Decomposing Trait and State Variance using Structural Equation Modeling

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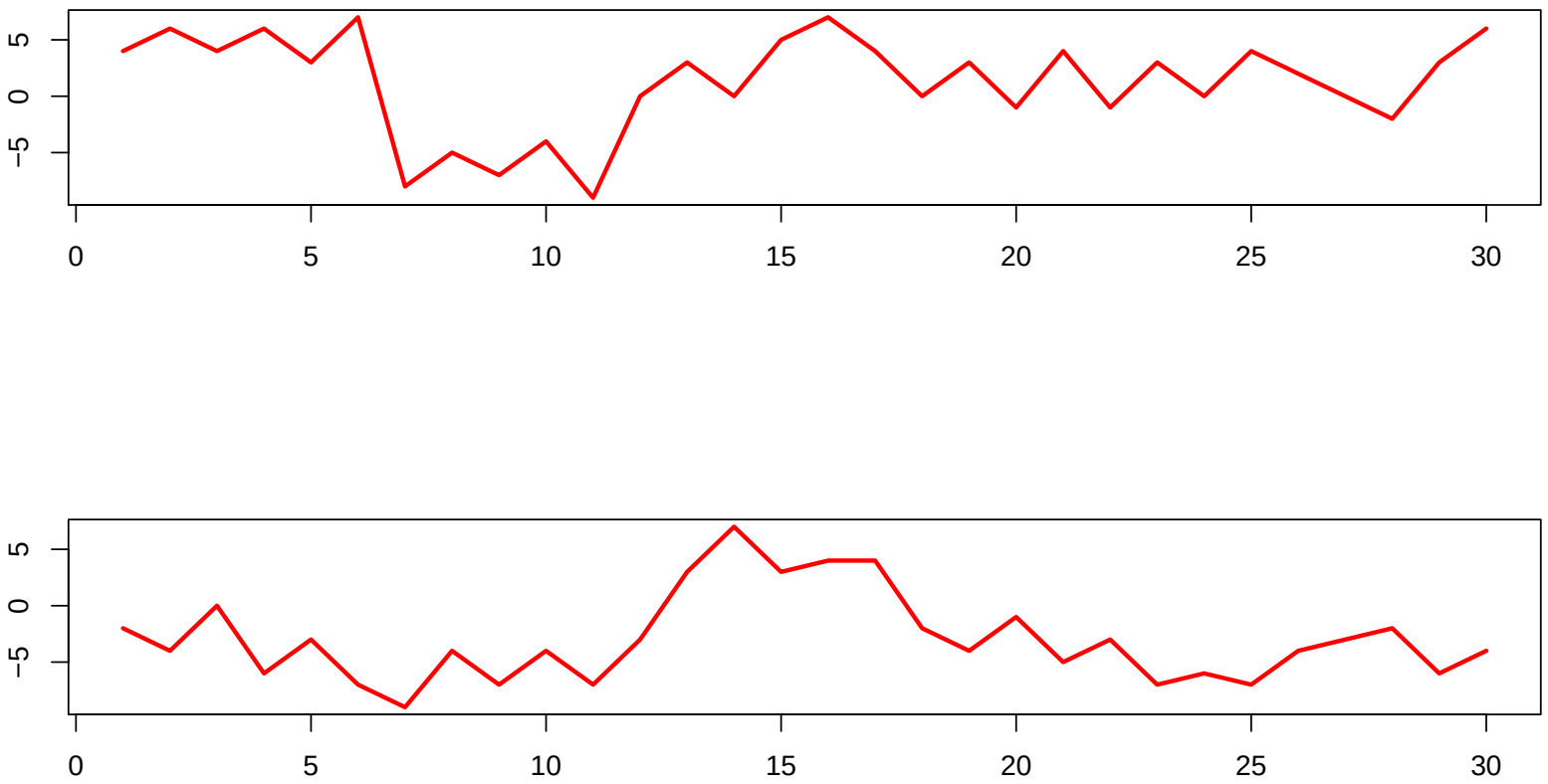
Overview

- Introduction
- Simulation Study
- Results
- Empirical Example
- Conclusion

Introduction

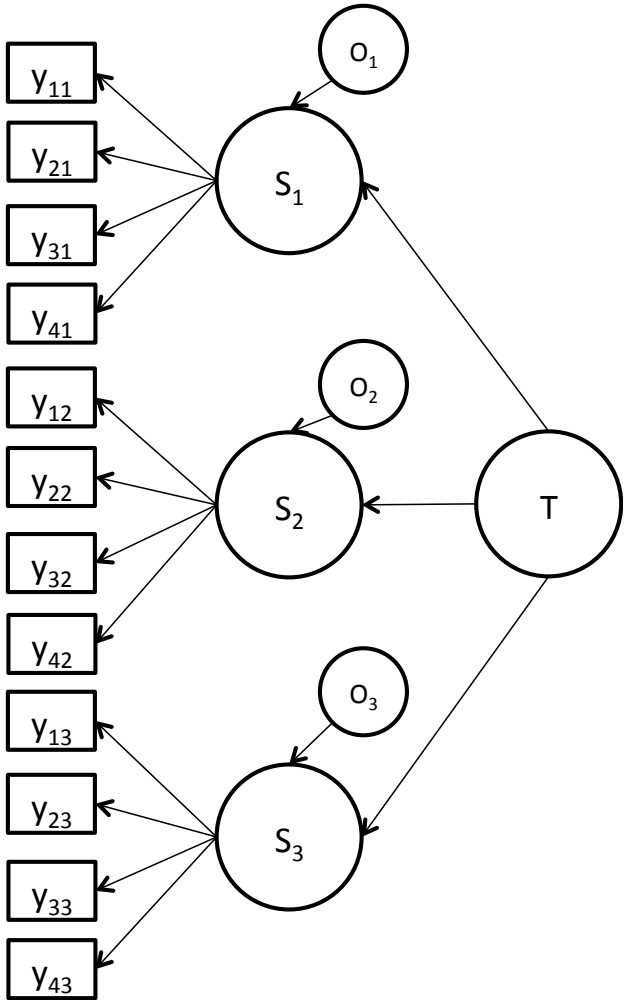


Introduction

Latent State Trait theory

Distinguishing four sources of variance

- trait
- state
- method
- error



In Practice

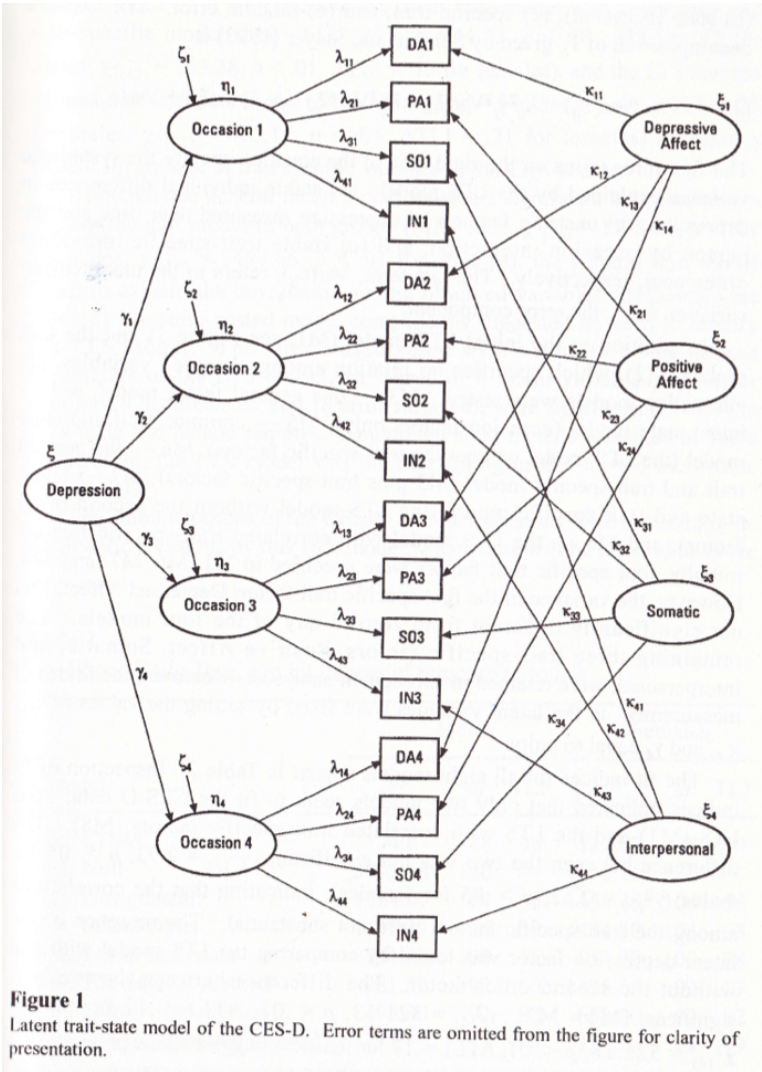


Figure 1
Latent trait-state model of the CES-D. Error terms are omitted from the figure for clarity of presentation.

LST model used in Dumenci and Windle (1996)

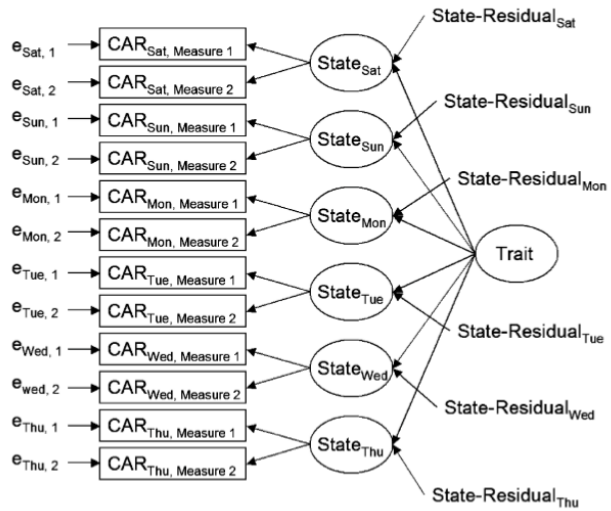


Figure 3 Multi-State Single-Trait for 2 parallel CAR measures (Measure 1, Measure 2) collected on 6 successive days (Saturday–Thursday). *Technical Note*: All error variances (*e*) were restricted to be equal within one day. No further restrictions were introduced for the error variances and the state-residual variances, and no restrictions were introduced for the loadings of the CAR measures on the latent states, and for the loadings of the latent states on the latent trait. Note that all exogenous variables were uncorrelated.

LST model used in Hellhammer et al. (2007)

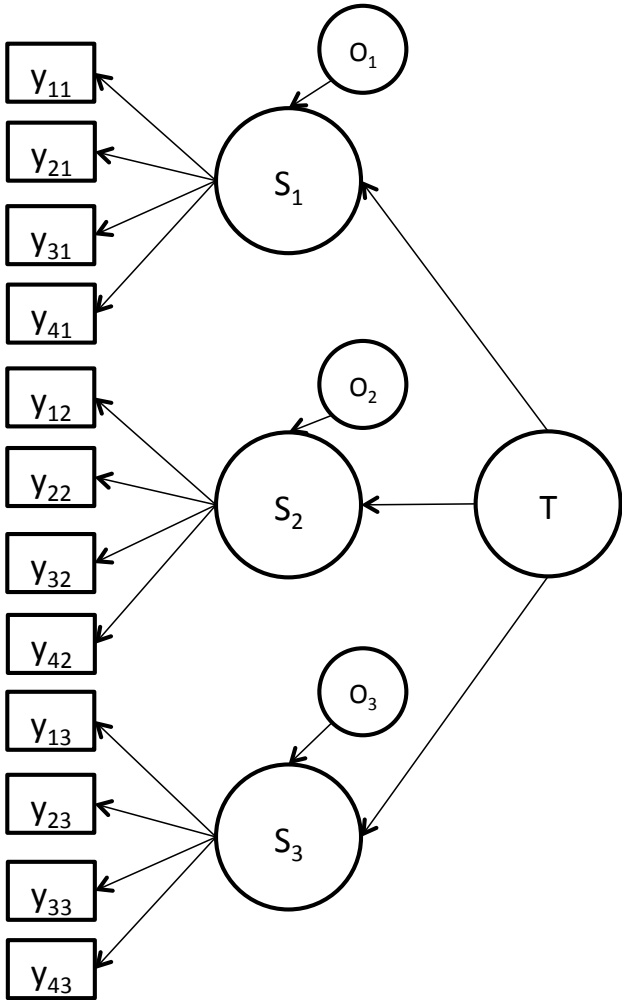
Model Equation

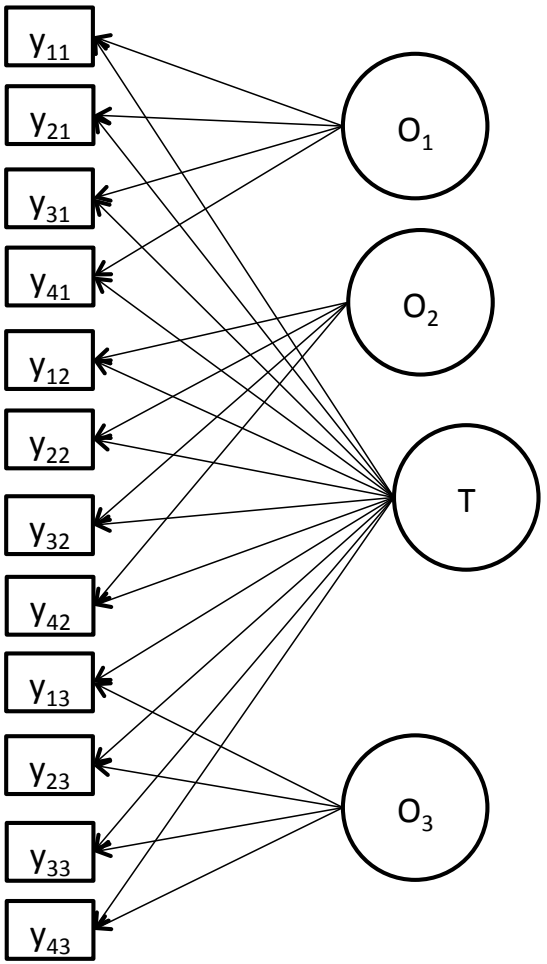
$$y_{jt} = \lambda_{jt} S_t + E_{jt} \tag{1}$$
$$S_t = \gamma_t T + O_t \tag{2}$$
$$y_{jt} = \lambda_{jt} \gamma_t T + \lambda_{jt} O_t + E_{jt} \tag{3}$$

Time-invariant versions

$$y_{jt} = \lambda_j S_t + E_{jt} \tag{4}$$
$$S_t = T + O_t \tag{5}$$
$$y_{jt} = \lambda_j T + \lambda_j O_t + E_{jt} \tag{6}$$

Comparison of Models





First-order Model (Geiser & Lockhart, 2012)

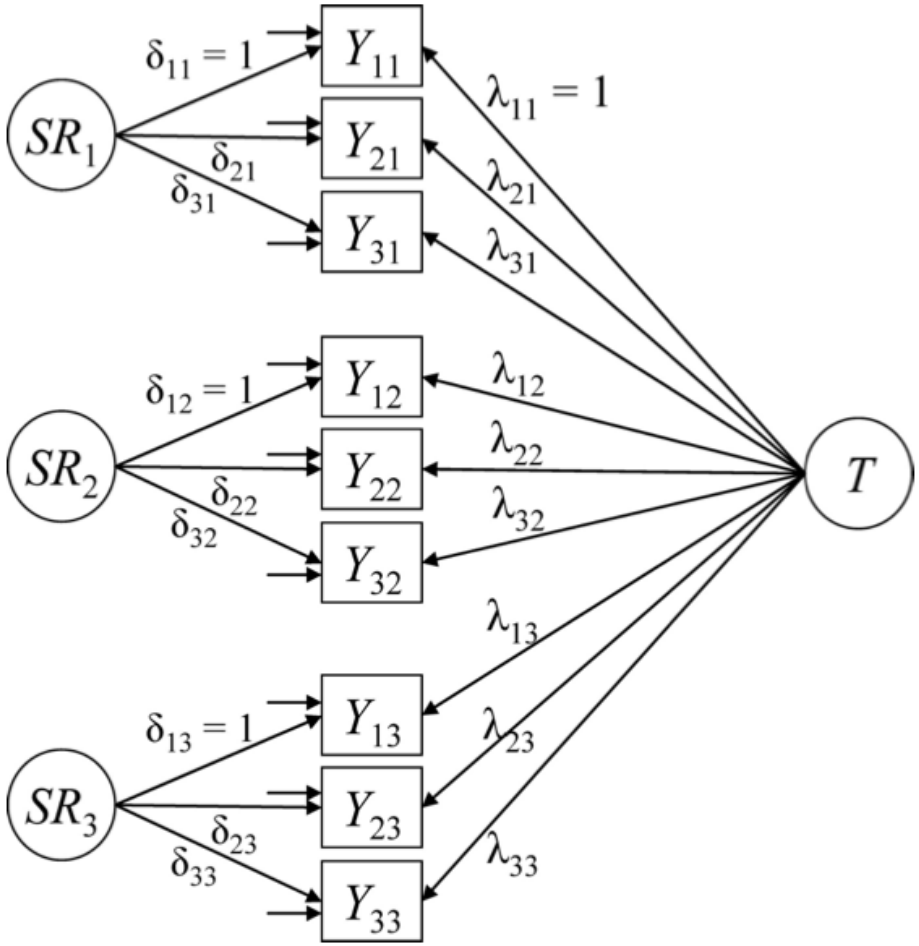


Figure 1. Latent state–trait model with no method factors. Y_{it} denotes the ith observed variable (indicator) measured at time t. T = latent trait factor; SR_t = latent state residual factor; λ_{it} = trait factor loading; δ_{it} = state residual factor loading.

Comparison of Models

$$y_{jt} = \lambda_{jt}\gamma_t T + \lambda_{jt} O_t + E_{jt} \quad (3)$$

$$y_{jt} = \psi_{jt} T + \lambda_{jt} O_t + E_{jt} \quad (7)$$

Equal when $\psi_{jt} = \lambda_{jt}\gamma_t$,
so: $\psi_{jt}/\lambda_{jt} = \gamma_t$

Time-invariant versions:

$$y_{jt} = \lambda_j T + \lambda_j O_t + E_{jt} \quad (6)$$

$$y_{jt} = \psi_j T + \lambda_j O_t + E_{jt} \quad (8)$$

Equal when $\psi_j = \lambda_j$

Question

Assumption

If the first-order LST model is true, does this show up in the fit of the higher-order LST model?

Simulation Study

Factor	Values
Sample size	$N = 250, 500, 1000$
Ratio trait state variance	More trait variance (2:1)
	Equal ratio (1:1)
	More state variance (1:2)
# occasions	2, 3, 4

Simulation Study: Factor Loadings

	trait	state
Set 1	1 - 0.8 - 0.6 - 0.4	1 - 0.6 - 0.8 - 0.4
Set 2	1 - 0.8 - 0.6 - 0.4	1 - 0.6 - 0.4 - 0.2
Set 3	1 - 0.8 - 0.6 - 0.4	1 - 0.8 - 0.6 - 0.4

Simulation Study: Fit Measures of interest

Fit indices HO-LST-model

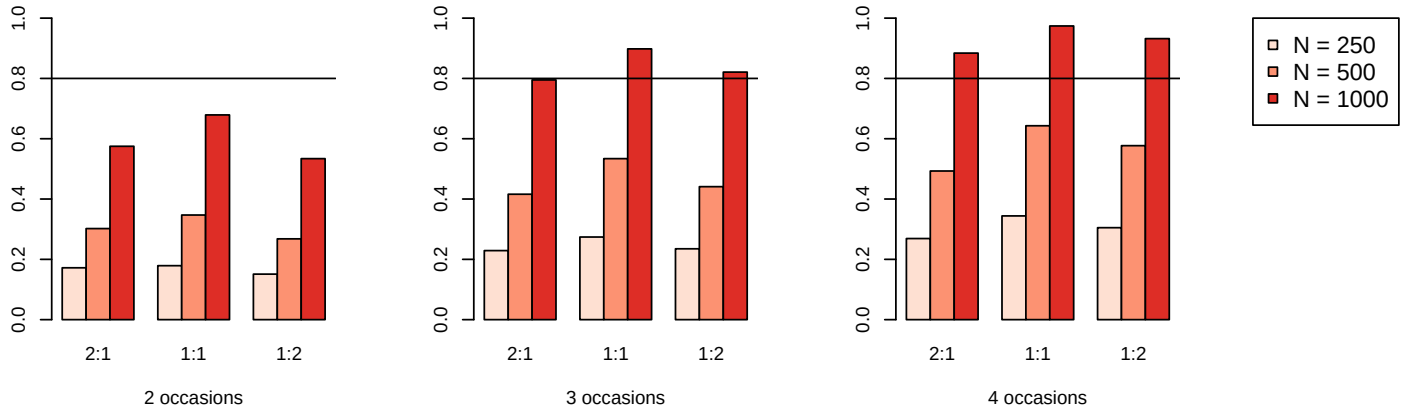
- χ^2-test
- CFI
- TLI
- RMSEA
- SRMR

Model comparison with FO-LST model

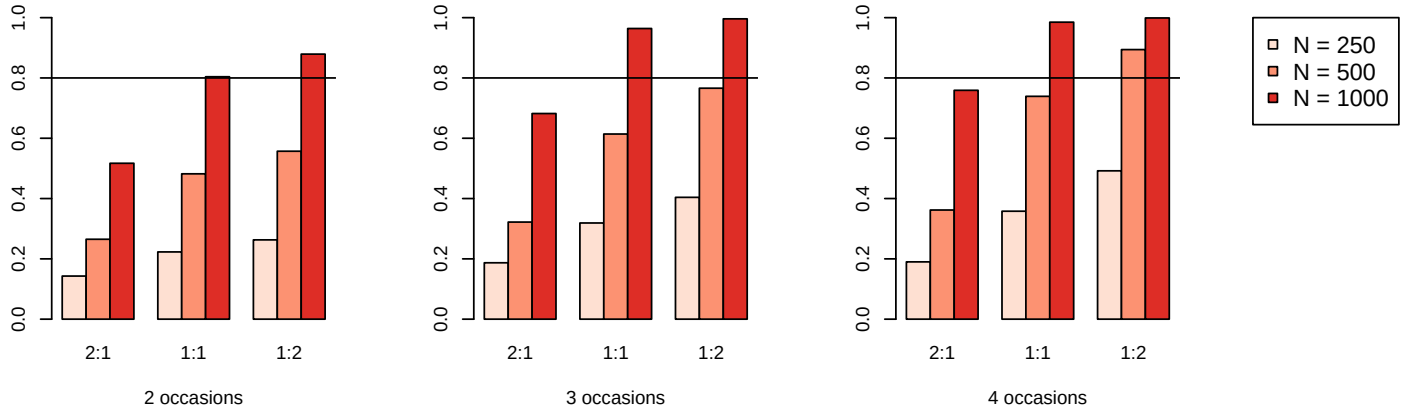
- χ^2-difference test
- AIC
- BIC

Results χ^2-test (fitted model is incorrect)

Factor loadings set 1



Factor loadings set 2



Other Fit Indices Set 1

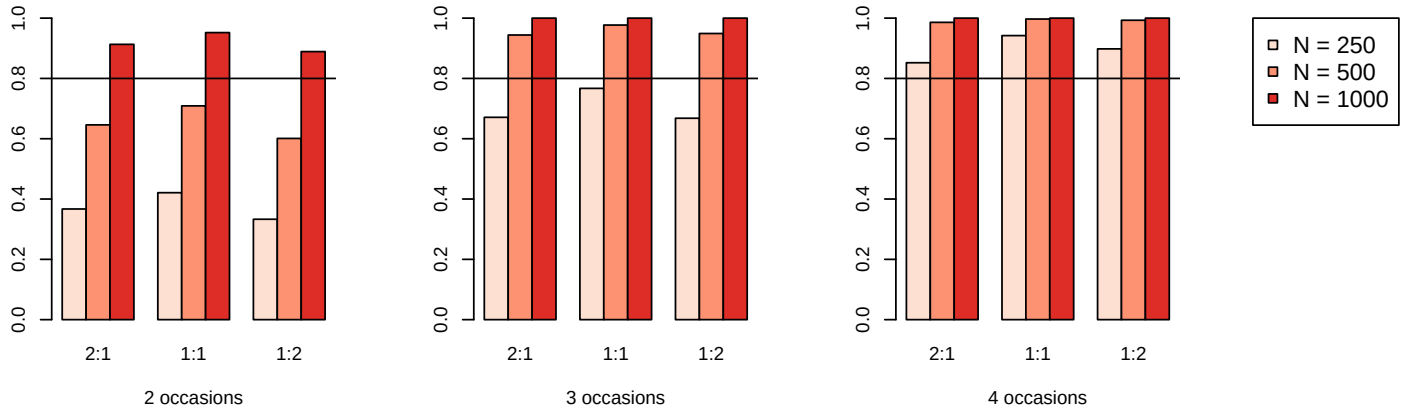
Occasions	Ratio	*N*	CFI	> .95	TLI	> .95	RMSEA	< .05	SRMR	< .05
		250	0.992	1	0.992	.986	0.024	.863	0.035	.983
	2:1	500	0.993	1	0.992	1	0.023	.976	0.027	1
		1,000	0.994	1	0.993	1	0.024	1	0.022	1
		250	0.990	.998	0.990	.981	0.026	.852	0.038	.935
2	1:1	500	0.992	1	0.991	1	0.025	.965	0.030	.999
		1,000	0.993	1	0.991	1	0.027	1	0.025	1
		250	0.991	.996	0.992	.984	0.023	.896	0.038	.934
	1:2	500	0.993	1	0.992	1	0.022	.978	0.030	.999
		1,000	0.994	1	0.993	1	0.023	1	0.025	1
		250	0.990	.999	0.990	.999	0.022	.981	0.044	.861
	2:1	500	0.992	1	0.991	1	0.022	1	0.033	.999
		1,000	0.992	1	0.991	1	0.023	1	0.026	1
		250	0.987	.998	0.987	.993	0.025	.962	0.048	.613
3	1:1	500	0.989	1	0.988	1	0.025	.999	0.037	.995
		1,000	0.990	1	0.988	1	0.026	1	0.030	1
		250	0.988	.995	0.988	.991	0.023	.972	0.049	534
	1:2	500	0.990	1	0.989	1	0.022	.999	0.038	.989
		1,000	0.991	1	0.990	1	0.023	1	0.031	1
		250	0.988	.997	0.989	.997	0.021	.997	0.047	.740
	2:1	500	0.991	1	0.991	1	0.020	1	0.035	.998
		1,000	0.992	1	0.991	1	0.021	1	0.027	1
		250	0.985	.996	0.985	.994	0.024	.996	0.052	.357
4	1:1	500	0.987	1	0.987	1	0.023	1	0.040	.991
		1,000	0.988	1	0.987	1	0.024	1	0.032	1
		250	0.985	.995	0.985	.990	0.022	.996	0.054	.233
	1:2	500	0.988	1	0.987	1	0.022	1	0.041	.969
		1,000	0.989	1	0.988	1	0.022	1	0.033	1

Other Fit Indices Set 1

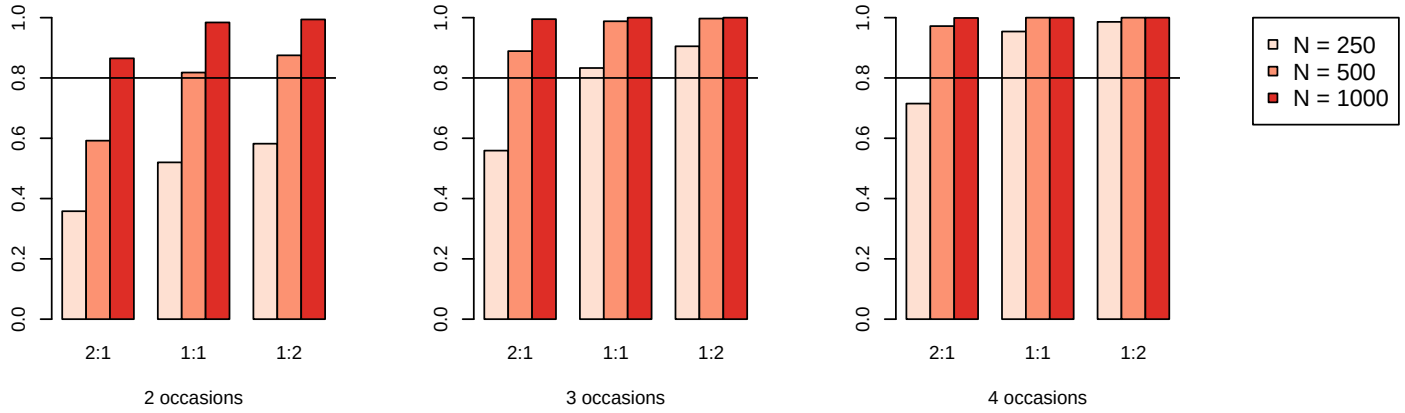
Occasions	Ratio	*N*	CFI	> .95	TLI	> .95	RMSEA	< .05	SRMR	< .05
		250	0.992	1	0.992	.986	0.024	.863	0.035	.983
	2:1	500	0.993	1	0.992	1	0.023	.976	0.027	1
		1,000	0.994	1	0.993	1	0.024	1	0.022	1
		250	0.990	.998	0.990	.981	0.026	.852	0.038	.935
2	1:1	500	0.992	1	0.991	1	0.025	.965	0.030	.999
		1,000	0.993	1	0.991	1	0.027	1	0.025	1
		250	0.991	.996	0.992	.984	0.023	.896	0.038	.934
	1:2	500	0.993	1	0.992	1	0.022	.978	0.030	.999
		1,000	0.994	1	0.993	1	0.023	1	0.025	1
		250	0.990	.999	0.990	.999	0.022	.981	0.044	.861
	2:1	500	0.992	1	0.991	1	0.022	1	0.033	.999
		1,000	0.992	1	0.991	1	0.023	1	0.026	1
		250	0.987	.998	0.987	.993	0.025	.962	0.048	.613
3	1:1	500	0.989	1	0.988	1	0.025	.999	0.037	.995
		1,000	0.990	1	0.988	1	0.026	1	0.030	1
		250	0.988	.995	0.988	.991	0.023	.972	0.049	534
	1:2	500	0.990	1	0.989	1	0.022	.999	0.038	.989
		1,000	0.991	1	0.990	1	0.023	1	0.031	1
		250	0.988	.997	0.989	.997	0.021	.997	0.047	.740
	2:1	500	0.991	1	0.991	1	0.020	1	0.035	.998
		1,000	0.992	1	0.991	1	0.021	1	0.027	1
		250	0.985	.996	0.985	.994	0.024	.996	0.052	.357
4	1:1	500	0.987	1	0.987	1	0.023	1	0.040	.991
		1,000	0.988	1	0.987	1	0.024	1	0.032	1
		250	0.985	.995	0.985	.990	0.022	.996	0.054	.233
	1:2	500	0.988	1	0.987	1	0.022	1	0.041	.969
		1,000	0.989	1	0.988	1	0.022	1	0.033	1

Model Comparison χ^2-difference test when H_a is true

Factor loadings set 1

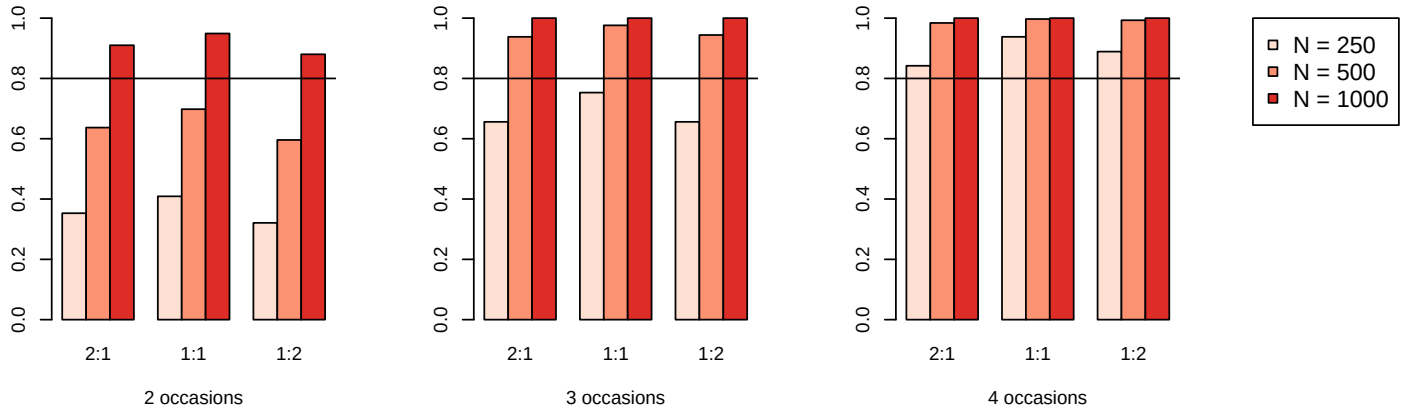


Factor loadings set 2

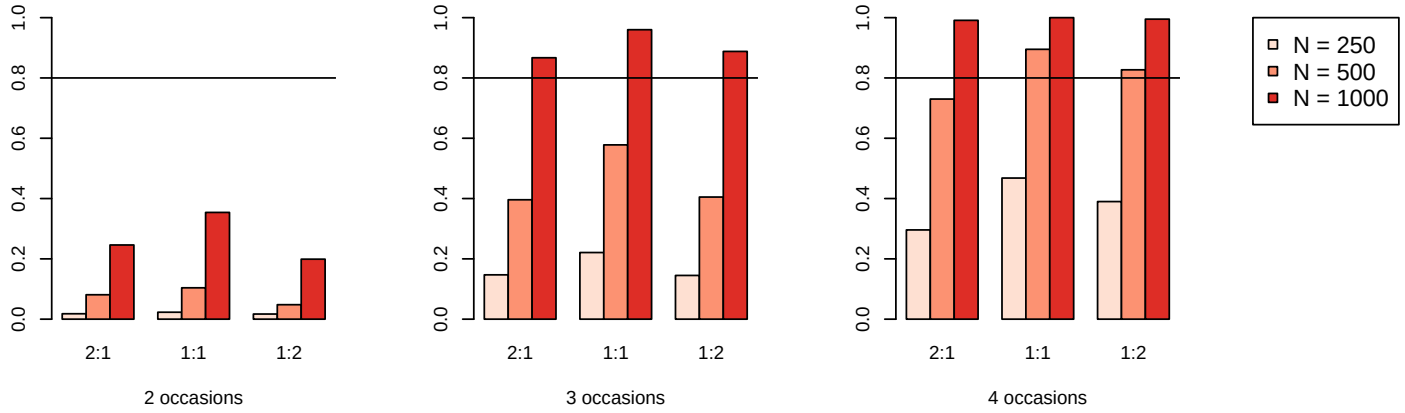


Model Comparison AIC and BIC when H_a is true

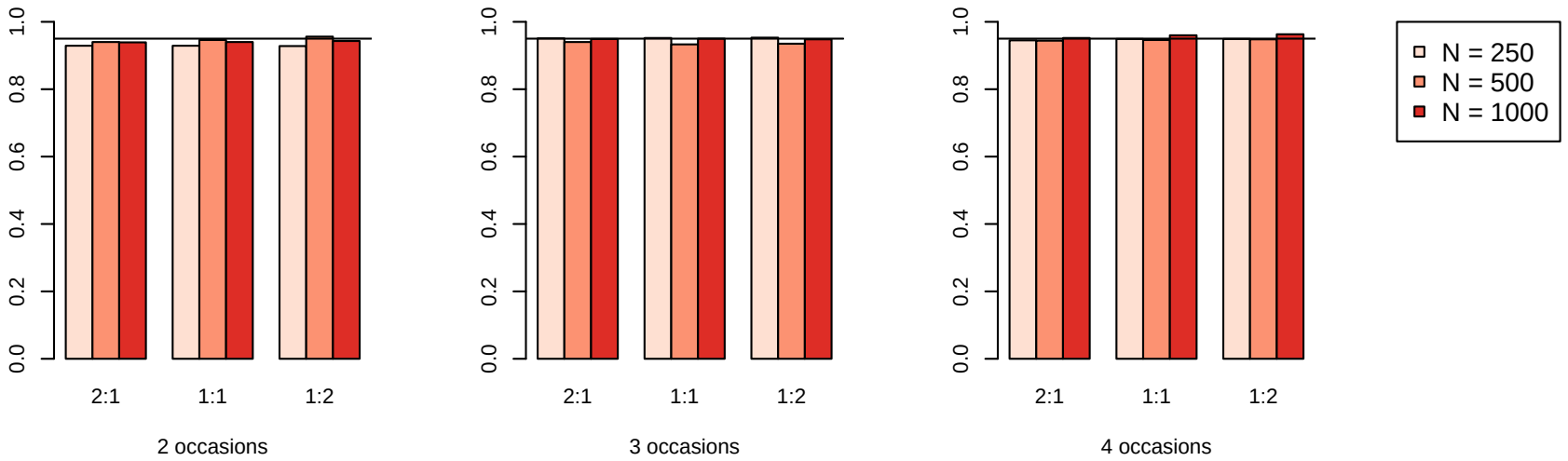
Factor loadings set 1: AIC



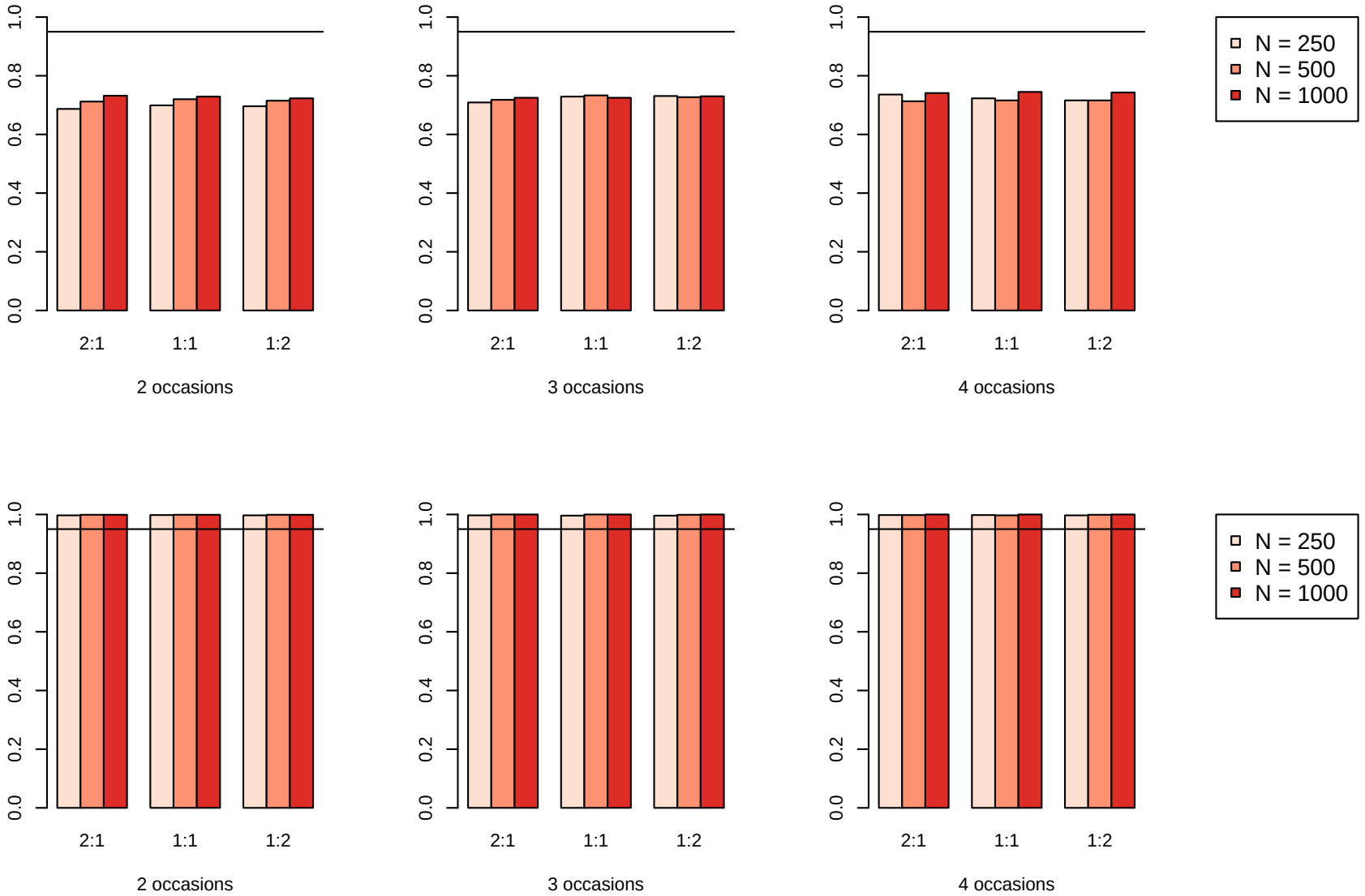
Factor loadings set 1: BIC



Model Comparison χ^2-difference test when H_0 is true



Model Comparison AIC and BIC when H_0 is true



Empirical Example

Depression in Adolescents (Dumenci & Windle, 1996), measured with CES-D scale

- depressed affect (DA)
- positive affect (PA)
- somatic complaints (SA)
- interpersonal (IN)

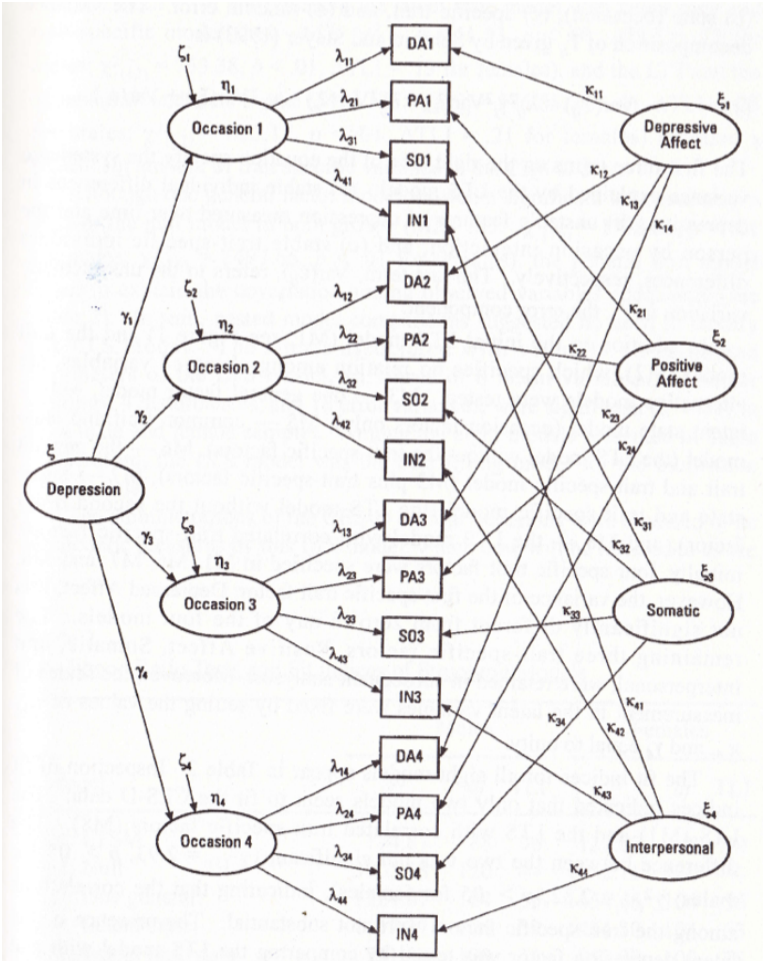


Figure 1
Latent trait-state model of the CES-D. Error terms are omitted from the figure for clarity of presentation.

Model results

Model	χ^2	df	AIC	BIC	CFI	TLI	RMSEA	SRMR
Males								
FO-LST model	126	73	25423	25670	.982	.970	.044	.034
FO-LST model, time-invariant	140	94	25395	25560	.984	.980	.036	.044
HO-LST model, time-invariant	182	97	25431	25584	.971	.964	.049	.070
Females								
FO-LST model	147	73	29574	29830	.978	.964	.048	.034
FO-LST model, time-invariant	149	94	31371	31542	.986	.983	.037	.067
HO-LST model, time-invariant	212	97	29591	29750	.966	.958	.052	.070

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Conclusion

- Power χ^2-test is not sufficient
- CFI, TLI, RMSEA & SRMR still indicate good fit
- Model comparison gives more power
- χ^2-difference test has sufficient power
- AIC has sufficient power (but high Type I error rate)
- BIC has no sufficient power (but low Type I error rate)

Take Home Message

Always compare the HO-LST model with the FO-LST model

References

Dumenci, L., & Windle, M. (1996). A latent trait-state model of adolescent depression using the center for epidemiologic studies-depression scale. *Multivariate Behavioral Research*, *31*(3), 313–330.

Geiser, C., & Lockhart, G. (2012). A comparison of four approaches to account for method effects in latent state–trait analyses. *Psychological methods*, *17*(2), 255.

Hellhammer, J., Fries, E., Schweisthal, O., Schlotz, W., Stone, A., & Hagemann, D. (2007). Several daily measurements are necessary to reliably assess the cortisol rise after awakening: state-and trait components. *Psychoneuroendocrinology*, *32*(1), 80–86.