Sample size planning for person-specific temporal network models in N=1 studies

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Introduction

Background

- **Network theory of psychopathology**: mental disorders are characterised by consistent interactions of symptoms over time
- **Person-specific network**: visualize such temporal interactions in intensive longitudinal data
- **Vector Autoregressive (VAR) model**: the statistical model behind networks – highly parameterized, used more for exploration than confirmation

$$\mathbf{y_t} = \mathbf{\Delta} + \mathbf{\Phi y_{t-1}} + \epsilon_\mathbf{t}$$
$$\epsilon_\mathbf{t} \sim \mathcal{N}(\mathbf{0}, \mathbf{\Sigma})$$

- **Overfitting**: model estimates represent too much random noise in a sample and cannot generalize well to the population, usually caused by
  - high model complexity and
  - small sample size
- Our current network studies might be guilty of both
- **Predictive accuracy analysis (PAA)**: simulation-based technique used to explicitly evaluate the risk of overfitting for networks (Revol et al., 2023)

The current study

Three main goals of the study includes:

Applying predictive accuracy analysis to investigate the quality of person-specific networks

Demonstrating its usage of sample size planning for `future` single-case network studies

and of evaluating the risk of overfitting for networks estimated in `past` network studies

PAA: stepwise procedures

- Step 1. Determine simulation parameters
- Step 2. Simulate datasets:
  - **Training sets**: multiple small datasets, imitating **samples** collected from a participant
  - **Test set**: one large dataset, imitating **future unseen data** of the participant
- Step 3. Estimate networks from all training sets and make predictions for the test set
- Step 4. Calculate **squared Mahalanobis distance** as the standardized multivariate prediction error and evaluate the predictive accuracy of each network
- Step 5. Calculate **predictive accuracy probability (PAP)**:
  - The probability that an estimated network can predict future unseen data accurately
  - A threshold of PAP can be set (e.g., 80%) to judge whether the risk of overfitting for an estimated network is sufficiently low

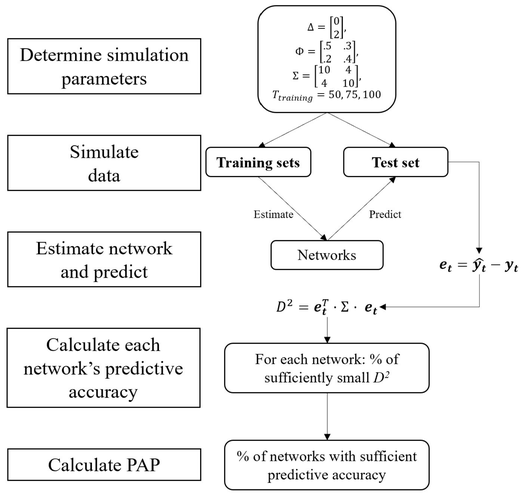

Figure 1. Stepwise procedures of PAA

Application 1: new studies

Key question: how many time-points in a sample are required for PAP of estimated networks to be high enough?

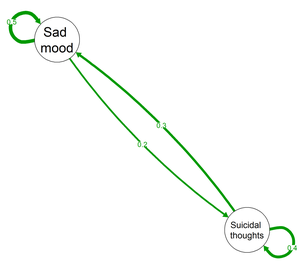

Figure 2. A hypothesized network

T	50	75	100
PAP	.493	.708	**.869**

Table 1. Results of PAA for the hypothetical network

Application 2: previous studies

Key question: given the number of time-points in the analysis of the study, how likely is it that the estimated network did not overfit the sample?

Standard network: Bringmann et al. (2013)

Note: Researchers of this study analyzed data of multiple participants using a multilevel approach. The following analysis is only based on data of one participant and should thus be taken with caution.

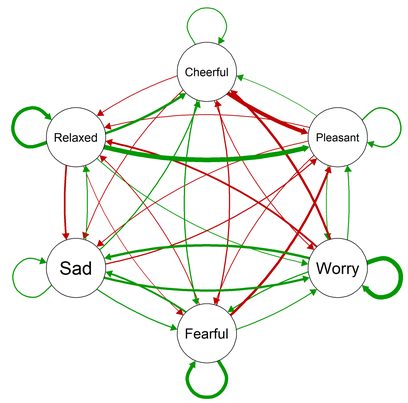

Figure 3. The estimated network in Bringmann et al. (2013)

	Actual					Required
T	71	100	150	200	225	250
PAP	.000	.001	.187	.606	.767	**.888**

Table 2. Results of PAA for Bringmann et al. (2013)

Regualrized network: Epskamp et al. (2018)

Regularization: to limit spurious edges, weak edges are shrinked to 0, which results in a sparser network

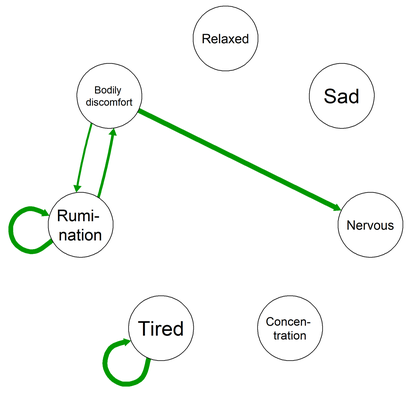

Figure 4. The estimated network in Epskamp et al. (2018)

	Actual		Required
T	47	75	100
PAP	.299	.733	**.923**

Table 3. Results of PAA for Epskamp et al. (2018)

Conclusion and discussion

- Empirical network studies have **insufficient PAP** and thus are at considerable risks of overfitting.
- **Regularization** can help avoid overfitting to some extent but not necessarily to a satisfactory level.
- **Careful sample size planning** is important. During sample size planning, other practical aspects should also be considered, for example how to handle
  - overnight lags,
  - missing data, etc.
- **Idealistic simulation setting**: should consider potential problems when analyzing actual data, for example
  - violations of model assumptions,
  - potential skewness in symptom measurements, etc.

Key reference

Revol, J., Lafit, G., & Ceulemans, E. (2023). *A new sample size planning approach for the (V)AR (1) model: Predictive Accuracy Analysis.* https://doi.org/10.31234/osf.io/2geh4