Discovering Psychological Dynamics

In Time-series Data

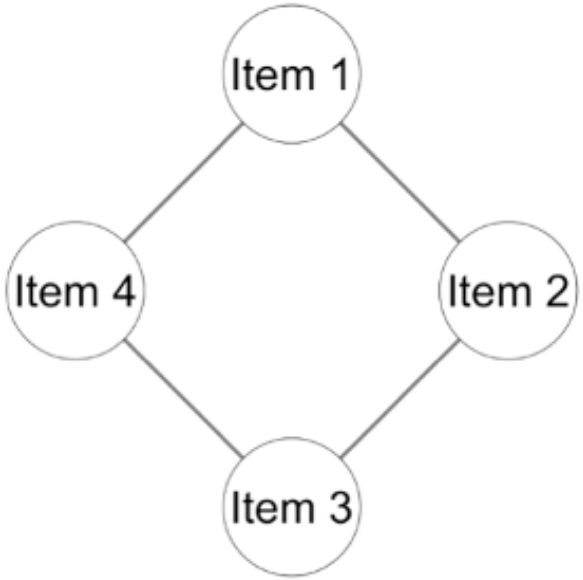
Sacha Epskamp

University of Amsterdam: Department of Psychological Methods

CCS 2016 — September 21, 2016

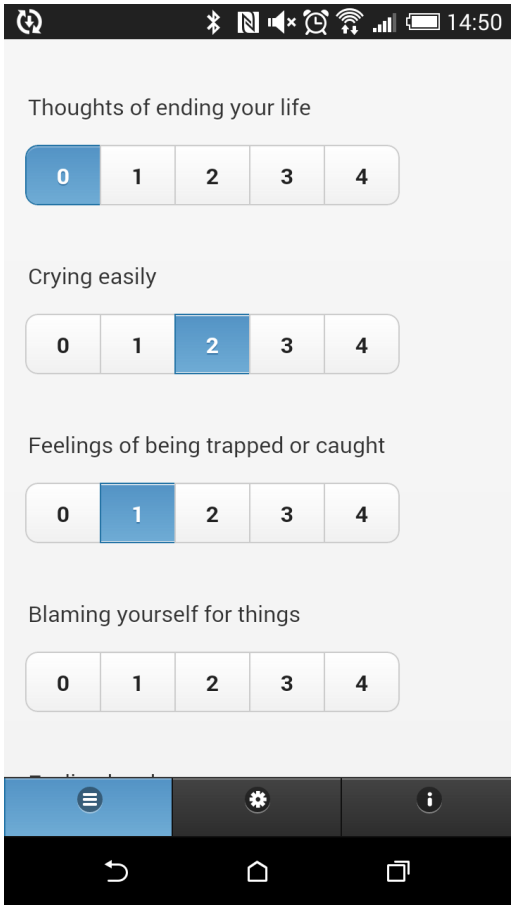
Network Psychometrics

	Item 1	Item 2	Item 3	Item 4
Subject 1	2	2	1	3
Subject 2	3	2	3	2
Subject 3	2	1	2	4
Subject 4	5	5	5	5
Subject 5	3	3	2	2
Subject 6	5	5	3	3
Subject 7	4	5	5	4
Subject 8	5	5	5	5
Subject 9	2	5	4	4
Subject 10	5	4	5	4



- What is the structure of psychology?
- *Psychological Networks*

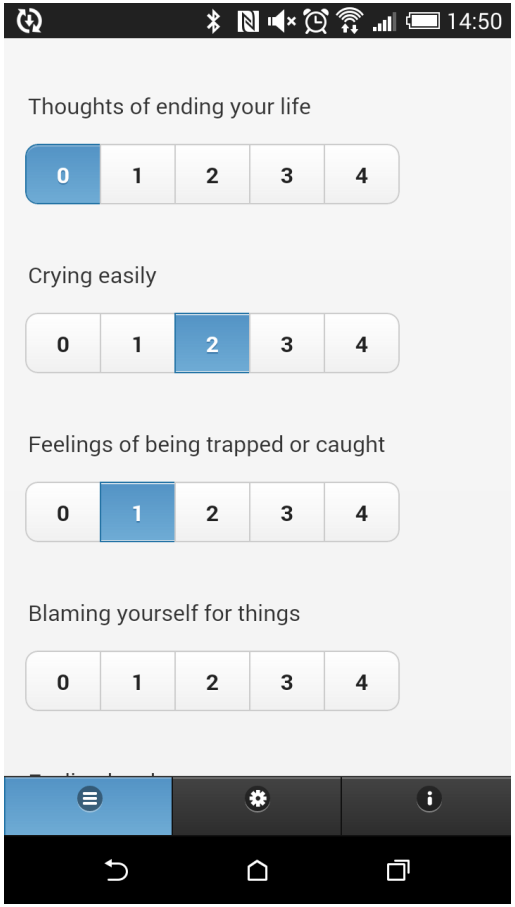
Psychological Data



Subject	Time	Item 1	Item 2	Item 3
Subject 1	Time 1	2	2	4
Subject 2	Time 1	4	1	2
Subject 3	Time 1	1	3	0

- Multiple people measured once: *cross-sectional analysis*

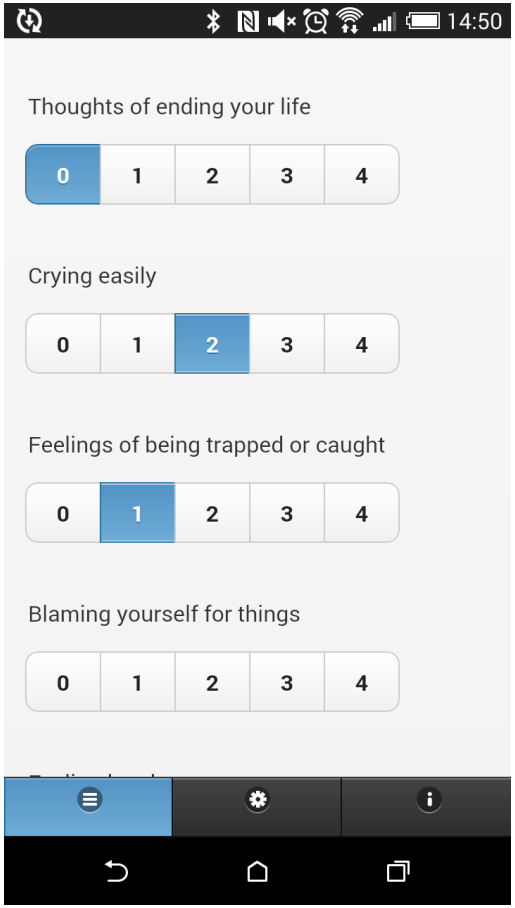
Psychological Data



Subject	Time	Item 1	Item 2	Item 3
Subject 1	Time 1	2	2	4
Subject 1	Time 2	2	4	4
Subject 1	Time 3	1	4	3

- Multiple people measured once: *cross-sectional analysis*
- One person measured multiple times: $N = 1$ *time-series*

Psychological Data



Subject	Time	Item 1	Item 2	Item 3
Subject 1	Time 1	2	2	4
Subject 1	Time 2	2	4	4
Subject 1	Time 3	1	4	3
Subject 2	Time 1	4	1	2
Subject 2	Time 2	3	1	2
Subject 2	Time 3	3	2	1
Subject 3	Time 1	1	3	0
Subject 3	Time 2	4	0	1
Subject 3	Time 3	0	3	3

- Multiple people measured once: *cross-sectional analysis*
- One person measured multiple times: $N = 1$ *time-series*
- Multiple people measured multiple times: $N > 1$ *time-series*

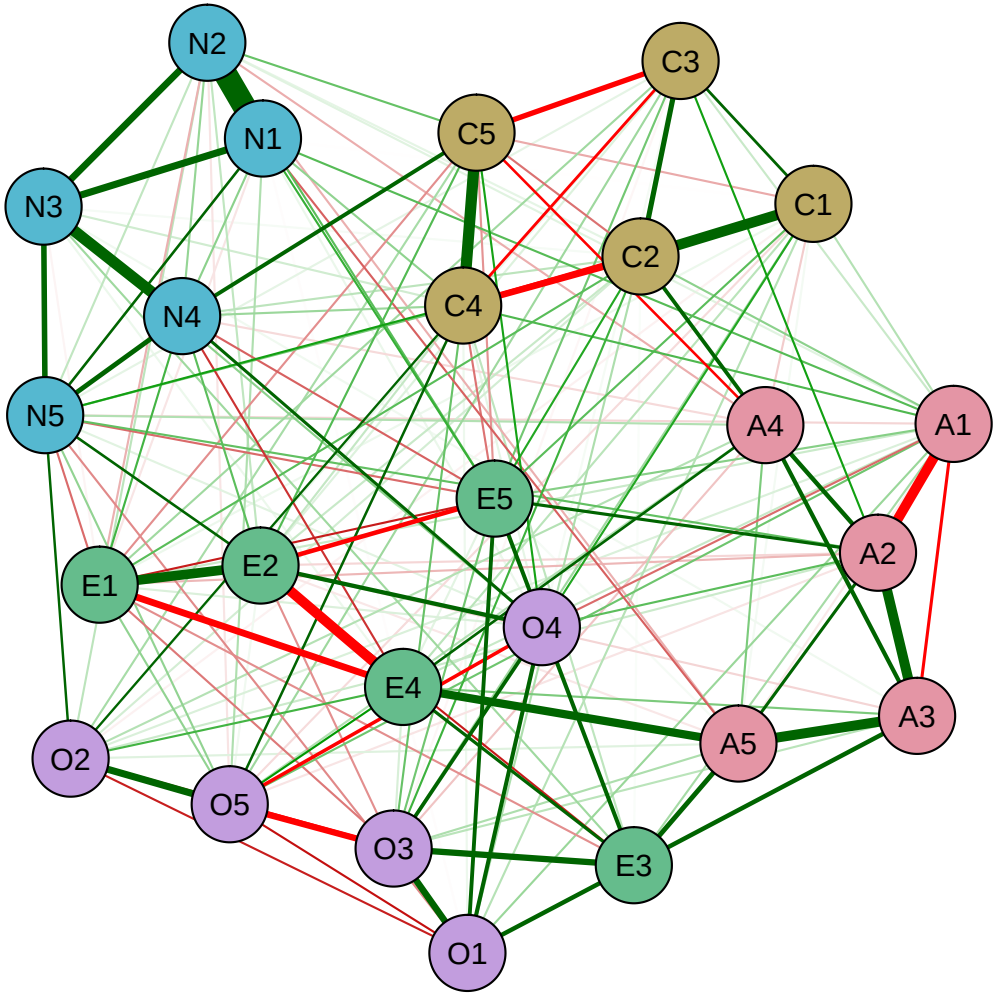
Three Types of Psychological Networks

Network	Gaussian	Binary	Mixed
Concentration	GGM	Ising	MGM
Contemporaneous	GGM	?	?
Temporal	VAR	Logistic VAR	MGM
Between-subjects	GGM	?	?

GGM = Gaussian graphical model; VAR = Vector Autoregression; MGM = Mixed graphical models

- Cross-sectional: concentration network
- $N = 1$ time-series: contemporaneous and temporal networks
  - The concentration network is the same as the contemporaneous network in time-series analysis
- $N > 1$ time-series: contemporaneous, temporal and between-subject networks

Concentration Networks



Agreeableness
- A1: Am indifferent to the feelings of others.
- A2: Inquire about others' well−being.
- A3: Know how to comfort others.
- A4: Love children.
- A5: Make people feel at ease.

Conscientiousness
- C1: Am exacting in my work.
- C2: Continue until everything is perfect.
- C3: Do things according to a plan.
- C4: Do things in a half−way manner.
- C5: Waste my time.

Extraversion
- E1: Don't talk a lot.
- E2: Find it difficult to approach others.
- E3: Know how to captivate people.
- E4: Make friends easily.
- E5: Take charge.

Neuroticism
- N1: Get angry easily.
- N2: Get irritated easily.
- N3: Have frequent mood swings.
- N4: Often feel blue.
- N5: Panic easily.

Openness
- O1: Am full of ideas.
- O2: Avoid difficult reading material.
- O3: Carry the conversation to a higher level.
- O4: Spend time reflecting on things.
- O5: Will not probe deeply into a subject.

The concentration network:

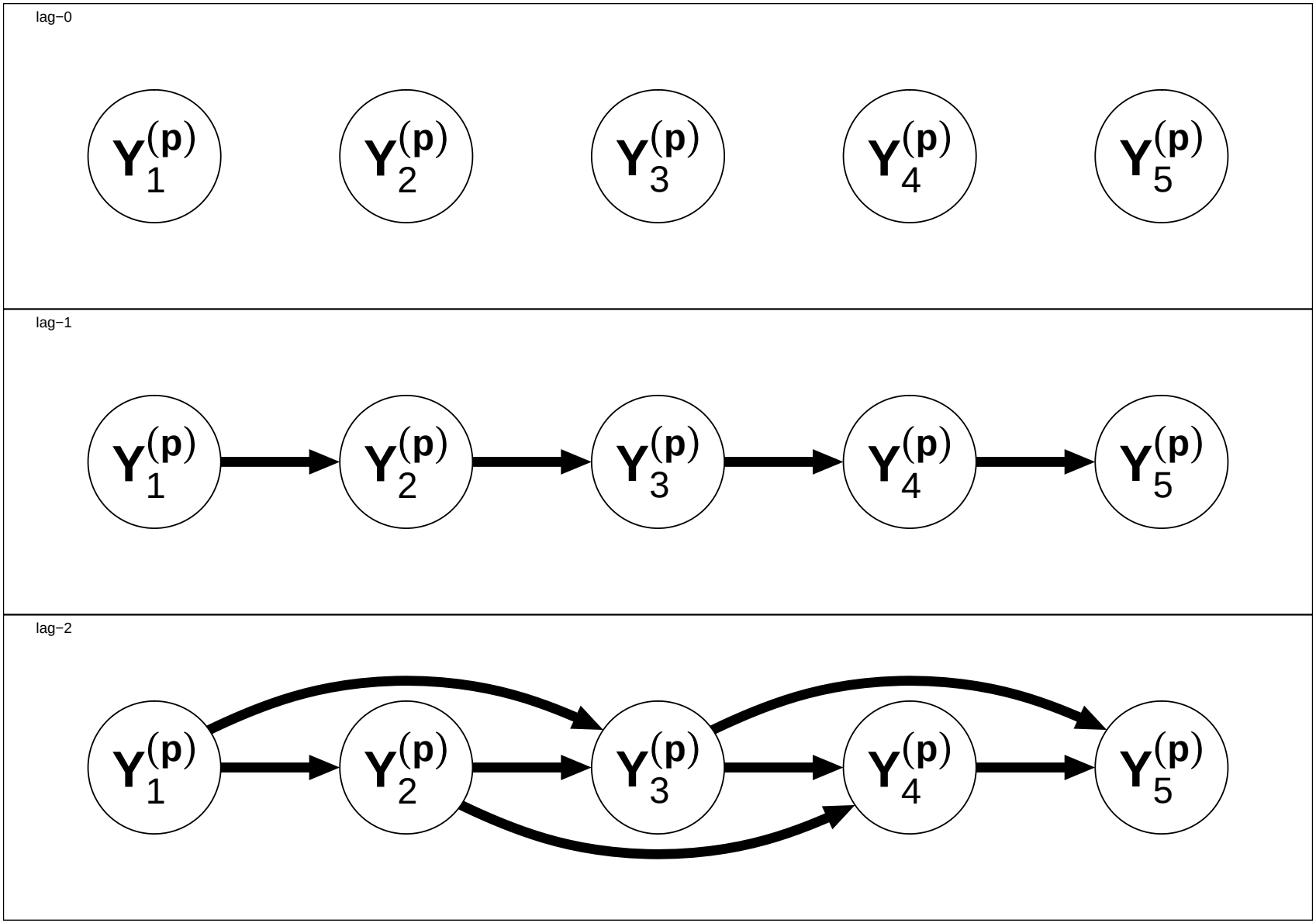
- Concentration $-$ Fatigue $-$ Insomnia

Is equivalent to three causal structures:

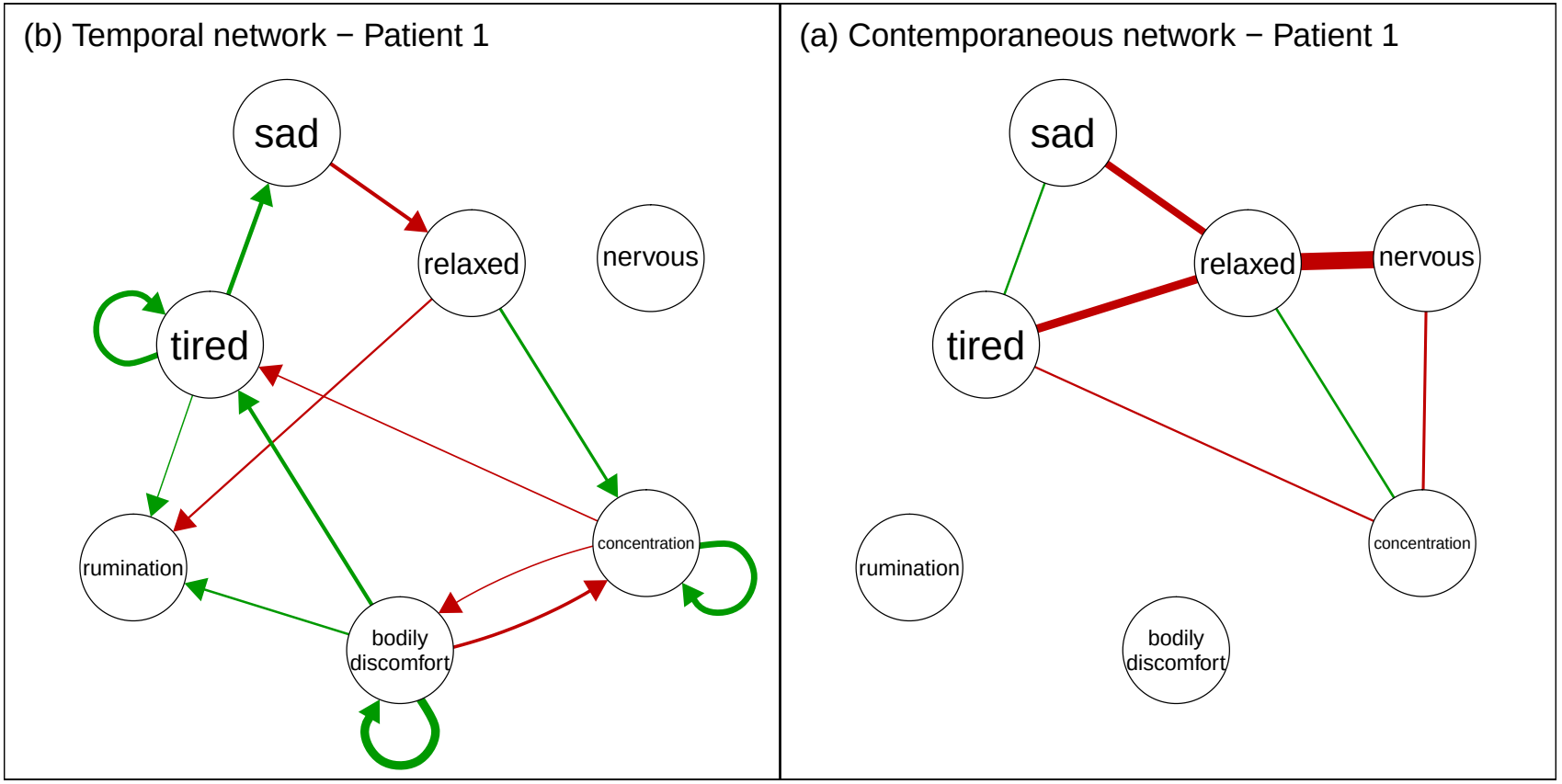
1. Concentration $\rightarrow$ Fatigue $\rightarrow$ Insomnia
2. Concentration $\leftarrow$ Fatigue $\rightarrow$ Insomnia
3. Concentration $\leftarrow$ Fatigue $\leftarrow$ Insomnia

Thus, the concentration network highlights potential causal pathways. In addition, the edge weights are *proportional* to predictive coefficients in (logistic) regression.

Time-series Analysis



Personalized Networks in Clinical Practice



- Contemporaneous network: conditional concentration given $t-1$
- Temporal network: regression coefficients between $t-1$ and t

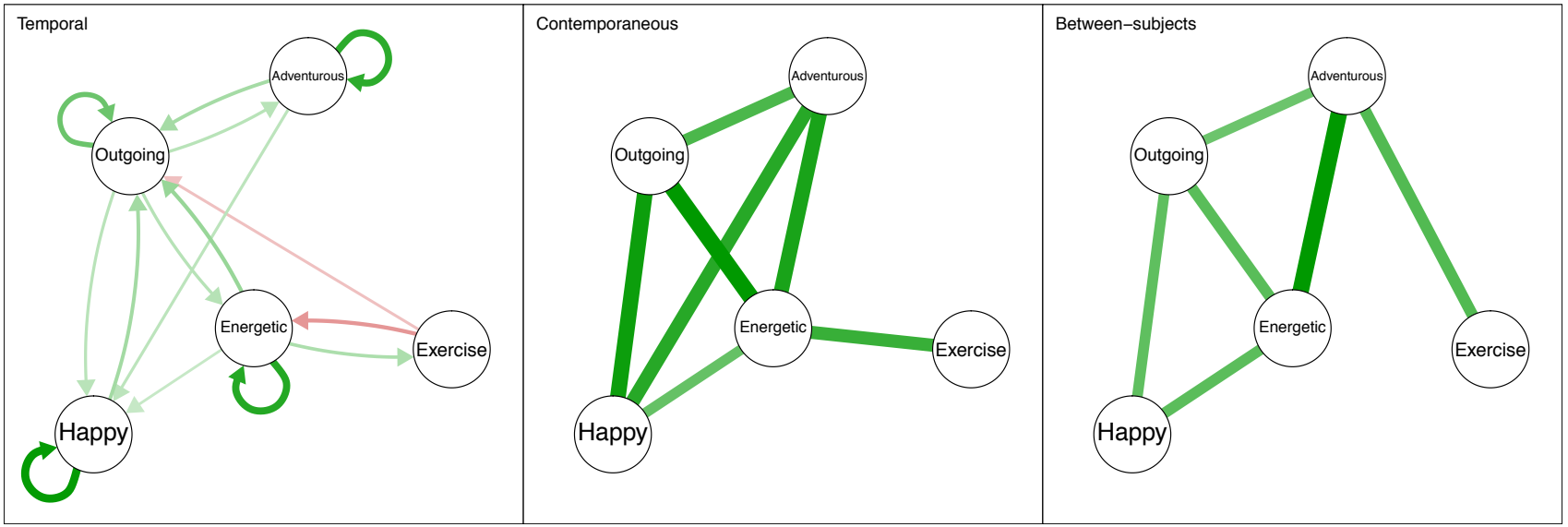
Personalized Network Modeling in Psychopathology: The Importance of Contemporaneous and Temporal Connections

Sacha Epskamp[1], Claudia D. van Borkulo[1], Date C. van der Veen[2], Michelle N. Servaas[2], Adela-Maria Isvoranu[1], Harriëtte Riese[2], Angelique O.J. Cramer[1]

1. University of Amsterdam, Department of Psychological Methods

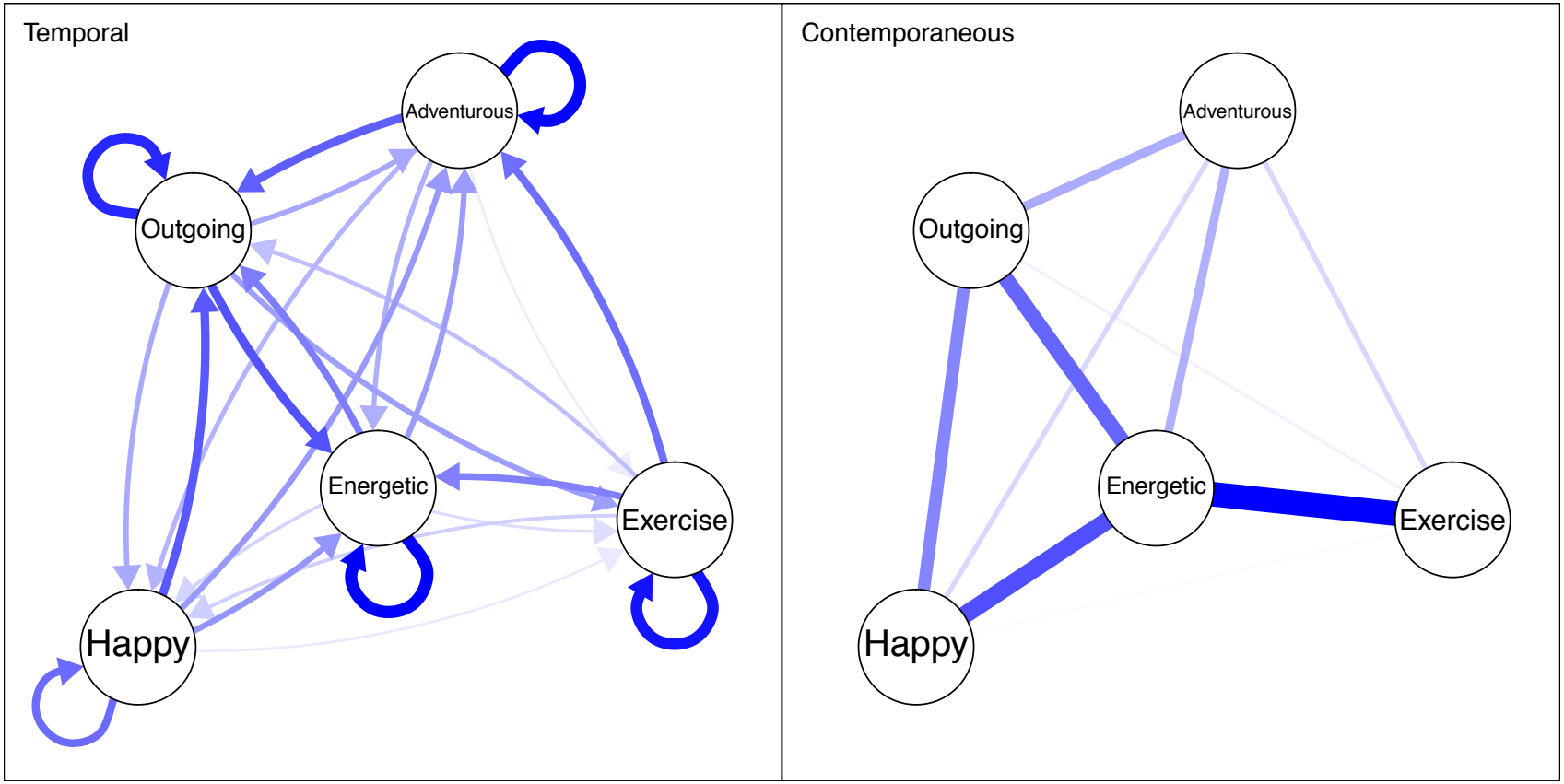
2. University of Groningen, University Medical Center Groningen, Department of Psychiatry, Interdisciplinary Center for Psychopathology and Emotion Regulation

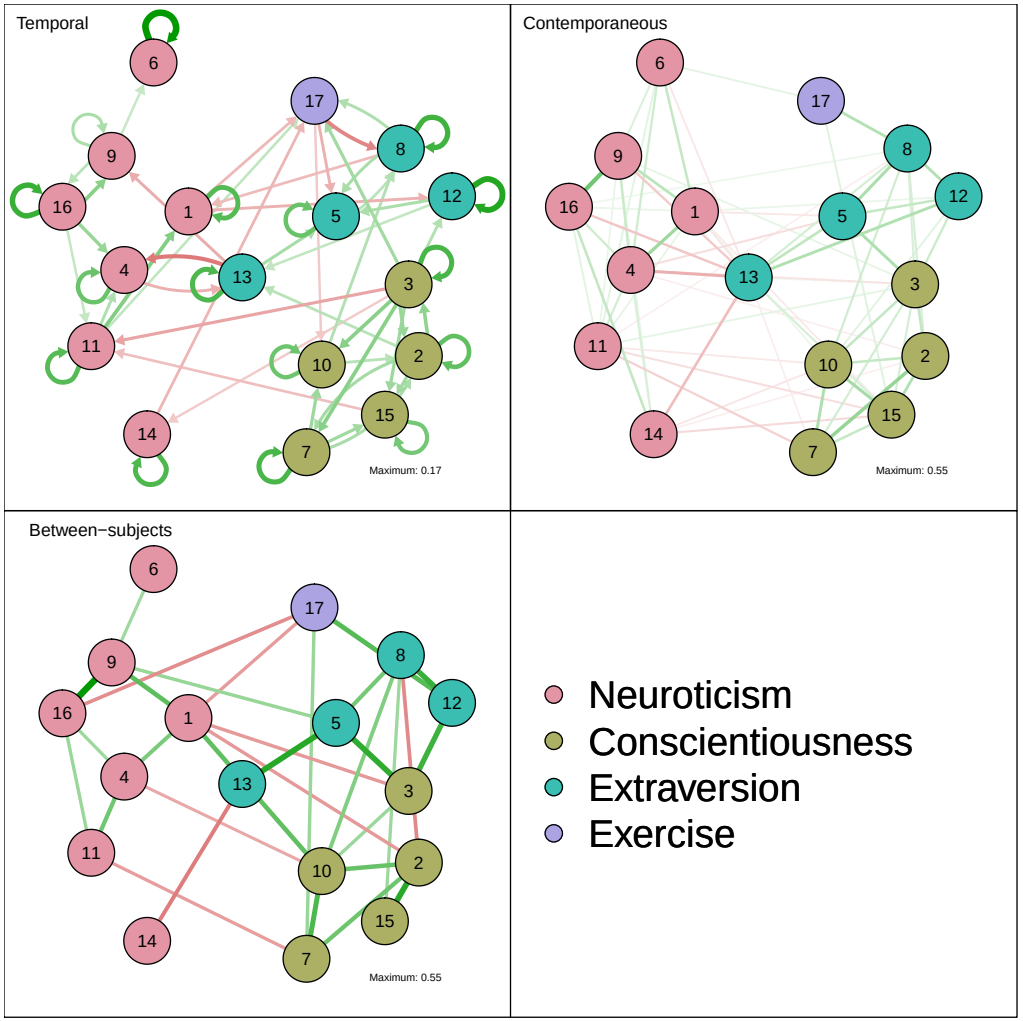
Time series: $N > 1$



- Between-subjects network: concentration network between stationary means
- Two-step multilevel VAR

Individual Differences





1 = “Worried”; 2 = “Organized”; 3 = “Ambitious”; 4 = “Depressed”; 5 = “Outgoing”; 6 = “Self-Conscious”; 7 = “Self-Disciplined”; 8 = “Energetic”; 9 = “Frustrated”; 10 = “Focused”; 11 = “Guilty”; 12 = “Adventurous”; 13 = “Happy”; 14 = “Control”; 15 = “Achieved”; 16 = “Angry”; 17 = “Exercise.”

arXiv.org > stat > arXiv:1609.04156

Search or Article-id (Help | Advanced search) All papers Go!

Statistics > Methodology

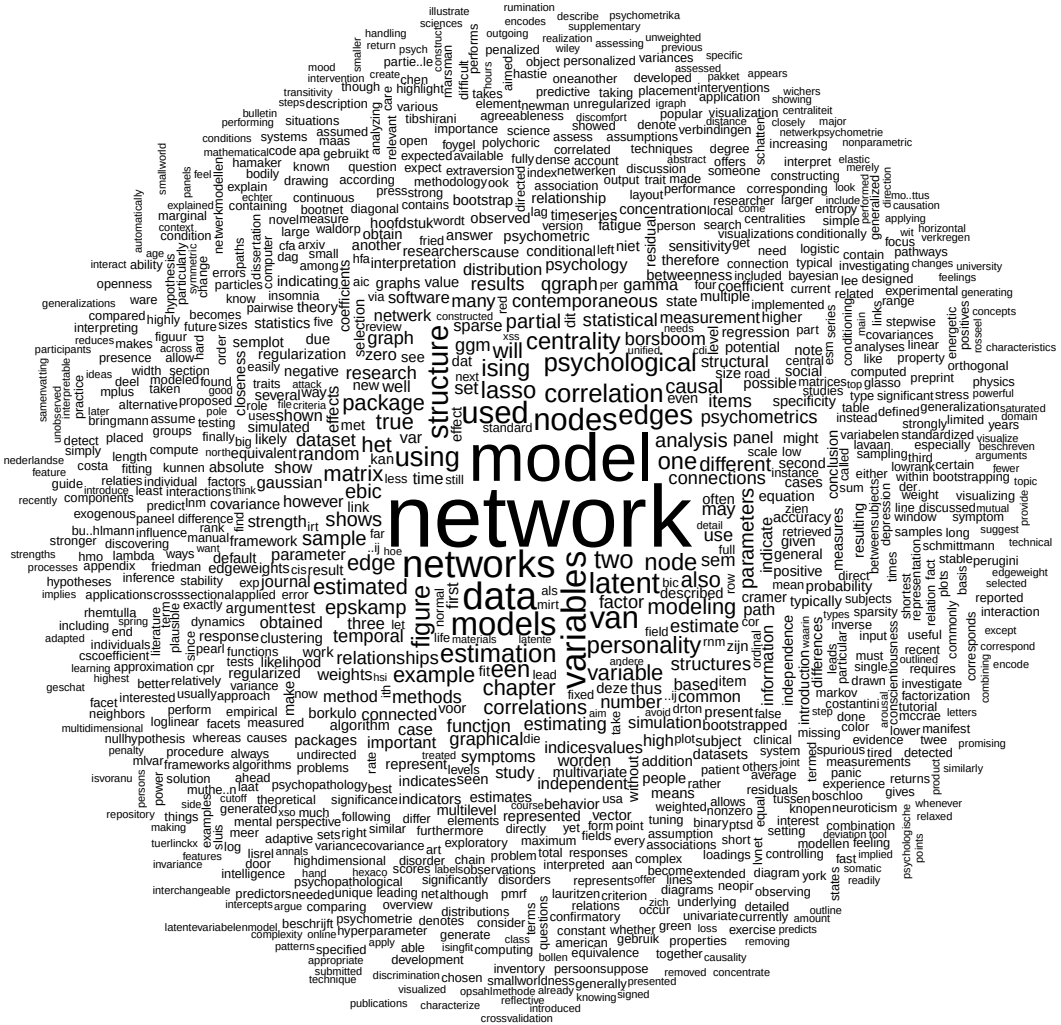
Discovering Psychological Dynamics in Time-Series Data

Sacha Epskamp, Lourens J. Waldorp, René Mõttus, Denny Borsboom

(Submitted on 14 Sep 2016)

This paper provides a methodological overview of statistical network models in cross-sectional and time-series data. The increasing trend of modeling psychological data through networks attempts to highlight potential causal relationships between observed variables. When data are cross-sectional, it is becoming increasingly popular to estimate a Gaussian graphical model (GGM; a network of partial correlation coefficients). In a time-series analysis, networks are typically constructed through the use of (multilevel) vector autoregression (VAR). VAR estimates a directed network that encodes temporal predictive effects – the temporal network. We show that GGM and VAR models are closely related: VAR generalizes the GGM by taking violations of independence between consecutive cases into account. VAR analyses can also return a GGM that encodes relationships within the same window of measurement – the contemporaneous network, which has not yet been extensively utilized in the literature. When multiple subjects are measured, multilevel VAR estimates fixed and random temporal networks. Proper centering can disentangle within- and between-subject variance in such processes. We show, for the first time, that the between-subject effects can be summarized in a GGM network – the between-subjects network. We argue that such between-subjects effects can also indicate causal pathways. Furthermore, we propose a novel two-step, multilevel estimation procedure to obtain fixed and random effects for contemporaneous network structures. We have implemented this procedure in the R package mlVAR. We present a simulation study to show the performance of mlVAR and to showcase the method in an empirical example on personality inventory items and physical exercise.

Pre-print online at `http://arxiv.org/abs/1609.04156`



http://sachaepskamp.com/ and http://psychosystems.org/

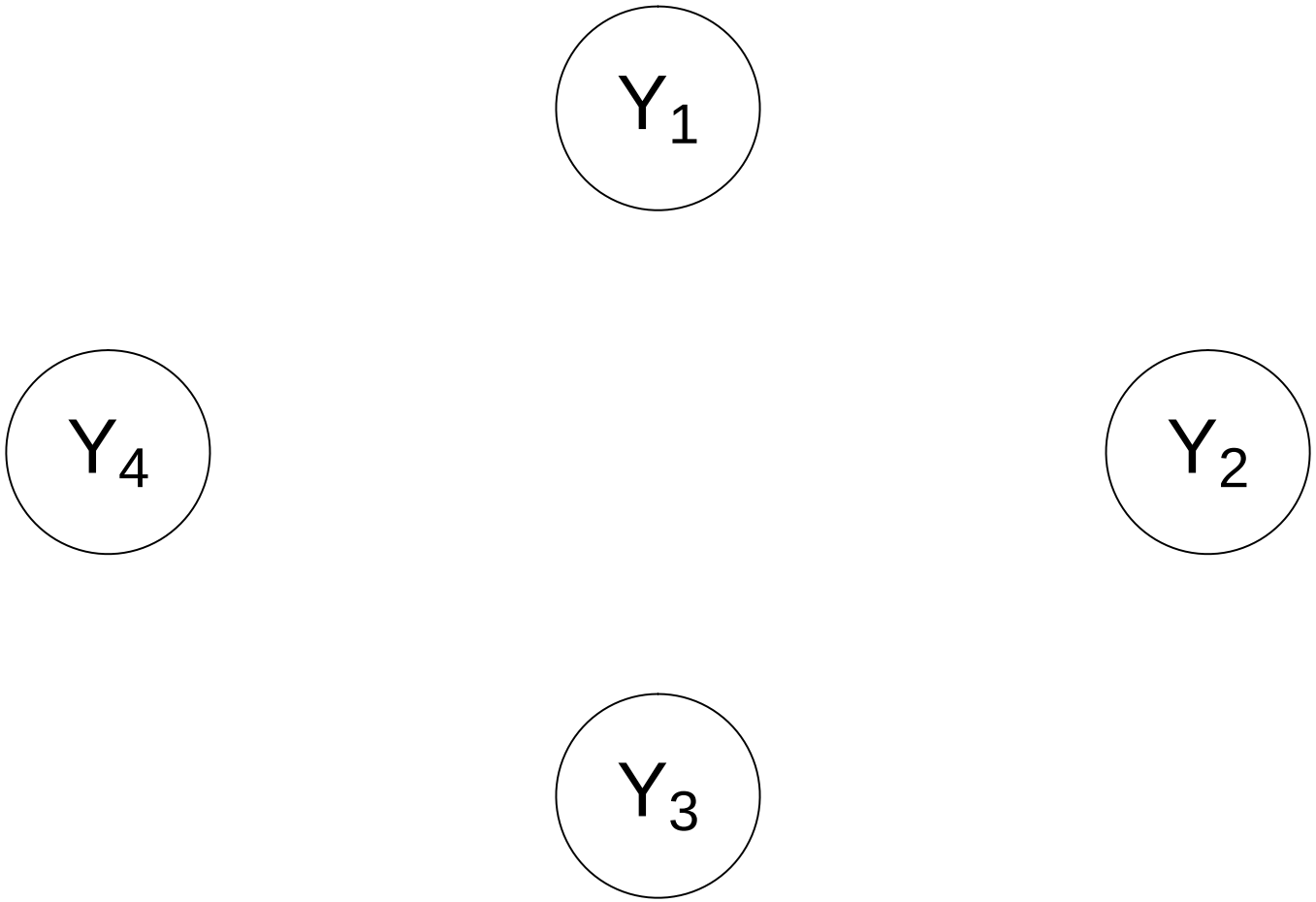
Acknowledgements

Special thanks to Hariëtte Riesse, Laura Bringmann, Noémi Schuurman and Ellen Hamaker for collaboration, helpful tips, and invigorating discussion.

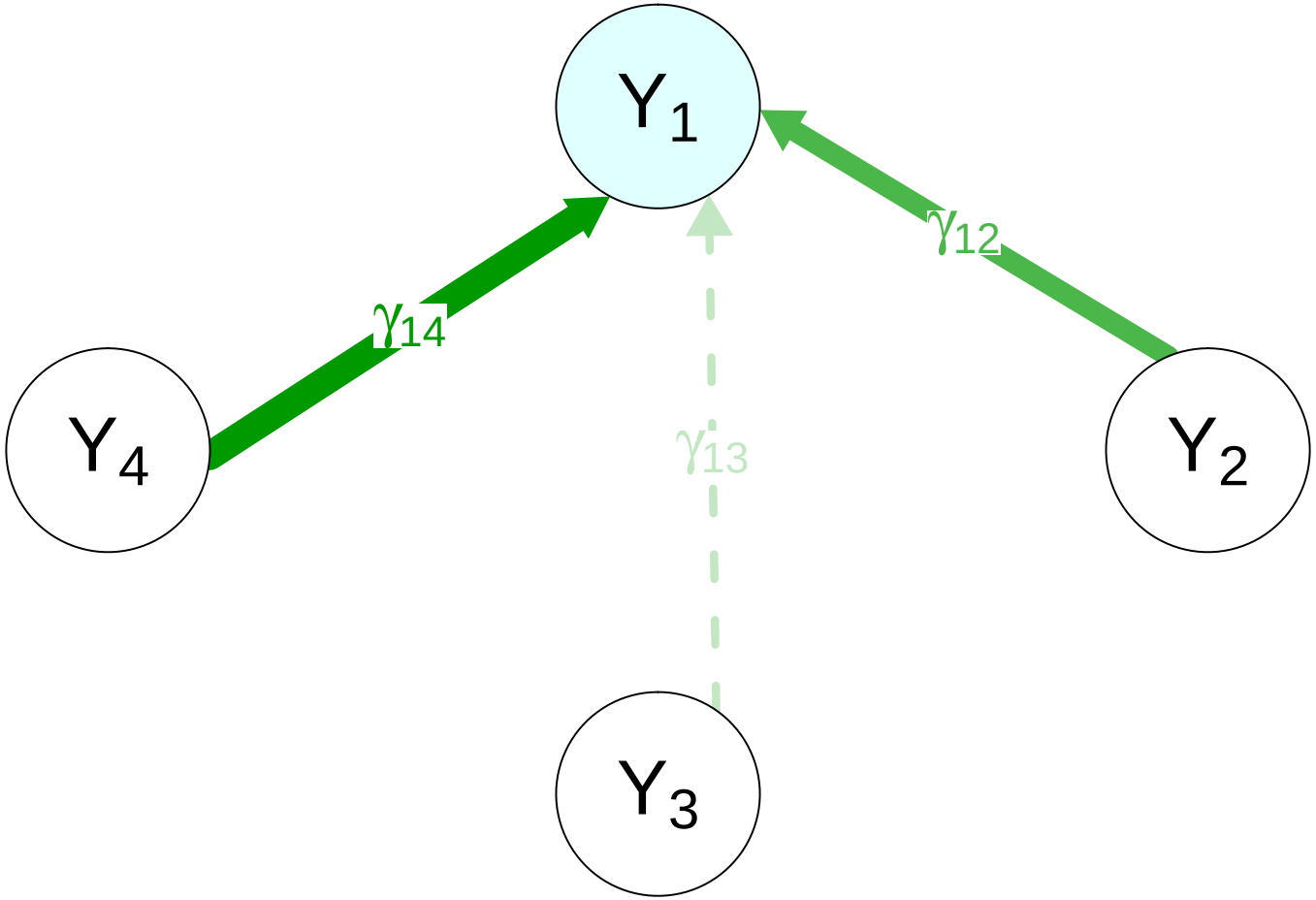
Thank you for your attention!

Extra slides: two-step multilevel VAR estimation

GGM and Multiple Regressions

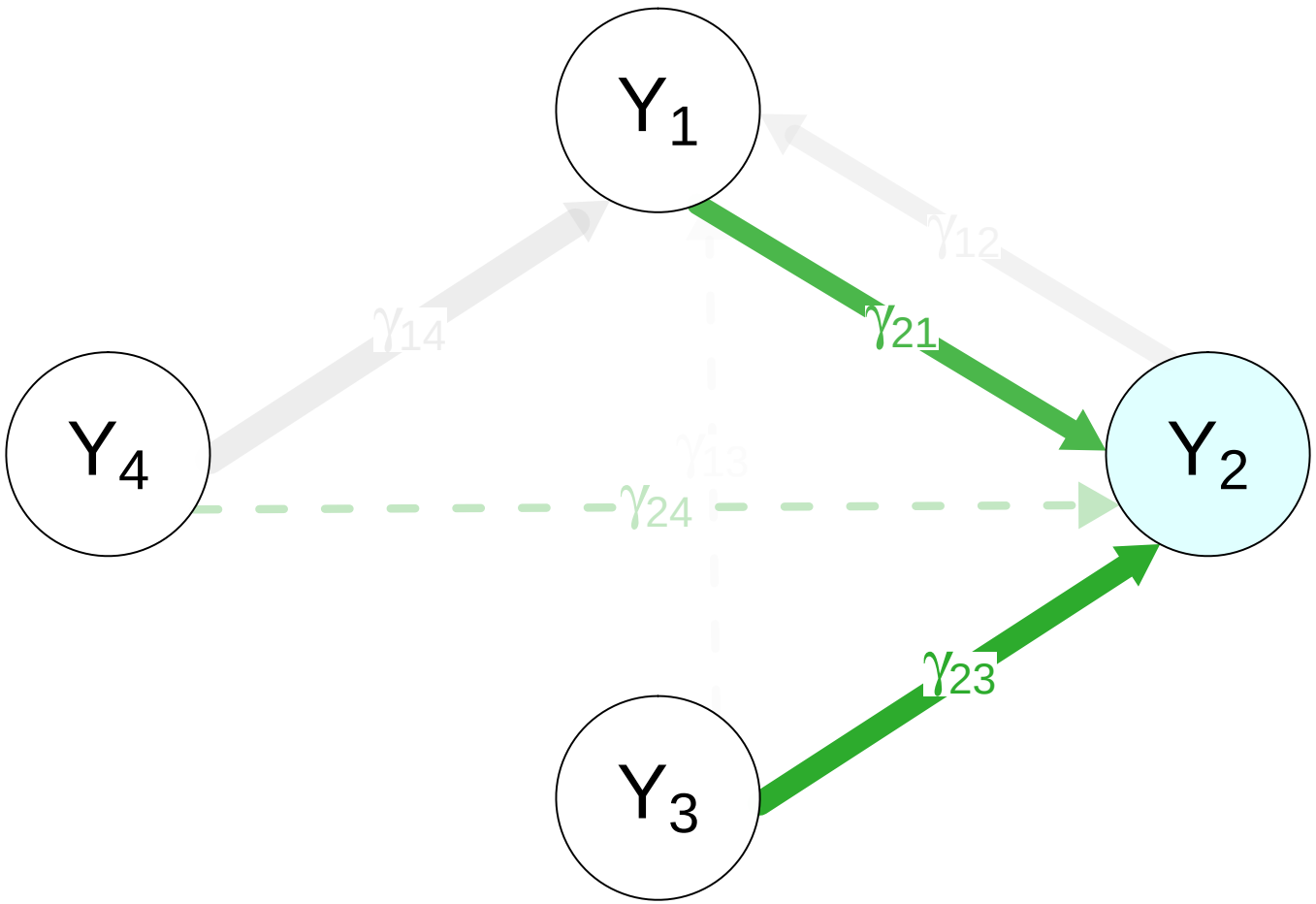


GGM and Multiple Regressions



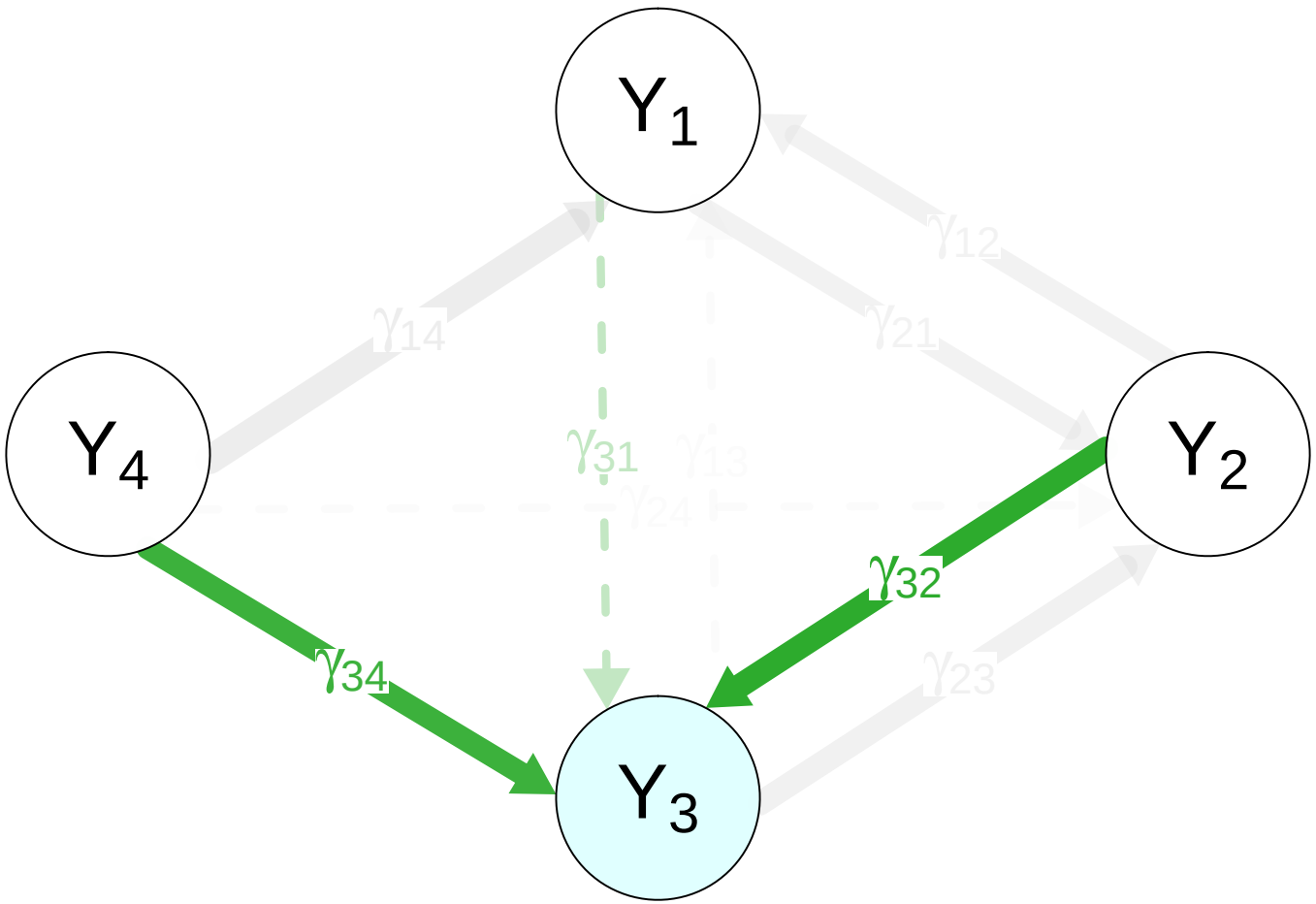
$$y_1 = \tau_1 + \gamma_{12} y_2 + \gamma_{13} y_3 + \gamma_{14} y_4 + \varepsilon_1$$

GGM and Multiple Regressions



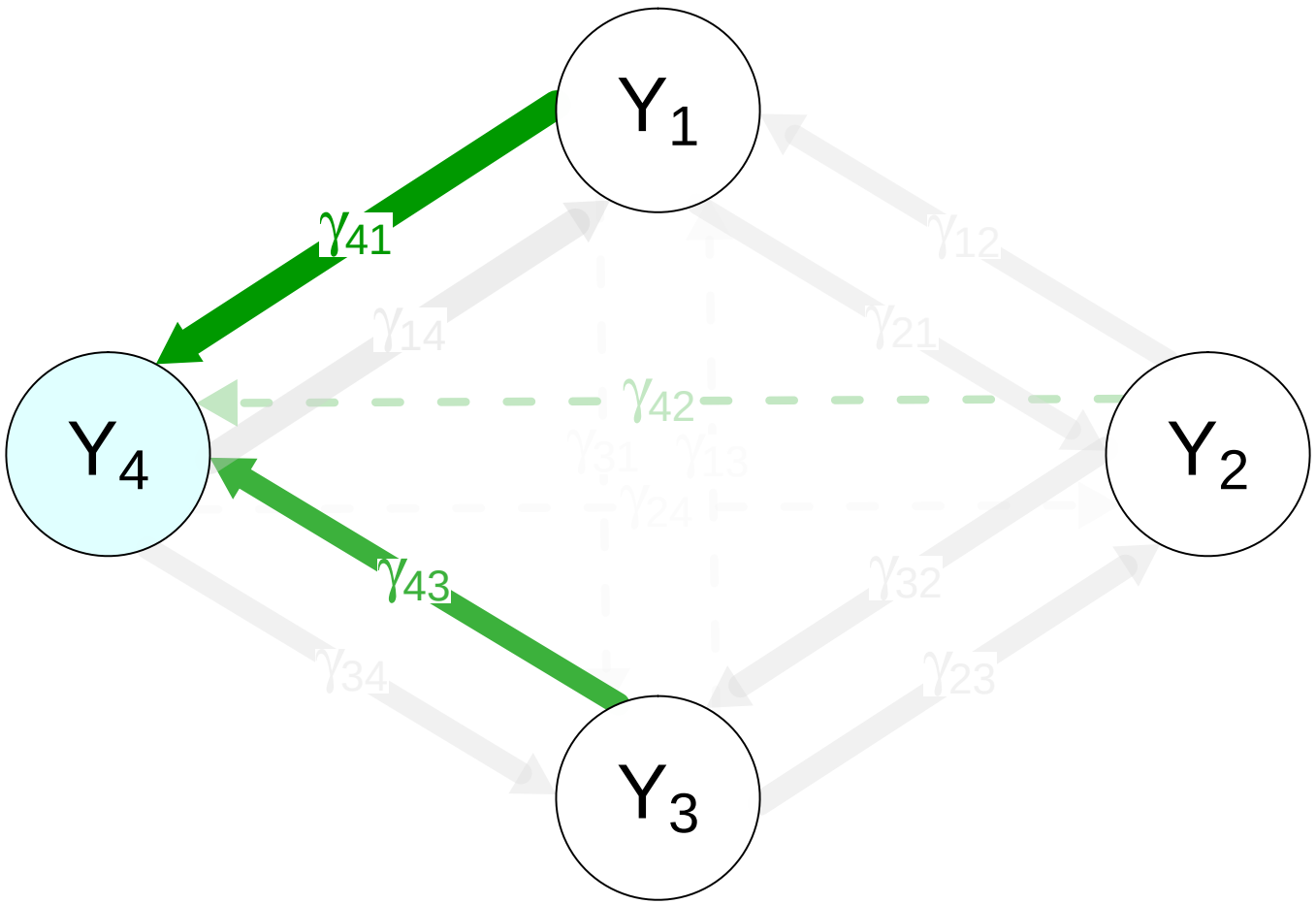
$$y_2 = \tau_2 + \gamma_{21} y_1 + \gamma_{23} y_3 + \gamma_{24} y_4 + \varepsilon_2$$

GGM and Multiple Regressions



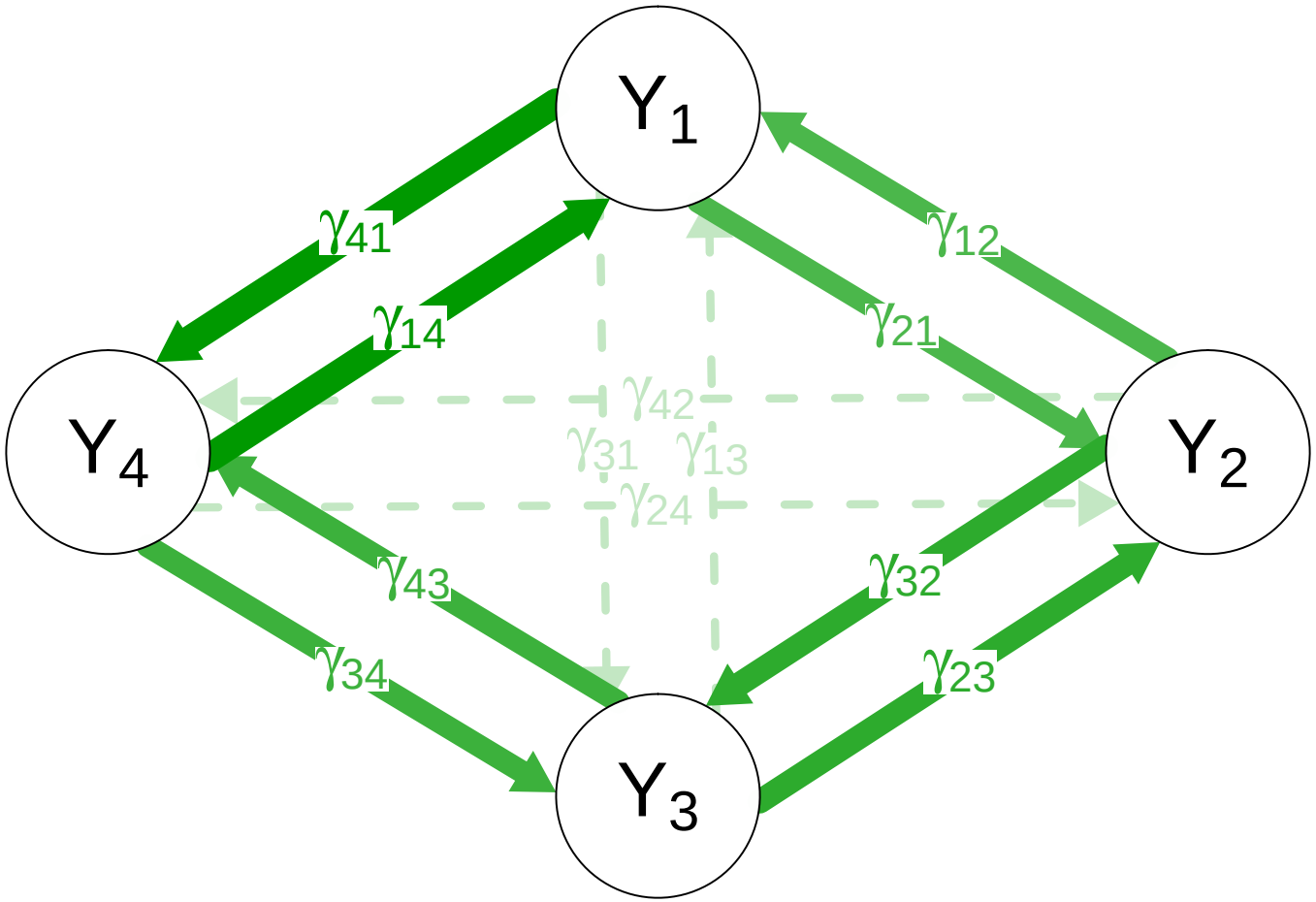
$$y_3 = \tau_3 + \gamma_{31} y_1 + \gamma_{32} y_2 + \gamma_{34} y_4 + \varepsilon_3$$

GGM and Multiple Regressions

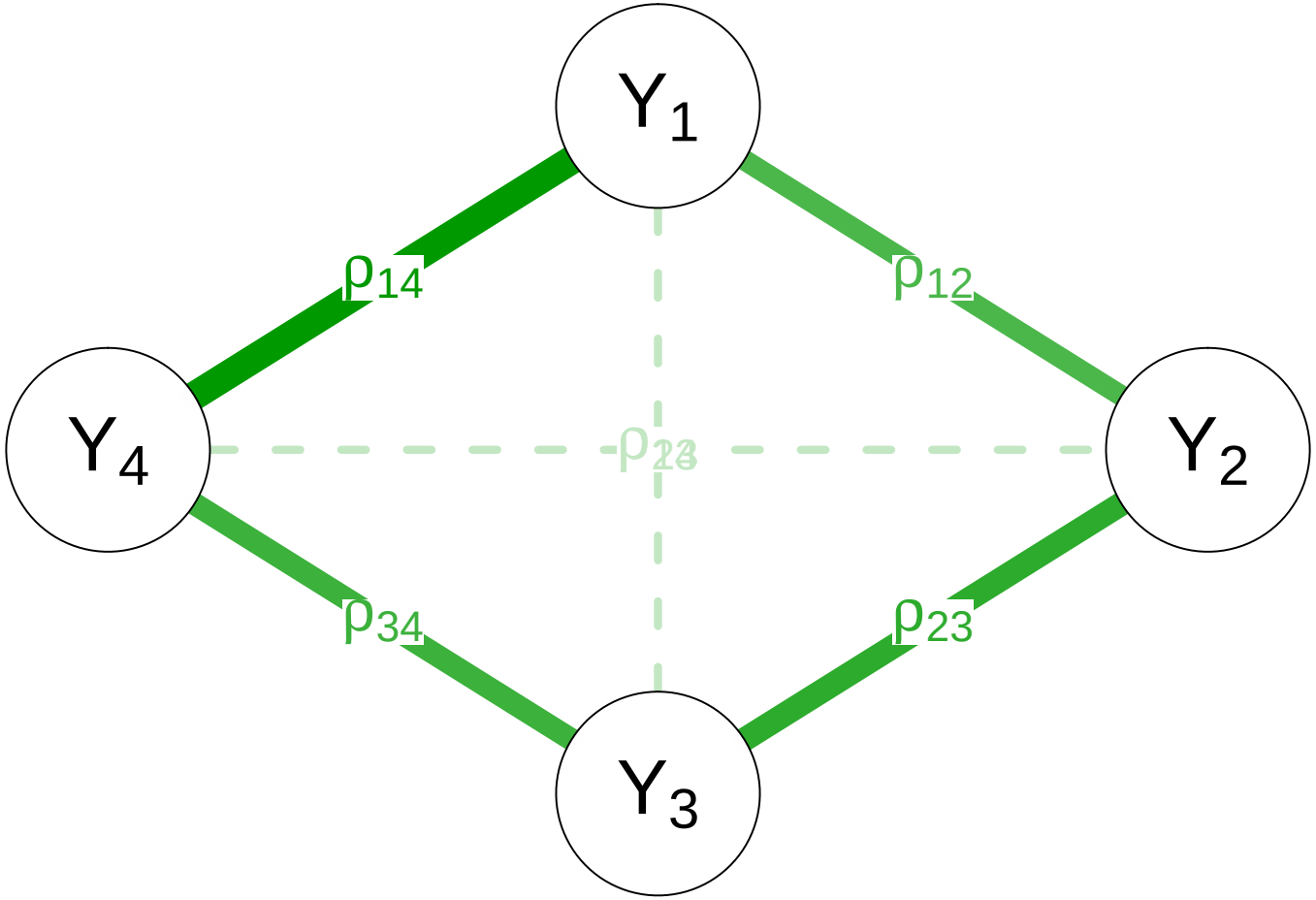


$$y_4 = \tau_4 + \gamma_{41} y_1 + \gamma_{42} y_2 + \gamma_{43} y_3 + \varepsilon_4$$

GGM and Multiple Regressions

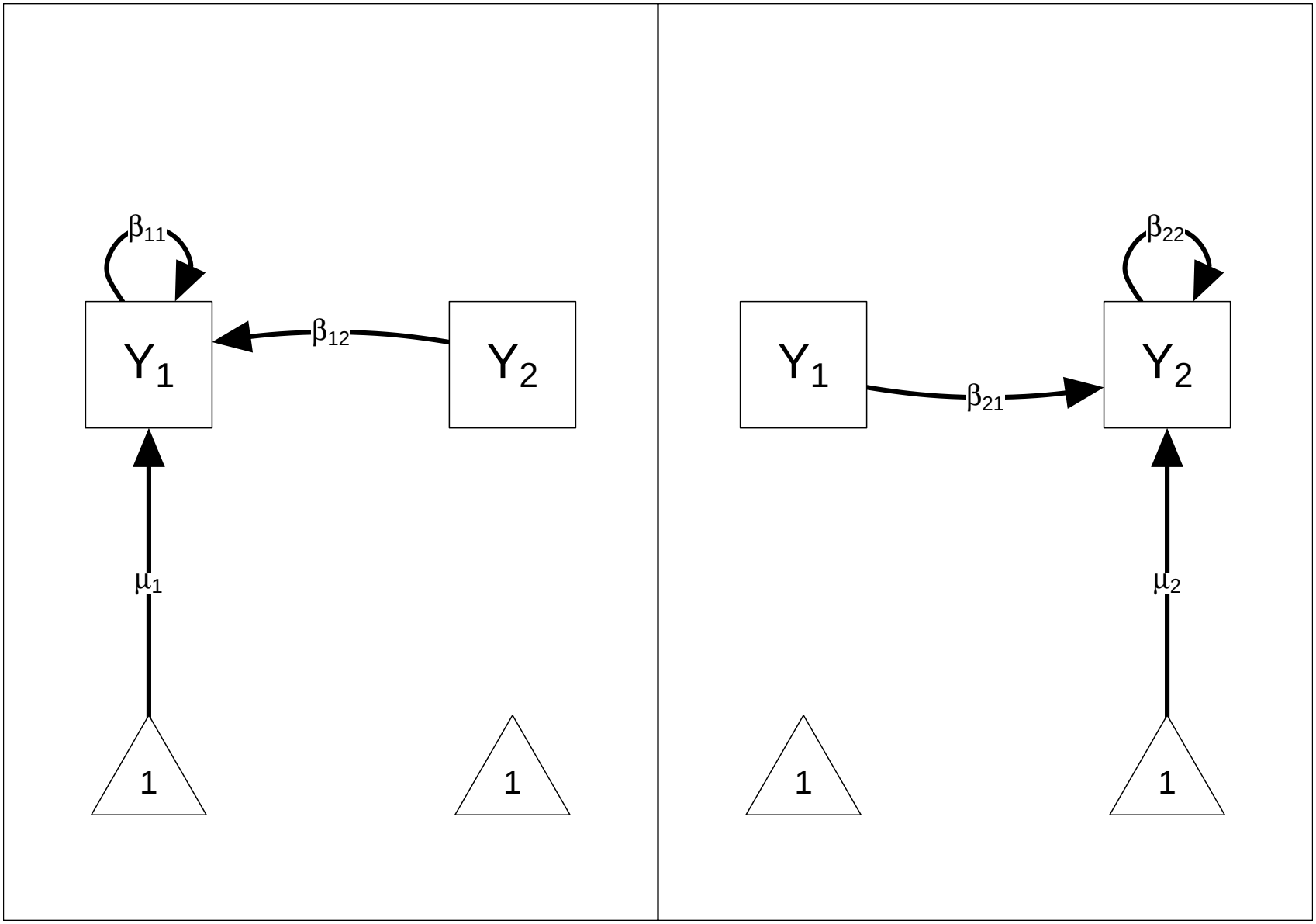


GGM and Multiple Regressions

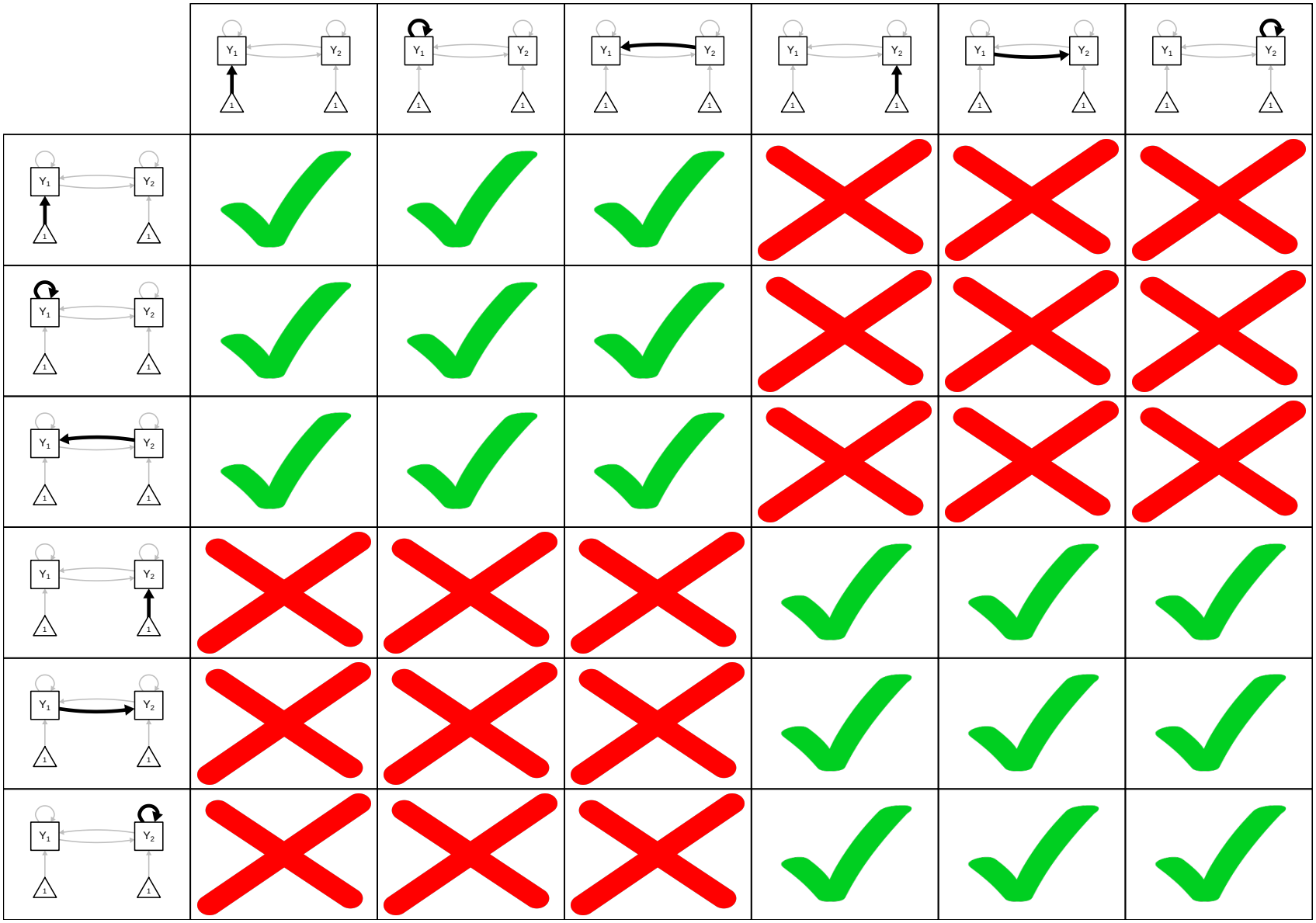


$$\rho_{ij} = \frac{\gamma_{ij}\mathrm{Var}\left(\varepsilon_j\right)}{\mathrm{Var}\left(\varepsilon_i\right)} = \frac{\gamma_{ji}\mathrm{Var}\left(\varepsilon_i\right)}{\mathrm{Var}\left(\varepsilon_j\right)}$$

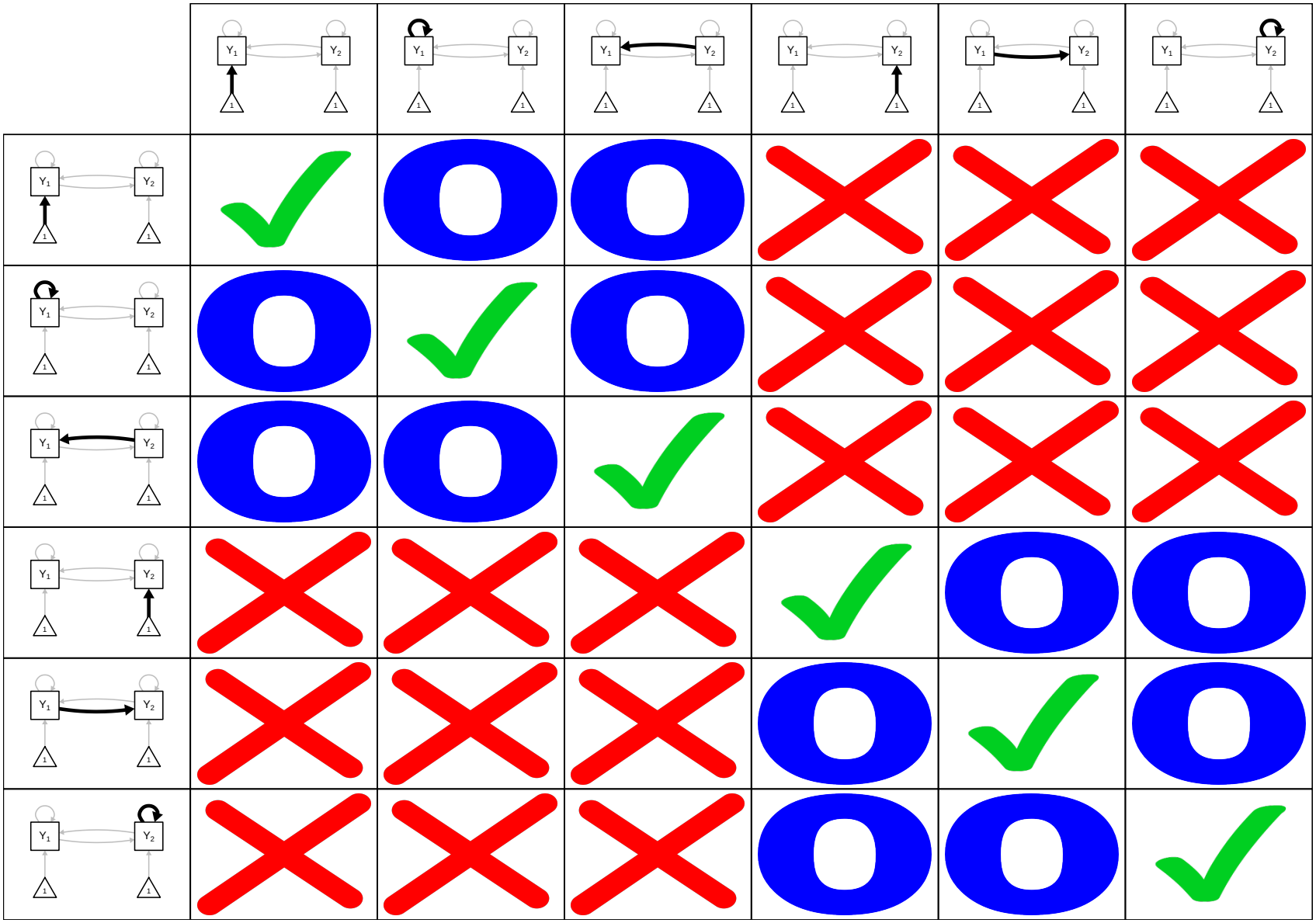
Temporal Estimation



Correlated Estimation



Orthogonal Estimation

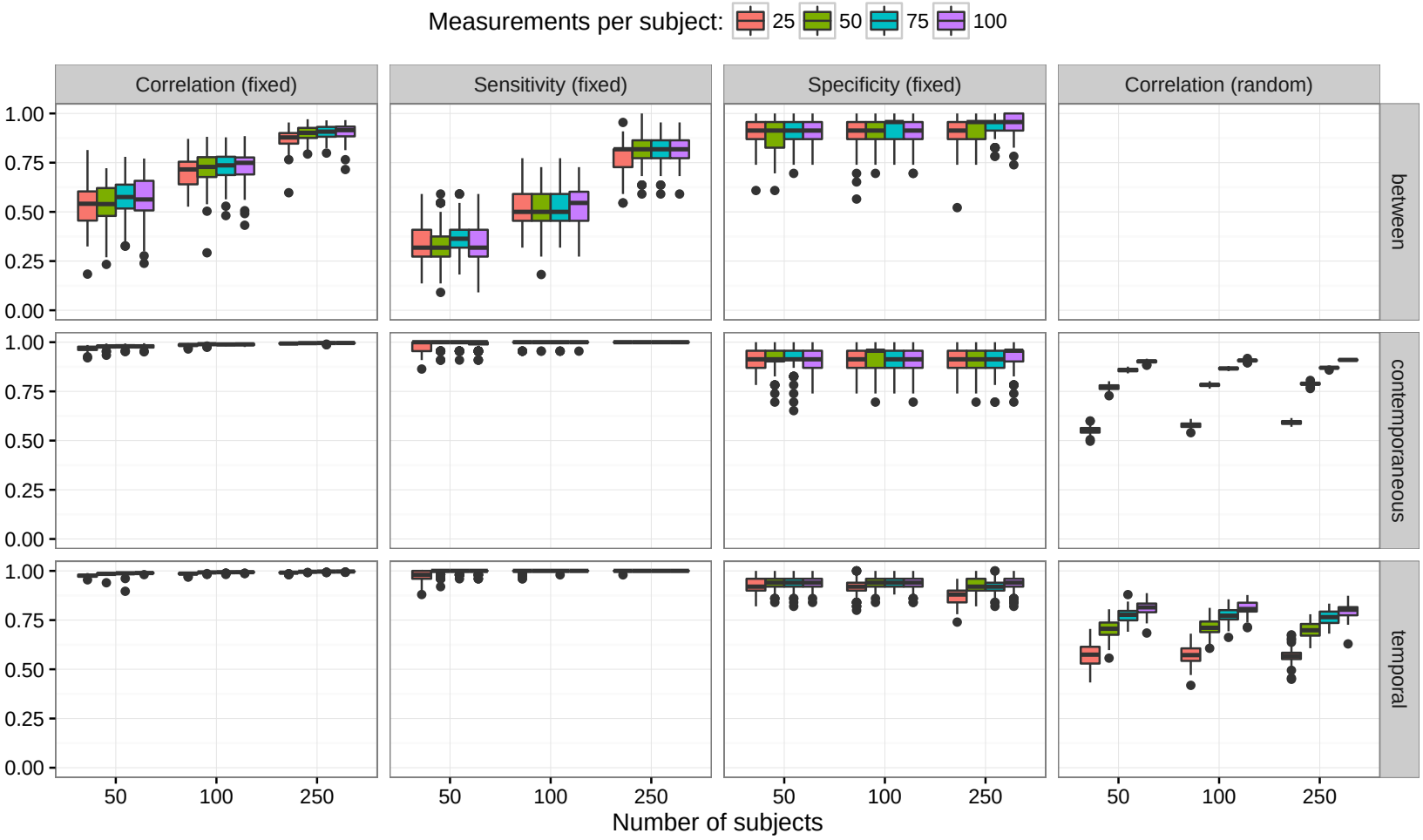


Between-subject Estimation

- Between subject effects can be obtained by centering predictors and adding the person-means as level 2 predictors
  - Hamaker, E. L., & Grasman, R. P. (2015). To center or not to center? Investigating inertia with a multilevel autoregressive model. Frontiers in psychology, 5, 1492.
- This can be seen as node-wise estimation of a GGM
- Thus, an estimate for the between-subjects GGM can be obtained by averaging the level-2 predictive effects standardized with the residual variances

Contemporaneous Estimation

- Contemporaneous networks need to be estimated post-hoc by investigating the residuals
- Either inverting the sample variance-covariance matrix of residuals:
  - Fixed
  - Unique
- Or as a second multilevel model using nodewise estimation of a GGM:
  - Correlated
  - Orthogonal


Measurements per subject: 25 50 75 100
Correlation (fixed)
Sensitivity (fixed)
Specificity (fixed)
Correlation (random)
between
contemporaneous
temporal
1.00
0.75
0.50
0.25
0.00
50
100
250
Number of subjects