

# Network Psychometrics



Sacha Epskamp

# Network Psychometrics

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor

aan de Universiteit van Amsterdam

op gezag van de Rector Magnificus

prof. dr. ir. K.I.J. Maex

ten overstaan van een door het College voor Promoties ingestelde

commissie, in het openbaar te verdedigen in de Agnietenkapel

op woensdag 5 April 2017, te 14:00 uur

door Sacha Epskamp

geboren te Blaricum

## Promotiecommissie

Promotor:	Prof. dr. D. Borsboom	Universiteit van Amsterdam
Copromotor:	Dr. L. J. Waldorp	Universiteit van Amsterdam
Overige leden:	Prof. dr. H. L. J. van der Maas	Universiteit van Amsterdam
	Prof. dr. G. K. J. Maris	Universiteit van Amsterdam
	Prof. dr. F. Tuerlinckx	Katholieke Universiteit Leuven
	Prof. dr. E. M. Wagenmakers	Universiteit van Amsterdam
	Dr. M. Rhemtulla	University of California, Davis
	Dr. R. Quax	Universiteit van Amsterdam
Faculteit:	Faculteit der Maatschappij- en Gedragwetenschappen	

*In loving memory of*



*Janneke de Kort*

*26/01/1984 - 25/05/2016*



*Zara Bamdad*

*19/03/1990 - 15/07/2016*



---

# Contents

---

<b>1</b>	<b>Introduction: Psychological Networks</b>	<b>1</b>
1.1	Introduction . . . . .	1
1.2	Psychological Networks . . . . .	2
1.3	Outline . . . . .	6
<b>I</b>	<b>A Practical Guide to Network Psychometrics</b>	<b>9</b>
<b>2</b>	<b>Regularized Partial Correlation Networks</b>	<b>11</b>
2.1	Introduction . . . . .	11
2.2	Partial Correlation Networks . . . . .	13
2.3	LASSO Regularization . . . . .	13
2.4	Example . . . . .	18
2.5	Common Problems and Questions . . . . .	20
2.6	Simulation Study . . . . .	24
2.7	Conclusion . . . . .	30
<b>3</b>	<b>Accuracy of Psychological Networks</b>	<b>33</b>
3.1	Introduction . . . . .	34
3.2	Estimating Psychological Networks . . . . .	37
3.3	Network Accuracy . . . . .	39
3.4	Tutorial . . . . .	43
3.5	Simulation Studies . . . . .	50
3.6	Conclusion . . . . .	54
<b>4</b>	<b>Network Estimation and Sparsity</b>	<b>59</b>
4.1	Introduction . . . . .	59
4.2	Network Psychometrics . . . . .	60
4.3	A Sparse Network Model of Psychopathology . . . . .	61
4.4	The Bet on Sparsity . . . . .	62
4.5	Estimating an Ising Model When the Truth Is Dense . . . . .	63
4.6	Conclusion . . . . .	69
<b>5</b>	<b>Personalized Network Modeling in Psychopathology</b>	<b>71</b>
5.1	Introduction . . . . .	72
5.2	Temporal and Contemporaneous Networks . . . . .	72
5.3	Causation at the Contemporaneous Level . . . . .	74

5.4	Partial Correlation Networks . . . . .	75
5.5	Generating Causal Hypotheses . . . . .	77
5.6	Clinical Example . . . . .	78
5.7	Conclusion . . . . .	80
<b>II Technical Advances in Network Psychometrics</b>		<b>83</b>
<b>6</b>	<b>Discovering Psychological Dynamics</b>	<b>85</b>
6.1	Introduction . . . . .	85
6.2	Characterizing Multivariate Gaussian Data . . . . .	87
6.3	The Gaussian Graphical Model . . . . .	88
6.4	When Cases Are Not Independent: $n = 1$ . . . . .	94
6.5	When Cases Are Not Independent: $n > 1$ . . . . .	98
6.6	Empirical Example . . . . .	106
6.7	Simulation Study . . . . .	107
6.8	Conclusion . . . . .	111
6.9	Appendix A: Simulating Multi-level VAR Models and Data . . . . .	114
<b>7</b>	<b>Generalized Network Psychometrics</b>	<b>115</b>
7.1	Introduction . . . . .	116
7.2	Modeling Multivariate Gaussian Data . . . . .	117
7.3	Generalizing Factor Analysis and Network Modeling . . . . .	122
7.4	Exploratory Network Estimation . . . . .	127
7.5	Empirical Example: Personality Inventory . . . . .	138
7.6	Conclusion . . . . .	140
<b>8</b>	<b>The Ising Model in Psychometrics</b>	<b>143</b>
8.1	Introduction . . . . .	143
8.2	Markov Random Fields . . . . .	145
8.3	The Ising Model in Psychometrics . . . . .	152
8.4	Estimating the Ising Model . . . . .	158
8.5	Interpreting Latent Variables in Psychometric Models . . . . .	164
8.6	Conclusion . . . . .	169
8.7	Appendix A: Proof of Equivalence Between the Ising Model and MIRT . . . . .	170
8.8	Appendix B: Glossary of Notation . . . . .	173
<b>III Visualizing Psychometrics and Personality Research</b>		<b>175</b>
<b>9</b>	<b>Network Visualizations of Relationships in Psychometric Data</b>	<b>177</b>
9.1	Introduction . . . . .	177
9.2	Creating Graphs . . . . .	179
9.3	Visualizing Statistics as Graphs . . . . .	185
9.4	Conclusion . . . . .	192
<b>10</b>	<b>State of the aRt Personality Research</b>	<b>195</b>

---

10.1 Introduction . . . . .	195
10.2 Constructing Personality Networks . . . . .	196
10.3 Analyzing the Structure of Personality Networks . . . . .	205
10.4 Conclusion . . . . .	218
<b>11 Unified Visualizations of Structural Equation Models</b>	<b>221</b>
11.1 Introduction . . . . .	221
11.2 General Use of the semPlot Package . . . . .	223
11.3 Algorithms for Drawing Path Diagrams . . . . .	231
11.4 Conclusion . . . . .	234
<b>IV Conclusion</b>	<b>235</b>
<b>12 Discussion: The Road Ahead</b>	<b>237</b>
12.1 Introduction . . . . .	237
12.2 Open Questions in Network Psychometrics . . . . .	238
12.3 Conclusion . . . . .	247
<b>V Appendices</b>	<b>249</b>
<b>A References</b>	<b>251</b>
<b>B Contributed Work</b>	<b>275</b>
B.1 Publications . . . . .	275
B.2 Software . . . . .	278
<b>C Nederlandse Samenvatting</b>	<b>281</b>
C.1 Introductie: Psychologische netwerken . . . . .	281
C.2 Deel I: Netwerkpsychometrie voor de empirische wetenschapper . .	282
C.3 Deel II: Technologische ontwikkelingen in de netwerkpsychometrie	290
C.4 Deel III: Visualisaties in de psychometrie en persoonlijkheidsonderzoek	295
C.5 Discussie: open vraagstukken in de netwerkpsychometrie . . . . .	296
<b>D Acknowledgements — Dankwoord</b>	<b>299</b>