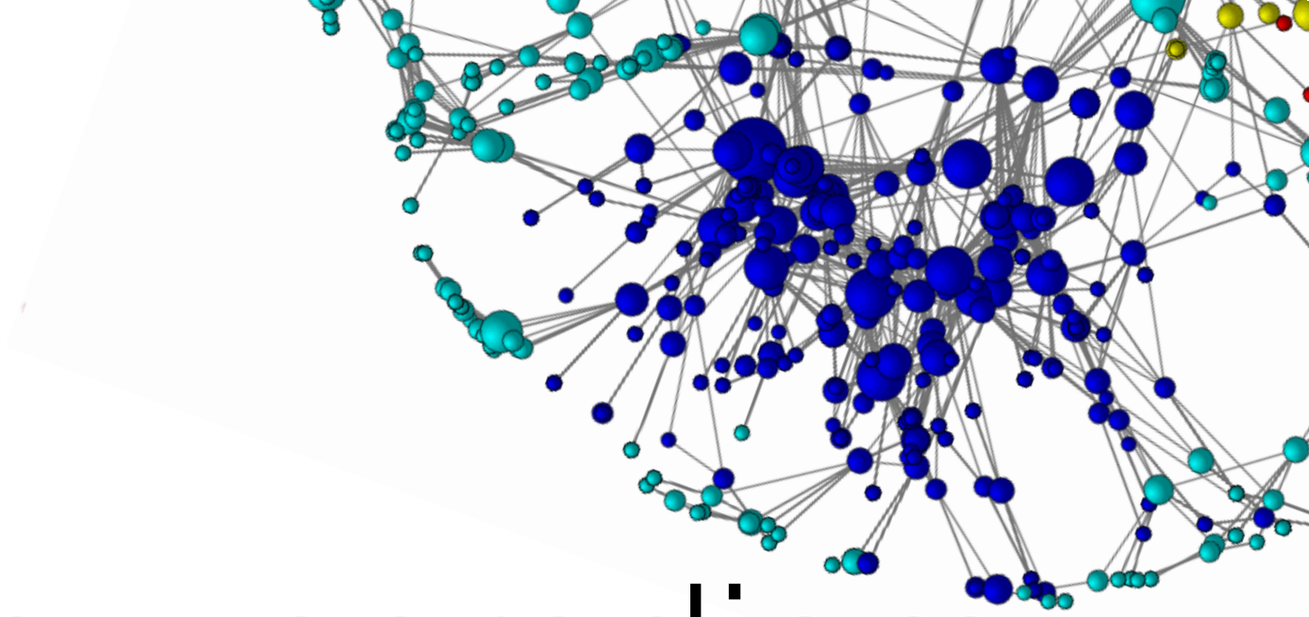


Time for a new paradigm

a network perspective on psychopathology

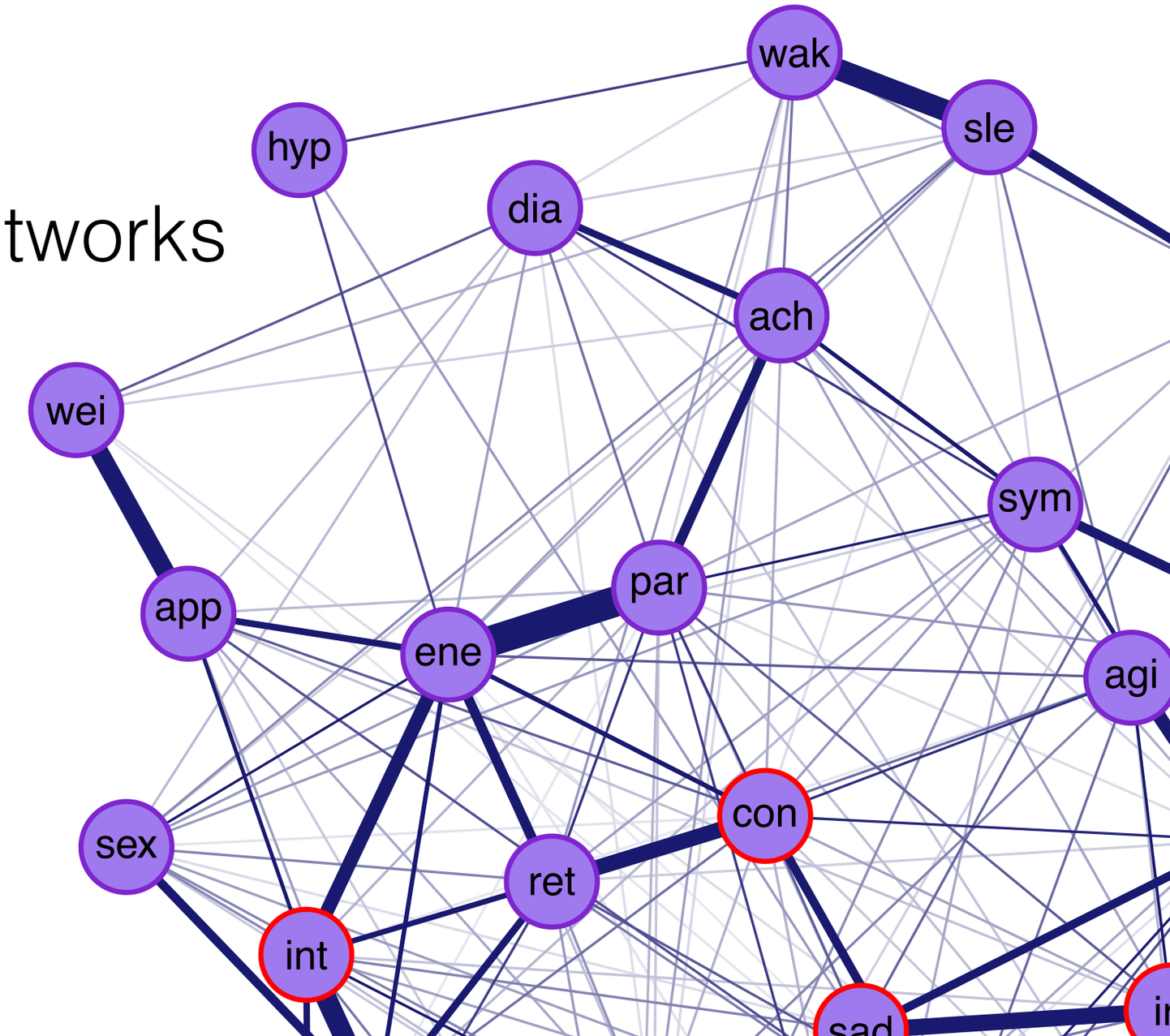
Claudia van Borkulo
UMCG-UvA

umcg

Universiteit van Amsterdam

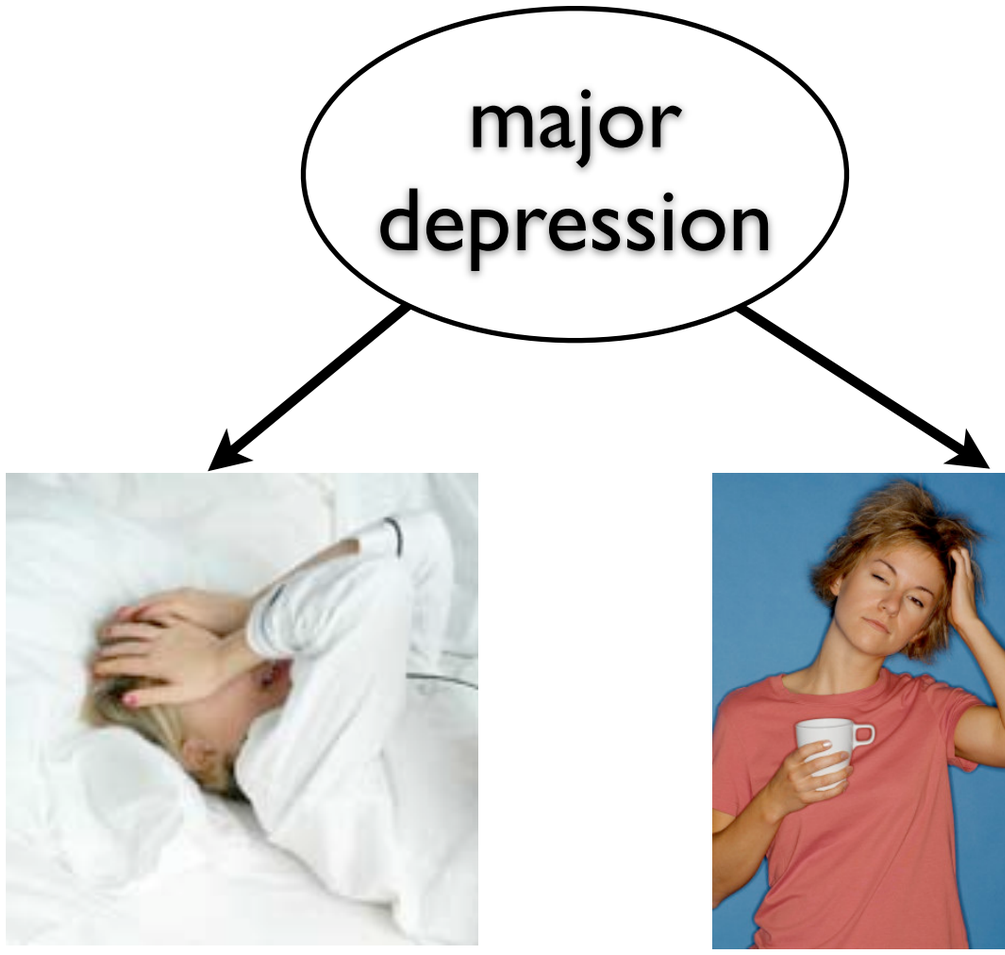
Overview

- About networks
- Psychopathology networks
  - cross-sectional
  - longitudinal
- Clinical application
- Discussion



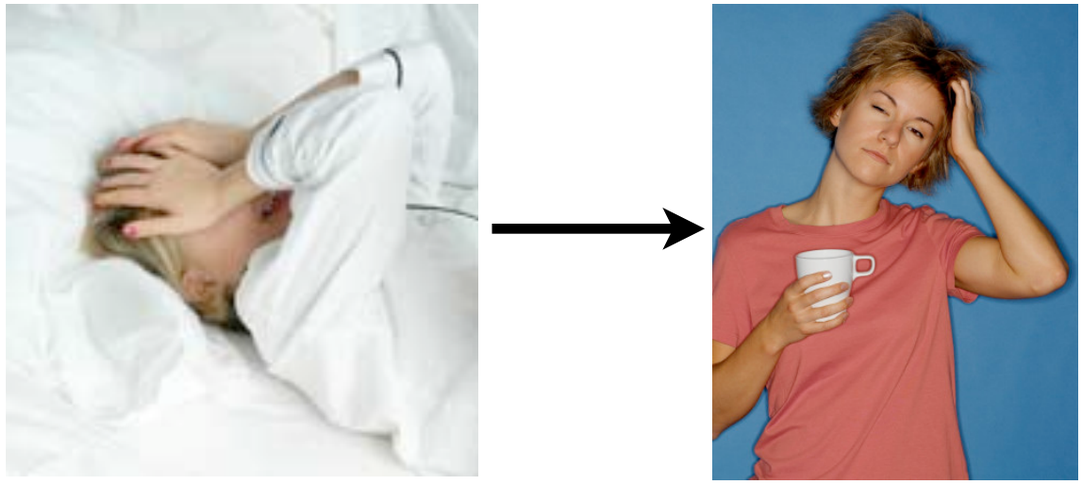
About networks

Direct relations



I don’t sleep and I’m tired

Direct relations



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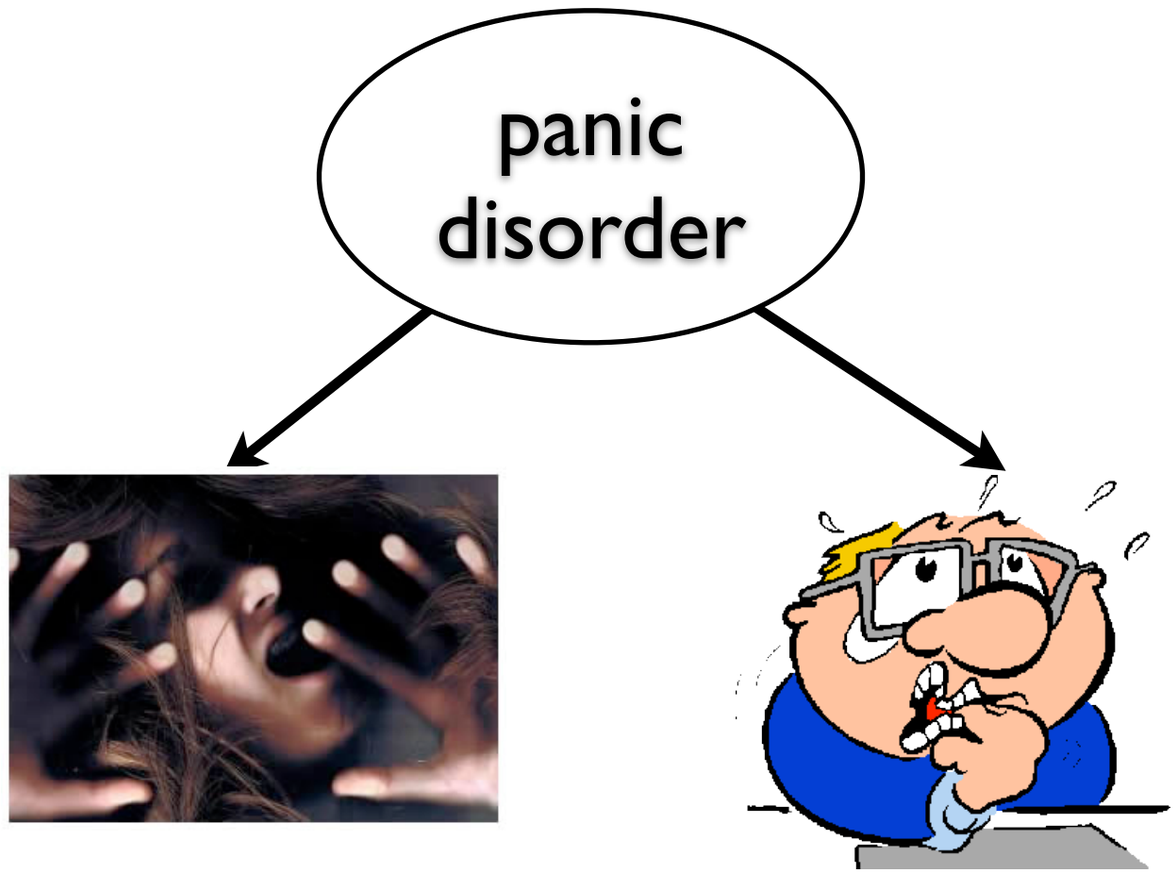
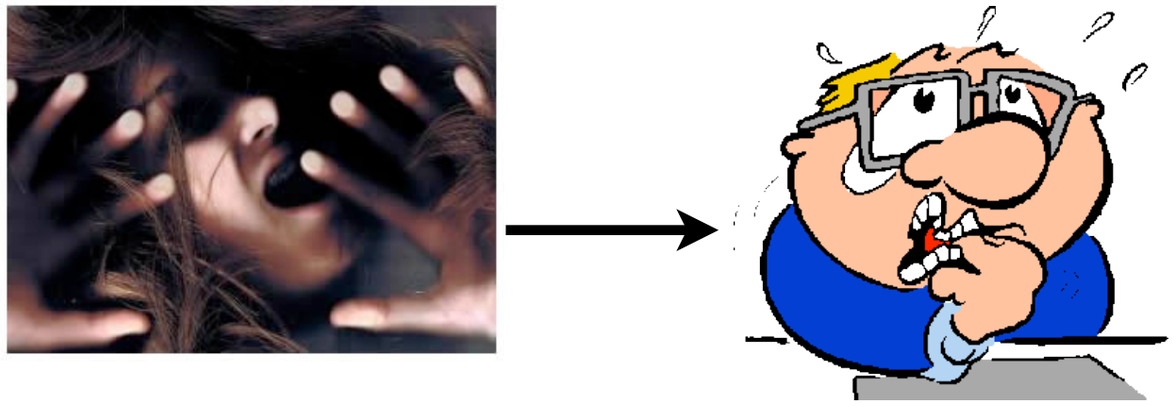


I had a panic attack and I'm afraid I'll have another one

Direct relations



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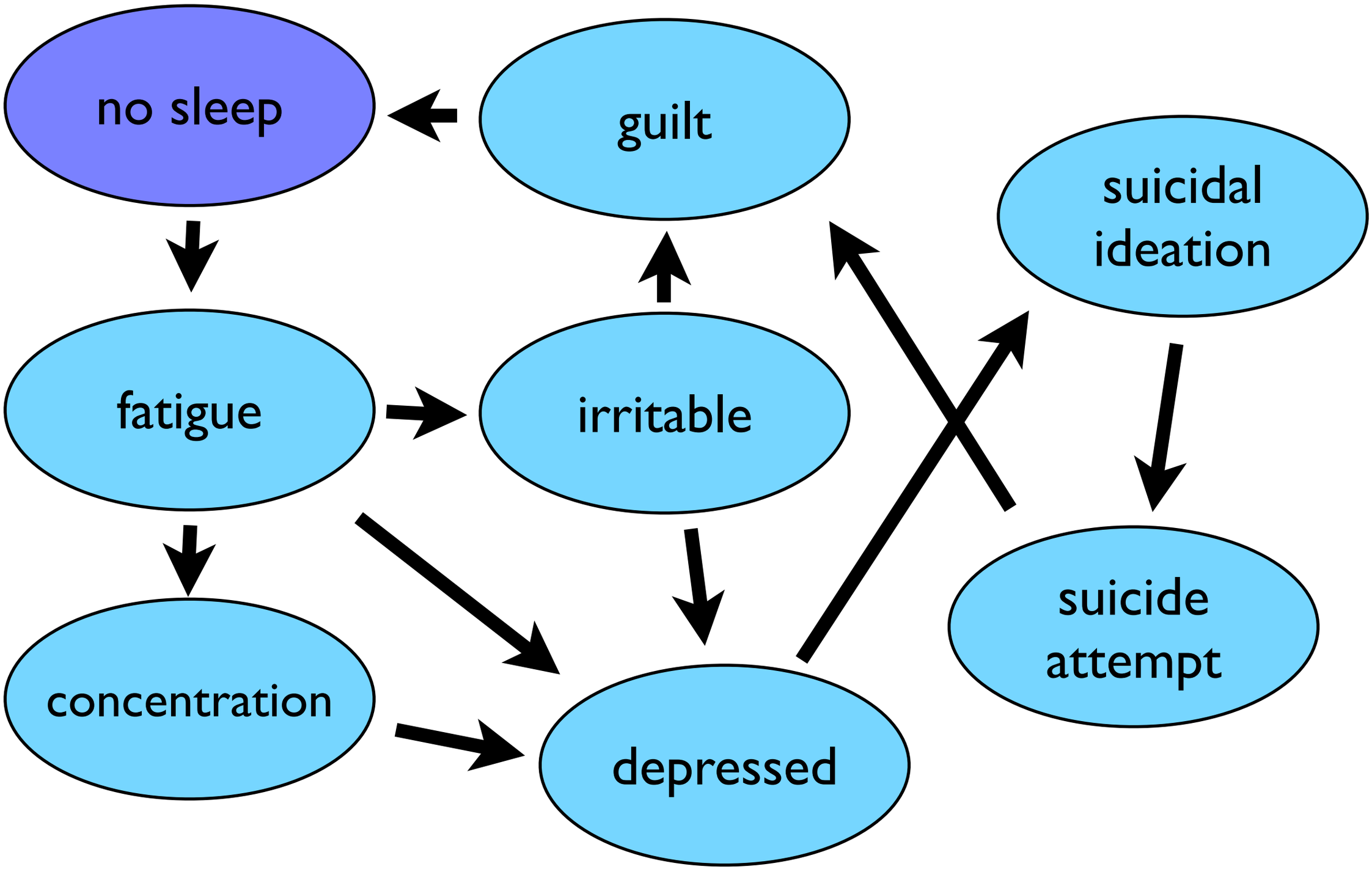
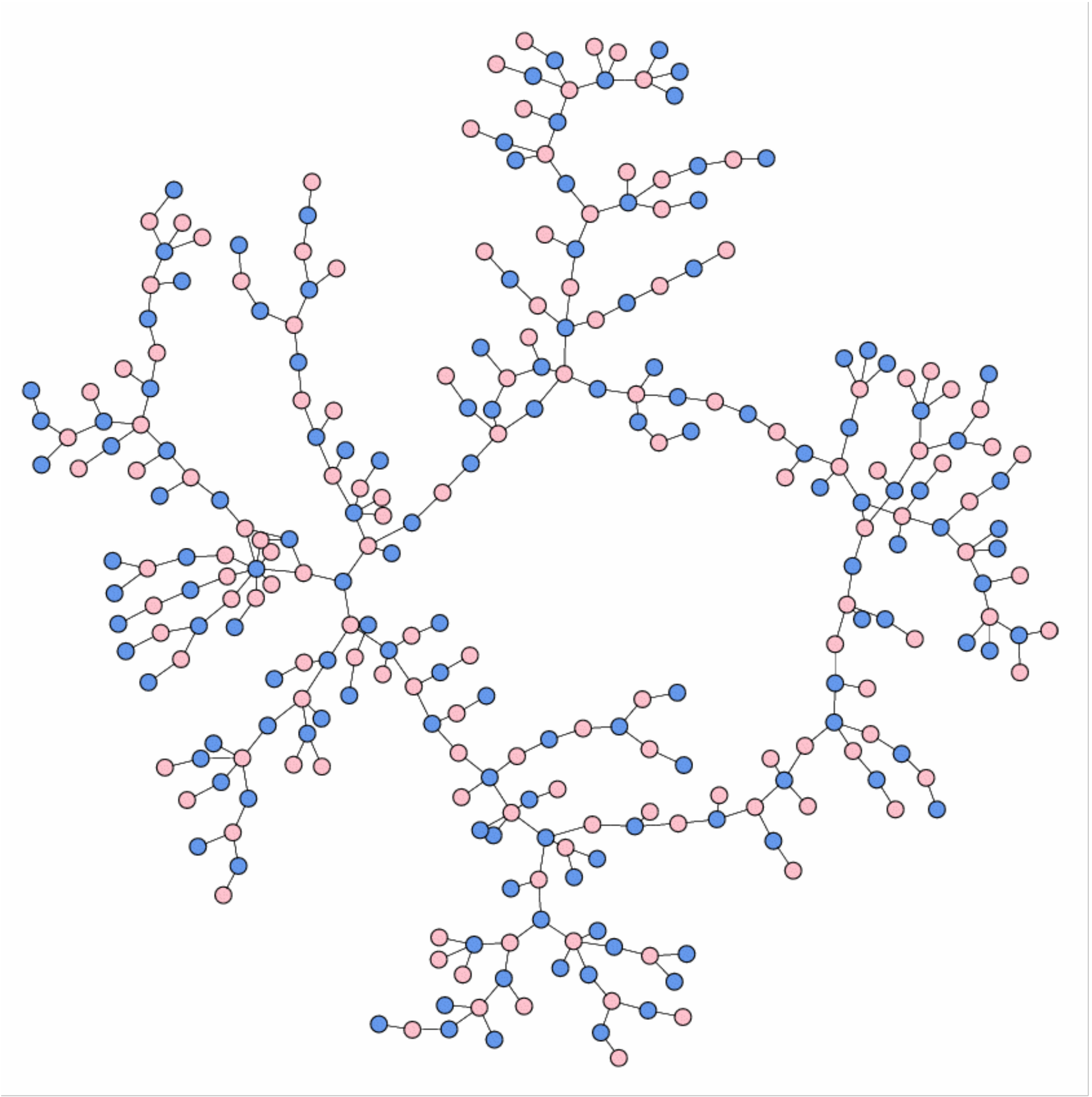
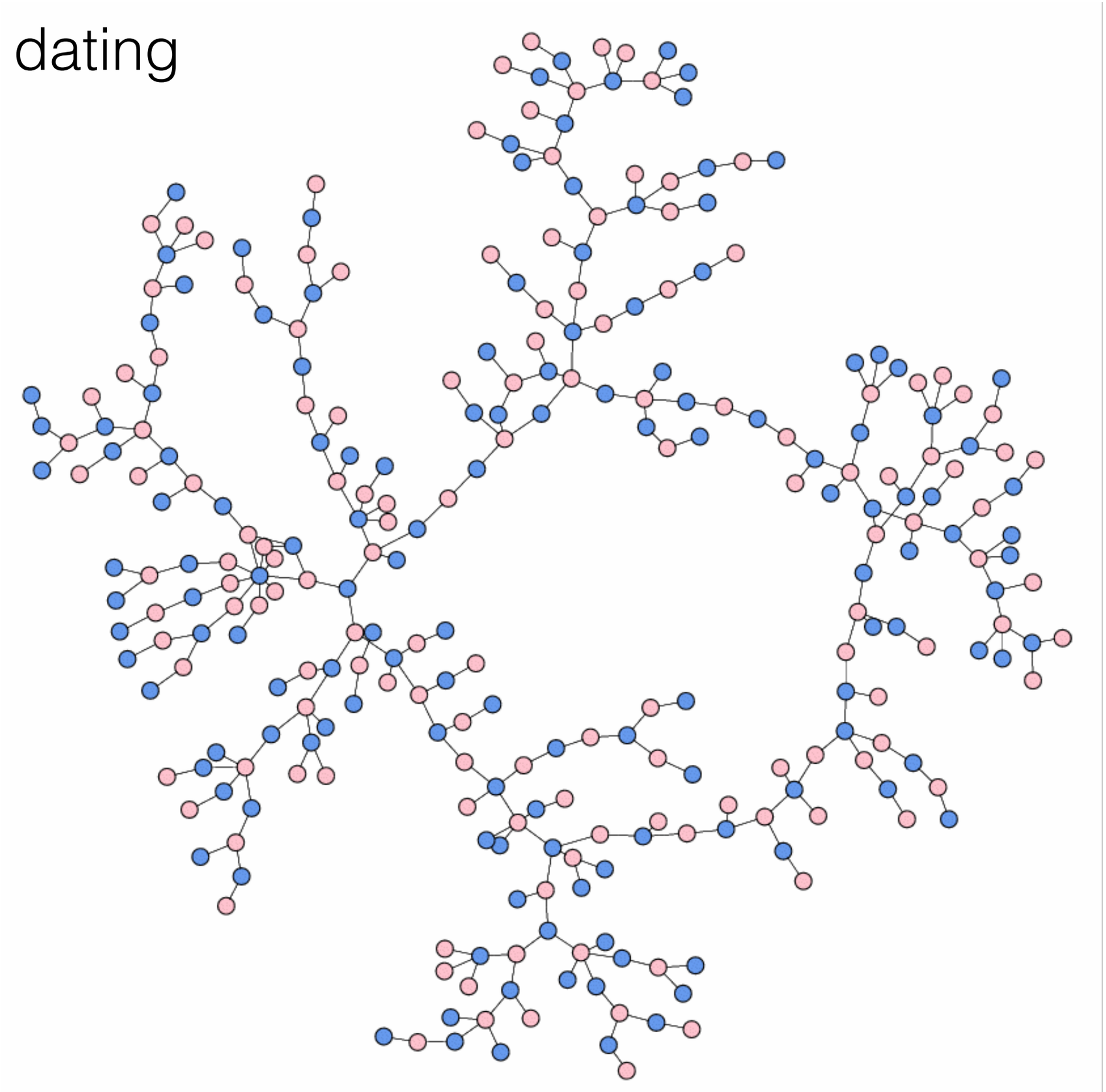

no sleep
guilt
suicidal ideation
fatigue
irritable
concentration
depressed
suicide attempt

About networks



High school dating



About networks

Facebook friends

Complexity of psychopathology

Classification systems

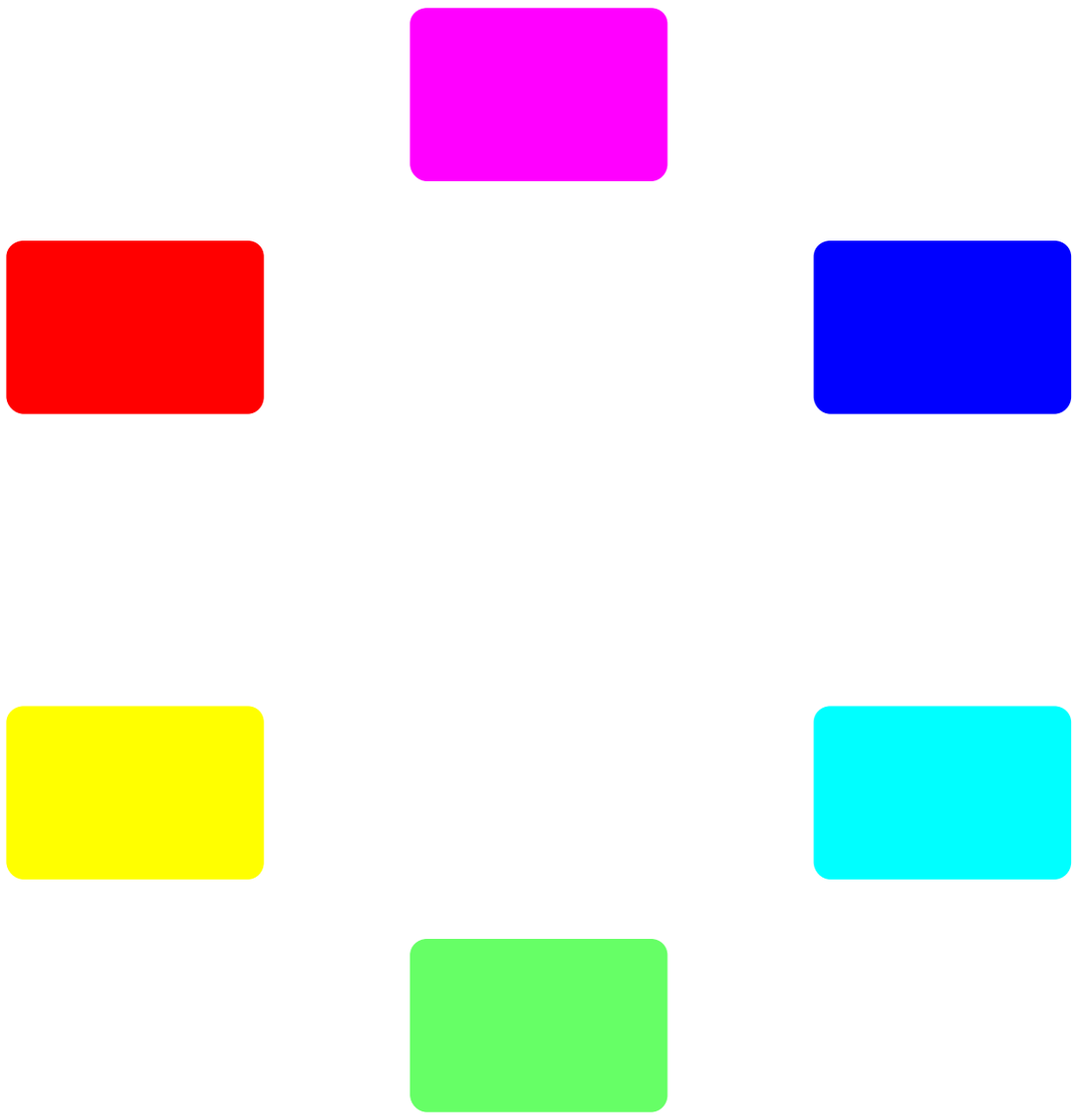
Complexity of psychopathology

Classification systems

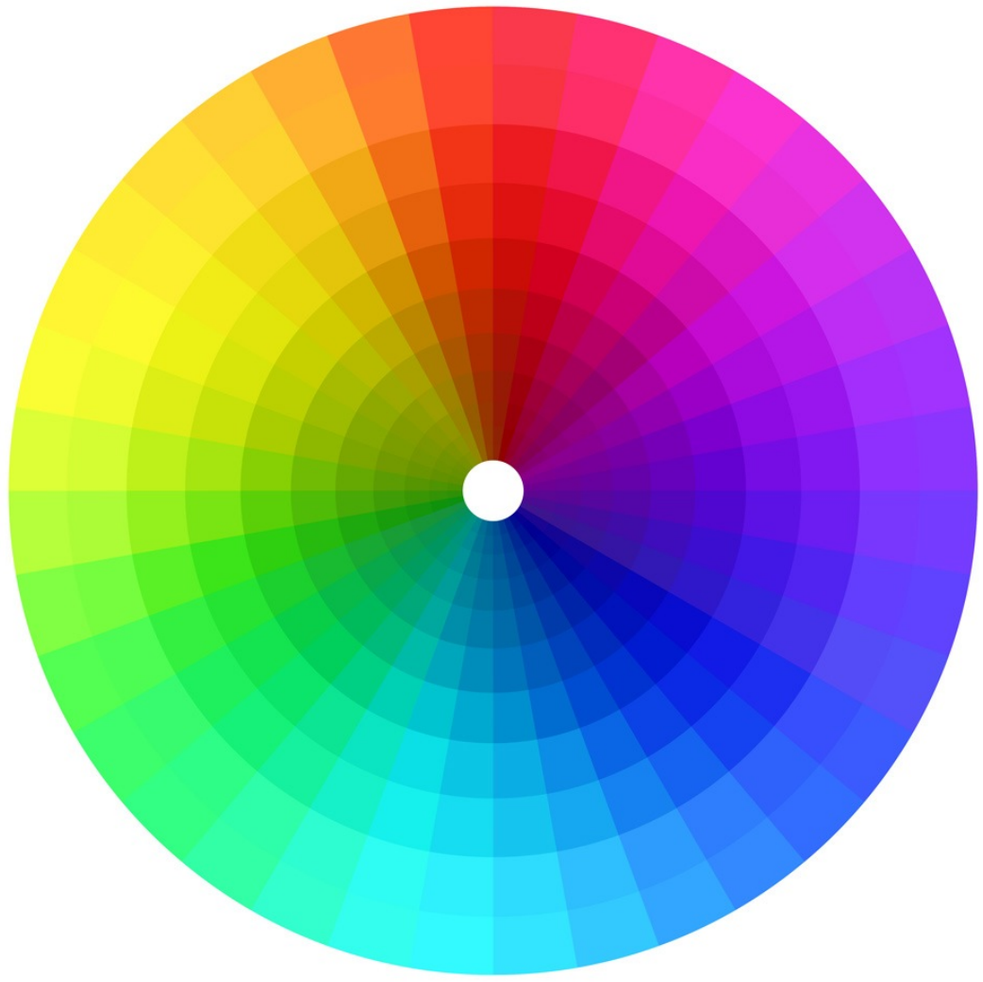
Clinical practice

Complexity of psychopathology

Classification systems

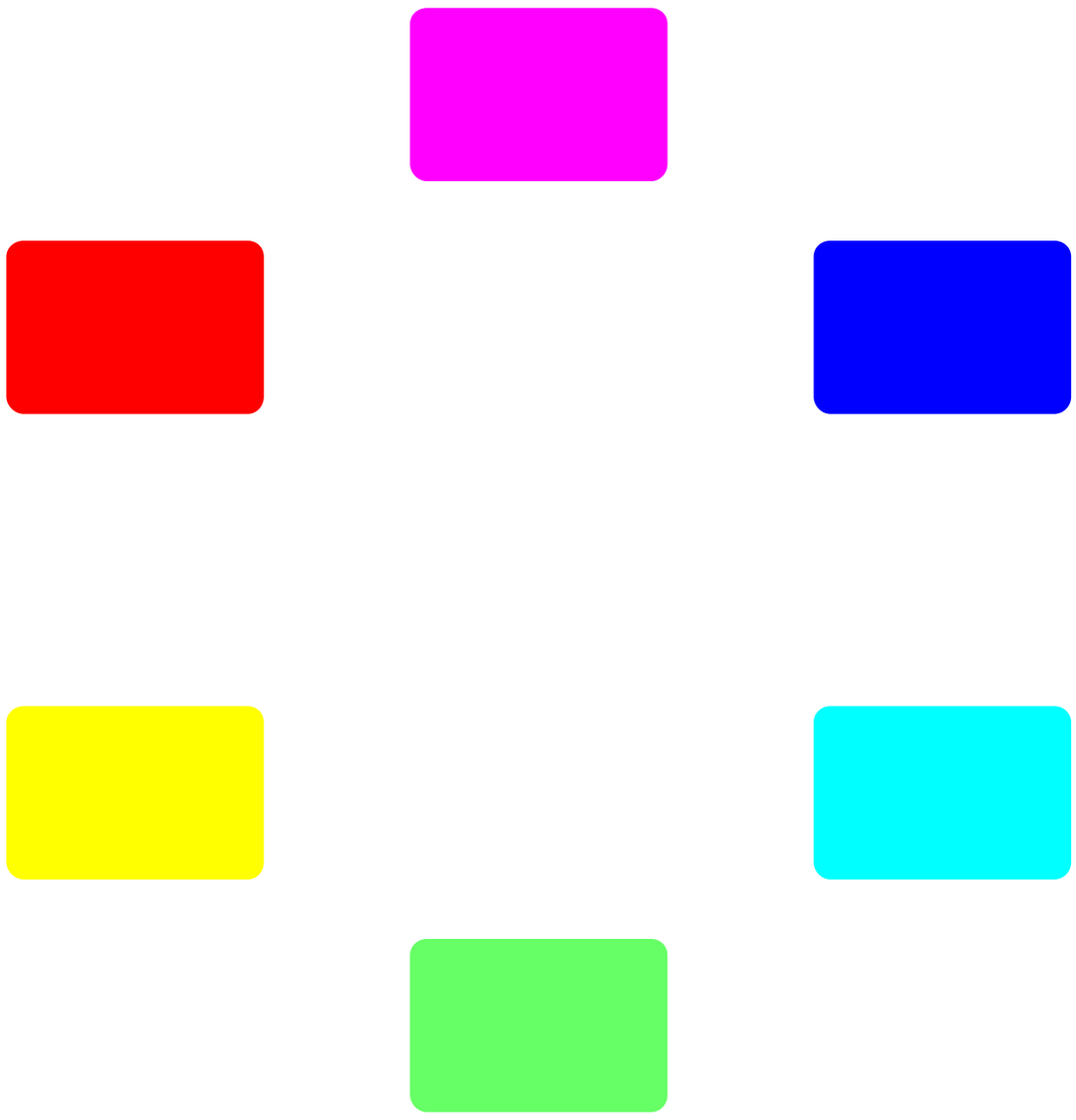


Clinical practice



Complexity of psychopathology

Classification systems



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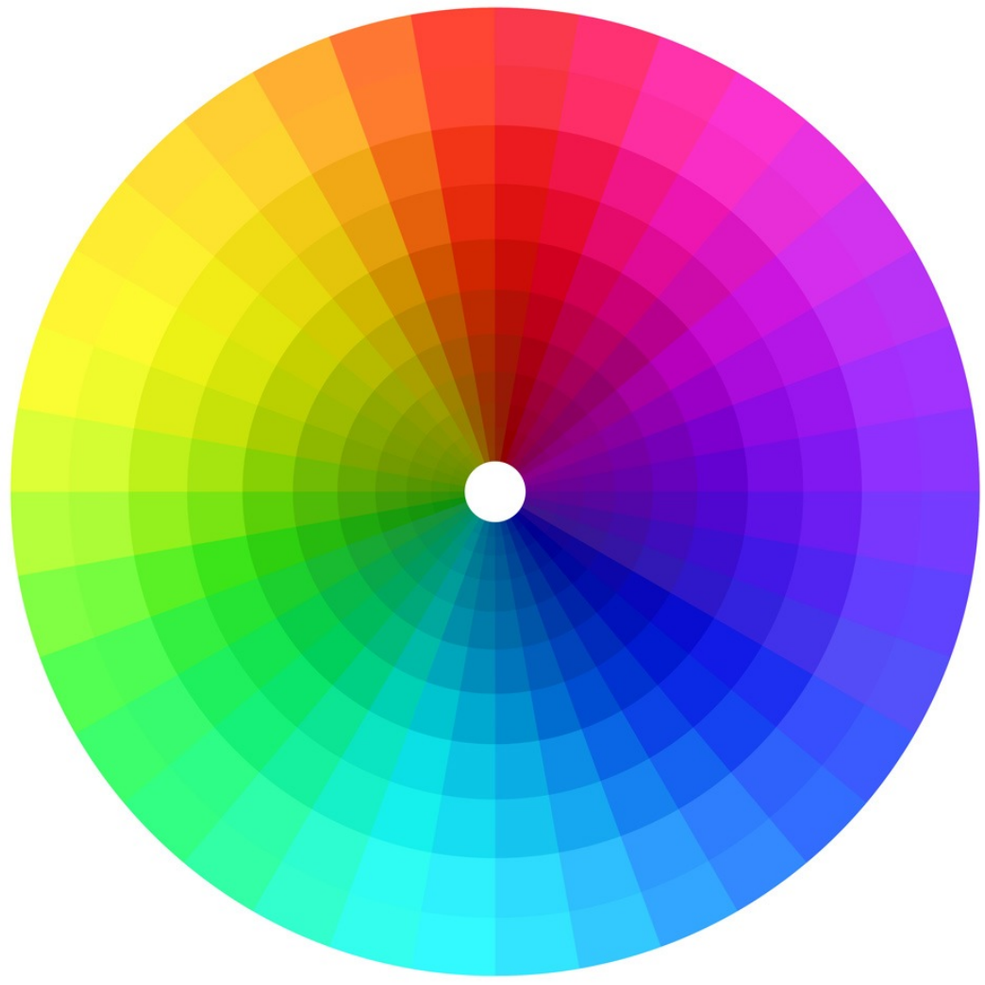
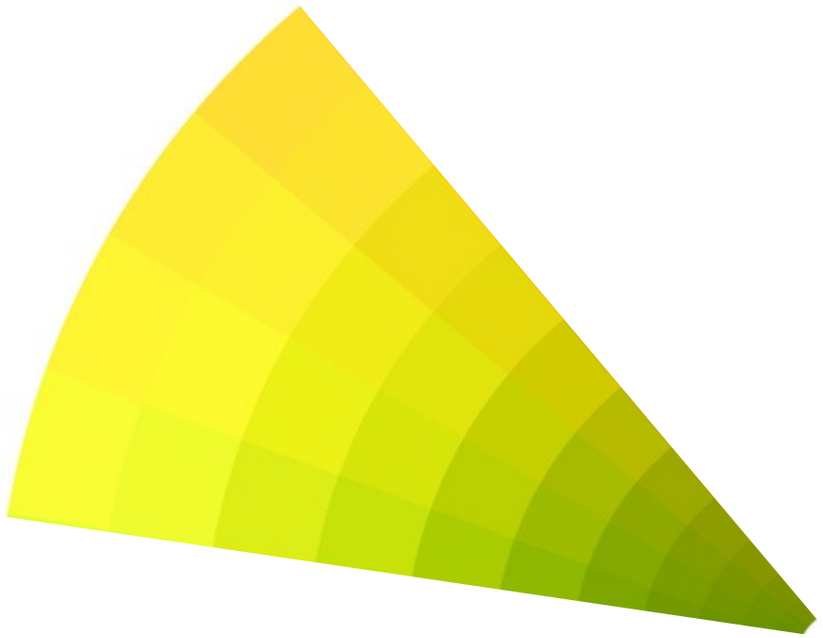
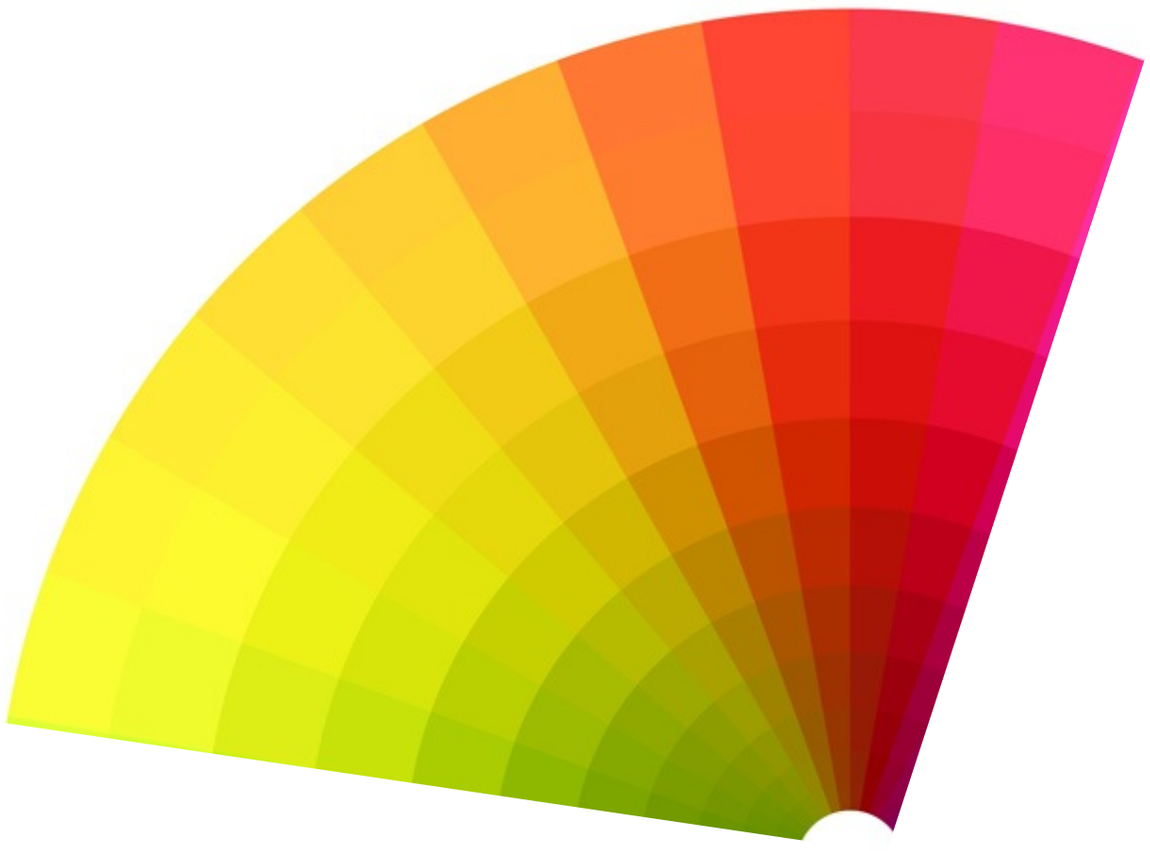
Clinical practice



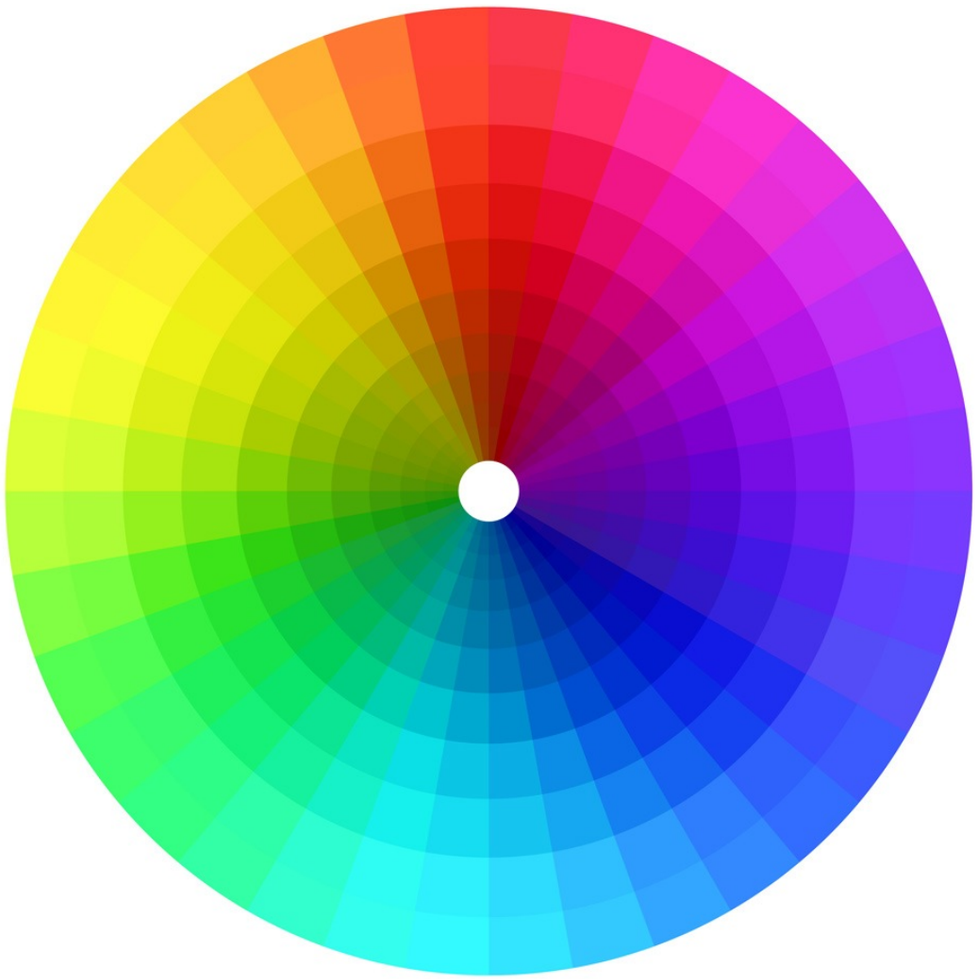
Heterogeneity within diagnoses



Comorbidity between diagnoses



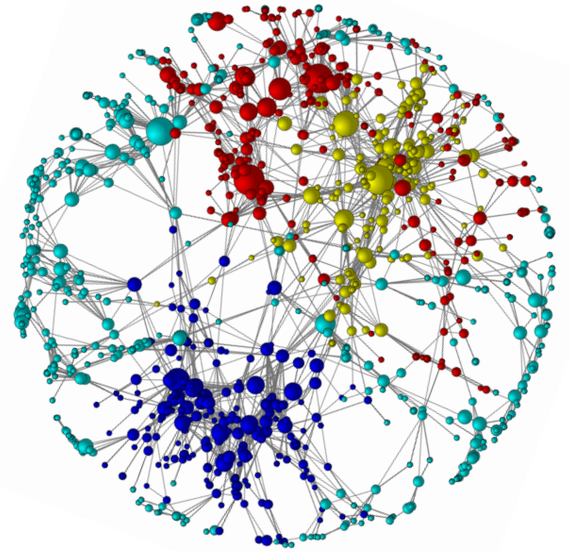
Hoe doe je recht aan complexiteit?



Met dank aan Lynn Boschloo

Psychopathology networks
cross-sectional

So, networks!



But what is the network structure of depression?

We need data

Empirical networks

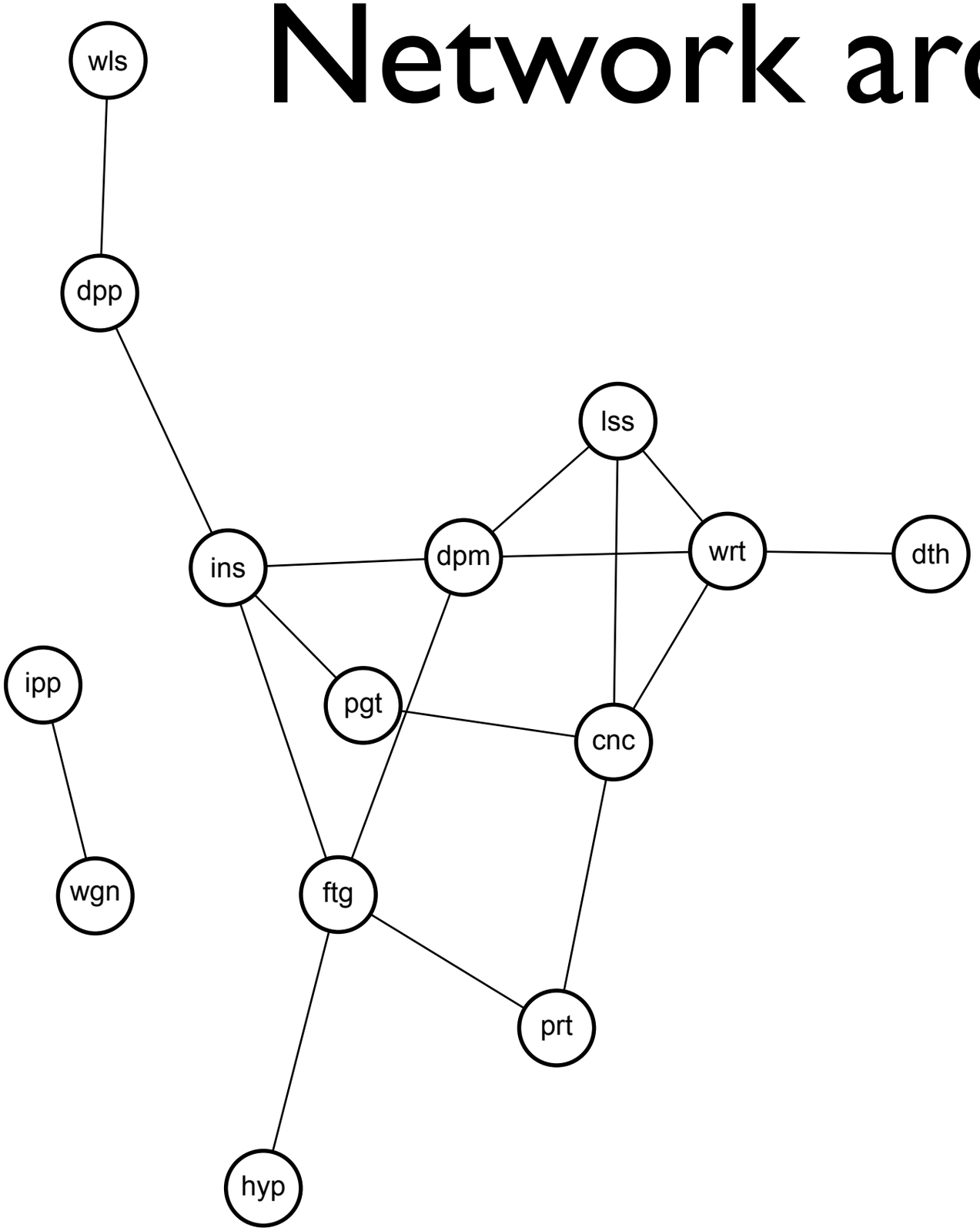
Based on empirical data

- VATSPUD study (Kendler & Prescott, 2006)
- > 8000 participants

Identification of node set:

- Symptoms of major depression in the DSM-IV

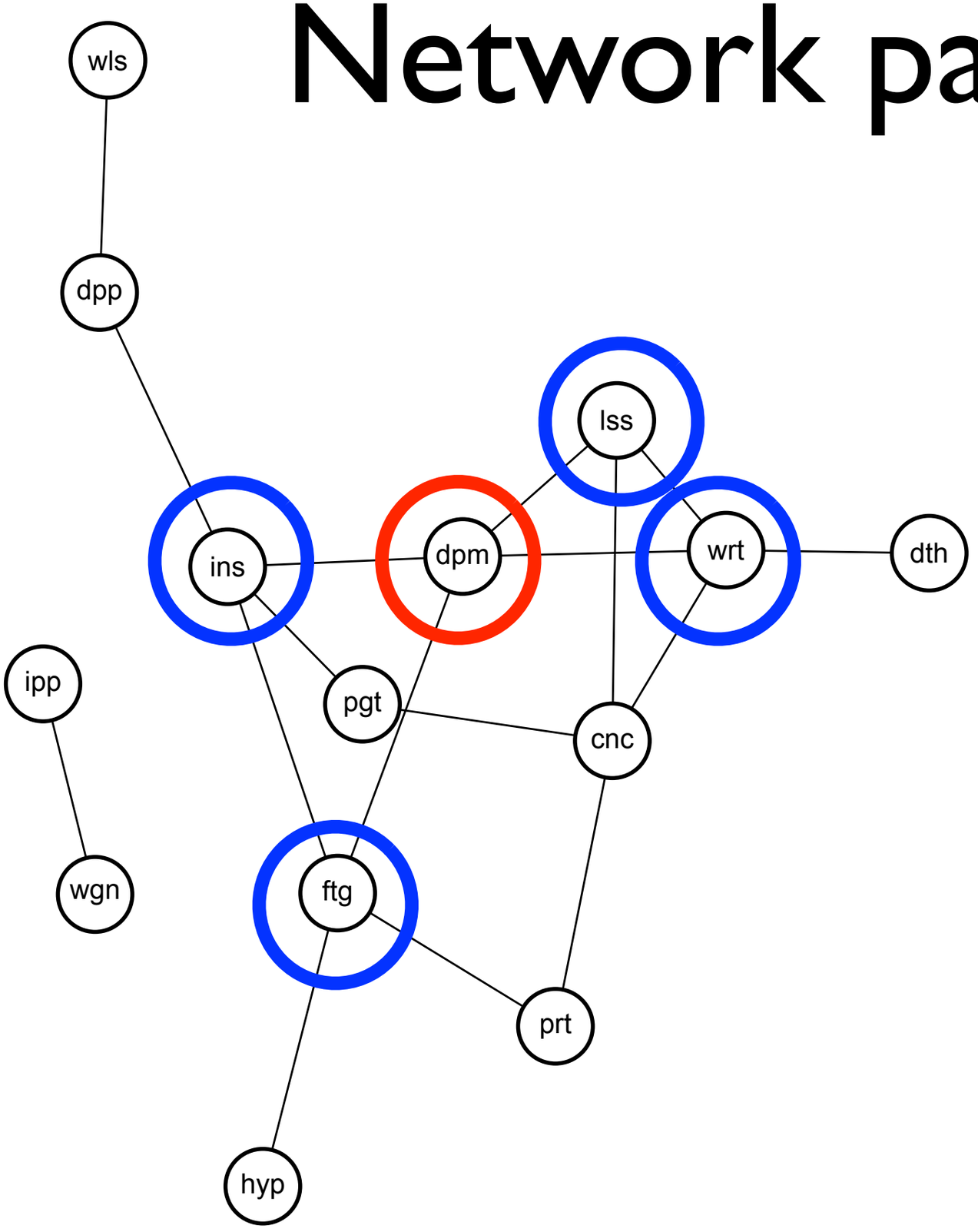
Network architecture



Symptoms (degrees)

dpm=depressed mood (4)
lss=loss of interest (3)
wls=weight loss (1)
wgn=weight gain (1)
dpp=decreased appetite (2)
ipp=increased appetite (1)
ins=insomnia (4)
hyp=hypersomnia (1)
pgt=psychomotor agit. (2)
prt=psychomotor ret. (2)
ftg=fatigue (4)
wrt=worthlessness (4)
cnc=concentration loss (4)
dth=thoughts of death (1)

Network parameters



Logistic regression of symptom on neighboring symptoms in the network gives

a) threshold

b) reactivity of symptom wrt neighbors = slope

Simulations

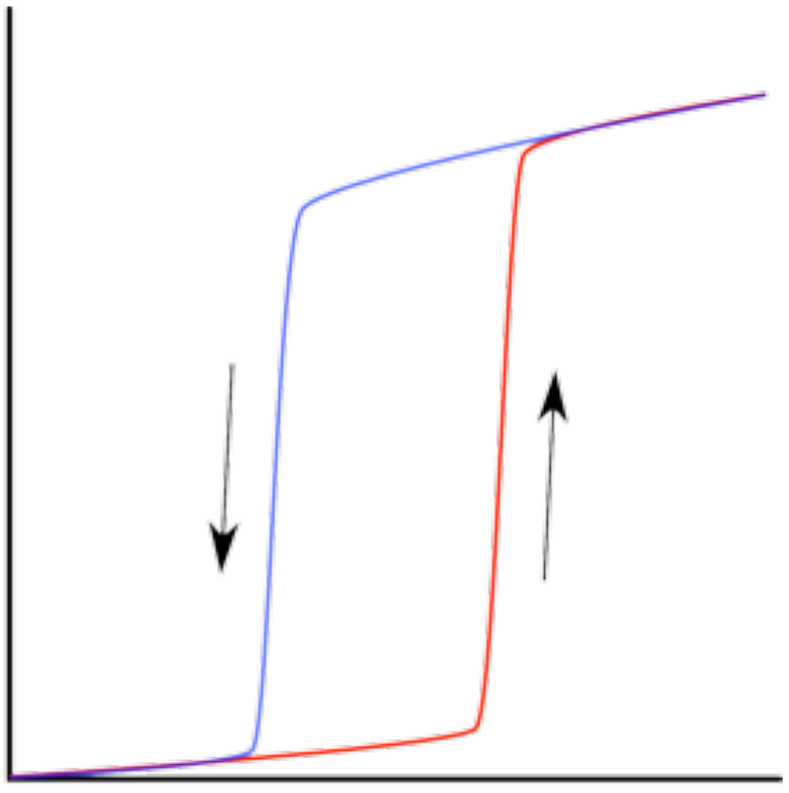
- Imagine that connected nodes can ‘infect’ each other, so that symptoms can spread through the network

- Two ways to manipulate network:

  - putting network under stress

  - changing network vulnerability (diathesis): increasing/decreasing connection strength

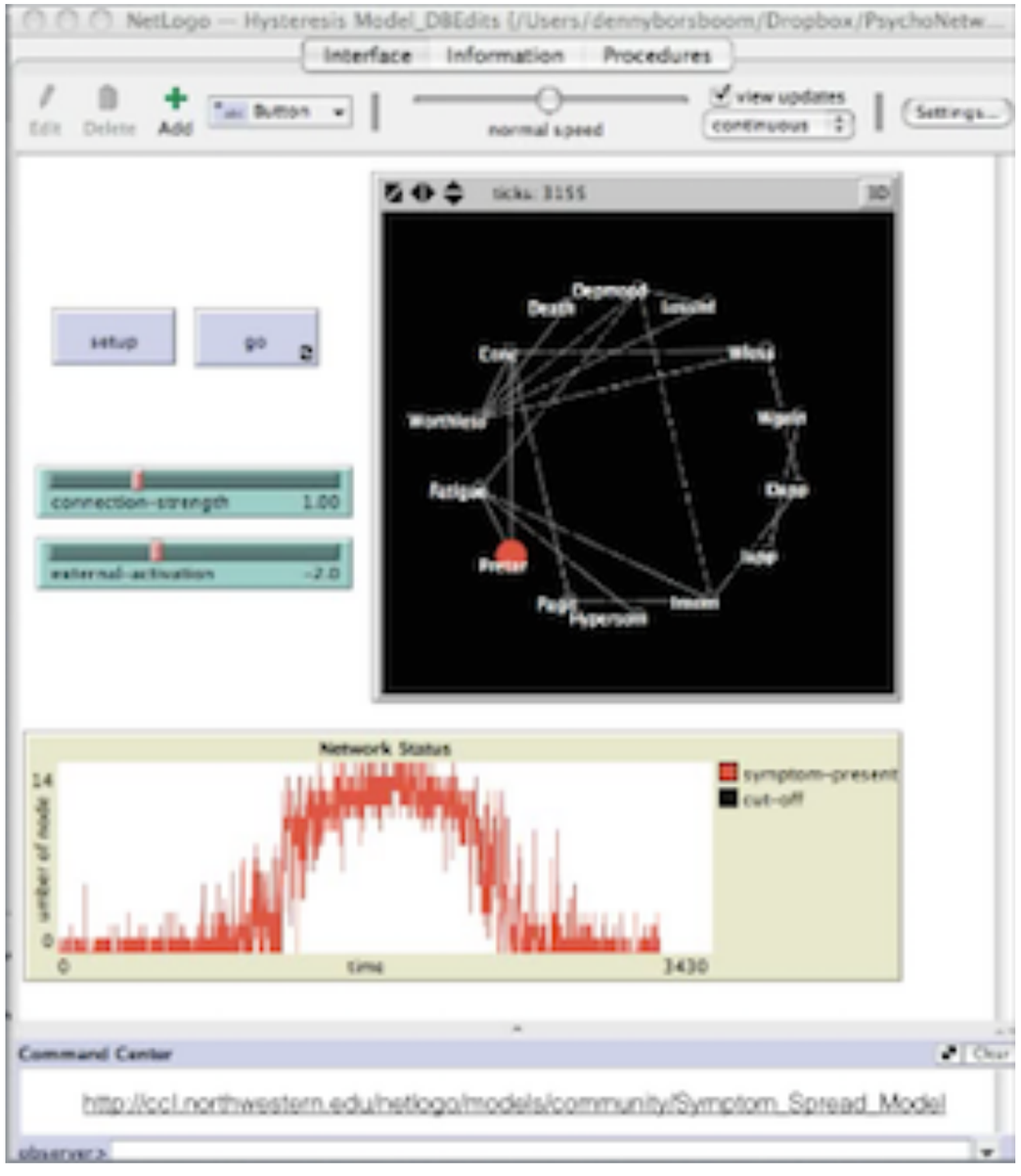
Hysteresis



- Bimodal behavior
- Sudden changes between modes
- Transitions at different values of control factors (depends on where you come from)
- Inaccessible zone

Simulations show…

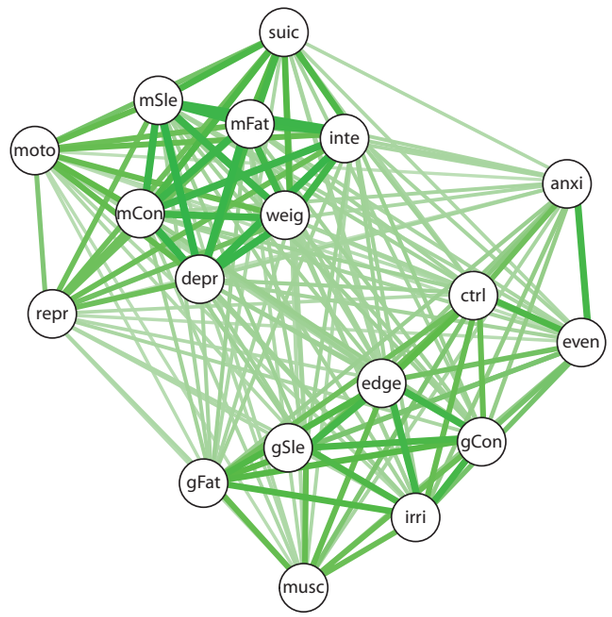
- … that dynamics of networks are associated with phase transitions
- … that connection strength is a plausible mechanistic realization of vulnerability (‘diathesis’)
- … that the presence of hysteresis potentially explains resistance to treatment in severe cases
- … that findings are robust to variations on parameter settings



Physics meets psychopathology

Issues with current methods to estimate network:

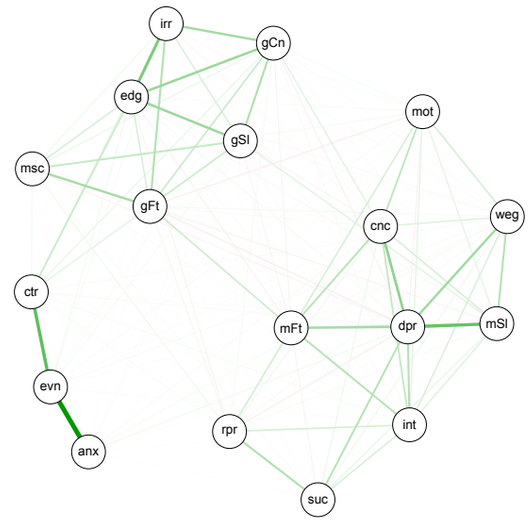
- significance level
- arbitrary cut-off



Correlation graph

A new method: eLasso

- based on Ising model
- ℓ_1-regularized logistic regression (Ravikumar, Wainwright & Lafferty, 2011)
- Goodness-of-fit measure (*extended* BIC) (Chen & Chen, 2008)

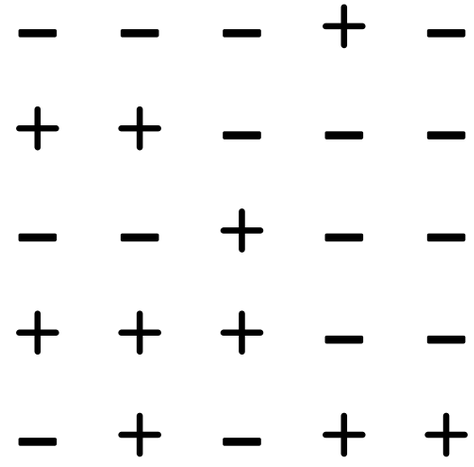


Partial correlation graph

Physics meets psychopathology

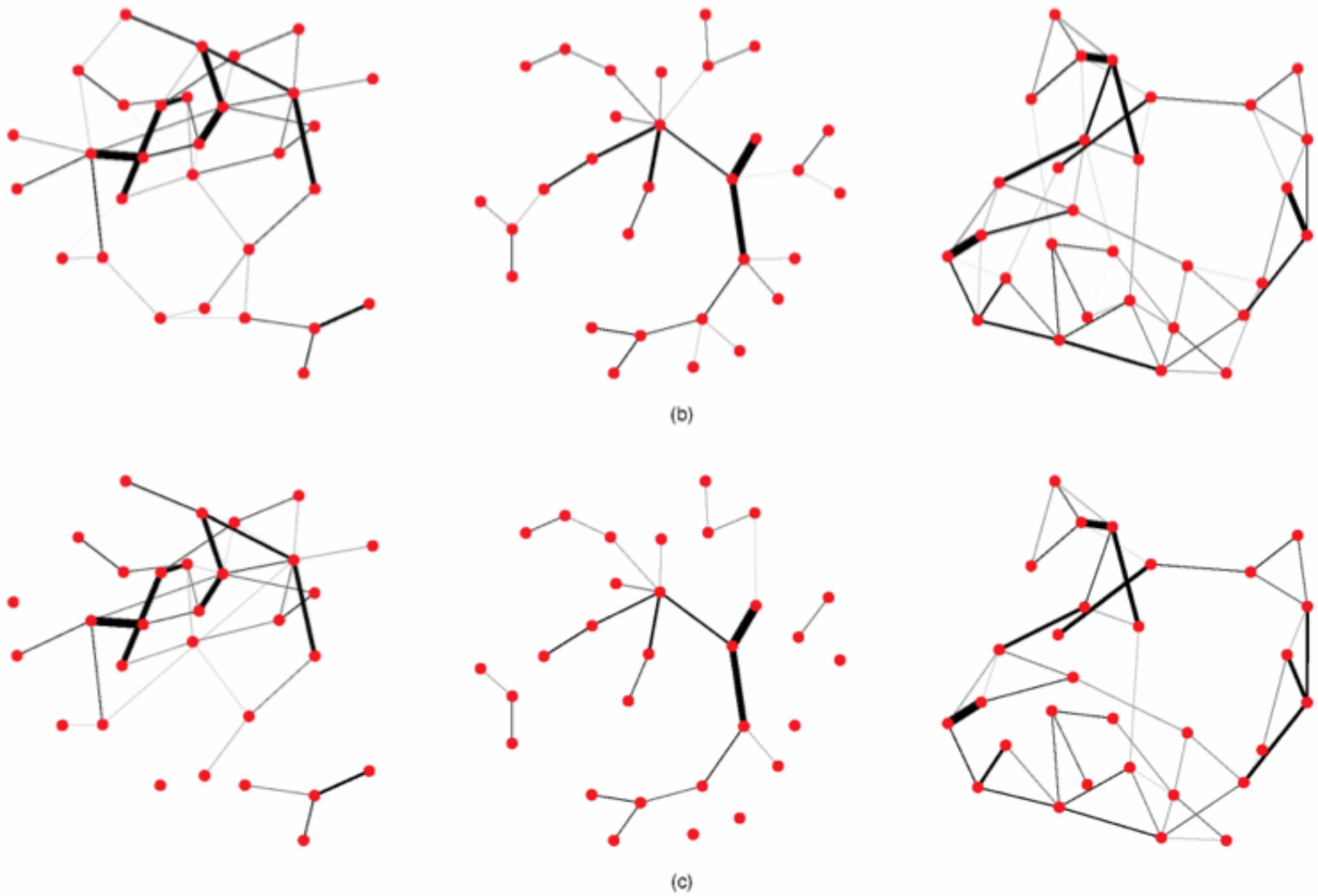
Ising model

- to explain ferromagnetism
- small dipoles (spins) can be ’spin up’ (+ 1) or ’spin down’ (- 1)
- can be generalized to other *objects* in a network (voter, neuron, tree)
- objects/variables can interact, but only with direct neighbors



Simulation study

- Create a network
- This is the “true” network
- Generate data according to Ising model
- Use simulated data to estimate network (with **R** package **IsingFit**)
- Does estimated network look like “true” network?



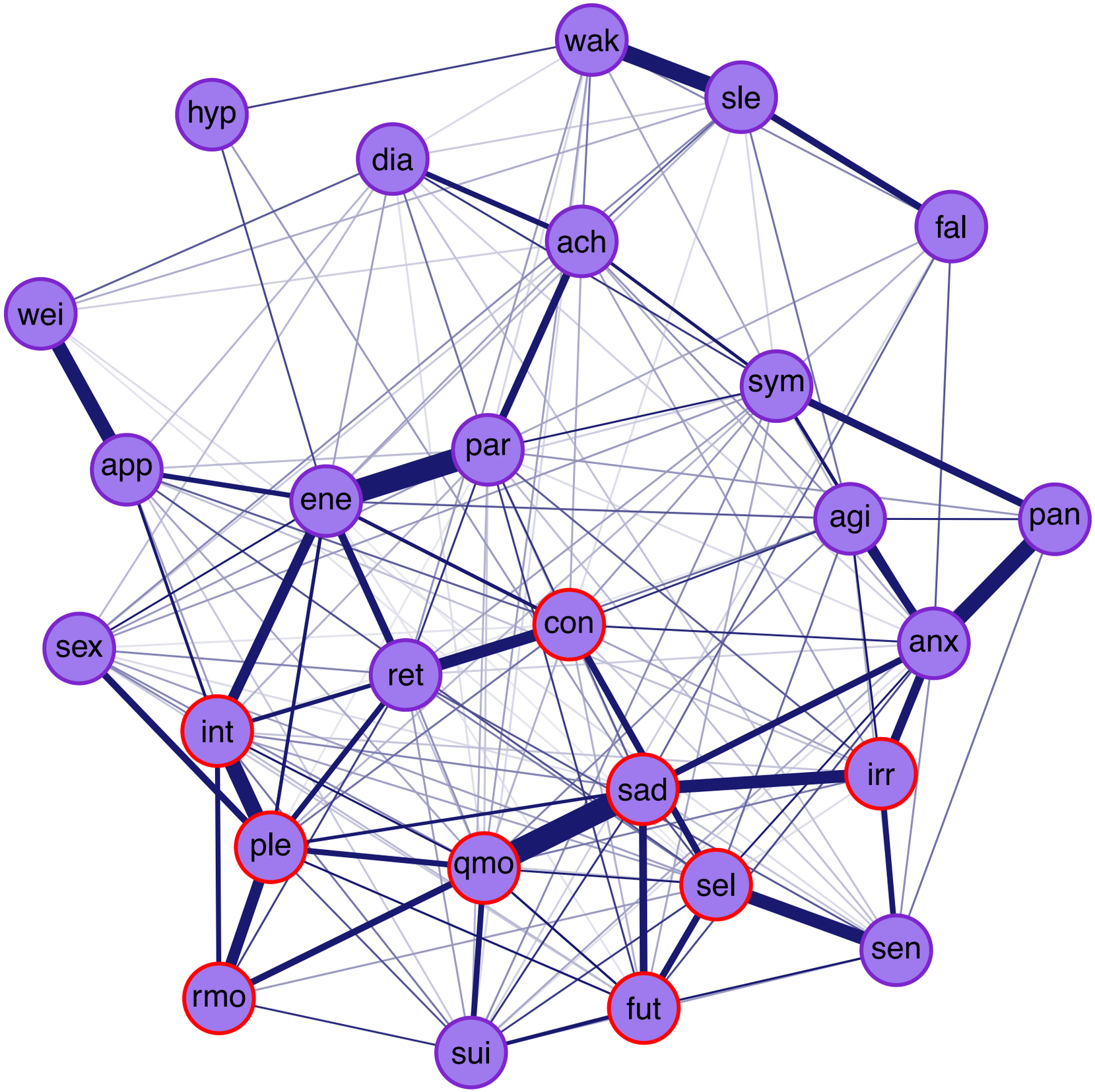
Van Borkulo, C. D., Borsboom, D., Epskamp, S., Blanken, T. F., Boschloo, L., Schoevers, R. A., Waldorp, L. J. Scientific Reports (2014).

Application to real data

- NESDA (Netherlands Study of Depression and Anxiety)
  - n=2981
  - Deelnemers via huisartsenpraktijken en GGZ-instellingen mét en zonder klachten

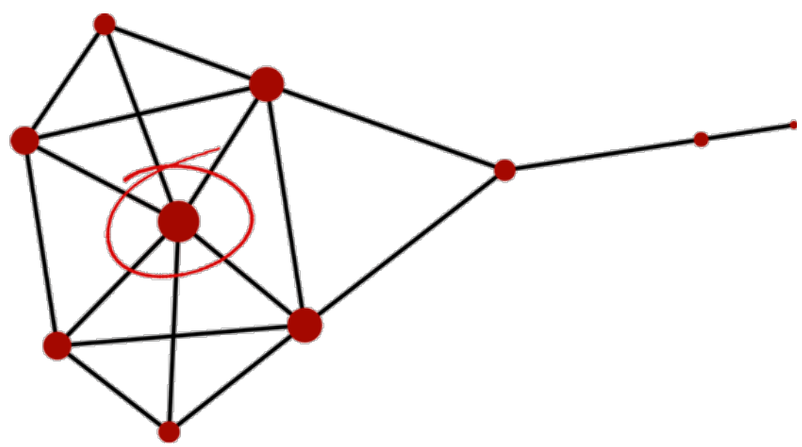
- IDS (Inventory of Depressive Symptomatology)
  - 27 depression and anxiety items

Psychopathology networks
cross-sectional

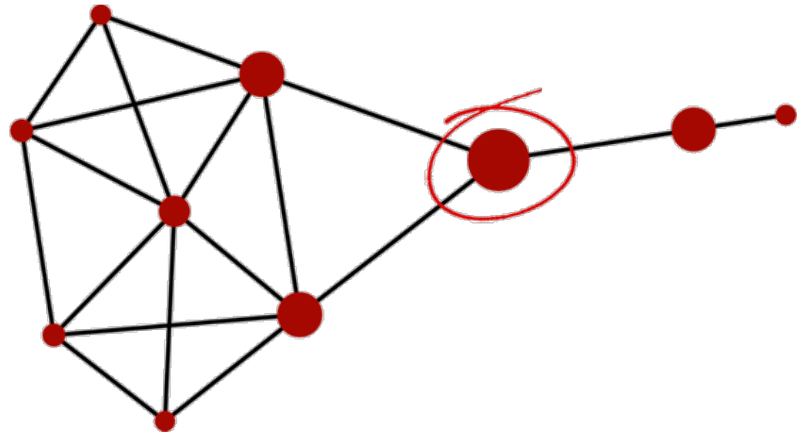


Centrality measures

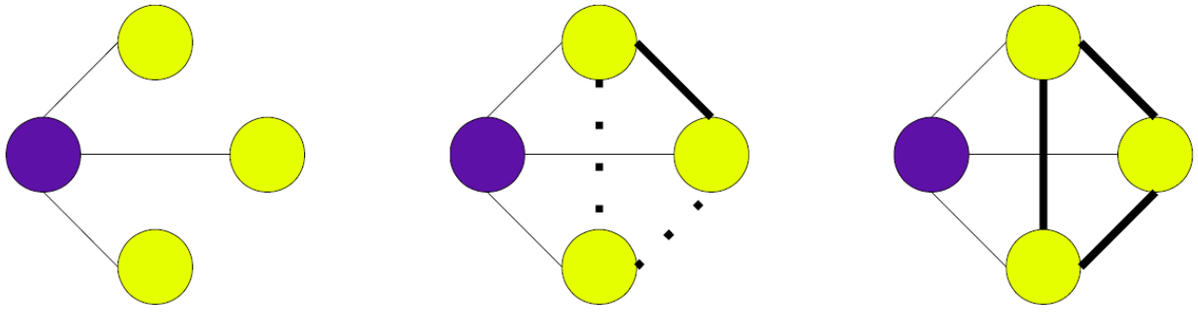
- Node strength: weighted sum of connections



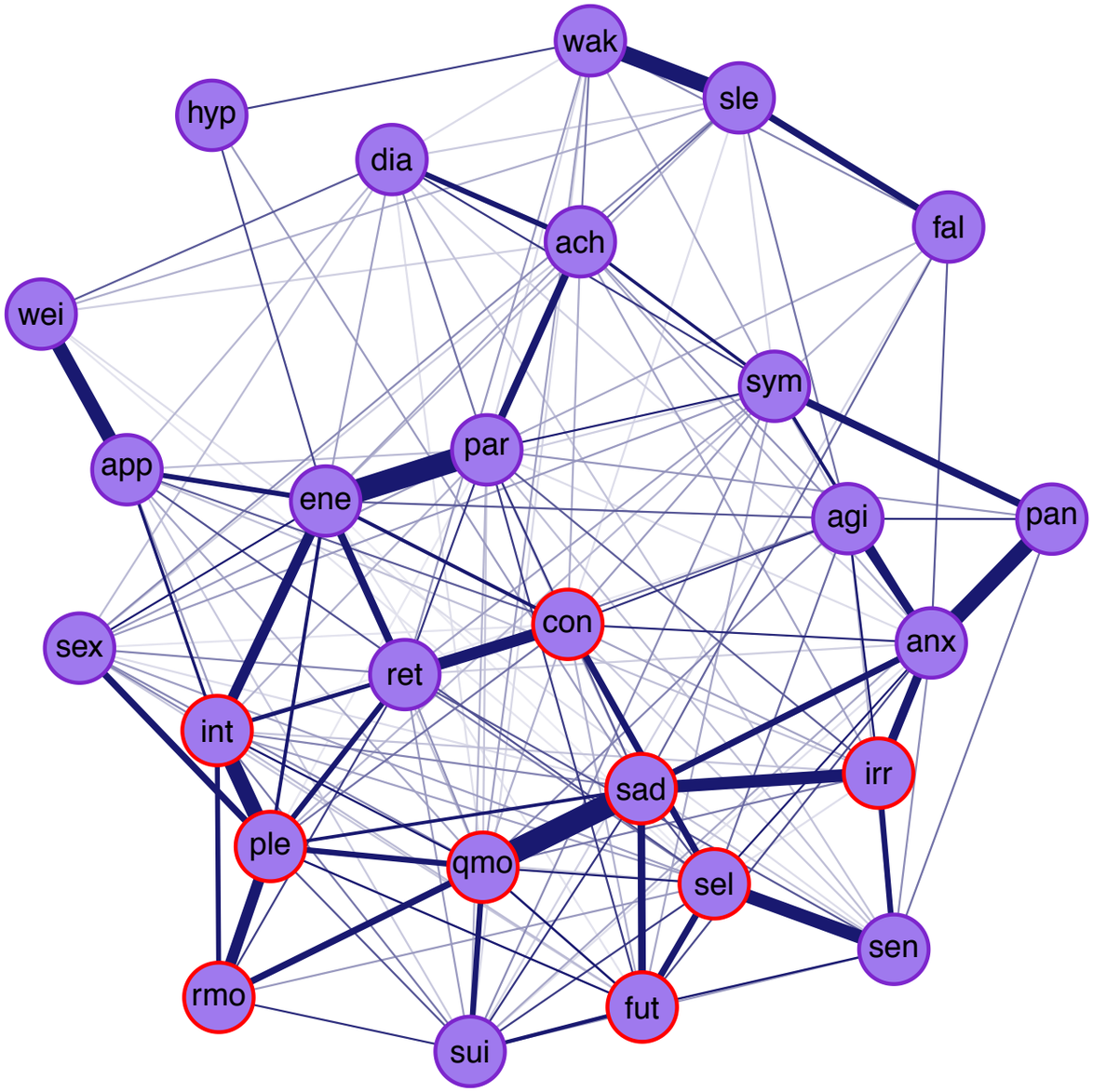
- Betweenness: how often node appears on (shortest) path between nodes in network

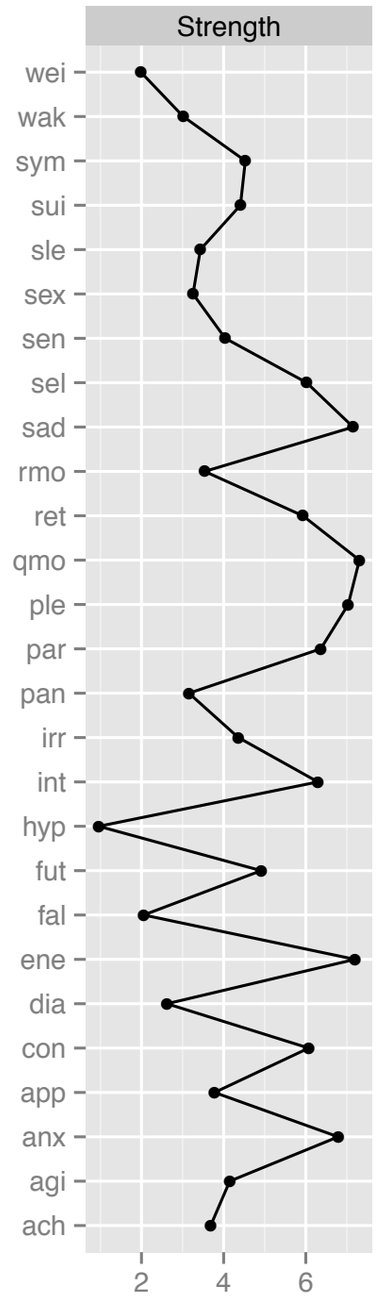


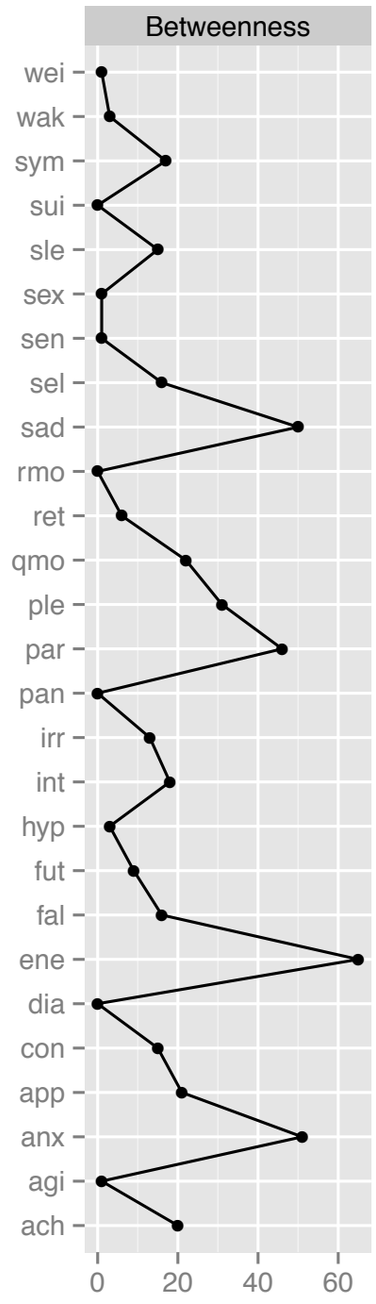
- Clustering coefficient: the capacity of the node to be a hub

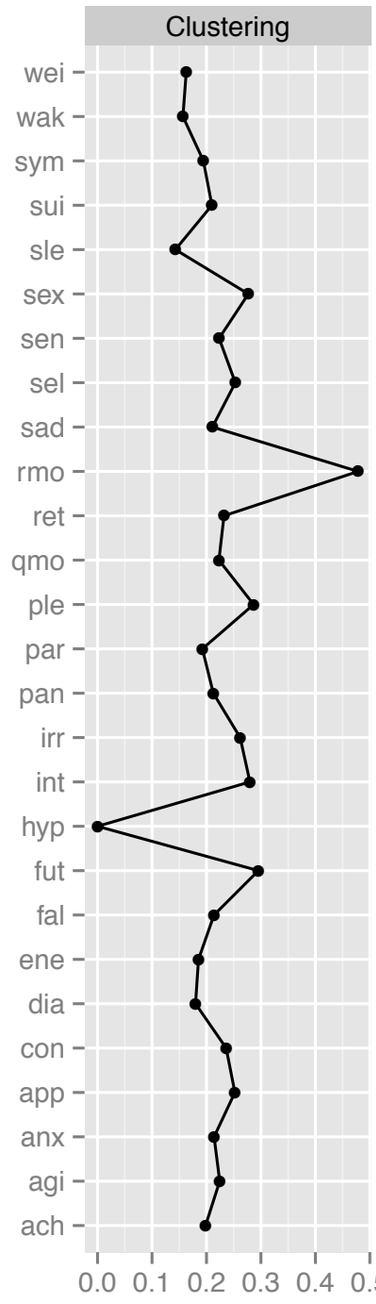


Psychopathology networks cross-sectional







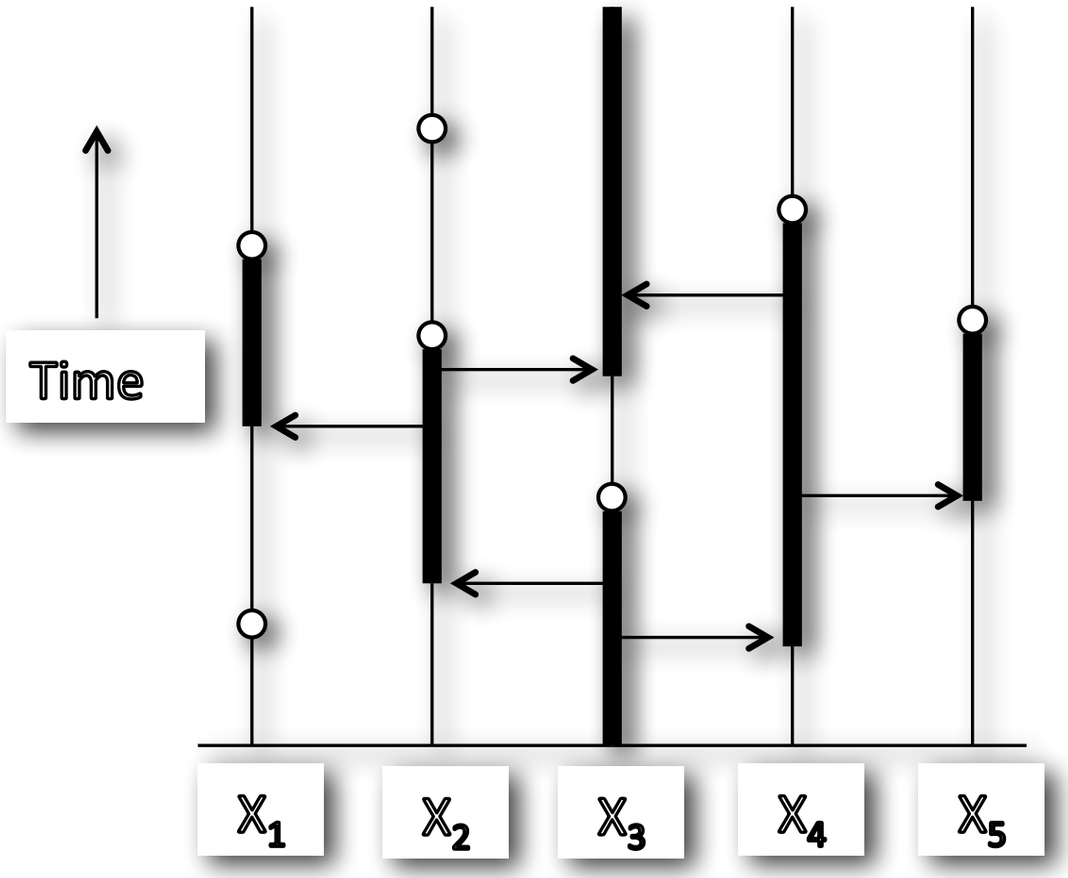


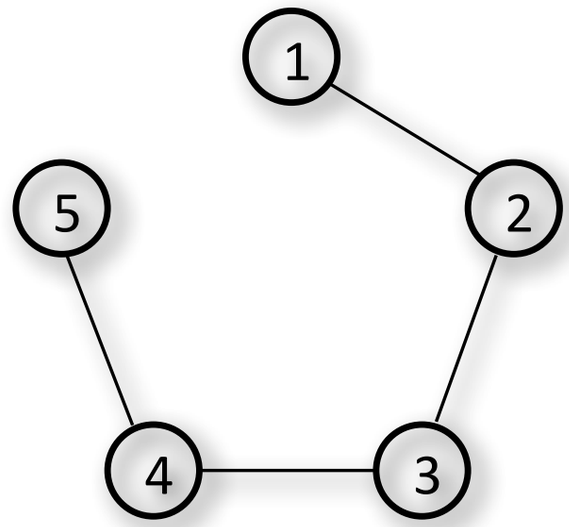
Interesting questions

- Is having ‘important’ symptoms predictive for having MDD later?
- Participants with MDD at baseline: does group that recover have a different network than those that do not recover?
- How are biomarkers involved in the depression network?
- Does micro-intervention based on individual network work?

Psychopathology networks
longitudinal

Contact process model



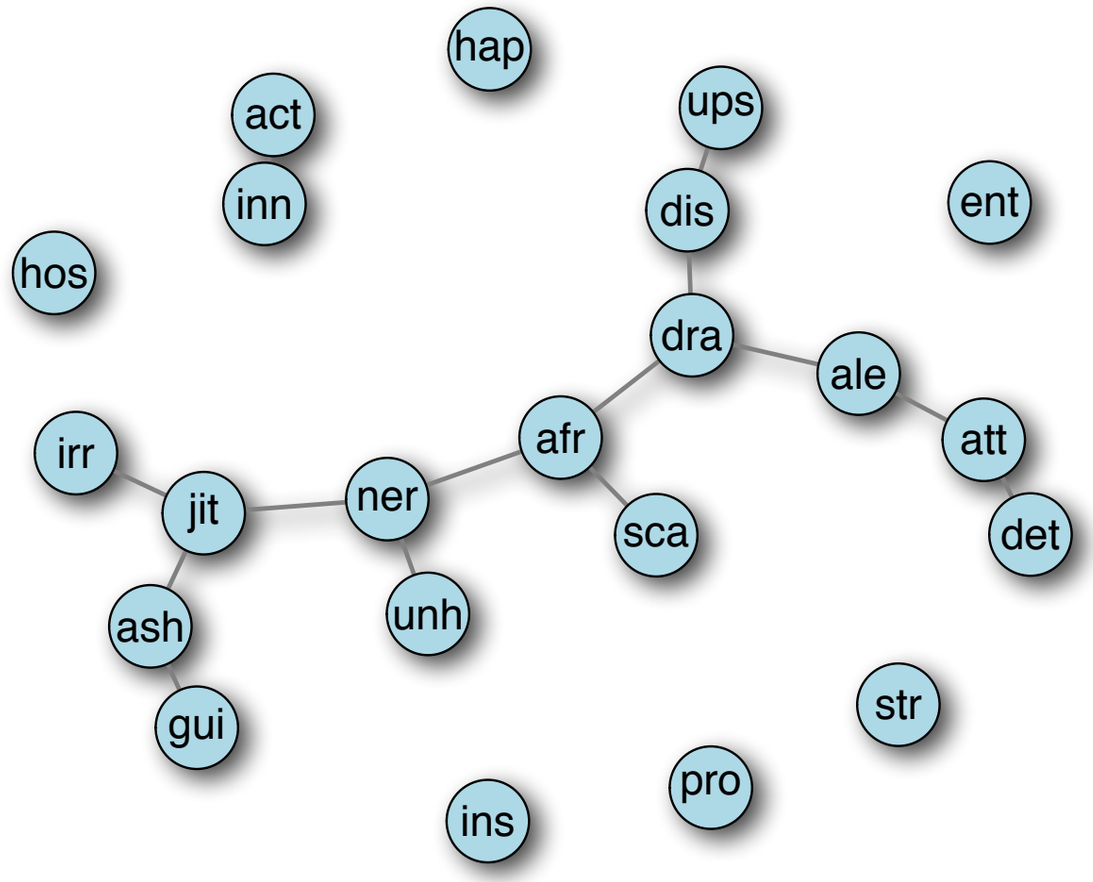


Two independent Poisson processes:
- infection (with parameter λ)
- recovery (with parameter μ)

Ratio $\rho = \lambda / \mu$
$\rho > 1$: supercritical case
process survives forever

What do we need?

- binary multiple observations
- network structure
- parameters for ratio ρ (λ and μ)



Contact process model

- Network structure: eLasso (`adjusted version of IsingFit` package in `R`)

- parameter: Percolation Indicator (PI)

Contact process model

- Network structure: eLasso (adjusted version of `IsingFit` package in R)

- parameter: Percolation Indicator (PI)

$$r(x, i; \lambda, \mu) = \lambda k_{i-1}(x)(1 - \xi_{i-1}(x))\delta_{i,i-1}(x) + \mu\xi_{i-1}(x)\delta_{i,i-1}(x) + (1 - \delta_{i,i-1}(x))$$

Fiocco, M., & van Zwet, W. (2004). Maximum likelihood estimation for the contact process. Lecture Notes-Monograph Series, 309–318.

Contact process model

- Network structure: eLasso (adjusted version of `IsingFit` package in R)

- parameter: Percolation Indicator (PI)

$$\hat{\lambda}_t = \frac{U_t}{A_t} \qquad \hat{\mu}_t = \frac{D_t}{B_t}$$

Fiocco, M., & van Zwet, W. (2004). Maximum likelihood estimation for the contact process. Lecture Notes-Monograph Series, 309–318.

Contact process model

- Network structure: eLasso (`adjusted version of IsingFit` package in `R`)

- parameter: Percolation Indicator (PI)

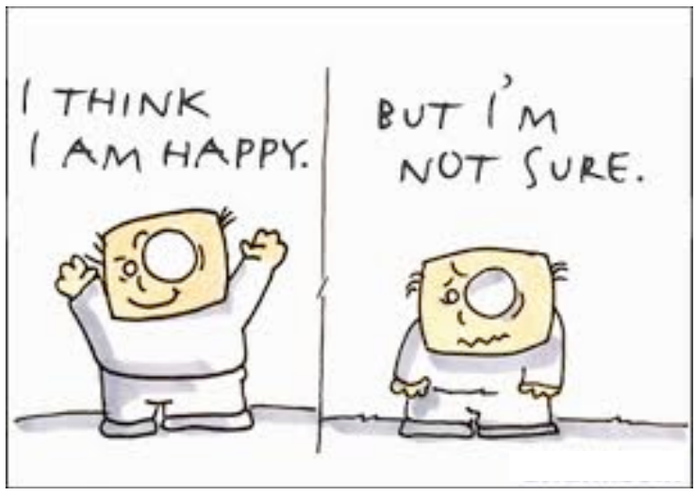
$$\hat{\rho}_t = \frac{U_t B_t}{A_t D_t}$$

Fiocco, M., & van Zwet, W. (2004). Maximum likelihood estimation for the contact process. Lecture Notes-Monograph Series, 309–318.

What do we have?

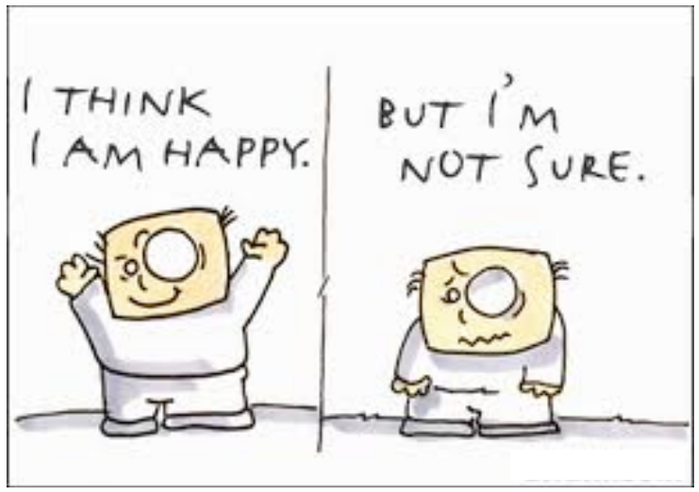
- Model that describes dynamics
- Fairly good estimate of the Percolation Indicator

- Applying to real data:
  - 1 rapid cycling bipolar patient
  - PANAS scores, daily, 90 days



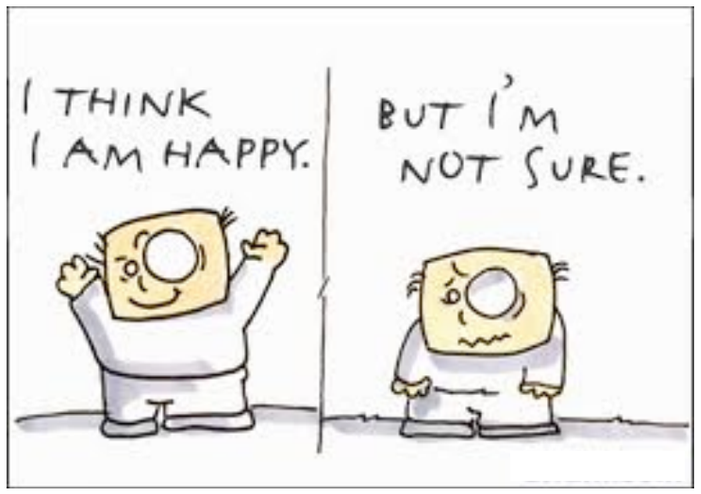
Pijck, L., Kamphuis, J. H., & Dolan, C. (2007). De ontwikkeling van affect over de tijd bij rapid cycling bipolaire patiënten. Unpublished master's thesis, University of Amsterdam, the Netherlands.

Results real data



Results real data

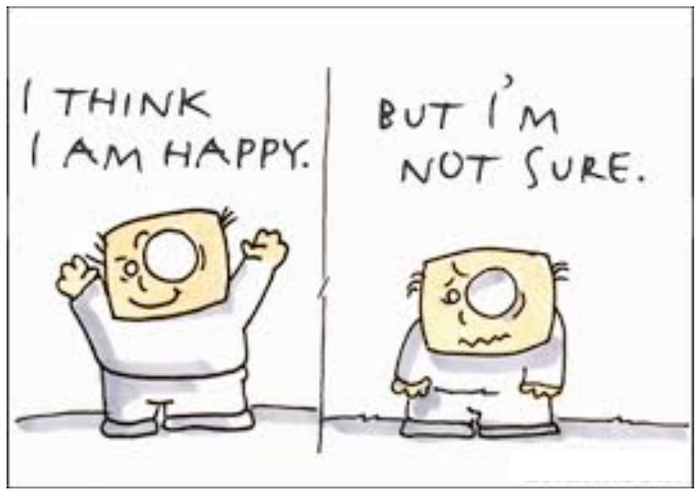
- Percolation indicator = 1.84
- *t*-test: is PI larger than 1?
- $p = 0.22$ ($t = 0.79$, df = 18)



Results real data

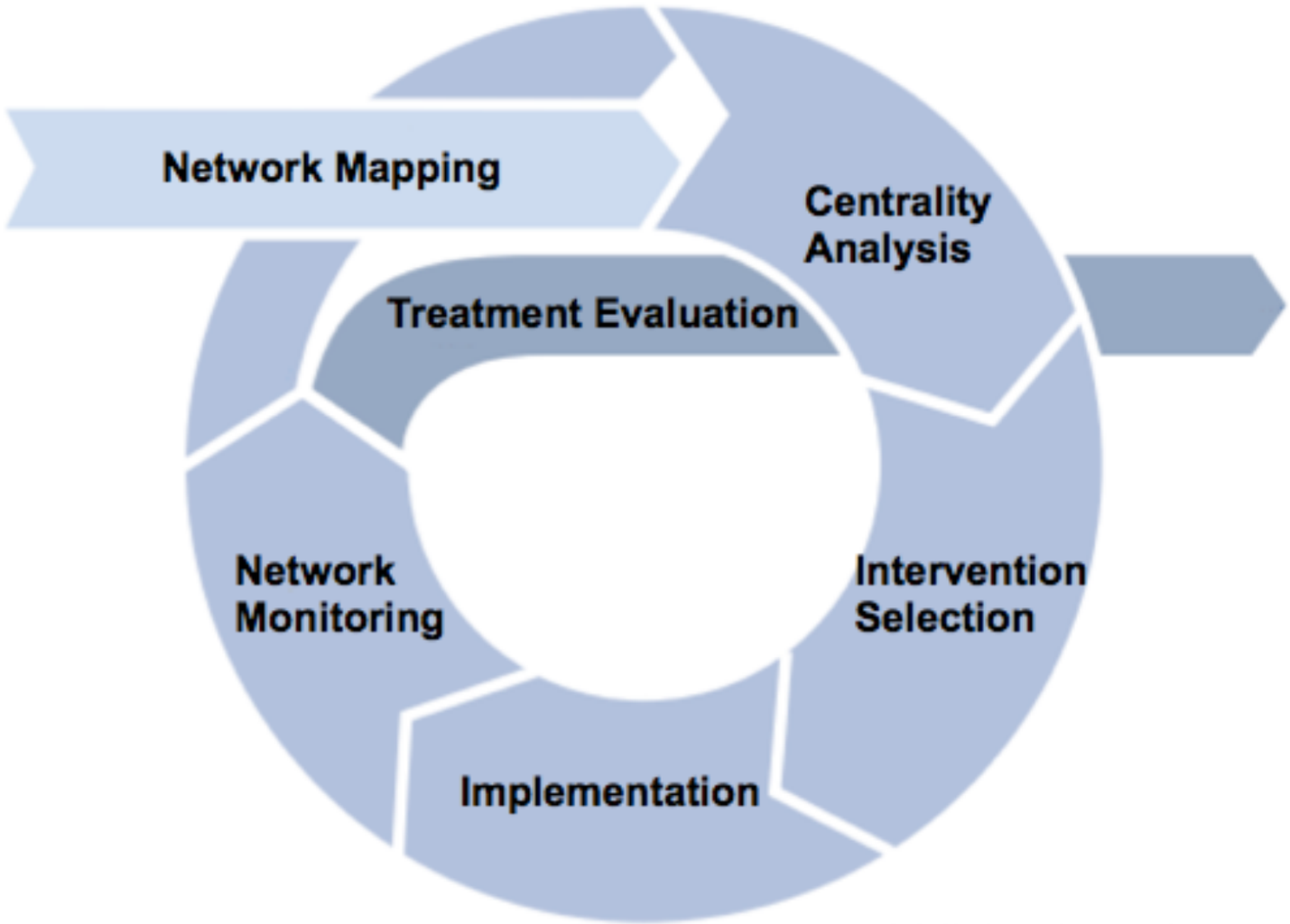
- Percolation indicator = 1.84
- *t*-test: is PI larger than 1?
- $p = 0.22$ ($t = 0.79$, df = 18)

- It is **inconclusive** whether infection will continue or die out



What could a clinical application look like?

An integrated tool and process

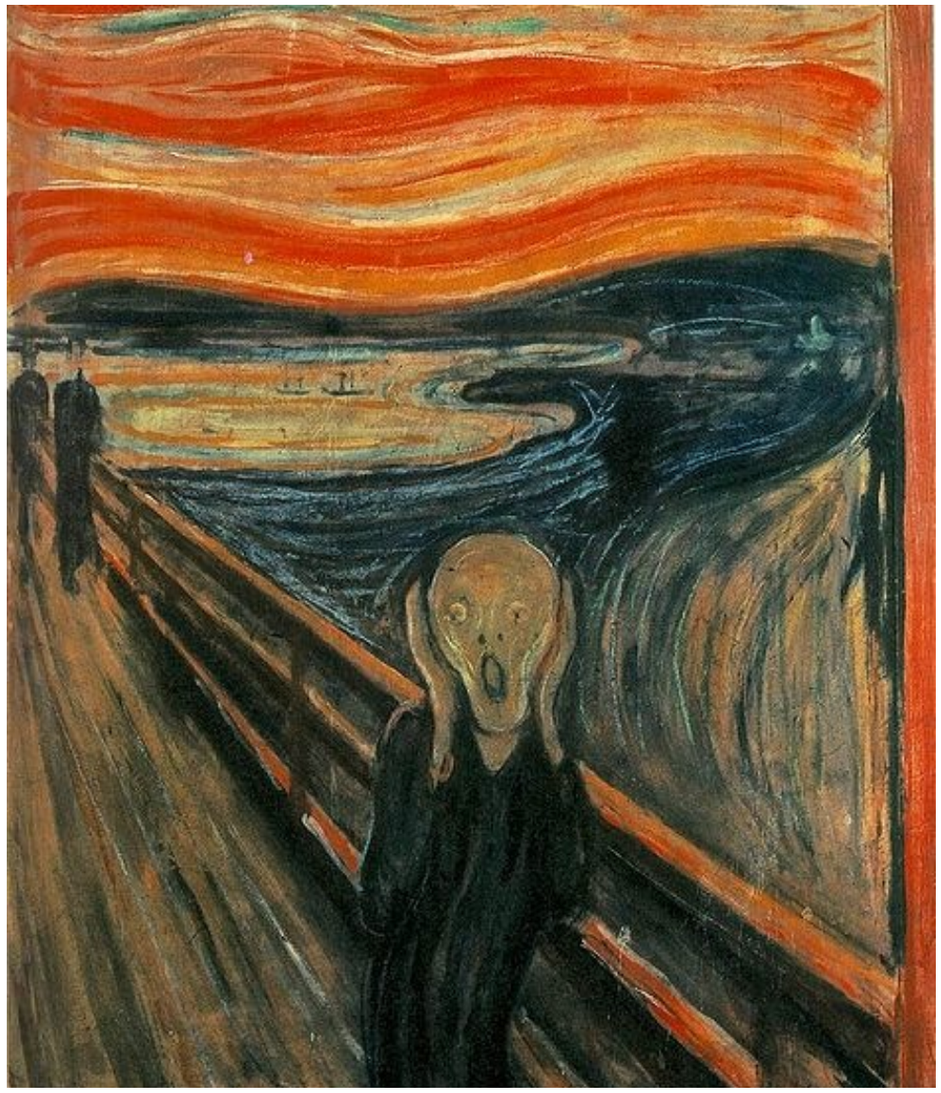


With thanks to Renske Kroeze

TWO FICTITIOUS PATIENTS

DOLORES & EDWARD

Suffering from MD & GAD symptoms



STEP 1: NETWORK MAPPING

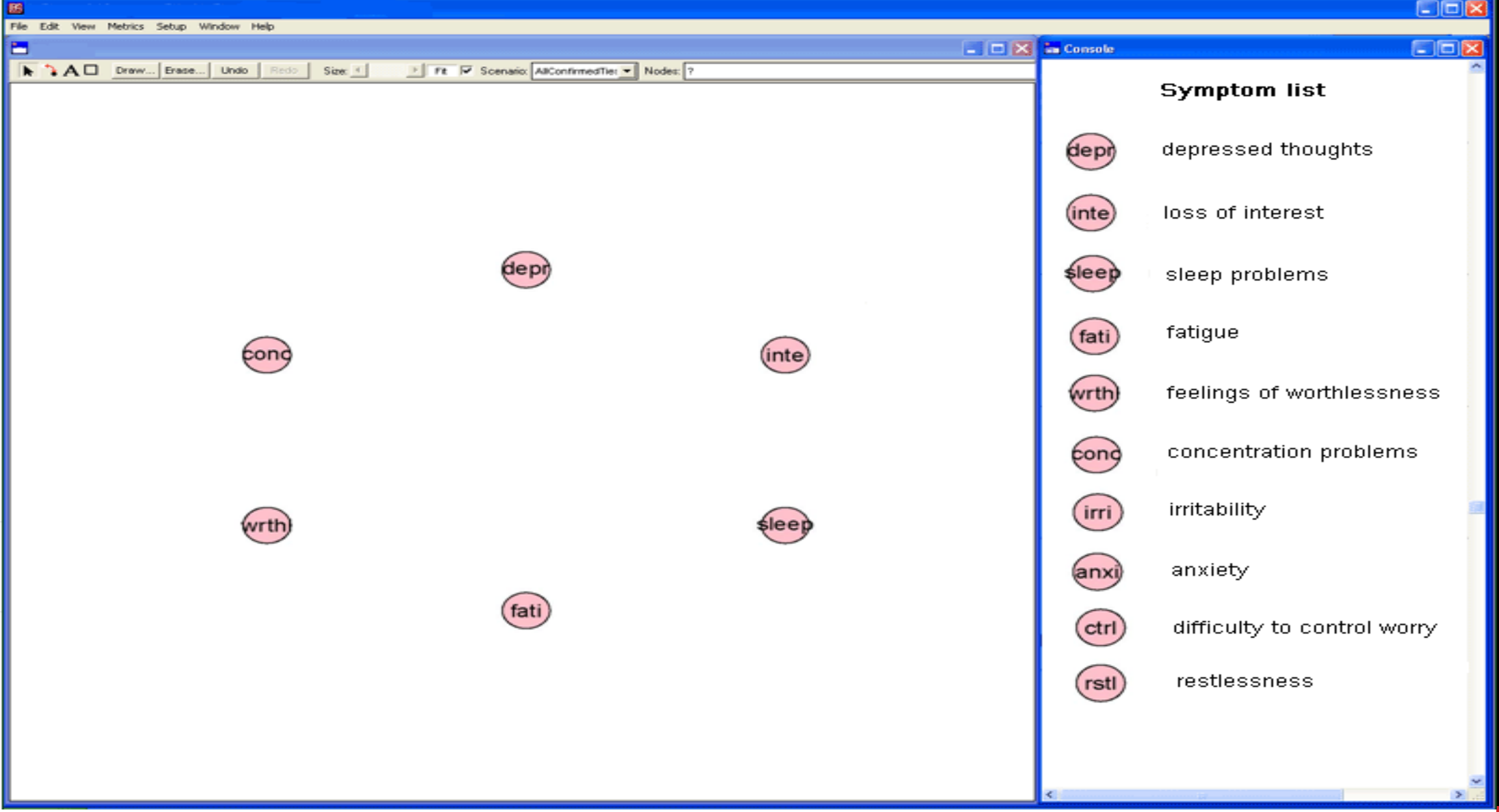
‘STATIC’ MAPPING

- **Perceived Causal Relationships (PCR) Scale[9]**
- **Assess symptoms present**
- **Perceived causality 1-10**

‘DYNAMIC’ MAPPING

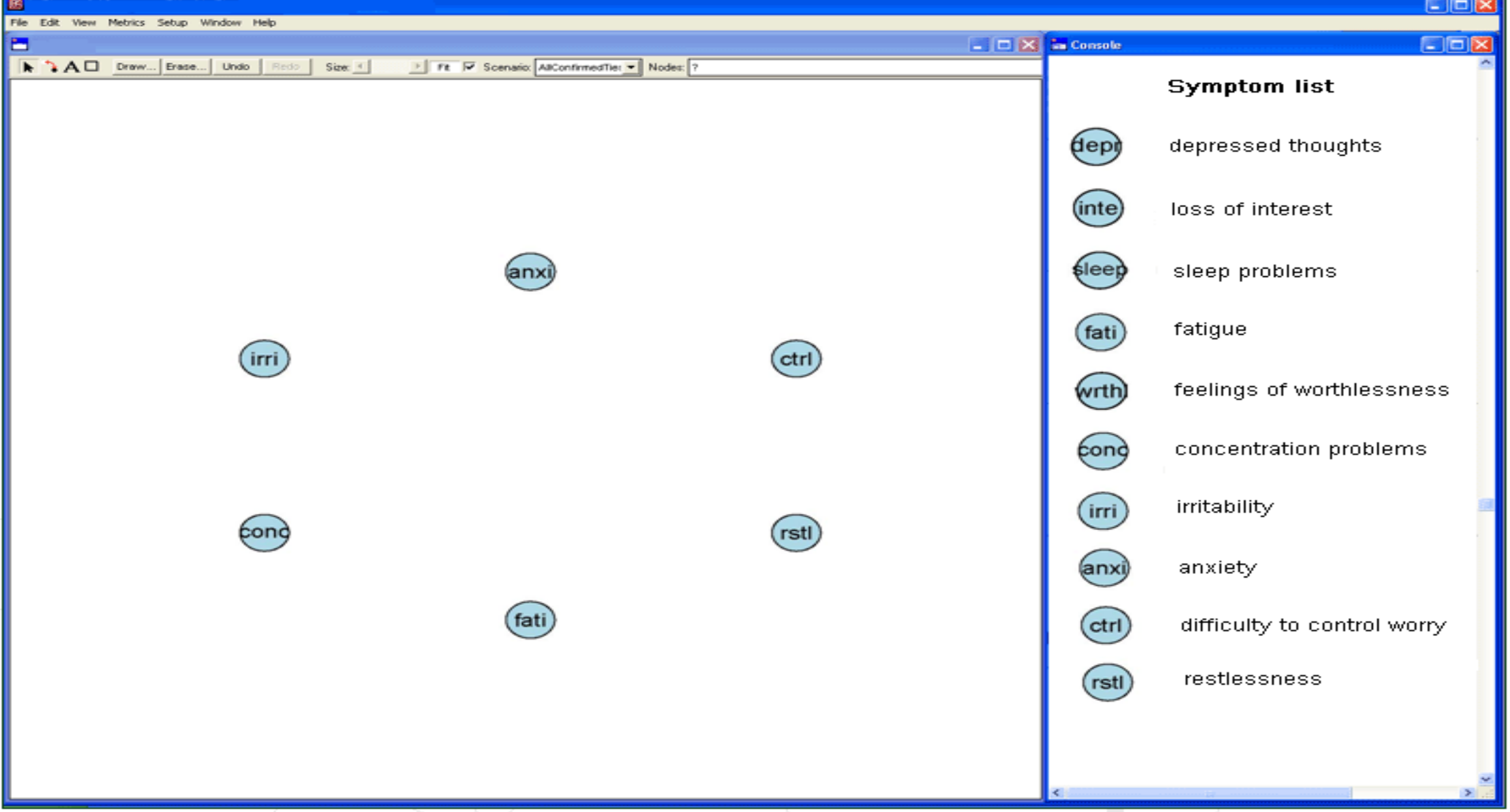
- **Experience Sampling Method (ESM)[10]**
- **Assess symptoms present at different time points**
- **Severity on scale**

9. Frewen et al. (2012)
10. Bringmann et al. (2013)



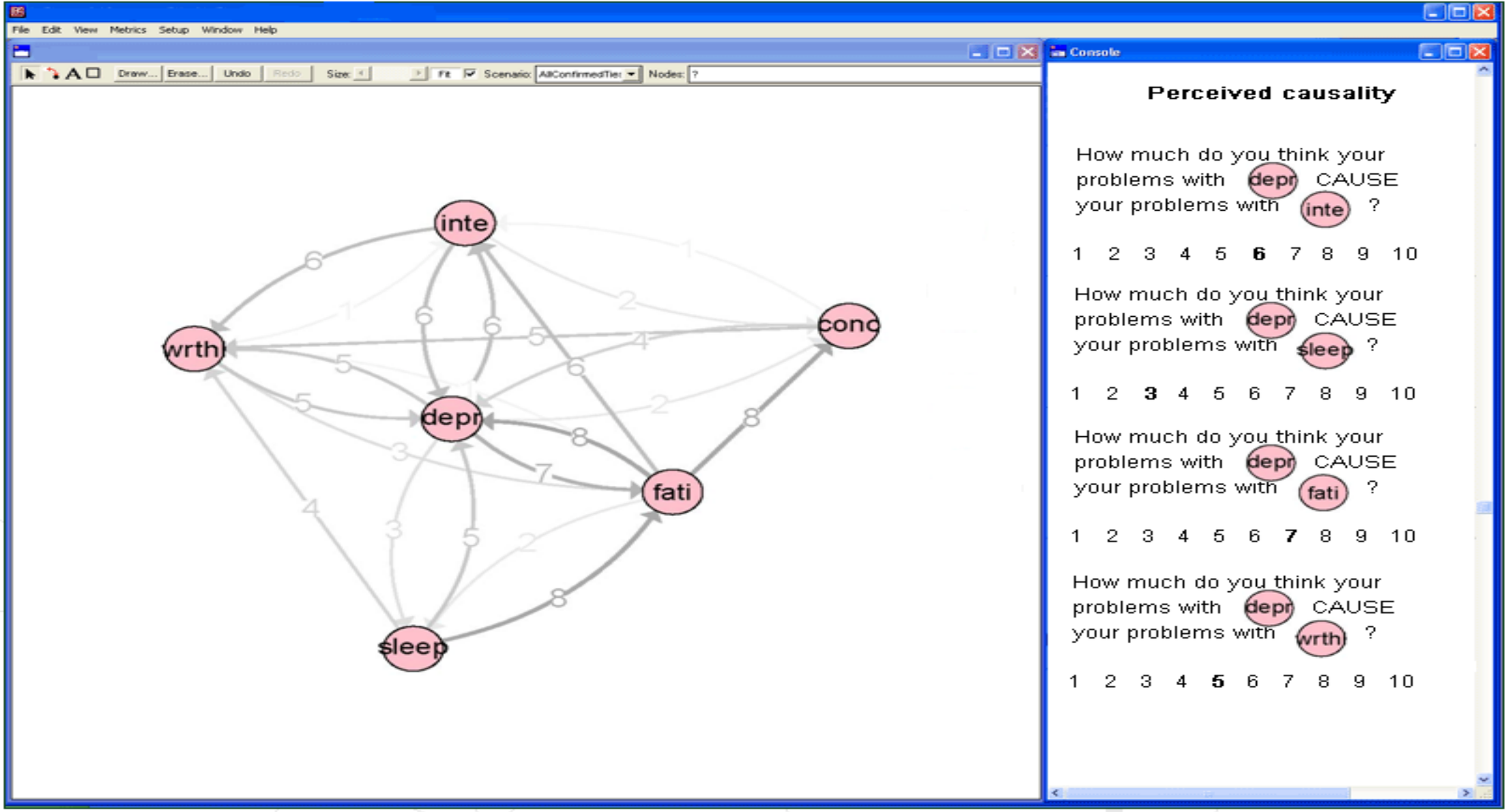
NETWORK MAPPING

First step in mapping Dolores' symptom network



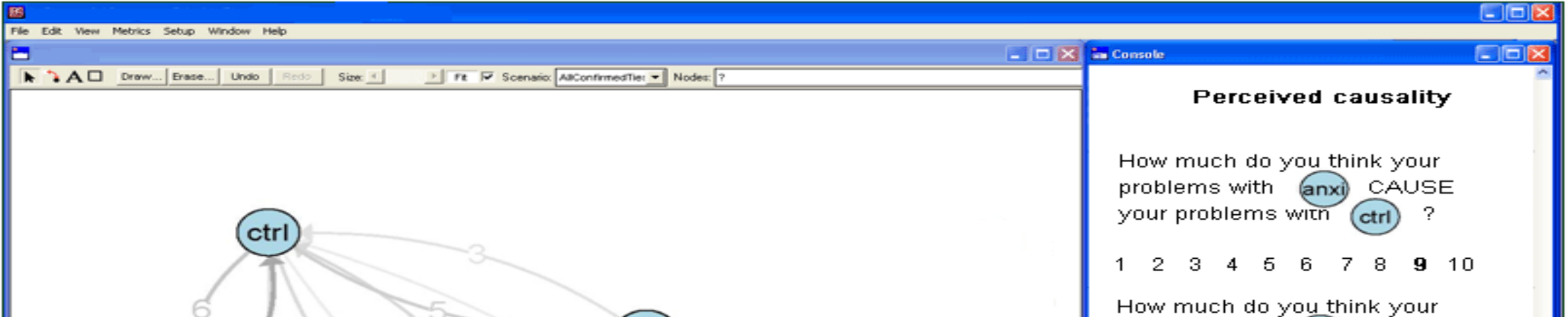
NETWORK MAPPING

First step in mapping Edward's symptom network



NETWORK MAPPING

Adding perceived causal relations to the network of Dolores



NETWORK MAPPING

Perceived causal relations of Edwards compose this network

NETWORK MAPPING

Using a PsyMate[11] resembling device or integrated in iPhone/iPad app

11. www.psymate.eu

STEP 2: CENTRALITY ANALYSIS

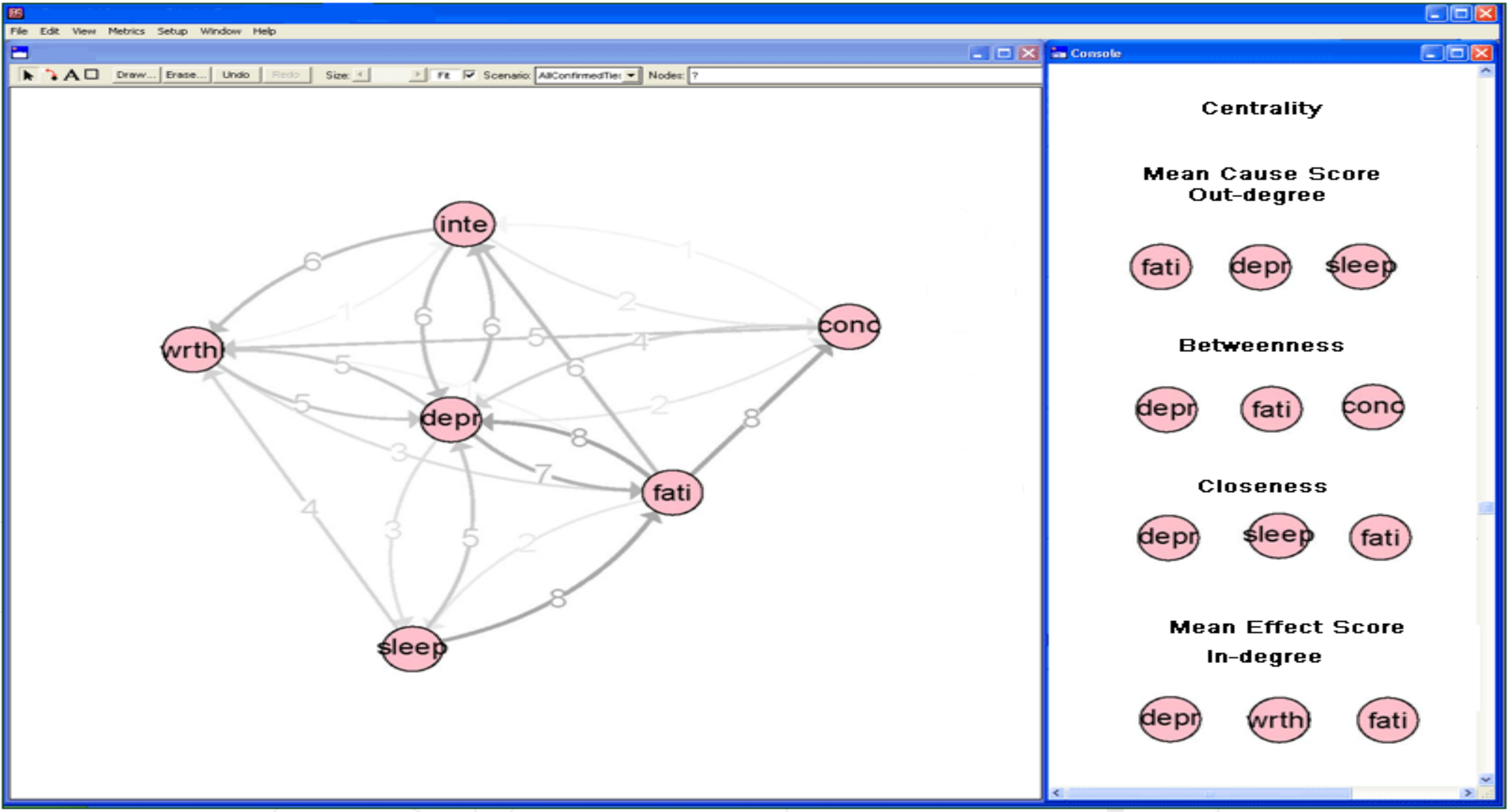
BASED ON CAUSE SCORES PCR SCALE

- Calculate mean causal association scores[12]

BASED ON NETWORK STRUCTURE

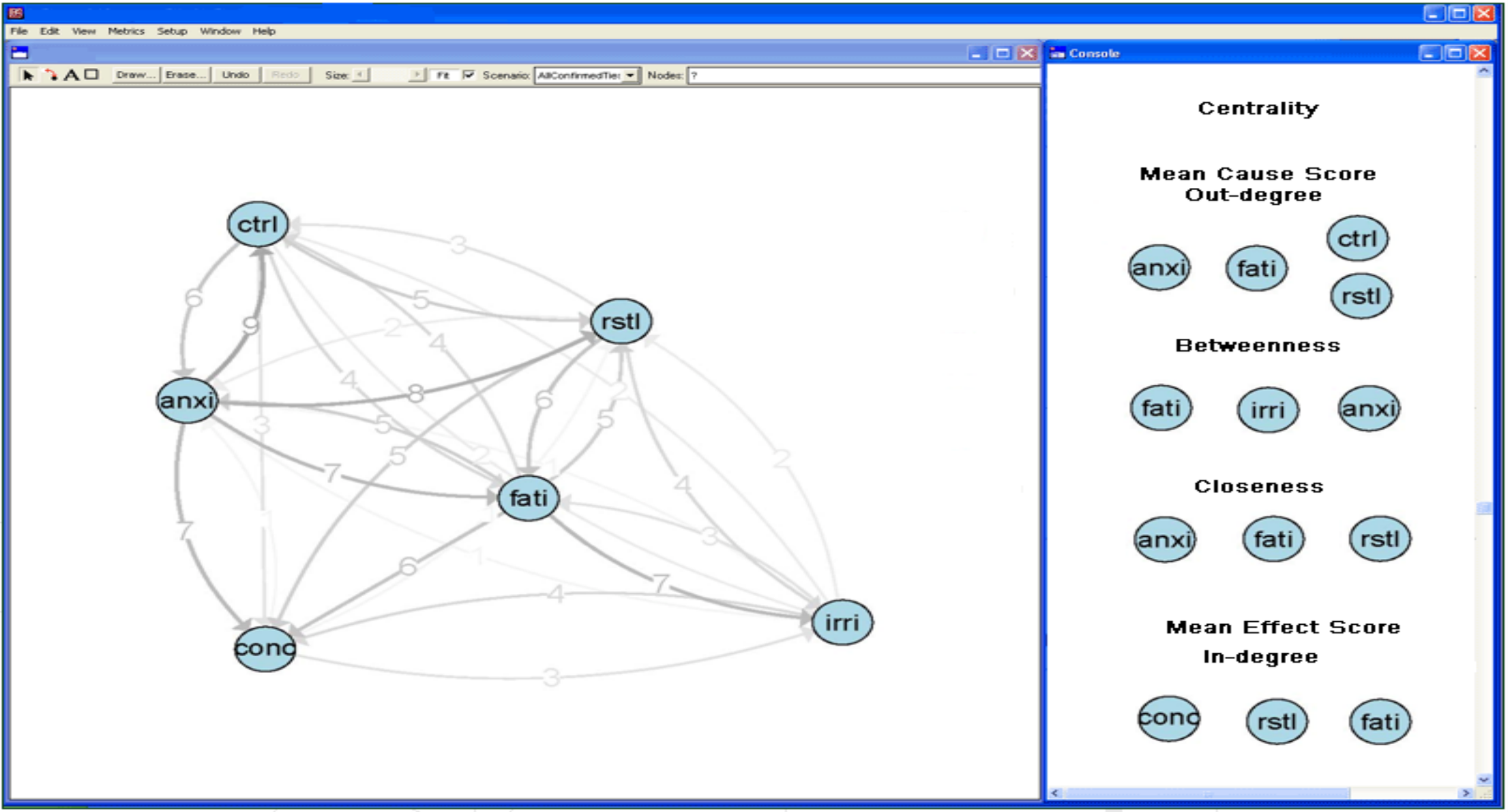
- Degree centrality
- Closeness[13]
- Betweenness[13]
- Eigenvector centrality
- Control centrality[14]

12. Frewen et al. (2012)
13. Opsahl et al. (2010)
14. Liu, Slotine & Barabasi (2012)



CENTRALITY ANALYSIS

Top-3 central symptoms provided for Dolores



CENTRALITY ANALYSIS

Top-3 central symptoms provided for Edward

STEP 3: SELECTING INTERVENTIONS

- **Systematic Treatment Selection (STS)[15]**
- **Mini-interventions[16]**
- **For both patients: sleep or cognitive-behavioral interventions**

15. Norcross & Beutler, 2005
16. http://www.trimbos.org/news/trimbos-news/symptom-oriented-mini-interventions-sleeplessness-worry-and-stress

STEP 4: IMPLEMENTATION

TECHNICAL SKILLS OF THERAPIST

- Executing interventions
- Connecting them to patient's context
- Network education

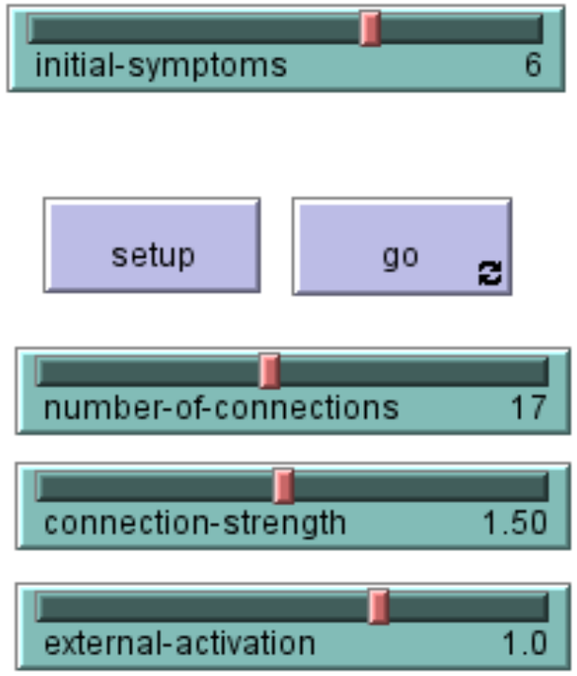
THERAPEUTIC RELATIONSHIP[17]

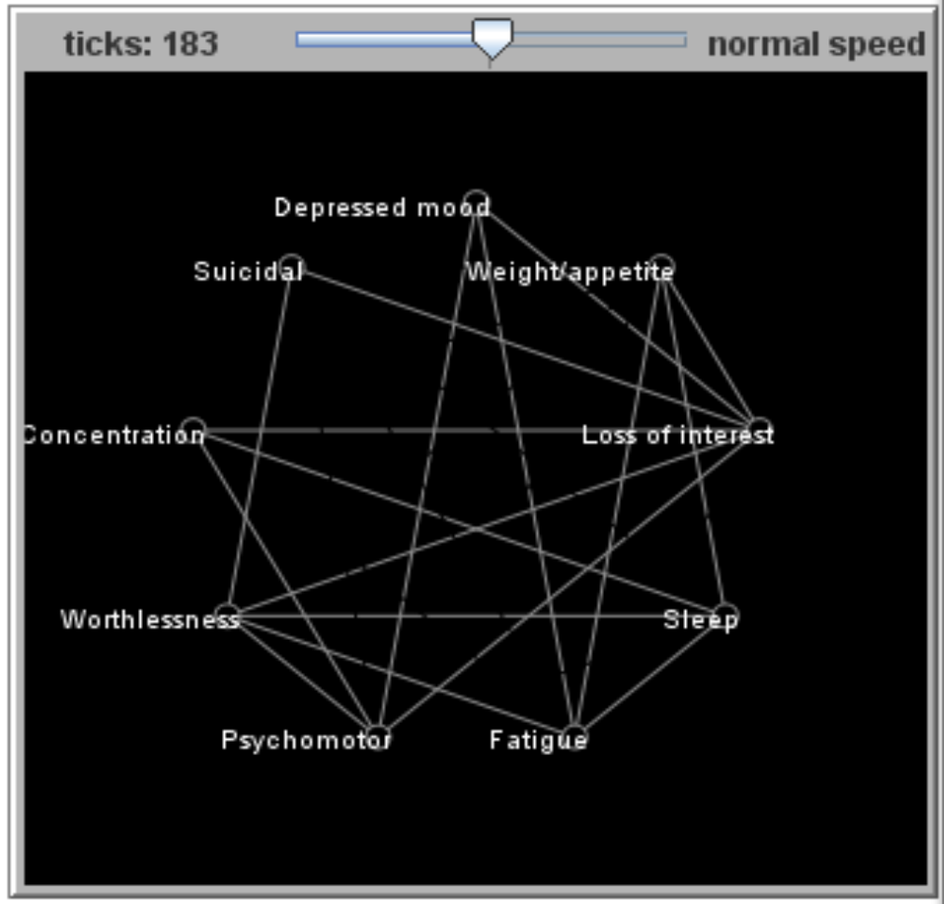
17. Ardito & Rabellino (2011)

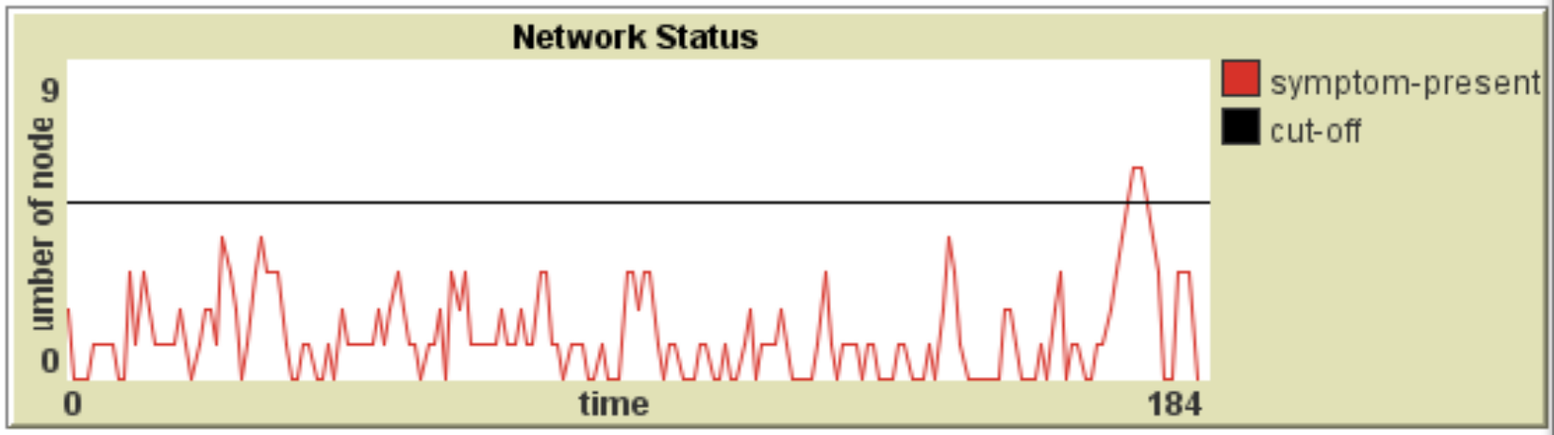
STEP 5: MONITORING THE NETWORK

Detect early warning signals

- **Autocorrelation[18]**
- **Variance[18]**
- **Growing dynamic causal impact over time[19]**





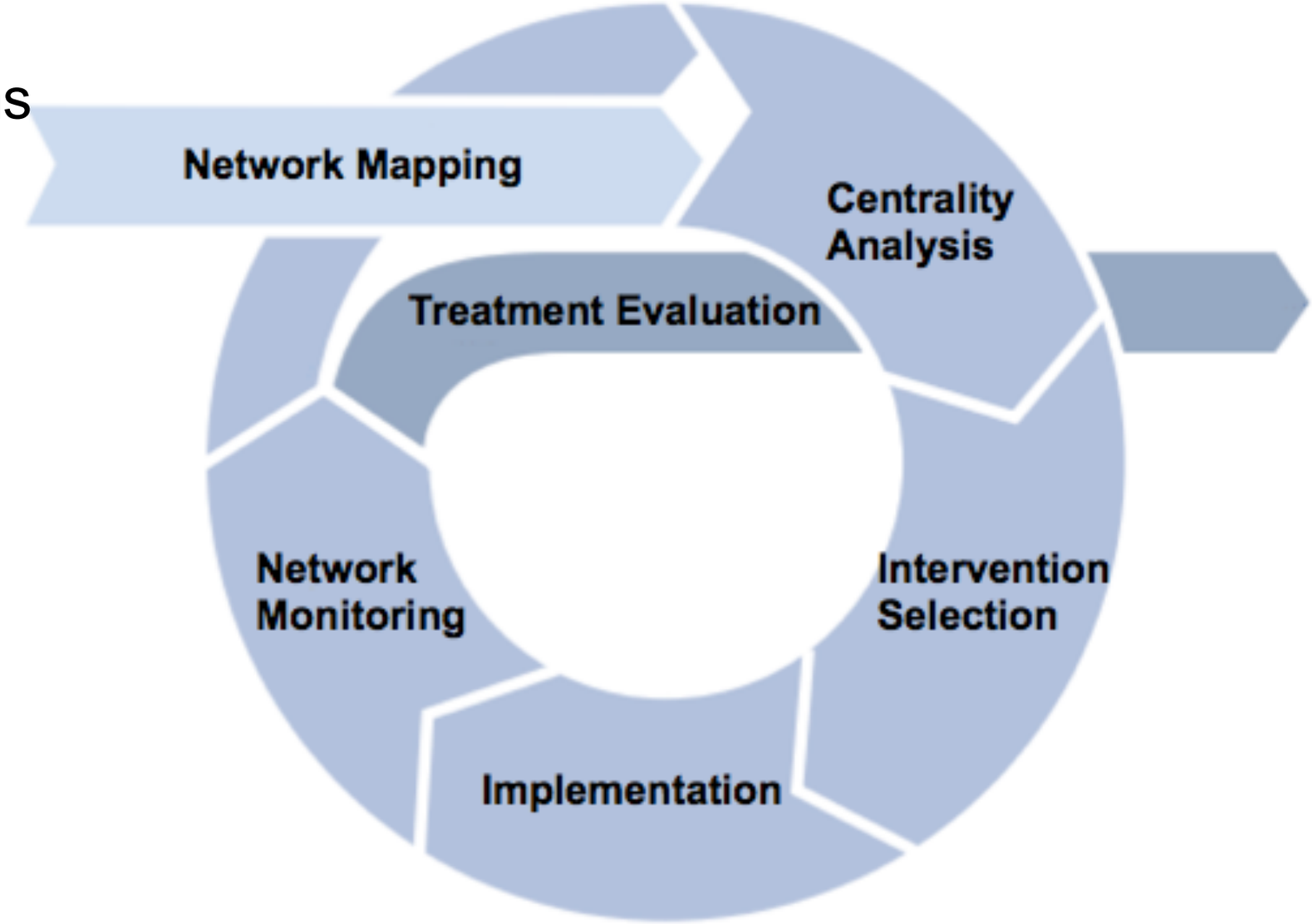


18. Dakos et al. (2012)
19. Wigman et al. (2013)

STEP 6: EVALUATING TREATMENT

Insightful for both

- **Therapist**
  - Effectiveness of chosen interventions
  - Dynamics constituting mental disorders
- **And patient**
  - Awareness of personal symptom dynamics
  - Sense of agency



With thanks to

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- Denny Borsboom

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- Lynn Boschloo

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- Lynn Boschloo

- Renske Kroeze