

# Time to spread the nets?

Introduction to Network Analysis, L1

Edita Chvojková

[edita.chvojkova@mail.muni.cz](mailto:edita.chvojkova@mail.muni.cz)

**I will tell you a story...**









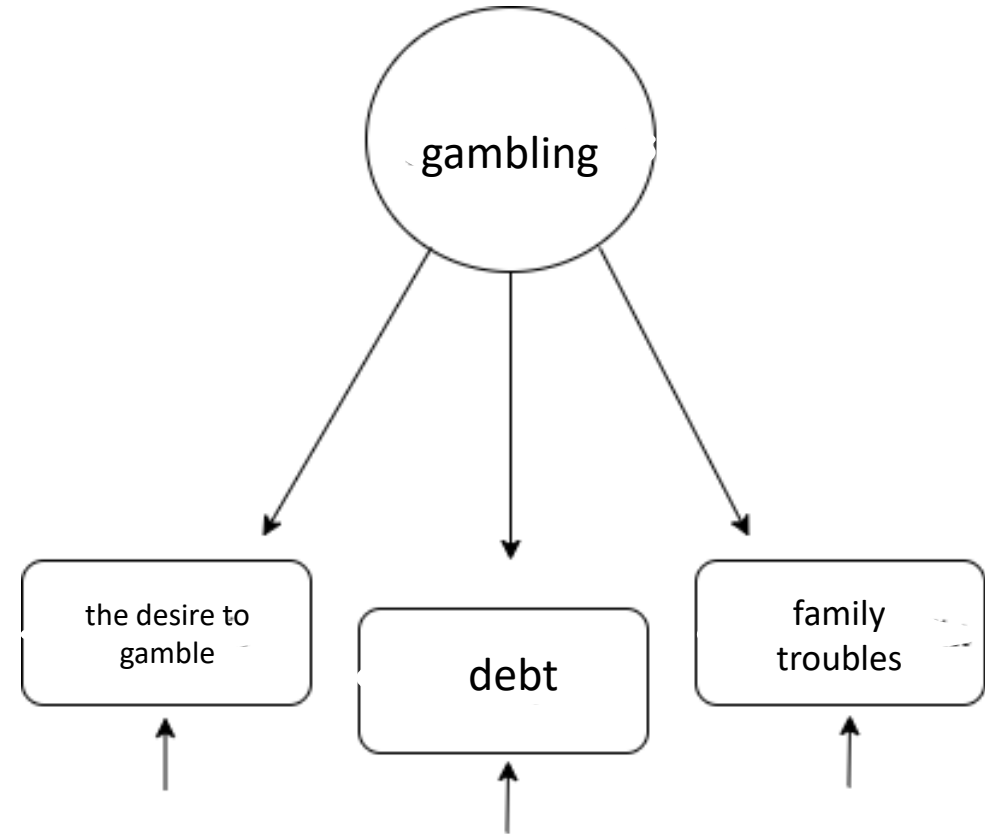










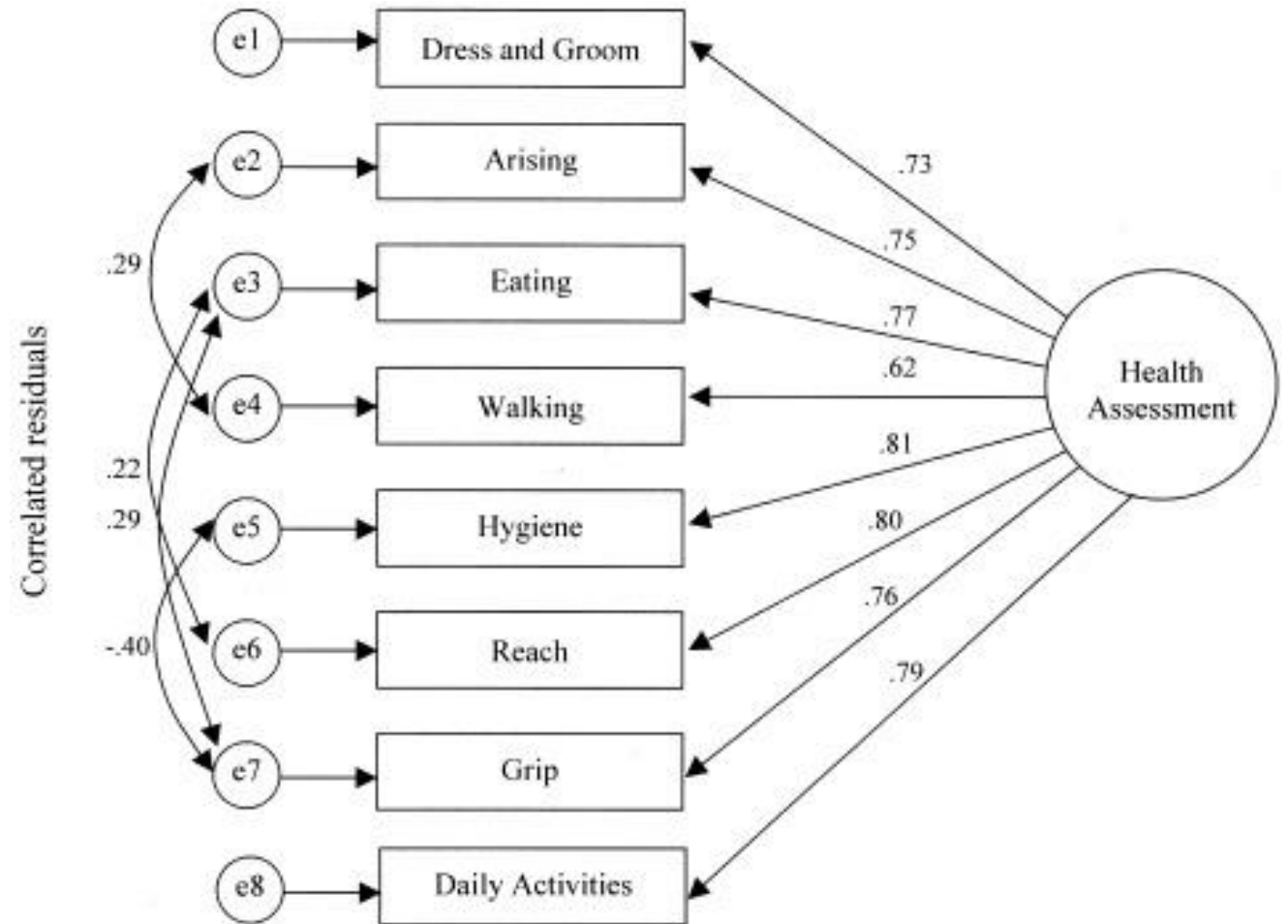


- the scale was published and everyone was happy
- What do you think about the CFM?

# The causal interpretation of CFM

assumption:

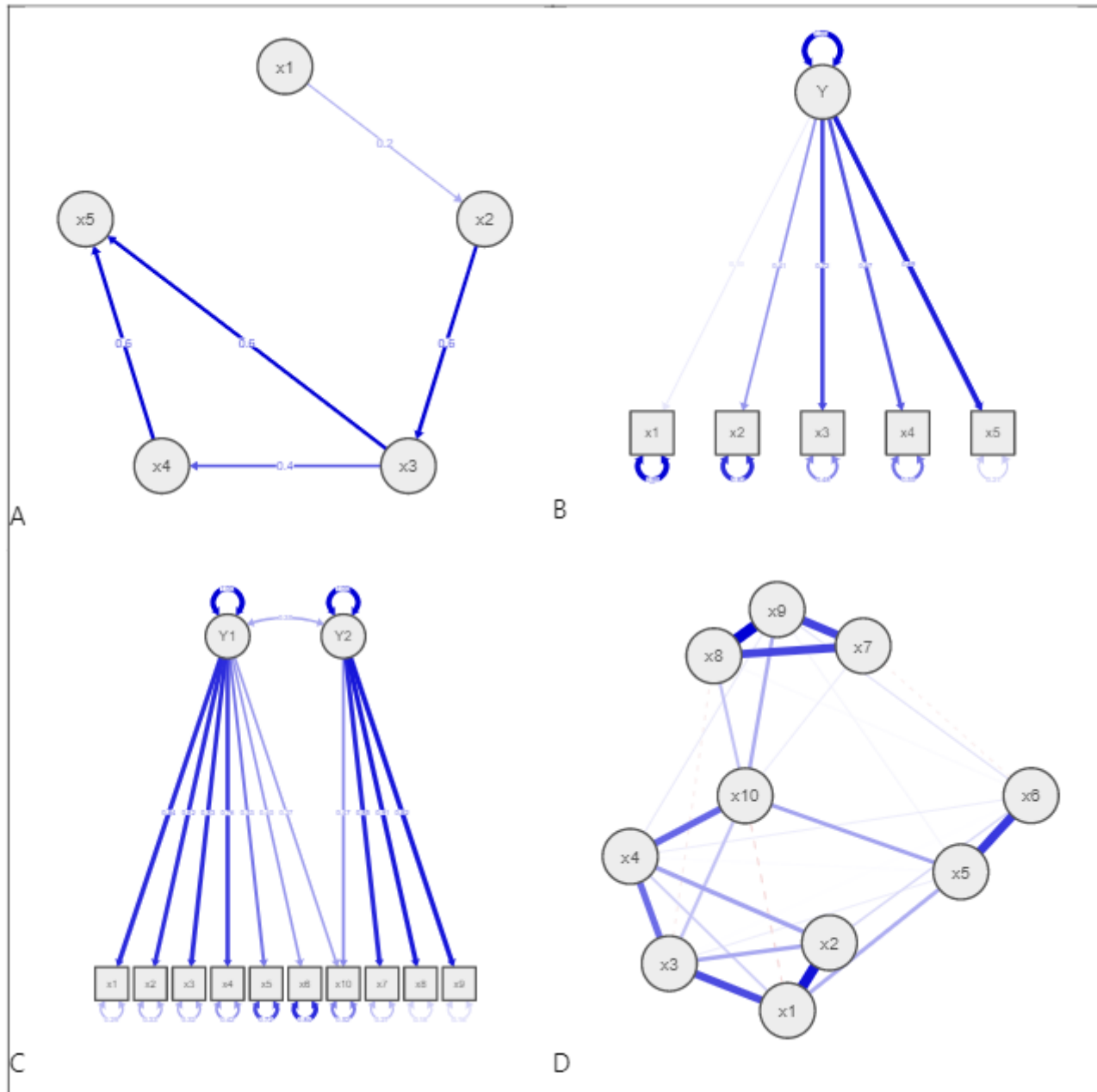
- local independence





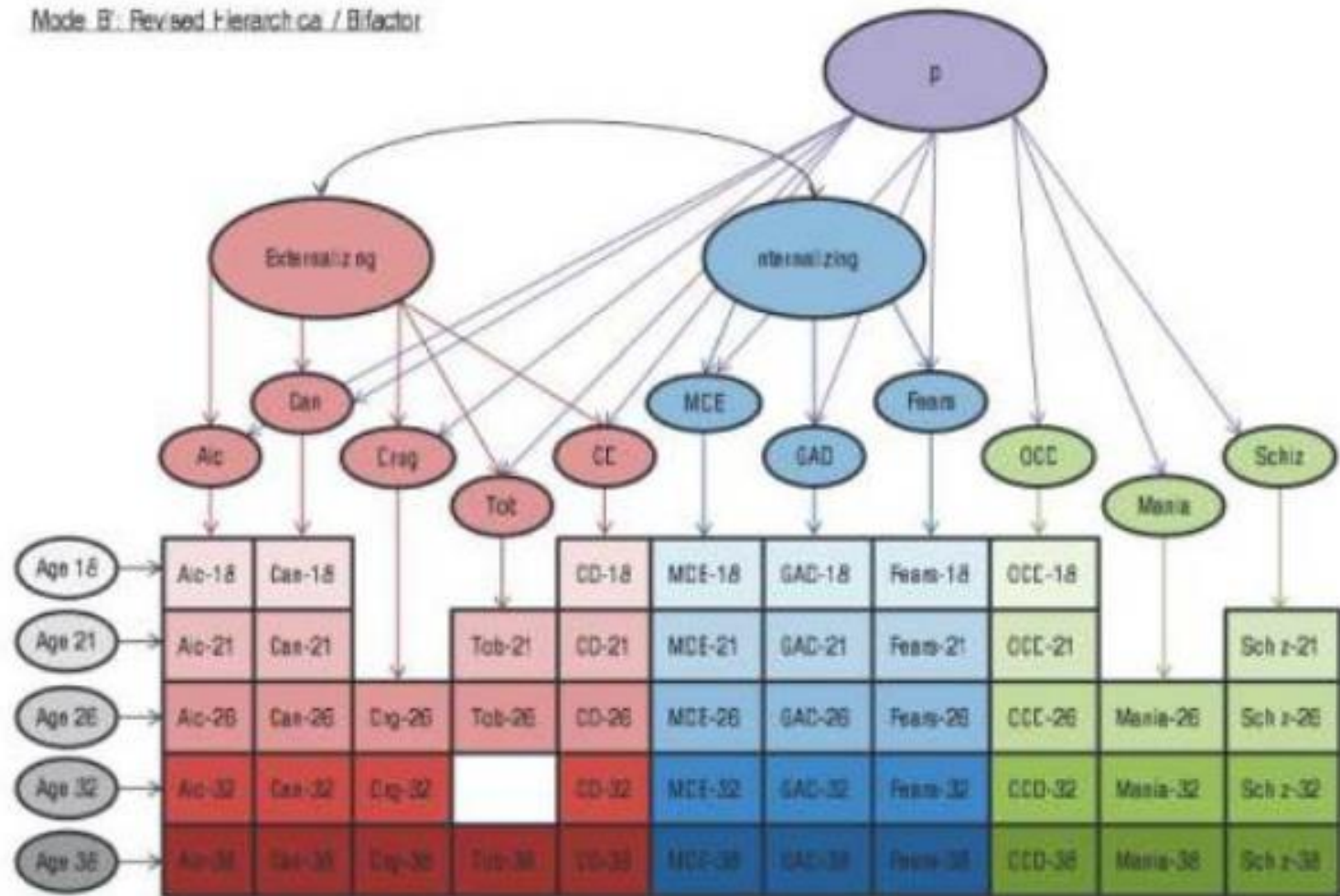
# Consequences of Network Theory (by Sacha, 2020)

- 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



# the p-factor of psychopathology

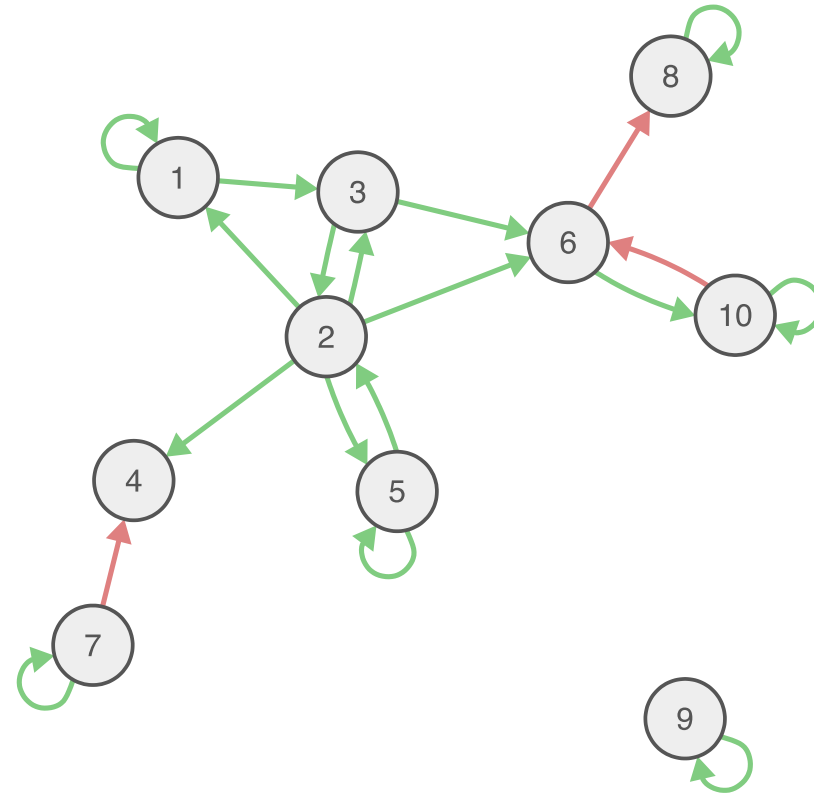
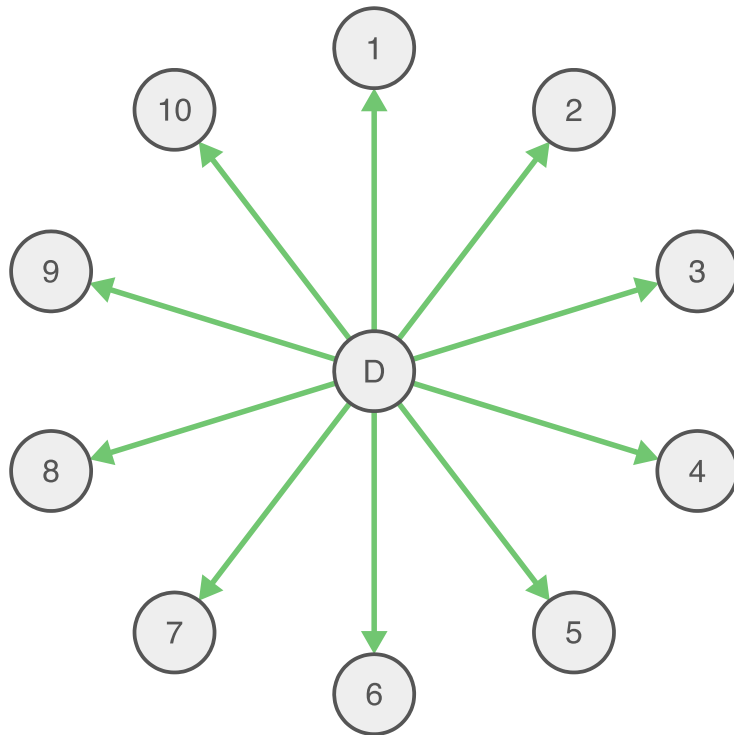
Model B: Revised Hierarchical / Bifactor



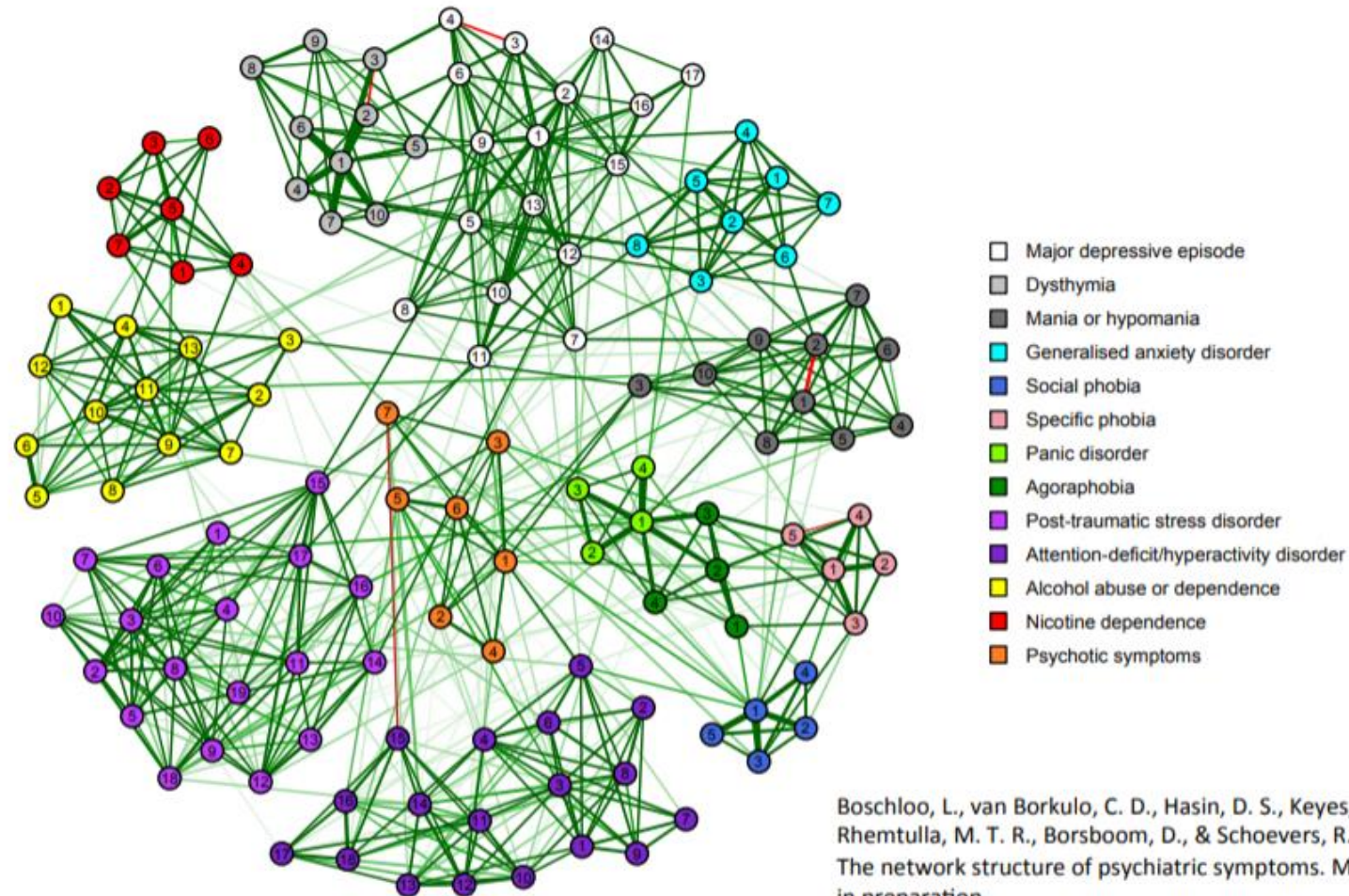


# Network Theory

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



# Ising model for the entire DSM-IV



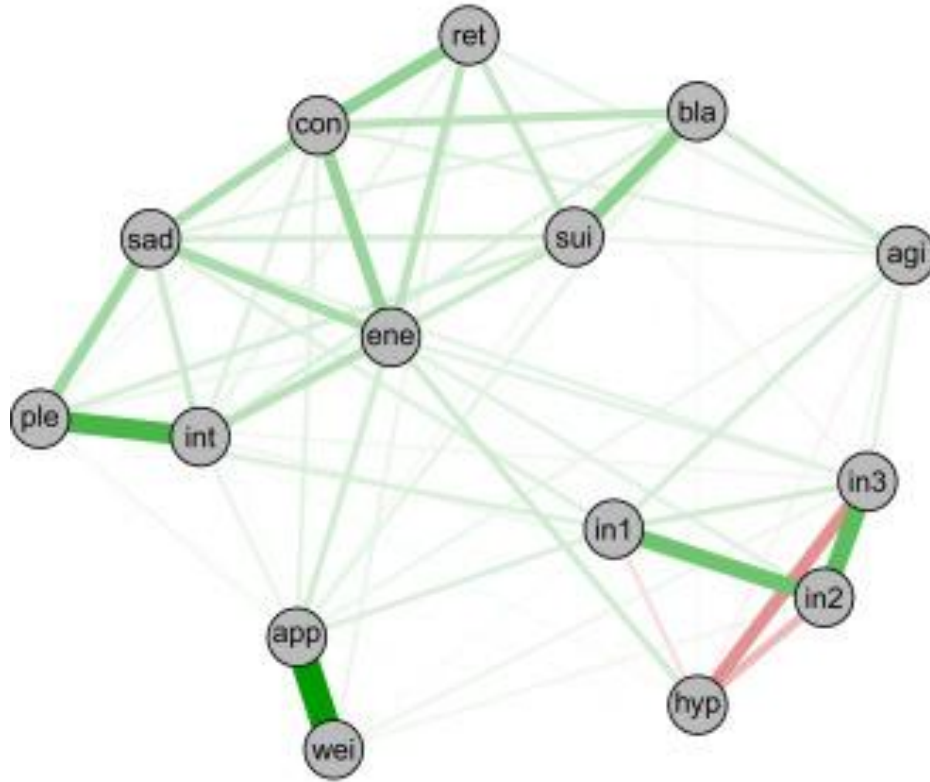
## Depression DSM-5 Diagnostic Criteria

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.

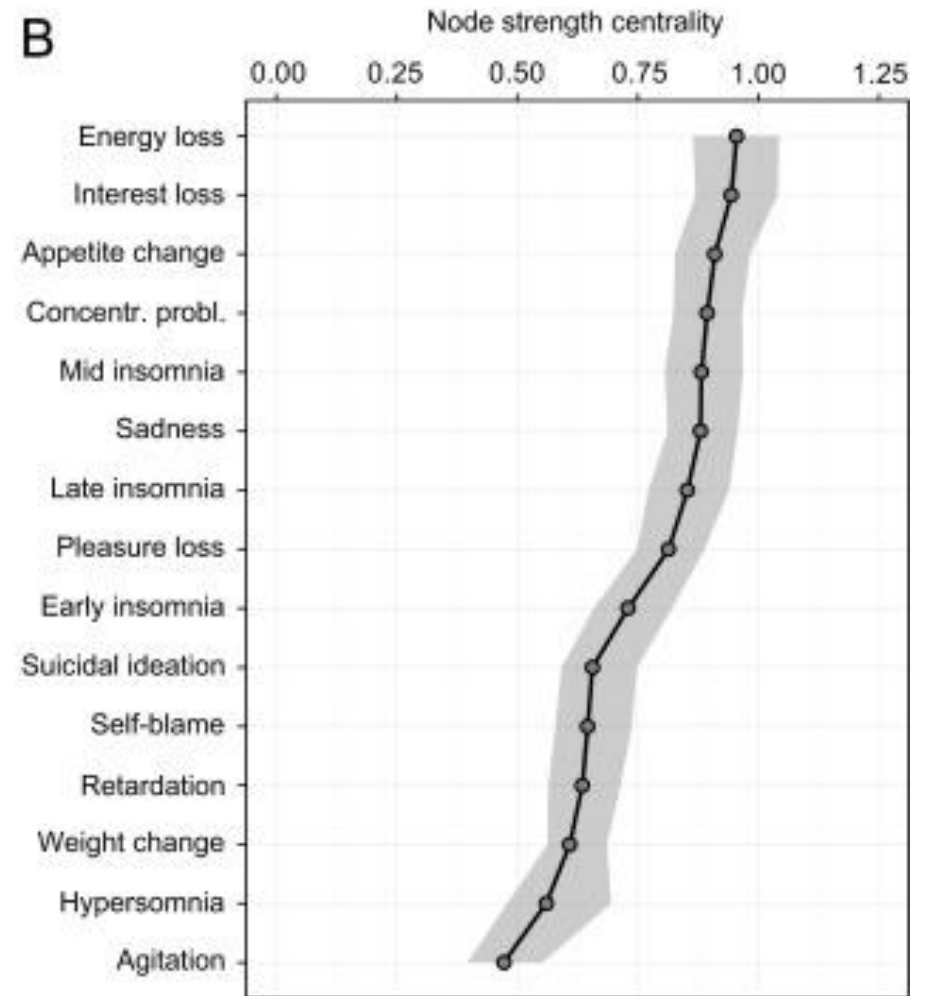
1. Depressed mood most of the day, nearly every day.
2. Markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day.
3. Significant weight loss when not dieting or weight gain, or decrease or increase in appetite nearly every day.
4. A slowing down of 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

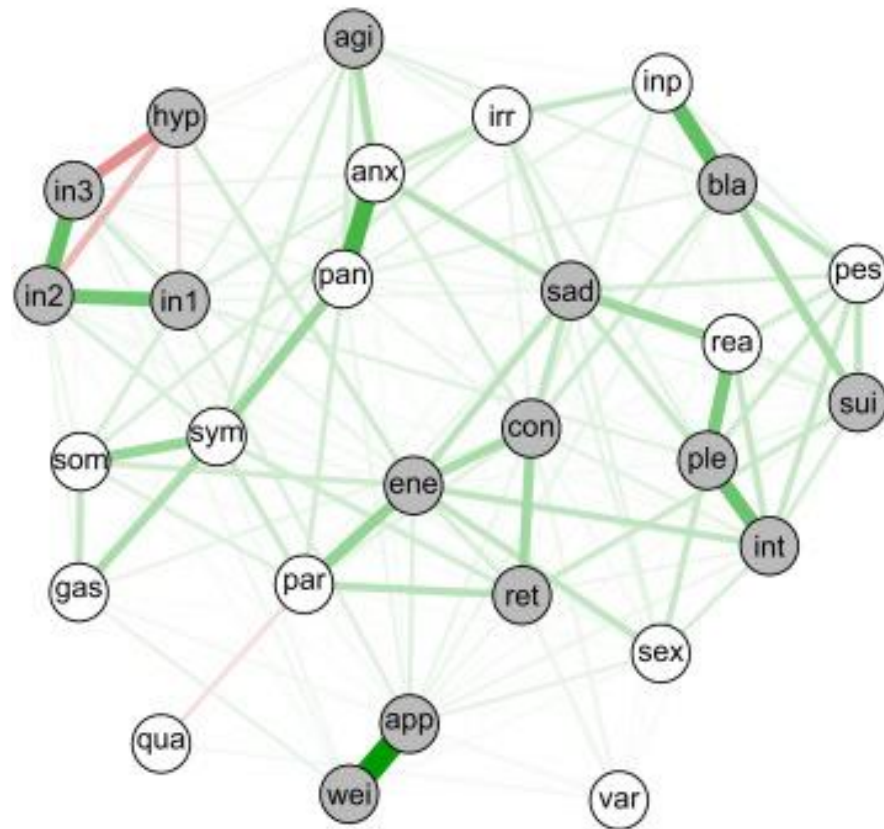


B



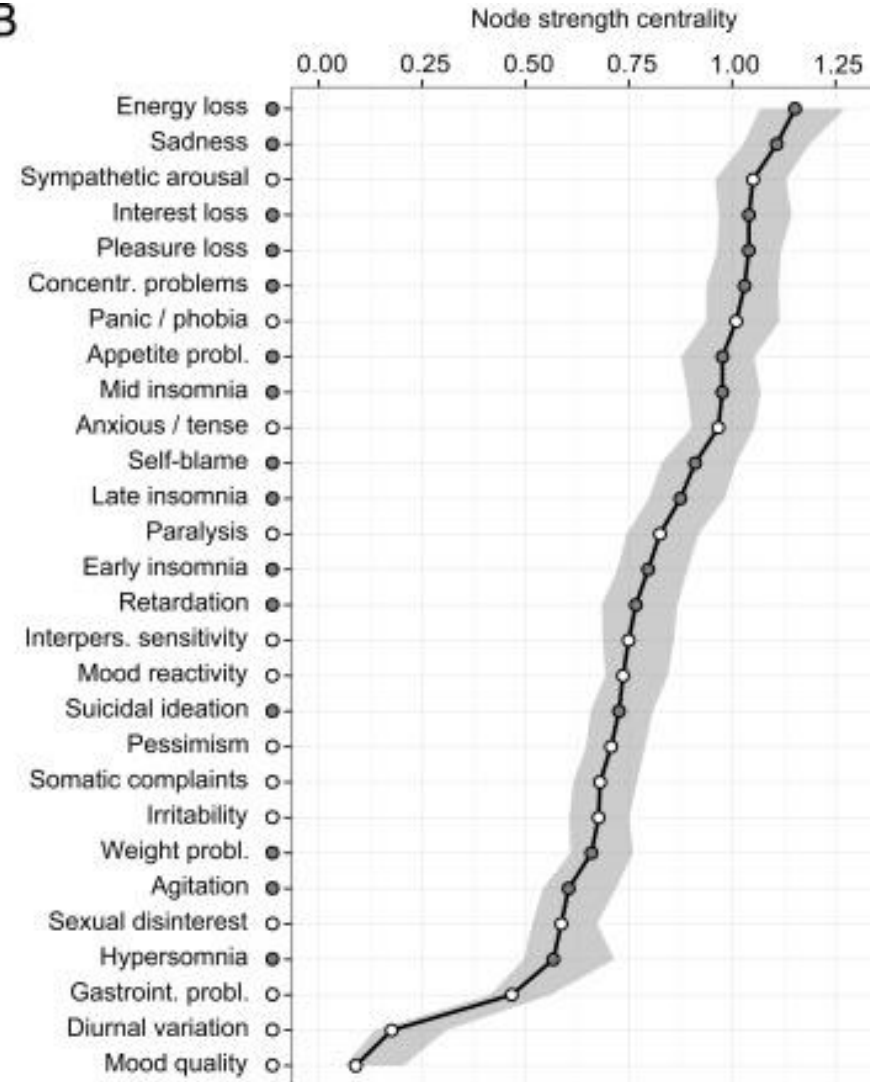
# Network of depression symptoms - extended

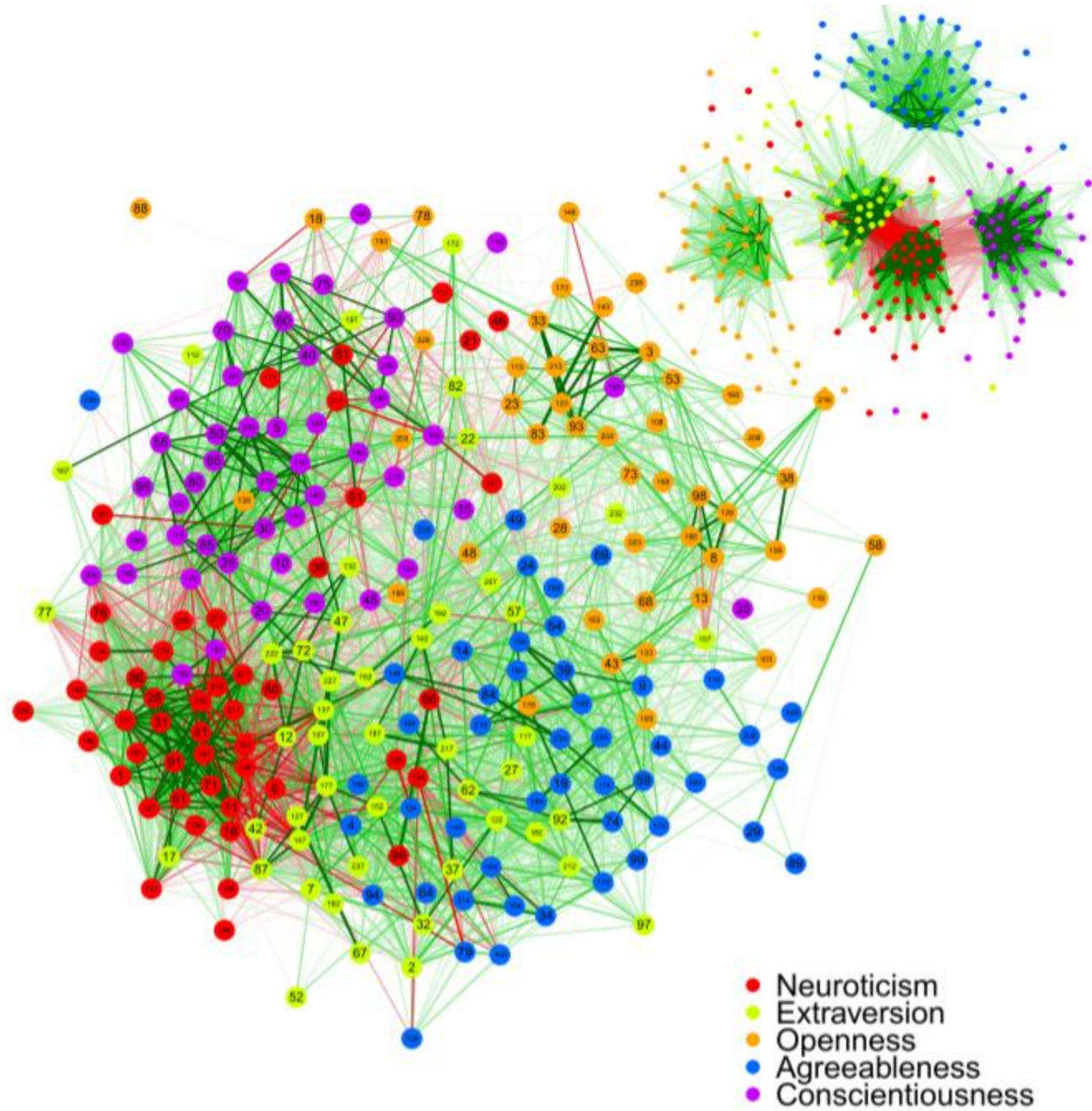
A



- DSM criterion symptom
- Non-DSM symptom

B



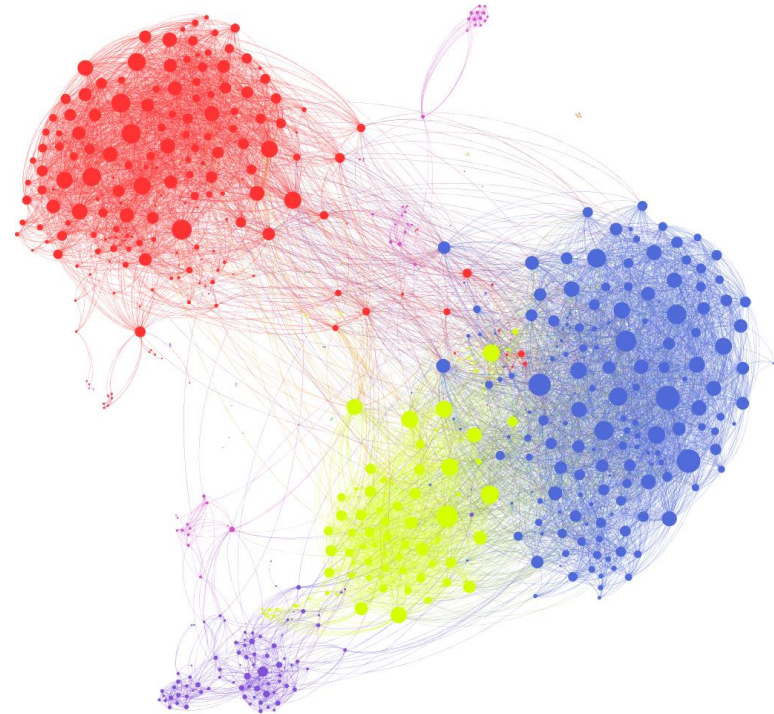


# Network Theory vs. Network Psychometrics

- 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

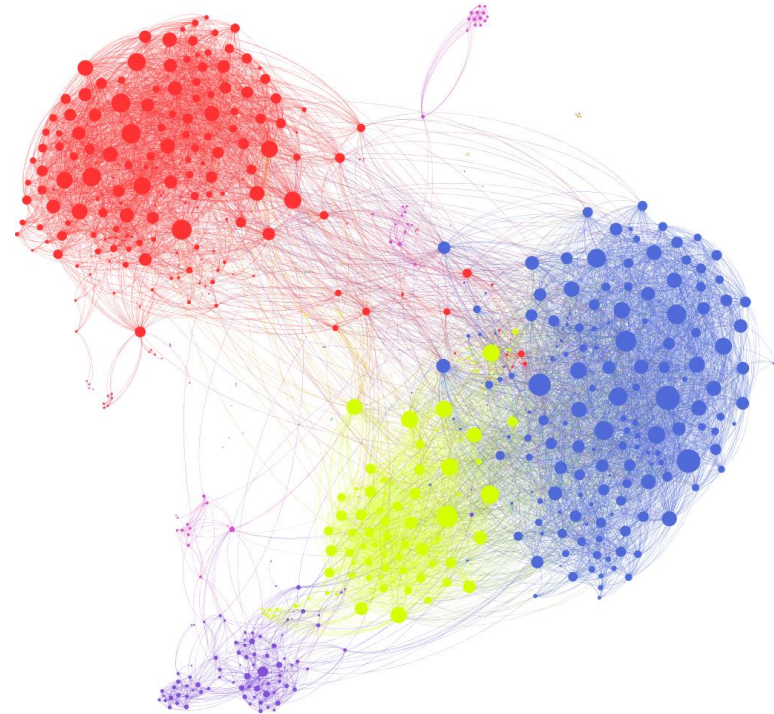




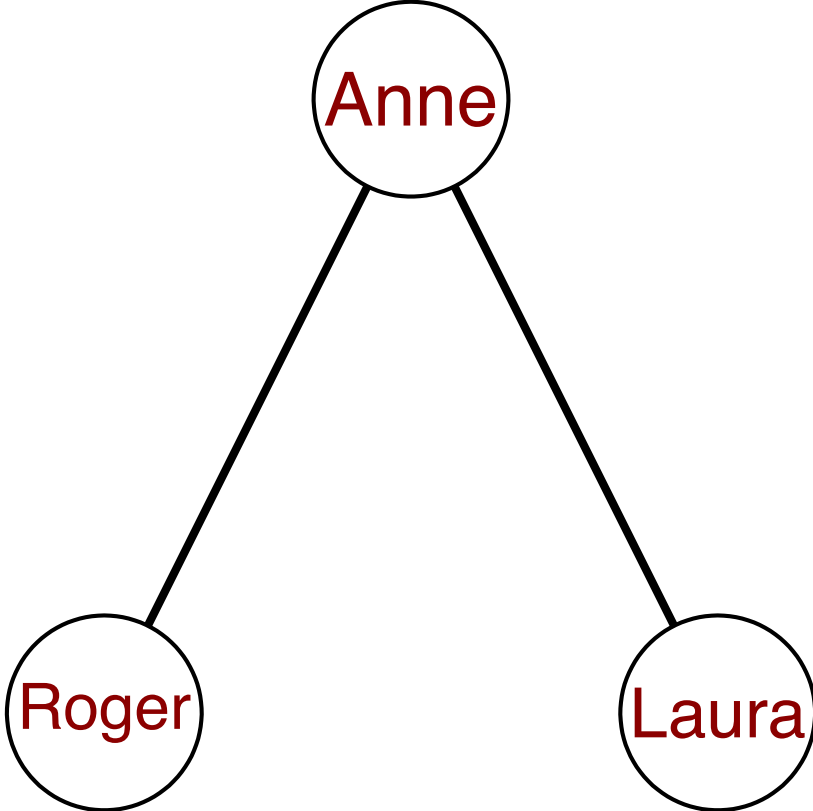
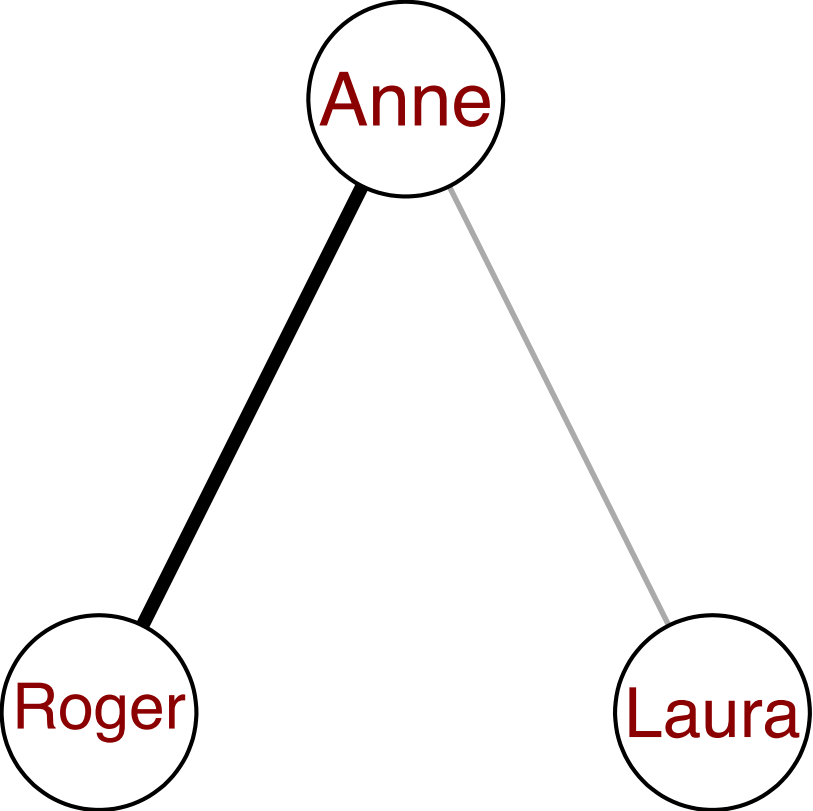
# What are Networks

An edge represents some connection between two nodes

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



Edges can be weighted or unweighted

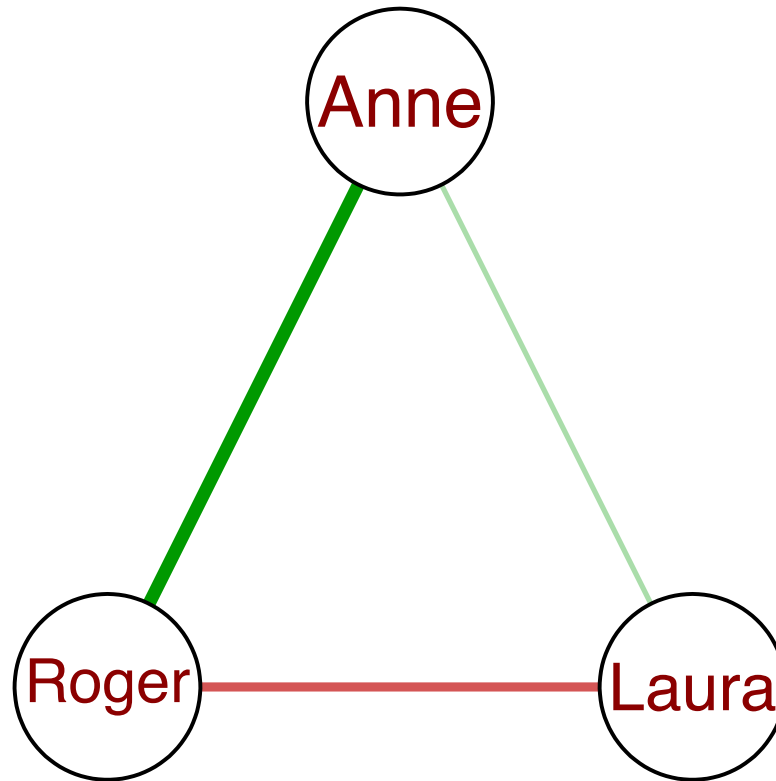


# Weighted networks

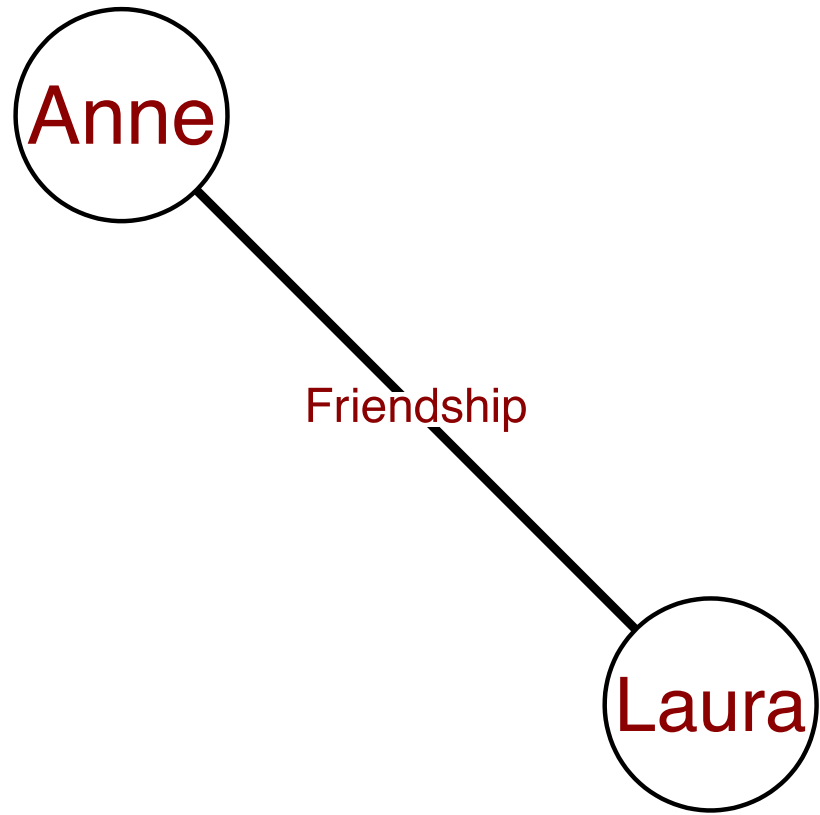
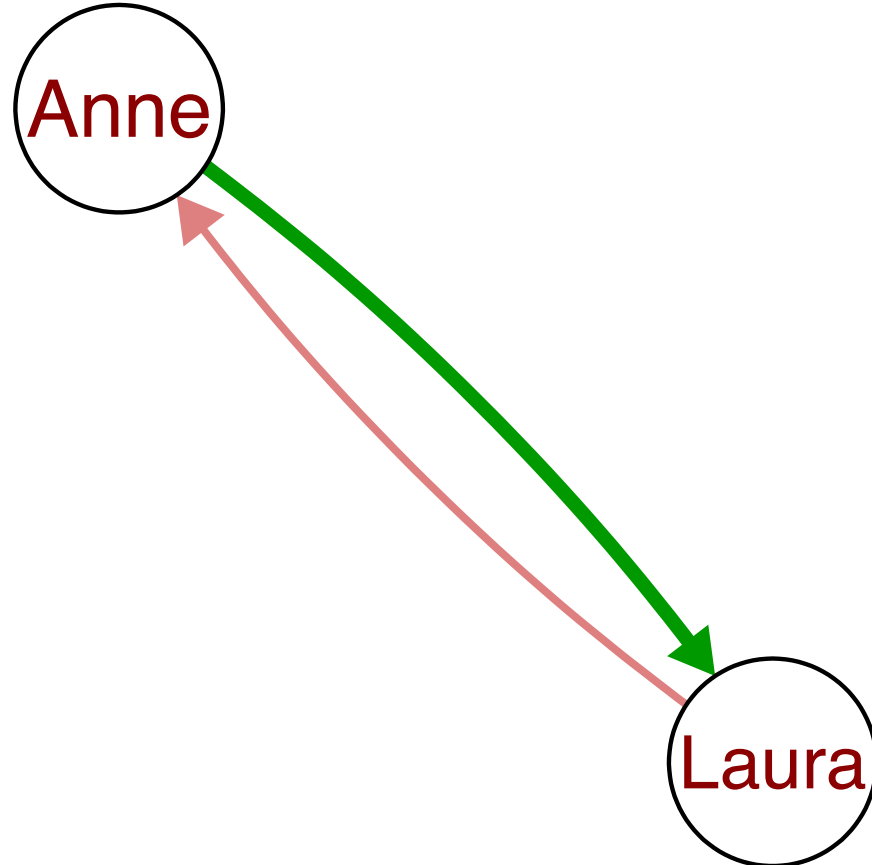
- Weights can be positive or negative, and indicate the *strength* of an edge, with zero indicating no strength (identical to the absence of an edge)
  - Nodes that are connected by a strong edge can be seen as close by or easily reachable from one to the other
- Sometimes an edge has a *length* rather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



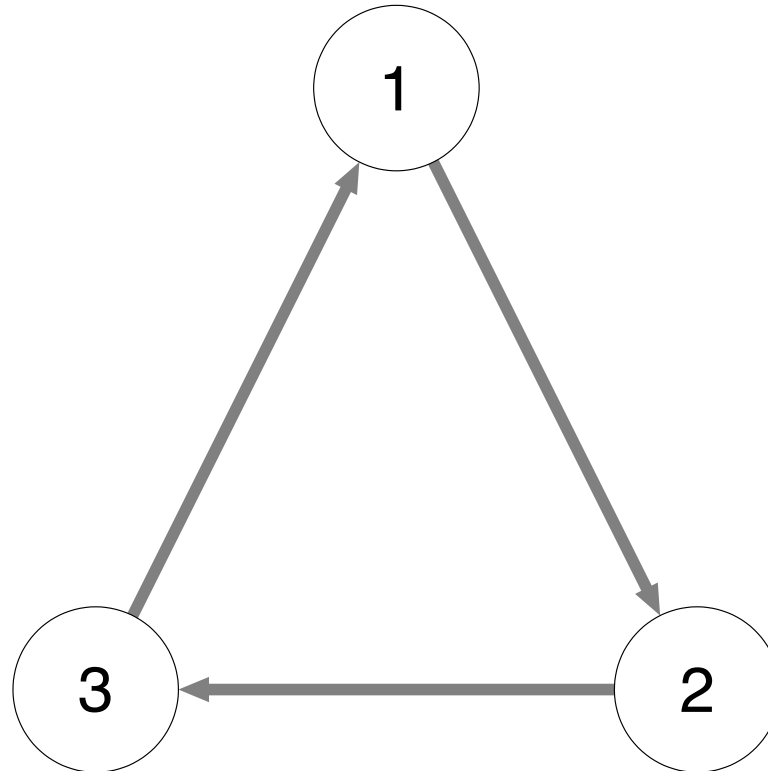
# Mathematical notation of graphs

A graph  $G$  is considered an ordered pair of a set  $N$  of nodes and a set  $E$  edges:

$$G = \{N, E\}$$

$$N = \{1, 2, 3\}$$

$$E = \{(1, 2), (2, 3), (3, 1)\}$$



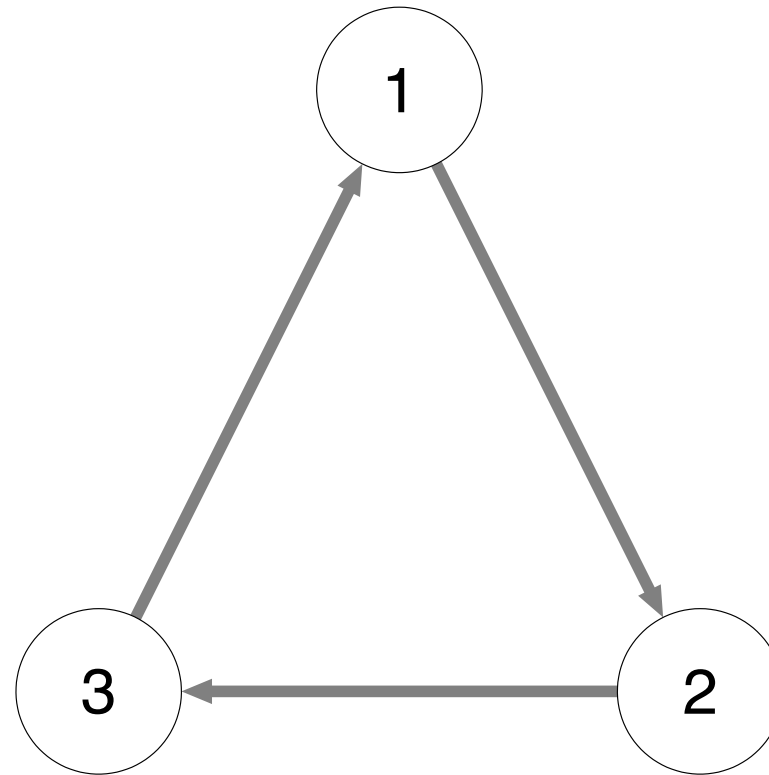
# Adjacency matrix

- An adjacency matrix is a square  $N \times N$  matrix in which each element is 0 or 1;  $N$  is the number of nodes.
- If there is a 1 in row  $i$  and column  $j$  it means there is an edge from node  $i$  to node  $j$
- A 0 denotes that there is no edge

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix}$$

# Adjacency matrix

$$\mathbf{A} = \begin{matrix} & \begin{matrix} \text{To} \\ 1 & 2 & 3 \end{matrix} \\ \begin{matrix} \text{From} \\ 1 \\ 2 \\ 3 \end{matrix} & \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \end{matrix}$$

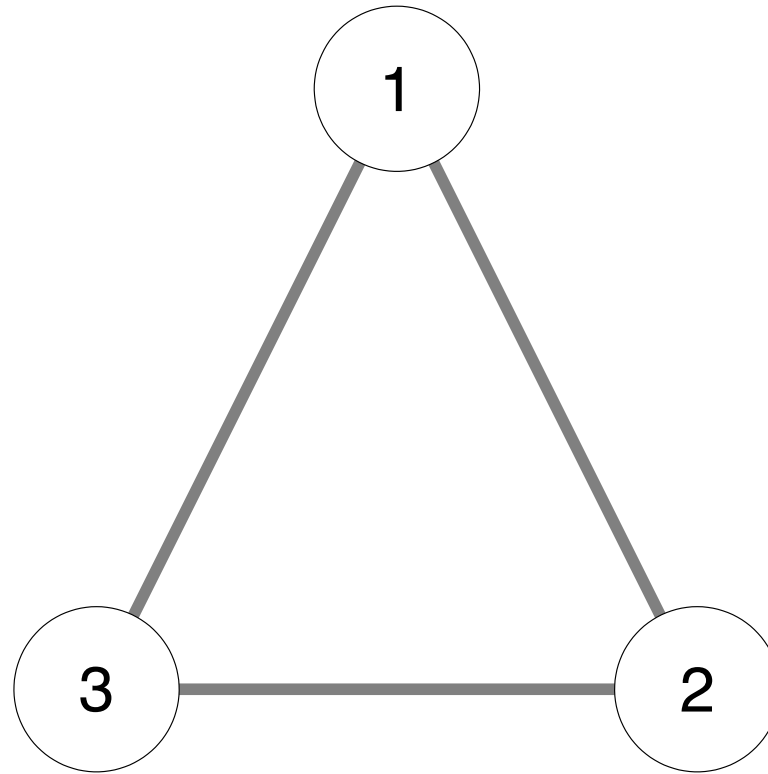




# Adjacency matrix

Undirected networks are encoded with a symmetrical adjacency matrix

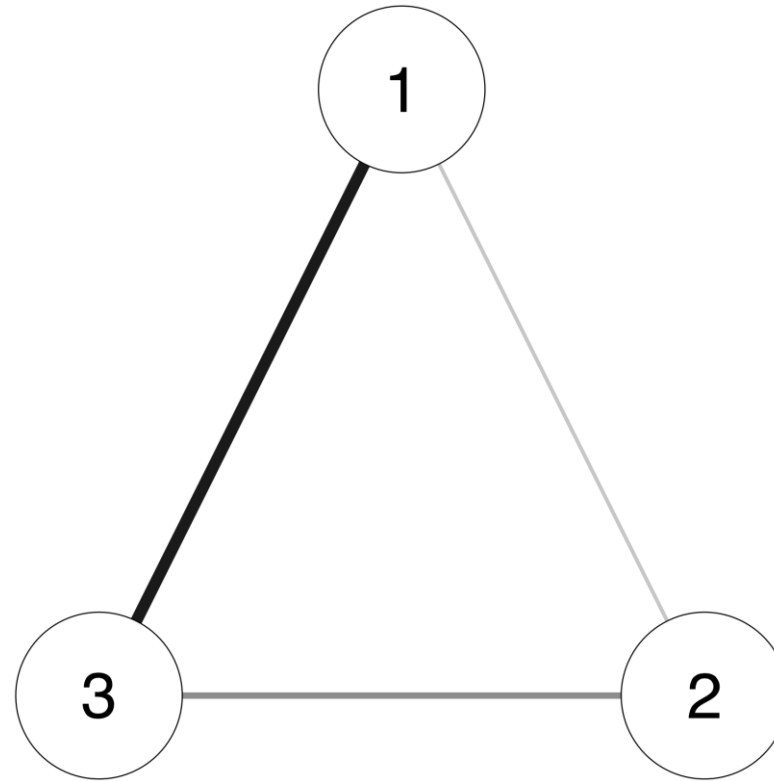
$$\mathbf{A} = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$



# Weights matrix

Weighted networks are encoded with a *weights matrix* (adjacency with other values than 0 and 1)

$$\mathbf{A} = \begin{matrix} & 0 & 1 & 3 \\ \begin{matrix} 0 & 1 & 3 \\ 1 & 0 & 2 \\ 3 & 2 & 0 \end{matrix} \end{matrix}$$



# 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

## 1. Node strength / degree centrality

1. Most common & intuitive
2. Sum of all absolute edge weights of edges connected to a given node

## 2. Closeness

## 3. Betweenness

## 4. Expected influence

<https://psych-networks.com/expected-influence-new-centrality-metric-robinough-et-al-2016/>

## 5. Predictability

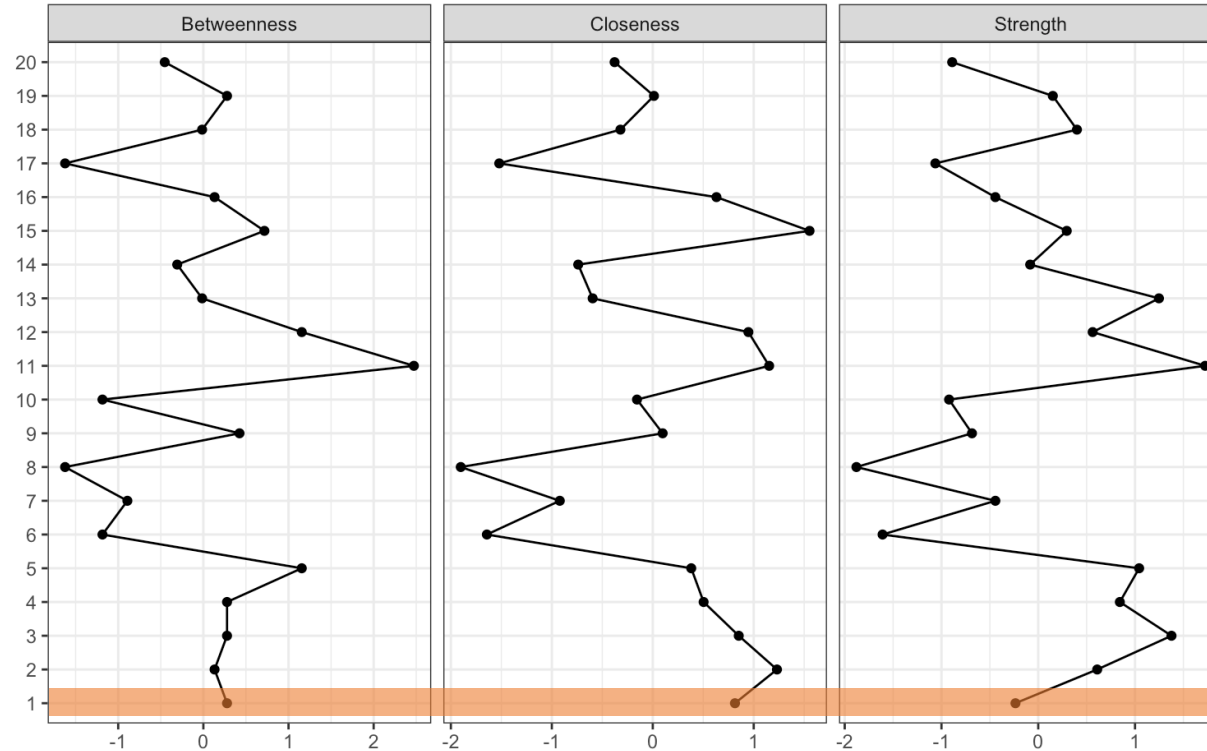
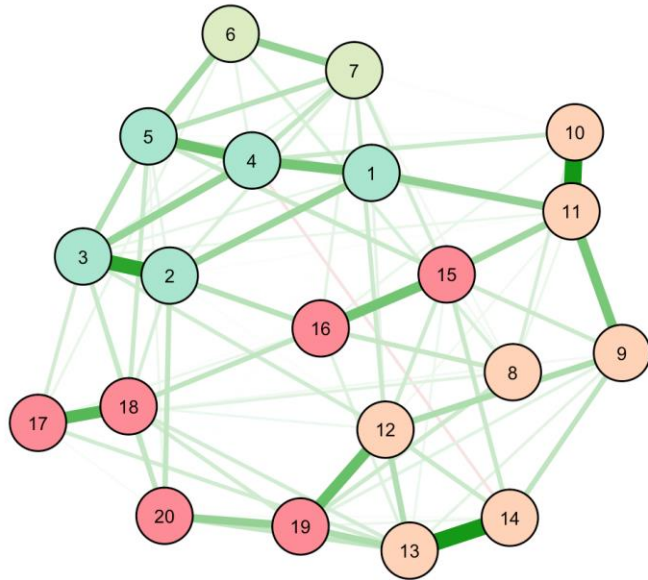
# Shortest paths

- **Closeness & Betweenness** rely on the concept of *shortest paths*
  - A shortest path is the most efficient way to get from one node to another (e.g., google maps)
- **Closeness** is inversely related to the sum of all shortest path lengths from one node to all other nodes
- **Betweenness** is related to how *often* a node is in shortest paths between other nodes

# 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. More in Module 2!**



# 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.
  - **Small-worldness** investigates if a network is clustered, but also has a short average shortest path between all nodes
  - **Centrality** investigates which nodes are important in a network

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