Time for a new paradigm

a network perspective on psychopathology

Claudia van Borkulo
UMCG-UvA
Overview

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

About networks
Direct relations

I don’t sleep and I’m tired
Direct relations

I don’t sleep and I’m tired
Direct relations

I had a panic attack and I’m afraid I’ll have another one.
I had a panic attack and I’m afraid I’ll have another one
Why networks

About networks

- no sleep
- fatigue
- concentration
- irritable
- depressed
- guilt
- suicidal ideation
- 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 ≠ Clinical practice
Heterogeneity within diagnoses
Comorbidity between diagnoses
Hoe doe je recht aan complexiteit?

Met dank aan Lynn Boschloo
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)
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

A new method: eLasso
- based on Ising model
- $\ell_1$-regularized logistic regression (Ravikumar, Wainwright & Lafferty, 2011)
- Goodness-of-fit measure (extended BIC) (Chen & Chen, 2008)
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?

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

- Psychopathology networks chart showing relationships between different symptoms.
- Strength, Betweenness, and Clustering graphs are also present, indicating the network's connectivity and structure.
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 $\lambda$)
- recovery (with parameter $\mu$)

Ratio $\rho = \lambda / \mu$
$\rho > 1$: supercritical case
process survives forever
What do we need?

- binary multiple observations
- network structure
- parameters for ratio $\rho$ ($\lambda$ and $\mu$)
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)

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

Contact process model

• **Network structure**: eLasso *(adjusted version of IsingFit package in R)*

• **parameter**: Percolation Indicator (PI)

\[
\hat{\lambda}_t = \frac{U_t}{A_t} \quad \hat{\mu}_t = \frac{D_t}{B_t}
\]

Contact process model

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

- **Parameter:** Percolation Indicator (PI)

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

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

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

10. Bringmann et al. (2013)
First step in mapping Dolores’ symptom network
First step in mapping Edward’s symptom network

Symptom list

- dep: depressed thoughts
- inte: loss of interest
- sleep: sleep problems
- fati: fatigue
- wrth: feelings of worthlessness
- conc: concentration problems
- irri: irritability
- anxi: anxiety
- ctrl: difficulty to control worry
- rstl: restlessness
NETWORK MAPPING

Adding perceived causal relations to the network of Dolores
Perceived causal relations of Edwards compose this network.
NETWORK MAPPING

Using a PsyMate\textsuperscript{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 scores¹²

BASED ON NETWORK STRUCTURE

• Degree centrality
• Closeness¹³
• Betweenness¹³
• Eigenvector centrality
• Control centrality¹⁴

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
STEP 4:
IMPLEMENTATION

TECHNICAL SKILLS OF THERAPIST

• Executing interventions
• Connecting them to patient’s context
• Network education

THERAPEUTIC RELATIONSHIP

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
With thanks to

• Denny Borsboom
With thanks to

• Denny Borsboom
• Lynn Boschloo
With thanks to

- Denny Borsboom
- Lynn Boschloo
- Renske Kroeze