

# Network Visualizations of Relationships in Psychometric Data and Structural Equation Models

Using the **qgraph** package for R

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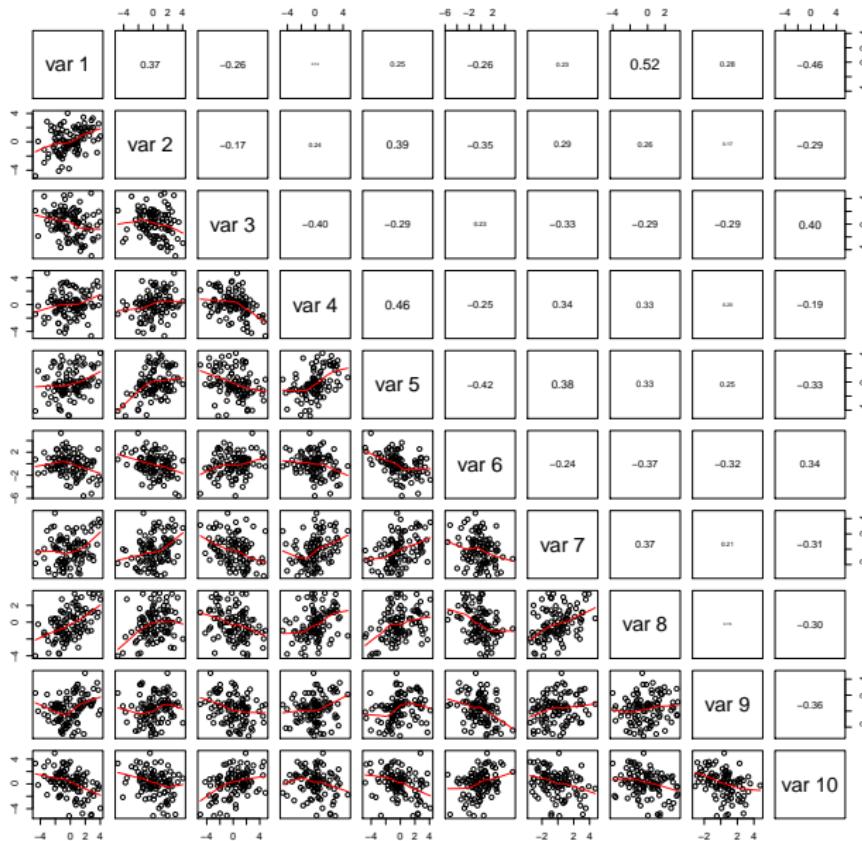
IMPS 2013



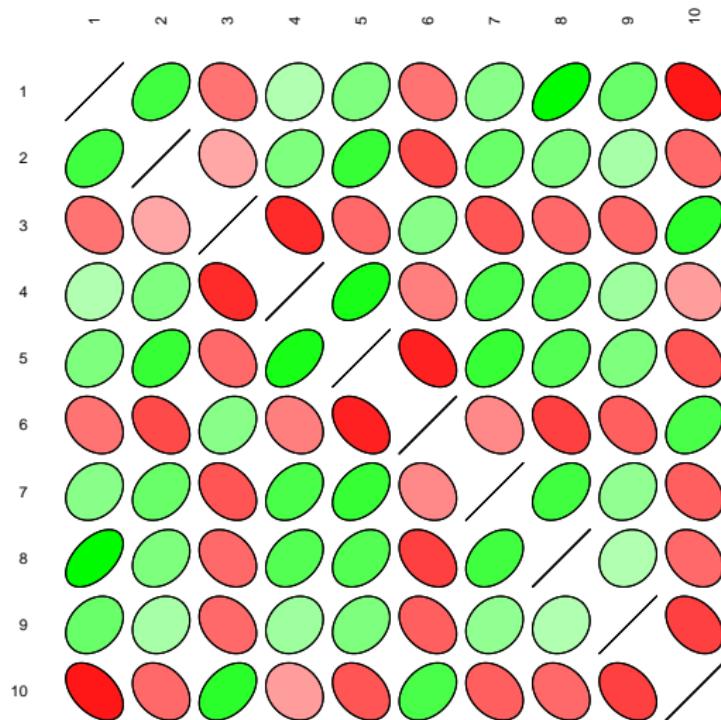
**Look at your data...**



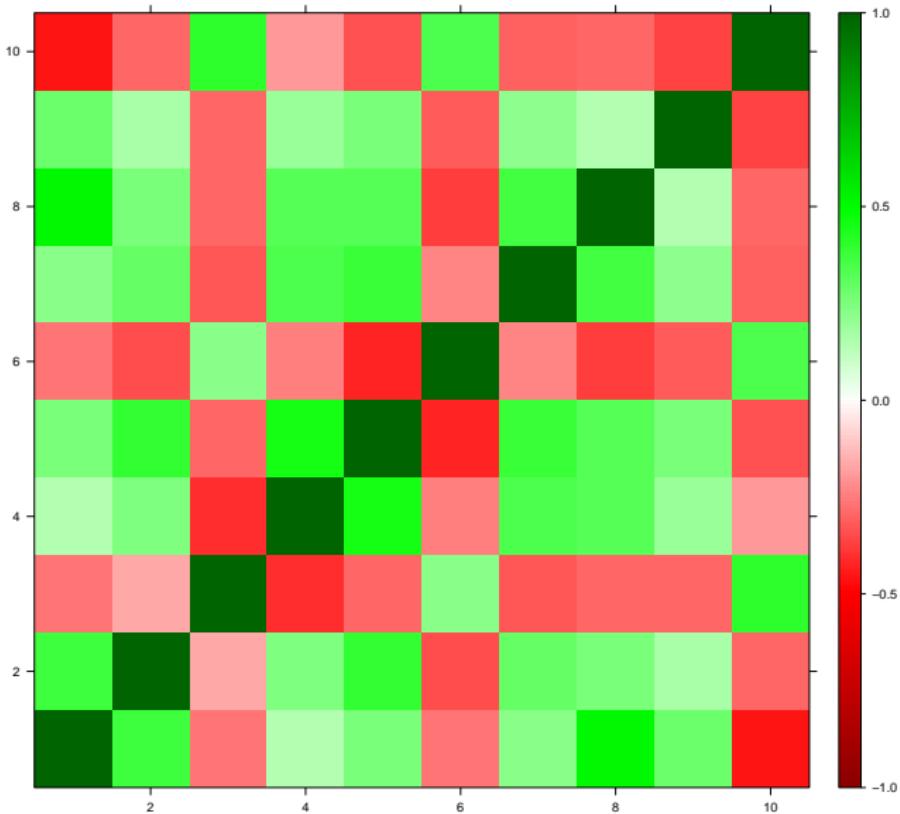
**Simulated data**



Simulated data



Simulated data

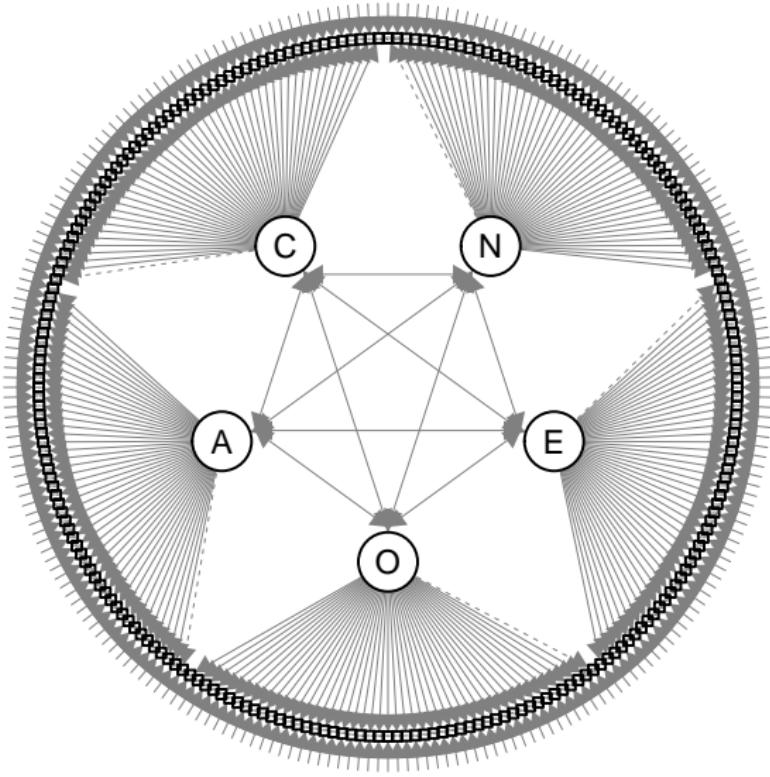


## Real data example

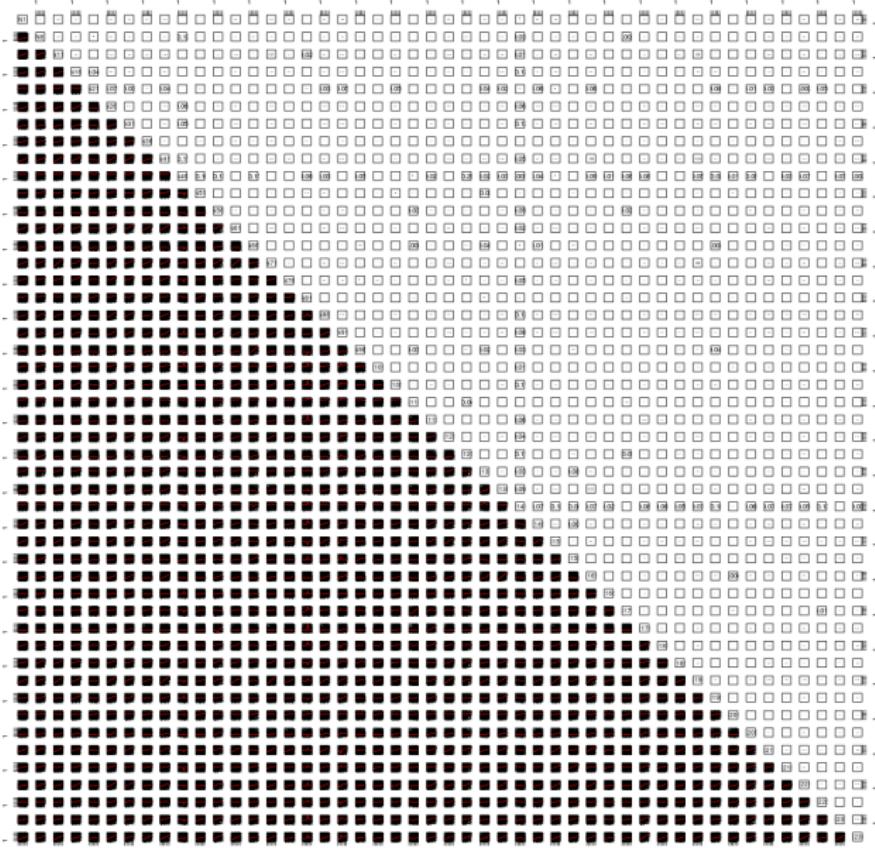
Included in **qgraph** is a dataset in which the Dutch translation of a commonly used personality test, the NEO-PI-R (Costa & McCrae, 1992; Hoekstra, de Fruyt, & Ormel, 2003), was administered to 500 first year psychology students (Dolan, Oort, Stoel, & Wicherts, 2009). The NEO-PI-R consists of 240 items designed to measure the five central personality factors:

- ▶ Neuroticism
- ▶ Extroversion
- ▶ Agreeableness
- ▶ Openness to Experience
- ▶ Conscientiousness

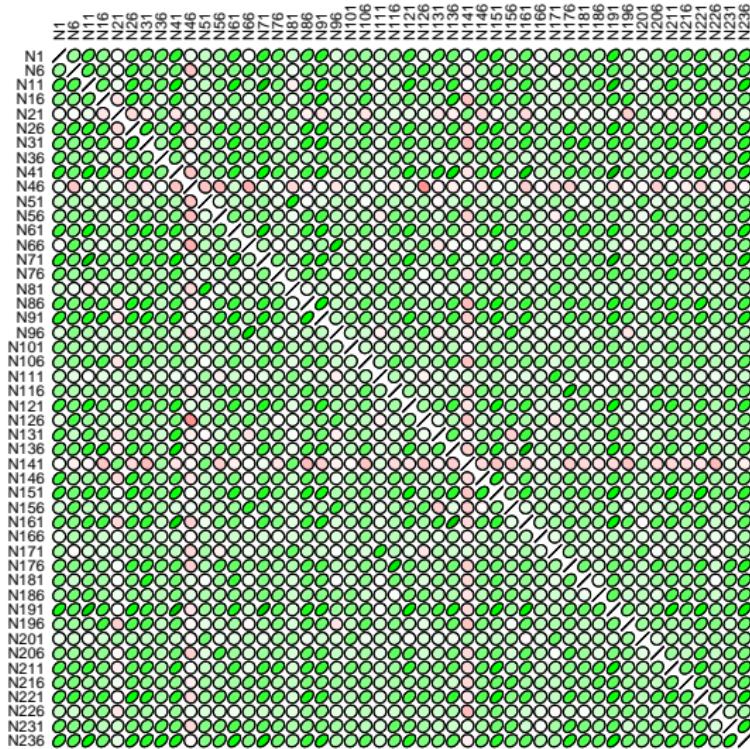




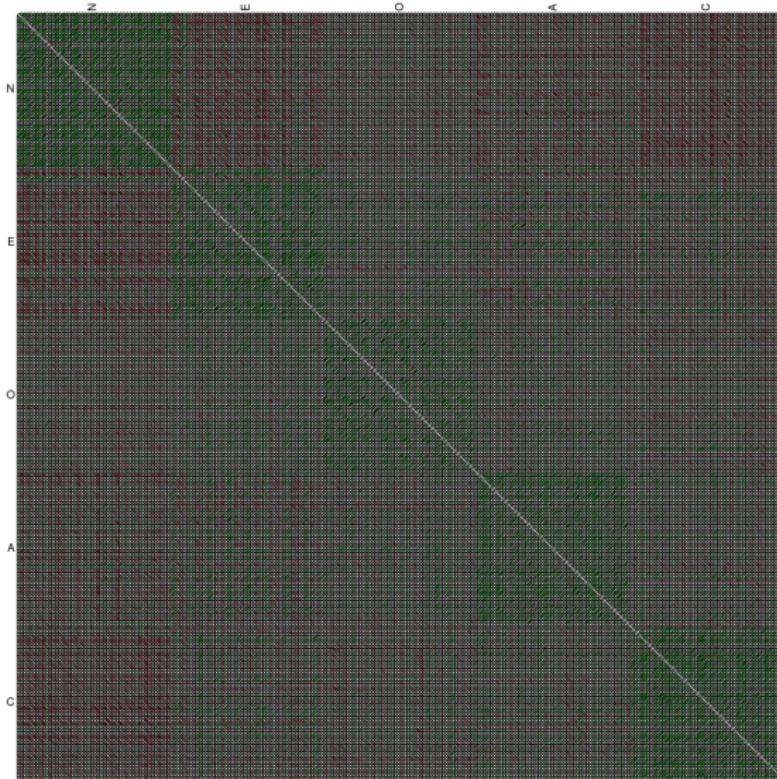
Neuroticism correlations



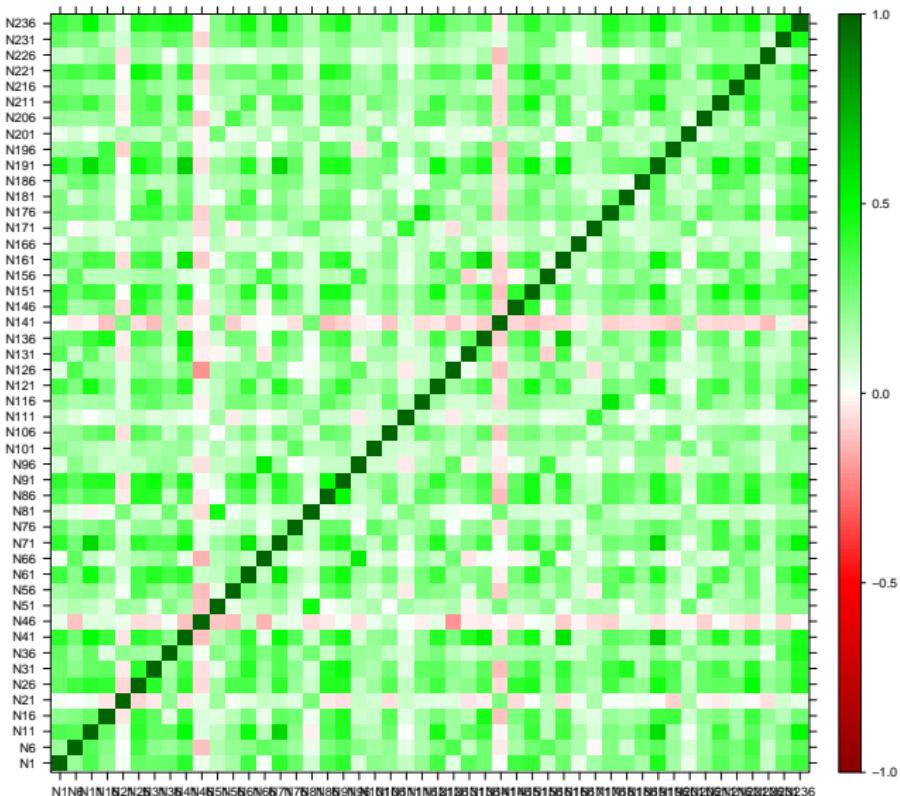
### Neuroticism correlations



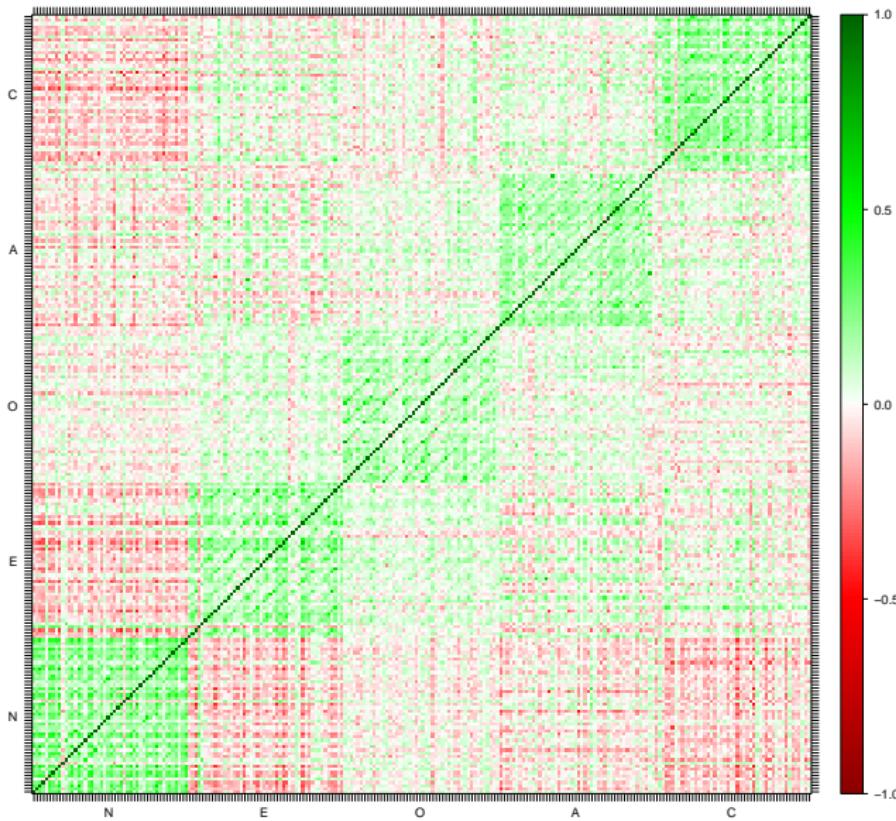
**Big 5 correlations**



Neuroticism correlations



**Big 5 correlations**



- ▶ When extended to the amount of variables commonly used in tests:
  - ▶ Scatterplot and ellipse visualizations become unreadable
  - ▶ Heatmaps plots do better, but only show trends
    - ▶ Very hard, if not impossible, to see important violations of trends
- ▶ We need another way to look at our data



# The Network Approach

Basic idea:

- ▶ Nodes represent variables
  - ▶ Possible to vary in color, shape, size and label to indicate different statistics
- ▶ Edges represent relationships
  - ▶ Green edges indicate positive relationships
  - ▶ Red edges indicate negative relationships
  - ▶ The wider and more saturated an edge, the stronger the absolute relationship

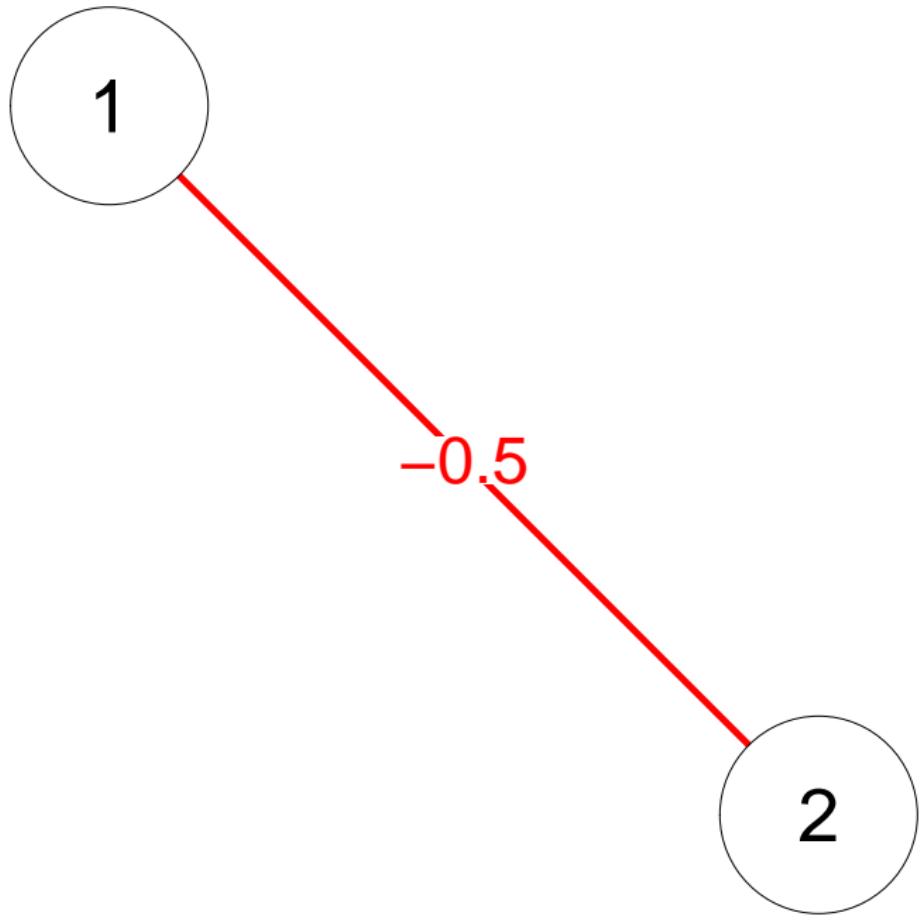


1

0.5

2



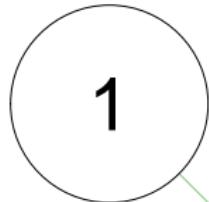


1

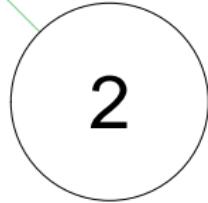
-0.5

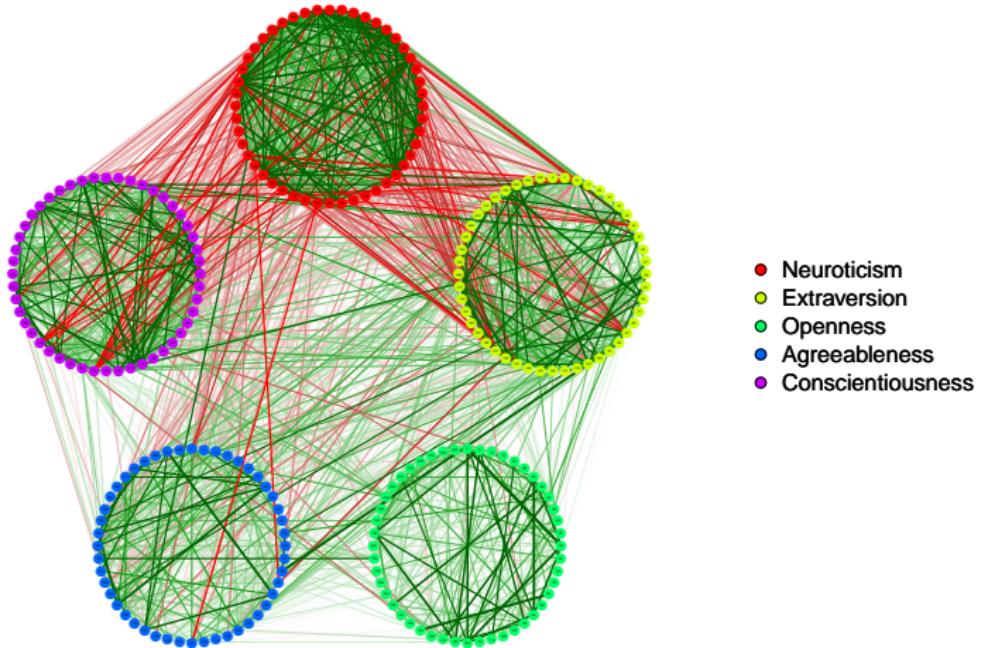
2

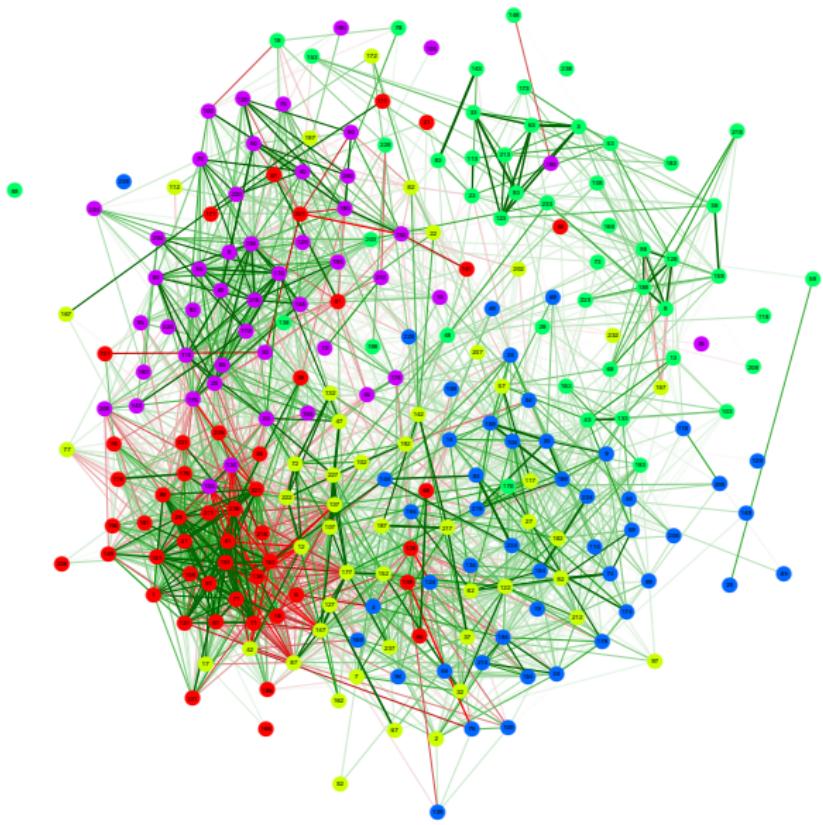




0.2

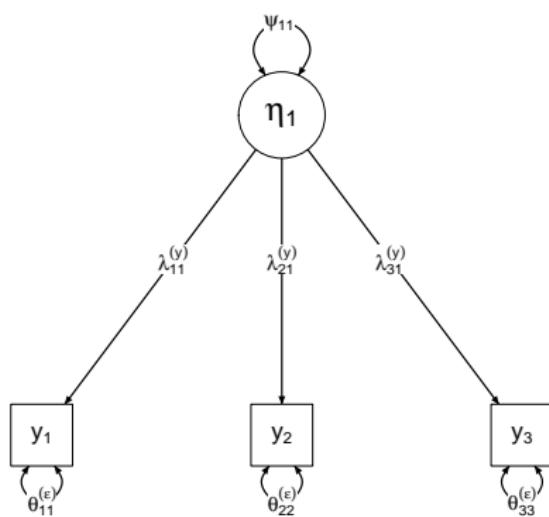




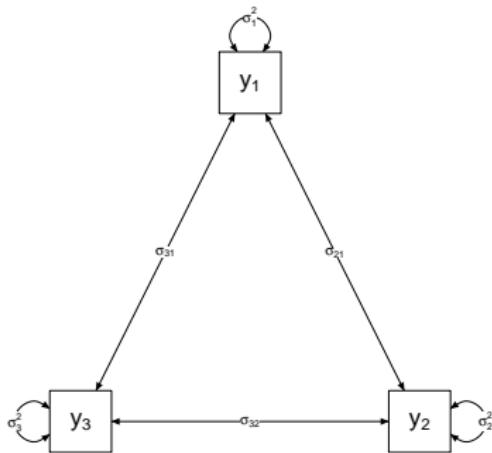


# Implied correlations

CFA model

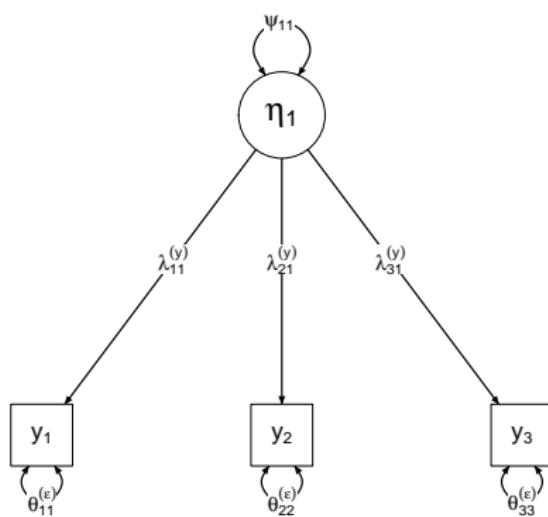


Covariance structure

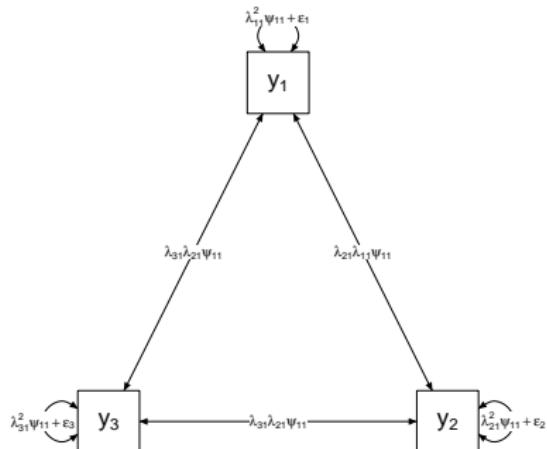


# Implied correlations

CFA model



Implied covariance structure



# Implied correlations

$$\boldsymbol{\Sigma} = \boldsymbol{\Lambda} \boldsymbol{\Psi} \boldsymbol{\Lambda}^\top + \boldsymbol{\Theta}$$

$$\begin{bmatrix} \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_2^2 & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_3^2 \end{bmatrix} = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \end{bmatrix} \begin{bmatrix} \psi_{11} \end{bmatrix} \begin{bmatrix} \lambda_1 & \lambda_2 & \lambda_3 \end{bmatrix} + \begin{bmatrix} \theta_{11} & 0 & 0 \\ 0 & \theta_{22} & 0 \\ 0 & 0 & \theta_{33} \end{bmatrix}$$
$$= \begin{bmatrix} \lambda_1^2 \psi_{11} + \theta_{11} & \lambda_1 \lambda_2 \psi_{11} & \lambda_1 \lambda_3 \psi_{11} \\ \lambda_2 \lambda_1 \psi_{11} & \lambda_2^2 \psi_{11} + \theta_{22} & \lambda_2 \lambda_3 \psi_{11} \\ \lambda_3 \lambda_1 \psi_{11} & \lambda_3 \lambda_2 \psi_{11} & \lambda_3^2 \psi_{11} + \theta_{33} \end{bmatrix}$$



## Implied correlations

$\psi$  can be set to 1 without loss of information.

$$\begin{bmatrix} \lambda_1^2 + \theta_{11} & \lambda_1\lambda_2 & \lambda_1\lambda_3 \\ \lambda_2\lambda_1 & \lambda_2^2 + \theta_{22} & \lambda_2\lambda_3 \\ \lambda_3\lambda_1 & \lambda_3\lambda_2 & \lambda_3^2 + \theta_{33} \end{bmatrix}$$

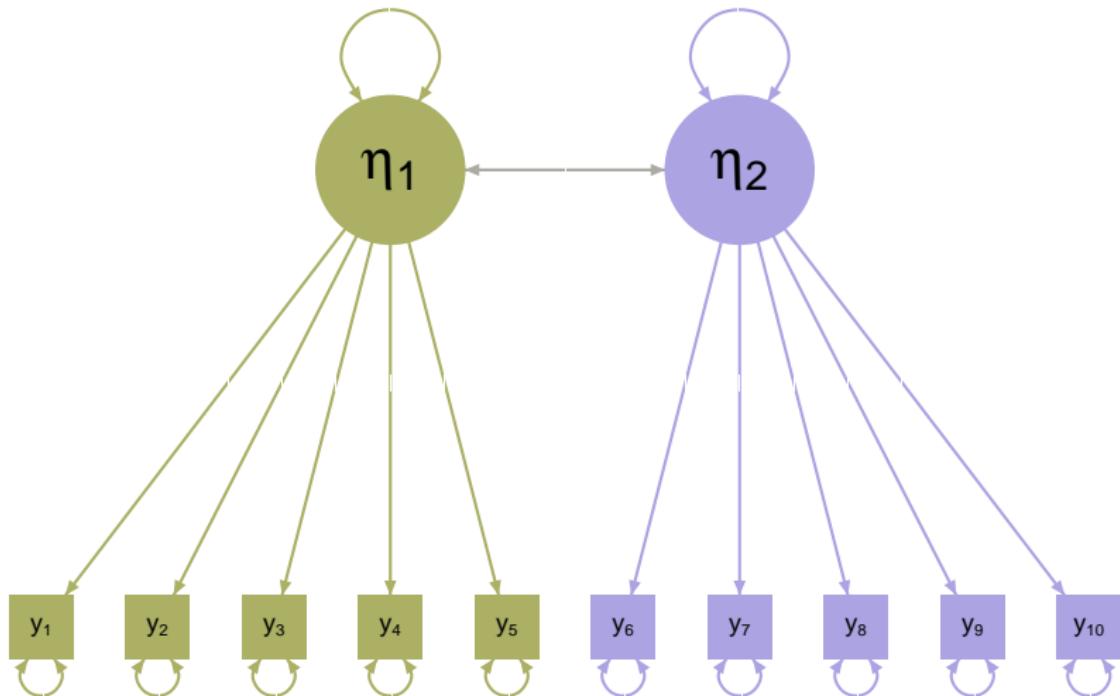


# Implied correlations

- ▶ The single factor model implies a very distinct correlational pattern:
  - ▶ Two variables are correlated highly if, and only if, they both load strongly on the factor
  - ▶ Because of this, if one factor underlies, for example, four variables, and we know there are strong correlations between two pairs of variables, then all other correlations between these four variables must be strong as well
- ▶ Multiple factors do not change this as long as there are no crossloadings

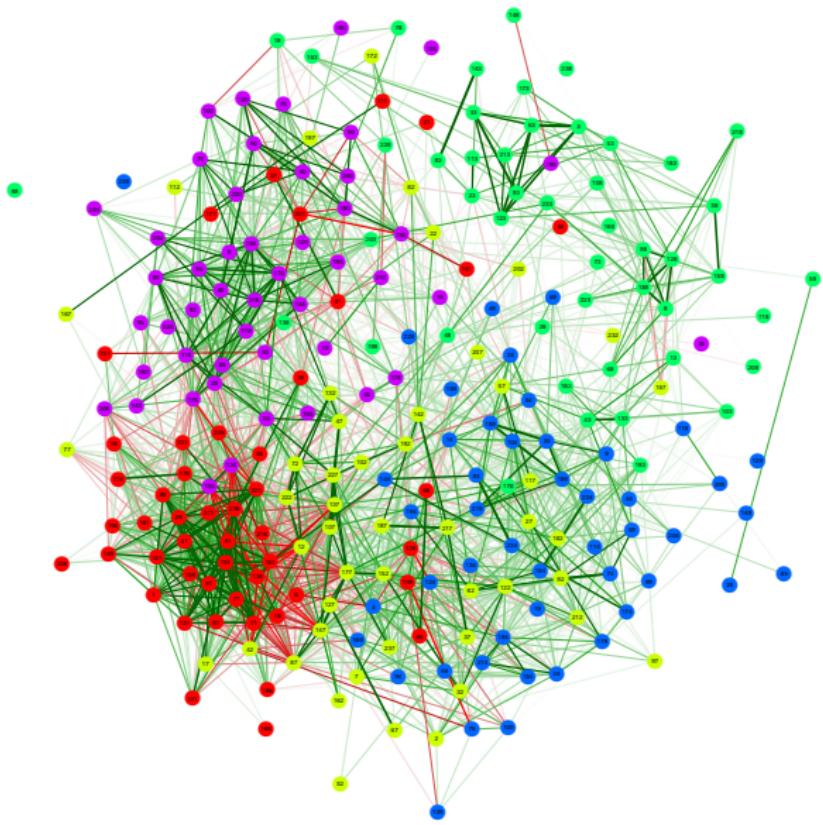


# Implied correlations

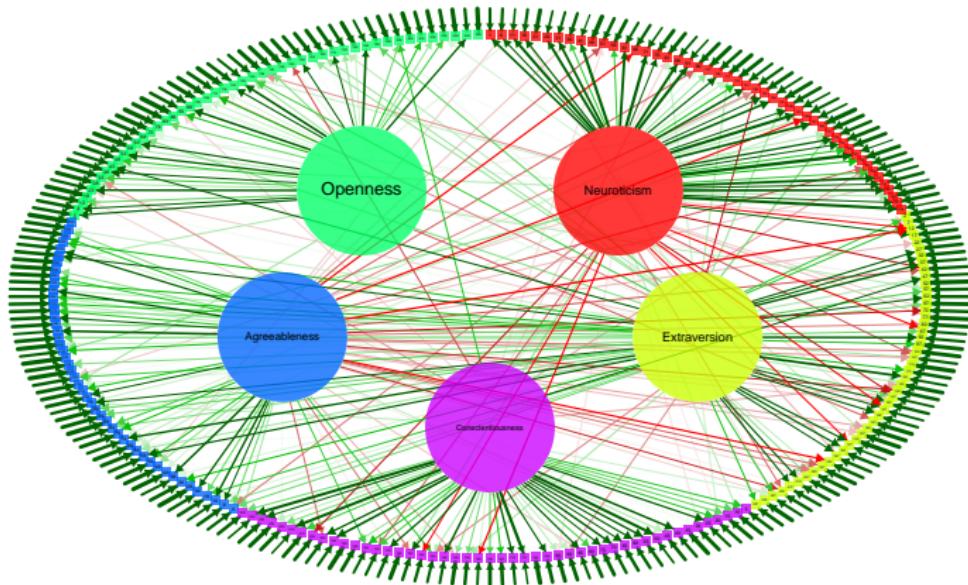


# Implied correlations

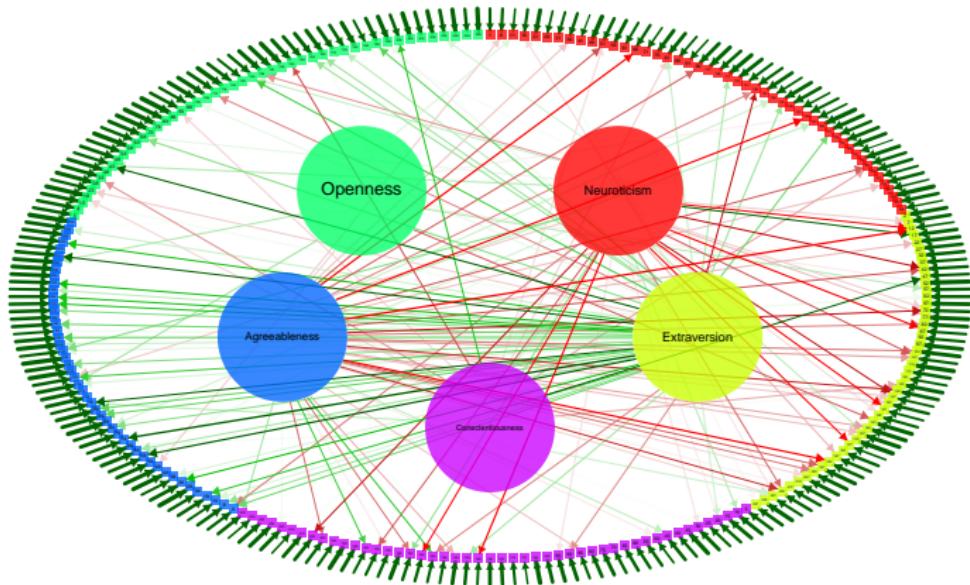




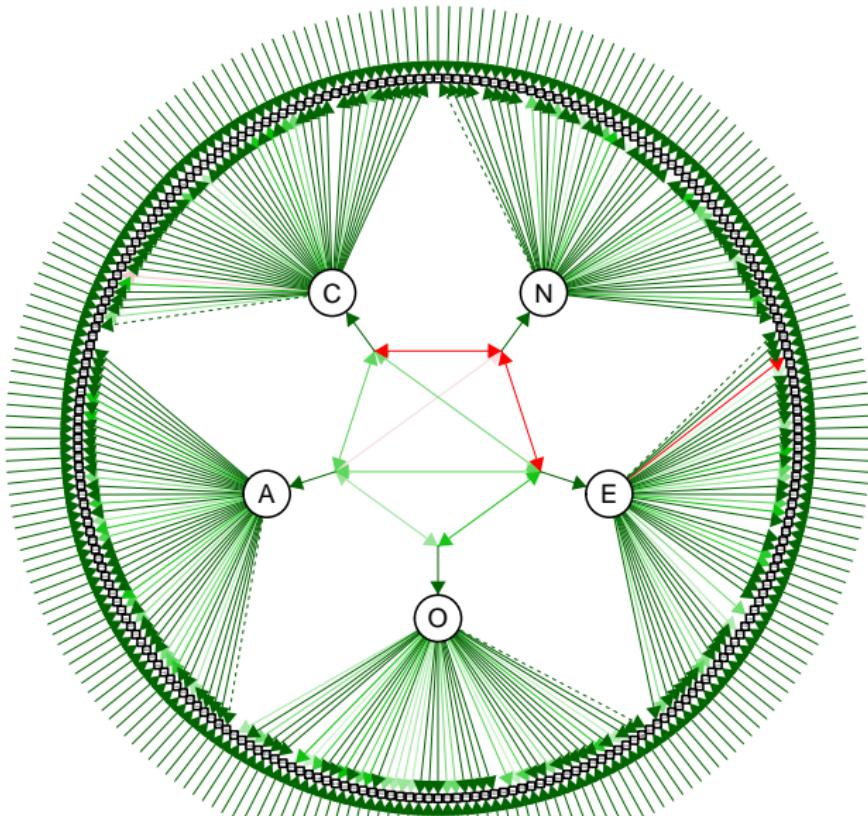
# Factor loadings: EFA



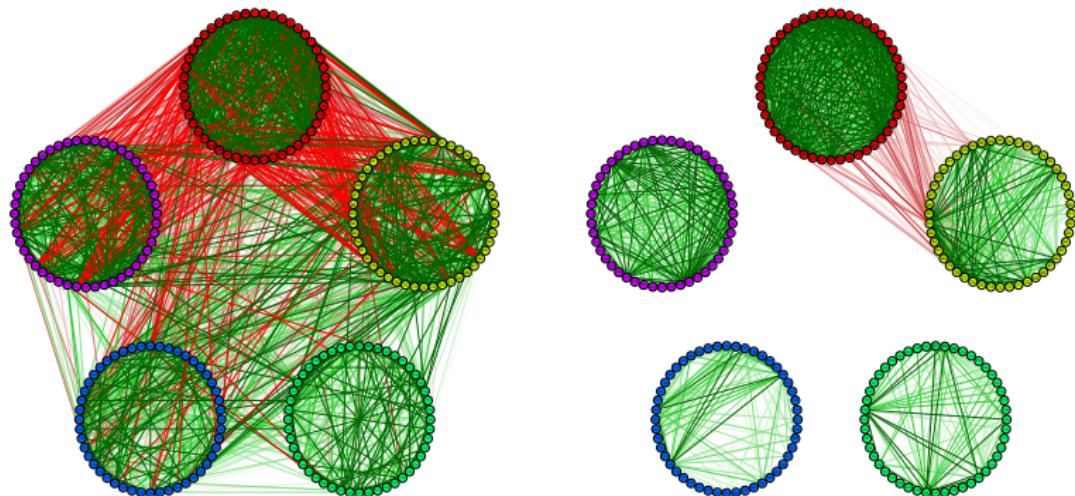
# Factor loadings: EFA crossloadings



# CFA model



# Correlations

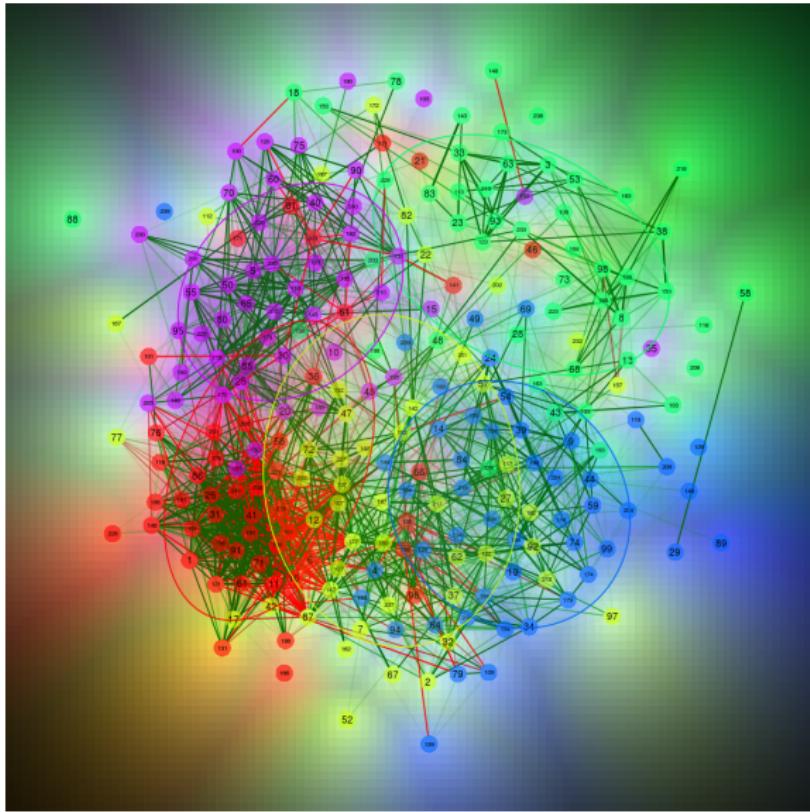


# **qgraph**

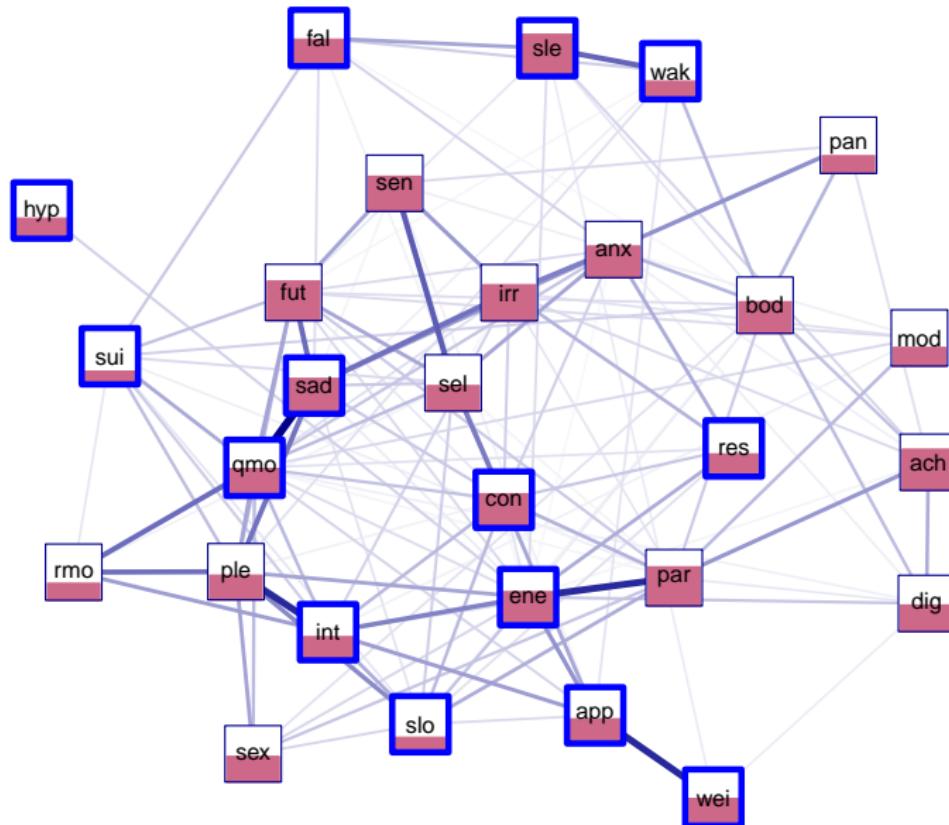
- ▶ **qgraph** is a network plotting package aimed at automatically visualizing fully connected weighted networks
- ▶ Can be used for many other kinds of networks as well
- ▶ **qgraph** objects can be exported to **igraph** objects
- ▶ Support for following classes:
  - ▶ "principal" (**psych**)
  - ▶ "loadings" (**stats**)
  - ▶ "factanal" (**stats**)
  - ▶ "graphNEL" (**Rgraphviz**)
  - ▶ "pcAlgo" (**pcaalg**)
  - ▶ ("bn" (**bnlearn**))
  - ▶ ("bn.strength" (**bnlearn**))
- ▶ Easy to use!



# Graphical options



# Graph by Claudia van Borkulo



# **semPlot**

Currently supported SEM software packages:

- ▶ **lavaan**
- ▶ **sem**
- ▶ **OpenMx** (RAM only)
- ▶ **MPlus** (using **MplusAutomation**)
- ▶ **LISREL** (using **LisrelToR**)

Other R functions:

- ▶ `lm`
- ▶ `factanal`
- ▶ `principal`

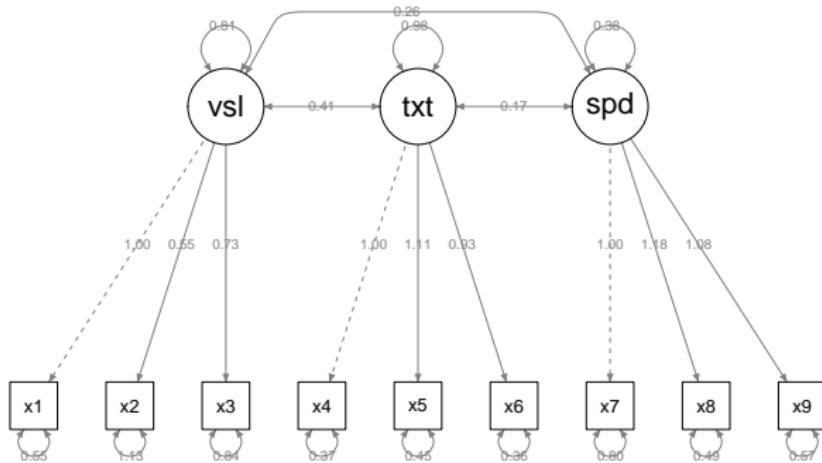
Supported modelling frameworks:

- ▶ lavaan
- ▶ LISREL matrix model
- ▶ RAM matrix model
- ▶ Mplus matrix model



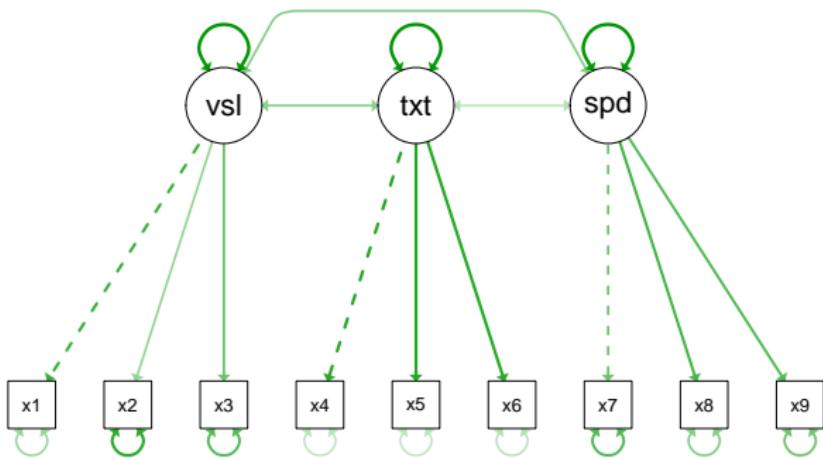
# semPlot

Holzinger and Swineford (1939) CFA example:



# semPlot

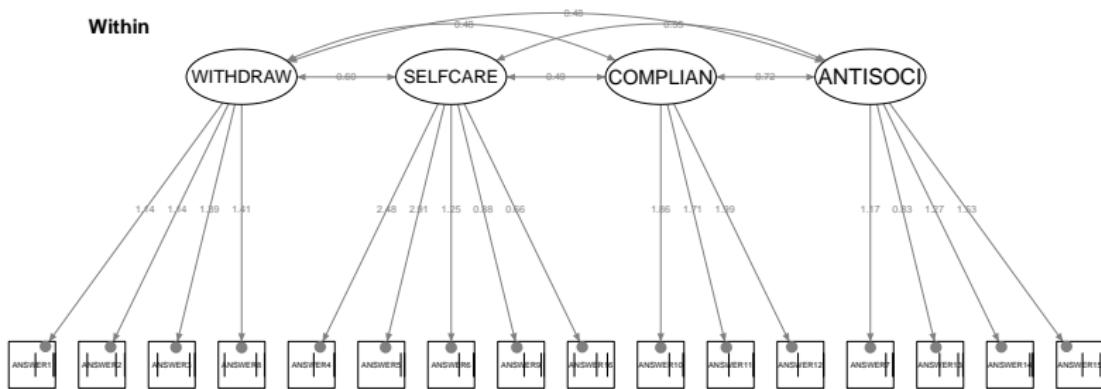
Holzinger and Swineford (1939) CFA example:



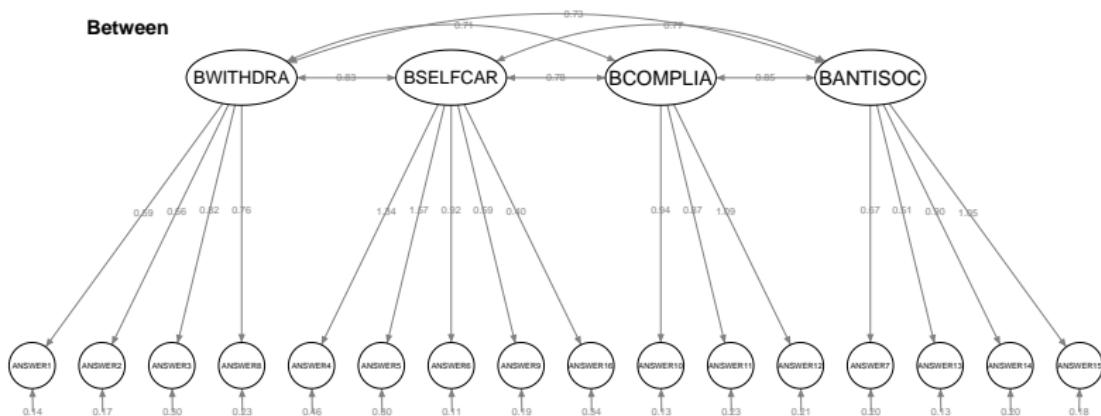
# semPlot

Based on output file from Little (in press).

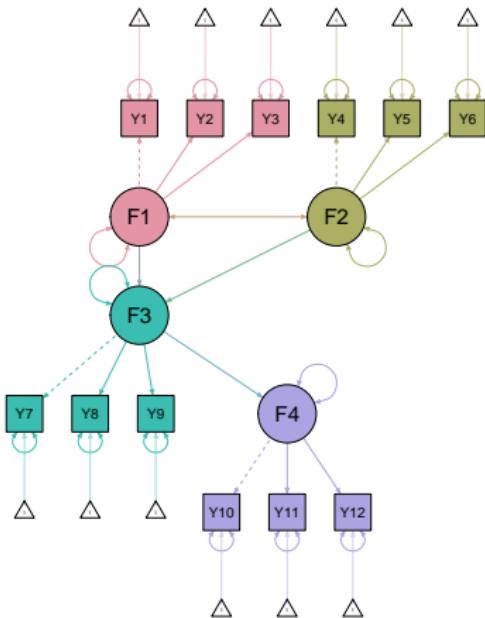
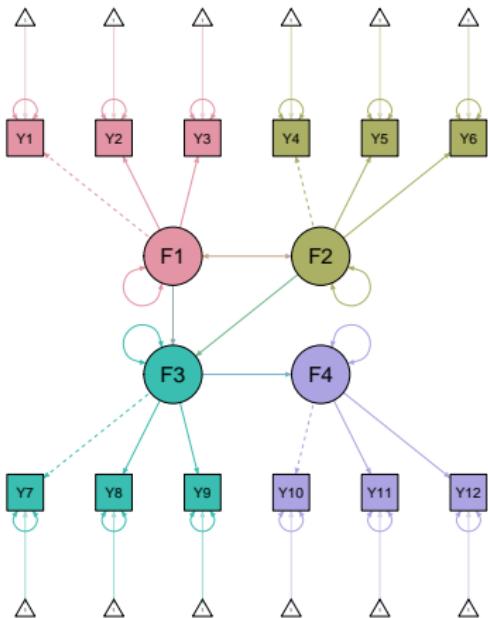
Within



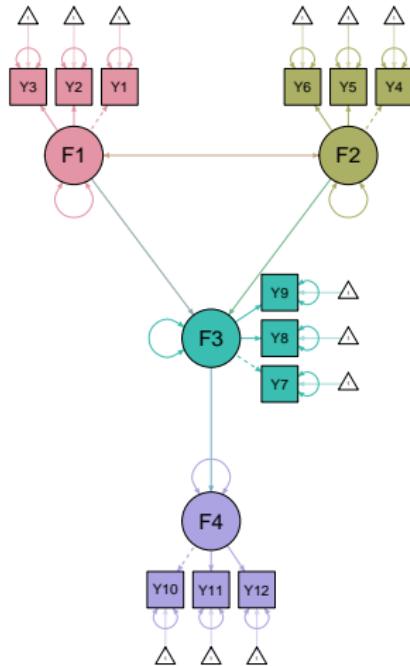
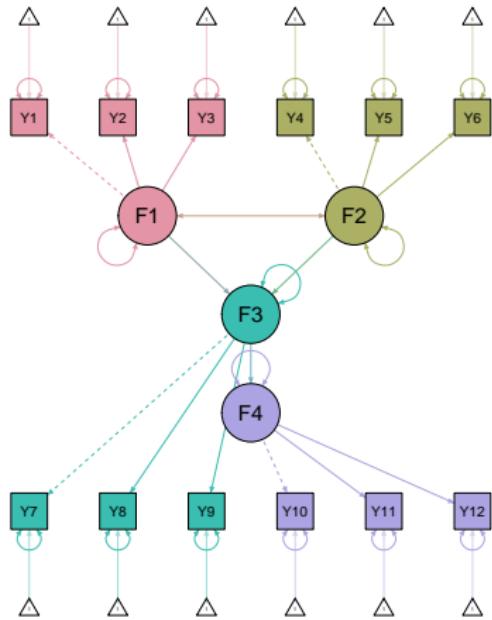
Between



# semPlot

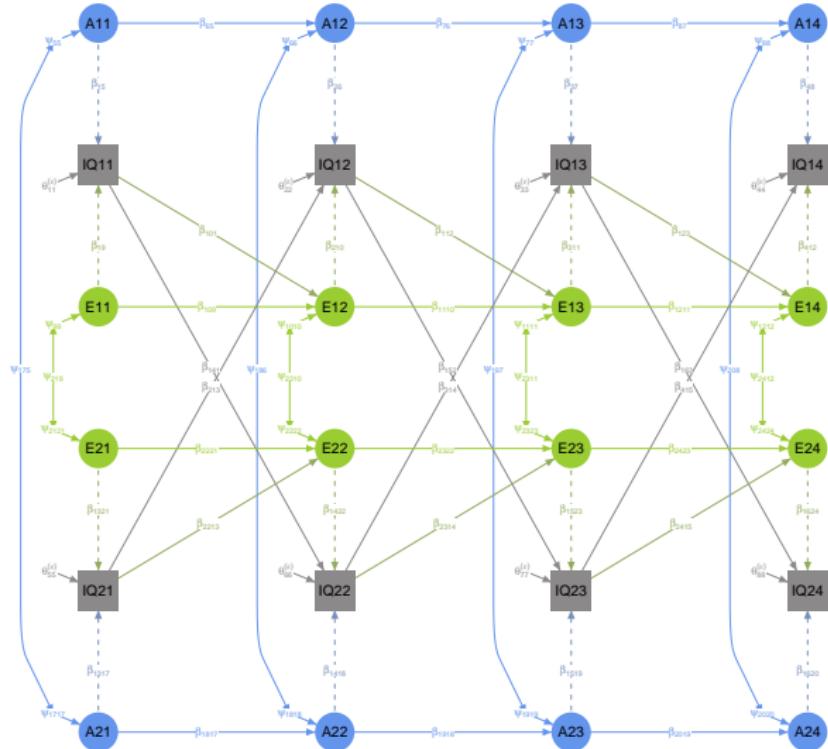


# semPlot



# semPlot

Model by Janneke de Kort



# Concluding comments

## **qgraph:**

- ▶ Paper in JSS: <http://www.jstatsoft.org/v48/i04>
- ▶ Stable versions on CRAN:  
[cran.r-project.org/package=qgraph](http://cran.r-project.org/package=qgraph)
- ▶ developmental version on Github:  
<https://github.com/SachaEpskamp/qgraph>

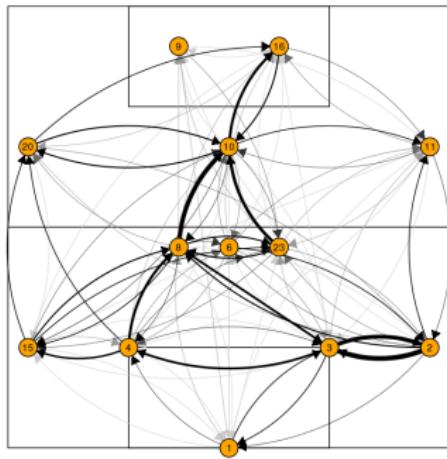
## **semPlot:**

- ▶ Paper in preparation
- ▶ Stable versions on CRAN:  
[cran.r-project.org/package=semPlot](http://cran.r-project.org/package=semPlot)
- ▶ developmental version on Github:  
<https://github.com/SachaEpskamp/semPlot>
- ▶ More info on my website: [sachaepskamp.com](http://sachaepskamp.com)

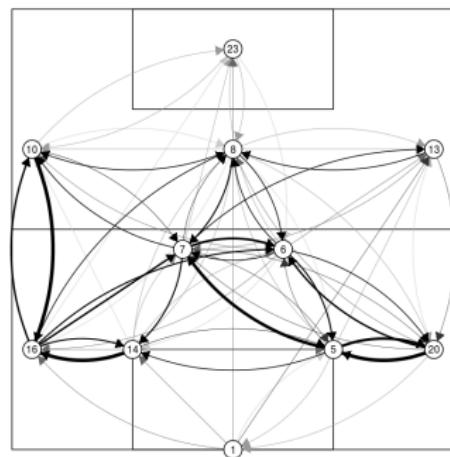


# And more...

Netherlands:



Germany:



Thank you for your attention!



## References

- Costa, P. T., & McCrae, R. R. (1992). *Neo personality inventory revised (neo pi-r)*. Psychological Assessment Resources.
- Dolan, C., Oort, F., Stoel, R., & Wicherts, J. (2009). Testing Measurement Invariance in the Target Rotated Multigroup Exploratory Factor Model. *Structural Equation Modeling: A Multidisciplinary Journal*, 16(2), 20.
- Hoekstra, H., de Fruyt, F., & Ormel, J. (2003). *Neo-Persoonlijkheidsvragenlijsten: NEO-PI-R, NEO-FFI [Neo personality questionnaires: NEO-PI-R, NEO-FFI]*. Lisse: Swets Test Services.
- Holzinger, K. J., & Swineford, F. (1939). A study in factor analysis: The stability of a bi-factor solution. *Supplementary Educational Monographs*.
- Little, J. (in press). Multilevel confirmatory ordinal factor analysis of the life skills profile-16. *Psychological Assessment*, xx.

