

# NETWORK PSYCHOMETRICS

## *uma introdução*

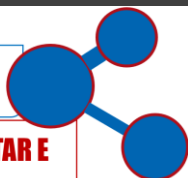
Prof. Dr. Wagner de Lara  
Machado

PPG Psicologia

Escola de Ciências da Saúde  
PUCRS

GRUPO DE PESQUISA

AVALIAÇÃO EM BEM-ESTAR E  
SAÚDE MENTAL



MELHOR  
PÓS-GRADUAÇÃO  
DO BRASIL

AVALIAÇÃO QUADRIENAL DA CAPES

PSICOLOGIA  
Nota 6

Excelência Internacional

# Quem sou eu?

- Psicólogo (ULBRA)
- Mestre e Doutor em Psicologia (UFRGS)
- Estágio de Pós-doutorado (UFRGS)
- Professor do PPG Psicologia da PUCRS (Nota 6 CAPES)
- Grupo de pesquisa:

Avaliação em Bem-estar e Saúde Mental







Network Analysis?



# Análise de rede aplicada à psicometria e a avaliação psicológica



Sacha Epskamp

Assistant Professor in Psychological Methods and Psychometrics at the University of Amsterdam

Wagner de Lara Machado

Pontifícia Universidade Católica de Campinas

João Ricardo Nickenig Vissoci

Faculdade Ingá e Duke University

Sacha Epskamp

Universiteit van Amsterdam



João Vissoci

Pesquisador na divisão de Emergency Medicine do departamento de Cirurgia, e na divisão Duke Global Neurosurgery and Neuroscience (DGNN) do departamento de Neurocirurgia, na Duke University

(vii) `qgraph(E3,directed=FALSE)`  
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`qgraph(E3)`  
`qgraph(E3,directed=FALSE,layout="spring")`

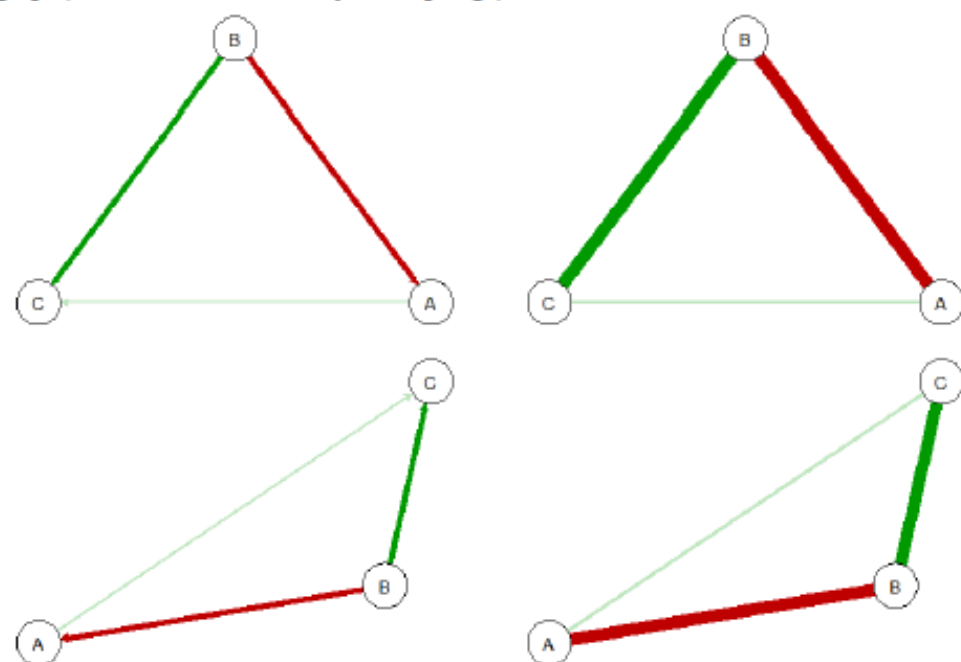


Figura 5. Redes ponderadas, direcionais e não-direcionais, sem (acima) e com (abaixo) o emprego do algoritmo de posicionamento.

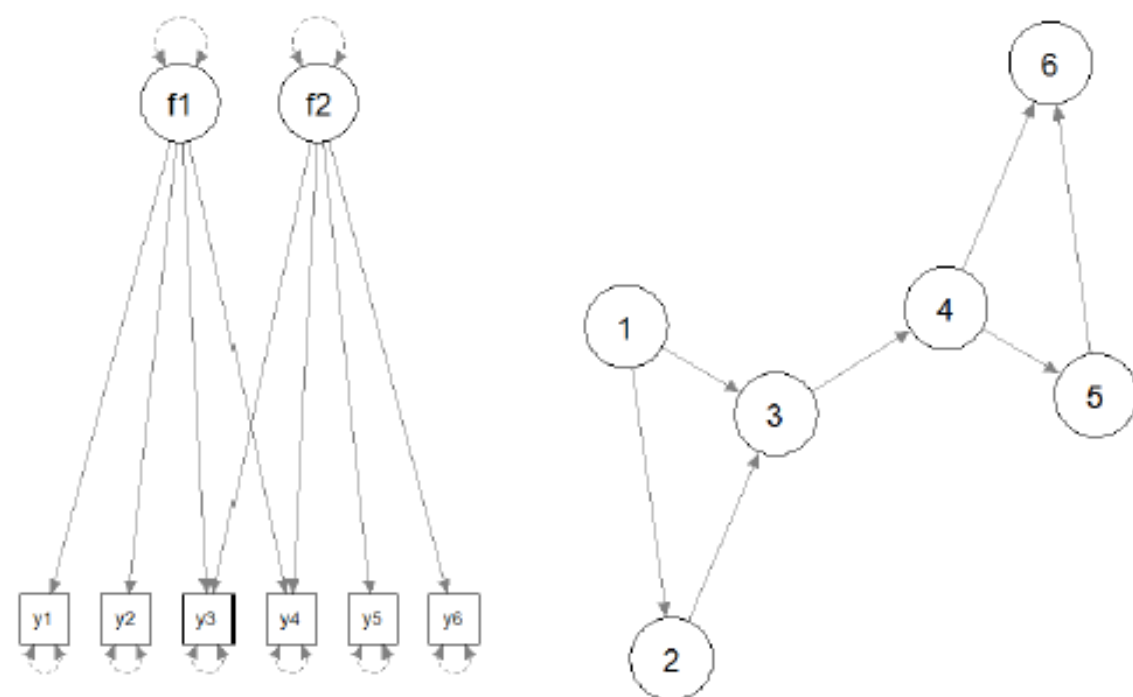


Figura 13. Modelo de traço latente (esquerda) e de rede (direita) da comorbidade.

# Positive Mental Health Scale: Validation of the *Mental Health Continuum – Short Form*

Wagner de Lara Machado – Pontifícia Universidade Católica de Campinas, Campinas, São Paulo, Brasil

Denise Ruschel Bandeira – Universidade Federal do Rio Grande do Sul, Porto Alegre, Brasil

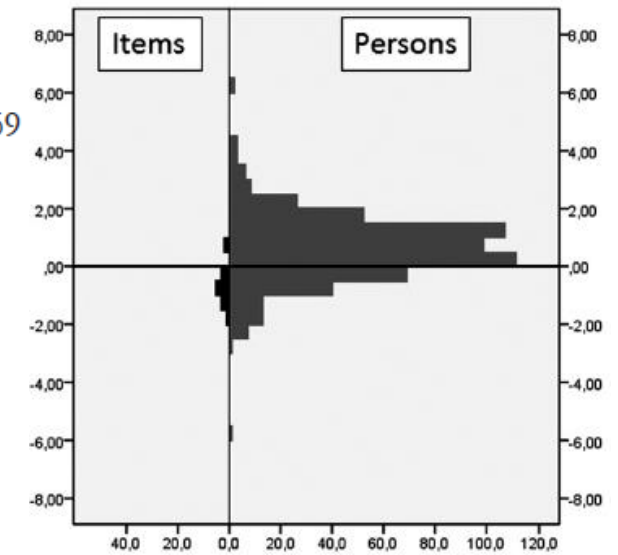


Figure 1. Map of items and persons. The vertical axis indicates the scale in logits. The distribution was obtained by fixing the contrary measure so the mean would be equal to zero.

Table 2

Item Factor Loadings and Reliability Measures of the MHC-SF in the Bifactor Model

| Item (summarized content)              | Factor loading |     |     |     |
|--|----------------|-----|-----|-----|
|  | General factor | EWB | SWB | PWB |
| 1 – Happy                              | .70            | .65 |     |     |
| 2 – Interested                         | .78            | .32 |     |     |
| 3 – Satisfied                          | .78            | .36 |     |     |
| 4 – Contribute to society              | .69            |     | .07 |     |
| 5 – Belong to community                | .67            |     | .23 |     |
| 6 – Society is becoming a better place | .62            |     | .63 |     |
| 7 – People are good                    | .62            |     | .41 |     |
| 8 – Way society works makes sense      | .57            |     | .56 |     |
| 9 – Likes own personality              | .79            |     |     | .21 |
| 10 – Manages responsibility well       | .70            |     |     | .19 |
| 11 – Relationships with others         | .72            |     |     | .24 |
| 12 – Grow and become a better person   | .62            |     |     | .39 |
| 13 – Confident to express own ideas    | .68            |     |     | .52 |
| 14 – Life has direction or meaning     | .83            |     |     | .12 |
| Average extracted variance             | .49            | .22 | .19 | .10 |
| Composite reliability                  | .93            | .43 | .47 | .34 |

Note. EWB = emotional well-being, SWB = social well-being, PWB = psychological well-being.

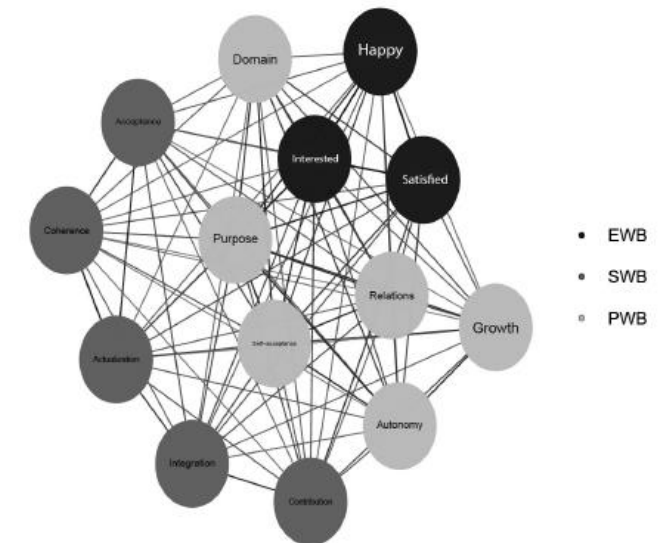
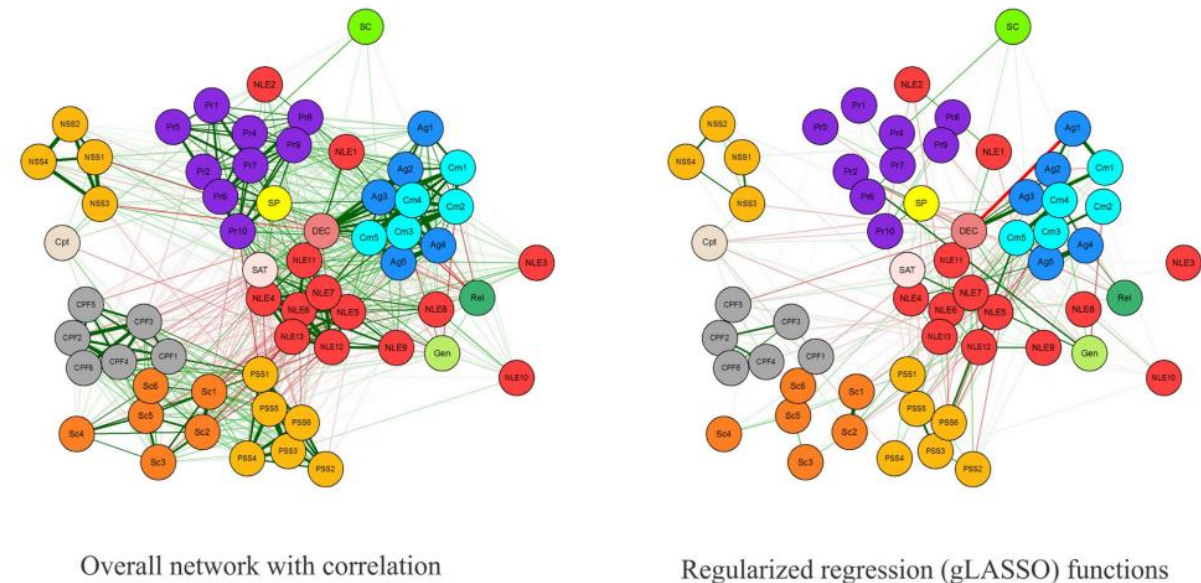


Figure 2. Network of positive mental health indicators. The covariance structure indicates that the MHC-SF items are strongly associated with the others, resulting in a dense component. The items in the emotional (EWB), social (SWB) and psychological (PWB) well-being subscales exhibit moderate to strong crossed associations. Purpose in life and self-acceptance are the central nodes of the system, meaning that they are more strongly associated with the remainder of the items. The stronger line represents the correlation between “happy” and “satisfied” ( $r_{1,3} = .78$ ); the fainter line represents the correlation between “relations” and “coherence” ( $r_{8,11} = .35$ ).



# The Experience of Sexual Stigma and the Increased Risk of Attempted Suicide in Young Brazilian People from Low Socioeconomic Group

Angelo Brandelli Costa<sup>1\*</sup>, Andrew Pasley<sup>2</sup>, Wagner de Lara Machado<sup>3</sup>, Ernesto Alvarado<sup>4</sup>, Luciana Dutra-Thomé<sup>4</sup> and Silvia Helena Koller<sup>4</sup>



**FIGURE 1 |** Overall network with correlation (left) and regularized regression (gLASSO) functions (right). Variables names match those in Table 1.

This study was intended to analyze the intersection of experience of sexual stigma low-socioeconomic status, and suicide attempt amongst young Brazilians (11–24 years old). In each of the data collection periods (2004–2006:  $n = 7185$ ; 2010–2012:  $n = 2734$ ), participants completed a questionnaire-based instrument. Network analysis provided support for a Minority Stress Model, oriented around whether participants had experienced sexual stigma. Although suicide attempts decreased by 20% for participants



# Iniciando...

- Acesse: <https://github.com/wagnerLM/>
- Selecione o curso\_redes: <https://github.com/wagnerLM/netusf>
- Abra seu RStudio
- Acesse o script em:  
<https://github.com/wagnerLM/netusf/blob/master/R%20script%20USF%202019.R>
- Acesse a apresentação em:  
<https://github.com/wagnerLM/netusf/blob/master/netUSF%20atual.pdf>

# RStudio

Open source and enterprise-ready  
professional software for R

[Download](#)[Download](#)[Discover RStudio](#)[Discover](#)

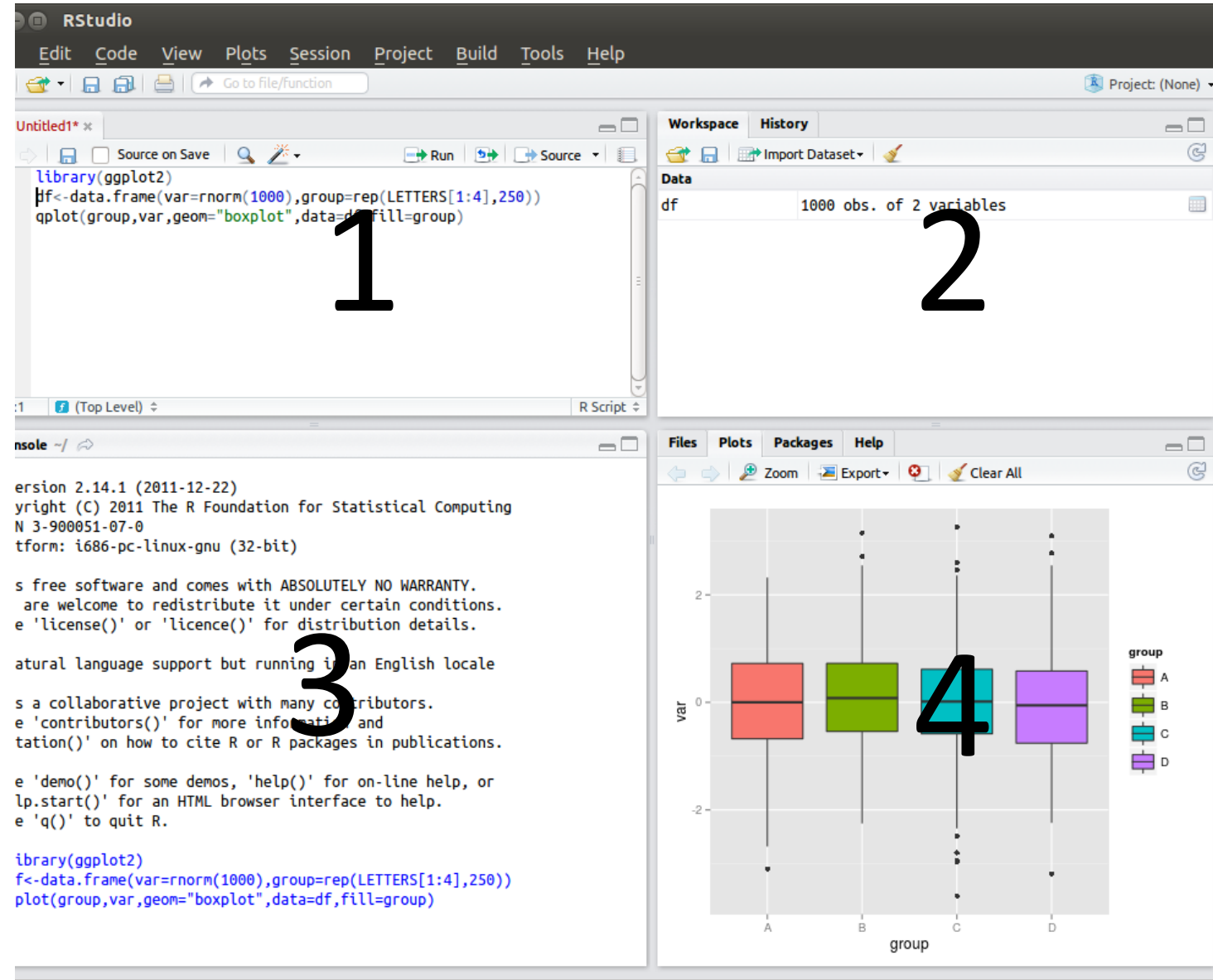
# RStudio

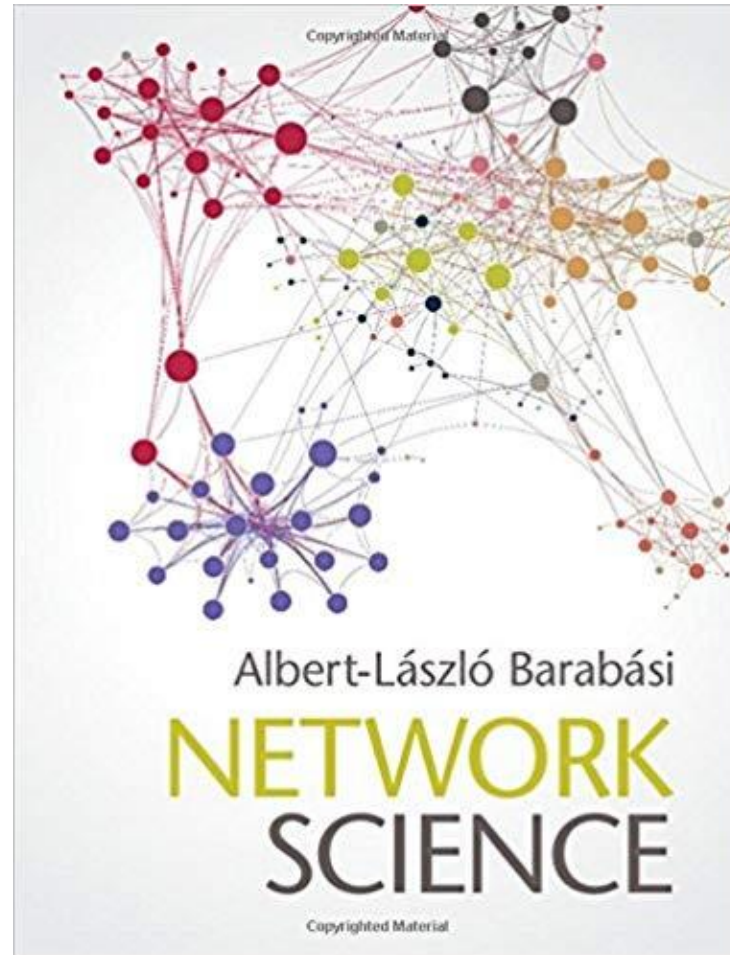
1 – script ou comandos; visualização de bancos de dados ou texto

2 – repositório de objetos e funções

3 – log de atividade

4 – gráficos e documentação







“Reductionism, as a paradigm, is expired, and complexity, as a field, is tired. Data-based mathematical models of complex systems are offering a fresh perspective, rapidly developing into a new discipline: network science.”

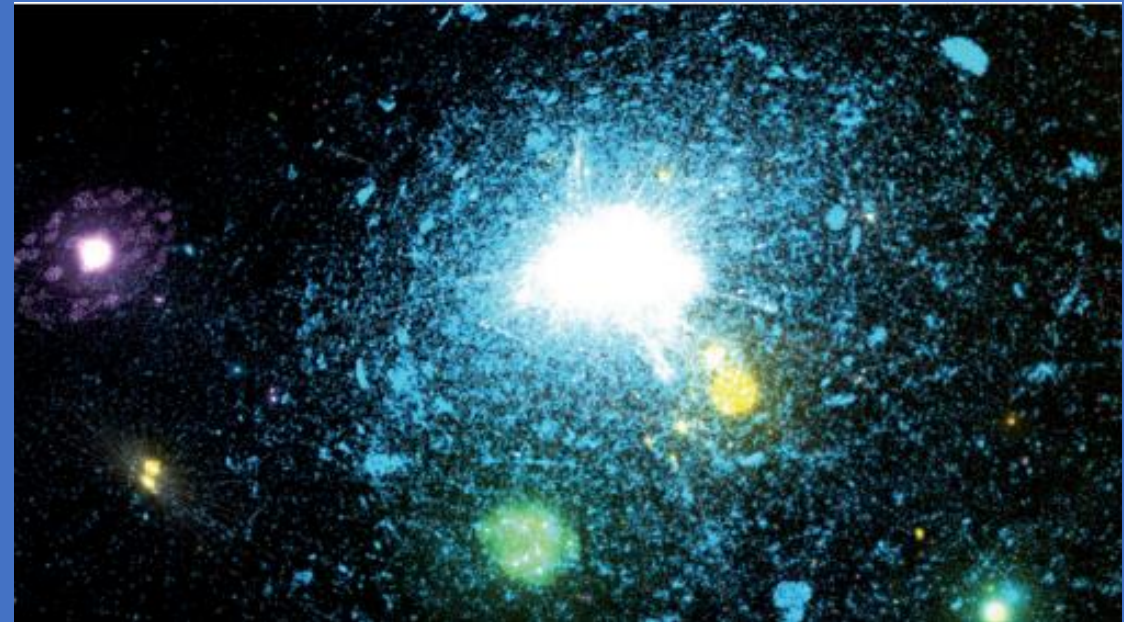
*NATURE PHYSICS* | COMMENTARY

# The network takeover

**Albert-László Barabási**

*Nature Physics* **8**, 14–16 (2012) | doi:10.1038/nphys2188

Published online 22 December 2011



# Modelos de rede na psicologia

- Algumas publicações importantes no estudo da psicopatologia (clínica) e personalidade

# Psychometric Perspectives on Diagnostic Systems

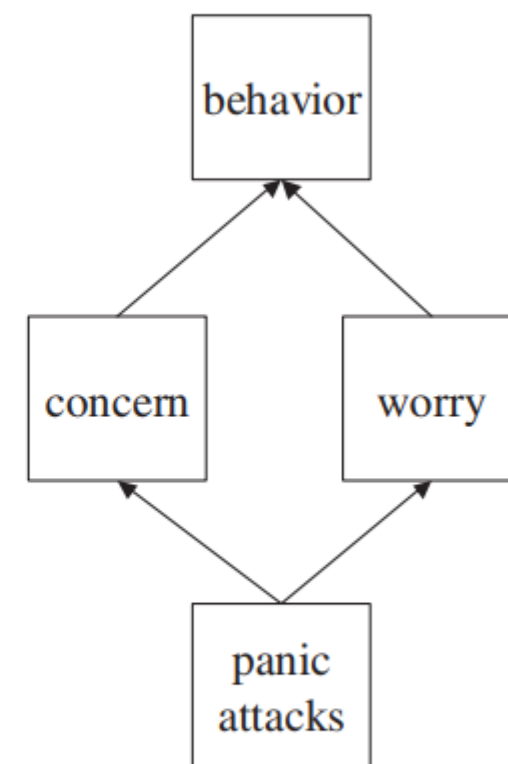
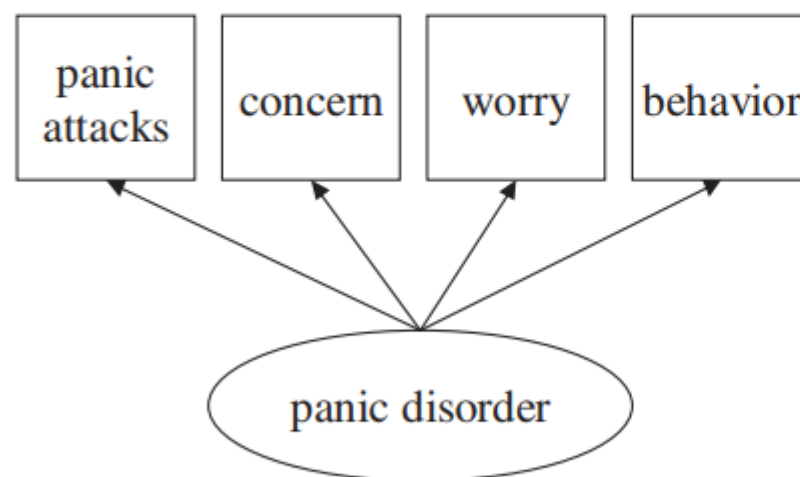


1102

*Journal of Clinical Psychology, September 2008*

Denny Borsboom

*University of Amsterdam*



*Figure 1.* The left panel shows the relation between panic disorder and its symptoms from a latent variable modeling point of view. The right panel shows a representation of these symptoms as a causal system.

## Comorbidity: A network perspective

Angélique O. J. Cramer

Department of Psychology, University of Amsterdam, 1018 WB Amsterdam,  
The Netherlands  
A.O.J.Cramer@uva.nl  
www.aojcramer.com

Lourens J. Waldorp

Department of Psychology, University of Amsterdam, 1018 WB Amsterdam,  
The Netherlands  
L.J.Waldorp@uva.nl  
http://users.fmg.uva.nl/lwaldorp

Han L. J. van der Maas

Department of Psychology, University of Amsterdam, 1018 WB Amsterdam,  
The Netherlands  
H.L.J.vanderMaas@uva.nl  
http://users.fmg.uva.nl/hvandermaas/

Denny Borsboom

Department of Psychology, University of Amsterdam, 1018 WB Amsterdam,  
The Netherlands  
D.Borsboom@uva.nl  
http://sites.google.com/site/borsboomdenny/dennyborsboom

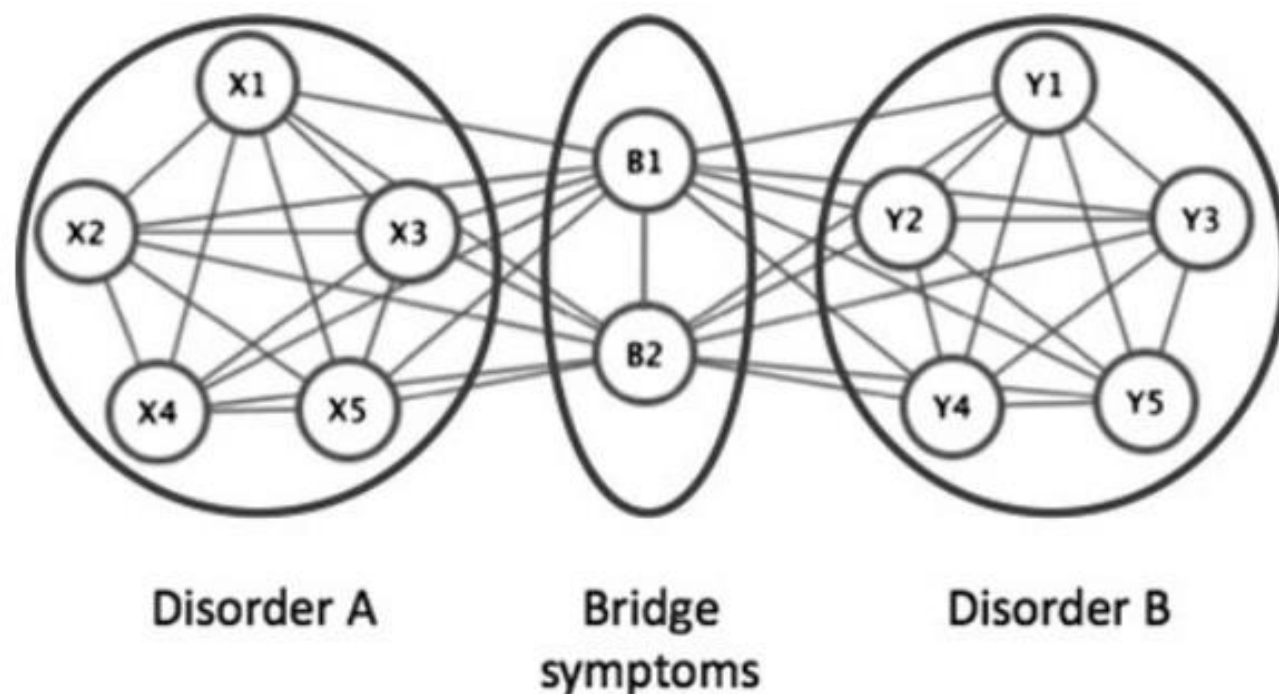


Figure 2. Comorbidity under a network approach. Disorder A consists of bidirectionally related symptoms  $X_1 - X_5$ , and disorder B consists of symptoms  $Y_1 - Y_5$ . Symptoms  $B_1$  and  $B_2$  are *bridge symptoms* that overlap between disorders A and B. In this model, comorbidity arises as a result of direct relations between the bridge symptoms of two disorders.

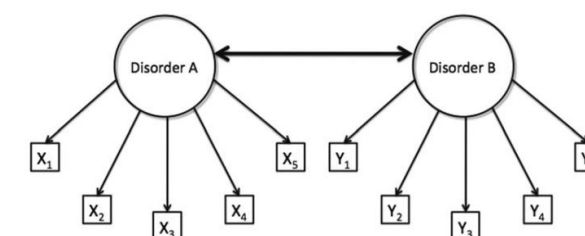
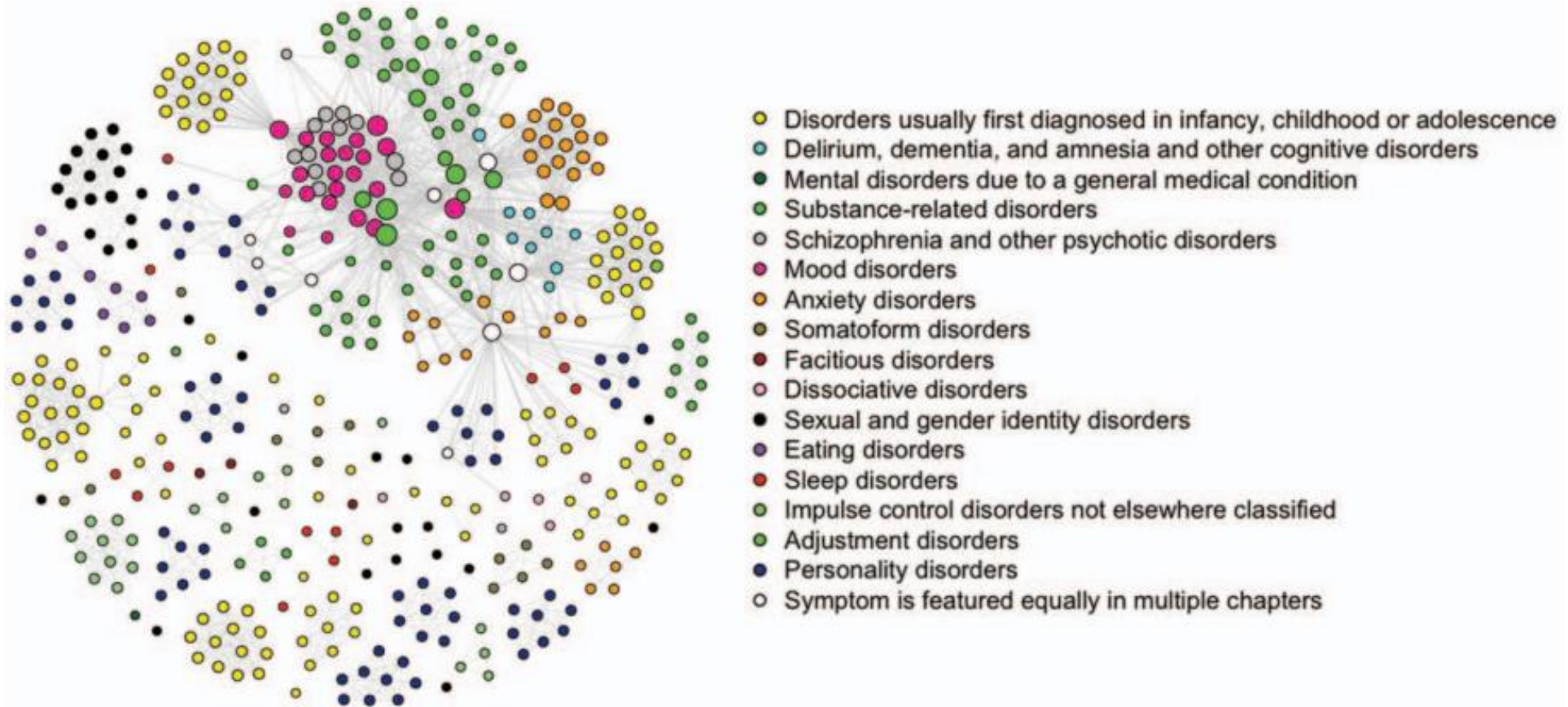


Figure 1. A model of comorbidity between disorders A and B, under the standard assumptions of latent variable modeling. The *circles* represent the disorders (i.e., latent variables) and the *rectangles* represent the observable core symptoms of those disorders (i.e.,  $X_1 - X_5$  for disorder A, and  $Y_1 - Y_5$  for disorder B). In this model, comorbidity is viewed as a correlation between the latent variables, visualized by the *thick bidirectional edge* between disorders A and B.



# The Small World of Psychopathology

Denny Borsboom\*, Angélique O. J. Cramer, Verena D. Schmittmann, Sacha Epskamp, Lourens J. Waldorp



**Figure 2. The DSM-IV symptom space.** Symptoms are represented as nodes and connected by an edge whenever they figure in the same disorder. Color of nodes represents the DSM-IV chapter in which they occur most often.

doi:10.1371/journal.pone.0027407.g002



# *Journal of Statistical Software*

May 2012, Volume 48, Issue 4.

<http://www.jstatsoft.org/>

## **qgraph: Network Visualizations of Relationships in Psychometric Data**

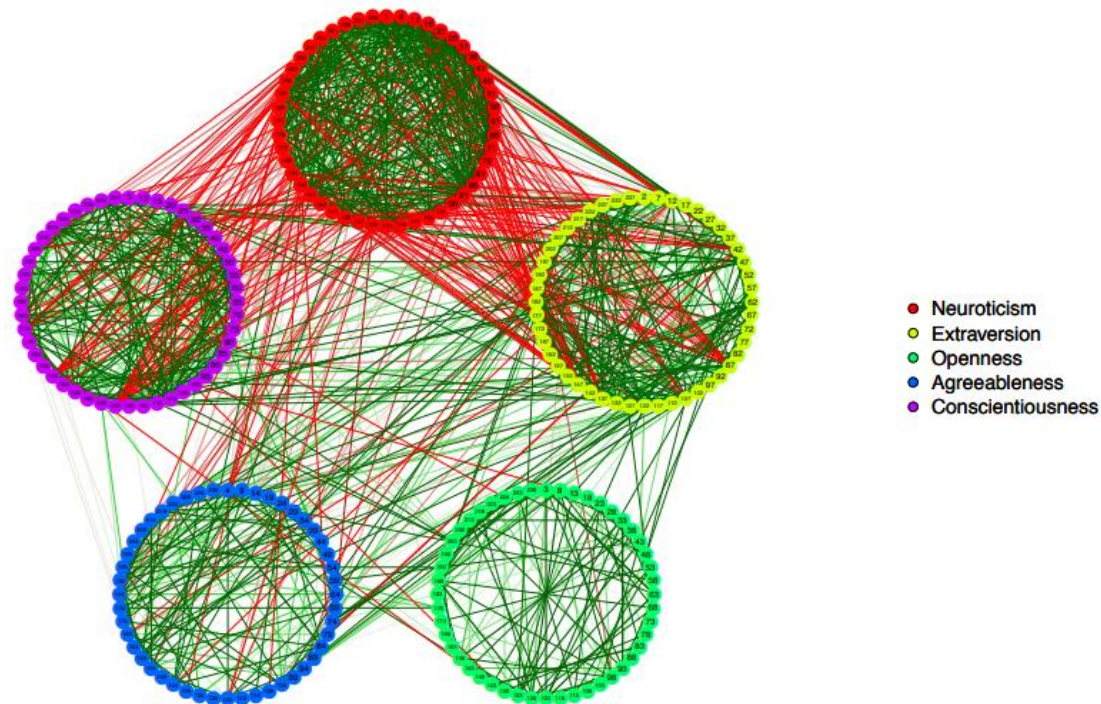
**Sacha Epskamp**  
University of Amsterdam

**Angélique O. J. Cramer**  
University of Amsterdam

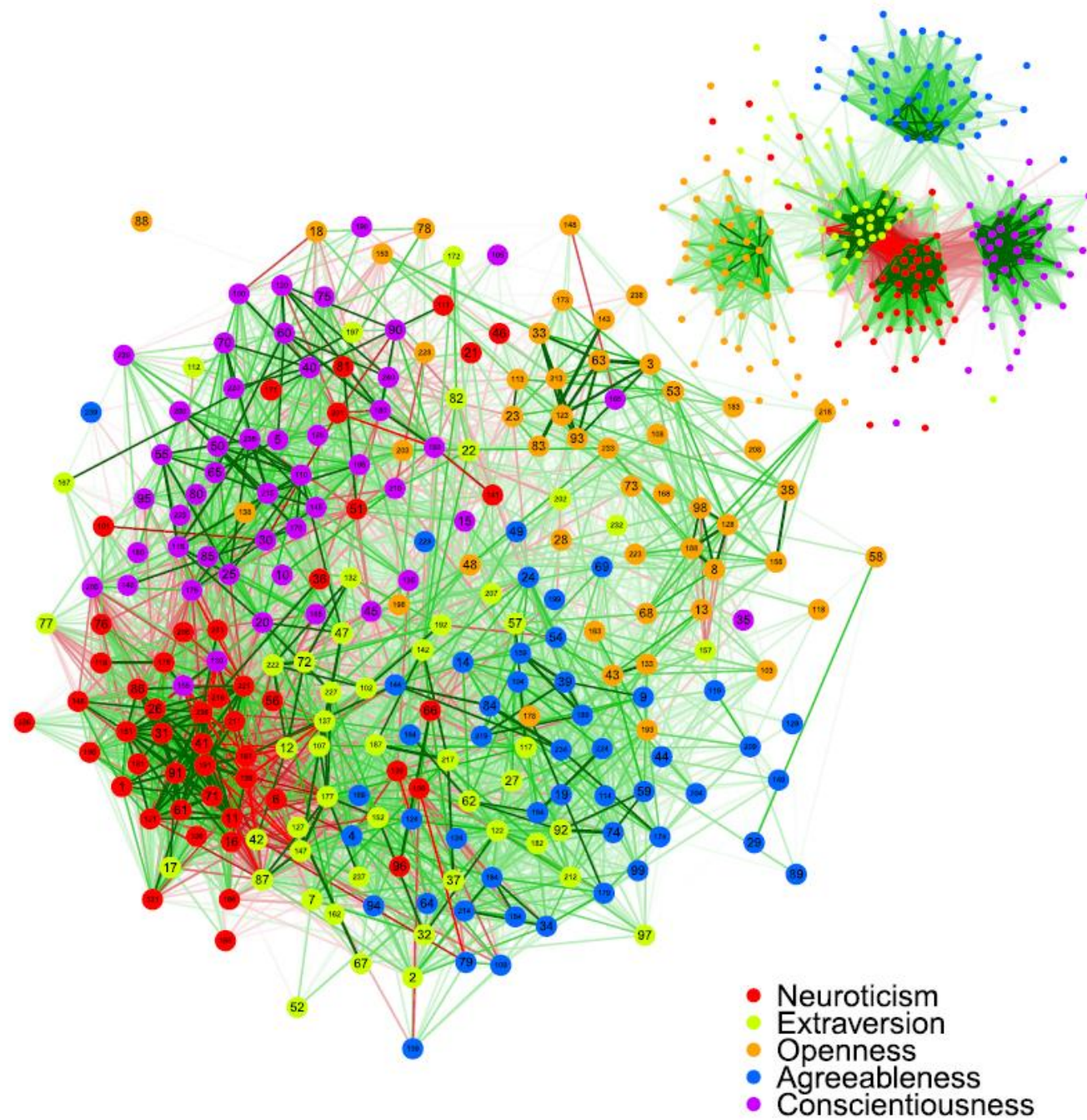
**Lourens J. Waldorp**  
University of Amsterdam

**Verena D. Schmittmann**  
University of Amsterdam

**Denny Borsboom**  
University of Amsterdam

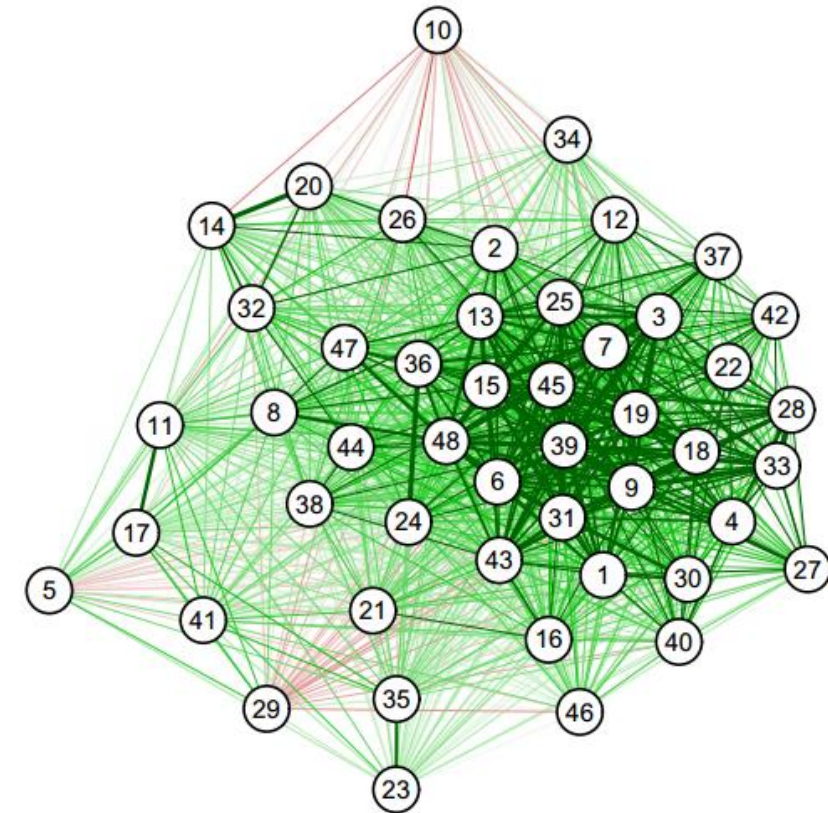
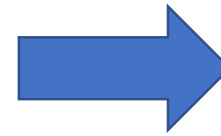
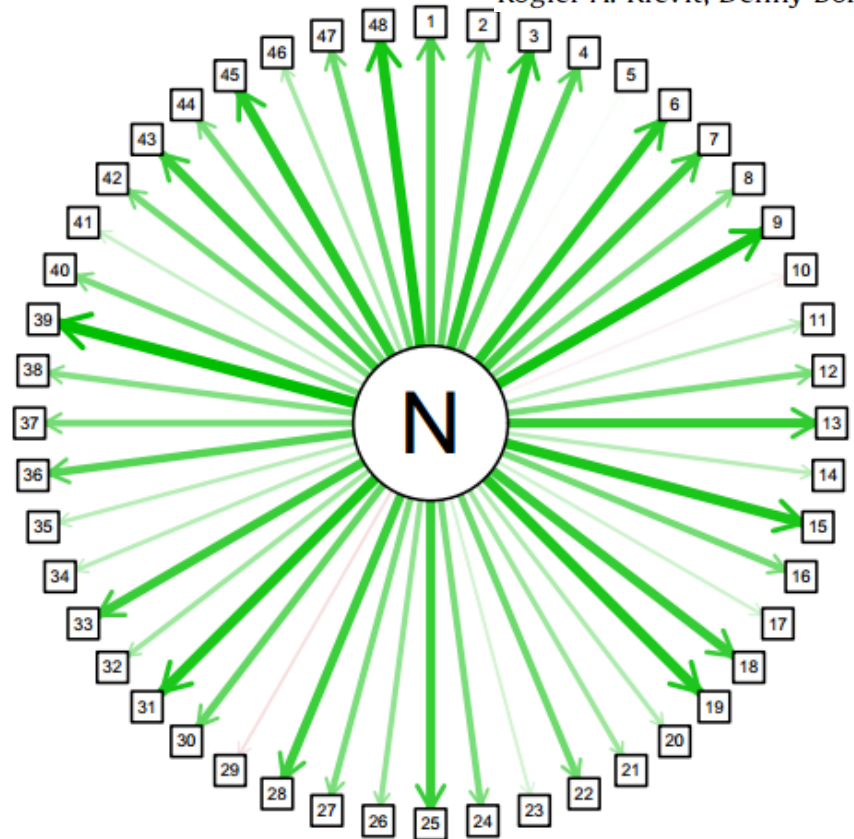






## Deconstructing the construct: A network perspective on psychological phenomena

Verena D. Schmittmann, Angélique O.J. Cramer, Lourens J. Waldorp, Sacha Epskamp, Rogier A. Kievit, Denny Borsboom\*





## Deconstructing the construct: A network perspective on psychological phenomena

Verena D. Schmittmann, Angélique O.J. Cramer, Lourens J. Waldorp, Sacha Epskamp, Rogier A. Kievit, Denny Borsboom\*



**Fig. 6.** The best fitting confirmative time series model of the following five constituents of depression: tiredness; concentration difficulties (*concentration*); self-content; sad mood; pleasure in current activity (*activity*).

# Análise de rede

- O que está em jogo é uma hipótese:

Para alguns fenômenos psicológicos os modelos de traços latentes não sejam os mais apropriados, mas sim aqueles que estimam a interação direta e recíproca entre seus componentes (e.g. redes)

- Analisar a informação útil em cada um dos modelos psicométricos

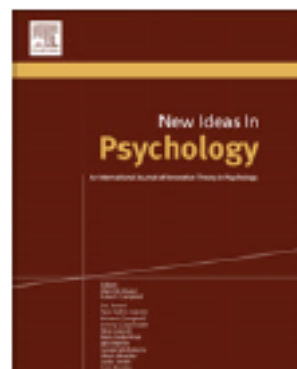


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## New Ideas in Psychology

journal homepage: [www.elsevier.com/locate/newideapsych](http://www.elsevier.com/locate/newideapsych)



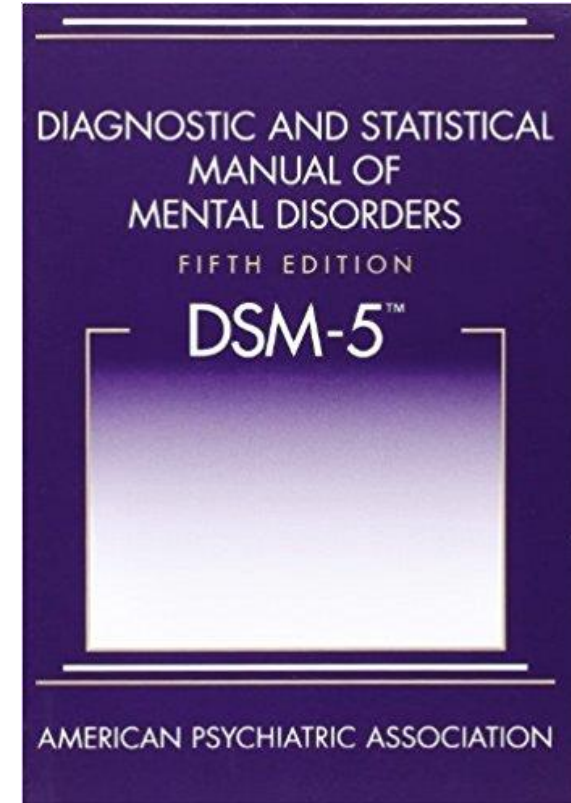
### Deconstructing the construct: A network perspective on psychological phenomena

Verena D. Schmittmann, Angélique O.J. Cramer, Lourens J. Waldorp, Sacha Epskamp, Rogier A. Kievit, Denny Borsboom\*

# Avaliação em saúde mental: traços latentes e redes

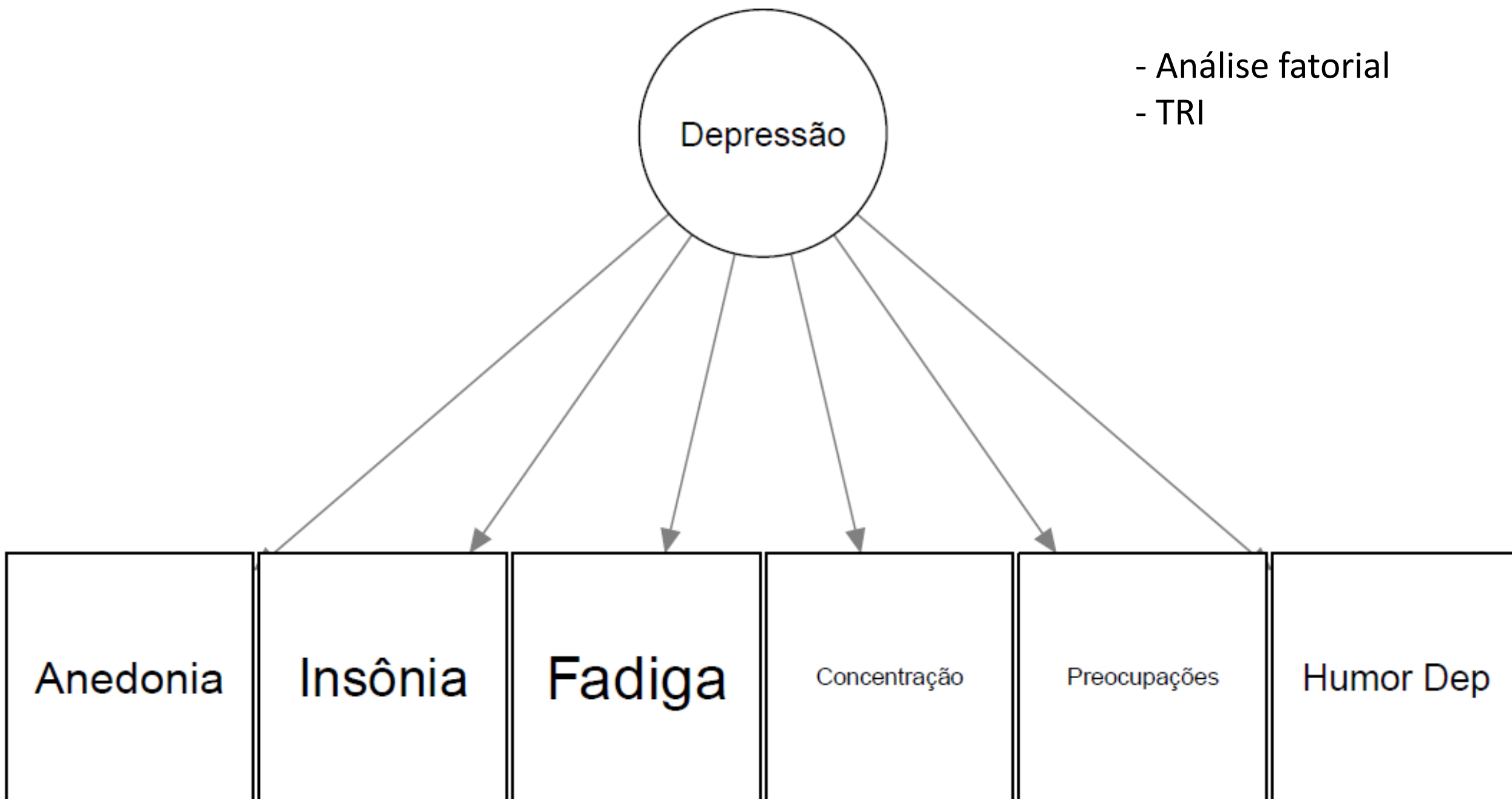
- **Transtorno depressivo maior:**

- Humor deprimido
- Diminuição do interesse ou prazer
- Perda ou ganho significativo de peso
- Insônia ou hipersonia
- Agitação ou retardo psicomotor
- Fadiga ou perda de energia
- Sentimentos de inutilidade ou culpa
- Capacidade diminuída para pensar ou se concentrar
- Pensamentos recorrentes de morte





- Análise fatorial
- TRI



# Measuring Depression Over Time . . . or not? Lack of Unidimensionality and Longitudinal Measurement Invariance in Four Common Rating Scales of Depression

Eiko I. Fried  
University of Leuven

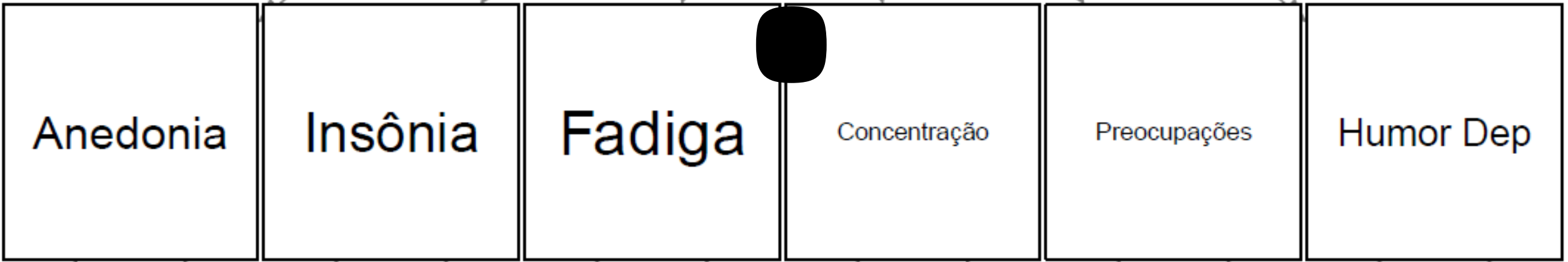
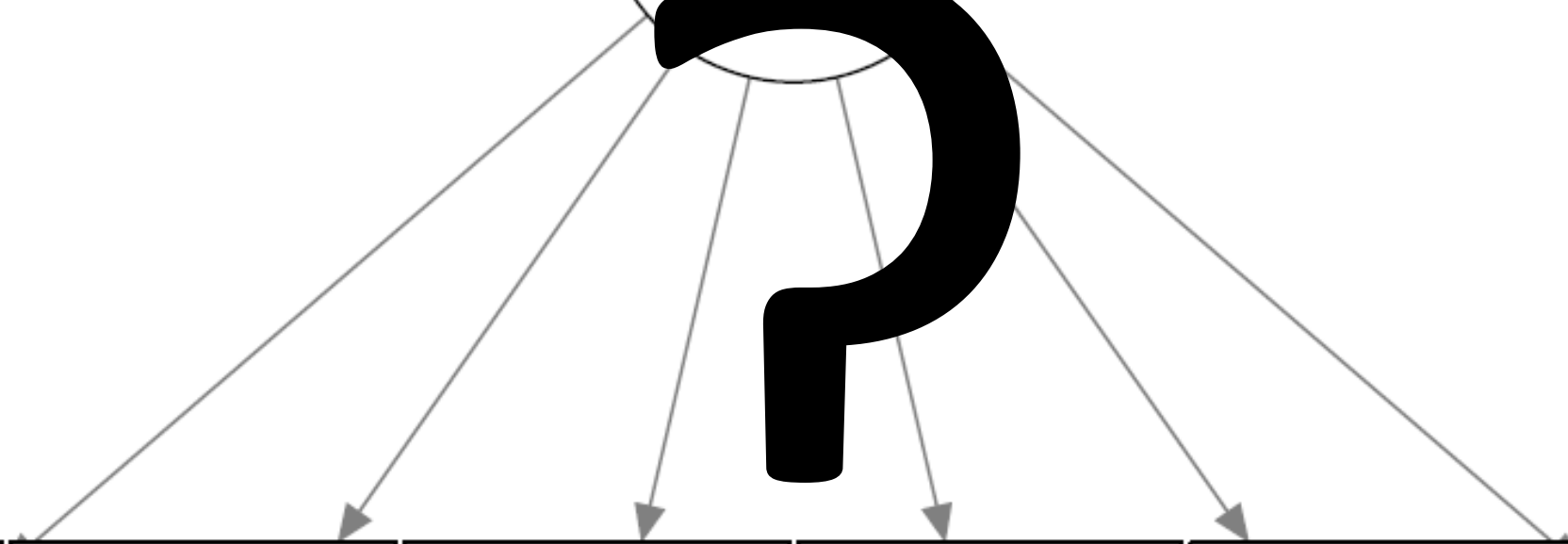
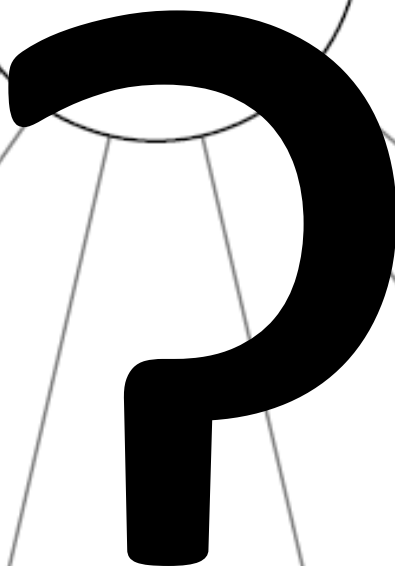
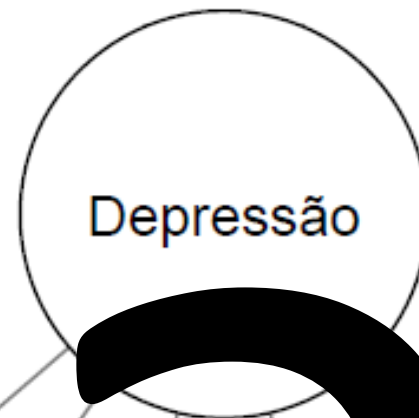
Claudia D. van Borkulo  
University of Groningen and University of Amsterdam

Sacha Epskamp  
University of Amsterdam

Robert A. Schoevers  
University of Groningen

Francis Tuerlinckx  
University of Leuven

Denny Borsboom  
University of Amsterdam



## Deconstructing the construct: A network perspective on psychological phenomena

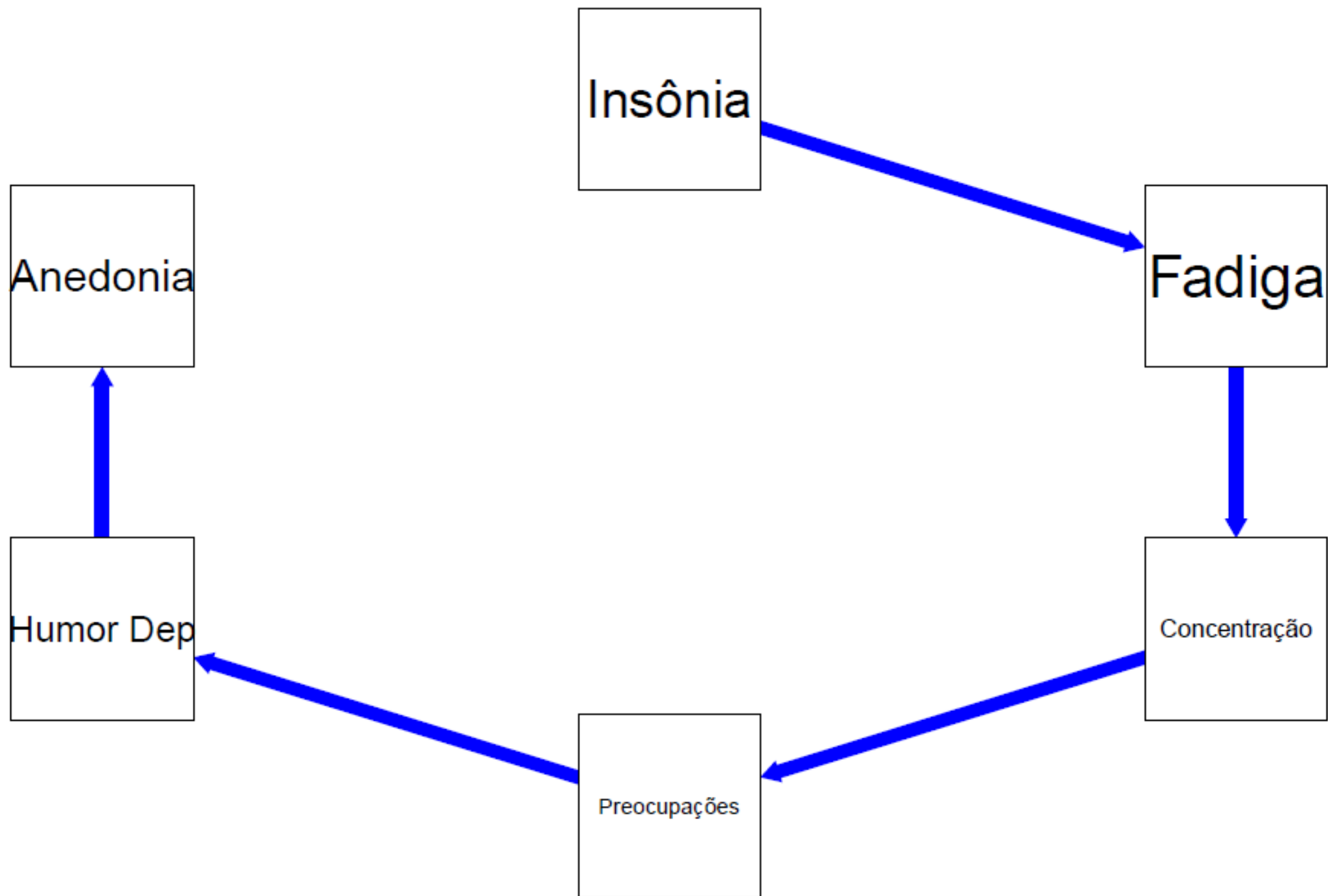
Verena D. Schmittmann, Angélique O.J. Cramer, Lourens J. Waldorp, Sacha Epskamp, Rogier A. Kievit, Denny Borsboom\*

Department of Psychology, University of Amsterdam, Roetersstraat 15, 1018 WB Amsterdam, The Netherlands



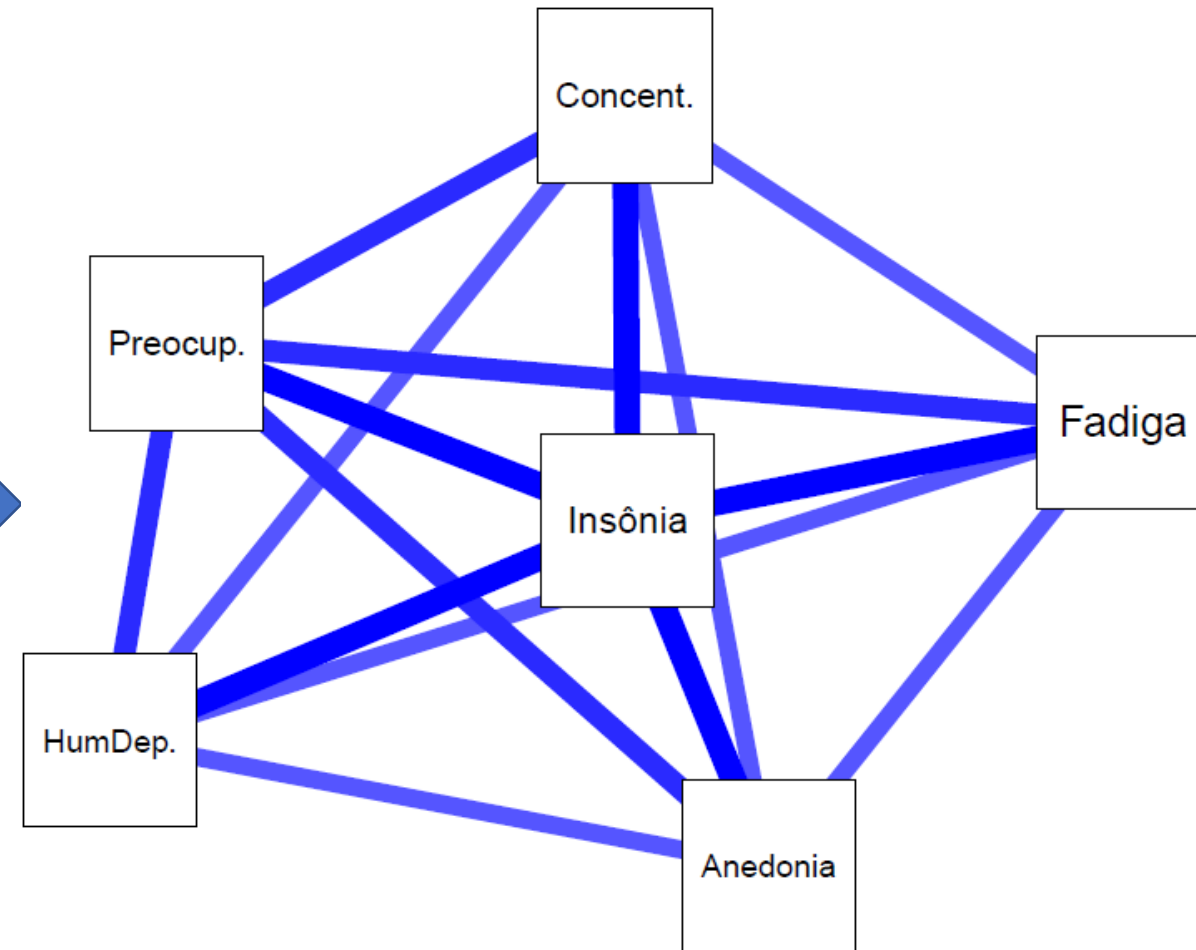
**Fig. 6.** The best fitting confirmative time series model of the following five constituents of depression: tiredness; concentration difficulties (*concentration*); self-content; sad mood; pleasure in current activity (*activity*).





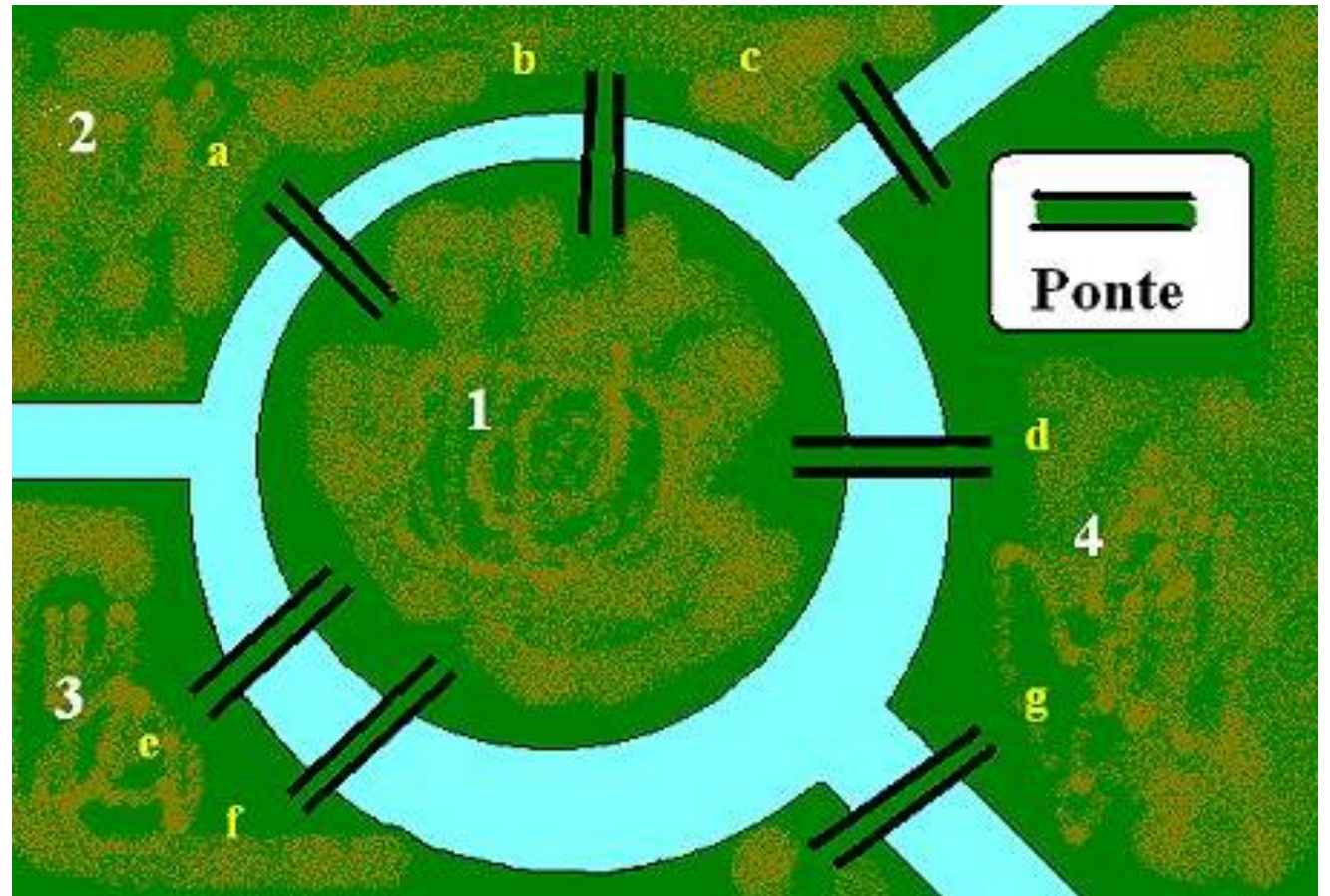
# Depressão: estrutura e dinâmica de um sistema

| ▲        | Insônia ▲ | Fadiga ▲ | Concent. ▲ | Preocup. ▲ | HumDep. ▲ | Anedonia ▲ |
|----------|-----------|----------|------------|------------|-----------|------------|
| Insônia  | 1.0       | 0.6      | 0.6        | 0.6        | 0.6       | 0.6        |
| Fadiga   | 0.6       | 1.0      | 0.4        | 0.5        | 0.4       | 0.4        |
| Concent. | 0.6       | 0.4      | 1.0        | 0.5        | 0.4       | 0.4        |
| Preocup. | 0.6       | 0.5      | 0.5        | 1.0        | 0.5       | 0.5        |
| HumDep.  | 0.6       | 0.4      | 0.4        | 0.5        | 1.0       | 0.4        |
| Anedonia | 0.6       | 0.4      | 0.4        | 0.5        | 0.4       | 1.0        |



# Teoria dos grafos

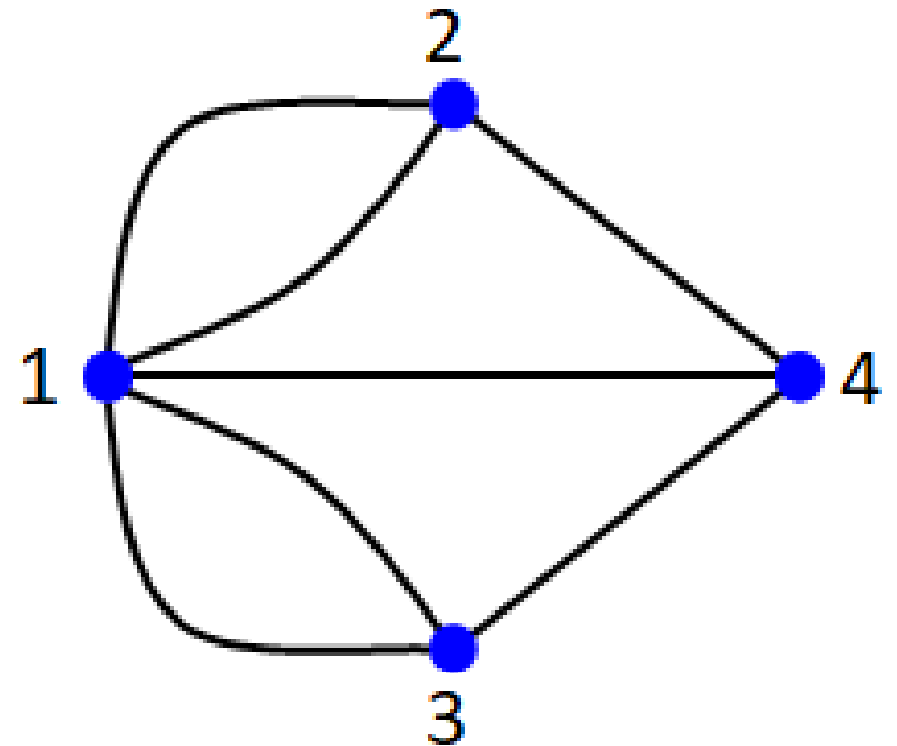
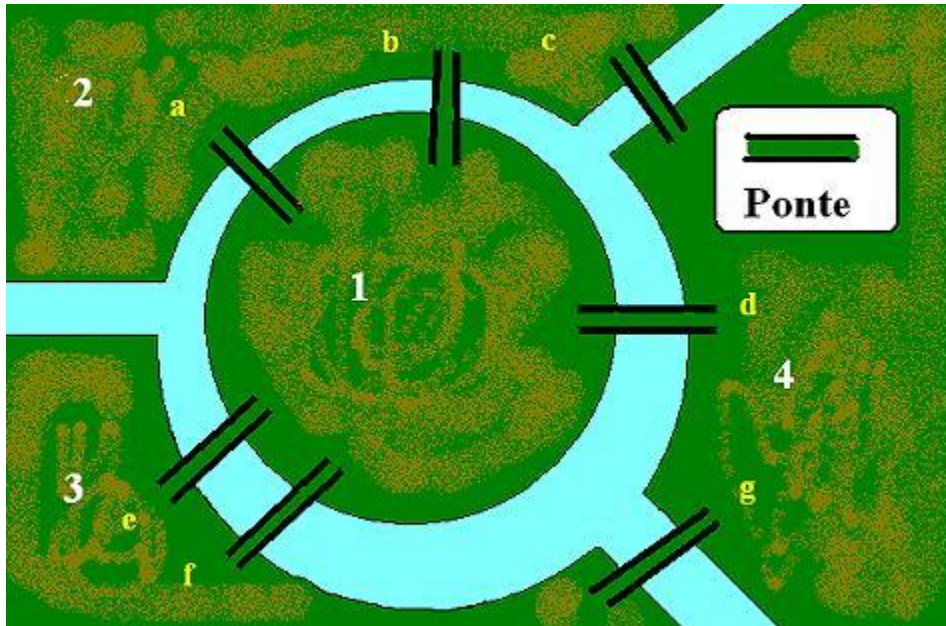
- O problema das pontes de Königsberg
- Discutia-se nas ruas da cidade a possibilidade de atravessar todas as pontes sem repetir nenhuma



[https://pt.wikipedia.org/wiki/Sete\\_pontes\\_de\\_K%C3%B6nigsberg](https://pt.wikipedia.org/wiki/Sete_pontes_de_K%C3%B6nigsberg)

# Teoria dos grafos

- Havia uma lenda popular sobre a possibilidade de resolução, quando Leonhard Euler, em 1736, provou que não existia caminho que possibilitasse tais restrições.

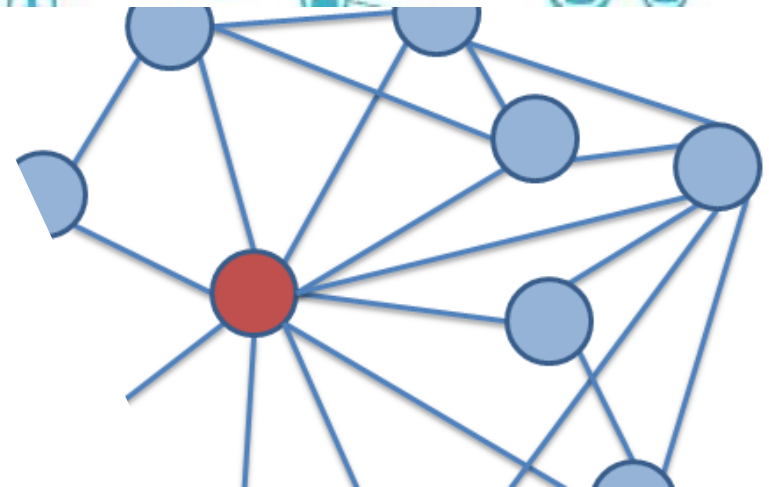


- Topologia



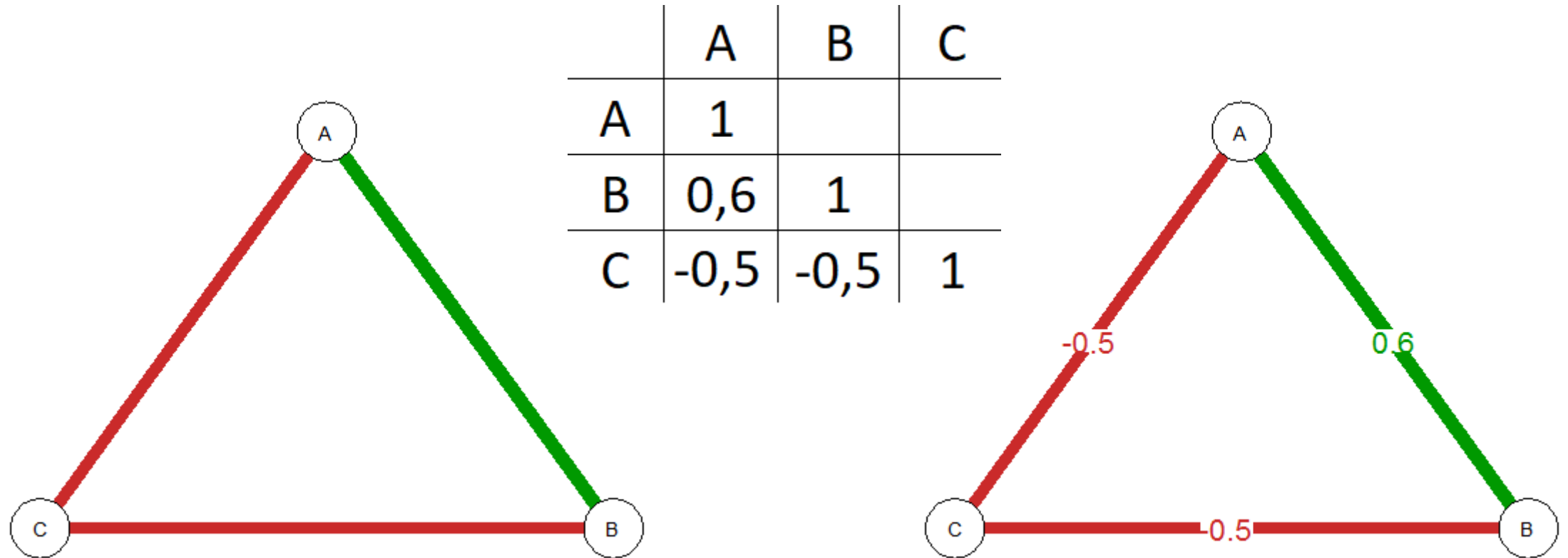
# O que é uma rede?

- Vértices (nodos) e arestas (linhas)
- Nodos representam variáveis
- As linhas representam a relação entre os nodos



# Medidas de associação entre variáveis

- Relação entre bem-estar (A), suporte social (B) e depressão (C)



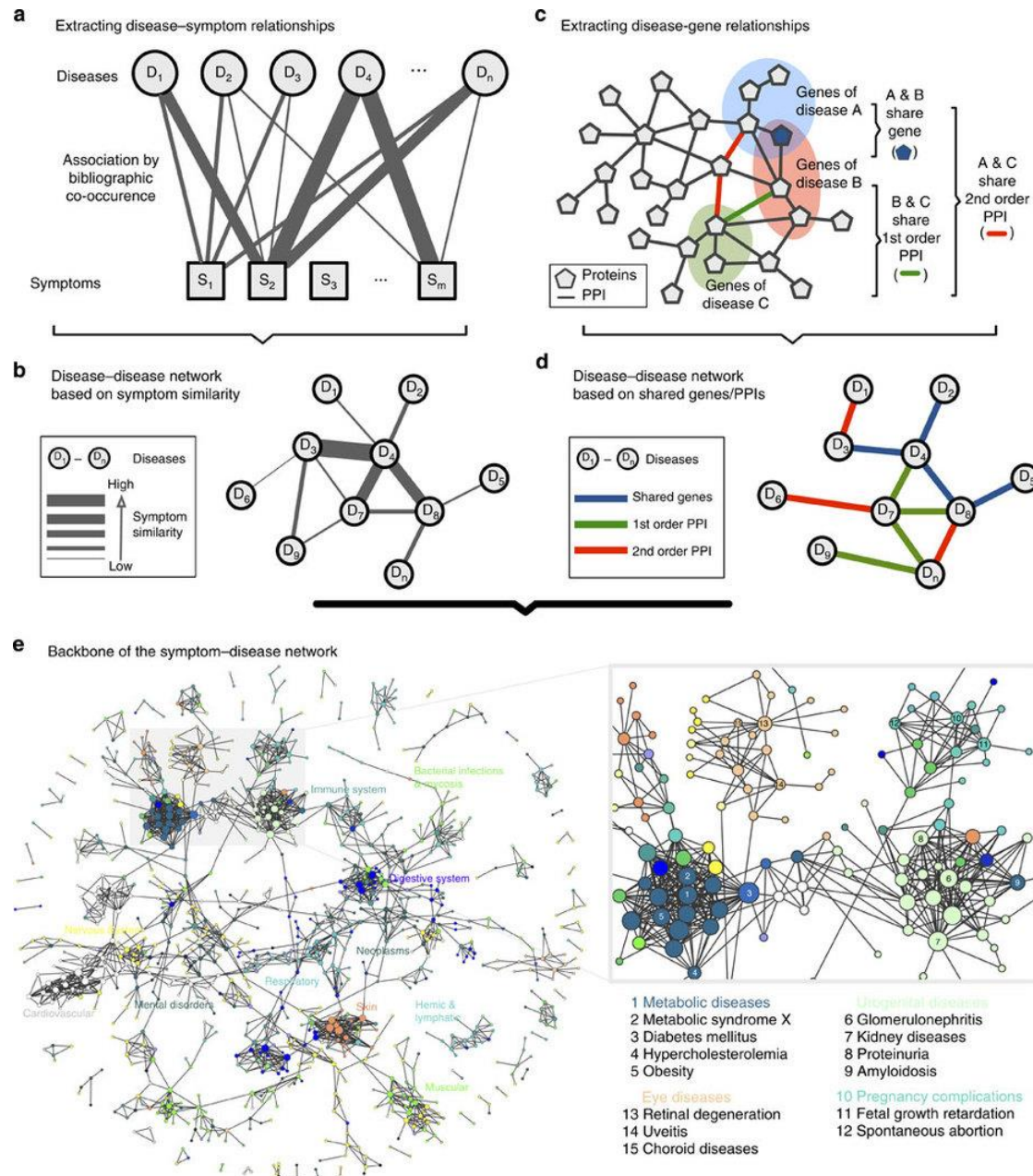
Article

# Human symptoms–disease network

XueZhong Zhou✉, Jörg Menche, Albert-László Barabási & Amitabh Sharma✉

*Nature Communications* 5,  
Article number: 4212 (2014)  
doi:10.1038/ncomms5212


Received: 07 November 2013  
Accepted: 27 May 2014  
Published online: 26 June 2014



We extracted **7,109,429** (about 35.5% in over twenty million records) PubMed bibliographic records with one or more disease/symptom terms in the MeSH metadata field (see Methods), yielding a total of 4,442 disease terms and 322 symptom terms

# Exemplos no script com a subescala depressão da DASS21

- RStudio



Universidade Federal de São Paulo  
Campus Baixada Santista

Programa de Pós-Graduação Interdisciplinar em Ciências da Saúde

**DASS – 21** Versão traduzida e validada para o português do Brasil  
Autores: Vignola, R.C.B. & Tucci, A.M.

**Instruções**  
Por favor, leia cuidadosamente cada uma das afirmações abaixo e circule o número apropriado **0,1,2 ou 3** que indique o quanto ela se aplicou a você durante a última semana, conforme a indicação a seguir:

0 Não se aplicou de maneira alguma

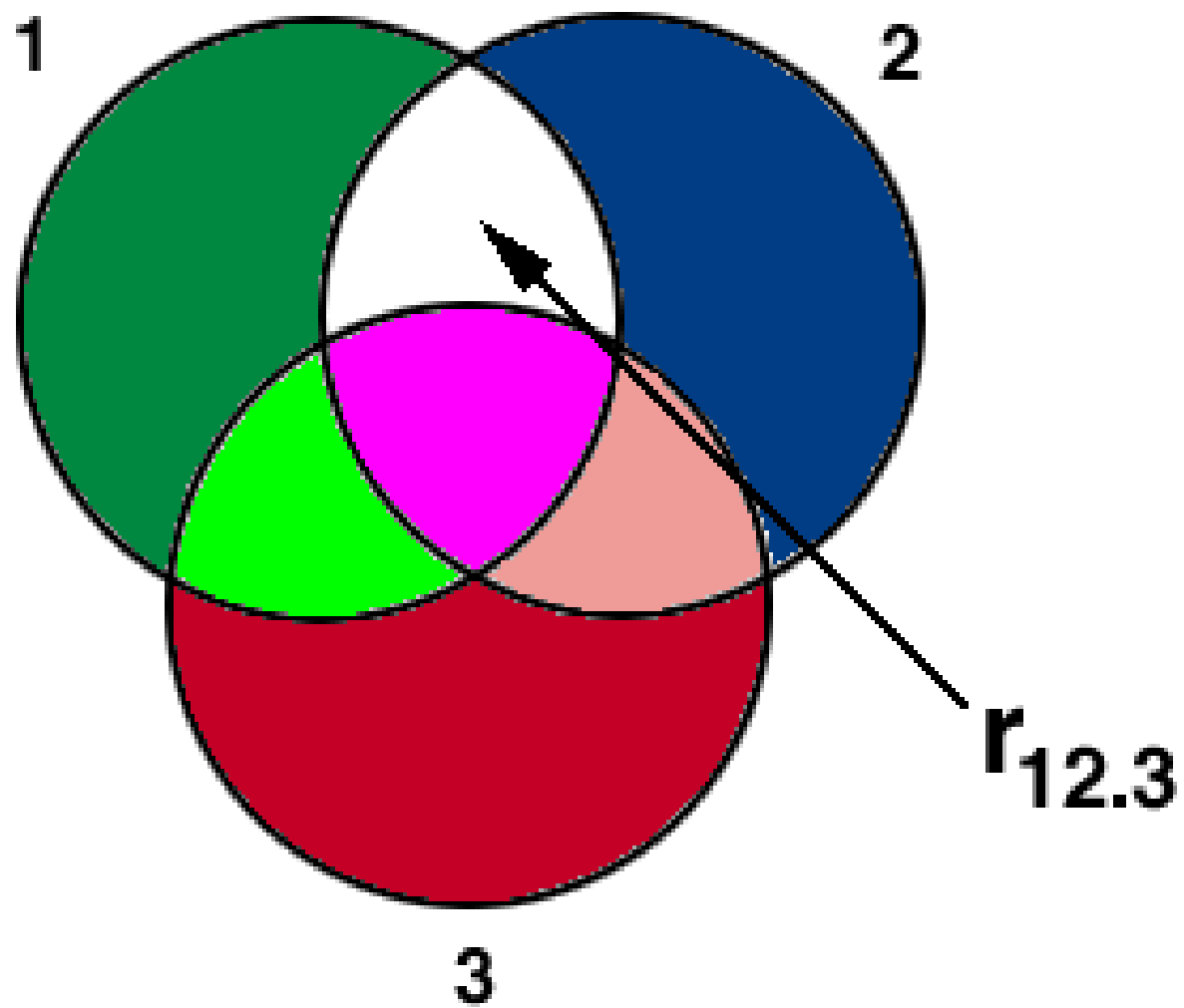
1 Aplicou-se em algum grau, ou por pouco de tempo

2 Aplicou-se em um grau considerável, ou por uma boa parte do tempo

3 Aplicou-se muito, ou na maioria do tempo

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | Achei difícil me acalmar                          | 0 | 1 | 2 | 3 |
| 2 | Senti minha boca seca                             | 0 | 1 | 2 | 3 |
| 3 | Não consegui vivenciar nenhum sentimento positivo | 0 | 1 | 2 | 3 |



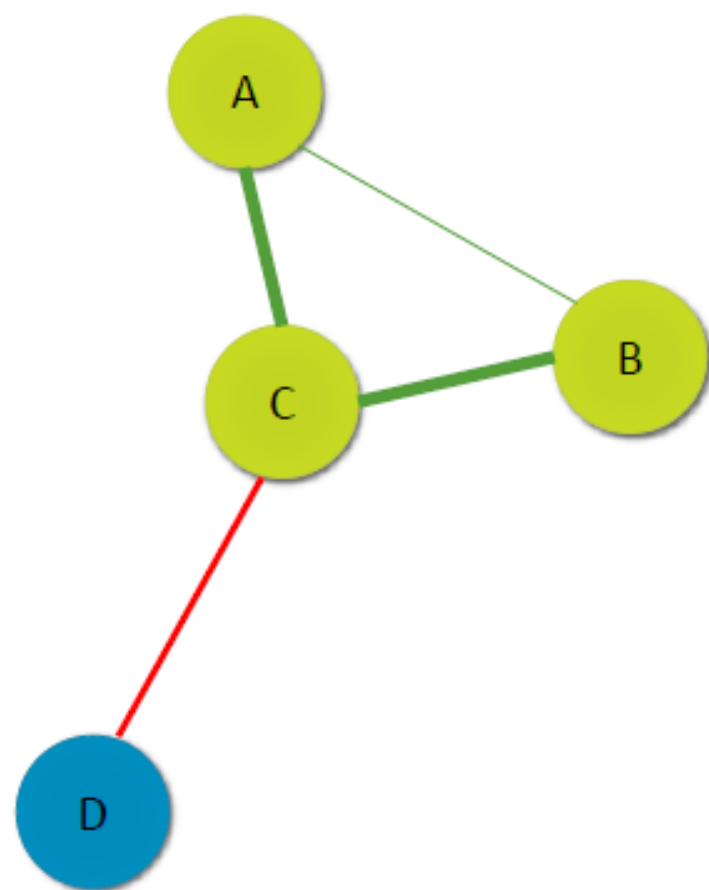


# Regressão parcial (semiparcial)

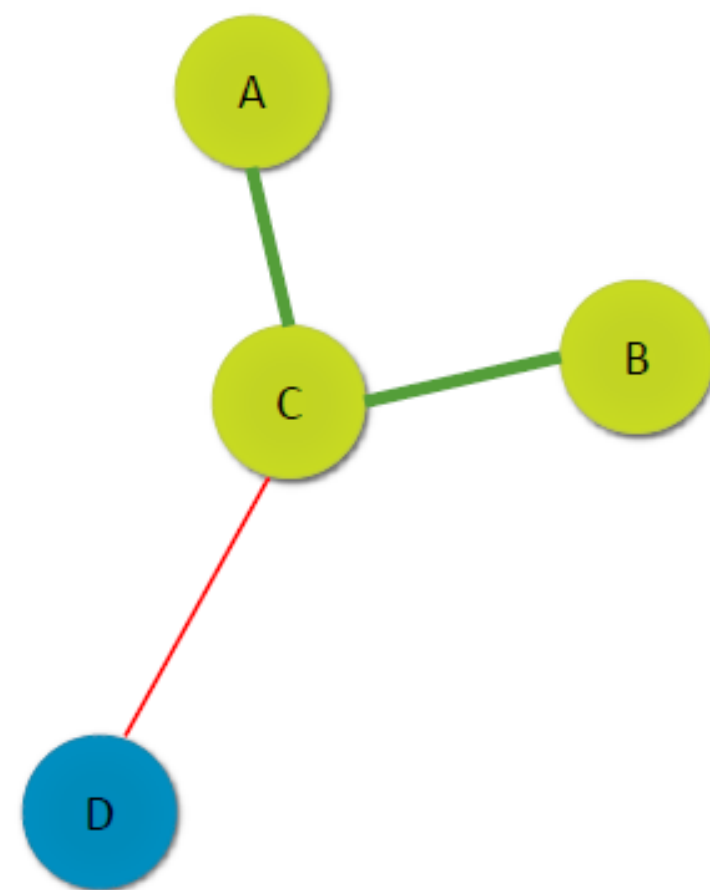
- Regressão Linear Múltipla
- AFE – matriz de precisão (correlações parciais)
- Problema da esparcialidade

# GeLasso estimation

- Graphical LASSO – (least absolute shrinkage and selection operator)
- Parâmetro de ajuste para o controle da esparsidade (fixa em zero as arestas com pesos muito pequenos, próximos à zero), chamado  $\lambda$
- São testados, por default, 100 valores de  $\lambda$
- A seleção do modelo com menor resíduo é feita por meio do Extended Bayesian Criteria (EBIC), que penaliza modelos complexos (muitas arestas), chamado hiperparâmetro  $\gamma$ . Se  $\gamma = 0$ , o método é o BIC.



*Rede esparsa, na qual os  
valores de baixa magnitude  
são fixados em zero*



Friedman, Hastie & Tibshirani (2008)



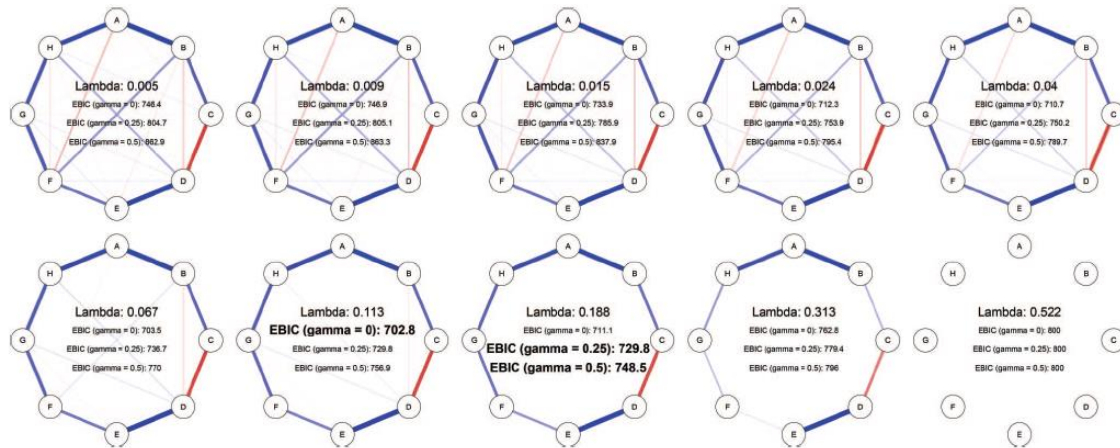


Figure 2. Ten different partial correlation networks estimated using lasso regularization. Setting the lasso tuning parameter  $\lambda$  that controls sparsity leads to networks ranging from densely connected to fully unconnected. Data were simulated under the network represented in Figure 1. The fit of every network was assessed using the EBIC, using hyperparameter  $\gamma$  set to 0, 0.25 or 0.5. The bold-faced EBIC value is the best, indicating the network which would be selected and returned using that  $\gamma$  value. See the online article for the color version of this figure.

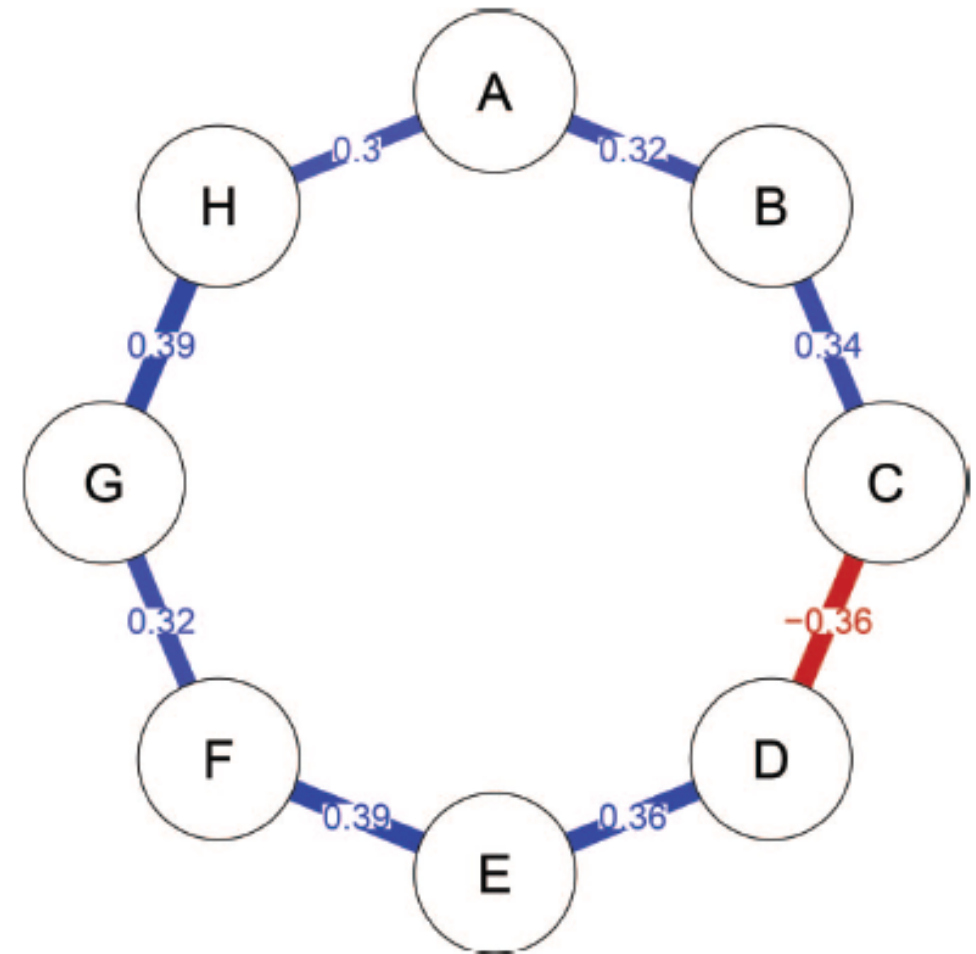


Figure 1. True network structure used in simulation example. The network represents a *partial correlation network*: nodes represent observed variables and edges represent partial correlations between two variables after conditioning on all other variables. The simulated structure is a *chain graph* in which all absolute partial correlation coefficients were drawn randomly between 0.3 and 0.4. See the online article for the color version of this figure.



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Psychological Methods

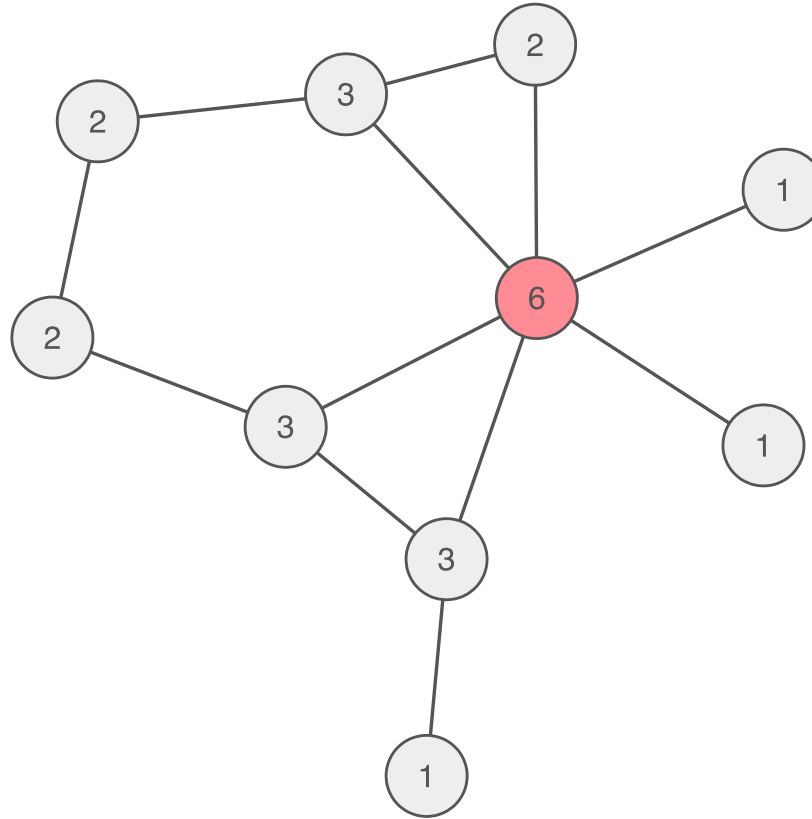
© 2018 American Psychological Association  
1082-989X/18/\$12.00

<http://dx.doi.org/10.1037/met0000167>

## A Tutorial on Regularized Partial Correlation Networks

Sacha Epskamp and Eiko I. Fried  
University of Amsterdam

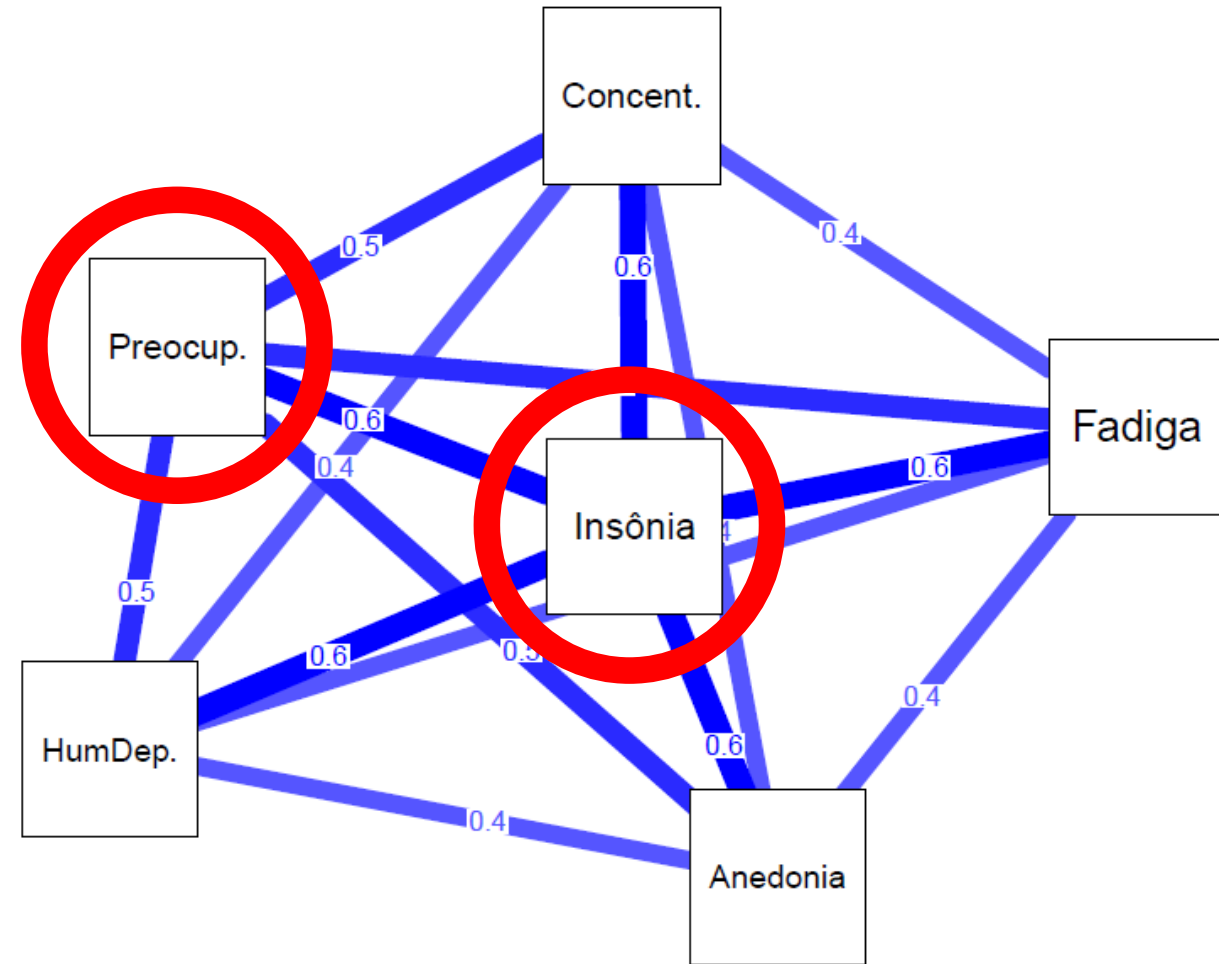
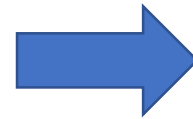
# Centralidade



Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social Networks*, 23, 245-251.

# Depressão: estrutura e dinâmica de um sistema

|          | Insônia | Fadiga | Concent. | Preocup. | HumDep. | Anedonia |
|----------|---------|--------|----------|----------|---------|----------|
| Insônia  | 1.0     | 0.6    | 0.6      | 0.6      | 0.6     | 0.6      |
| Fadiga   | 0.6     | 1.0    | 0.4      | 0.5      | 0.4     | 0.4      |
| Concent. | 0.6     | 0.4    | 1.0      | 0.5      | 0.4     | 0.4      |
| Preocup. | 0.6     | 0.5    | 0.5      | 1.0      | 0.5     | 0.5      |
| HumDep.  | 0.6     | 0.4    | 0.4      | 0.5      | 1.0     | 0.4      |
| Anedonia | 0.6     | 0.4    | 0.4      | 0.5      | 0.4     | 1.0      |



# Centralidade

- Força (strength): soma modular ponderada das arestas de um nodo
- Proximidade (closeness): distância dos vértices adjacentes (inverso da distância)
- Conectividade (betweenness): vezes pelas quais o vértice é a menor distância (shortest path) entre outros dois vértices

Opsahl, T., Agneessens, F., & Skvoretz, J. (2010). Node centrality in weighted networks: Generalizing degree and shortest paths. *Social Networks*, 23, 245-251.



# Expected Influence

- Influência esperada: soma das arestas dos nodos adjacentes em primeiro e segundo graus



Published in final edited form as:

*J Abnorm Psychol.* 2016 August ; 125(6): 747–757. doi:10.1037/abn0000181.

## Identifying Highly Influential Nodes in the Complicated Grief Network

Donald J. Robinaugh<sup>1,2</sup>, Alexander J. Millner<sup>3</sup>, and Richard J. McNally<sup>3</sup>


<sup>1</sup>Massachusetts General Hospital, Department of Psychiatry

<sup>2</sup>Harvard Medical School

<sup>3</sup>Department of Psychology, Harvard University

# Exemplos com todos os itens da DASS21

- RStudio



Universidade Federal de São Paulo  
Campus Baixada Santista

Programa de Pós-Graduação Interdisciplinar em Ciências da Saúde

**DASS – 21** Versão traduzida e validada para o português do Brasil  
Autores: Vignola, R.C.B. & Tucci, A.M.

**Instruções**  
Por favor, leia cuidadosamente cada uma das afirmações abaixo e circule o número apropriado **0,1,2 ou 3** que indique o quanto ela se aplicou a você durante a última semana, conforme a indicação a seguir:

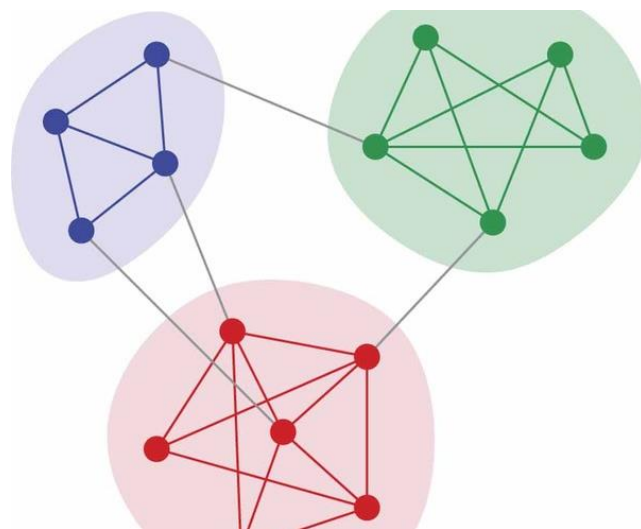
0 Não se aplicou de maneira alguma

1 Aplicou-se em algum grau, ou por pouco de tempo

2 Aplicou-se em um grau considerável, ou por uma boa parte do tempo

3 Aplicou-se muito, ou na maioria do tempo

|   |   |   |   |   |   |
|---|---|---|---|---|---|
| 1 | Achei difícil me acalmar                          | 0 | 1 | 2 | 3 |
| 2 | Senti minha boca seca                             | 0 | 1 | 2 | 3 |
| 3 | Não consegui vivenciar nenhum sentimento positivo | 0 | 1 | 2 | 3 |



Article | [OPEN](#)

## A Comparative Analysis of Community Detection Algorithms on Artificial Networks

Zhao Yang , René Algesheimer & Claudio J. Tessone

Scientific Reports 6, Article number: 30750  
(2016)  
doi:10.1038/srep30750

Received: 31 March 2016  
Accepted: 07 July 2016  
Published online: 01 August 2016

# Análise de comunidades

- Existem subgrupos de variáveis ou observações na rede?
- Três métodos mais populares:
- Waltrap – parte de passos aleatórios e vai decompondo o conjunto em N-1 comunidades, calculando a distância das arestas entre e dentro comunidades
- Spinglass – baseado também em um modelo do ferromagnetismo (Potts), baseado na ideia de “spin state” e fluxo de energia
- **Multinível** – decomposição e permutação dos vértices até encontrar a solução que otimiza a modularidade (divisão em módulos ou grupos)

RESEARCH ARTICLE

# Exploratory graph analysis: A new approach for estimating the number of dimensions in psychological research

Hudson F. Golino<sup>1,2\*</sup>, Sacha Epskamp<sup>3</sup>

# Exemplo com dados dicotômicos/binários

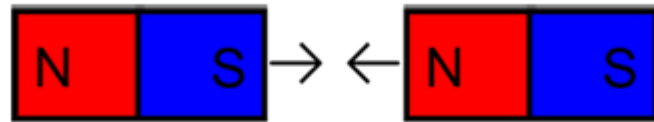
- Ising Model e TRI multidimensional



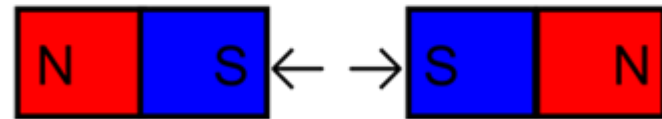


# Ising model

- Estudo do ferromagnetismo



Opposite poles **attract**



Same poles **repel**

OPEN

A new method for constructing networks from binary data

SUBJECT AREAS:

PSYCHOLOGY  
SIGNS AND SYMPTOMS

Claudia D. van Borkulo<sup>1,2</sup>, Denny Borsboom<sup>2</sup>, Sacha Epskamp<sup>2</sup>, Tessa F. Blanken<sup>2</sup>, Lynn Boschloo<sup>1</sup>, Robert A. Schoevers<sup>1</sup> & Lourens J. Waldorp<sup>2</sup>

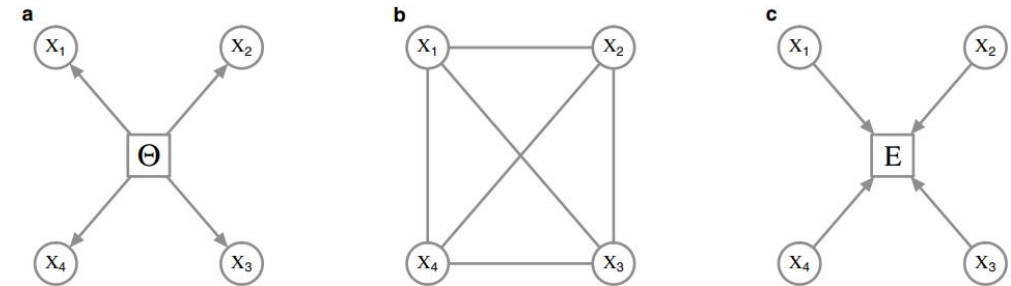
$$\mathbb{P}_{\Theta}(x_j | x_{\setminus j}) = \frac{\exp \left[ \tau_j x_j + x_j \sum_{k \in V_{\setminus j}} \beta_{jk} x_k \right]}{1 + \exp \left[ \tau_j + \sum_{k \in V_{\setminus j}} \beta_{jk} x_k \right]}, \quad (1)$$

where  $\tau_j$  and  $\beta_{jk}$  are the node parameter (or threshold) and the pairwise interaction parameter respectively.

# SCIENTIFIC REPORTS

## OPEN Three representations of the Ising model

Joost Kruis<sup>1</sup> & Gunter Maris<sup>1,2</sup>



**Figure 1.** Three frameworks for explaining observed associations in the parametrisation of their prototypical statistical models. (a) The Rasch model from the common cause framework as a DAG. (b) The Curie-Weiss model from the reciprocal affect framework as an undirected graph. (c) The collider selection bias model from the common effect framework as a DAG.

## The relation between the Ising model and item response theory

In this section we will show that the Ising model is closely related to the modeling framework of IRT, which is of central importance to psychometrics. In fact, we will show that the Ising model is equivalent to a special case of the multivariate two-parameter logistic model (MIRT). However, instead of being hypothesized common causes of the item responses, in our representation the latent variables in the model are *generated* by cliques in the network.

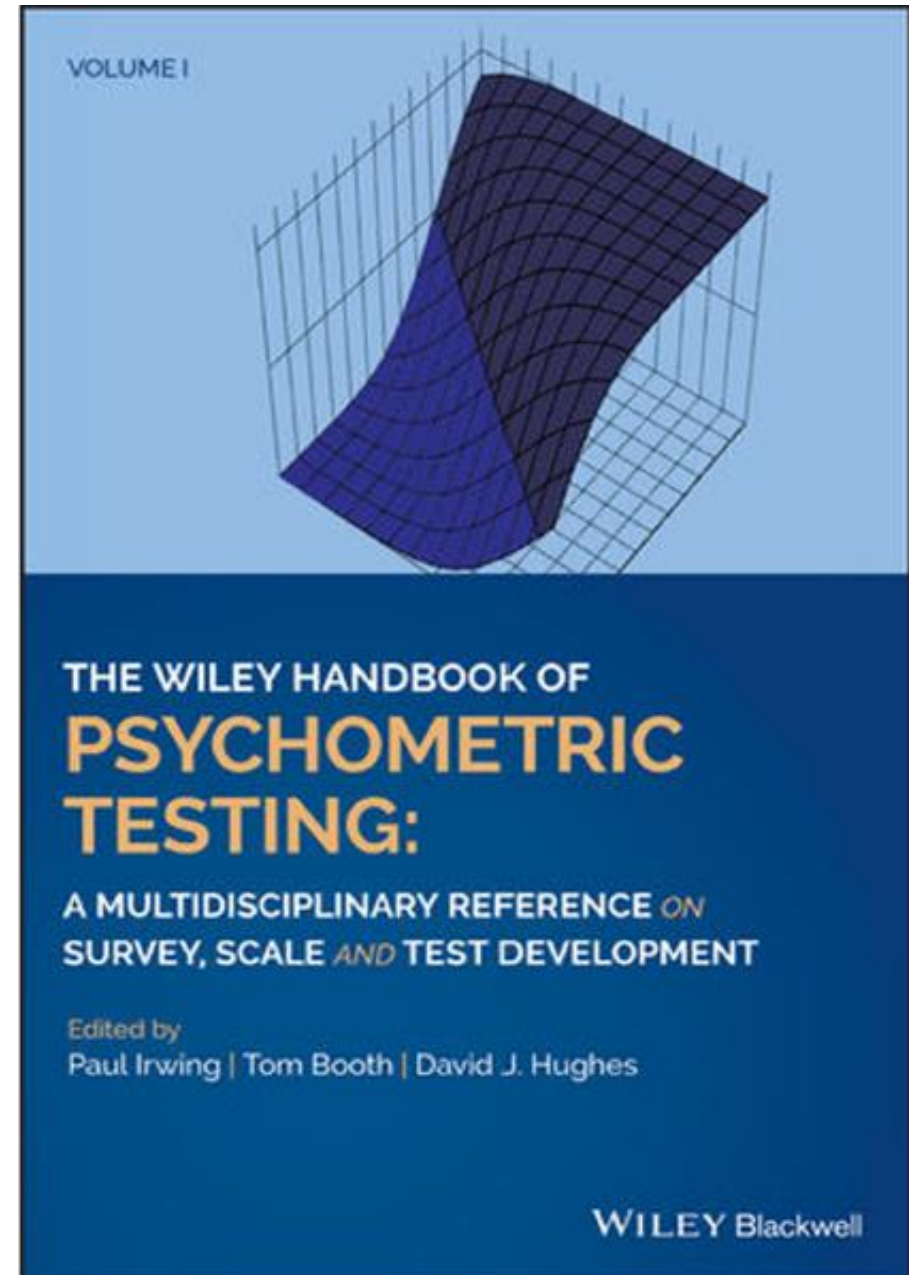
In IRT, the responses on a set of binary variables  $X$  are assumed to be determined by a set of  $M$  ( $M \leq P$ ) latent variables  $\Theta^\top = [\Theta_1 \Theta_2 \dots \Theta_M]$ . These latent variables are often termed *abilities*, which betrays the roots of the model in educational testing. In IRT, the probability of obtaining a realization  $x_i$  on the variable  $X_i$ —often called *items*—is modeled through item response functions, which model the probability of obtaining one of the two possible responses (typically, scored 1 for correct responses and 0 for incorrect responses) as a function of  $\theta$ . For instance, in the (Rasch, 1960) model, also called the one-parameter logistic model (1PL), only one latent trait is assumed ( $M = 1$  and  $\Theta = \theta$ ) and the conditional probability of a response given the latent trait takes the form of a simple logistic function:

$$\Pr(X_i = x_i \mid \Theta = \theta)_{1PL} = \frac{\exp(x_i \alpha (\theta - \delta_i))}{\sum_{x_i} \exp(x_i \alpha (\theta - \delta_i))},$$

30

## Network Psychometrics

Sacha Epskamp, Gunter Maris, Lourens J. Waldorp,  
and Denny Borsboom



# Parâmetros do modelo

- Interação par a par (pairwise interaction) via regressão logística com covariáveis ( $\beta$ )
- Parâmetro do item ( $\tau$ )
- Exemplo no RStudio



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# NETWORK PSYCHOMETRICS *uma introdução*

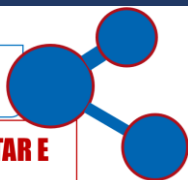
Prof. Dr. Wagner de Lara  
Machado

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**Nota 6**

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