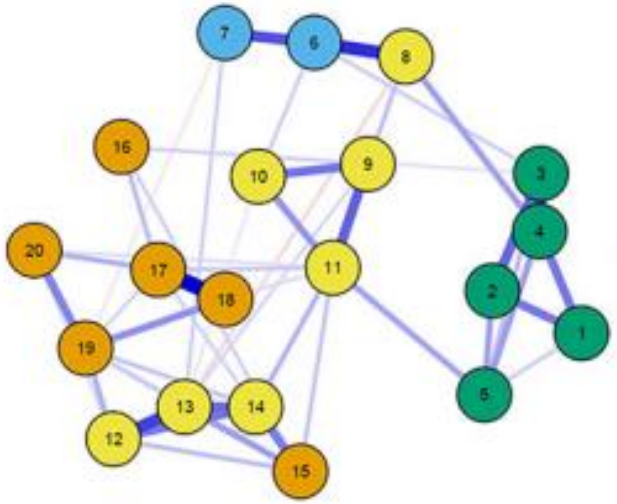


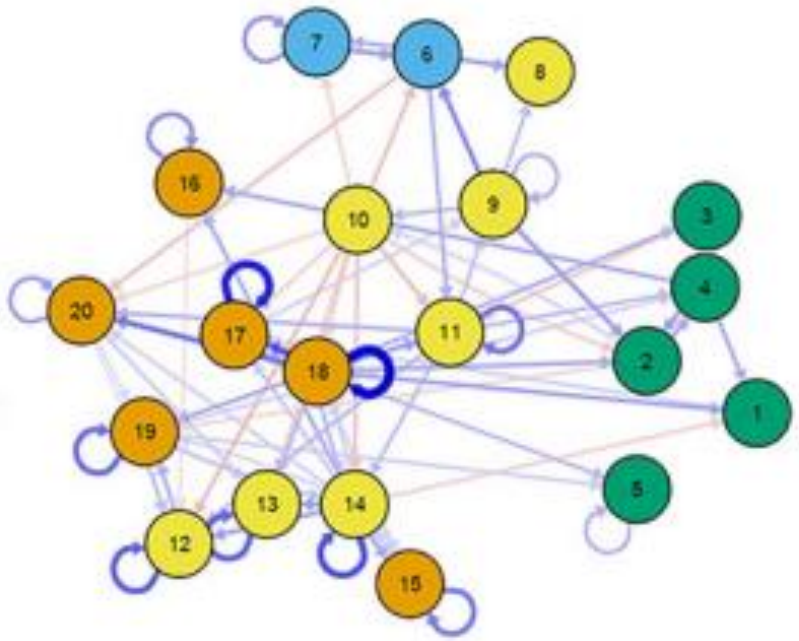
Psychopathology networks

ISBP Summer School

Talya Greene

Community Mental Health

University of Haifa



Networks

- ‘Trendy’ topic
- Complex systems
- Computing, biology, social sciences, neuroscience, economics
- Psychopathology networks – Probably > 150 papers. Increasing exponentially

Overview

- Network theory and psychopathology
- Terminology – ways to interpret a network
- Cross-sectional and intensive longitudinal networks
  - Examples
- Questions/discussion

Resources

- http://psychosystems.org/
- http://eiko-fried.com/
- http://sachaepskamp.com/
- http://psych-networks.com/





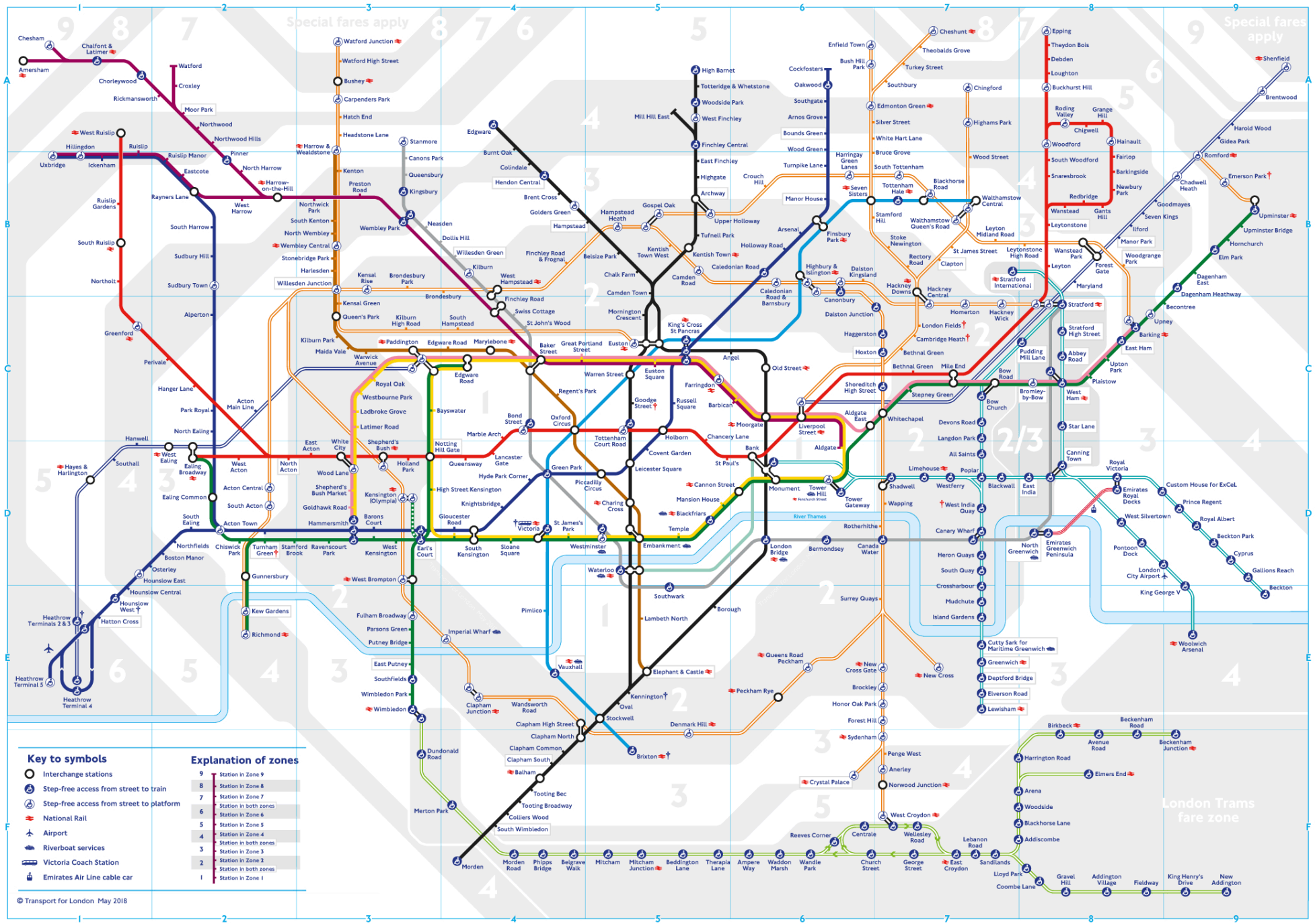


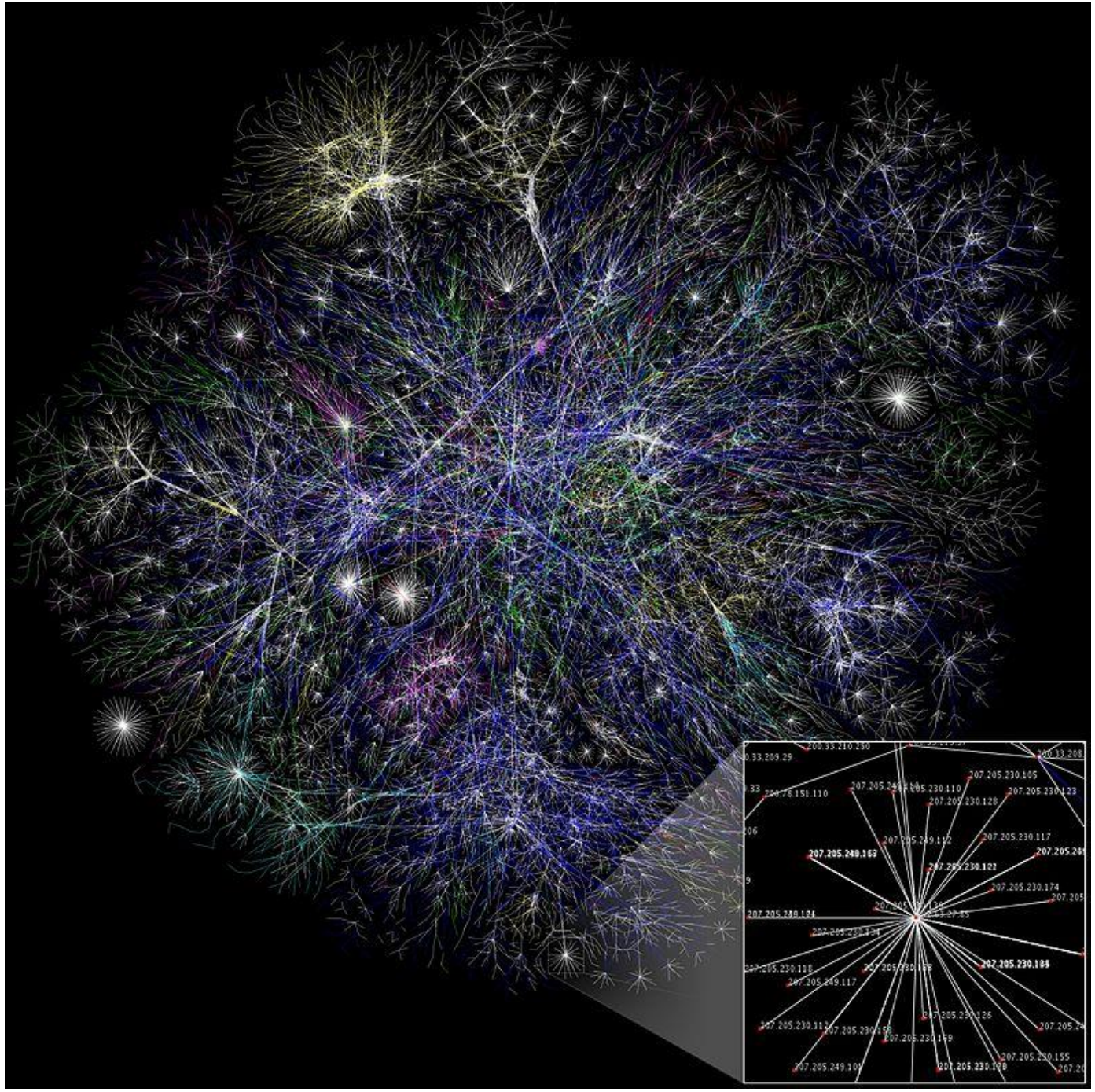


The Psych Systems Project

What is a network?

- A network consists of different **entities** that are **connected** in some way


Special fares apply
Special fares apply
Chesham
Amersham
Chalfont & Latimer
Chorleywood
Rickmansworth
Watford
Croxley
Moor Park
Northwood
Northwood Hills
Pinner
North Harrow
Harrow-on-the-Hill
West Ruislip
Hillingdon
Uxbridge
Ickenham
Ruislip
Ruislip Manor
Eastcote
Ruislip Gardens
South Ruislip
Northolt
Greenford
Perivale
Rayners Lane
West Harrow
South Harrow
Sudbury Hill
Sudbury Town
Alperton
Hanger Lane
Park Royal
North Ealing
Acton Main Line
Hanwell
West Ealing
Ealing Broadway
Southall
Hayes & Harlington
Ealing Common
South Ealing
Acton Town
Northfields
Boston Manor
Osterley
Hounslow East
Hounslow Central
Hounslow West
Hatton Cross
Heathrow Terminals 2 & 3
Heathrow Terminal 5
Heathrow Terminal 4
West Acton
North Acton
East Acton
White City
Acton Central
South Acton
Chiswick Park
Turnham Green
Stamford Brook
Ravenscourt Park
Gunnersbury
Kew Gardens
Richmond
Watford Junction
Watford High Street
Bushey
Carpenders Park
Hatch End
Headstone Lane
Harrow & Wealdstone
Kenton
Preston Road
Northwick Park
South Kenton
North Wembley
Wembley Central
Stonebridge Park
Harlesden
Willesden Junction
Kensal Rise
Kensal Green
Queen's Park
Brondesbury Park
Brondesbury
Kilburn High Road
South Hampstead
Kilburn Park
Maida Vale
Warwick Avenue
Paddington
Edgware Road
Marylebone
Stanmore
Canons Park
Queensbury
Kingsbury
Wembley Park
Neasden
Dollis Hill
Willesden Green
Kilburn
West Hampstead
Finchley Road
Swiss Cottage
St John's Wood
Edgware
Burnt Oak
Colindale
Hendon Central
Brent Cross
Golders Green
Hampstead
Finchley Road & Frognal
Belsize Park
Hampstead Heath
Gospel Oak
Chalk Farm
Camden Town
Mornington Crescent
Kentish Town West
Camden Road
Kentish Town
Caledonian Road
Caledonian Road & Barnsbury
Highbury & Islington
Canonbury
Dalston Junction
Dalston Kingsland
Hackney Central
Hackney Downs
Homerton
Hackney Wick
London Fields
Cambridge Heath
Bethnal Green
Mile End
Bethnal Green
Haggerston
Hoxton
Shoreditch High Street
Stepney Green
Bow Road
Bow Church
Devons Road
Langdon Park
All Saints
Poplar
Limehouse
Westferry
West India Quay
Canary Wharf
Heron Quays
South Quay
Crossharbour
Mudchute
Island Gardens
Cutty Sark for Maritime Greenwich
Greenwich
Deptford Bridge
Elverson Road
Lewisham
Blackwall
East India
Canning Town
Star Lane
Pudding Mill Lane
Abbey Road
West Ham
Bromley-by-Bow
Stratford International
Stratford
Stratford High Street
Forest Gate
Maryland
Leytonstone
Wanstead Park
Leyton
Leytonstone High Road
Leyton Midland Road
Walthamstow Central
Blackhorse Road
Tottenham Hale
Stamford Hill
Walthamstow Queen's Road
Stoke Newington
Rectory Road
Clapton
St James Street
Seven Sisters
Finsbury Park
Arsenal
Holloway Road
Highgate
Archway
Upper Holloway
Tufnell Park
Crouch Hill
Manor House
Turnpike Lane
Harringay Green Lanes
Wood Green
Bounds Green
Arnos Grove
Southgate
Oakwood
Cockfosters
Enfield Town
Bush Hill Park
Southbury
Edmonton Green
Silver Street
White Hart Lane
Bruce Grove
South Tottenham
Cheshunt
Theobalds Grove
Turkey Street
Chingford
Highams Park
Wood Street
Epping
Theydon Bois
Debden
Loughton
Buckhurst Hill
Roding Valley
Grange Hill
Chigwell
Woodford
South Woodford
Snaresbrook
Redbridge
Wanstead
Gants Hill
Hainault
Fairlop
Barkingside
Newbury Park
Shenfield
Brentwood
Harold Wood
Gidea Park
Romford
Emerson Park
Upminster
Upminster Bridge
Hornchurch
Elm Park
Dagenham East
Dagenham Heathway
Becontree
Upney
Barking
East Ham
Upton Park
Plaistow
Chadwell Heath
Goodmayes
Seven Kings
Ilford
Manor Park
Woodgrange Park
High Barnet
Totteridge & Whetstone
Woodside Park
West Finchley
Finchley Central
East Finchley
Mill Hill East
Moorgate
Barbican
Farringdon
Angel
Old Street
Liverpool Street
Aldgate East
Aldgate
Whitechapel
Shadwell
Wapping
Rotherhithe
Bermondsey
Canada Water
Surrey Quays
New Cross Gate
New Cross
Brockley
Honor Oak Park
Forest Hill
Sydenham
Penge West
Anerley
Norwood Junction
West Croydon
Wellesley Road
Centrale
Reeves Corner
Lebanon Road
Sandilands
Lloyd Park
Coombe Lane
Gravel Hill
Addington Village
Fieldway
King Henry's Drive
New Addington
Addiscombe
Blackhorse Lane
Woodside
Arena
Elmers End
Harrington Road
Birkbeck
Avenue Road
Beckenham Junction
Beckenham Road
Crystal Palace
Royal Oak
Westbourne Park
Ladbroke Grove
Latimer Road
Shepherd's Bush
Shepherd's Bush Market
Goldhawk Road
Hammersmith
Holland Park
Kensington (Olympia)
Barons Court
West Kensington
Earl's Court
West Brompton
Fulham Broadway
Parsons Green
Putney Bridge
East Putney
Southfields
Wimbledon Park
Wimbledon
Dundonald Road
Merton Park
Morden
Morden Road
Phipps Bridge
Belgrave Walk
Mitcham
Mitcham Junction
Beddington Lane
Therapia Lane
Ampere Way
Waddon Marsh
Wandle Park
Church Street
George Street
East Croydon
Sandilands
Wood Lane
Notting Hill Gate
Queensway
Bayswater
Lancaster Gate
Marble Arch
Bond Street
Hyde Park Corner
High Street Kensington
Knightsbridge
Gloucester Road
South Kensington
Sloane Square
Victoria
St James's Park
Westminster
Pimlico
Vauxhall
Clapham Junction
Wandsworth Road
Clapham High Street
Clapham North
Clapham Common
Clapham South
Balham
Tooting Bec
Tooting Broadway
Colliers Wood
South Wimbledon
Stockwell
Oval
Kennington
Brixton
Denmark Hill
Peckham Rye
Queens Road Peckham
Elephant & Castle
Lambeth North
Waterloo
Southwark
Borough
London Bridge
Monument
Tower Hill
Tower Gateway
Bank
Cannon Street
Mansion House
Blackfriars
Temple
Embankment
Charing Cross
Leicester Square
Covent Garden
Holborn
Chancery Lane
St Paul's
Tottenham Court Road
Oxford Circus
Regent's Park
Great Portland Street
Baker Street
Euston
Euston Square
Warren Street
Goodge Street
Russell Square
Piccadilly Circus
Green Park
Edgware Road
Marylebone
Royal Victoria
Custom House for ExCeL
Prince Regent
Royal Albert
Beckton Park
Cyprus
Gallions Reach
Beckton
Emirates Royal Docks
West Silvertown
Pontoon Dock
London City Airport
King George V
Woolwich Arsenal
North Greenwich
Emirates Greenwich Peninsula
River Thames
London Trams fare zone
Key to symbols
Interchange stations
Step-free access from street to train
Step-free access from street to platform
National Rail
Airport
Riverboat services
Victoria Coach Station
Emirates Air Line cable car
Explanation of zones
9 Station in Zone 9
8 Station in Zone 8
7 Station in Zone 7
6 Station in both zones
6 Station in Zone 6
5 Station in Zone 5
4 Station in Zone 4
3 Station in both zones
3 Station in Zone 3
2 Station in Zone 2
2 Station in both zones
1 Station in Zone 1
© Transport for London May 2018


207.205.230.105
207.205.230.110
207.205.230.126
207.205.230.117
207.205.230.174
207.205.230.124
207.205.230.186
207.205.249.117
207.205.230.155

Psychopathology networks

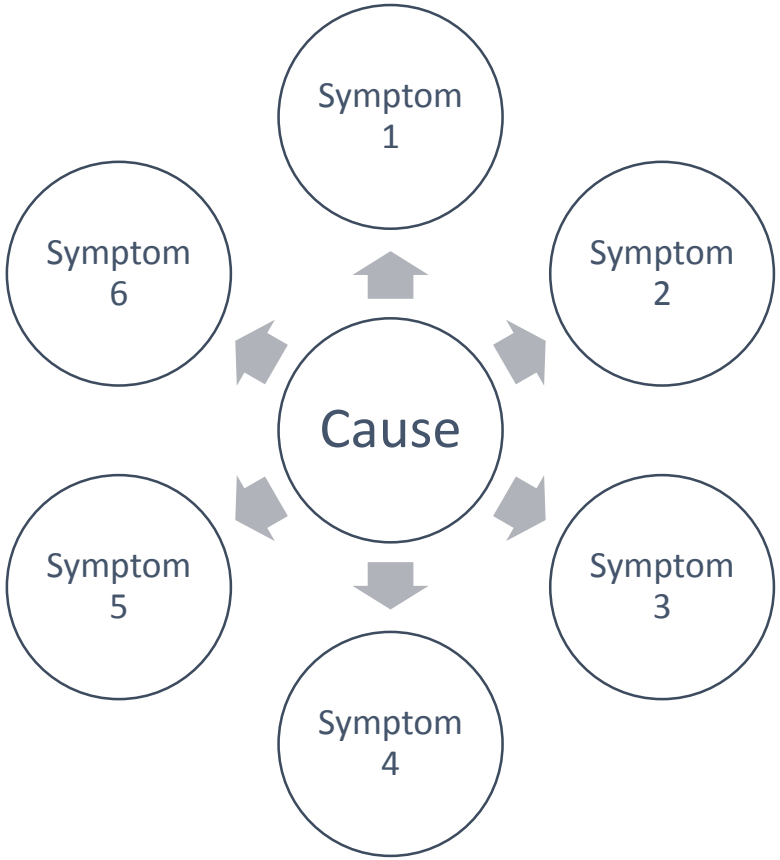
Common cause model

- Robert Koch 1905– Received Nobel Prize
- Microbiologist – identified specific causative agents of specific diseases
- E.g., TB, cholera, anthrax
- Emil Kraepelin – Argued Dementia Praecox = neurobiological origin

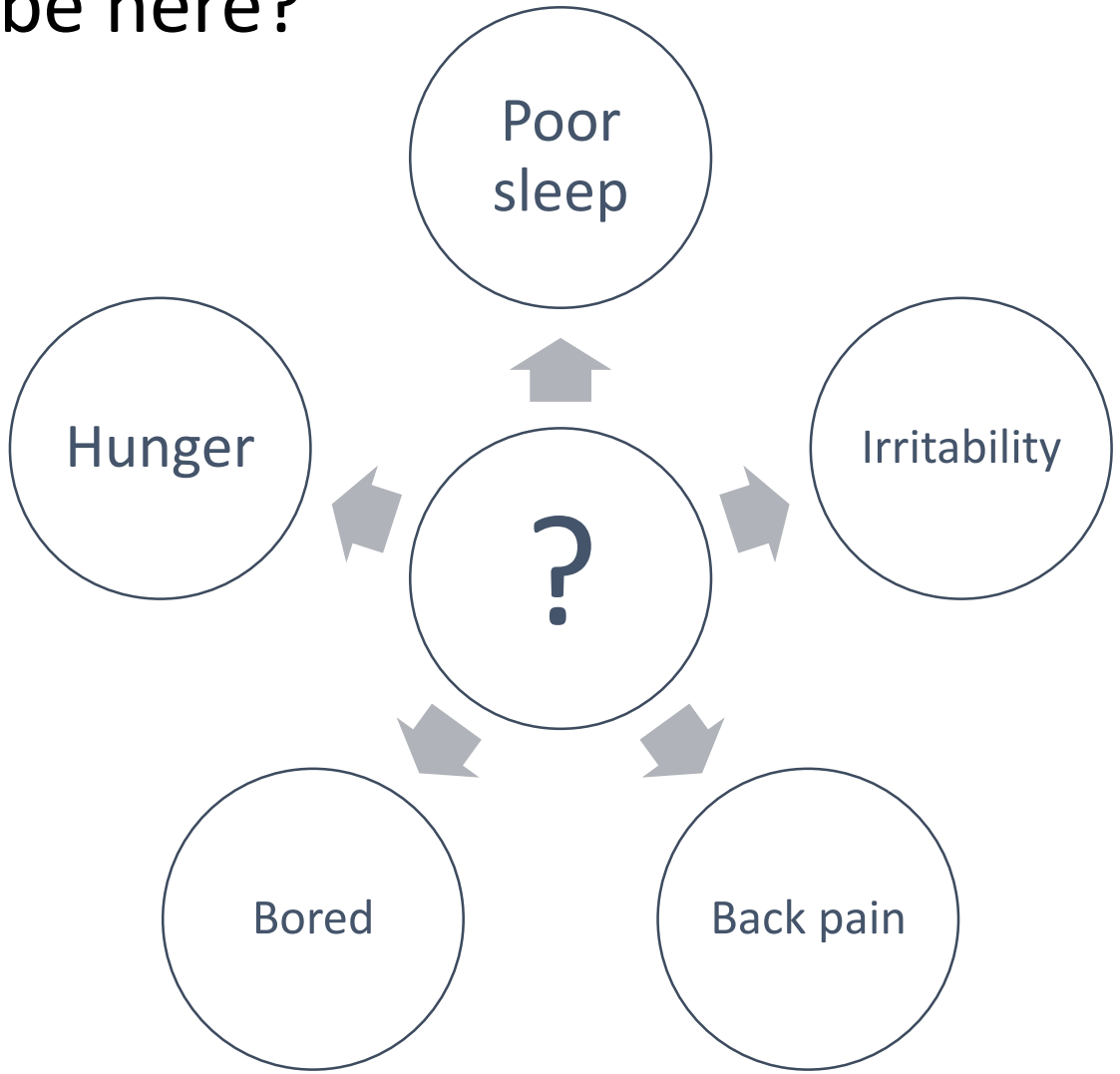
- Disorder/disease *causes* symptoms.

Common cause model

- Assumption = a latent causal factor
- Symptoms result from this cause
- We observe the symptoms and often infer cause



What could the common cause be here?

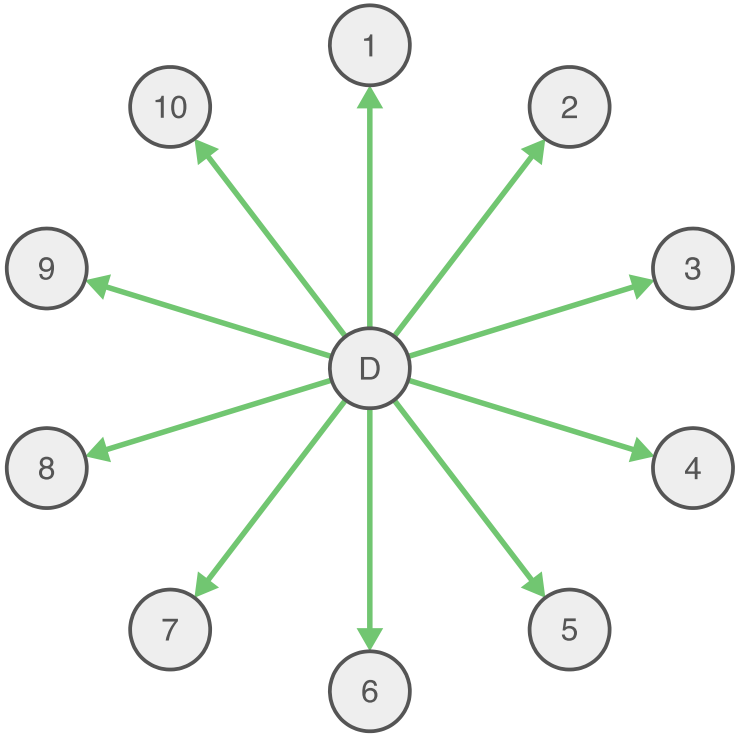


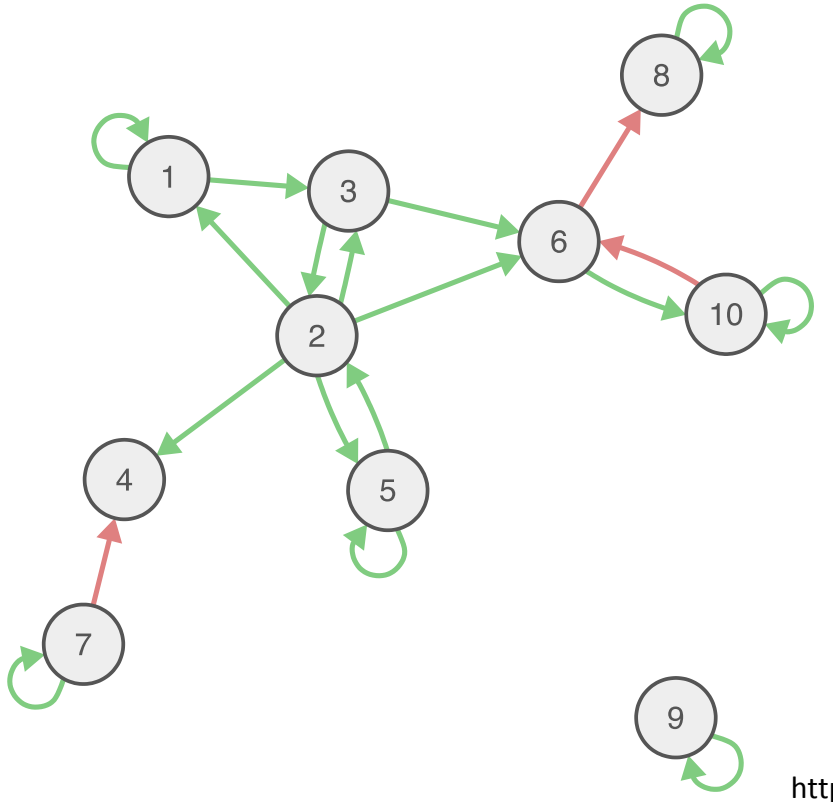
Network perspective and psychopathology

- Common cause/latent variable approaches are flawed
- Symptoms interact in meaningful ways
- Symptoms are not interchangeable
- These symptoms can be understood as a causal system
- The symptoms *constitute the disorder* rather than *resulting from the disorder*
- McNally (2016): Network analysis could potentially transform understanding and treatment of psychopathology

Network perspective

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

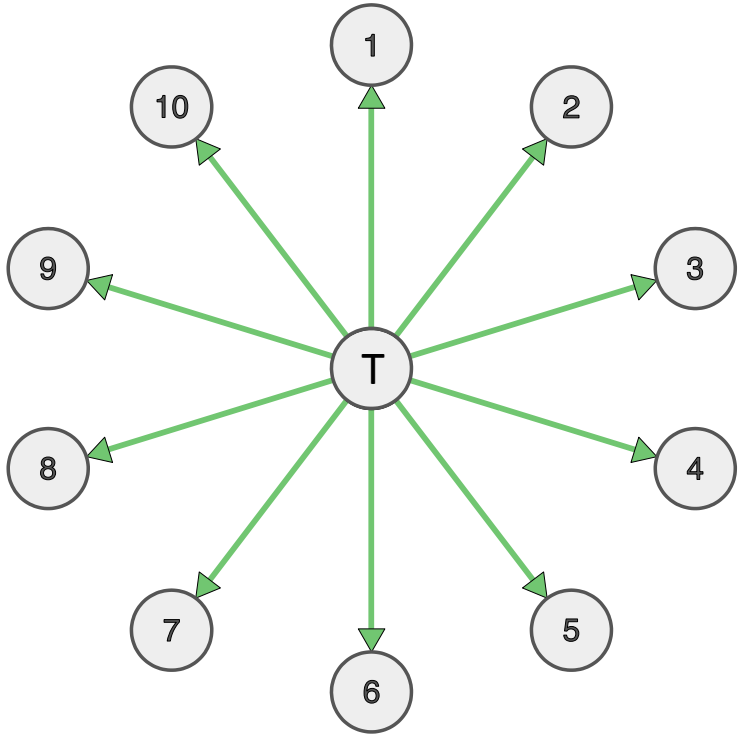


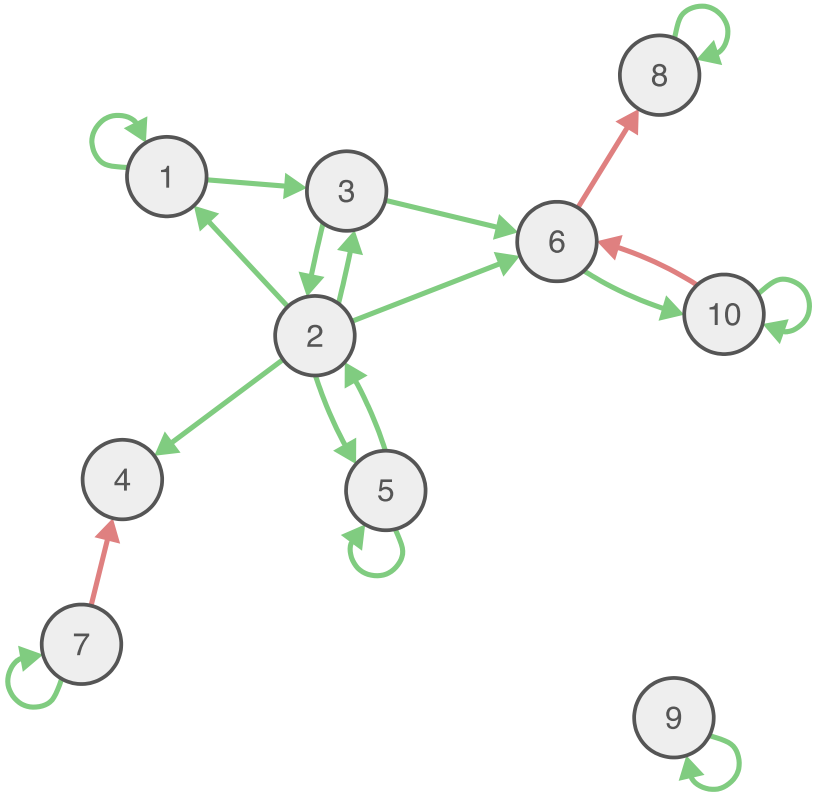


http://eiko-fried.com/vgct2017/

Hybrid models

- ONSET: Trauma → Acute stress/PTSD symptoms
- Build-up or maintenance of symptoms





Fried, E. I., & Cramer, A. O. (2017). Moving forward: challenges and directions for psychopathological network theory and methodology. *Perspectives on Psychological Science*, *12*(6), 999-1020.

Network terminology

Network theory

Network models are statistical models and need to be clearly distinguished from network theory

SPECIAL ARTICLE

A network theory of mental disorders

Denny Borsboom

Department of Psychology, University of Amsterdam, Amsterdam 1018 XA, The Netherlands

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry*, *16*(1), 5-13.

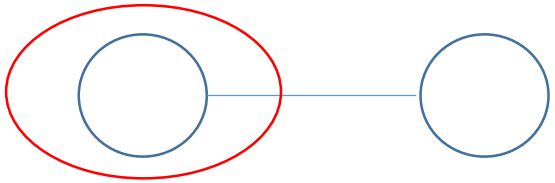
Exploratory

- Networks are exploratory
- **Generate hypotheses**
- Can’t be use to confirm hypotheses

Terminology

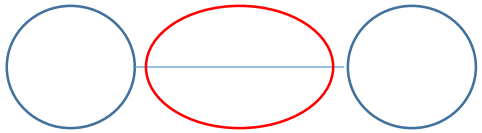
- Entities are called ***nodes***

  Can be anything – person, train station, behavior, symptom



- Connections are called ***edges***

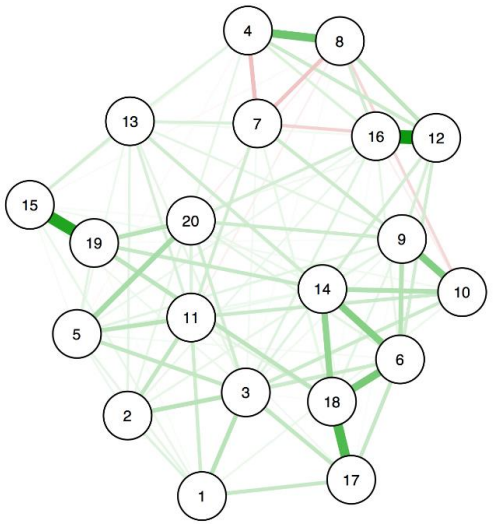
  Represent a relationship – interaction, effect, distance, etc.

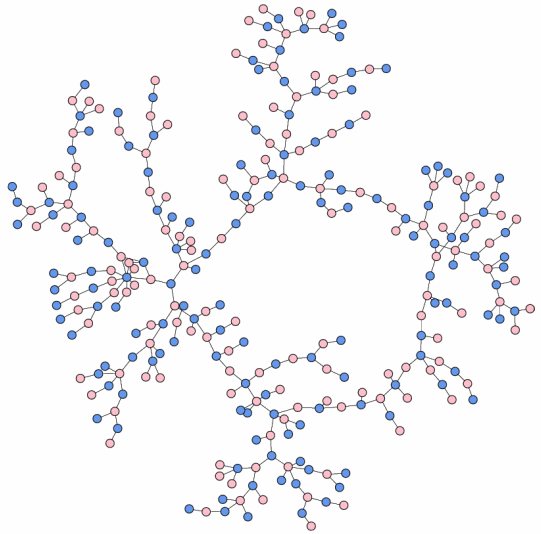


Psychological networks

In psychological networks, nodes are items (e.g., symptoms, emotions), and edges are statistical relationships

Unlike social networks, edges are unobserved and therefore need to be estimated.

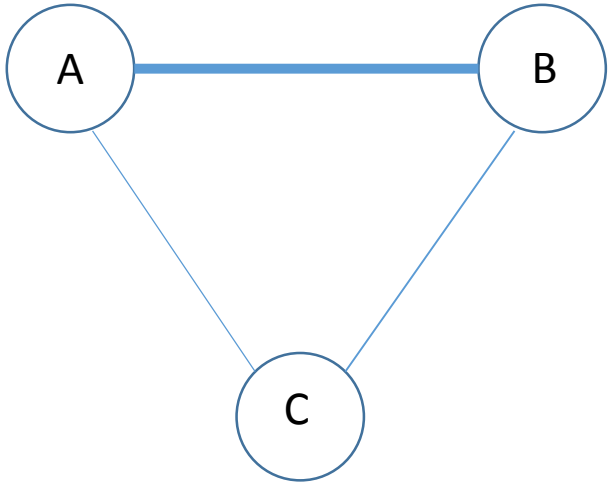


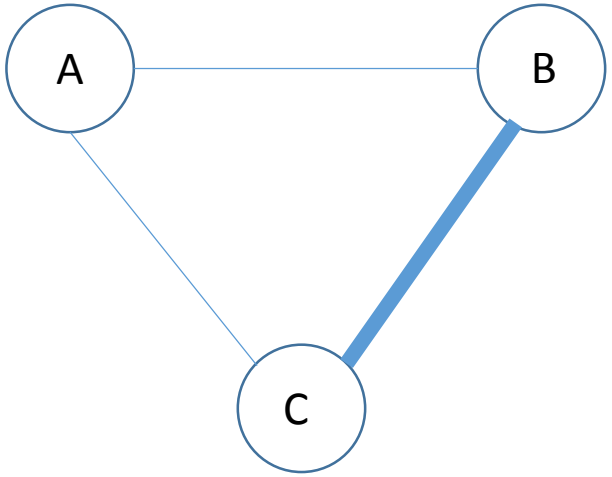


http://eiko-fried.com/vgct2017/

Edge weights

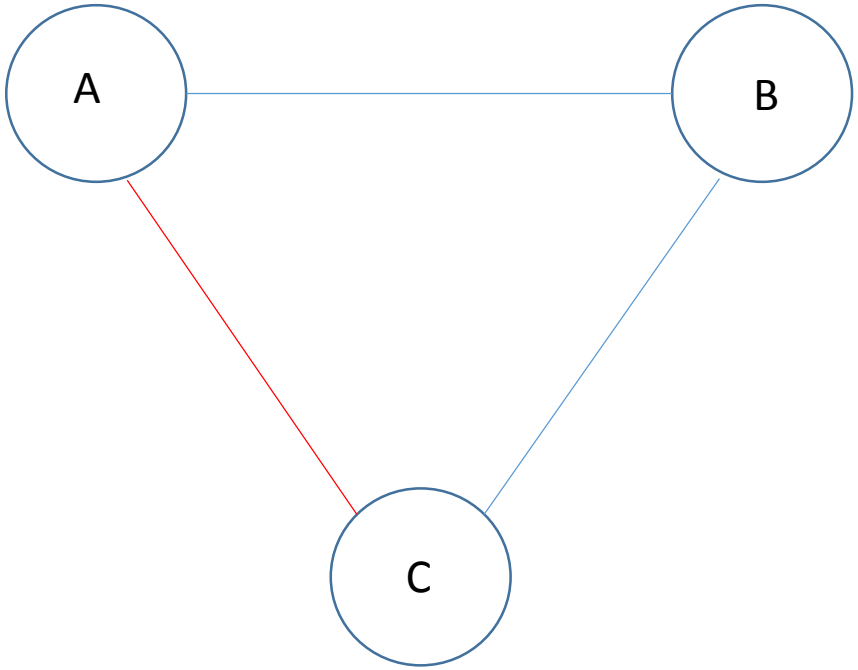
- Edges can *weighted* to represent the strength of the relationship
- Weights are represented by line thickness





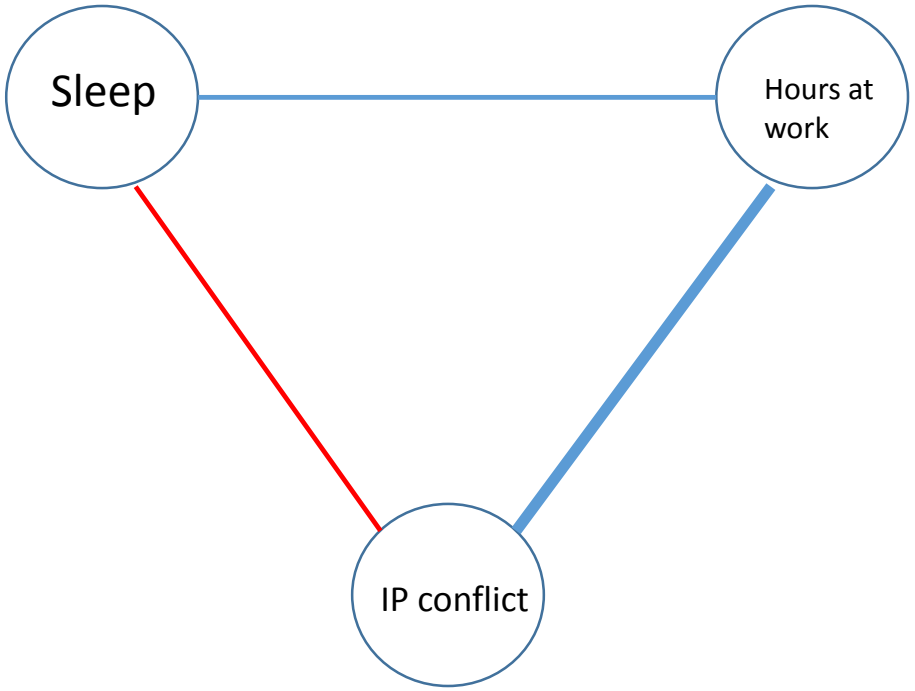
Signs of edges

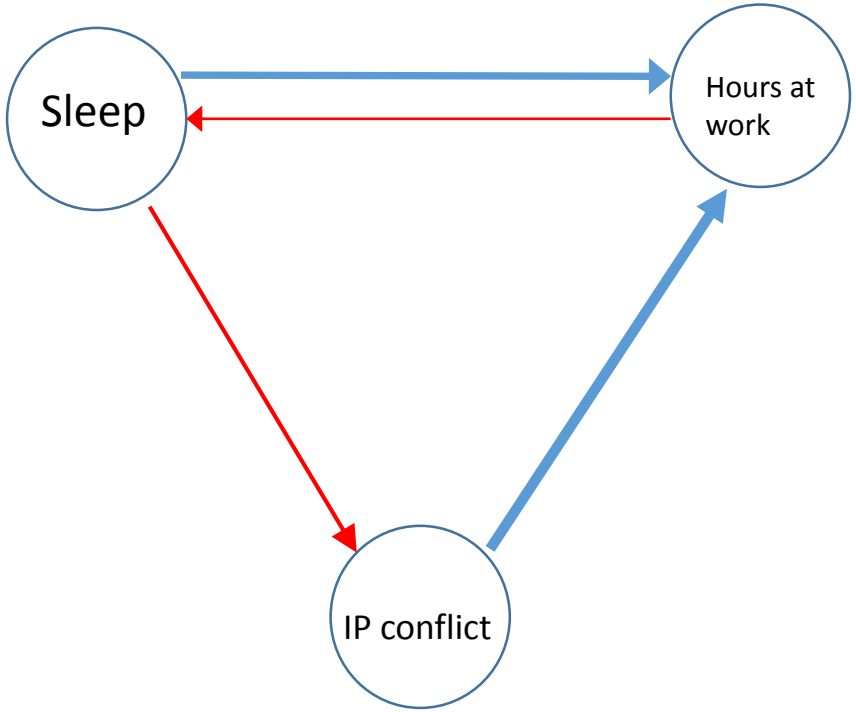
- Edges can have a sign
- Usually coloured to show positive or negative associations
- Typically green/blue = positive and red = negative



Directed edges

Networks can be *undirected* or *directed*





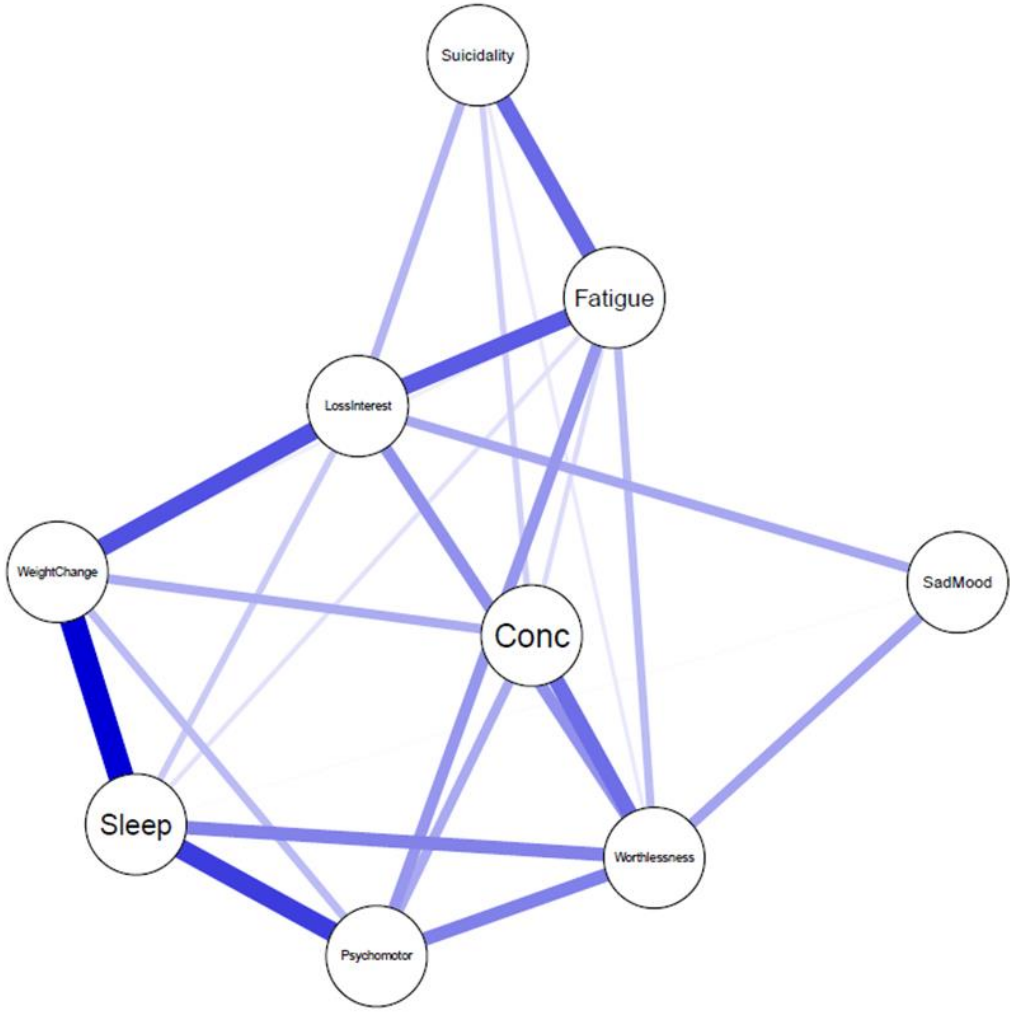
Centrality

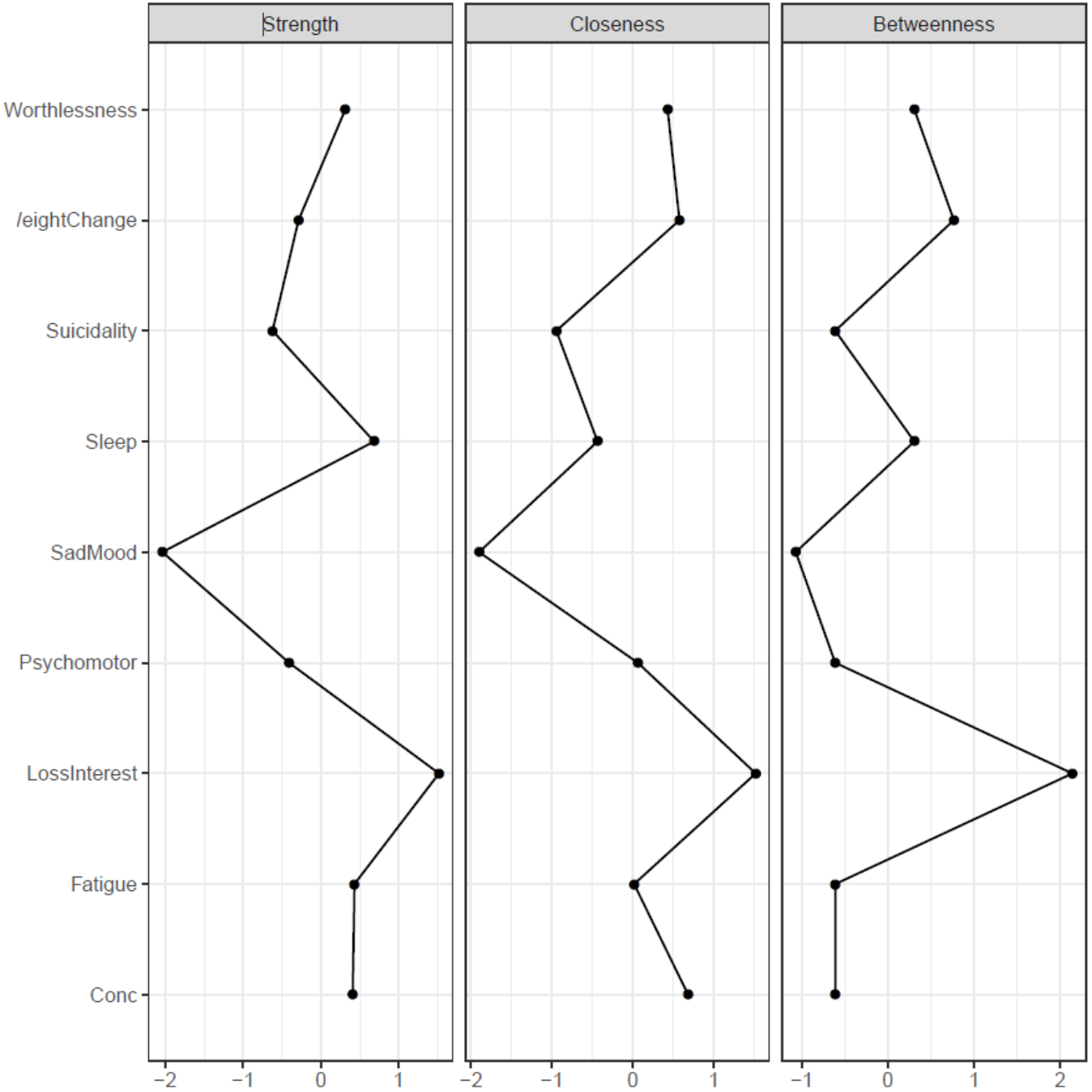
- A central symptom is one that is important to the network – highly connected
- Activating this symptom could spread symptom activation throughout the network
- Peripheral symptoms have fewer connections and less influence on the network

Centrality

- Centrality represents the connectedness of a given symptom with all other symptoms in the network
- **Node strength centrality / degree centrality:** sum of all direct associations a given symptom exhibits with all other nodes
- **Betweenness centrality:** how many times a symptom lies along the shortest paths between other pairs of symptoms
- **Closeness centrality:** inverse of the sum of all shortest paths between a node and all other nodes in the network

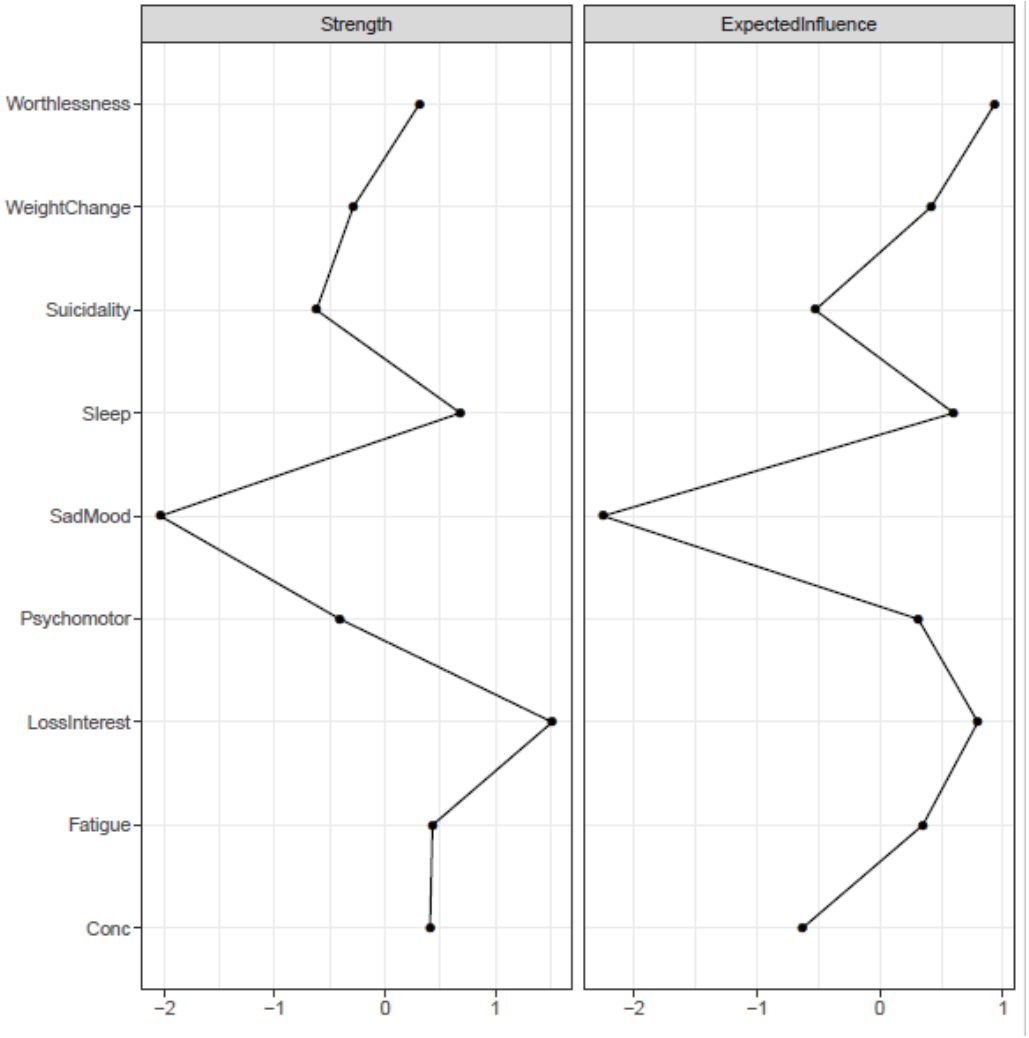
Centrality


Suicidality
Fatigue
LossInterest
WeightChange
SadMood
Conc
Sleep
Worthlessness
Psychomotor


Strength
Closeness
Betweenness
Worthlessness
/eightChange
Suicidality
Sleep
SadMood
Psychomotor
LossInterest
Fatigue
Conc
−2
−1
0
1
−2
−1
0
1
−1
0
1
2

Expected influence

- New metric – expected influence
- The sum of all edges extending from a given node (maintaining the sign)



Important *R*-packages

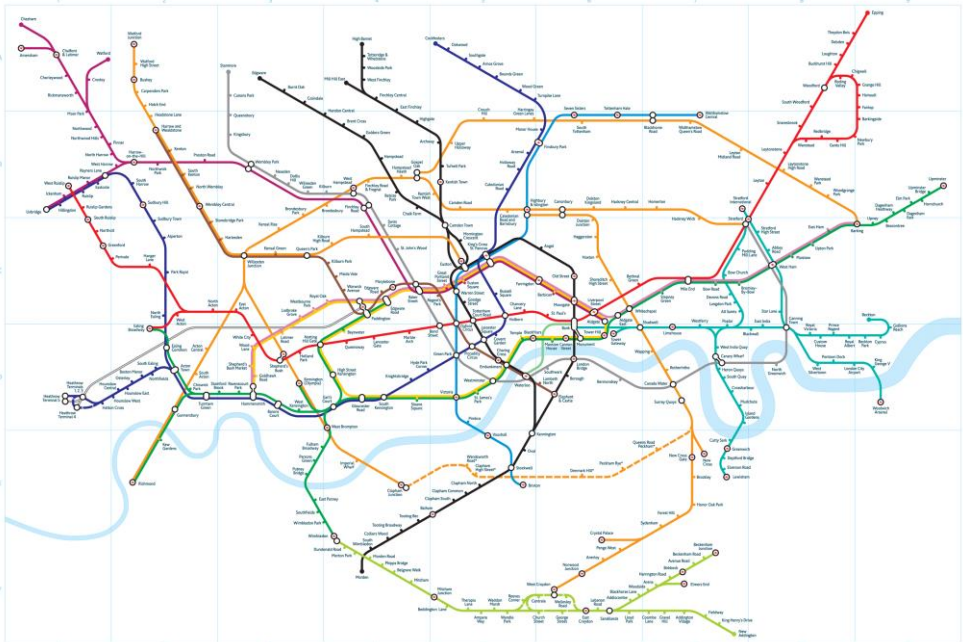
Commonly use R and the program R-Studio

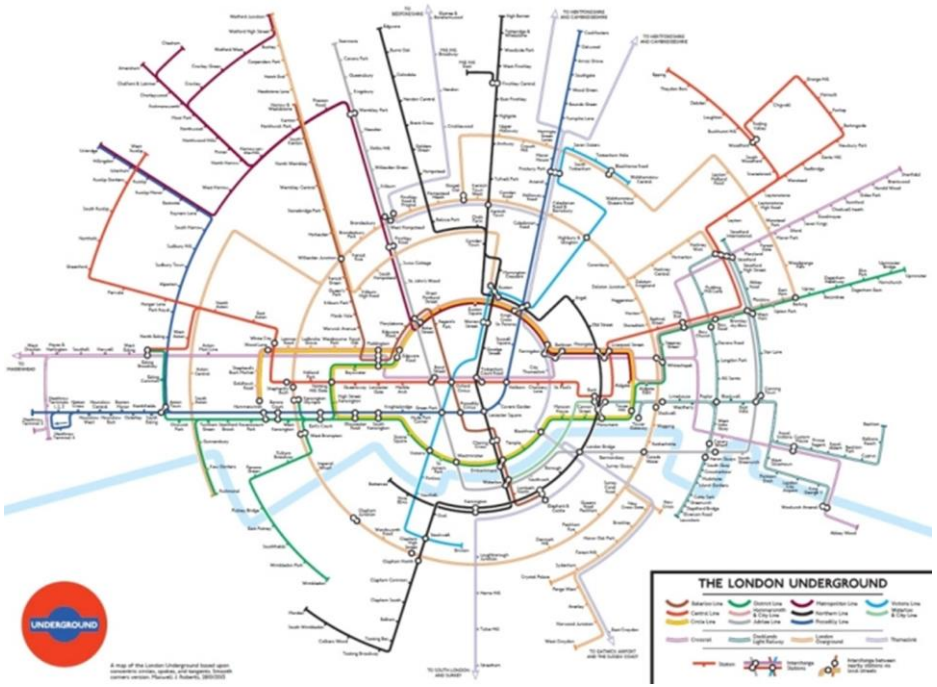
- **qgraph**: estimation and visualization of correlation networks, partial correlation networks, and GGMs
- **IsingFit**: estimation of Ising Models
- **bootnet**: testing the stability of networks
- **mlvar:** multilevel models
- **networktools:** Expected influence and bridge centrality
- And more – **graphicalVAR, igraph**
- Also JASP - https://jasp-stats.org/2018/03/20/perform-network-analysis-jasp/

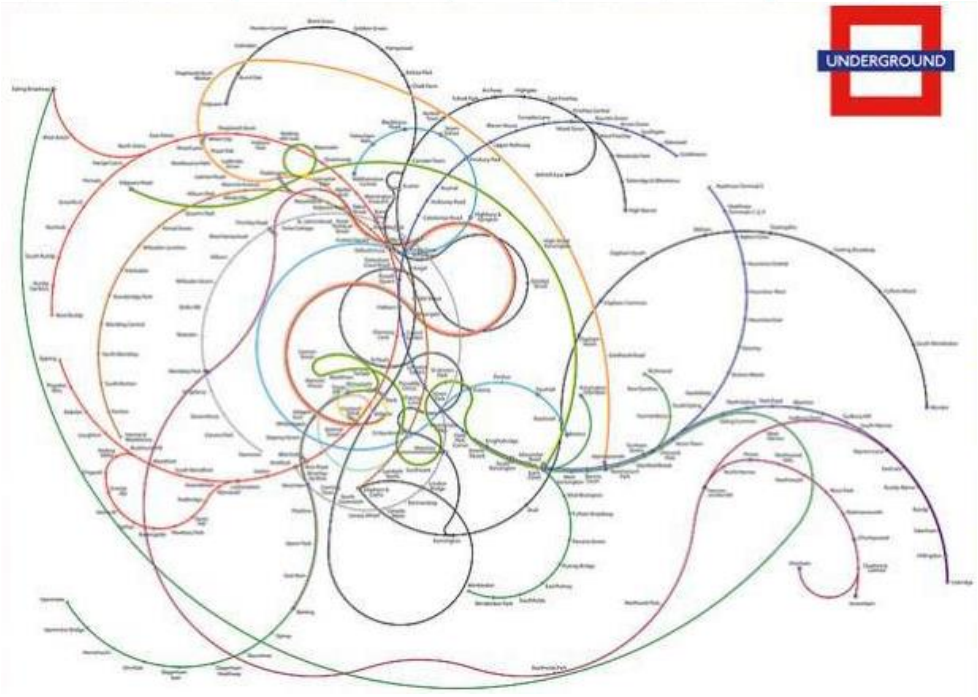
Visualization in qgraph

- In **qgraph**, the Fruchterman-Reingold algorithm is used that iteratively computes optimal placement of nodes
  - Most central nodes will end up more in the center, least central nodes more in the periphery
- *Can‘t interpret the network just by looking at it.*
- Need the centrality indices


Key to symbols
Explanation of zones



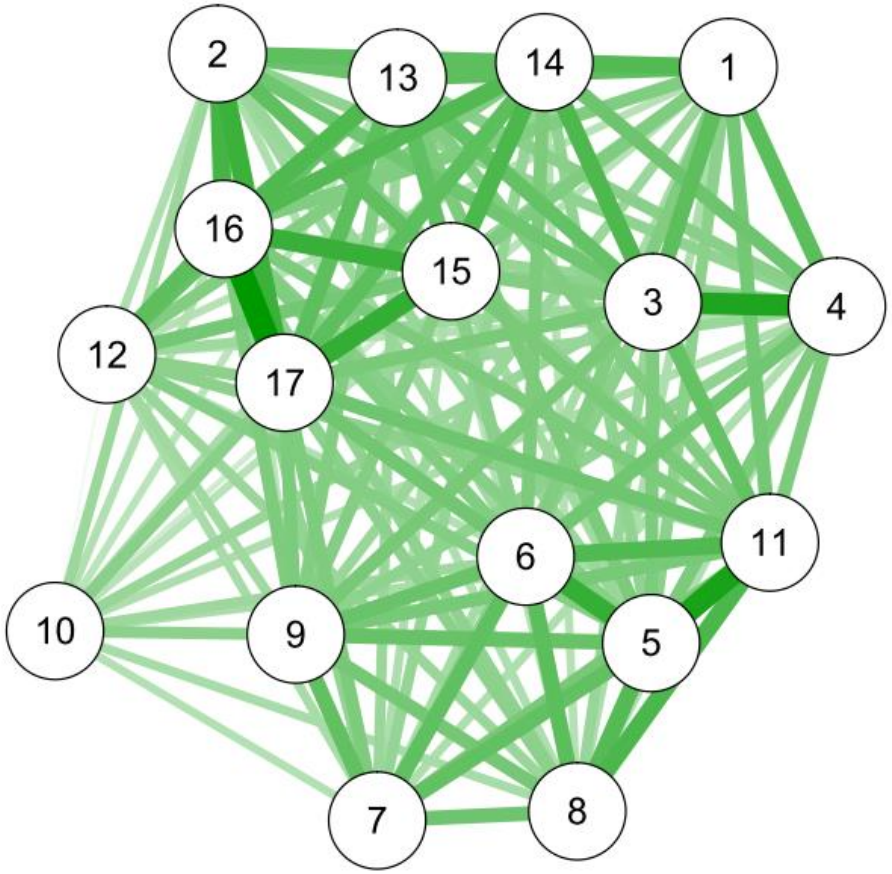

UNDERGROUND
THE LONDON UNDERGROUND


UNDERGROUND

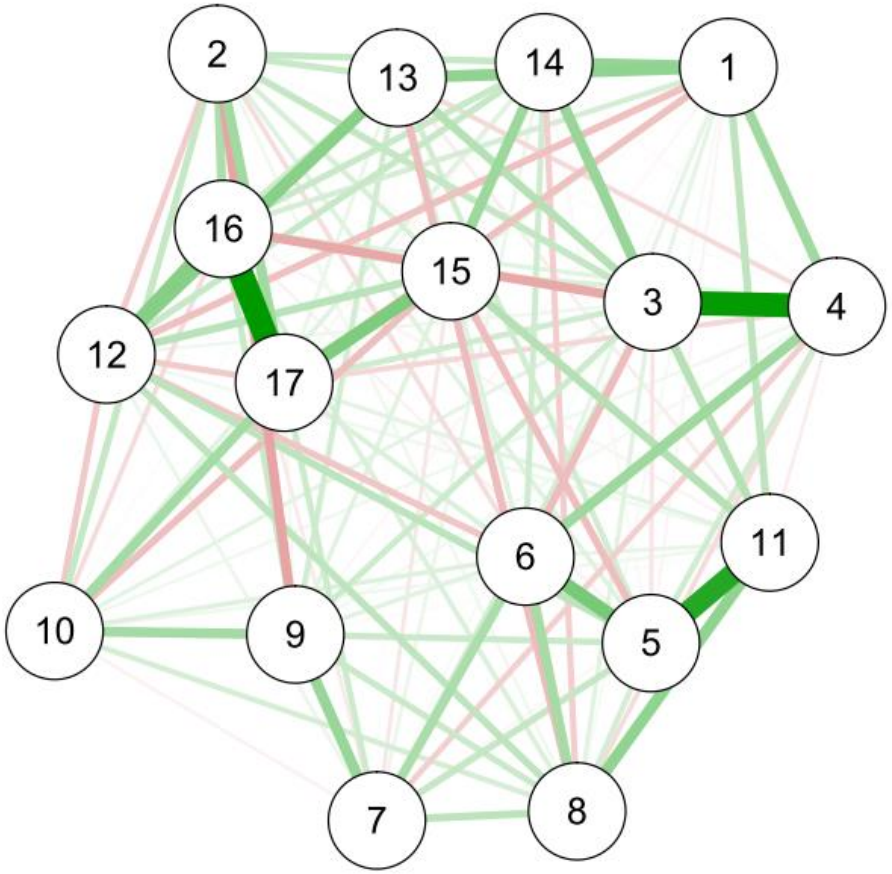
Conditional independence

- Not just interested in the relationships between nodes, but in the **unique effects** between them having controlled for the effects of the others (e.g., multiple regression)
- **Conditional independence relationships** - in networks we want to know how symptoms A and B are related *after controlling for all other symptoms*

Conditional independence



Correlation network



Partial correlation network

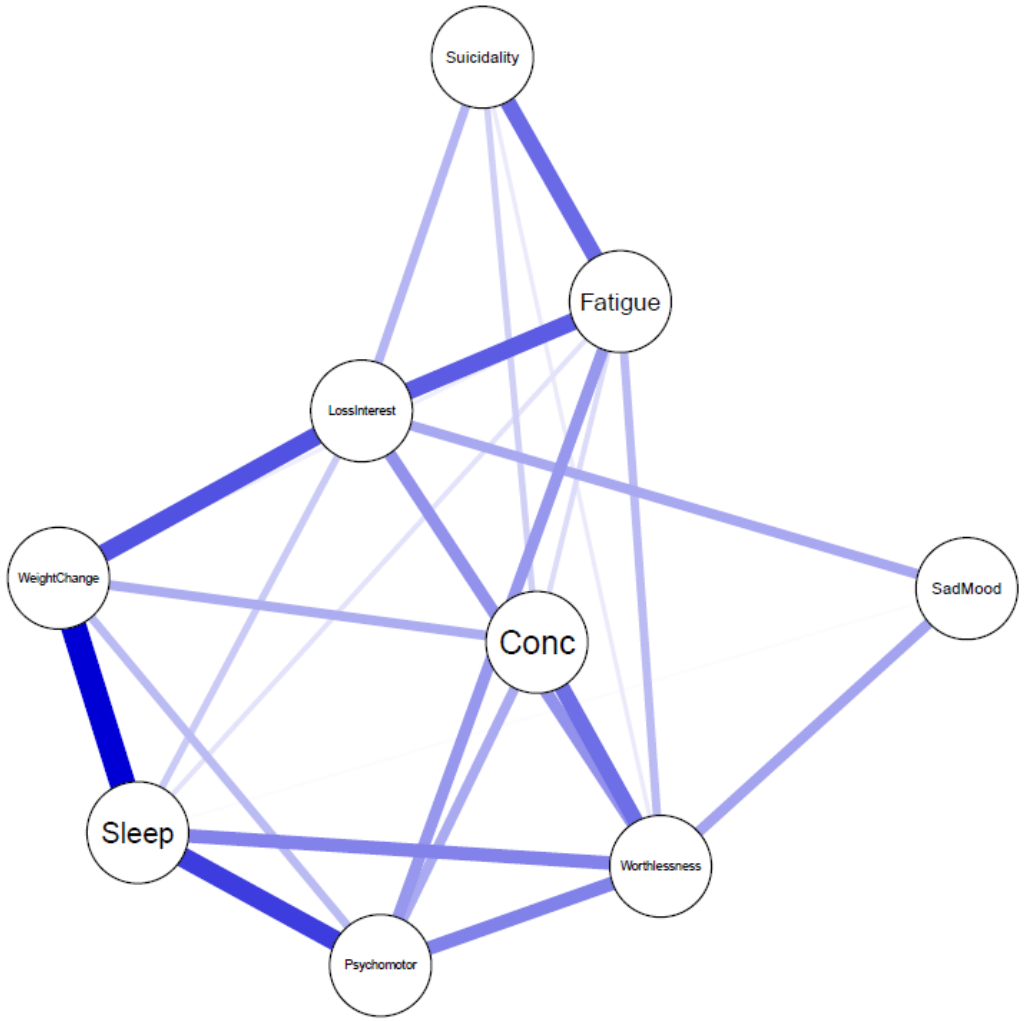
http://eiko-fried.com/aps2017/

Regularization

- Solution: estimate networks (Gaussian graphic models) with the **least absolute shrinkage and selection operator** (lasso)
- The lasso shrinks all regression coefficients, and small ones are set to zero (drop out of the model)
  - Interpretability: only relevant edges retained in the network
  - Stability/replicability: avoids obtaining *spurious* edges only due to chance
  - We also have fewer parameters to estimate
- Regularization returns a **sparse network**: few edges are used to explain the covariation structure in the data (parsimony)

http://eiko-fried.com/aps2017/

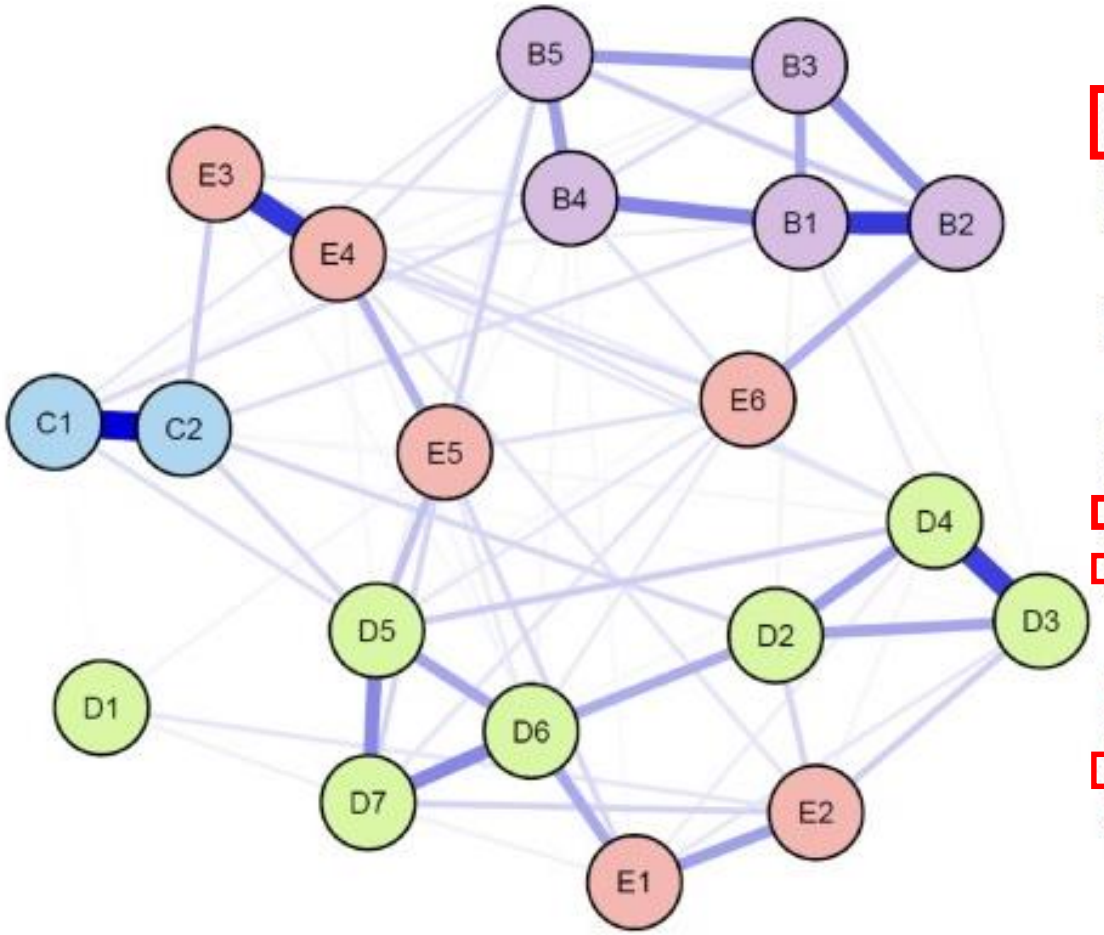
Gaussian Graphical Model (GGM)



Cross-sectional networks

- Correlation network/partial correlation/regularized GGM network
- Undirected
- Weighted
- Between-persons (average effects)
- Subject to all the limitations of cross-sectional research

Treatment-seeking veterans PTSD



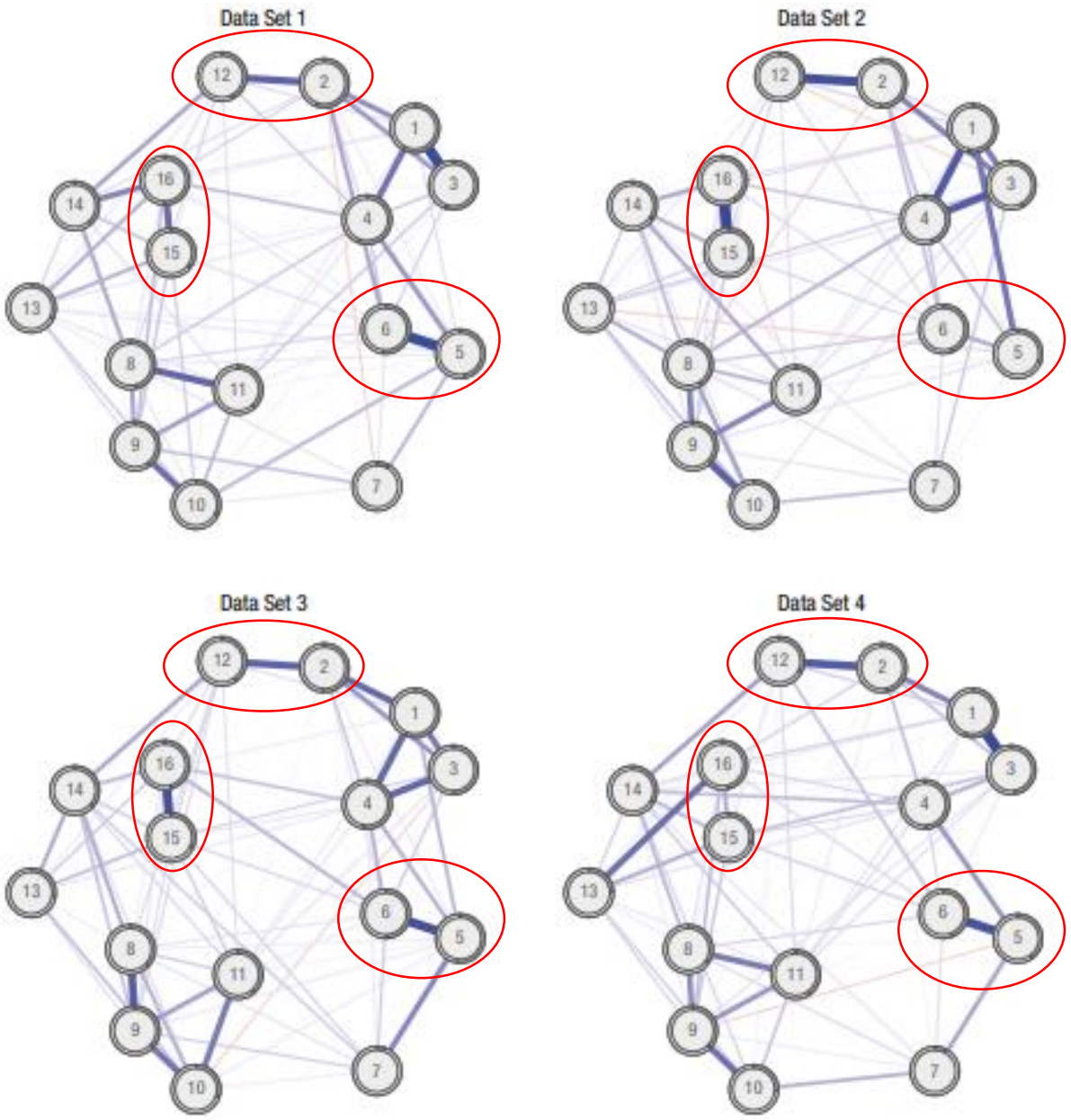
Re-experiencing
- B1: Recurrent thoughts
- B2: Nightmares
- B3: Flashbacks
- B4: Psychological cue reactivity
- B5: Physiological cue reactivity

Avoidance
- C1: Avoidance of thoughts
- C2: Avoidance of reminders

Negative alterations in cognition and mood
- D1: Memory impairment
- D2: Negative beliefs
- D3: Distorted blame
- D4: Negative emotional state
- D5: Diminished interest
- D6: Detachment
- D7: Restricted affect

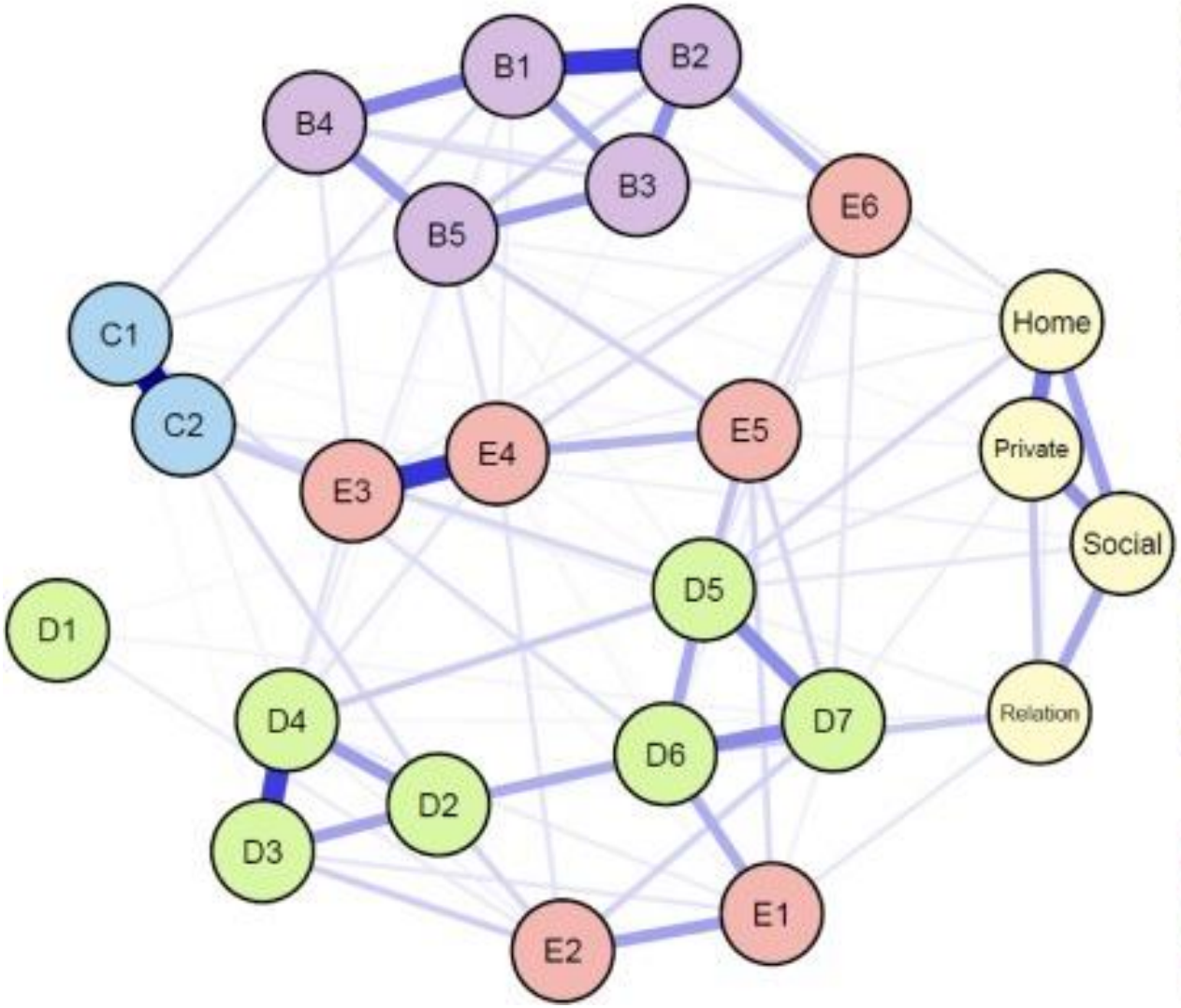
Alterations in arousal and reactivity
- E1: Irritability or anger
- E2: Reckless or self-destructive behaviour
- E3: Hypervigilance
- E4: Exaggerated startle
- E5: Difficulty concentrating
- E6: Sleeping difficulties

Ross, J., Murphy, D., & Armour, C. (2018). A network analysis of DSM-5 posttraumatic stress disorder and functional impairment in UK treatment-seeking veterans. *Journal of Anxiety Disorders*.



1	Intrusions
2	Nightmares
3	Flashbacks
4	Physiological/psychological reactivity
5	Avoidance of thoughts
6	Avoidance of situations
7	Amnesia
8	Disinterest in activities
9	Feeling detached
10	Emotional numbing
11	Foreshortened future
12	Sleep problems
13	Irritability
14	Concentration problems
15	Hypervigilance
16	Startle response

Fried, E. I., Eidhof, M. B., Palic, S., Costantini, G., Huisman-van Dijk, H. M., Bockting, C. L., ... & Karstoft, K. I. (2018). Replicability and Generalizability of Posttraumatic Stress Disorder (PTSD) Networks: A Cross-Cultural Multisite Study of PTSD Symptoms in Four Trauma Patient Samples. *Clinical Psychological Science*, 2167702617745092.



Functional impairment
- Home: Impaired home management
- Social: Impaired social activities
- Private: Impaired private activities
- Relation: Impaired relationships

Re−experiencing
- B1: Recurrent thoughts
- B2: Nightmares
- B3: Flashbacks
- B4: Psychological cue reactivity
- B5: Physiological cue reactivity

Avoidance
- C1: Avoidance of thoughts
- C2: Avoidance of reminders

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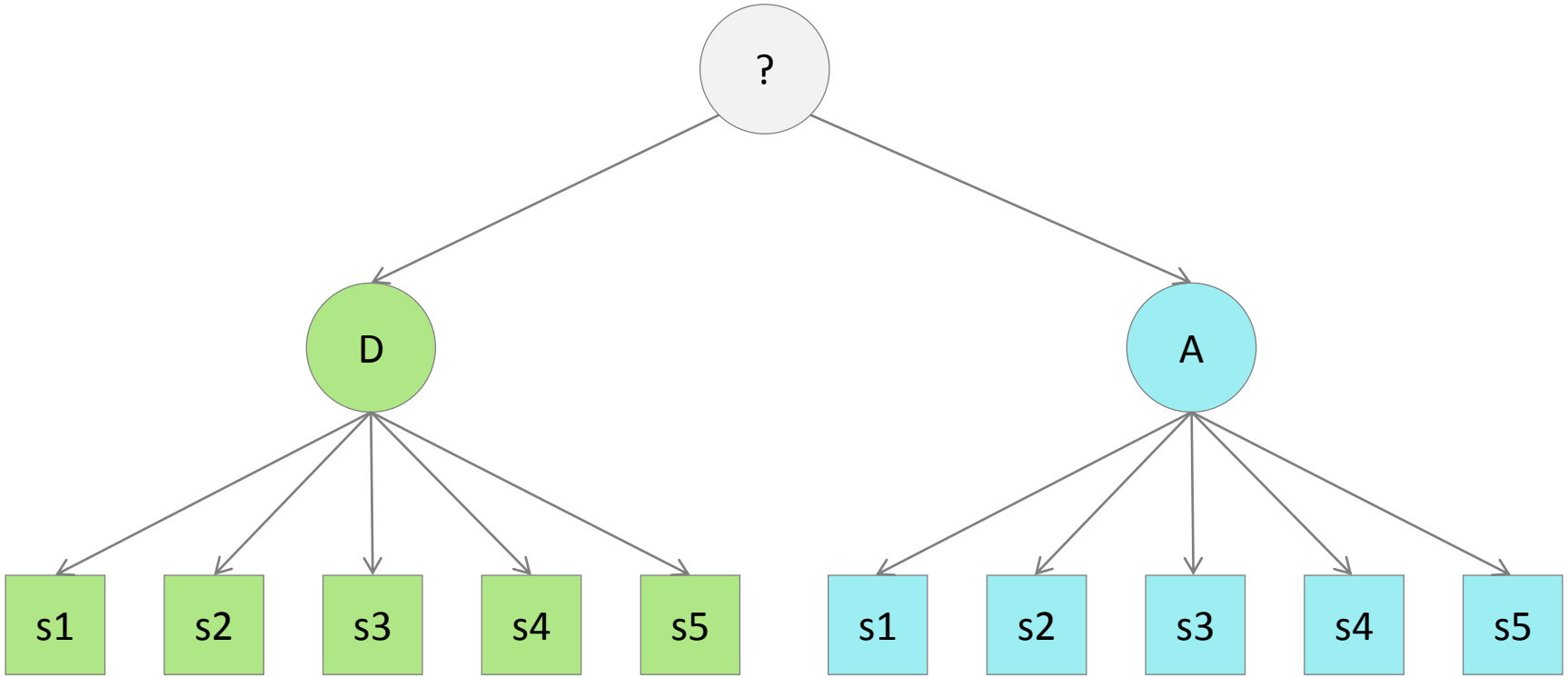
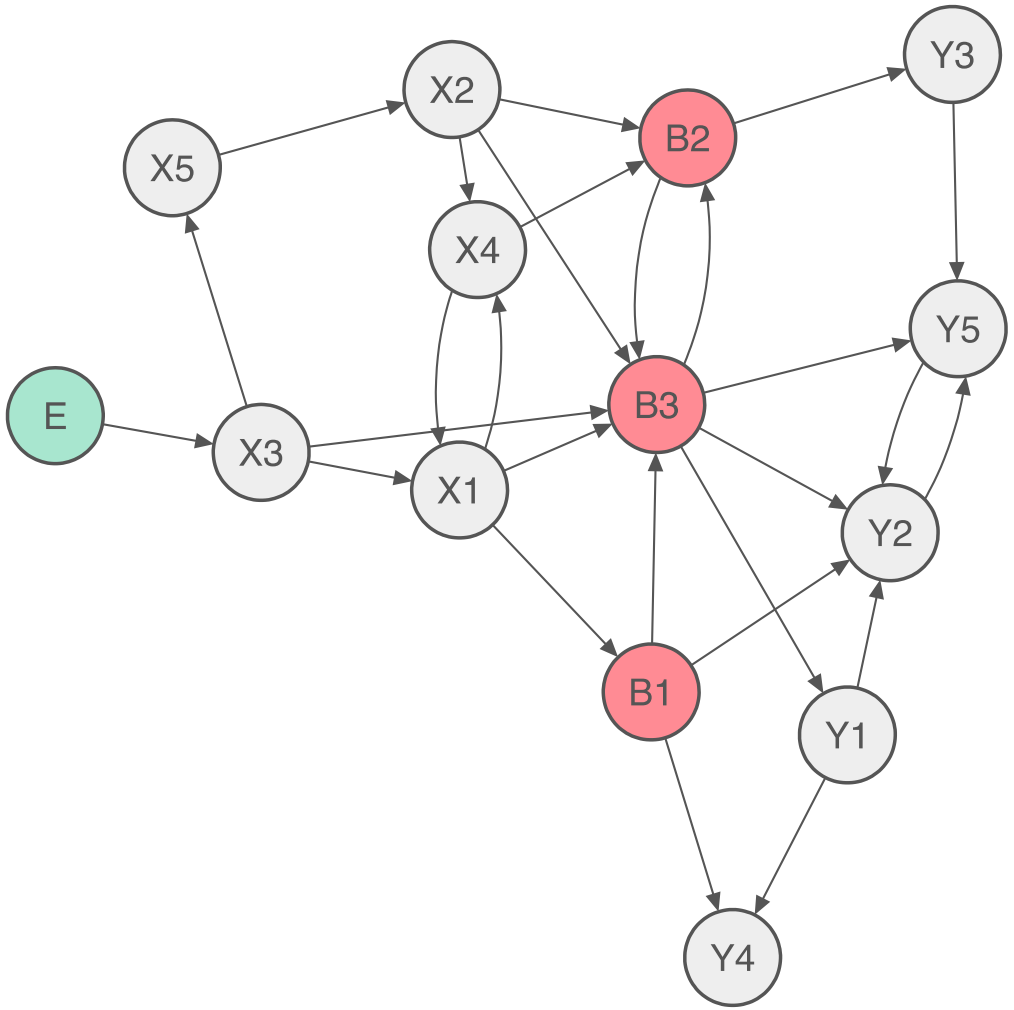
Ross et al. 2018. Journal of Anxiety Disorders

Comorbidity



Comorbidity

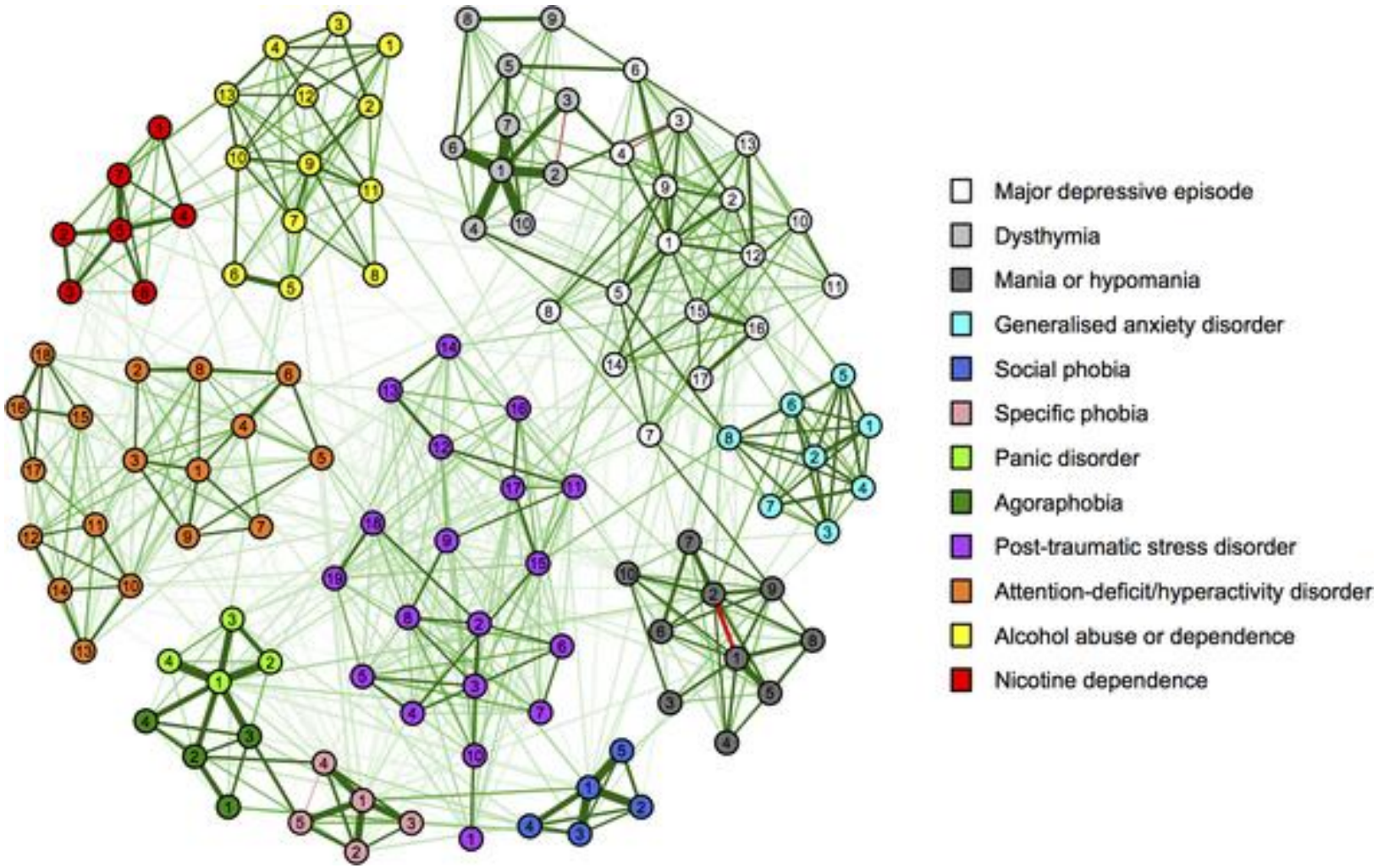


- E = Stressor
- Develops disorder X in reaction to E
- Then bridge symptoms B
- And finally disorder Y

- Can conceptualize X as MDD
- Y as GAD
- Bridge symptoms = sleep, fatigue, concentration problems

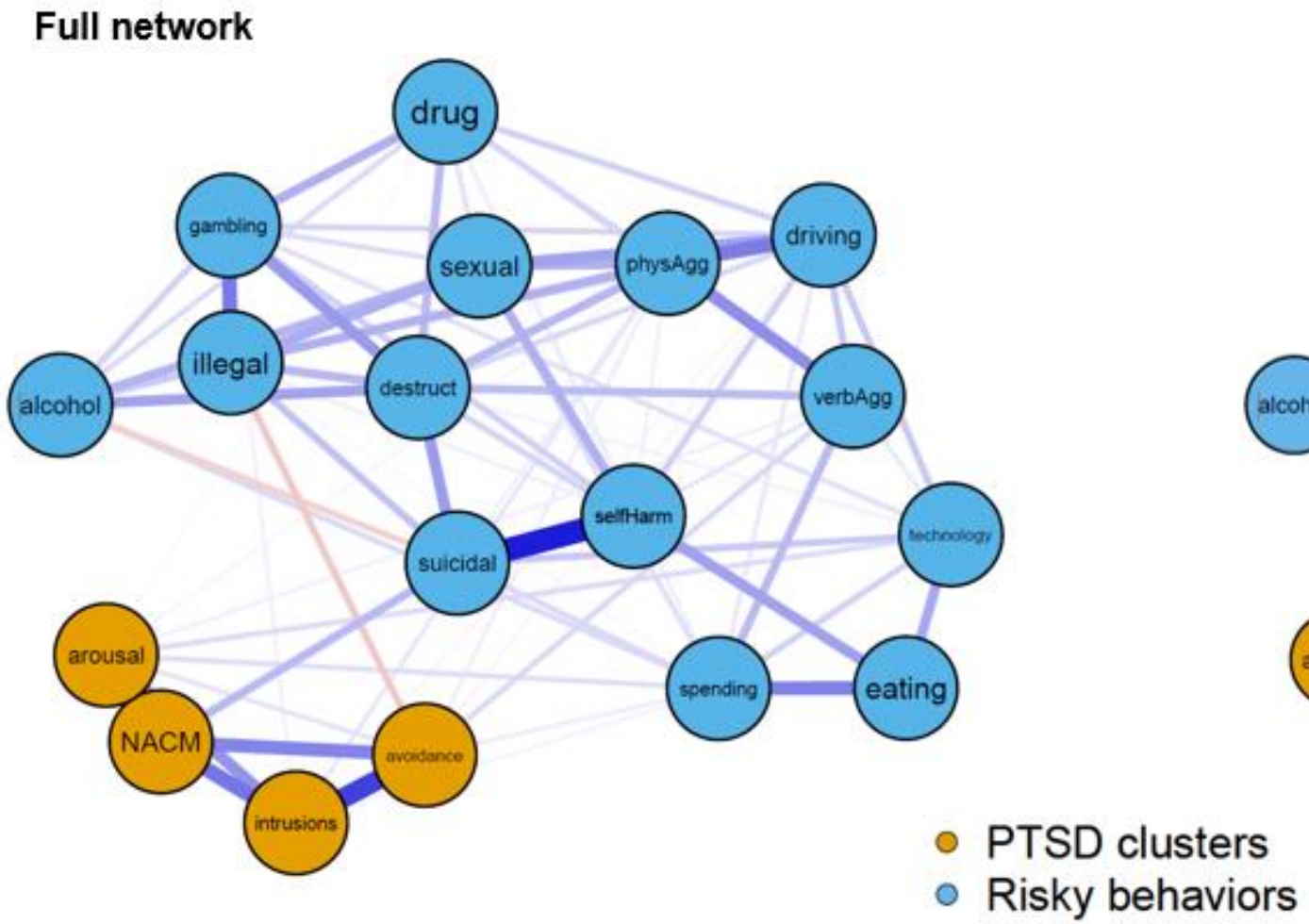
Fried, E. I., van Borkulo, C. D., Cramer, A. O., Boschloo, L., Schoevers, R. A., & Borsboom, D. (2017). Mental disorders as networks of problems: a review of recent insights. *Social Psychiatry and Psychiatric Epidemiology*, *52*(1), 1-10.

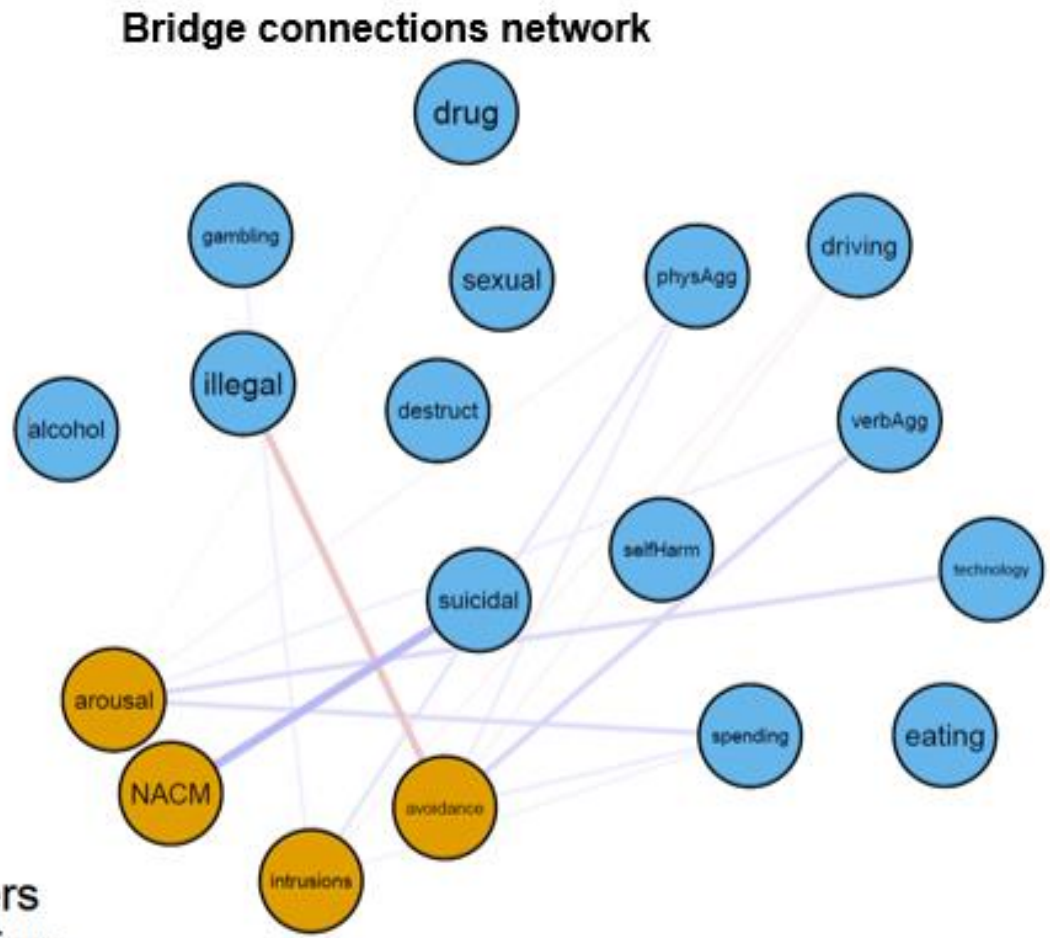
Fig 1. Empirical network of 120 psychiatric symptoms.



Boschloo L, van Borkulo CD, Rhemtulla M, Keyes KM, Borsboom D, et al. (2015) The Network Structure of Symptoms of the Diagnostic and Statistical Manual of Mental Disorders. PLOS ONE 10(9): e0137621. https://doi.org/10.1371/journal.pone.0137621

Bridge connections





Armour, Greene, Contractor, Weiss, Dixon Gordon, Ross. Posttraumatic stress disorder symptoms and risky behaviors: A network analysis. In preparation.

Time-series models

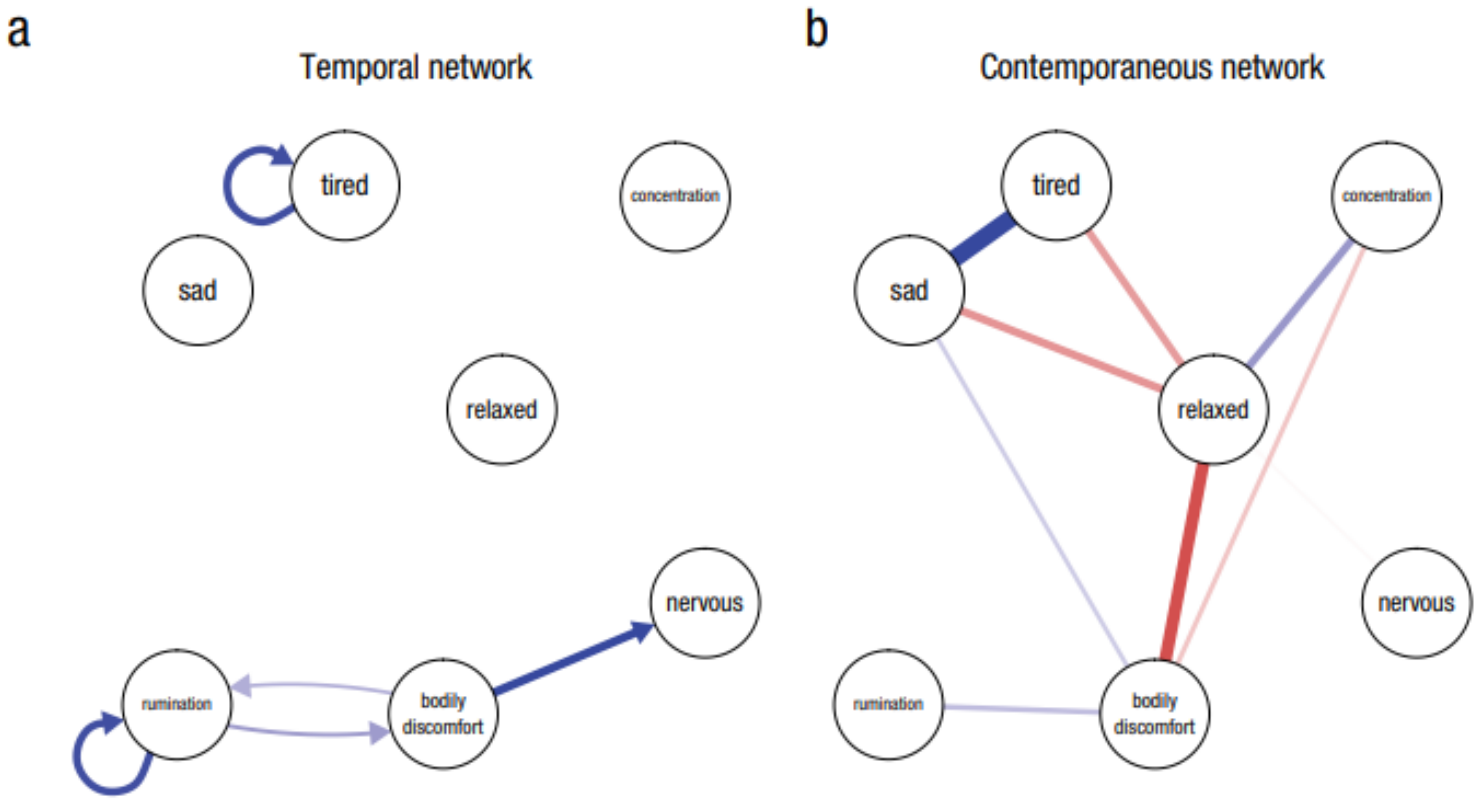
- N=1
- N>1
- Use a vector auto-regressive (VAR) model
- Lagged relationships
- Can be applied to 1 person or multiple people (multi-level)
- Intensive longitudinal data: e.g. repeated assessments over a short time period (daily diary, ESM, EMA etc.), often use smartphones
- Directed edges
- Can‘t make causal inferences, but can infer *potential causal relations*

Temporal and contemporaneous networks

- Temporal = lagged relations
- Contemporaneous = within time window associations
- Temporal relations estimated first.

- Directed networks allow for estimation of in-strength and out-strength
- In-strength = the extent to which a given node is predicted by the other nodes at the previous measurement
- Out-strength = the extent to which a given node predicts other nodes at the previous measurement
- Auto-regressive symptoms – symptoms which predict themselves at the following measurement

Idiographic networks n=1

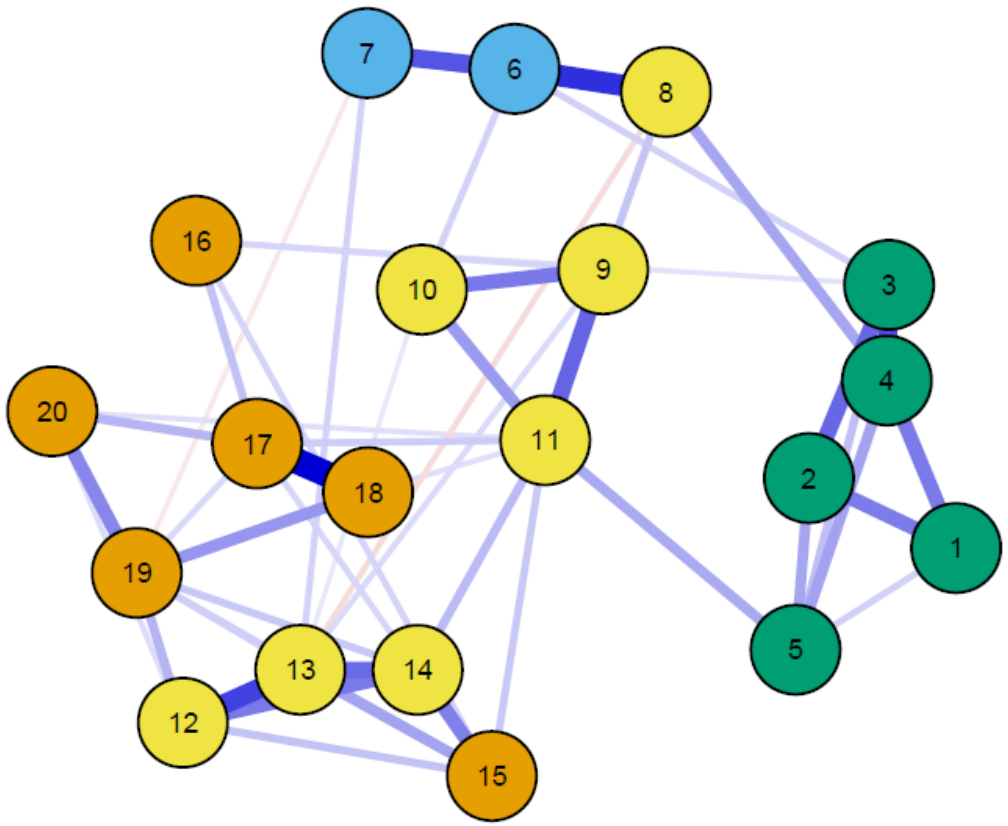


- Clinical patient – 47 ESM reports over two weeks

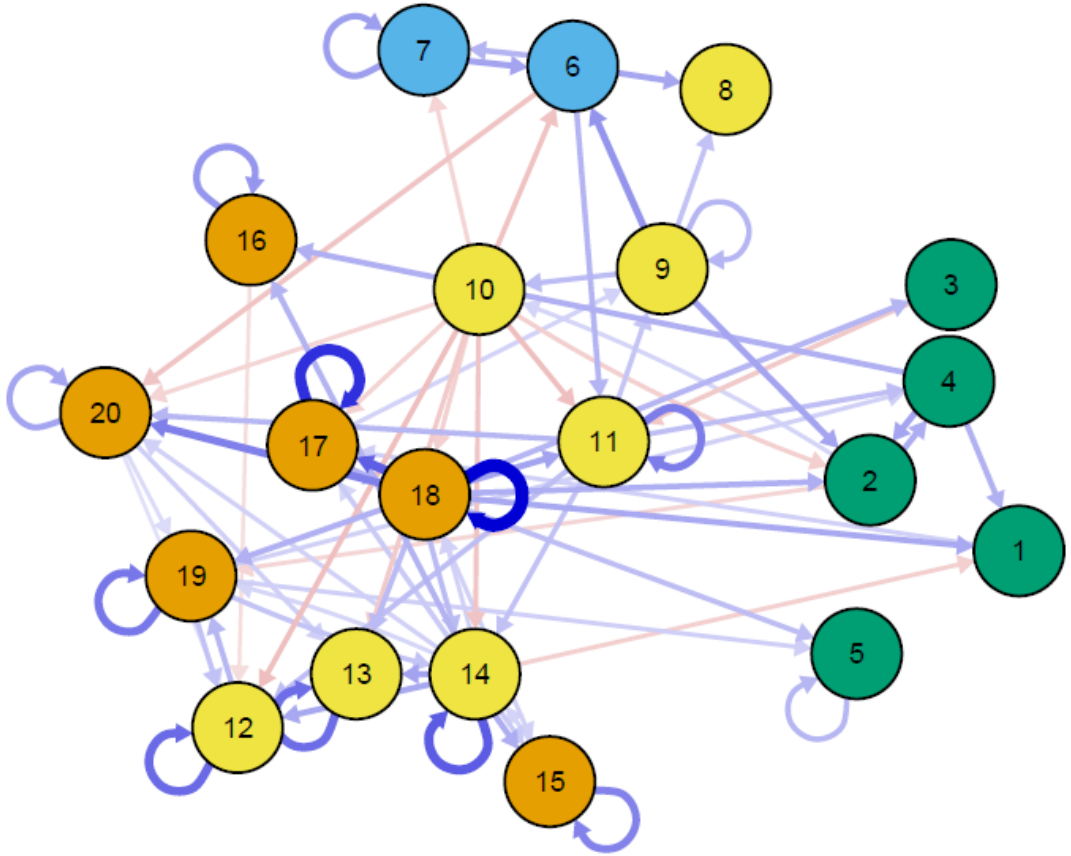
Epskamp, S., van Borkulo, C. D., van der Veen, D. C., Servaas, M. N., Isvoranu, A. M., Riese, H., & Cramer, A. O. (2017). Personalized network modeling in psychopathology: The importance of contemporaneous and temporal connections. *Clinical Psychological Science*, 2167702617744325.

N>1 networks

Contemporaneous



Temporal



Limitations

- Not yet modeling time varying processes (coming soon)
- Few replications
- Missing nodes? Misrepresent the networks
- Power
- Heterogeneity – don’t (yet) have network mixture models (probably need very large samples)
- Exploratory – therefore not necessarily generalizable
- Emerging field with many unanswered questions

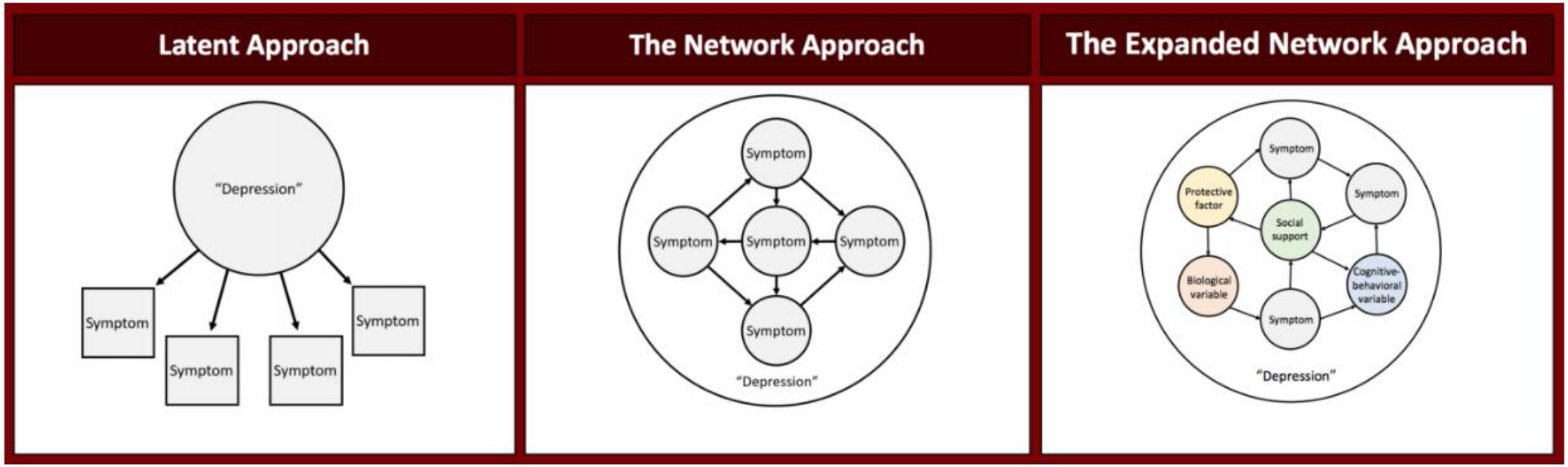
Future directions

Idiographic networks for treatment?

- First stages
- Rubel et al. 2017 – translating n=1 network models into personalized treatments by developing a treatment algorithm
- Van der Veen, Riese, Kroeze - choose items to track, then discuss the networks with the patients as treatment tool
- Bastiaansen et al. (in preparation) – time-series data from one patient to many analysts – little agreement on treatment approach

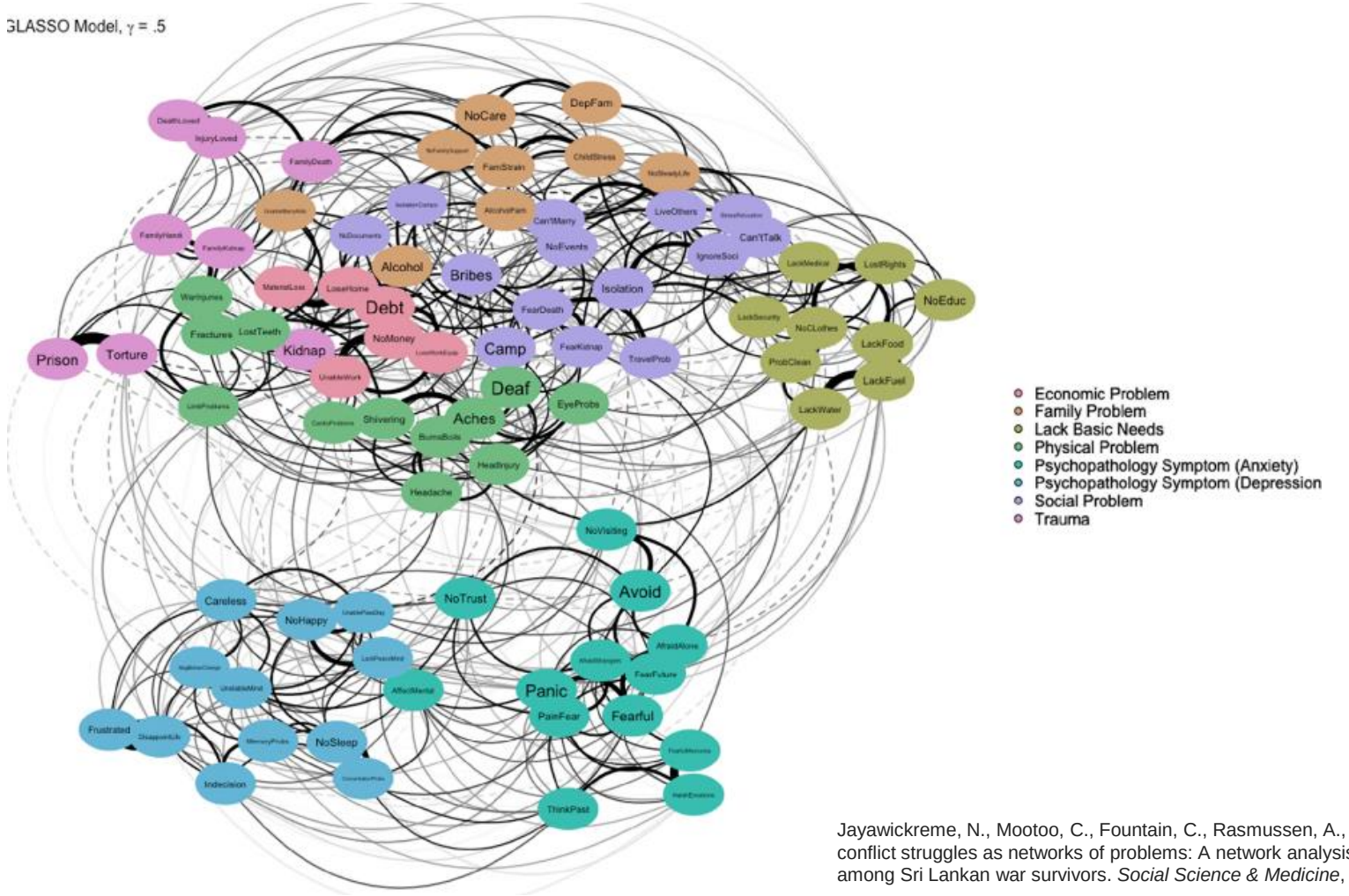
Expanded network approach

Payton Jones (2017)



http://psych-networks.com/expanded-network-approach-moving-beyond-symptoms/

Networks of problems



Jayawickreme, N., Mootoo, C., Fountain, C., Rasmussen, A., Jayawickreme, E., & Bertuccio, R. F. (2017). Post-conflict struggles as networks of problems: A network analysis of trauma, daily stressors and psychological distress among Sri Lankan war survivors. *Social Science & Medicine*, *190*, 119-132.

Conclusions

- Important to separate between network theory and network models
- Network models have potential to gain insight into symptom level relations, potentially causal interactions, comorbidity, among others
- Can generate hypotheses about between-person processes, and also within-person processes
- Can help us to understand comorbidity
- Potential clinical application

Thank you!

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Twitter: @talyagreene

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University of Haifa
جامعة حيفا

Brain and Behavior Research Foundation
Narsad Young Investigator Award
The Moshe Hess Foundation
Israel Science Foundation

Dynamic networks during conflict

- 2014 Israel-Gaza Conflict (8 July- 26 August)
- Airstrikes, ground invasion from Israel to Gaza
- Rockets, mortars, tunnels from Gaza to Israel
- Participant accessibility

Psychological Medicine

cambridge.org/psm

Original Article

Cite this article: Greene T, Gelkopf M,

Dynamic networks of PTSD symptoms during conflict

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University of Haifa
جامعة حيفا

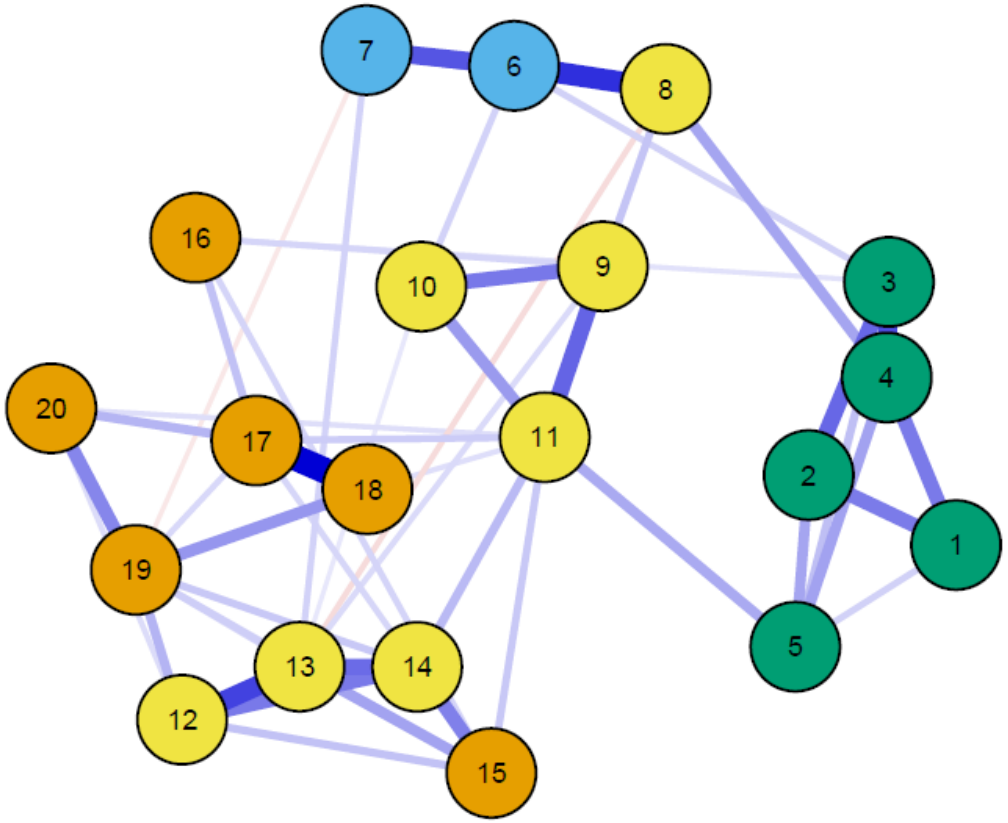
NATAL
Israel Trauma and Resiliency Center

Overview

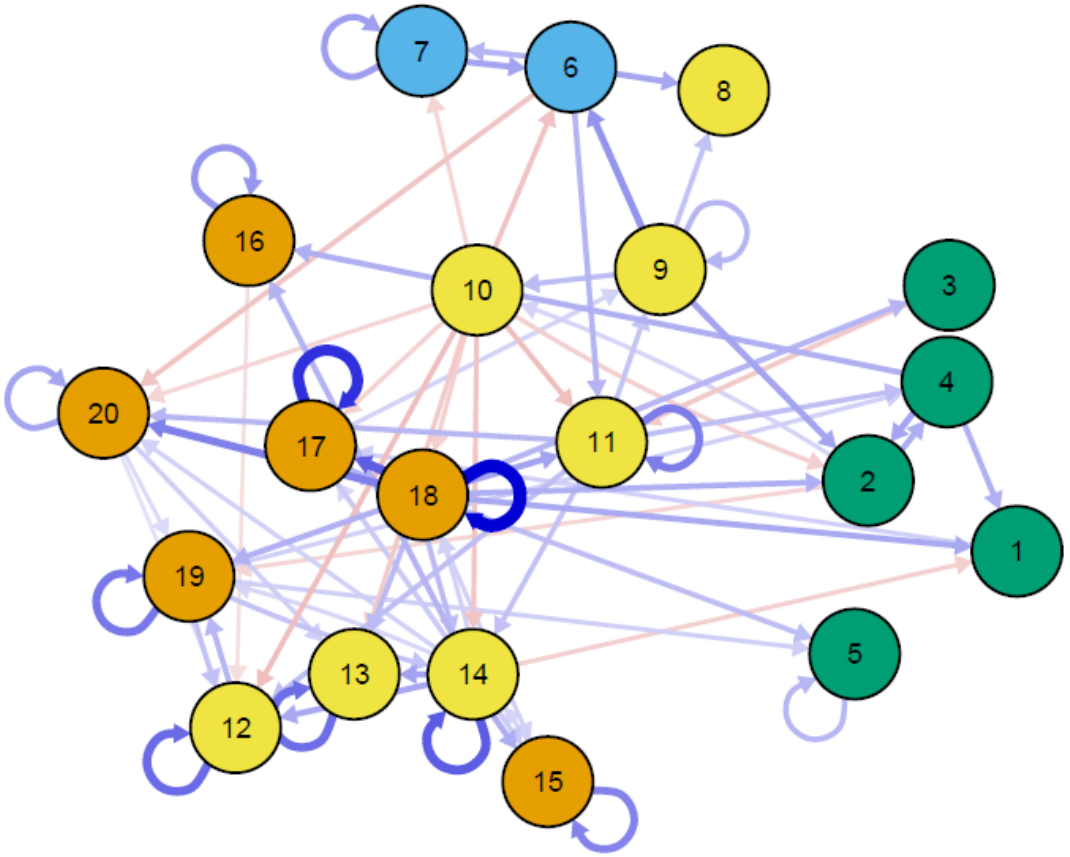
- General population sample of Israeli adult civilians exposed to rocket fire (n=96) (part of a larger study)
- Twice-daily ESM reports of PTSD symptoms via smartphone for 30 days (Greene et al., 2017)
- Multilevel vector auto-regression model in R

Dynamic PTSD networks during conflict

Contemporaneous



Temporal



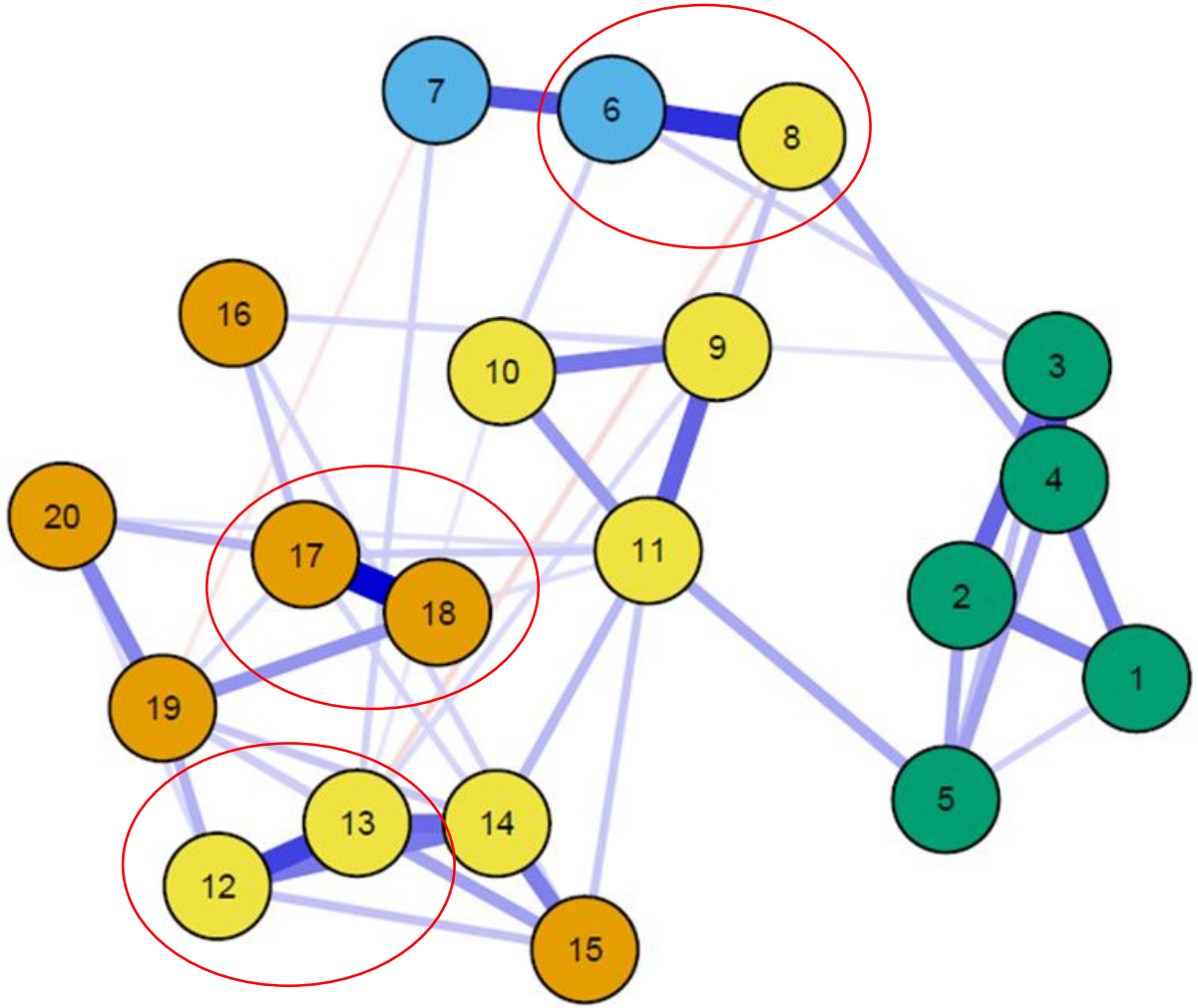
Intrusions
- 1: Intrusive thoughts
- 2: Nightmares
- 3: Flashbacks
- 4: Emotional cue reactivity
- 5: Physiological cue reactivity

Avoidance
- 6: Avoidance of thoughts
- 7: Avoidance of reminders

Negative alterations in mood and cognitions
- 8: Trauma-related amnesia
- 9: Negative beliefs
- 10: Blame of self or others
- 11: Negative trauma-related emotions
- 12: Loss of interest
- 13: Detachment
- 14: Restricted affect

Alterations in arousal and reactivity
- 15: Irritability/anger
- 16: Self-destructive/reckless behavior
- 17: Hypervigilance
- 18: Exaggerated startle response
- 19: Difficulty concentrating
- 20: Sleep disturbance

Contemporaneous network (within time window)



Mostly positive (blue edges)

Some pairs strongly associated:

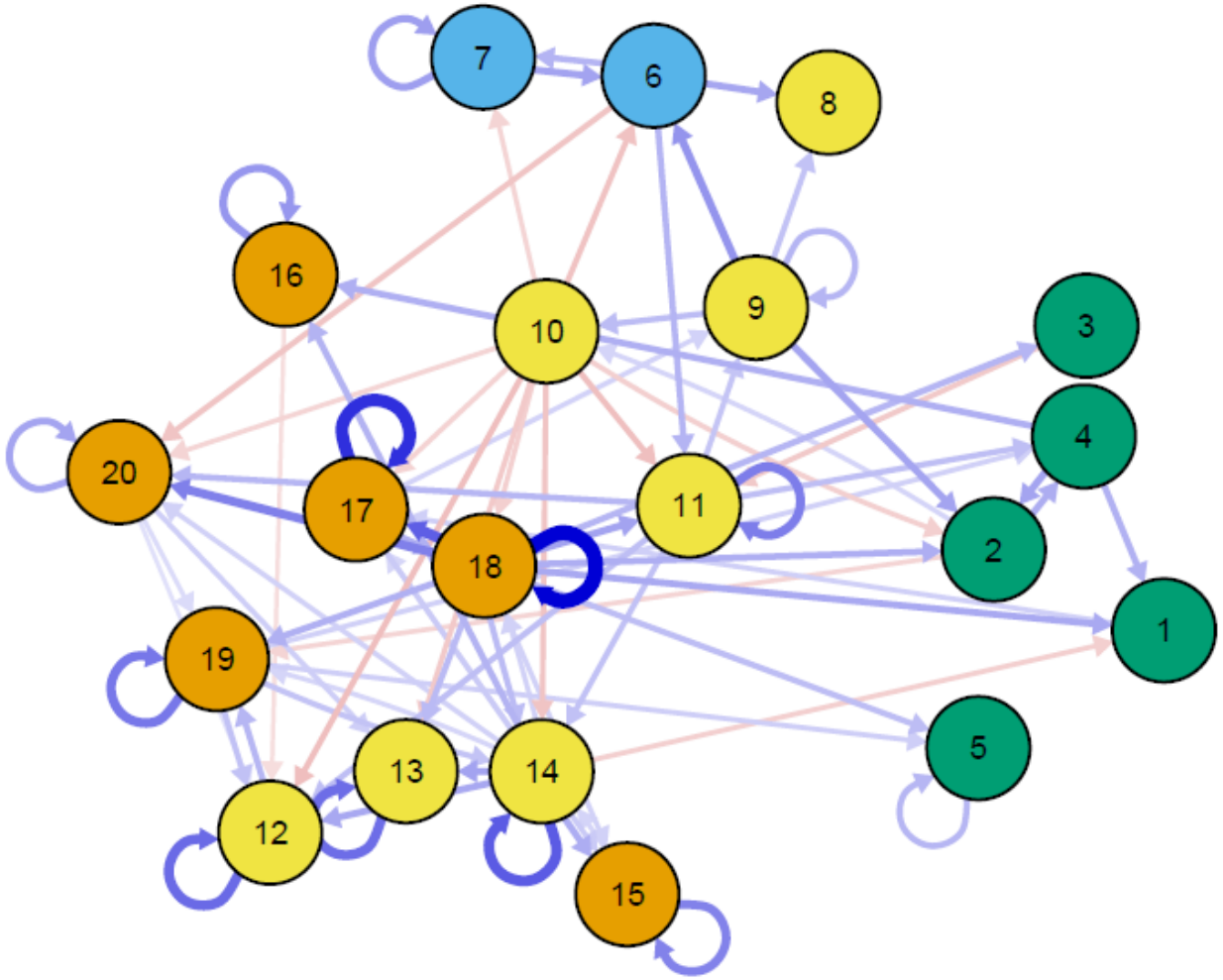
- Hypervigilance (17) ↔ startle (18)
- Avoidance thoughts (6) ↔ amnesia (8)
- Loss of interest (12) ↔ detachment (13)

Close to DSM-5 clusters

Exceptions

- Amnesia (8) - avoidance
- Anger (15) - negative mood and cognitions

Temporal network (lagged associations)



Some negative edges (red)

- Blame (10)

Out-strength – symptoms which predict other symptoms at the next measurement (intervention targets?)

- Startle (18), Blame (10), restricted affect (14), negative emotions (11), avoidance of thoughts (6)

In-strength – influenced by other variables at the previous measurement

- Sleep disturbance (20), loss of interest (12)

Strong auto-correlations

- Startle (18), Hypervigilance (17)