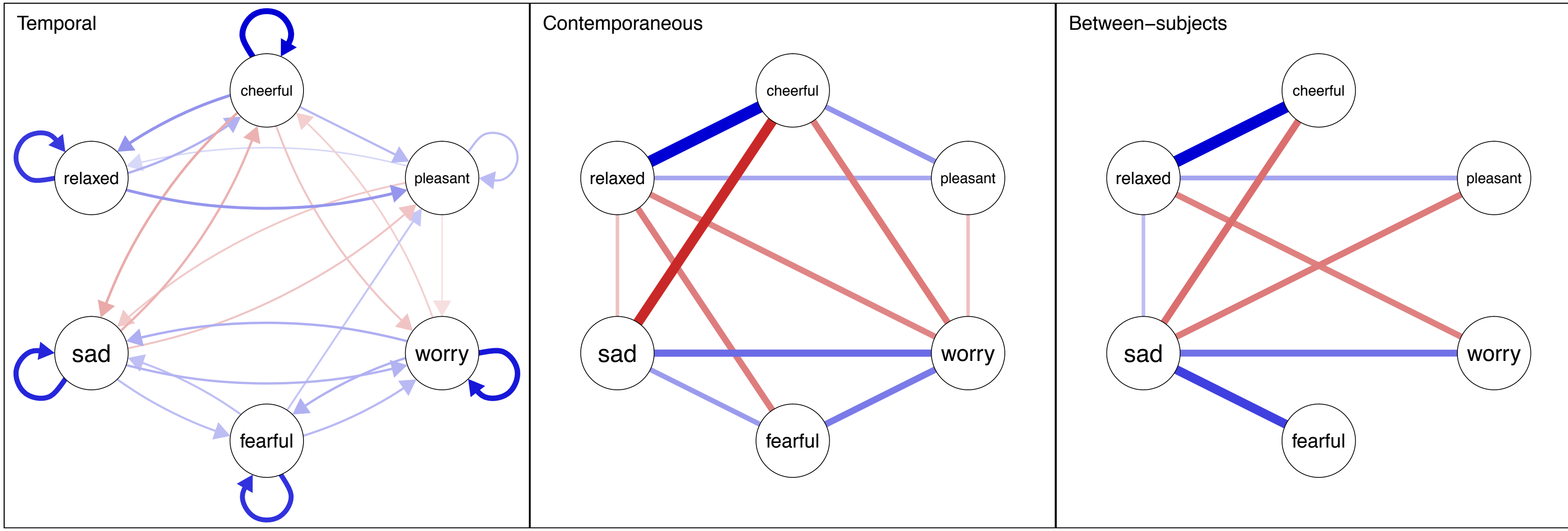
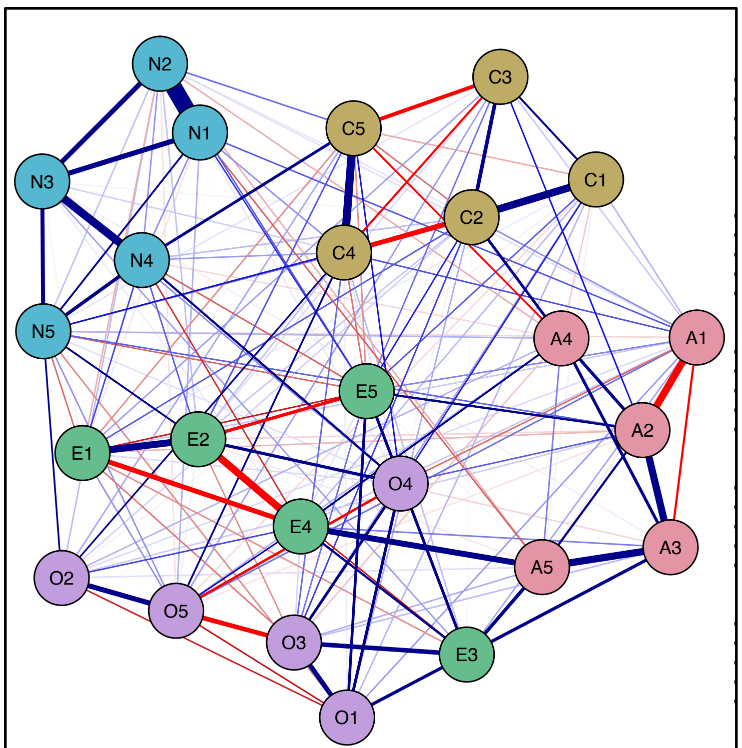
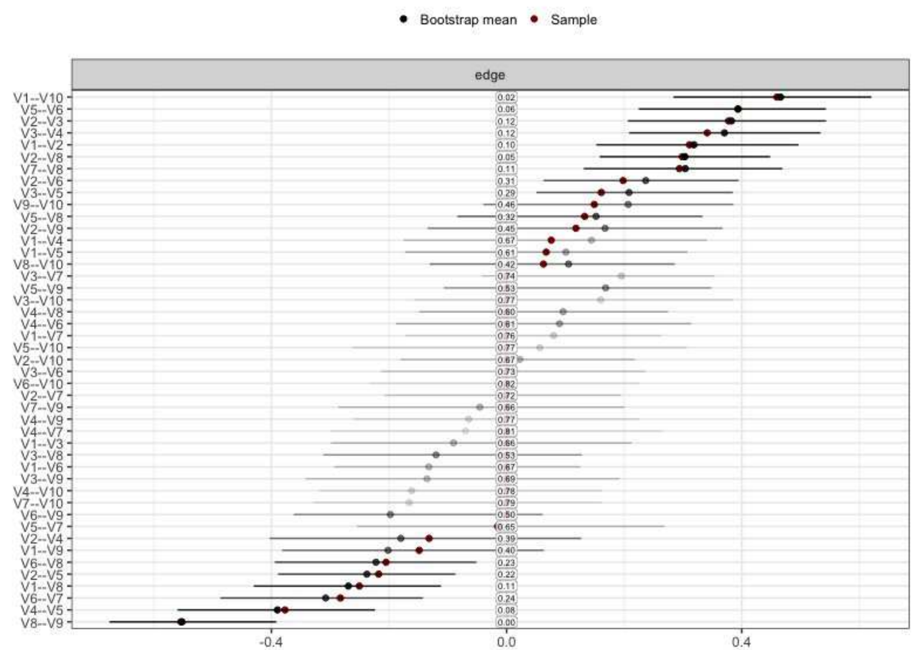
Network Psychometrics

PHASE 2

Sacha Epskamp – ICPS 2019

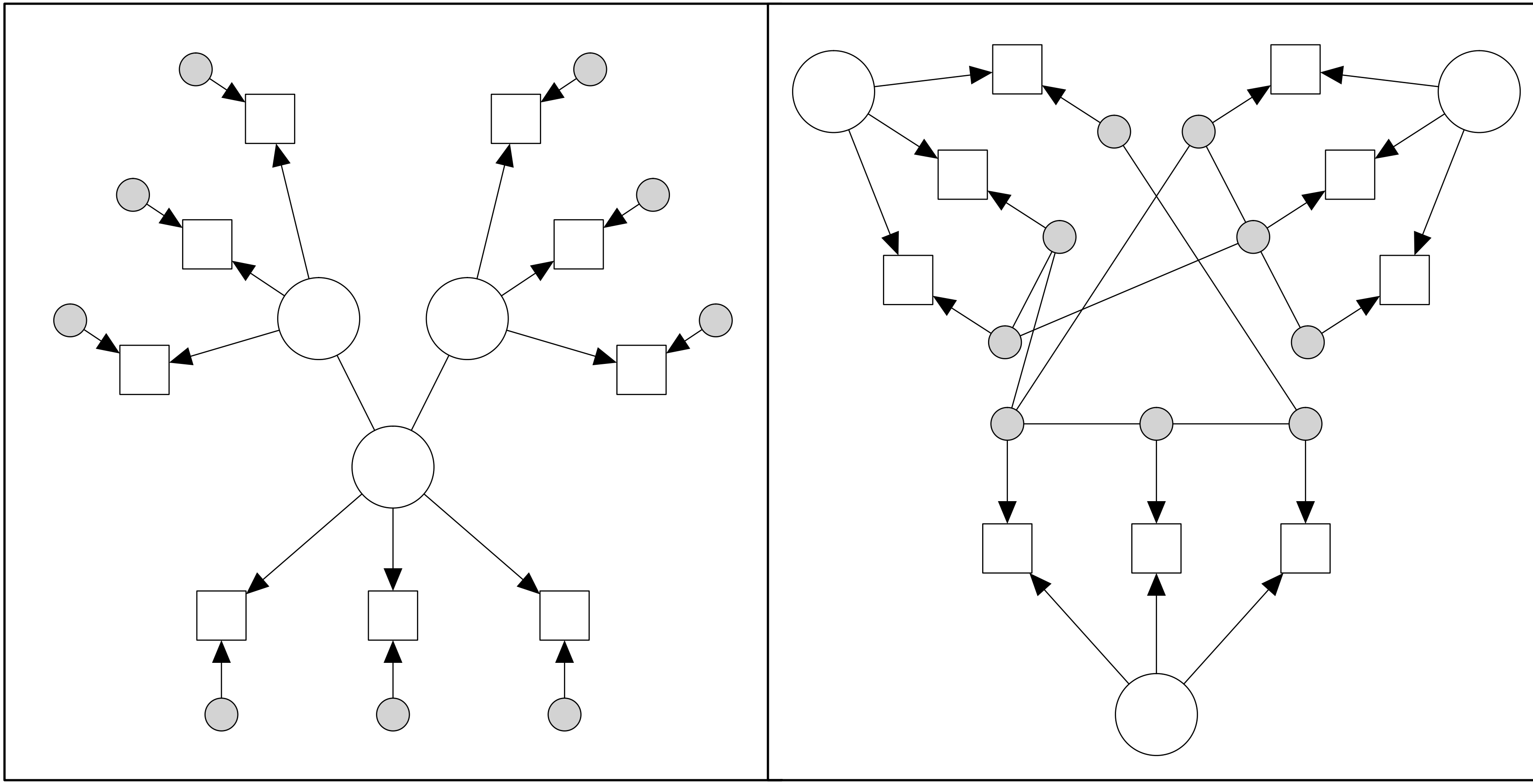






http://sachaepskamp.com/Dissertation

Latent network model | Residual network model



Epskamp, S., Rhemtulla, M. T., & Borsboom, D. (2017). Generalized Network Psychometrics: Combining Network and Latent Variable Models. *Psychometrika*, *82*(4), 904–927.

Model fit & Multi-group analysis

TABLE 1.
Fit measures for three models estimated on the BFI dataset in the psych R package. CFA is the correlated five-factor model.

	df	chisq	AIC	BIC	EBIC	RMSEA	TLI	CFI
CFA	265	4715.62	230,250.58	230,606.82	231,559.30	0.08	0.75	0.78
RNM	163	688.74	226,427.69	227,389.55	229,961.26	0.03	0.95	0.97
RNM+LNM	168	723.89	226,452.85	227,385.01	229,877.35	0.03	0.95	0.97

RNM is the same model as the CFA model with a residual network. RNM+LNM denotes the same model as the RNM model in which edges of the latent network have been removed.

Epskamp, S., Rhemtulla, M., & Borsboom, D. (2017). Generalized network pschometrics: Combining network and latent variable models. *Psychometrika*, *82*(4), 904-927.

Table 2
Showing the fit statistics of obtained in Application 1 (analysis of the Wechsler Adult Intelligence Scale – Fourth Edition).

Model	-2LL	χ^2	df	P	AIC	BIC	SABIC	CFI	NNFI	RMSEA	$CI95_l$	$CI95_u$	P_{RMSEA}
Saturated model	11,568.16	0	0	1.00	240.00	899.47	518.23	1.00	1.00	0.00	–	–	–
Measurement model	12,464.85	896.70	99	< 0.01	968.70	1.166.54	1.052.17	0.95	0.93	0.07	0.068	0.079	0.00
Second order *g*-model	12,490.71	922.56	101	< 0.01	990.56	1.177.41	1.069.39	0.95	0.93	0.07	0.068	0.079	0.00
Network	**11,698.10**	**129.94**	**71**	**< 0.01**	**257.94**	**609.65**	**406.33**	**1.00**	**0.99**	**0.02**	**0.014**	**0.028**	**1.00**

Note. Abbreviations: -2LL: minus 2 times the log-likelihood, df: degrees of freedom, $CI95_l$ and CI95u: lower and upper boundaries of the 95% confidence interval of the RMSEA value; P_{RMSEA}: the P-value associated with this interval. Preferred model bold faced and underlined.

Kan, K. J., van der Maas, H. L., & Levine, S. Z. (2019). Extending psychometric network analysis: Empirical evidence against g in favor of mutualism?. *Intelligence*, *73*, 52-62.

A comprehensive overview of research on missing data analysis in network psychometrics:

```
                     _                      _        _
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| |         __/ |
|_|        |___/
```

An R package for confirmatory network modeling

psychonetrics

Models

- ✓ Cholesky decomposition
- ✓ Covariance matrix
- ✓ Gaussian graphical model
- ✓ Latent network model
    - (CFA)
- ✓ Residual Network model
    - (SEM)
- ✓ Graphical VAR for time-series
- ○ Graphical VAR for panel data
- ○ Structural VAR
- ○ Ising model
- ○ Fused latent and graphical IRT

Output

- ✓ Fit indices
- ✓ Modification indices
- ✓ Parameter estimates
- ✓ Standard errors
- ✓ Model comparison
- ○ Markdown document
- ○ Logbook / graph

Techniques

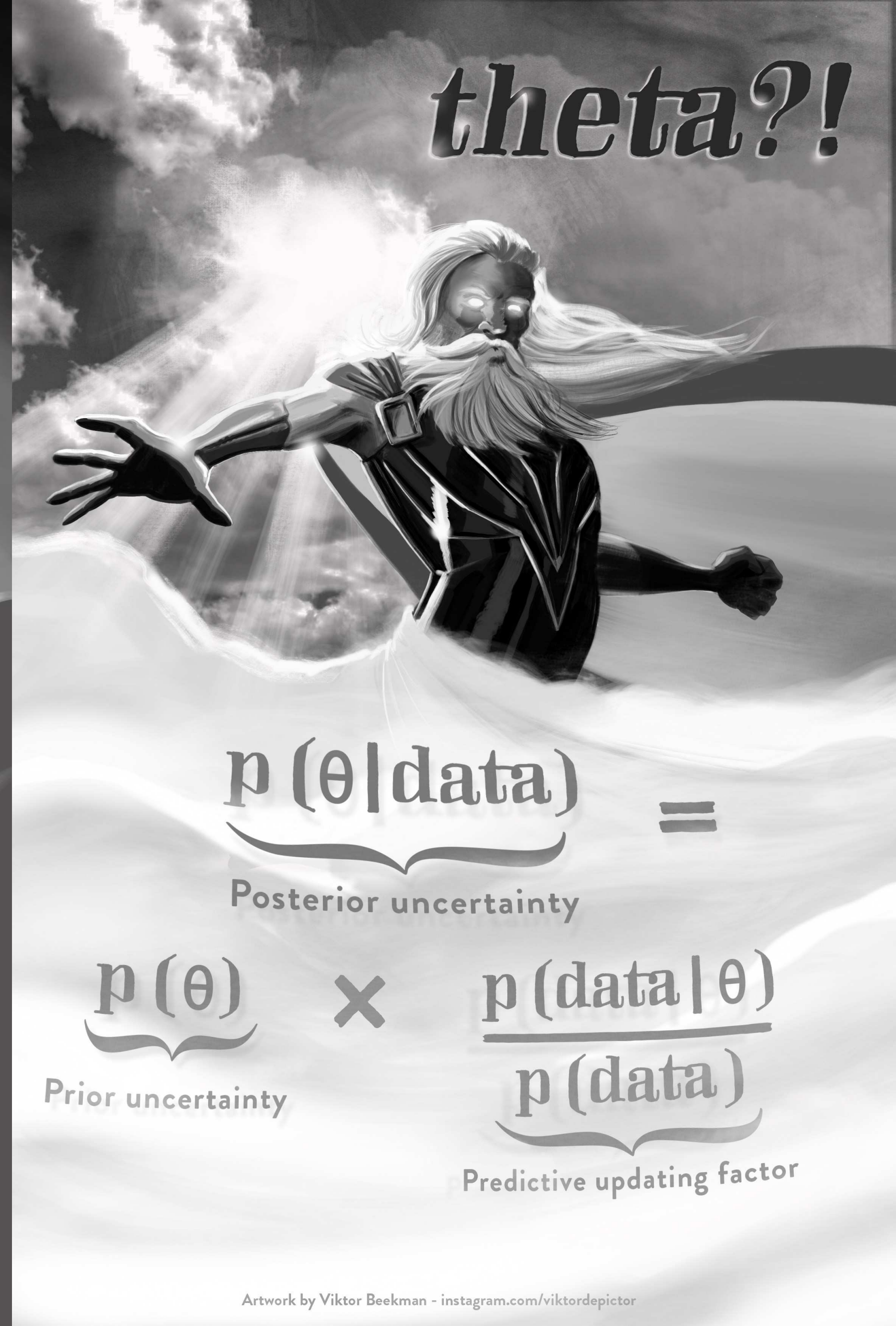
- ✓ MI model search
- ✓ Significance pruning
- ✓ Multi-group models
- ✓ Equality constrains
- ○ GIMME-like model search
- ○ Meta-analysis

Estimators

- ✓ Maximum likelihood (summary statistics)
- ✓ Full-information maximum likelihood
    - Toeplitz for GVAR
- ○ Raw time-series GVAR
- ✓ Least-squares
- ○ (diagonally) weighted least squares
- ○ Robust ML estimation

Unstable alpha version:
github.com/SachaEpskamp/psychonetrics


p<.05
Artwork by Viktor Beekman
instagram.com/viktordepictor


theta?!
$\underbrace{p(\theta|data)}_{\text{Posterior uncertainty}} = \underbrace{p(\theta)}_{\text{Prior uncertainty}} \times \underbrace{\frac{p(data|\theta)}{p(data)}}_{\text{Predictive updating factor}}$
Artwork by Viktor Beekman - instagram.com/viktordepictor

Frequentism versus Bayes

- Disclaimer: Artwork might not accurately represent frequentism or Bayesianism
  - Source: https://www.bayesianspectacles.org/, powered by https://jasp-stats.org/
- psychonetrics will be purely frequentist, implementing many maximum likelihood estimators
- There is also promising Bayesian work in this area
  - BGGM package by Donald Willaims (https://psyarxiv.com/x8dpr/)
  - Bdgraph package by Reza Mohammadi

Confirmatory fit of GGMs

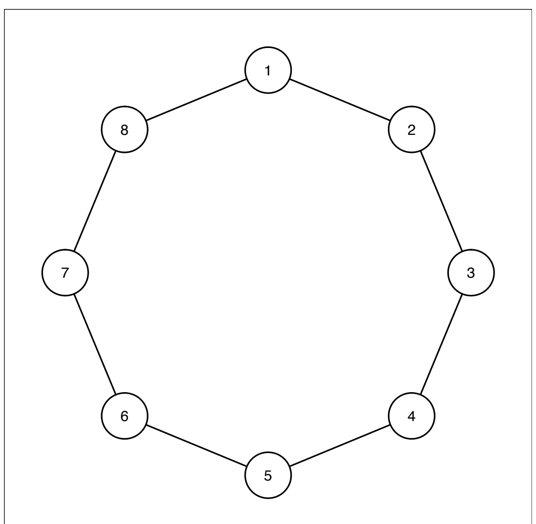
Simulation study:

- 100 repetitions in each condition
- Sample size 100, 250, 1000 & 2500
- Randomness 0, 0.1, 0.25, 0.5, 1
- Chi-square test and RMSEA

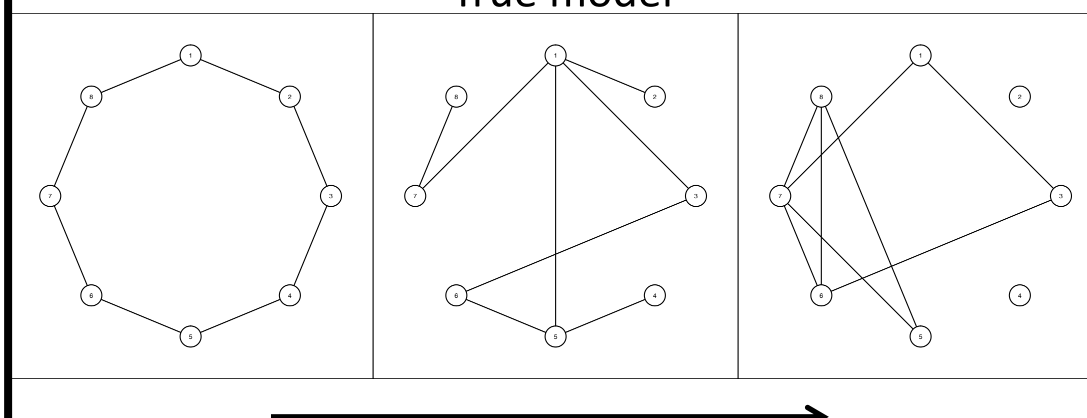
Code

```
library("parSim")
sims <- parSim(
  nSample = c(100,250,1000,2500),
  randomness = c(0,0.1,0.25,0.5,1),
  nNode = 8,
  reps = 100,
  nCores = 8,
  expression = {
    library("bootnet")
    library("psychonetrics")
    library("dplyr")
    # Simulate true model:
    trueNet <- genGGM(nNode,p = randomness)
    # Simulate data:
    Data <- ggmGenerator()(nSample,trueNet)
    # Model to fit (chain):
    adj <- 1 * (genGGM(nNode) != 0)
    # Form psychonetrics model:
    mod <- ggm(Data, omega = adj)
    # Run model:
    mod <- mod %>%
       runmodel(verbose=FALSE, addMIs=FALSE)
    # Return fit indices:
    mod@fitmeasures
  }
)
```

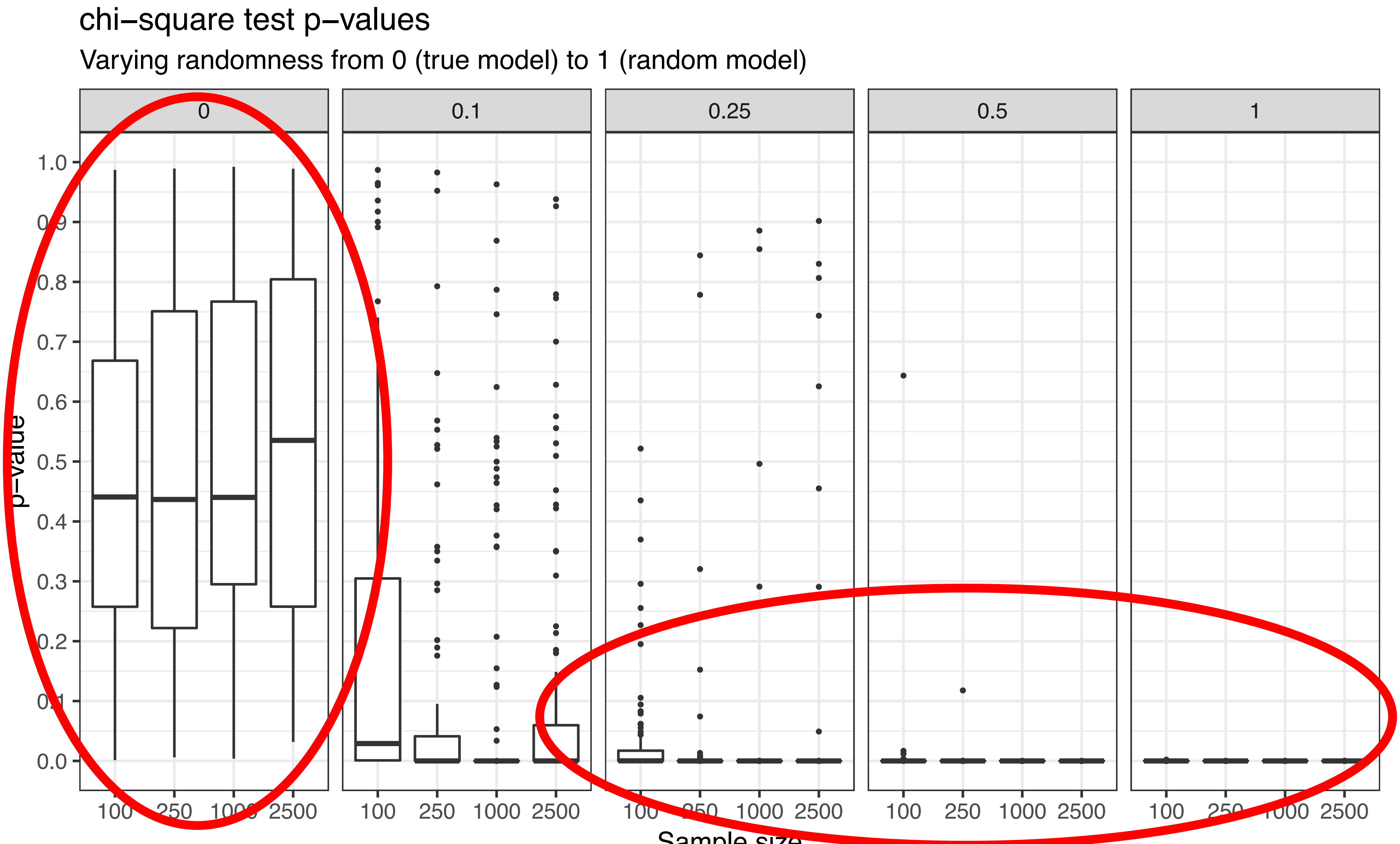
Fitted model



True model

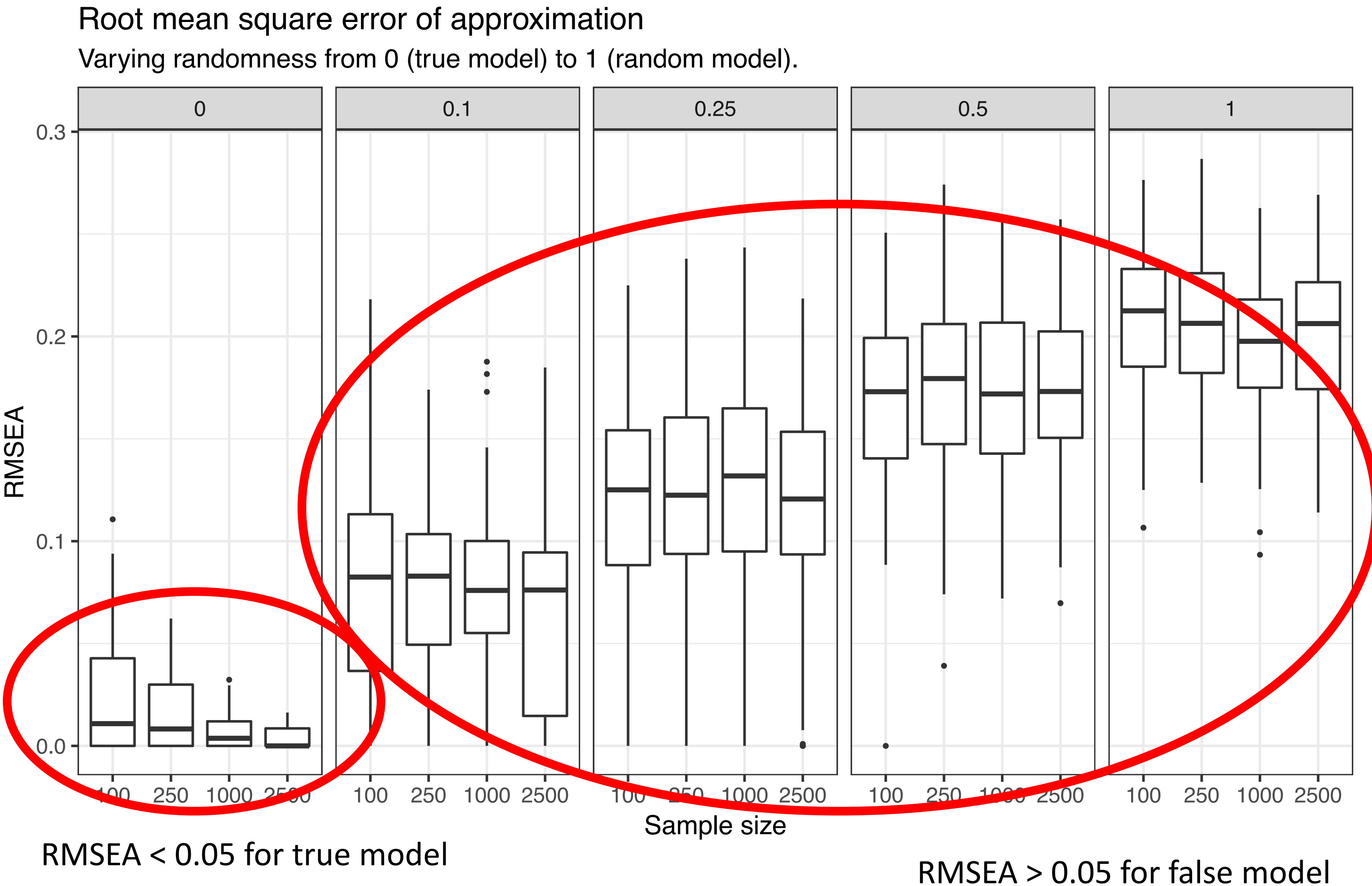


Randomness



Uniform *p*-values for true model

High power to reject false model


Root mean square error of approximation
Varying randomness from 0 (true model) to 1 (random model).
0
0.1
0.25
0.5
1
0.3
0.2
0.1
0.0
RMSEA
100
250
1000
2500
Sample size
RMSEA < 0.05 for true model
RMSEA > 0.05 for false model

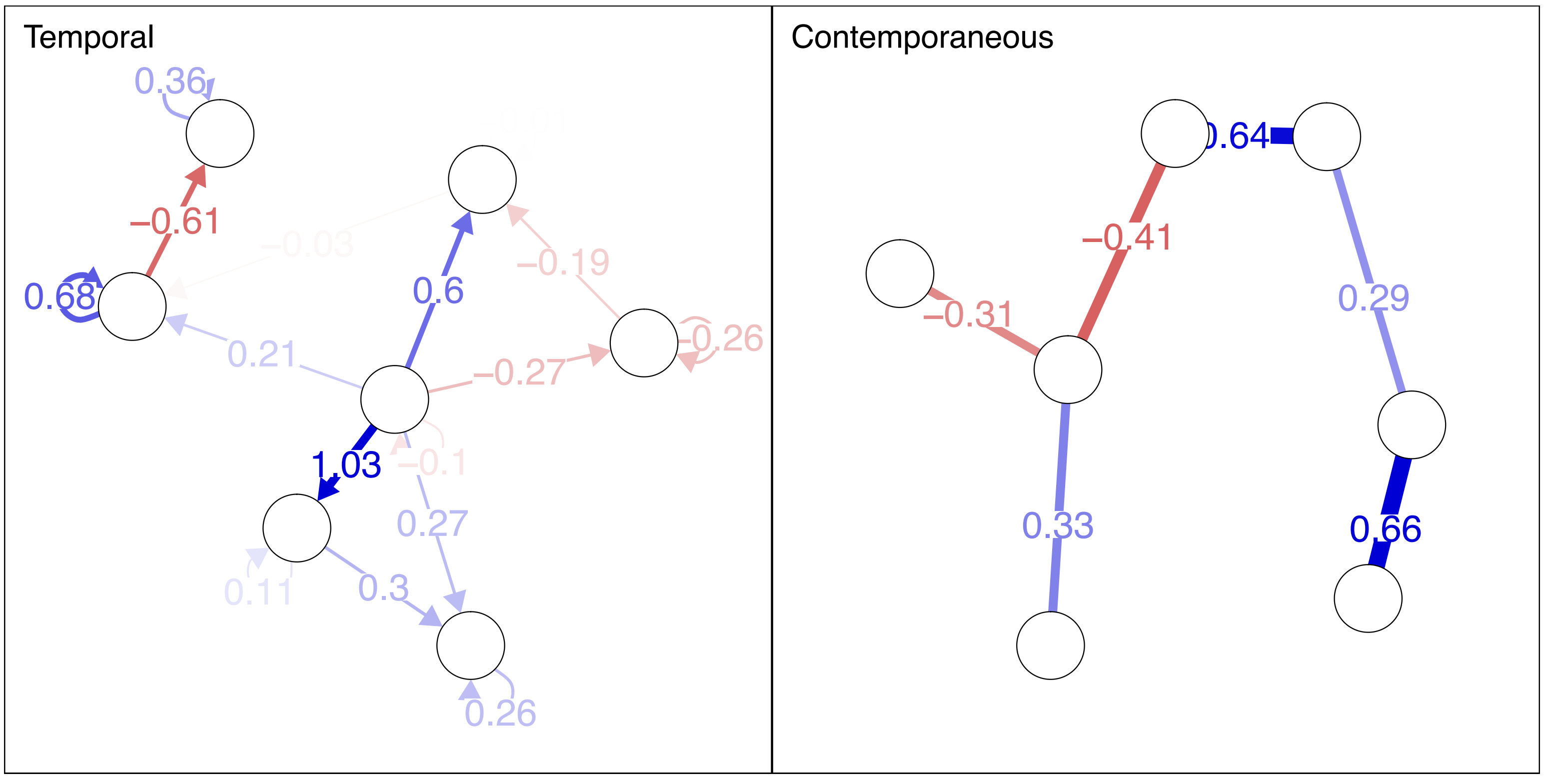
Missing data in graphical VAR models

Simulation setup:

- 100 repetitions in each condition
- 75 time points
- 0%, 10% or 25% missingness (at random)

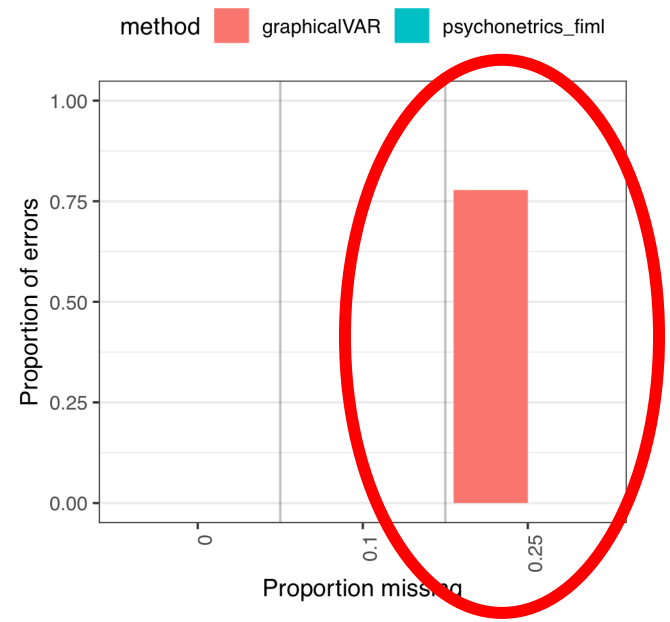
Estimation

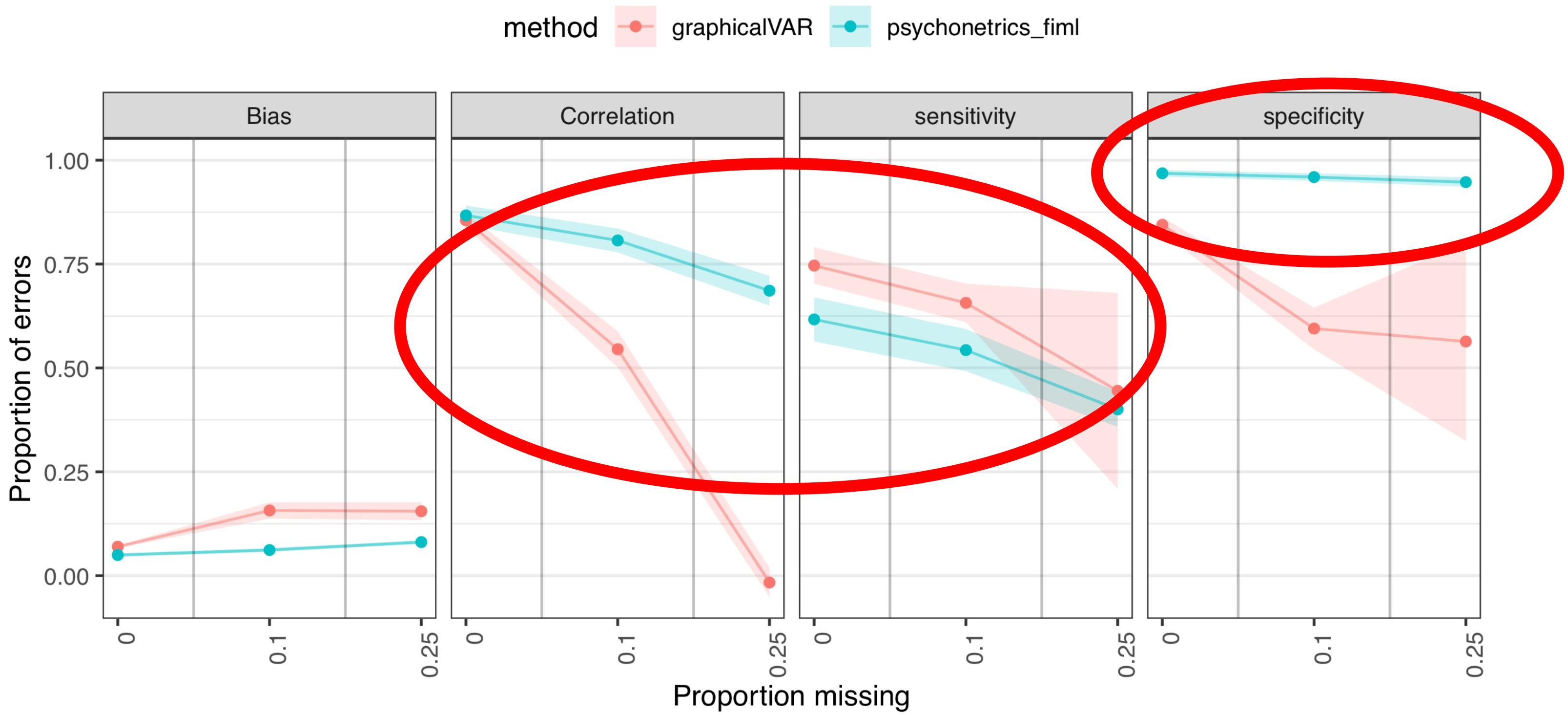
- graphicalVAR (LASSO) with BIC selection
- Psychonetrics FIML
  - Stepup via MIs -> prune nonsig

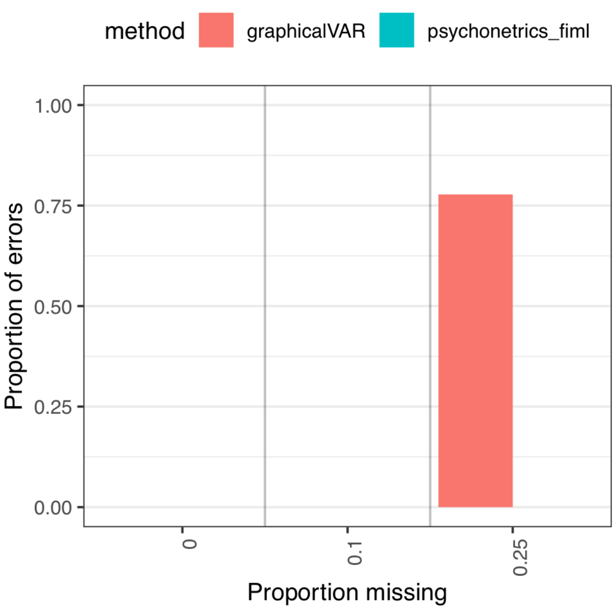


Based on data of Epskamp, S., van Borkulo, C. D., van der Veen, D. C., Servaas, M. N., Isvoranu, A. M., Riese, H., & Cramer, A. O. (2018). Personalized network modeling in psychopathology: The importance of contemporaneous and temporal connections. *Clinical Psychological Science*, *6*(3), 416-427.

- graphicalVAR completely breaks down with missing data

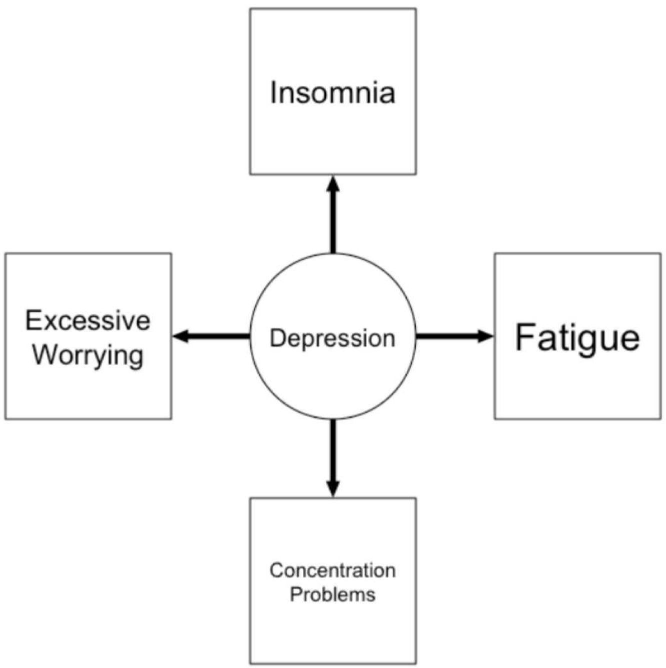


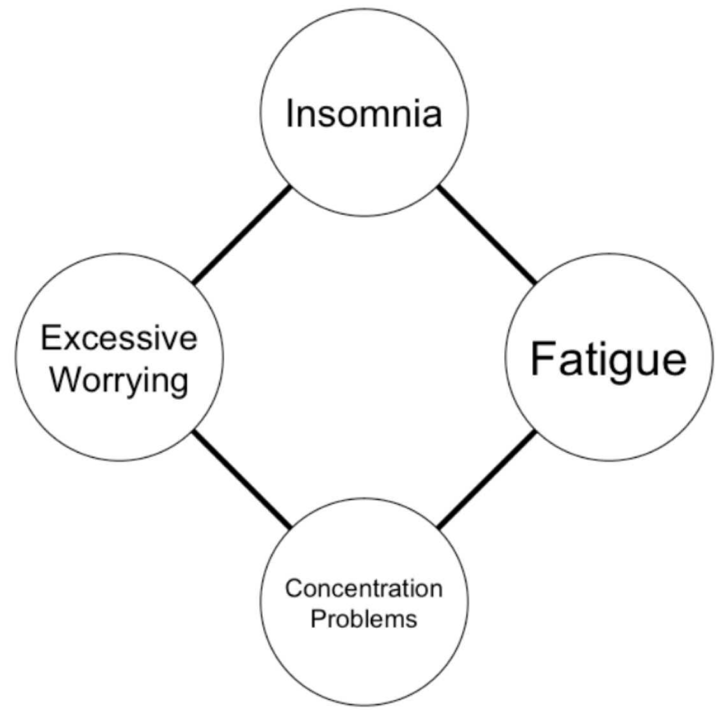


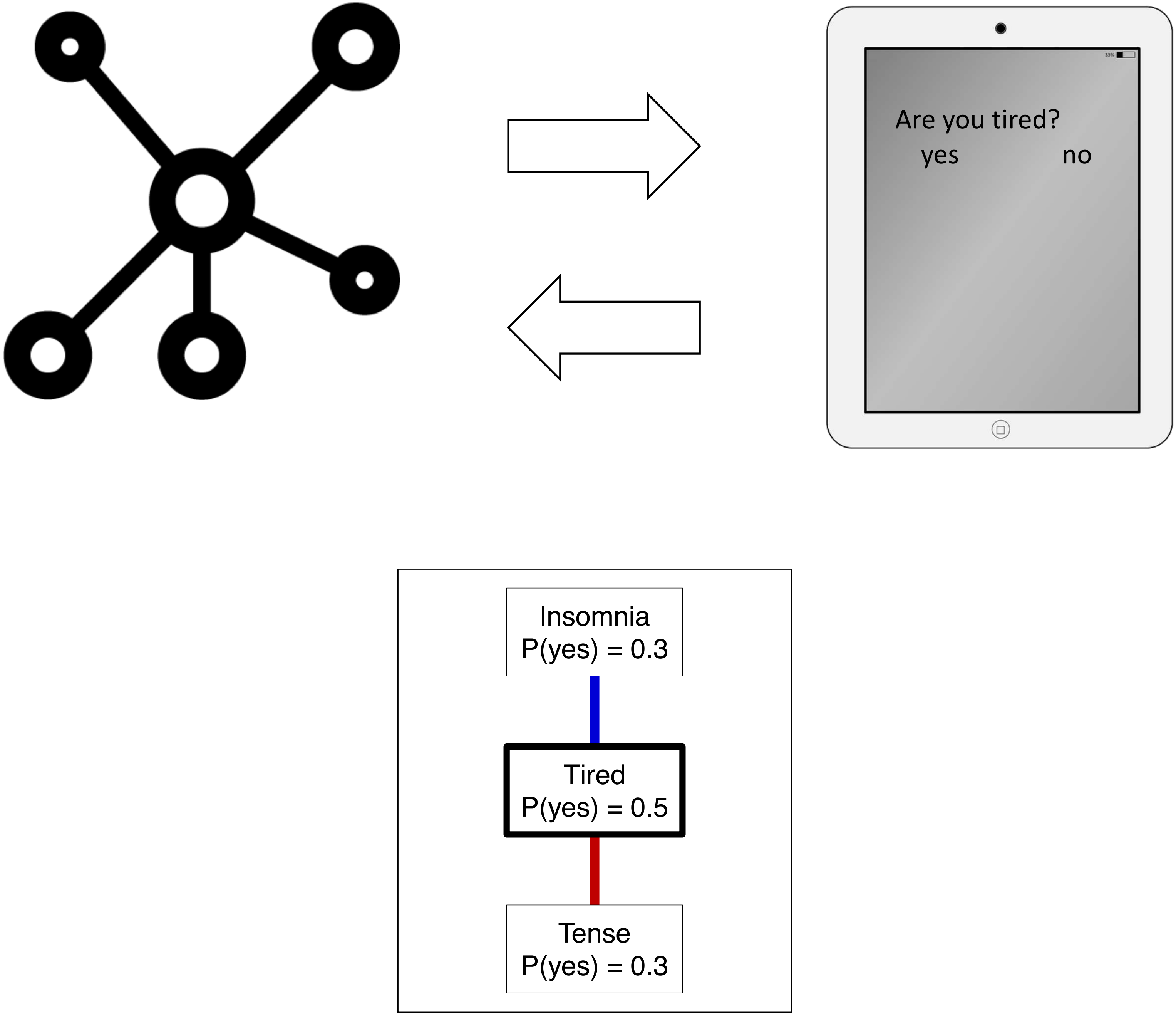


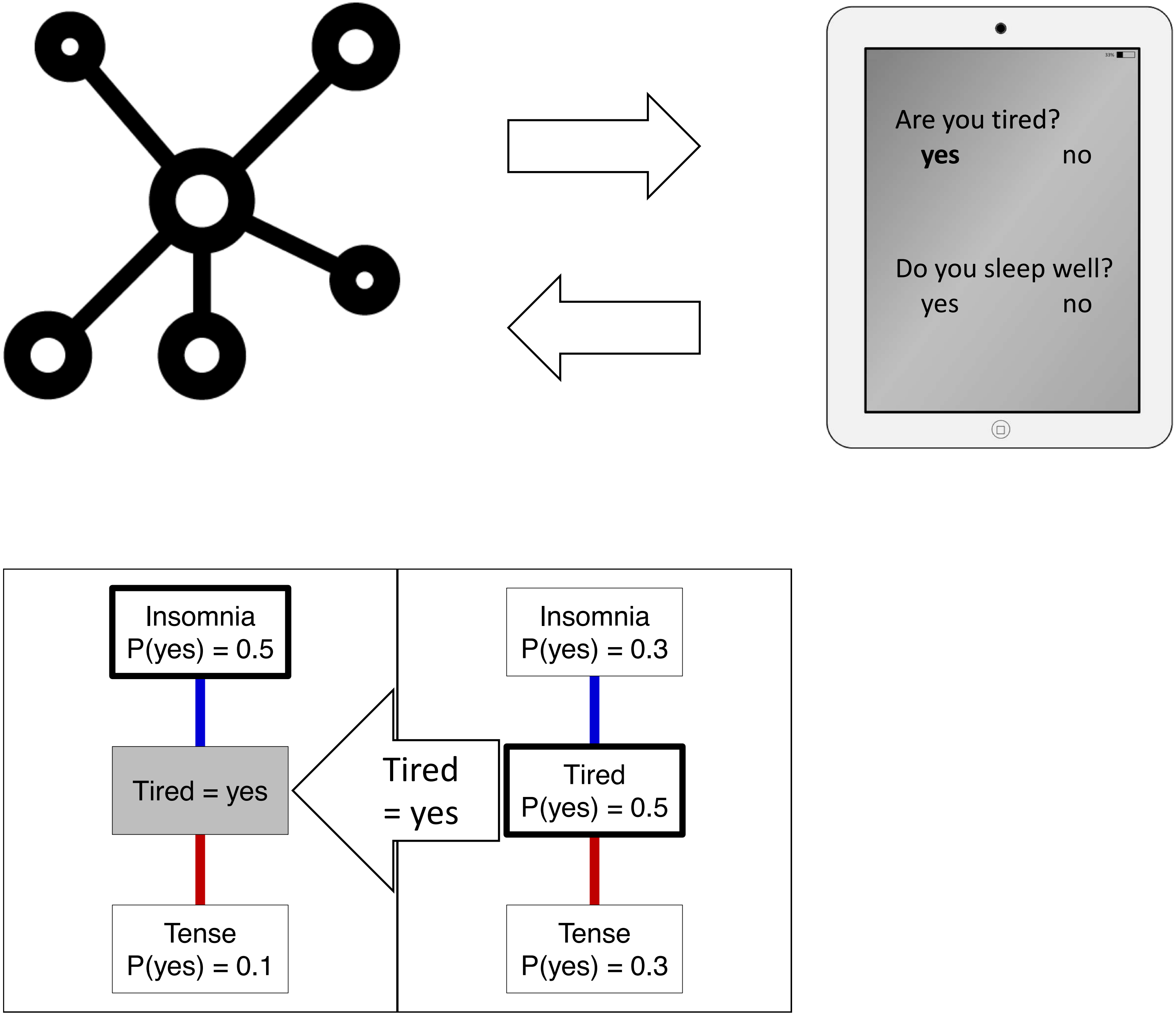
- graphicalVAR completely breaks down with missing data
- FIML stepup estimation using psychometrics:
  - Remains conservative
  - Has decent performance still with high missingness

Measurement from a network perspective

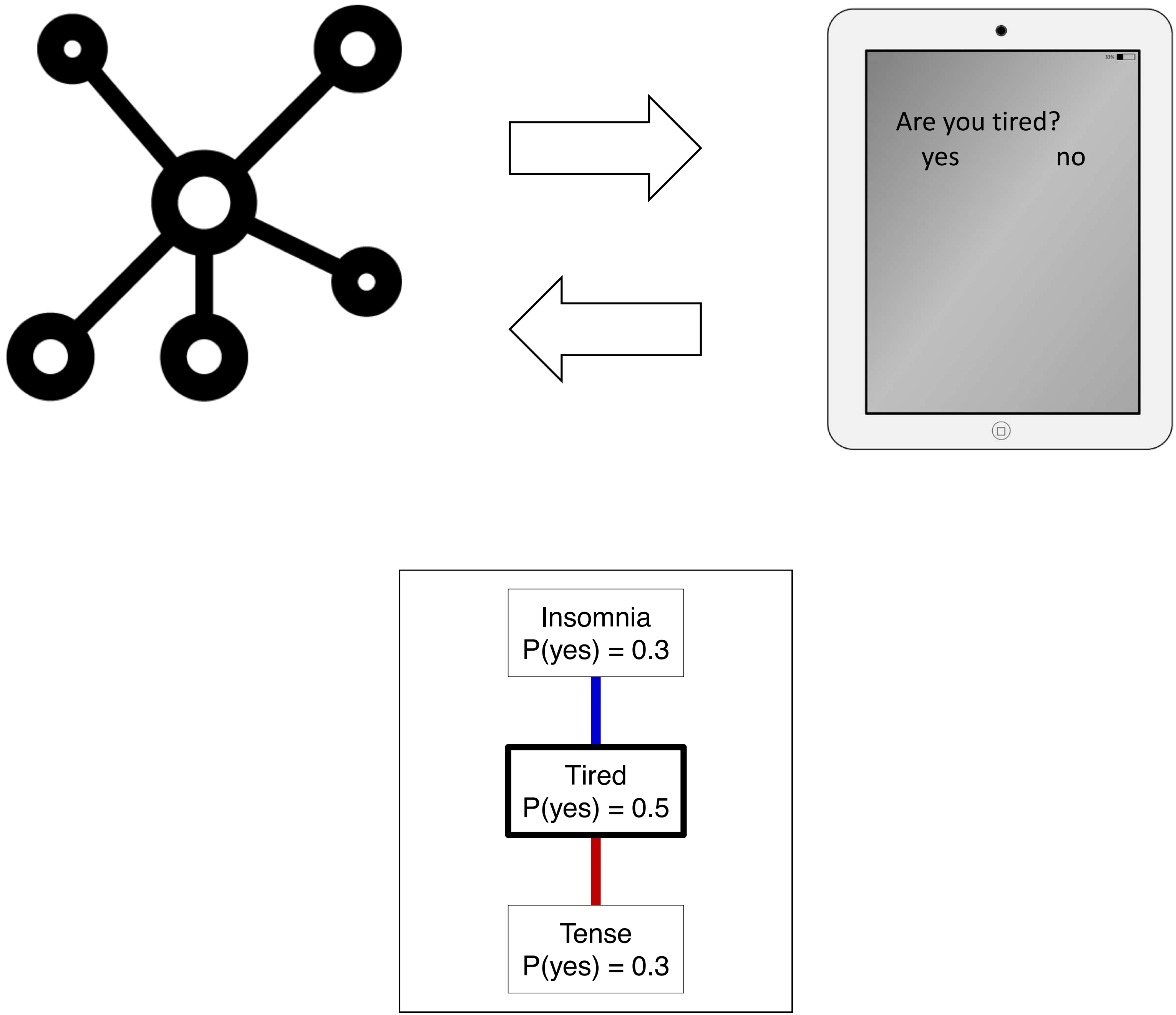




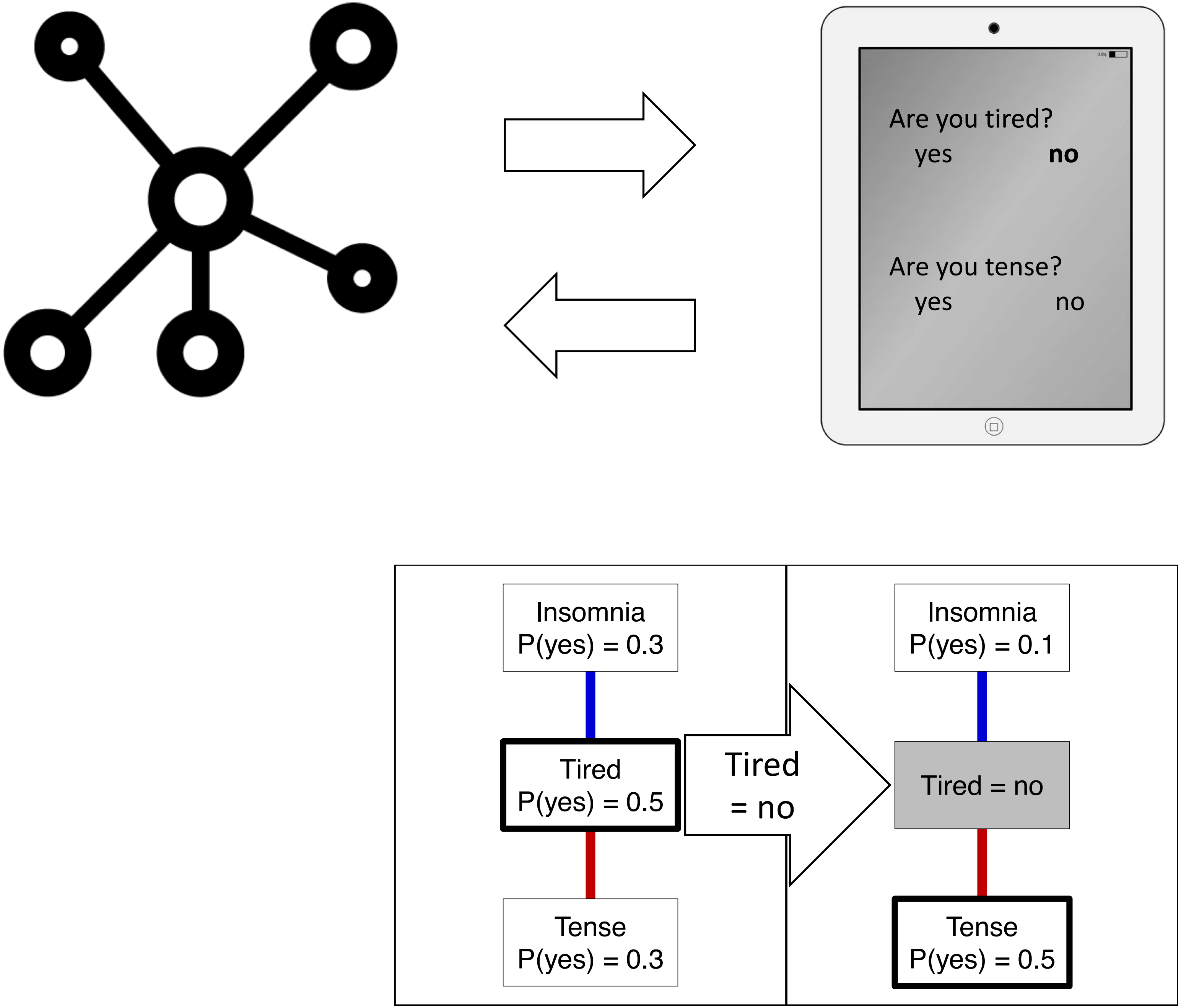

Are you tired?
yes
no
Insomnia
P(yes) = 0.3
Tired
P(yes) = 0.5
Tense
P(yes) = 0.3



Are you tired?
yes
no
Do you sleep well?
yes
no
Insomnia
P(yes) = 0.5
Tired = yes
Tense
P(yes) = 0.1
Tired
= yes
Insomnia
P(yes) = 0.3
Tired
P(yes) = 0.5
Tense
P(yes) = 0.3



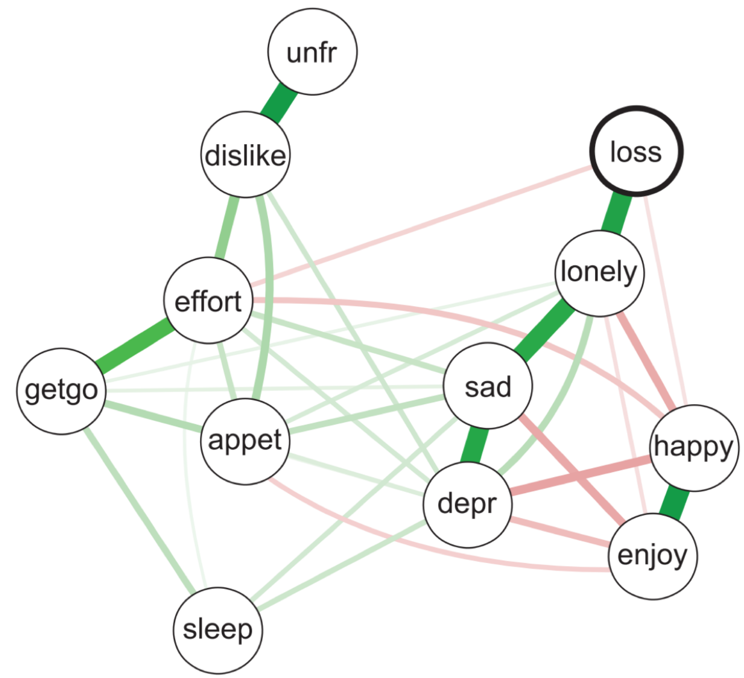
Are you tired?
yes
no
Insomnia
P(yes) = 0.3
Tired
P(yes) = 0.5
Tense
P(yes) = 0.3

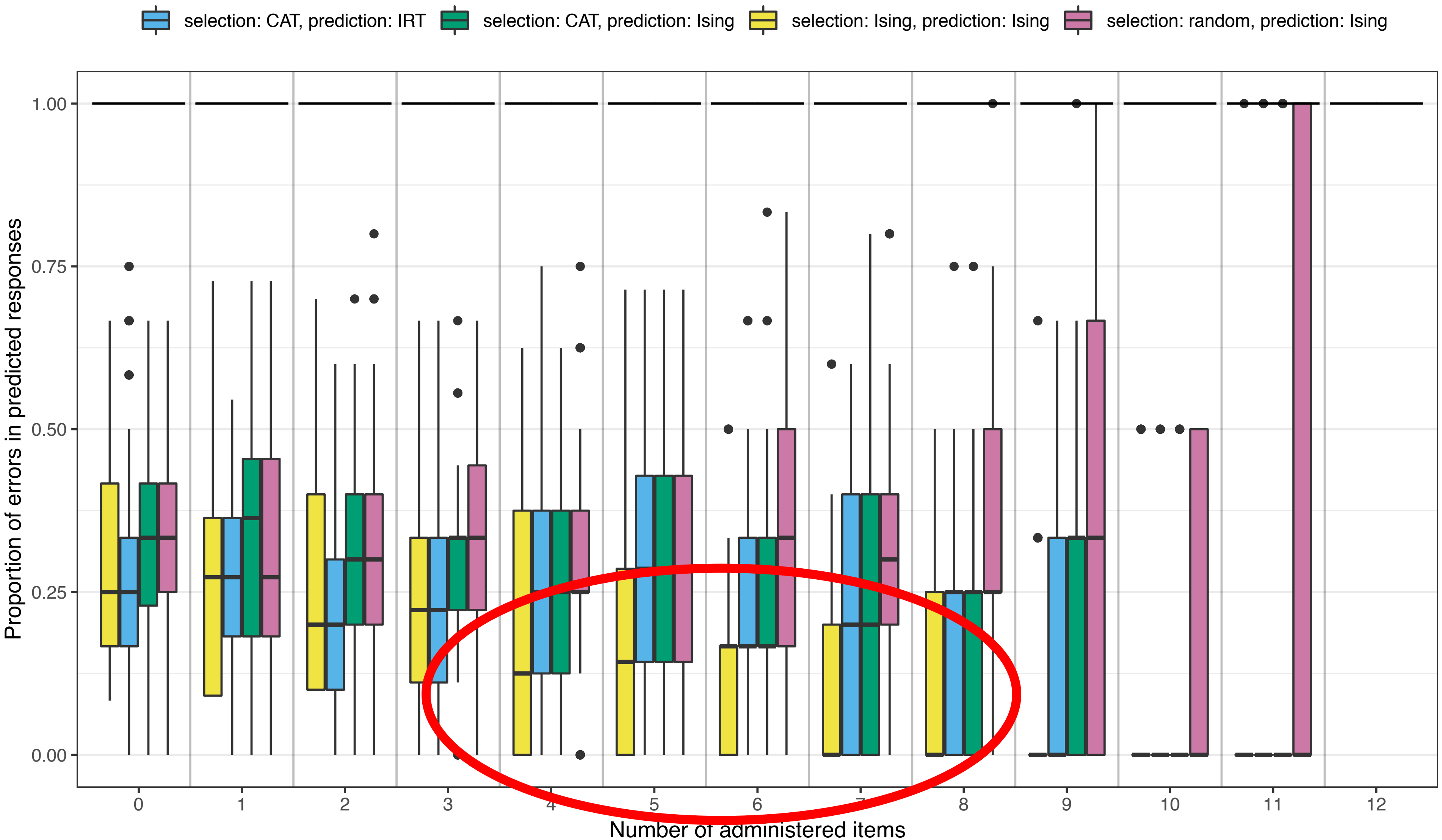


Are you tired?
yes no
Are you tense?
yes no
Insomnia
P(yes) = 0.3
Tired
P(yes) = 0.5
Tense
P(yes) = 0.3
Tired
= no
Insomnia
P(yes) = 0.1
Tired = no
Tense
P(yes) = 0.5

Simulation Study

- Empirical Ising model used as true structure
  - Fried, E. I., Bockting, C., Arjadi, R., Borsboom, D., Tuerlinckx, F., Cramer, A., Epskamp, S., Amshoff, M., Carr, D., & Stroebe, M. (2015). From loss to loneliness: The relationship between bereavement and depressive symptoms. *Journal of Abnormal Psychology, 124*, 256-265.
- Generate 1 case from true model
- Simulate adaptive assessment, using the true model, or IRT model based on N = 100,000 databank
- Each condition replicated 100 times





Better predictive power for network based adaptive testing

Network Psychometrics
PHASE 2

- From exploratory expedition to confirmatory methodology
- Move towards fine-grained analysis
  - Which edge can be added or removed?
  - Does edge A – B differ between two groups?
  - Does a theoretical model fit the data?
- Proper handling if missingness & nonnormality
- Network meta-analysis
- Network-based adaptive assessment

Thank you for your attention!

Publications & presentations:
www.sachaepskamp.com

Facebook group:
facebook.com/groups/PsychologicalDynamics