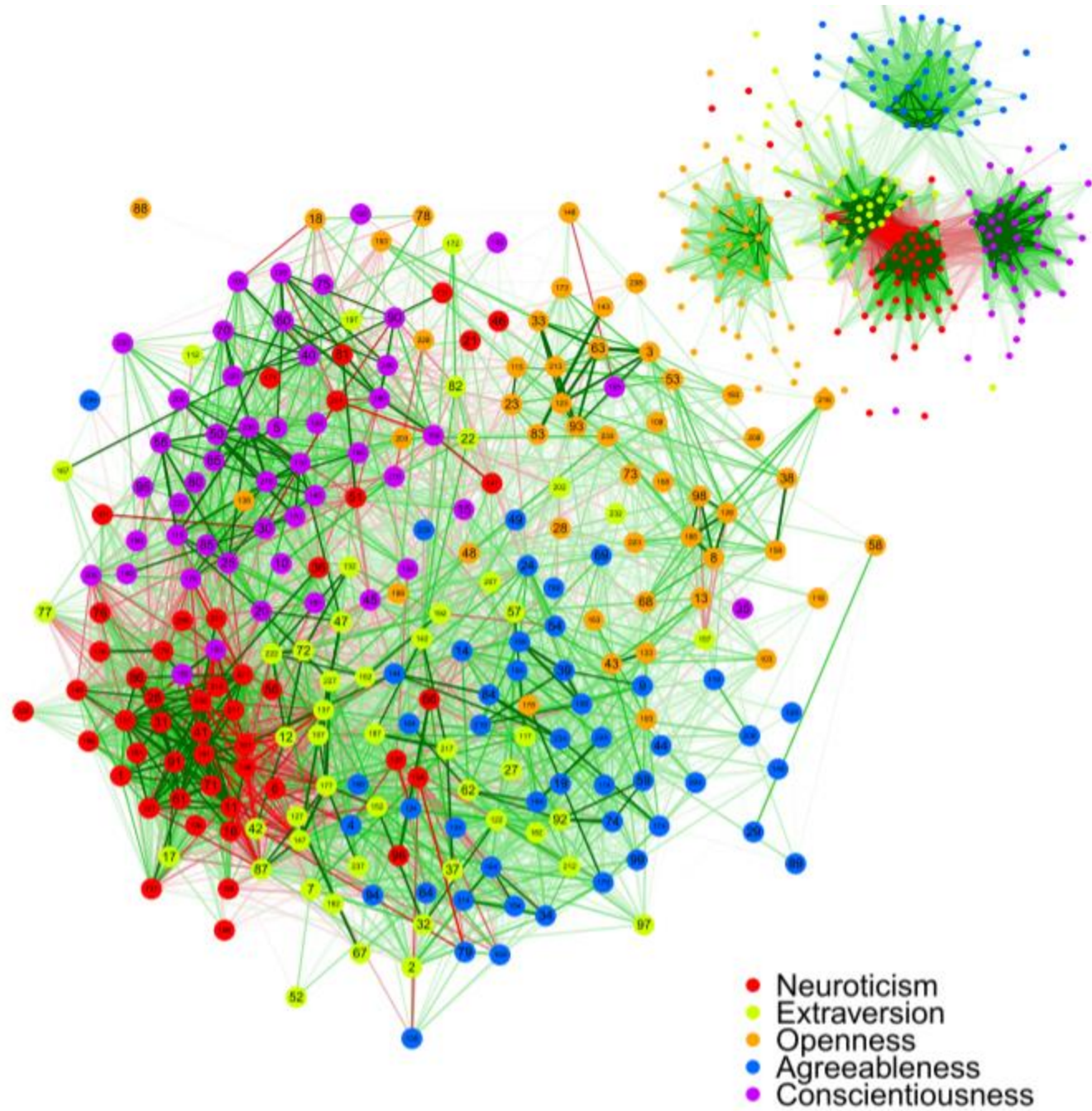
A



- DSM criterion symptom
- Non-DSM symptom

B



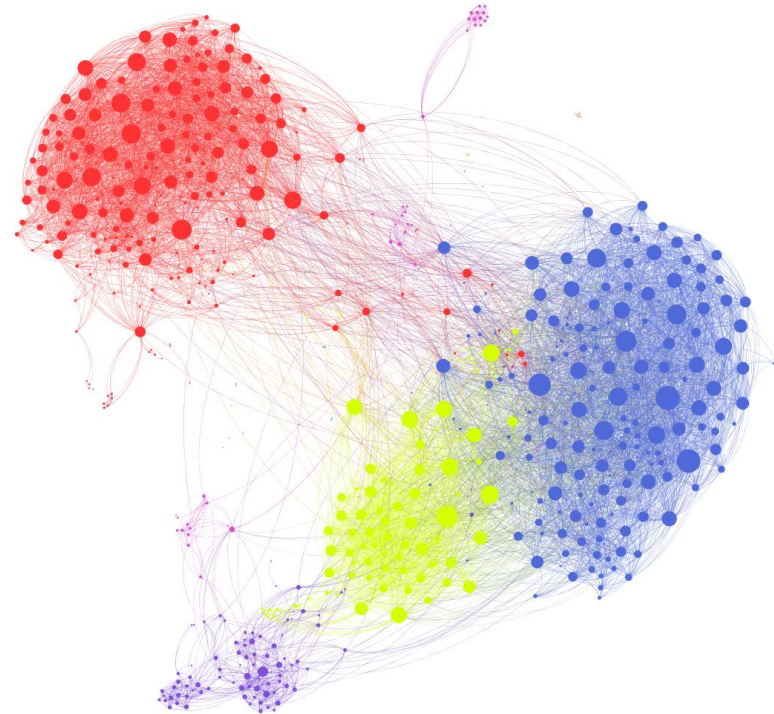


Network Theory vs. Network Psychometrics

- Many authors agree with network theory (e.g., symptoms are active causal agents, and every person has a different system)
- **Network theory** may be disjoint from network psychometrics! Believing symptoms influence one-another is not equal to believing an Ising model underlies the data
- **Network psychometrics**, however, is now often applied as an (exploratory) way of estimating potential network structures

What are Networks?

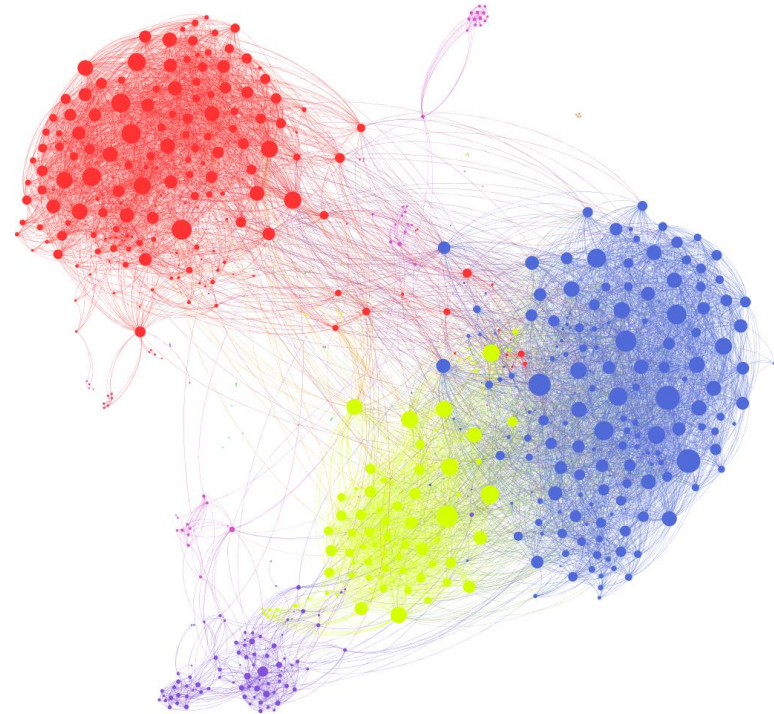
- A network is a set of **nodes** connected by a set of **edges**
 - Nodes are also called *vertices*
 - Edges are also called *links*
 - Networks are also called *graphs*
- A node represents an entity
 - People
 - Cities
 - Symptoms
 - Psychological construct/item



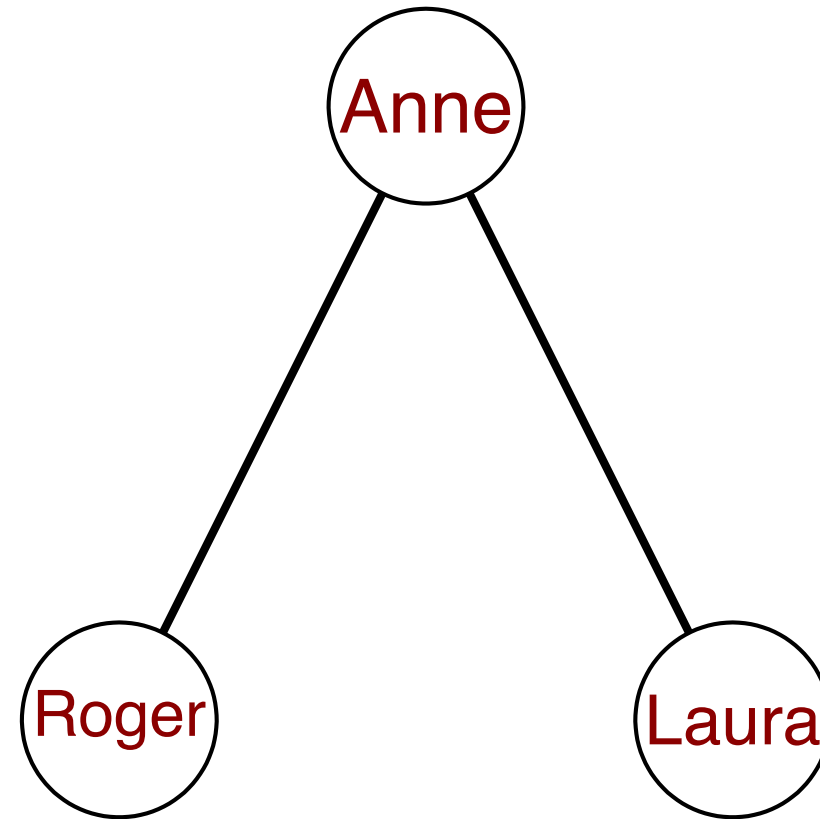
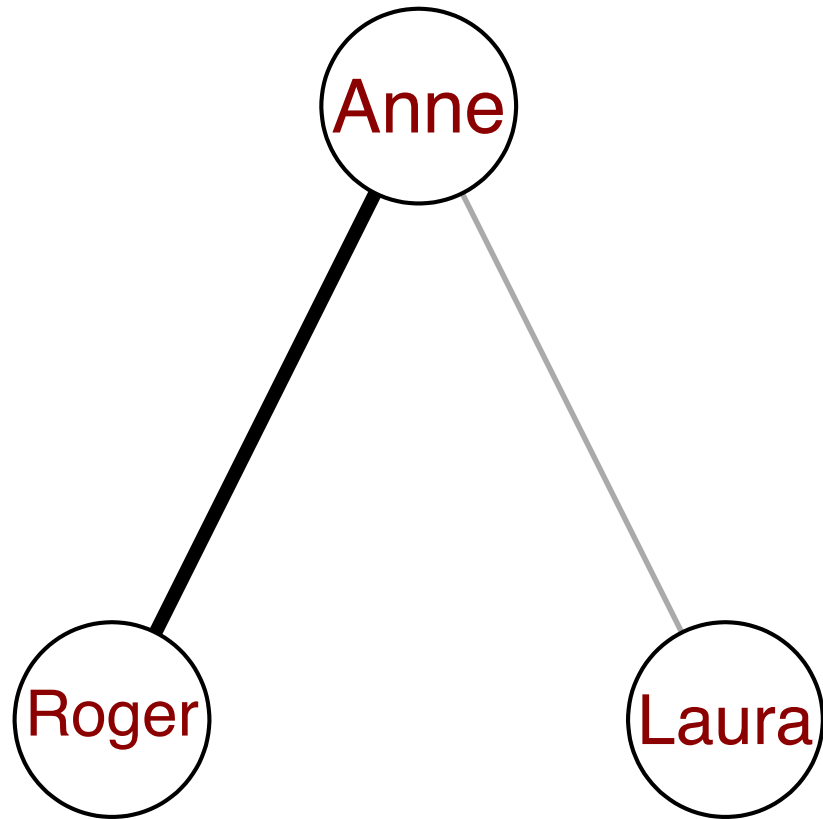
What are Networks

An edge represents some connection between two nodes

- Friendship / contact
- Distance
- Comorbidity
- Causality
- Interaction



Edges can be weighted or unweighted

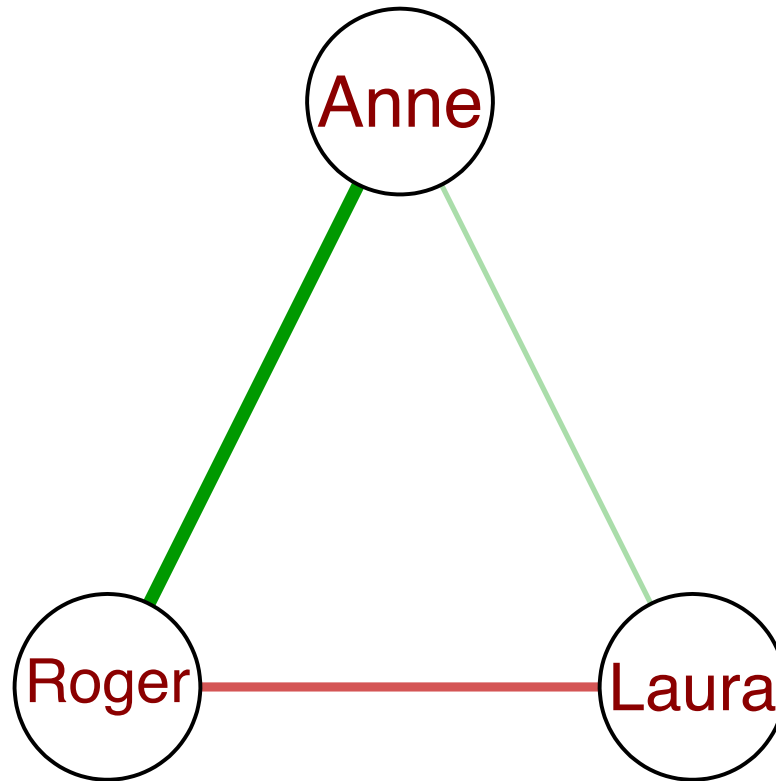


Weighted networks

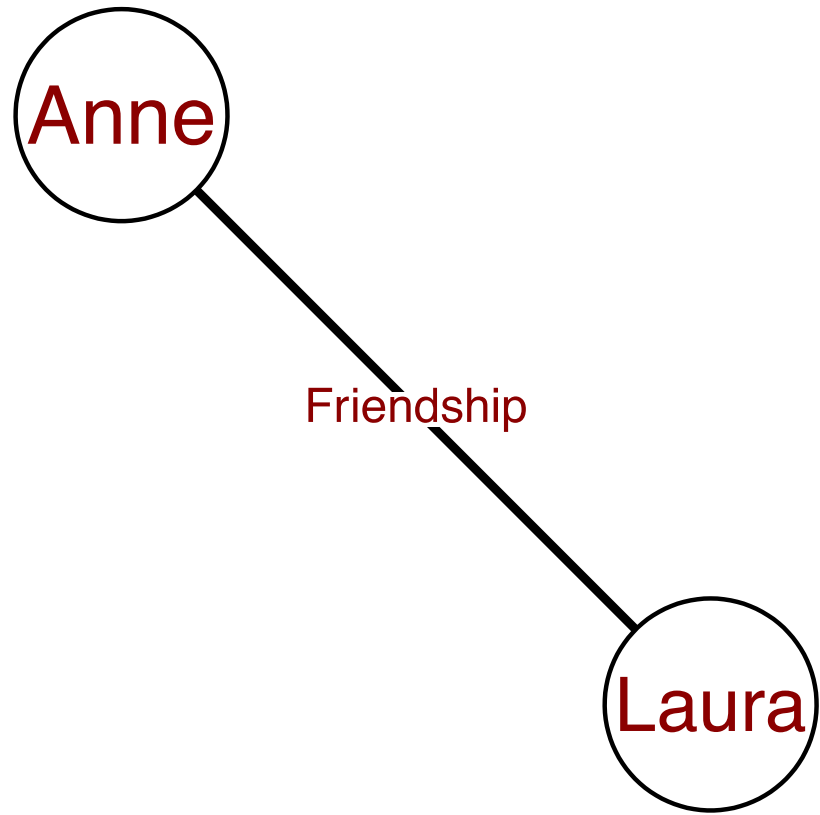
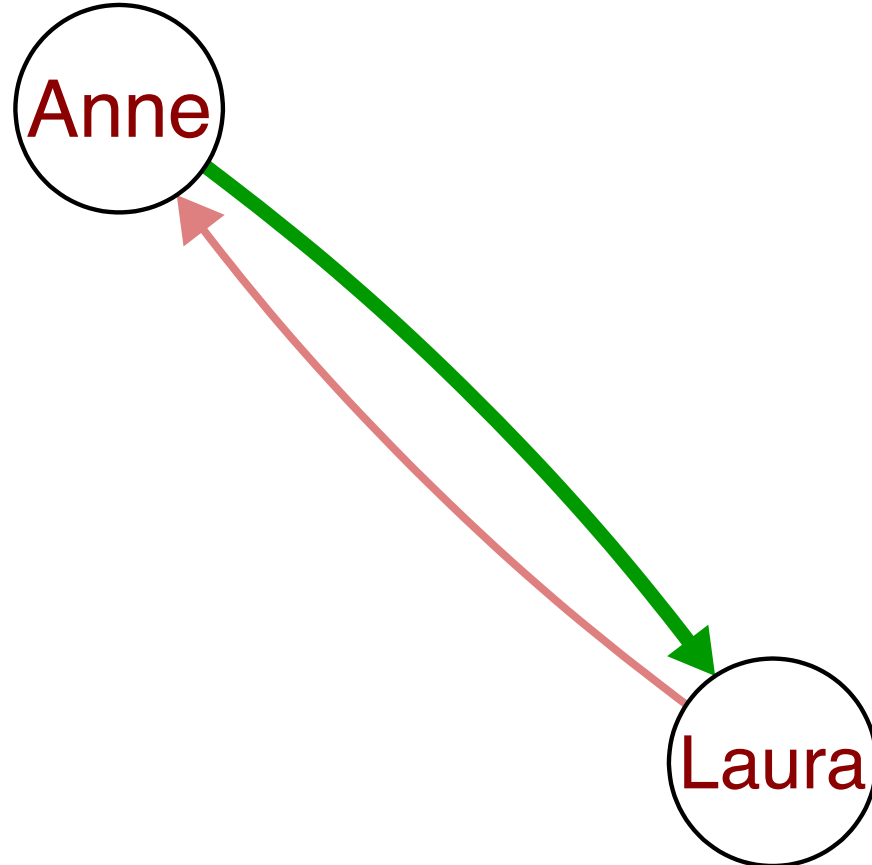
- Weights can be positive or negative, and indicate the *strength* of an edge, with zero indicating no strength (identical to the absence of an edge)
 - Nodes that are connected by a strong edge can be seen as close by or easily reachable from one to the other
- Sometimes an edge has a *length* rather than a weight
 - This is a positive value indicating the distance between two nodes
 - A length of ∞ indicates no edge
 - A weight is often recoded to a length by taking the inverse of the absolute value of the weight

Signs of edges

Edges can have a sign (positive / negative)



Networks can be *directed* or *undirected*



Network Inference

- Once a network has been estimated, descriptive measures can be computed to investigate and summarize the structure
- Global inference
 - E.g., Small-worldness, density (network resilience)
 - Mostly still in development for weighted networks and MRFs
- **Local inference (nodes/edges)**
 - e.g., node centrality, edge centrality, clustering
 - many researchers in psychology focused on node centrality to obtain most “important” nodes
- **Important: These measures were developed in in networks such as railway and social networks; real interpretation in psychological networks is not trivial**

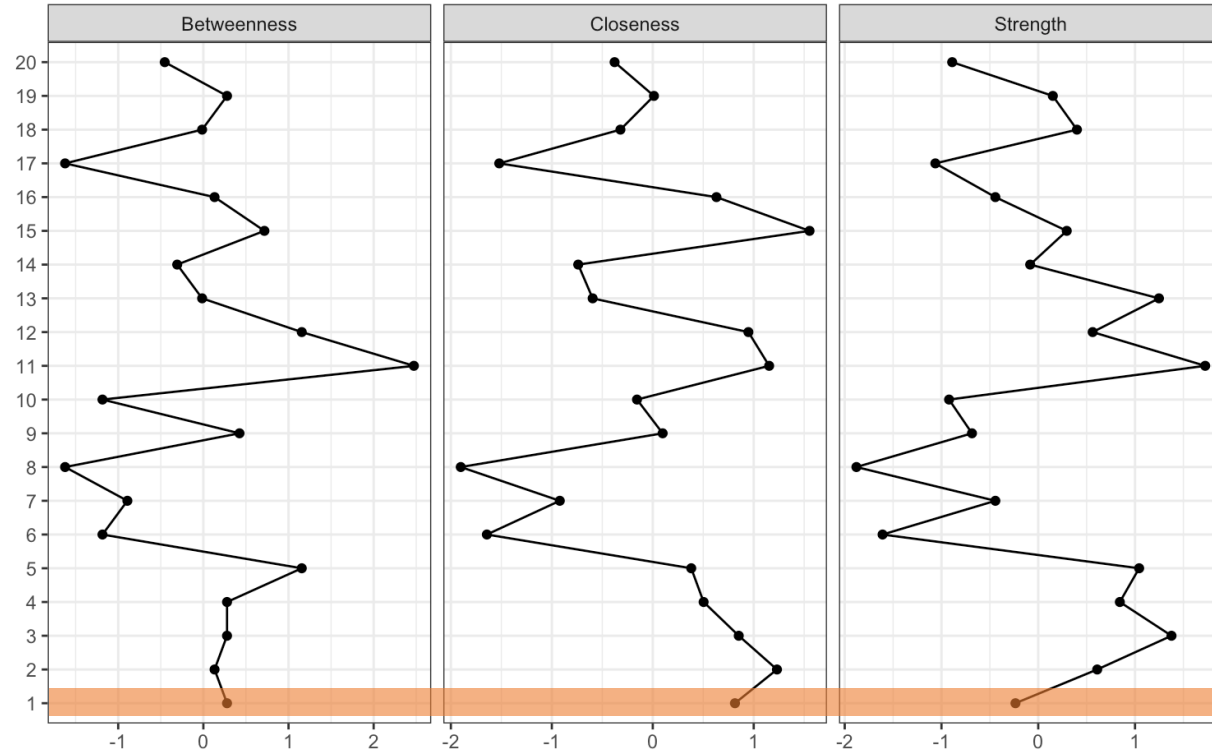
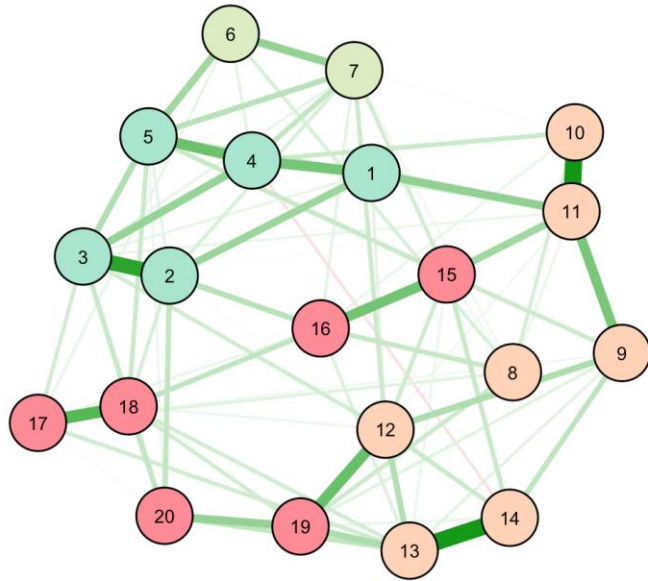
Centrality

- Centrality measures aim to assess the connectedness of a given variable with all other variables in the network
- Many exist for unweighted networks; fewer for weighted networks
 - Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social networks*, 32(3), 245-251.

Centrality

- **Node strength:** how strongly a node is *directly* connected
 - A central railway station is one with many railways running through it
- **Closeness:** how strongly a node is *indirectly* connected
 - A central railway station is one located in the center of the country, close to all destinations
- **Betweenness:** how well one node connects other nodes
 - A central railway station is an important transit station
- Often similar results, but not necessarily

Centrality

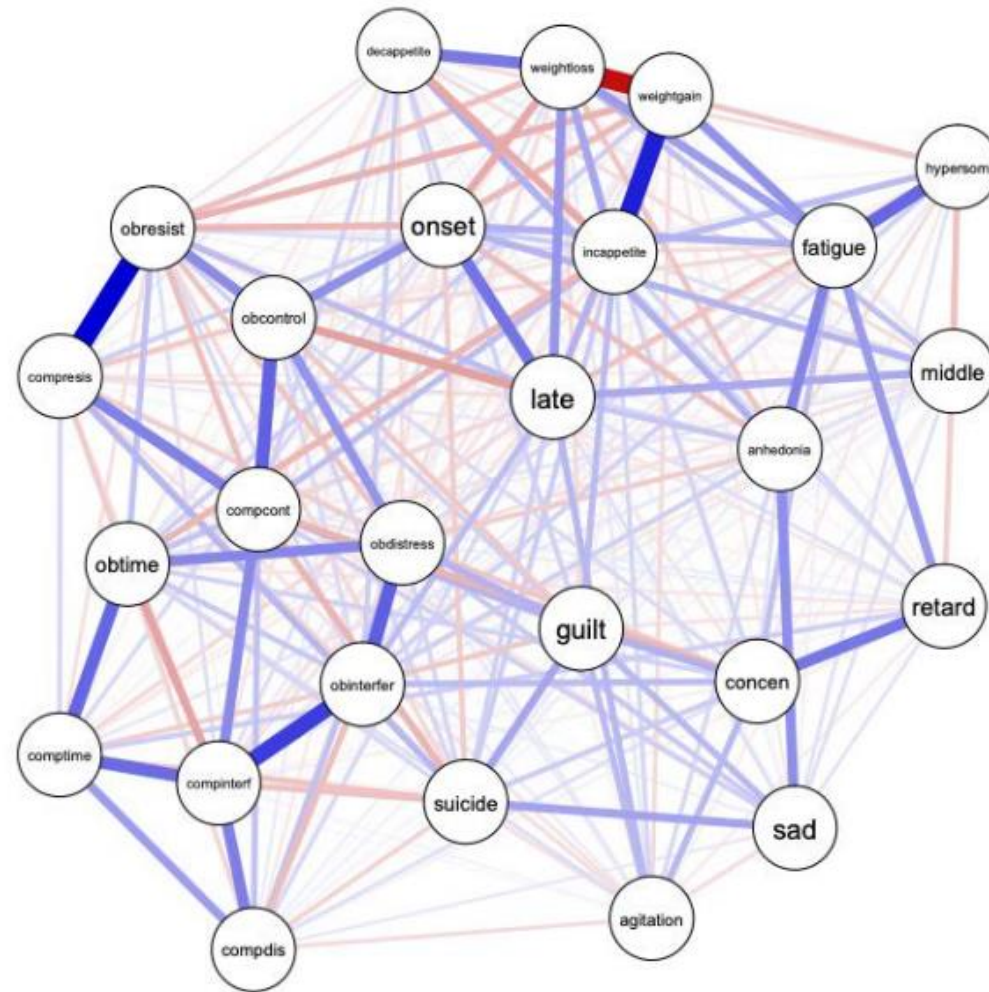


Important: When estimating psychological networks centrality differences need to be tested for accuracy and stability.

How do I get the edges?

- We often use undirected network models (Markov random fields – graphical model of joint probability distribution)
 - Gaussian data: Gaussian graphical model (bootnet)
- Edges show conditional dependencies
 - In the GGM: partial correlations
- Models based on either:
 - **inverting the variance-covariance matrix**
 - nodewise regressions
 - joint estimation

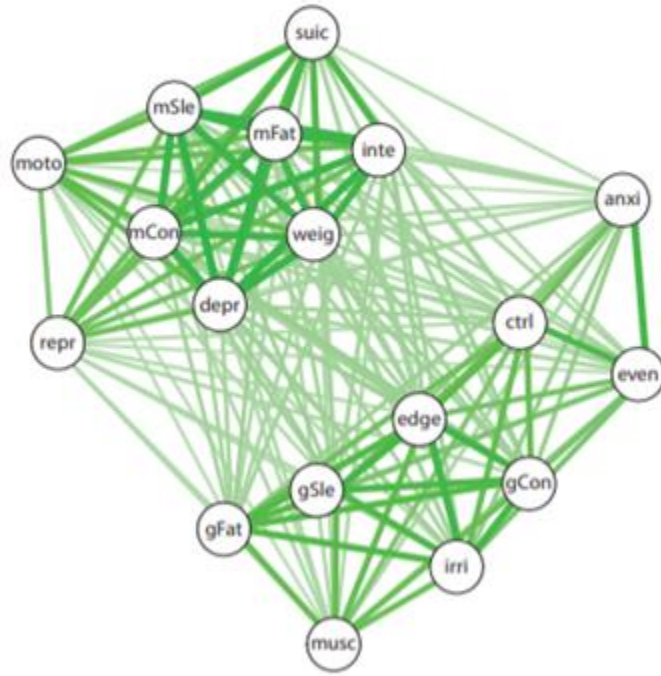
Do you see any potential problems?



Coffeebreak



Population data



Correlation graph
of MDE-GAD



Partial correlation graph
of MDE-GAD

We need get rid of the edges!

Networks based on either:

- **inverting the variance-covariance matrix**
 - *pruning* – we are removing an edge depending on a significance test, I can correct against multiple testing (e.g., bonferroni)
- nodewise regressions
 - *regularisation* – I suppress edges with low weights (lasso)
- joint estimation
 - *model search* – we are seeking the best fitting model – the estimation ends when we cannot add/remove an edge based on a criterion

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Robustness & stability of your model

- *what happened when networks emerged?*
- networks are complex and complicated
- estimation is mostly quite demanding
- and sampling variability can ruin it
- *what statistics can we be interested in?*
 - edge weights, centrality indices

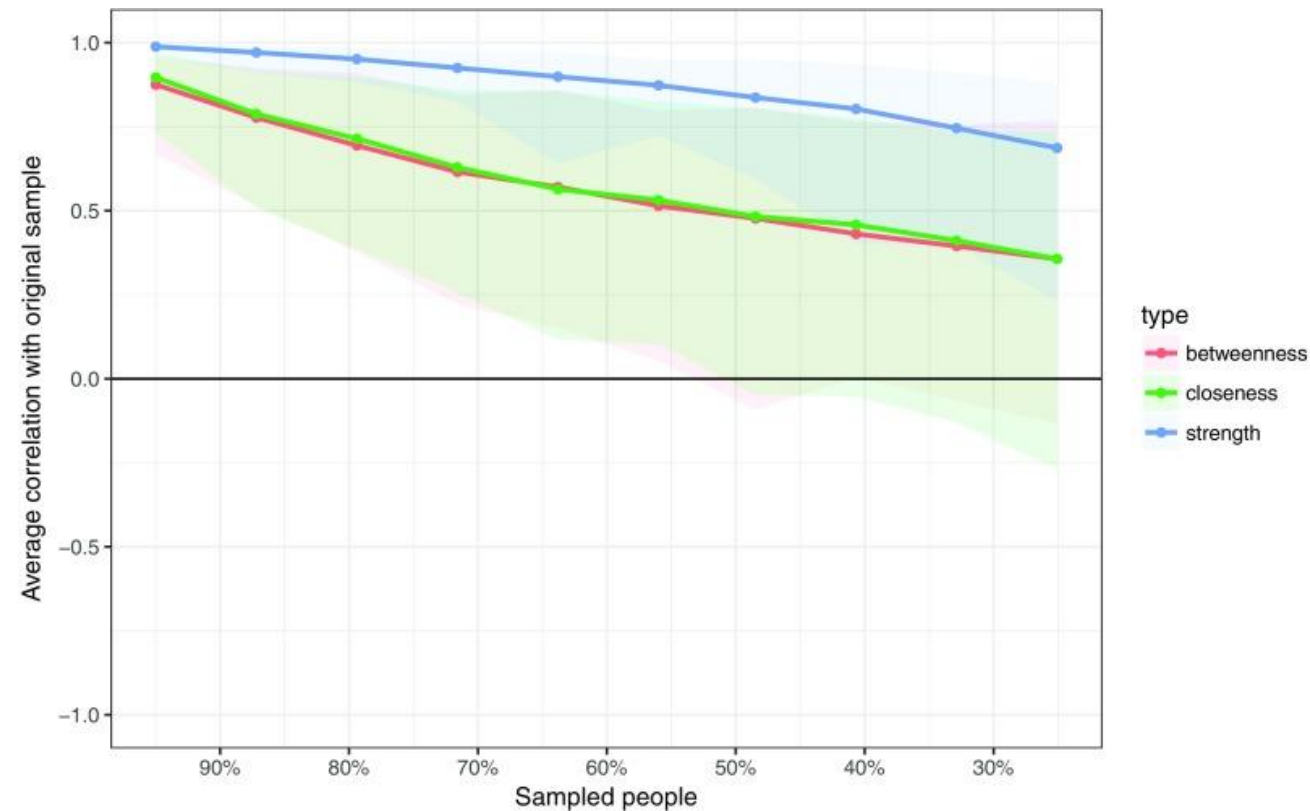
Non-parametric bootstrap

- the sampling variability problem
- we compute a statistic (e.g. edge weight)
- we generate a new dataset by repeated sampling from the original one
- I recompute the statistic
- and repeat -> get confidence intervals

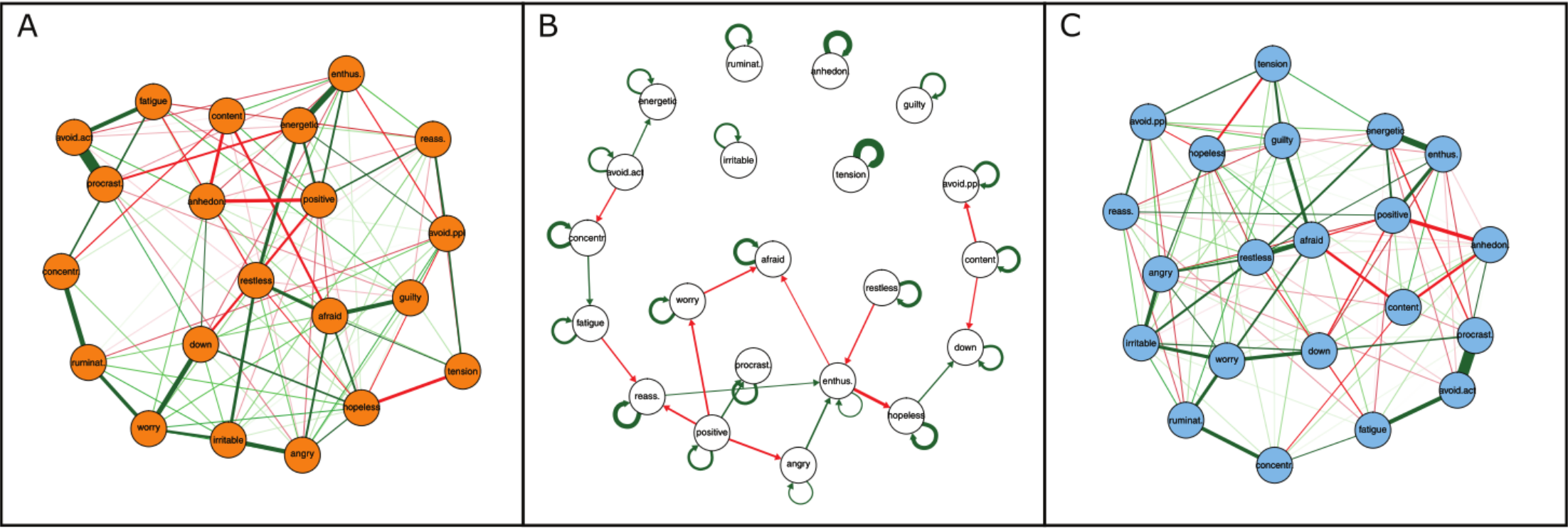


Case-drop bootstrap – “kick-out bootstrap”

- we are asking a question about **how many cases can I kick out to keep my centrality estimates stable**



Time series within EMS



Temporal effects

	relaxed [^]	sad [^]	nervous [^]	concentration [^]	tired [^]	rumination [^]	bodily.discomfort [^]	time [^]
31	5	6	4	5	6	4	4	2014-05-01 10:15:00
32	3	5	4	5	6	4	5	2014-05-01 13:15:00
33	NA	NA	NA	NA	NA	NA	NA	2014-05-01 16:15:00
34	3	5	4	5	6	4	4	2014-05-01 19:15:00
35	4	6	4	4	7	5	4	2014-05-01 22:15:00
36	4	3	3	5	5	2	3	2014-05-02 10:15:00
37	4	3	4	5	5	3	2	2014-05-02 13:15:00

- The temporal network shows that one variable predicts another variable in the *next* measurement occasion

Contemporaneous effects

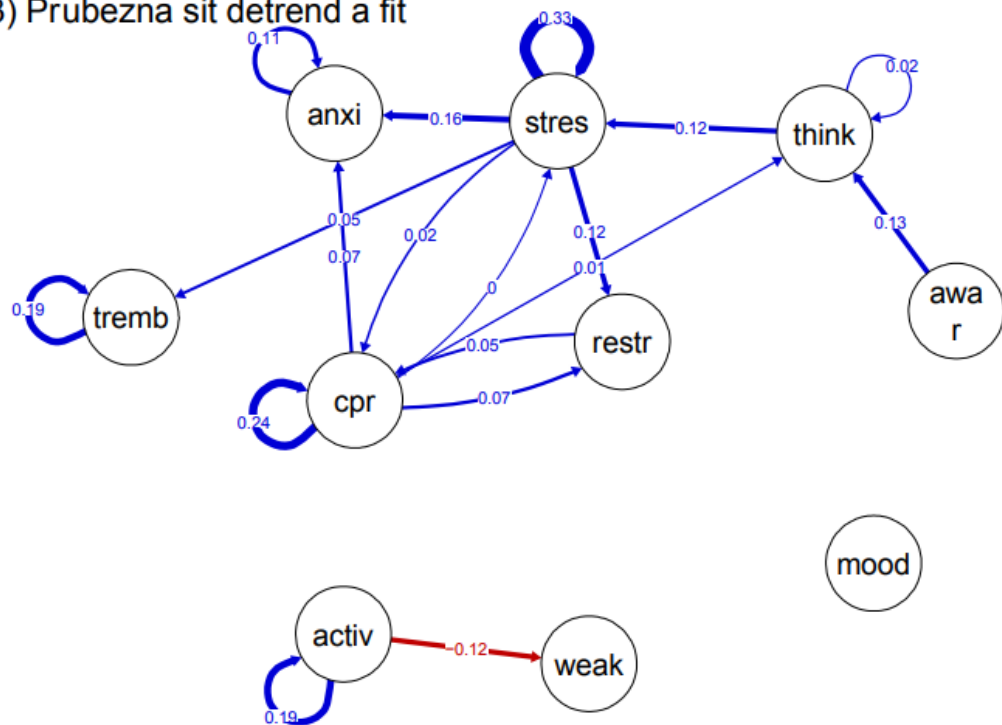
	relaxed	sad	nervous	concentration	tired	rumination	bodily.discomfort	time
31	5	6	4	5	6	4	4	2014-05-01 10:15:00
32	3	5	4	5	6	4	5	2014-05-01 13:15:00
33	NA	NA	NA	NA	NA	NA	NA	2014-05-01 16:15:00
34	3	5	4	5	6	4	4	2014-05-01 19:15:00
35	4	6	4	4	7	5	4	2014-05-01 22:15:00
36	4	3	3	5	5	2	3	2014-05-02 10:15:00
37	4	3	4	5	5	3	2	2014-05-02 13:15:00

- The contemporaneous network shows that two variables predict one-another after taking temporal information into account

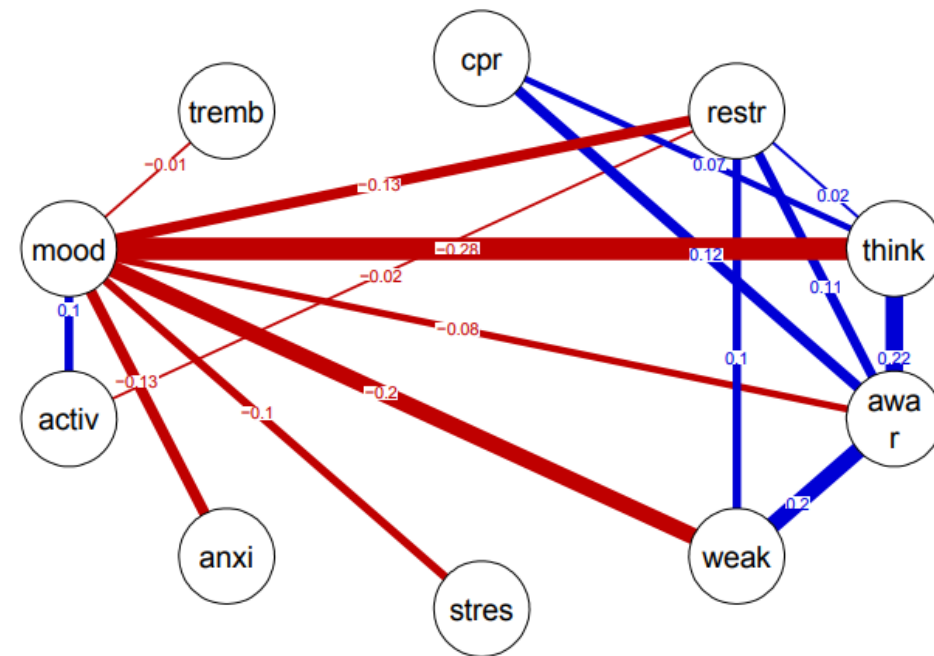
Pacient 1

Muž, 42 let. Přijat na skupinovou terapii v pobytovém stacionáři Psychosomatické kliniky v Praze. V současné době na čekací listině. U pacienta se projevovaly následující symptomy: úzkost, nervozita, bušení srdce, ztuhlost, výboje na šíji, rozostřené vidění, náhlá ztráta energie a bolesti nohou, otoky kloubů (diagnostikována revmatoidní artritida, nyní v remisi). Za hlavní spouštěč byla v anamnéze označena pracovní i mimopracovní zátěž. V rozhovoru před spuštěním měření byl seznam symptomů aktualizován. Vzhledem k upravenému pracovnímu režimu se pracovní zátěž povedlo omezit. Situace u mimopracovní zátěže přetrvává v důsledku vážně nemocného blízkého člověka v rodině. Pacient je velice aktivní. Sportuje, věnuje se horské turistice, má dvě zaměstnání. Potíže se začaly projevovat po velké zátěži, která byla spojená s vlastnoruční rekonstrukcí rodinného domu. Významnou roli hrála také stresující a špatně organizovaná práce v jeho tehdejších zaměstnání.

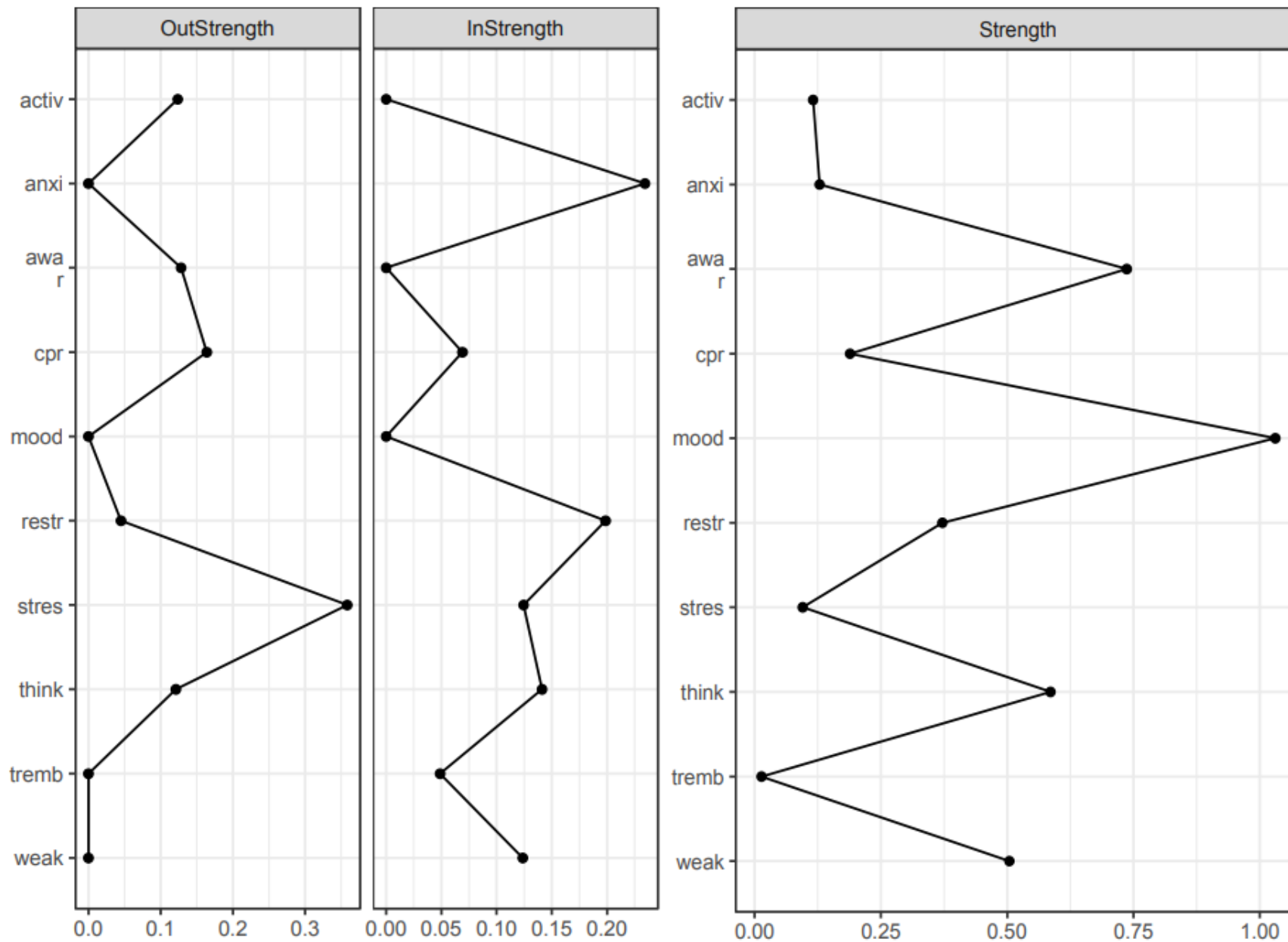
(a3) Prubezna sit detrend a fit



(b3) Soubezna sit detrend a fit



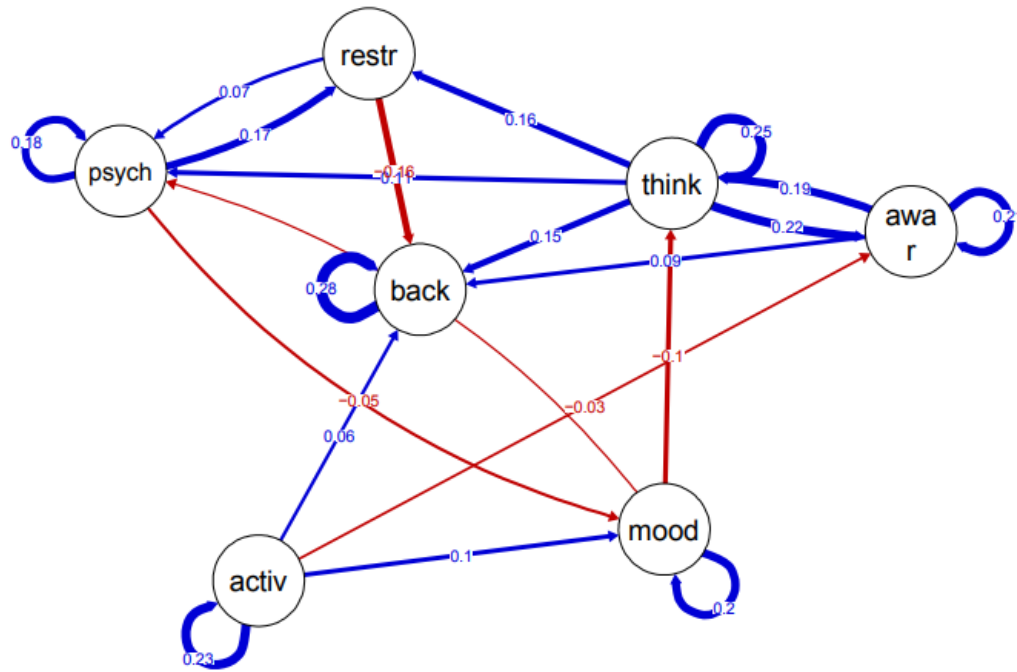
Pozn.: **crp** = mám pocit tlaku v oblasti hrudníku, **restr** = moje tělesné obtíže mi zabraňují dělat to, co chci, **think** = aktuálně myslím na své tělesné obtíže, **awa.r** = právě v tomto okamžiku si všímám, kde v těle co cítím, **weak** = cítím se zesláblý, **tremb** = třesou se mi ruce / nohy, **stres** = jsem v napětí, **anxi** = mám z něčeho obavy, **activ** = právě se věnuji aktivitě, která mě naplňuje, **mood** = celkově se cítím takto: (vizualizace grafickými znaky s mírou zamračením – úsměvu), **hand** = cítím bolest v dlaních / chodidlech, **neck** = Cítím výboje na šíji, **help.r** = aktuálně potřebuji kontakt s jinými lidmi, **Coll** = aktuálně jsem s kolegou, **Home** = aktuálně jsem doma.



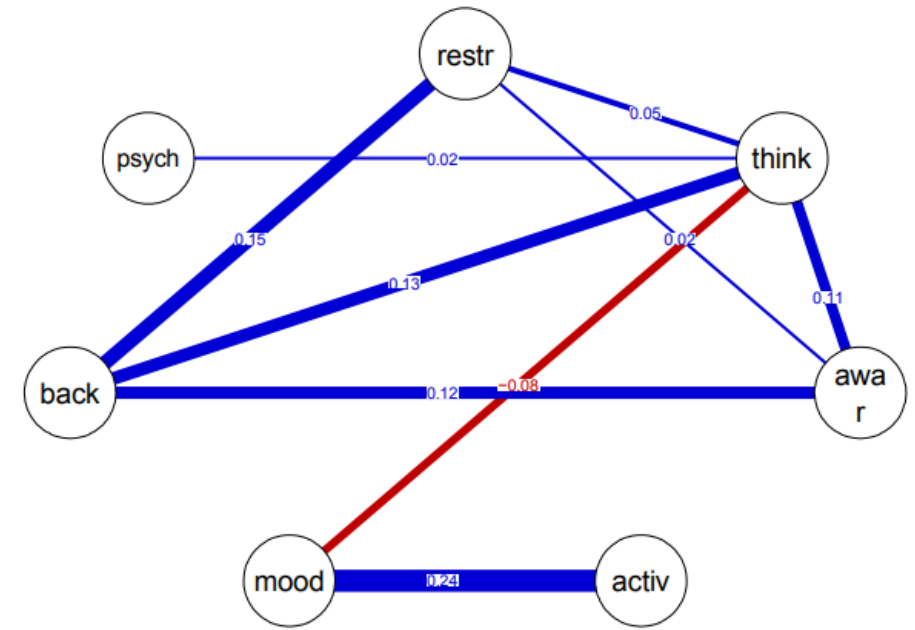
Pacient 2

Žena, 51 let. Přijata na skupinovou terapii do pobytového stacionáře Psychosomatické kliniky v Praze. V době výzkumu byla na čekací listině. Týden po ukončení sběru dat nastoupila do terapie. Mezi klíčové symptomy patří bolesti zad a svalů jako reakce na zátěžové situace. Před započítím sběru dat byl s pacientkou uskutečněn rozhovor pro aktualizaci symptomů a možných spouštěčů. Pacientka při rozhovoru měla silné bolesti zad, nicméně dokázala si nastavit sezení v křesle, abychom dokázali vše potřebné zvládnout.

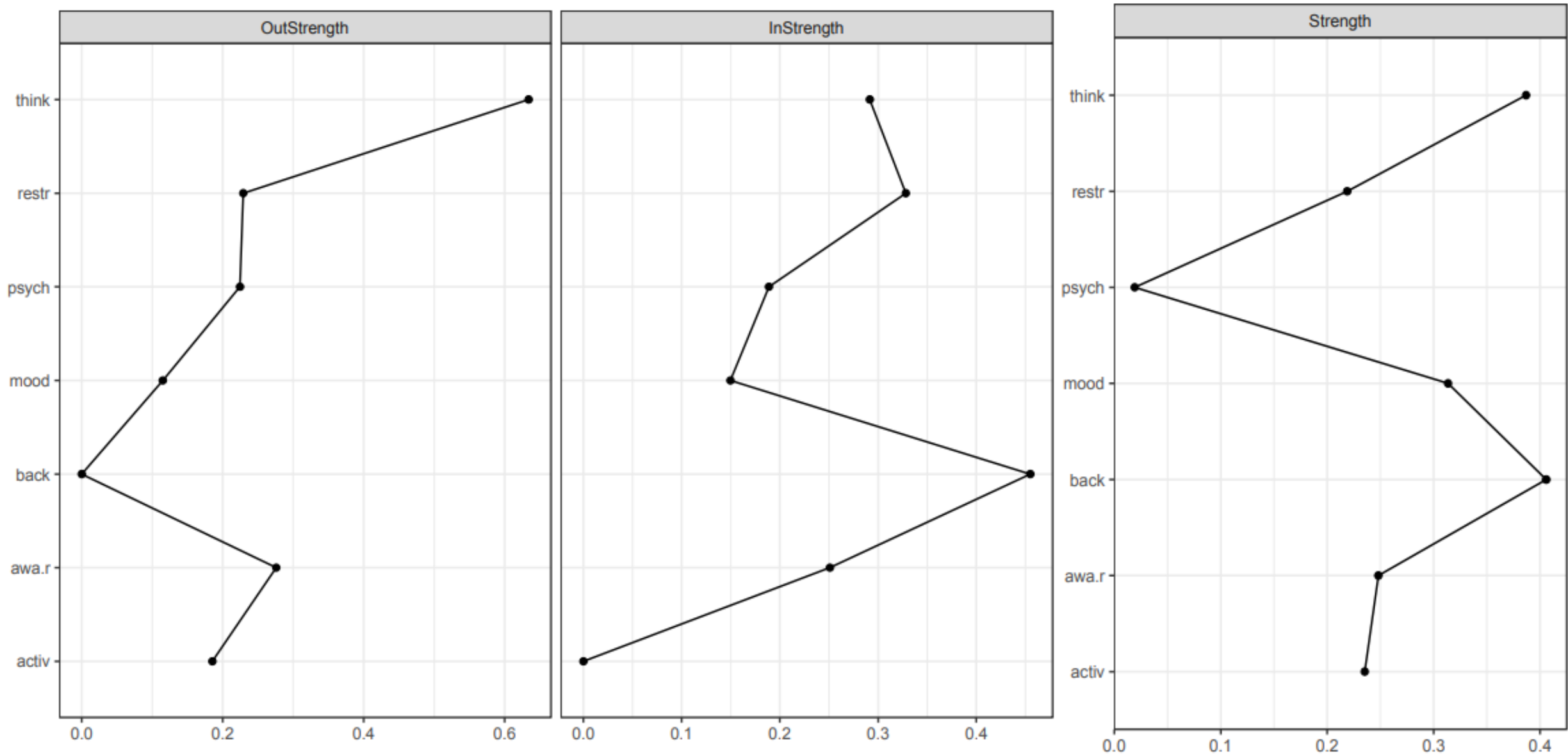
(a3) Prubezná síť detrend a fit



(b3) Soubezna síť detrend a fit



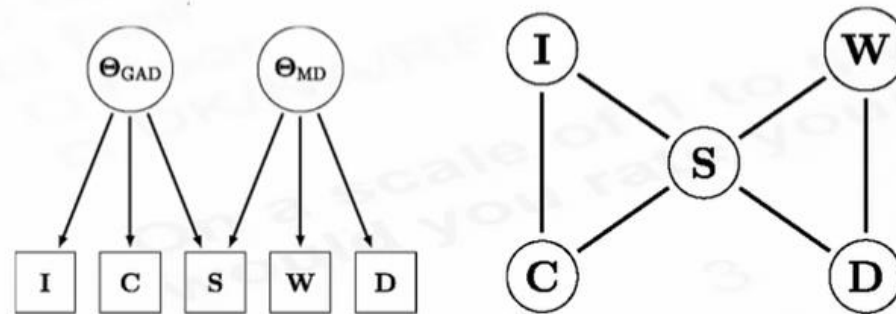
Poznámka. *crp* = mám pocit tlaku v oblasti hrudníku, *restr* = moje tělesné obtíže mi zabraňují dělat to, co chci, *think* = aktuálně myslím na své tělesné obtíže, *awa.r* = právě v tomto okamžiku si všímám, kde v těle co cítím, *stres* = jsem v napětí, *anxi* = mám z něčeho obavy, *activ* = právě se věnuji aktivitě, která mě naplňuje, *mood* = celkově se cítím takto: (vizualizace grafickými znaky s mírou zamračení – úsměvu), *trape* = bolí mě trapézový sval, *back* = bolí mě záda v oblasti beder, *help.r* = aktuálně potřebuji kontakt s jinými lidmi, *psych* = cítím se psychicky vyčerpaná, *muscl* = bolí mě svaly, *nause* = je mi nevolno, *avoid* = vyhýbám se fyzické aktivitě, protože aktuálně šetřím síly, *fatig* = jsem unavená, *Home* = aktuálně jsem doma, *Child* = aktuálně jsem s vnučkou/dcerou.



Sítě a latentní proměnné

- data v psychologii – model musí umět nechat všechno korelovat – **proto taky faktorový model funguje tak dobře**
- latent variable model je ekvivalentní network modelu, kde každý klastr je definovaný latentní proměnnou

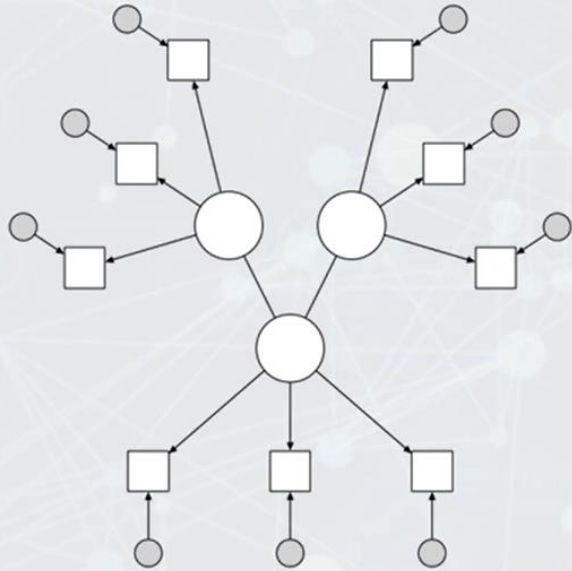
Clusters in network = latent variables



Golino, H. F., & Epskamp, S. (2017). Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research. *PLoS one*, 12(6): e0174035.

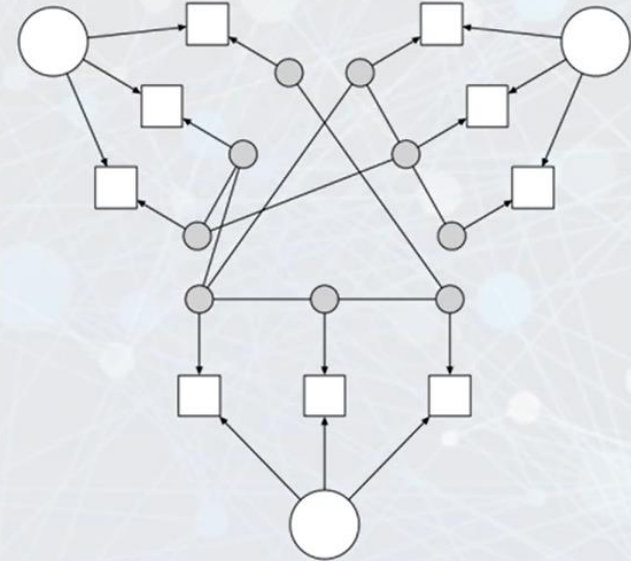
Latent and residual network models

Latent network modeling



$$\Sigma = \Lambda (I - B)^{-1} \Sigma_{\zeta} (I - B)^{-1T} \Lambda^T + \Sigma_{\varepsilon}$$
$$\Sigma_{\zeta} = \Delta_{\zeta} (I - \Omega_{\zeta})^{-1} \Delta_{\zeta}$$

Residual network modeling



$$\Sigma = \Lambda (I - B)^{-1} \Sigma_{\zeta} (I - B)^{-1T} \Lambda^T + \Sigma_{\varepsilon}$$
$$\Sigma_{\varepsilon} = \Delta_{\varepsilon} (I - \Omega_{\varepsilon})^{-1} \Delta_{\varepsilon}$$

Take-home message

- **Network theory** (a.k.a. the network perspective/mutualism) views psychological behavior as a complex interplay of psychological and other components
- **Network psychometrics** has been developed in response, allowing exploratory and confirmatory estimation of network models from data
- **Network models** themselves have routinely been used to study social interactions/traffic/information flow.
 - **Centrality investigates which nodes are important in a network**

**Thank you for your attention and good luck
with the reading!**