Network Analysis
Applications of networks in Psychology and beyond

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TNO
Outline

- What is a network?
- What can we do with networks?
- How can we obtain a network structure?
- Example of network analysis on radicalization data
MD
Insomnia
Fatigue
Concentration
Worry
MD

Insomnia

Worry

Fatigue

Concentration
MD
Insomnia
Fatigue
Concentration
Worry
What is a network?
What is a network?

- A network is a set of nodes connected by a set of edges.
What is a network?

- A network is a set of nodes connected by a set of edges
  - A node represents an entity, this can be anything:
    - People
    - Cities
    - Symptoms
  - An edge represents some connection between two nodes. Again, this can be anything:
    - Friendship / contact
    - Distance
    - Comorbidity
Anne is friends with Laura:
Anne is friends with Laura and Roger, but Laura is not friends with Roger:
Networks can be weighted
Anne is better friends with met Roger than Laura:
Weights can be signed
Anne is friends with Roger and Laura, but Roger and Laura don’t like each other at all!
Networks can be directed

Anne likes Laura, but Laura doesn’t like Anne:
Networks can model causality

If it rains the grass becomes wet:

Rain → Grass wet
If the sprinkler is on the grass also becomes wet:
What can we do with networks?
What can we do with networks?

Besides providing a interpretable structure of a complex system, we can also use networks to compute unique measures such as:

- **Distance**
  - How fast can symptom A influence symptom B?
- **Centrality**
  - Which symptom is the most important?
- **Connectivity**?
  - How well are symptoms connected?
Distance

Node A is much further away from node B than node C:
Centrality

Node A is much more influential than node B:
Connectivity

The left network is much denser connected than the right one:
Friendship
Relationships
Sexual contacts
Networks can be simulated given sufficient information about a population:
Psychopathology as a virus...
How to get a network?
qgraph: Network Visualizations of Relationships in Psychometric Data

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Abstract

We present the qgraph package for R, which provides an interface to visualize data through network modeling techniques. For instance, a correlation matrix can be represented as a network in which each variable is a node and each correlation an edge; by varying the width of the edges according to the magnitude of the correlation, the structure of the data can be visualized. qgraph can also be used as a psychometric tool, as it performs exploratory and confirmatory factor analysis, using the sem and lavaan packages; the output of these packages is automatically visualized in qgraph, which may aid the interpretation of results. In this article, we introduce qgraph by applying the package functions to data from the NEO-PI-R, a widely used personality questionnaire.

Keywords: R, networks, correlations, data visualization, factor analysis, graph theory.
Correlation networks

- Correlation networks are useful as a visualization tool.
- But correlations are not easily interpreted as networks due to many *spurious* connections.
- A partial correlation network, in which you display the correlations conditional on all other variables in the network, is easier interpretable:
  - Two nodes are connected if and only if there is covariance between those nodes that cannot be explained by any other variable in the network.
- Such a network is called a Markov Random Field.
Markov Random Fields

- A specific type of network is called a Markov Random Field
- Undirected networks with the property that a node is independent of all other nodes given its neighbors (connected nodes)
- Interpretable
- High predictive power
- If data is assumed normal these are called Gaussian random fields or Partial correlation matrices
- If the data is binary these are called the Ising model
- Typically we want to estimate a sparse structure, which we can do using a LASSO penalty
Markov Random Fields

- A predicts C and B, but C better
- C predicts A, and B via A
- B predicts A, and C via A
- B and C are *independent given* A
# Load packages:
library("qgraph")
library("parcor")

# Read data:
Data <- read.csv("HEXACOfacet.csv")

# Plot correlations:
qgraph(cor(Data), layout = "spring")

# Plot partial correlations:
qgraph(cor(Data), layout = "spring", graph = "concentration")

# Plot LASSO network:
adls <- adalasso.net(Data)
network <- as.matrix(forceSymmetric(adls$pcor.adalasso))
qgraph(network, layout = "spring")
Partial correlations (using adaptive lasso)

Paper by Jolanda J. Kossakowski, Jacobien M. Kieffer, Sacha Epskamp & Denny Borsboom in preparation
Zooming in: Physical Functioning en Item 2

Wordt u door uw gezondheid op dit moment beperkt bij ongeveer honderd meter lopen?

Hoe beoordeelt u uw gezondheid over het algemeen, vergeleken met een jaar geleden?

Wordt u door uw gezondheid op dit moment beperkt bij een paar honderd meter lopen?

Wordt u door uw gezondheid op dit moment beperkt bij een trap lopen?

Wordt u door uw gezondheid op dit moment beperkt bij meer dan een kilometer lopen?

Wordt u door uw gezondheid op dit moment beperkt bij uzelf wassen of aankleden?

Wordt u door uw gezondheid op dit moment beperkt bij een paar trappen oplopen?

Wordt u door uw gezondheid op dit moment beperkt bij bukken, knielen of hurken?

Wordt u door uw gezondheid op dit moment beperkt bij boodschappen tillen of dragen?

Wordt u door uw gezondheid op dit moment beperkt bij forse inspanning?

Wordt u door uw gezondheid op dit moment beperkt bij matige inspanning?
Three datasets

Figure: Left: AMC cancer. Middle: NKI cancer. Right: NKI healthy.

- General health
- Physical functioning
- Mental health
- Role limitations physical
- Role limitations emotional
- Bodily pain
- Social functioning
- Vitality
- No dimension
Ising Network

Paper by Claudia D. van Borkulo, Denny Borsboom, Sacha Epskamp, Tessa F. Blanken, Lynn Boschloo, Robert A. Schoevers & Lourens J. Waldorp submitted
Individual networks
A subject over time...
Example of network analysis in Radicalization
Determinants of Radicalization of Islamic Youth in the Netherlands: Personal Uncertainty, Perceived Injustice, and Perceived Group Threat

Bertjan Doosje*
University of Amsterdam

Annemarie Loseman and Kees van den Bos
Utrecht University

In this study among Dutch Muslim youth (N = 131), we focus on the process of radicalization. We hypothesize that this process is driven by three main factors: (a) personal uncertainty, (b) perceived injustice, and (c) perceived group threat. Using structural equation modeling, we demonstrate that personal uncertainty, perceived injustice, and group-threat factors are important determinants of a radical belief system (e.g., perceived superiority of Muslims, perceived illegitimacy of Dutch authorities, perceived distance to others, and a feeling of being disconnected from society). This radical belief system in turn predicts attitudes toward violence by other Muslims, which is a determinant of own violent intentions. Results are discussed in terms of the role of individual and group-based determinants of radicalization.
Doosje, Loseman, and Bos (2013) investigated the process of radicalization of Dutch youth. They looked at possible determinants for adopting a radical beliefs system, which in turn can cause the basis for violent attitudes. An oversimplified version of their model is:

\[
\text{Determinants} \rightarrow \text{Radical beliefs system} \rightarrow \text{Violent attitudes}
\]

To test this model they measured several constructs in 131 Islamic youths in the Netherlands.
Radical belief system:

- Perceived illegitimacy of authorities
- Perceived in-group superiority
- Perceived distance to other people
- Perceived societal disconnectedness
Determinants:

- Personal uncertainty
- Perceived injustice
- Perceived group threat
Background variables:

- In-group identification
- Individualistic relative deprivation
- Collective relative deprivation
Table 1. The Means, Standard Deviations, and Inter-Correlations of All the Constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>M</th>
<th>SD</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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<th>8</th>
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<th>12</th>
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<td>–</td>
<td>−.19*</td>
<td>.08</td>
<td>−.25*</td>
<td>.42*</td>
<td>.07</td>
<td>.08</td>
<td>−.06</td>
<td>−.28*</td>
<td>.09</td>
<td>−.17</td>
<td>−.25*</td>
<td>−.04</td>
<td>−.07</td>
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<tr>
<td>Ind. Rel. Depri.</td>
<td>2.39</td>
<td>0.81</td>
<td>–</td>
<td>.49*</td>
<td>.36*</td>
<td>.23*</td>
<td>.50*</td>
<td>.21*</td>
<td>.50*</td>
<td>.25*</td>
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<td>.17</td>
<td>.21*</td>
<td>.12</td>
<td>.09</td>
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<td>Col. Rel. Depri.</td>
<td>3.31</td>
<td>0.92</td>
<td>–</td>
<td>.11</td>
<td>.54*</td>
<td>.62*</td>
<td>.26*</td>
<td>.38*</td>
<td>.21</td>
<td>.31*</td>
<td>.18*</td>
<td>.09</td>
<td>.20*</td>
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<td>0.17</td>
<td>–</td>
<td>.01</td>
<td>.15</td>
<td>.19*</td>
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<td>.35*</td>
<td>.08</td>
<td>.22*</td>
<td>.26*</td>
<td>.18*</td>
<td>.14</td>
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<td>3.46</td>
<td>0.76</td>
<td>–</td>
<td>.64*</td>
<td>.21*</td>
<td>.24*</td>
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<td>0.88</td>
<td>–</td>
<td>.27*</td>
<td>.34*</td>
<td>.16</td>
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<td>.26*</td>
<td>.16</td>
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<td>–</td>
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<td>.08</td>
<td>.29*</td>
<td>.18</td>
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<td>.30*</td>
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<td>–</td>
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<td>.03</td>
<td>.23*</td>
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<td>Perc. Ingr. Superior.</td>
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<td>0.93</td>
<td>−</td>
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<td>.08</td>
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<td>.30*</td>
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<td>Distance</td>
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<tr>
<td>Disconnected</td>
<td>2.79</td>
<td>0.96</td>
<td>−</td>
<td>.24*</td>
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<tr>
<td>Moslem Violence</td>
<td>2.89</td>
<td>1.06</td>
<td>−</td>
<td>.47*</td>
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<tr>
<td>Violent Intentions</td>
<td>2.08</td>
<td>0.91</td>
<td>−</td>
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</tbody>
</table>

Note. 2 = Individual Relative Deprivation, 3 = Collective Relative Deprivation, 4 = Intergroup Anxiety, 5 = Symbolic Threat, 6 = Realistic Threat, 7 = Personal Emotional Uncertainty, 8 = Perceived Procedural Injustice, 9 = Perceived Illegitimacy, 10 = Perceived Ingroup Superiority. *p < .05.
Correlations

The qgraph package can be used to visualize correlations as a network (Epskamp et al., 2012):

1: In-group Identification
2: Individual Deprivation
3: Collective Deprivation
4: Intergroup Anxiety
5: Symbolic Threat
6: Realistic Threat
7: Personal Emotional Uncertainty
8: Perceived Injustice
9: Perceived Illegitimacy authorities
10: Perceived In-group superiority
11: Distance to Other People
12: Societal Disconnected
13: Attitude towards Muslim Violence
14: Own Violent Intentions
To test the hypothesized model, Doosje et al. (2013) used Structural Equation Modelling (SEM). SEM is a powerful modeling framework that has been one of the main focuses of Psychometrics for decades. In essence, it can be seen as confirmatory testing a network of observed and unobserved variables where typically is assumed that:

- All paths are directed and indicate linear effects
- All variables are assumed normally distributed
- The network is *acyclic*
Determinants of perceived injustice, personal uncertainty, and group threat.

As hypothesized, perceived injustice is predicted most strongly by individual deprivation. When people feel personally deprived, they experience this as unjust. Collective deprivation was another significant predictor of perceived injustice. Collective deprivation was the only predictor of personal uncertainty: to the extent that people experience deprivation as group members, they feel personally uncertain. As expected, realistic group threat was most strongly predicted by collective deprivation, and individual deprivation constituted another significant predictor. Again in line with hypotheses, when people perceived a high level of collective deprivation and in-group identification, they experienced high levels of symbolic threat. Finally, high intergroup anxiety was associated with high levels of individual deprivation, and unexpectedly, low in-group identification was associated with higher levels of intergroup anxiety.

Determinants of radical belief system.

As expected, perceived illegitimacy of Dutch authorities was predicted by symbolic threat as well as intergroup anxiety. Thus, to the extent that people feel symbolically threatened and experience...
The hypothesized model had a good fit: Chi-square (65) = 76.58, \( p = .154 \), CFI = .98, NFI = .87, GFI = .93, SRMR = .082, and RMSEA = .037. La Grange Multiplier Test suggested including two direct paths: from collective deprivation to perceived illegitimacy of Dutch authorities, and from perceived distance to own violent intentions. When we included these paths, the fit became better. Our final model is presented in Figure 1. It has a very good fit: Chi-square (62) = 58.13, \( p = .650 \), CFI = 1.00, NFI = .90, GFI = .94, SRMR = .070, and RMSEA = .000. All paths included in the model are significant. We discuss this model in steps from left to right.
Interpreting SEM results

SEM can be used to test if the data rejects a theorized model. But care should be taken in that a fitting SEM model does not mean the model is correct. Many equivalent models could fit the data just as well.
Equivalent model

- Anxiety
- Symmetric threat
- Real threat
- Uncertainty
- Injustice
- Illegitimacy
- Superiority
- Distance
- Disconnected
- Muslim violence
- Own violent identification
- In_dep
- Col_dep
Equivalent models
Equivalent models
Equivalent models
Equivalent models
Interpreting SEM results

- Direction of causation can often not be inferred
- Assumption of no cycles is very strict and in psychology often not tenable
- SEM is very powerful in testing strict theories where the acyclic assumption is met. In more exploratory settings however, using partial correlation networks can be preferred:
  - Shows relationships present in the data
  - No equivalent models
  - Naturally cyclic
  - Optimally predicts each node given all others
1: In-group Identification
2: Individual Deprivation
3: Collective Deprivation
4: Intergroup Anxiety
5: Symbolic Threat
6: Realistic Threat
7: Personal Emotional Uncertainty
8: Perceived Injustice
9: Perceived Illegitimacy authorities
10: Perceived In-group superiority
11: Distance to Other People
12: Societal Disconnected
13: Attitude towards Muslim Violence
14: Own Violent Intentions
Partial correlation network

1: In-group Identification
2: Individual Deprivation
3: Collective Deprivation
4: Intergroup Anxiety
5: Symbolic Threat
6: Realistic Threat
7: Personal Emotional Uncertainty
8: Perceived Injustice
9: Perceived Illegitimacy authorities
10: Perceived In-group superiority
11: Distance to Other People
12: Societal Disconnected
13: Attitude towards Muslim Violence
14: Own Violent Intentions
Partial correlation network

After glasso (Friedman, Hastie, & Tibshirani, 2011):

1: In-group Identification
2: Individual Deprivation
3: Collective Deprivation
4: Intergroup Anxiety
5: Symbolic Threat
6: Realistic Threat
7: Personal Emotional Uncertainty
8: Perceived Injustice
9: Perceived Illegitimacy authorities
10: Perceived In-group superiority
11: Distance to Other People
12: Societal Disconnected
13: Attitude towards Muslim Violence
14: Own Violent Intentions
Centrality

Betweenness

Closeness

Strength

- Symbolic Threat
- Societal Disconnected
- Realistic Threat
- Personal Emotional Uncertainty
- Perceived Injustice
- Perceived In-group superiority
- Perceived Illegitimacy authorities
- Own Violent Intentions
- Intergroup Anxiety
- In-group Identification
- Individual Deprivation
- Distance to Other People
- Collective Deprivation
- Attitude towards Muslim Violence
<table>
<thead>
<tr>
<th></th>
<th>Muslim Violence</th>
<th>Violent Intentions</th>
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<td>In-group Identification</td>
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<td>Individual Deprivation</td>
<td>20.10</td>
<td>23.87</td>
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<tr>
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<td>18.58</td>
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<tr>
<td>Perceived In-group superiority</td>
<td>3.16</td>
<td>6.93</td>
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<td>Distance to Other People</td>
<td>5.70</td>
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<td>Societal Disconnected</td>
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<td>Own Violent Intentions</td>
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Shortest path length

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<td>Own Violent Intentions</td>
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Conclusion

Preliminary network analysis agrees with Doosje et al. (2013) that Perceived In-group superiority, Distance to Other People and to a lesser extent Societal Disconnected are strong predictors for attitudes towards Muslim violence which in turn predicts own violent intents. The fourth element of the radical beliefs system, Perceived Illegitimacy authorities, plays a lesser role in the network. Personal Emotional Uncertainty is the only variable whose predictive power on the violent variables is not mediated by the radical beliefs system.
Thank you for your attention!
