Examining the Factor Structure of Personality with Bayesian SEM

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Alfonso J. Martinez

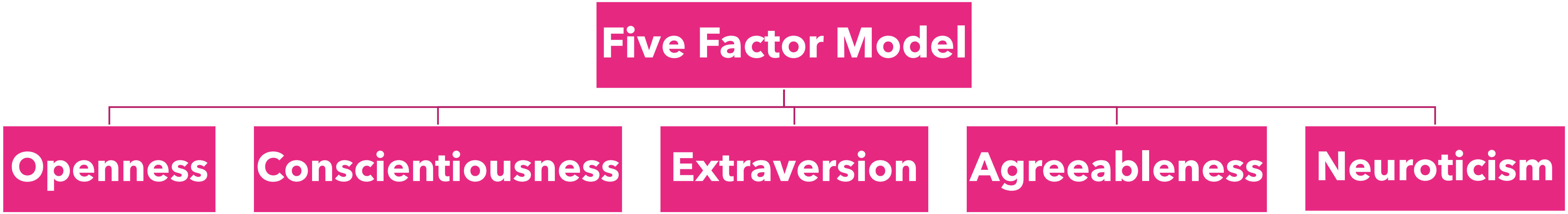
University of Iowa

Hyeri Hong

California State University, Fresno

Personality Inventories

- Personality inventories that measure personality traits under the (Big) **Five Factor Model** are widely used in psychological research
  - Predicting well-being from personality (Anglim et al., 2020)
  - Changes in personality traits during the pandemic (Sutin et al., 2020)
  - Association between personality and student achievement (Meyer et al., 2023)
  - Influence of personality traits on attitudes towards AI (Kaya et al., 2024)



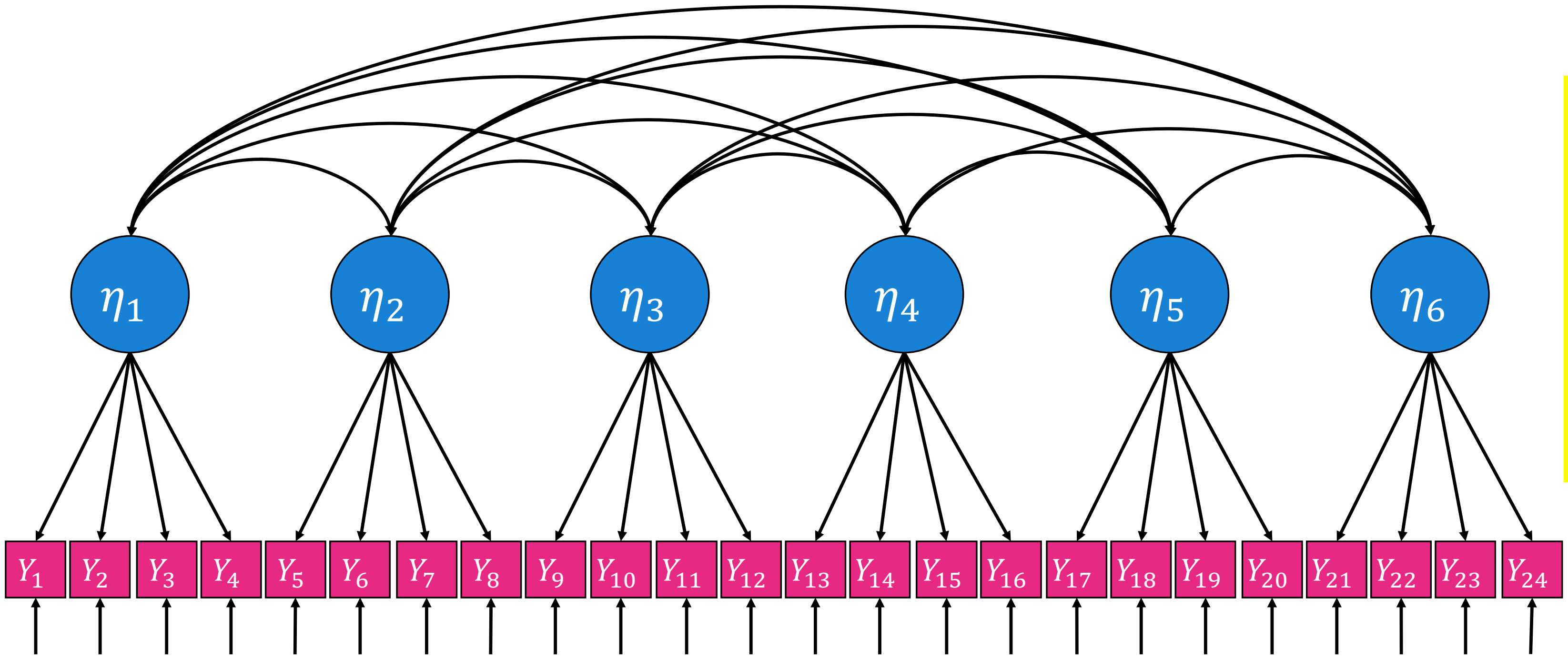
- Popular personality inventories include **NEO PI-R** (Costa & McCrae, 2000), **BFI-2** (Soto & John, 2017), **IPIP-NEO-120** (Johnson, 2014), and variants of these

Independent Cluster Structures in Personality Research

- It is common to analyze responses from personality inventories with **confirmatory factor analysis** under an **independent cluster** structure (McDonald, 2013)

- IC-CFA models assume that **indicators load onto a single factor**

Visual representation of IC-CFA for conscientiousness domain of the IPIP-NEO-120



Conscientiousness facets
η_1: Self-efficacy
η_2: Orderliness
η_3: Dutifulness
η_4: Achievement-striving
η_5: Self-discipline
η_6: Cautiousness

Are Independent Cluster Structures To Restrictive?

- ❑ Quantitative methodologists have argued that IC-CFA is **overly restrictive**
  - ❑ It is **unlikely** that indicators are **"pure"** measures of a factor (Asparouhov et al., 2015)
  - ❑ Item **residuals** likely **covary** (Zyphur & Oswald, 2015)
  - ❑ IC-CFA models in applied research **fail to meet acceptable fit criteria** (Marsh et al., 2014)

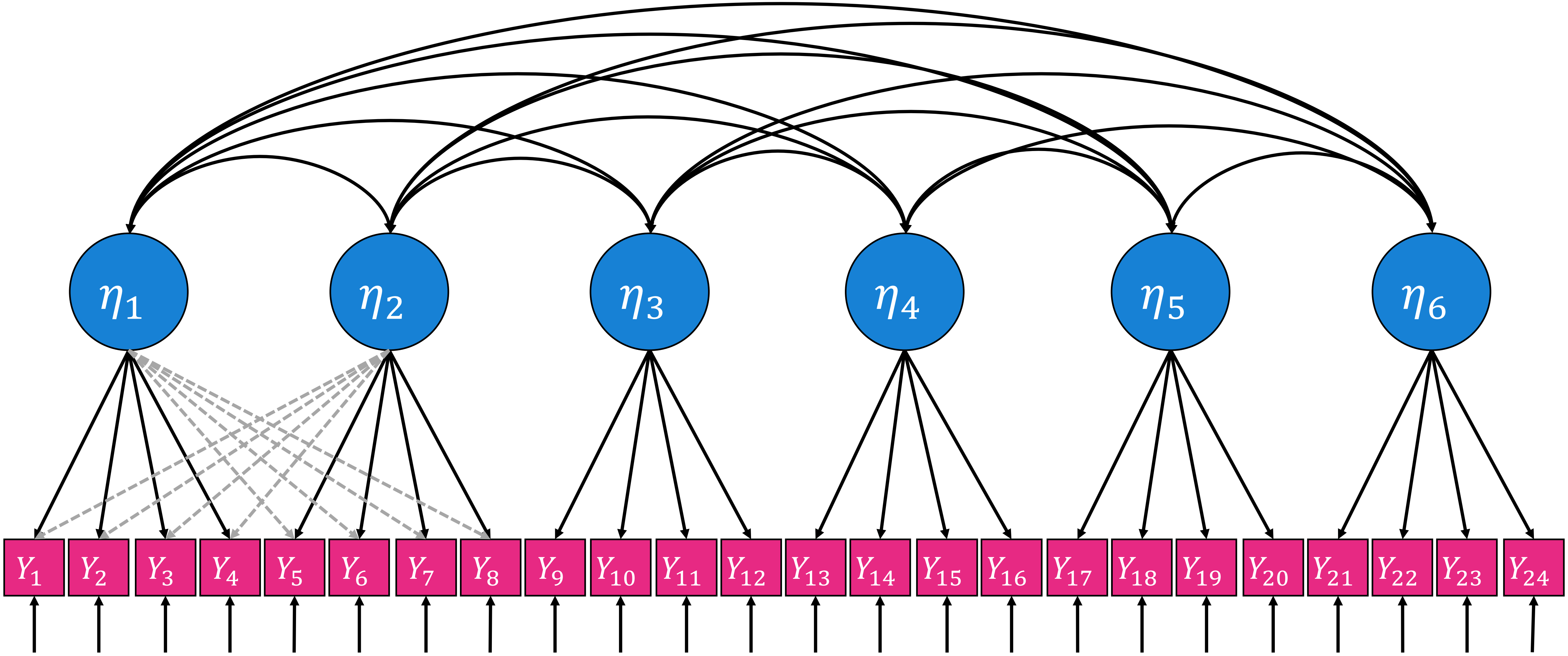
What Happens if we impose IC Structures when we Shouldn't?

- ❑ Factor correlations are **overestimated**
- ❑ **Biased structural coefficients** when predicting external variables
- ❑ **Error propagation** (other parts of the model "absorb" the error)

What are Some Solutions/Alternatives?

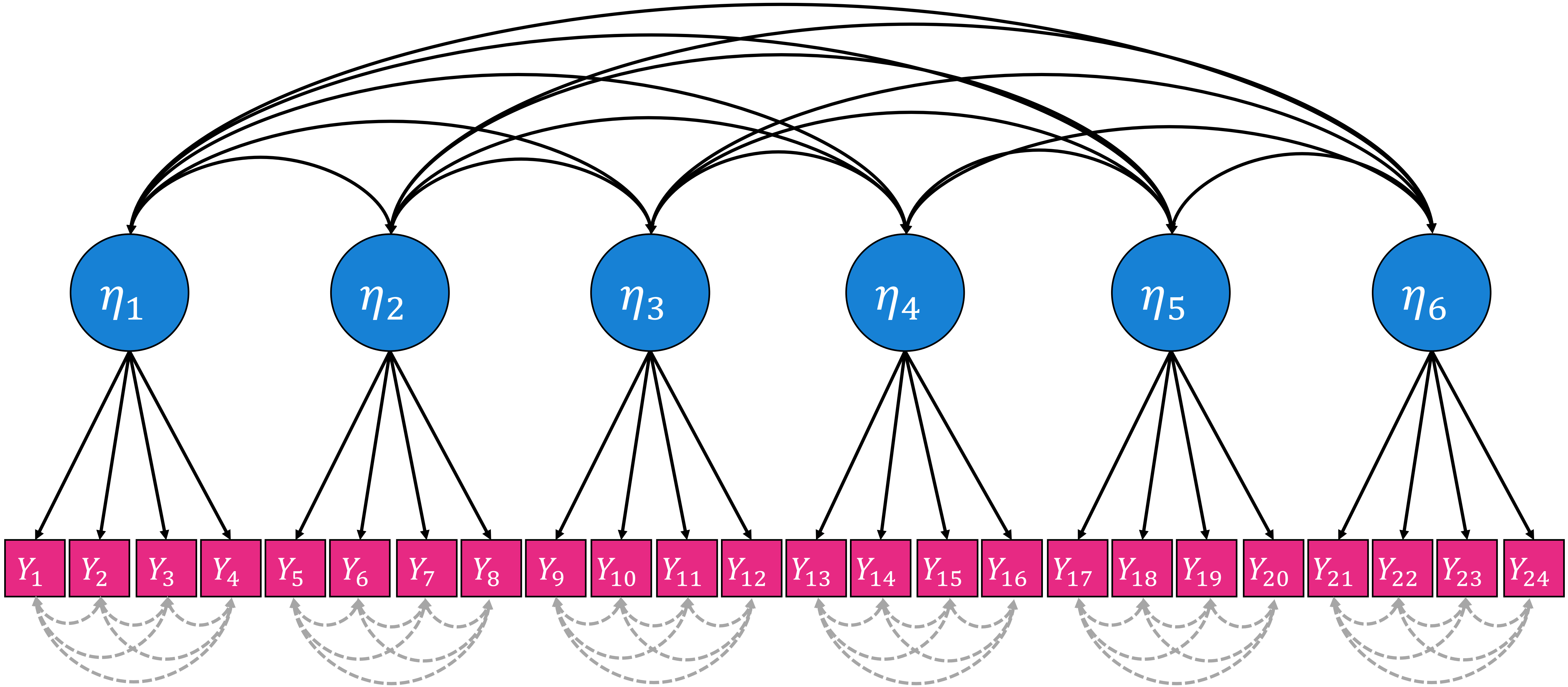
- ❑ Allowing cross-loadings
- ❑ Estimating within-factor residual covariances

Cross-loadings (CLs)



- Cross-loadings reflect the hypothesis that **indicators are never "pure" reflections** of a factor and load onto more than one factor

Residual Covariances (RCs)



- Residual covariances capture any otherwise **unmodeled sources of variation** not attributable to the factor (e.g., similarities in wording)

Challenges with Estimating Models with CL or RCs

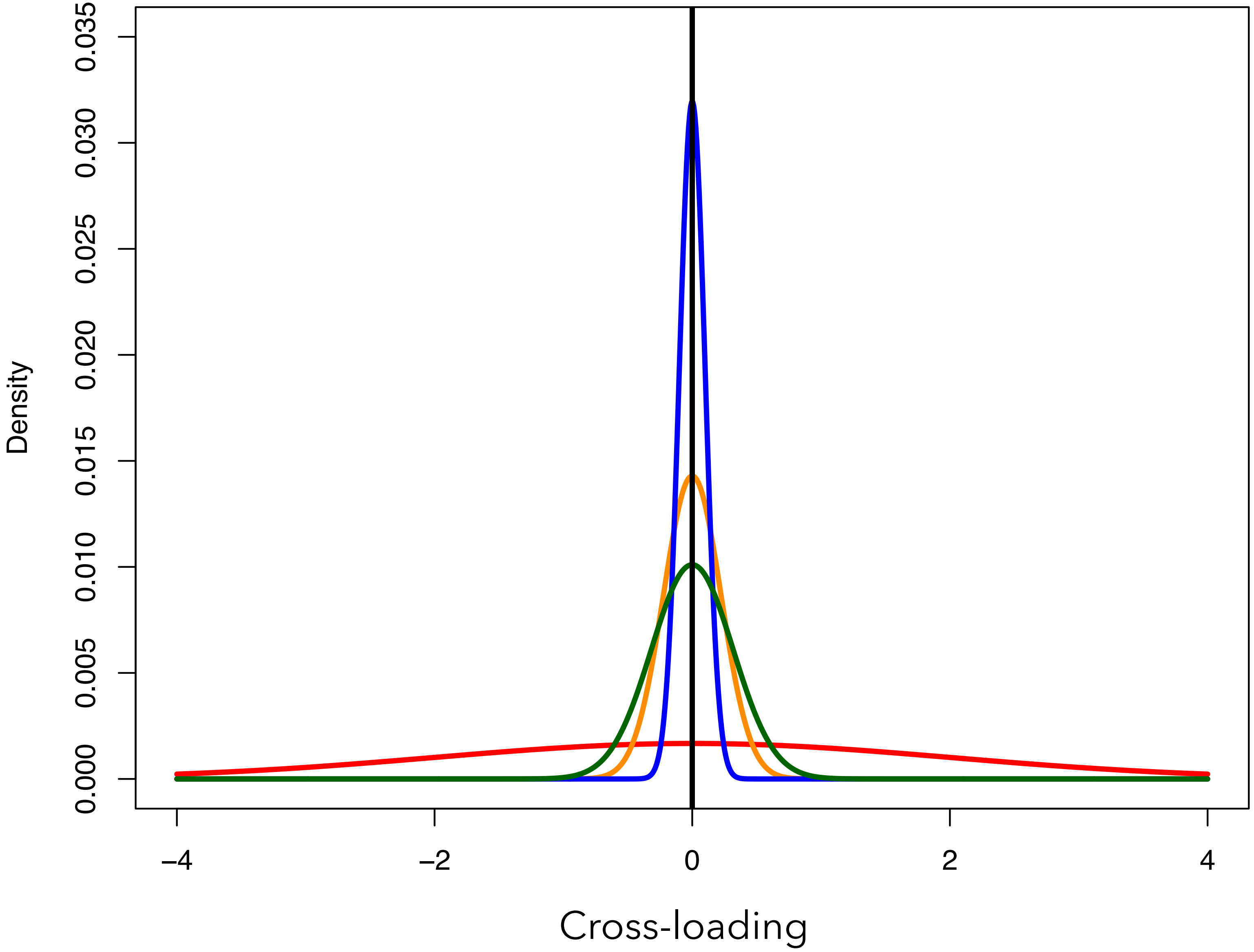
- **Estimating CL or RCs** is difficult when models are estimated with **maximum likelihood**
  - Identification issues (models can become **unidentified**)
  - No way to **"control"** the amount of influence the CL or RCs have on estimates
  - Number of parameters can **increase** substantially

Bayesian Structural Equation Models (BSEM)

- **BSEM** leverages the **Bayesian** framework to estimate CLs and/or RCs

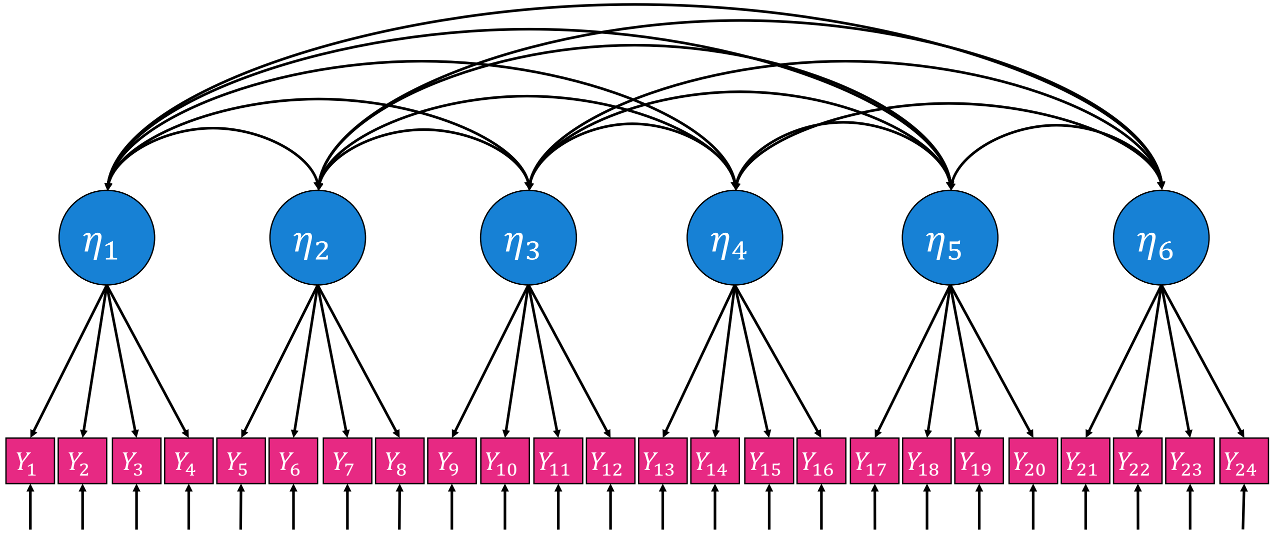
- **Small-variance priors (aka informative priors)** to reflect hypotheses that CLs/RCs are ***near*** zero but not ***exactly*** zero
  - Researcher can choose what ***near*** zero means by specifying a value for the prior variance

Examples of Different Small-Variance Priors

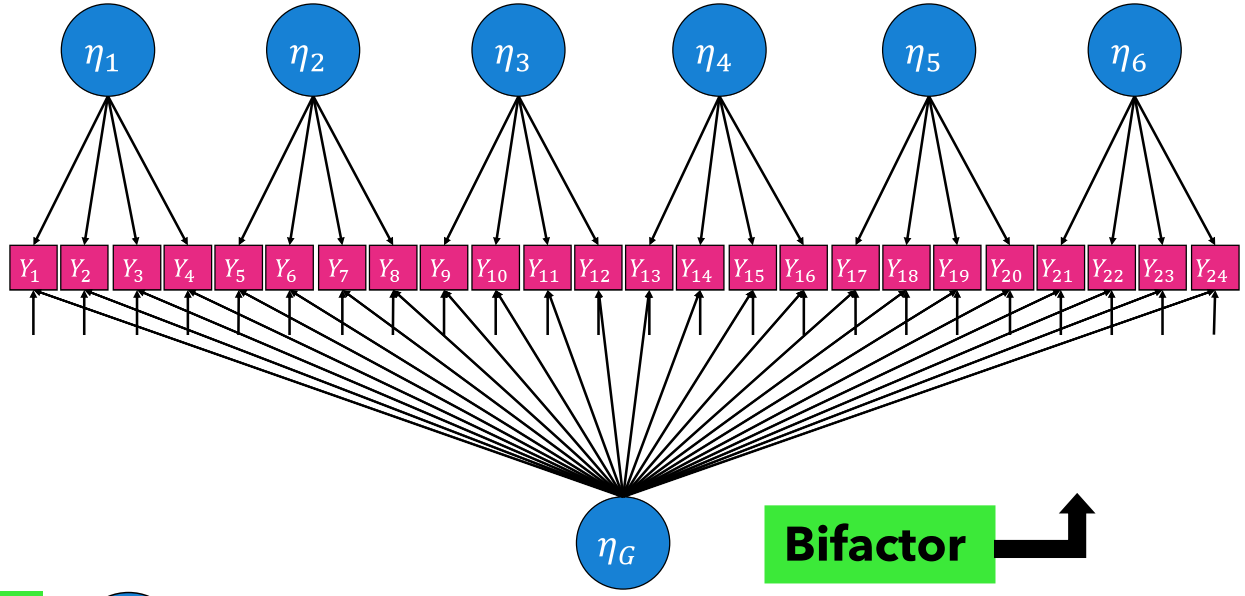


Prior	Informativeness	95%
$N(0,0)$	Extremely informative	0
$N(0,0.01)$	Informative	± 0.196
$N(0,0.05)$	Informative	± 0.438
$N(0,0.10)$	Informative	± 0.619
$N(0,4)$	Uninformative	± 3.919

What's the Best Way to Represent the Structure of Personality Domains?

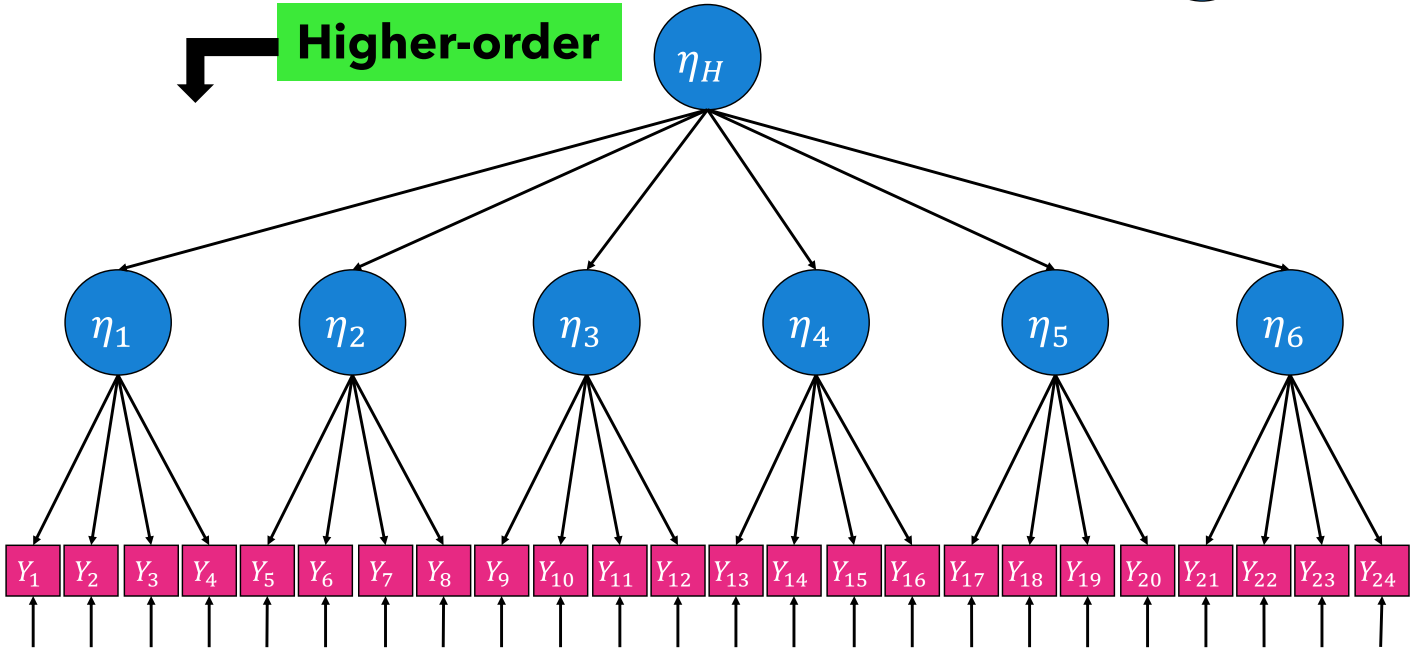


Correlated factors



Bifactor

Higher-order



<u>Conscientiousness facets</u>

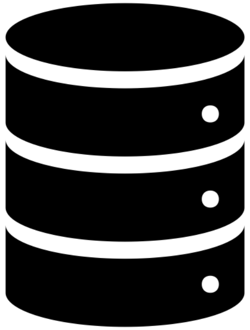
η_1: Self-efficacy
η_2: Orderliness
η_3: Dutifulness
η_4: Achievement-striving
η_5: Self-discipline
η_6: Cautiousness

Research Questions

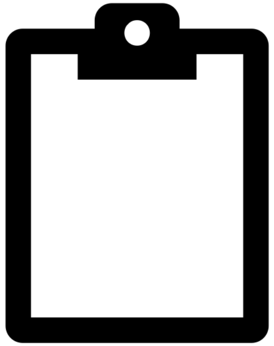
- ❑ **Research question 1: Does BSEM with small-variance priors offer an improvement over IC-CFA in personality inventories with respect to model fit indices?**

- ❑ **Research question 2: According to BSEM model fit indices, which factor structure (correlated factors, bifactor, higher-order) fits the data the best?**

Methods

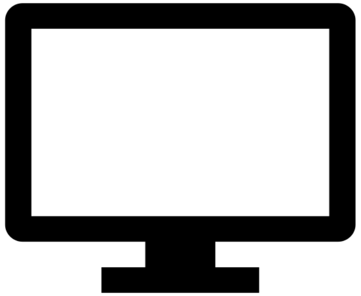


- **Data Source**: International Personality item Pool (IPIP)
- **IPIP-120-NEO** is a public version of the **NEO PI-R**
- Open-access dataset
  - 440,000+ responses
  - Random sample of $N = 500$ individuals from US analyzed in this study



- **Conscientiousness** factor
  - Six 4-item facets

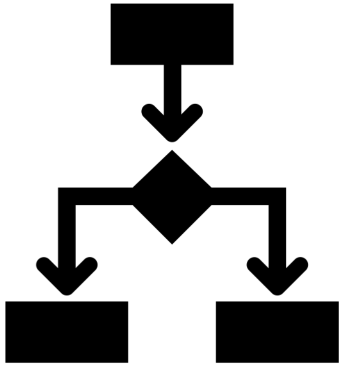
Conscientiousness Facet
Self-efficacy
Orderliness
Dutifulness
Achievement-striving
Self-discipline
Cautiousness



- 18 Bayesian models fit in **Mplus** v8.8

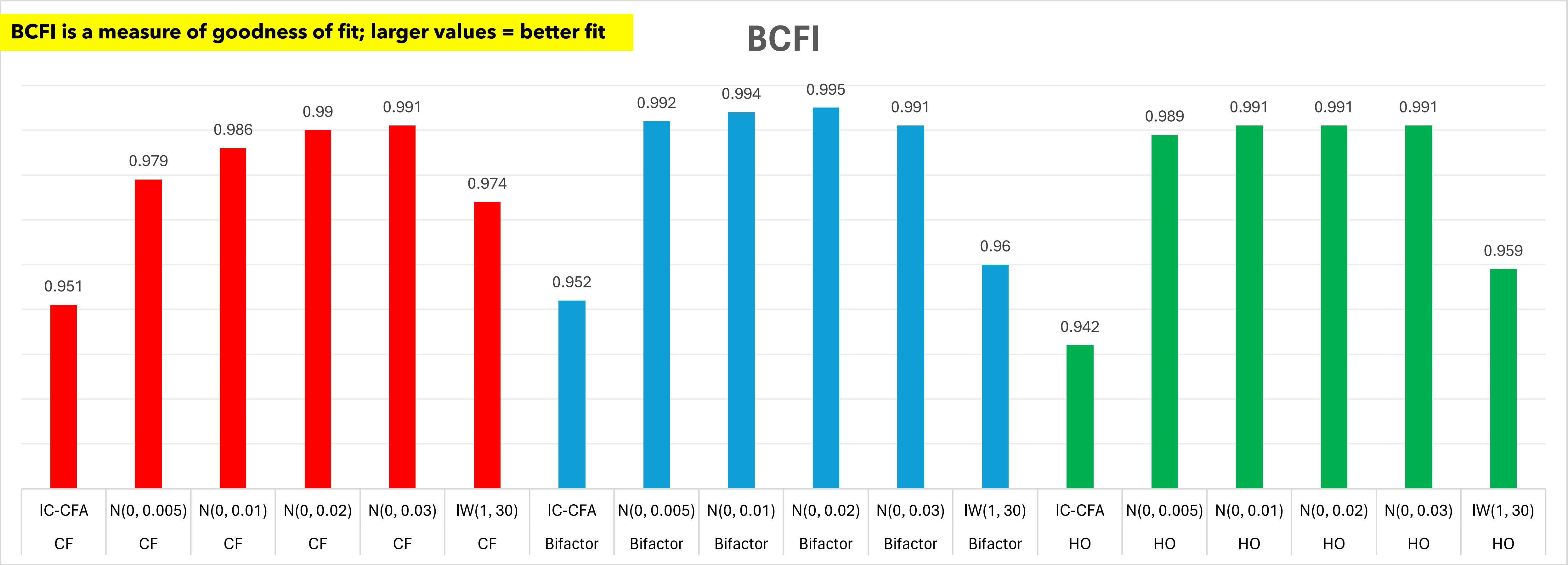
Factor Structure	Model Type
Correlated factor	IC-CFA
Bifactor	CLs only
Higher-order	RCs only

- For CLs models, prior was $\mathrm{N}(0, v)$ where $v =$ **0.005, 0.01, 0.02, 0,03**; for RCs models, prior was **IW(1, 30)**



- **Outcomes** (model fit):
  - Bayesian information criterion (**BIC**)
  - Deviance information criterion (**DIC**)
  - Comparative fit index (**BCFI**)
  - Tucker-Lewis index (**BTLI**)
  - Root mean square error of approximation (**BRMSEA**)

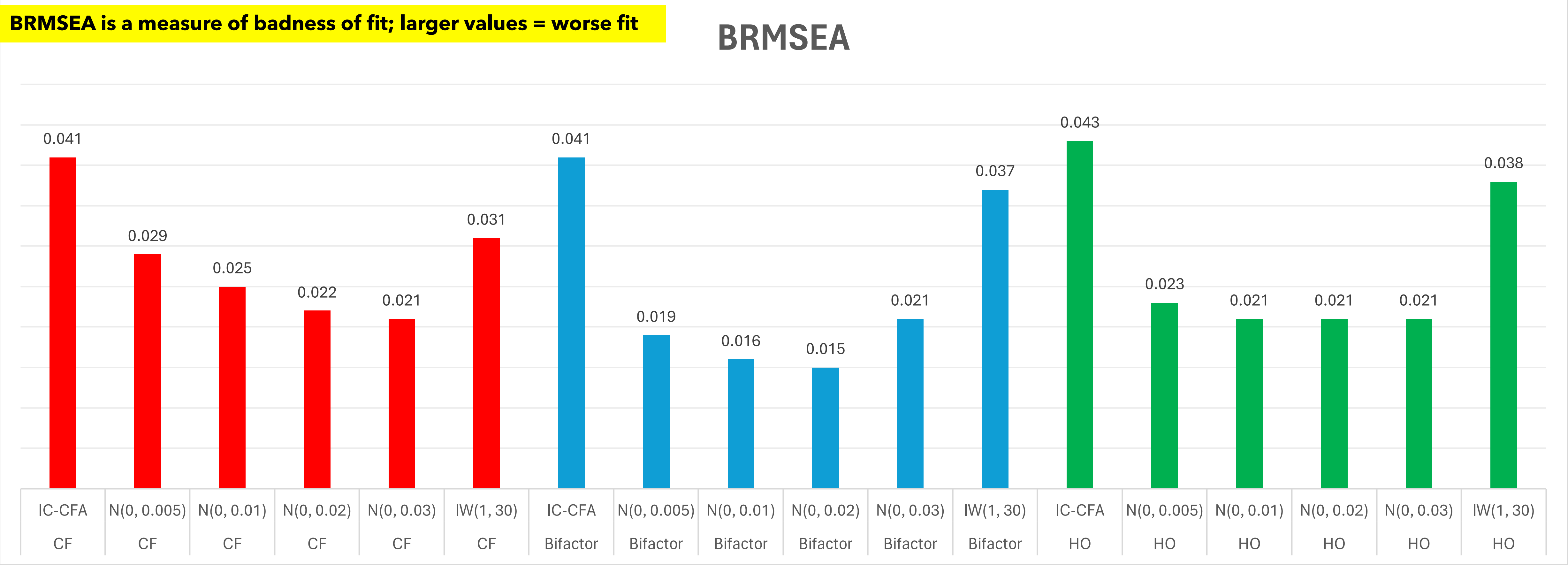
Results



- ❑ IC-CFA < BSEM-RC < BSEM-CL
- ❑ **Bifactor models fit better** (marginally) than CF and HO models
- ❑ **Increasing variance prior** in BSEM-CL models had almost **no impact** in bifactor and HO models; slight improvement in CF models
- ❑ Results from TLI were nearly identical to CFI

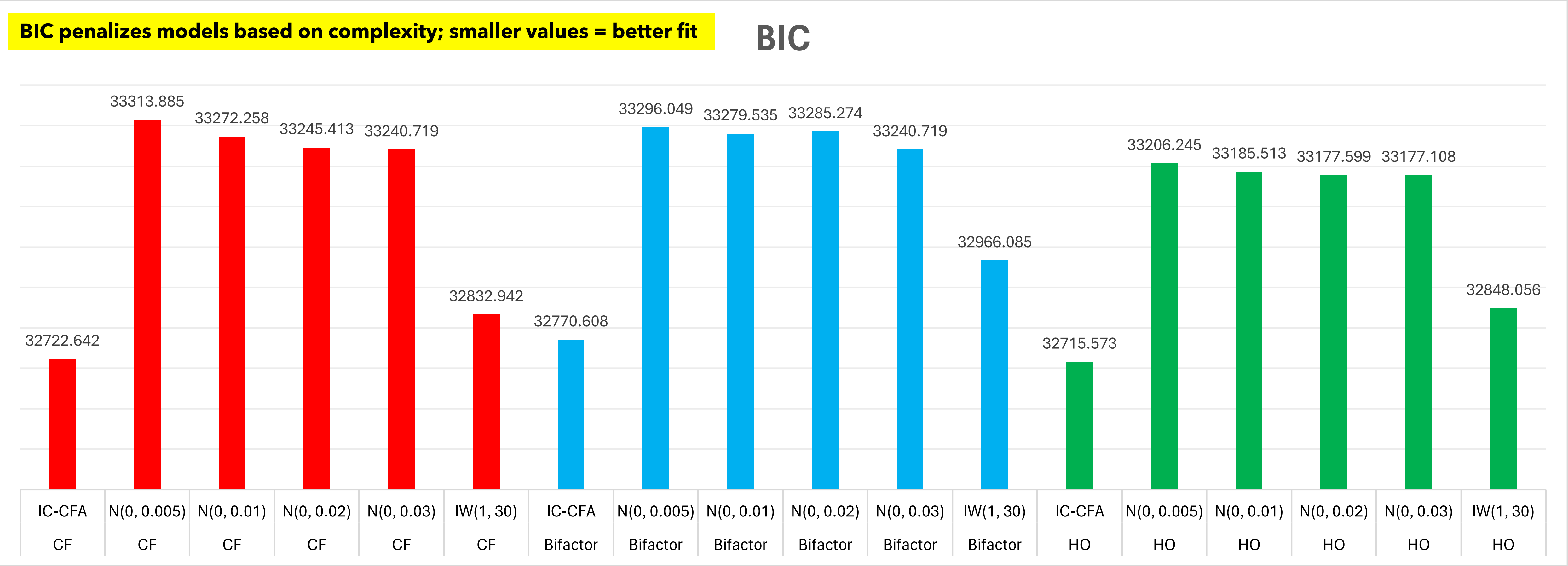
Results

BRMSEA is a measure of badness of fit; larger values = worse fit



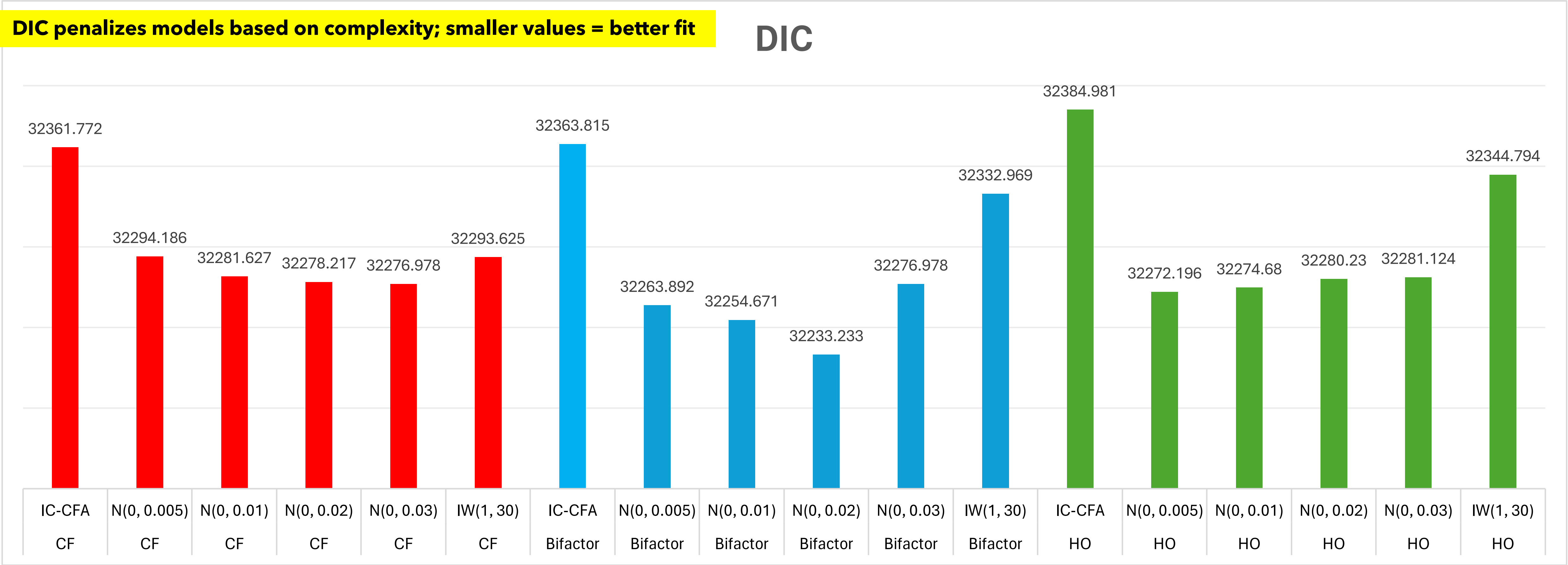
- ❑ IC-CFA > BSEM-RC > BSEM-CL
- ❑ **Bifactor models fit better** than CF and HO models
- ❑ **Increasing variance prior** in BSEM-CL models had **differential impact** depending on factor structure

Results



- **BIC preferred IC-CFA** over BSEM-RC and BSEM-CL models
- **BIC preferred HO IC-CFA** over CF IC-CFA and bifactor IC-CFA
- Within factor structure, BIC values for BSEM models were mostly consistent

Results



- ❑ According to DIC, IC-CFA **fit worse** than BSEM
- ❑ Out of all 18 models, **bifactor BSEM-CL** with N(0, 0.02) prior fit best
- ❑ All **BSEM-CL models fit better** than BSEM-RC models

Discussion & Implications

- We found the **BSEM-CLs** provided the best fit across factor structures
- We found evidence that **bifactor** structures fit conscientiousness data better than CT and HO factor structures when **SEM-based fit measures** were considered; **BIC** preferred **IC-CFA**; **DIC** preferred **bifactor**

Limitations

- We focused on one personality domain (conscientiousness), not all five
- **Possible** that we are **overfitting** data in BSEM-CL and BSEM-RC models
- Only considered measures of model fit (**theory should take precedence**)

Future Research

- Do we really need all those CLs and/or RCs?
- Do we see the same trend in other personality domains?
- Are slight increases in model fit practically important and meaningful to substantive researchers?

Thank You!

Alfonso J. Martinez
PhD Candidate, University of Iowa
Email: alfonso-martinez@uiowa.edu
Website: ajmquant.com
Twitter/X: alfonsoMpsych

Hyeri Hong, PhD
Asst. Prof., California State University, Fresno
Email: hyerihong@mail.fresnostate.edu
Website:
https://kremen.fresnostate.edu/about/directory/hong-hyeri.html

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Extra Slides

Number of Parameters in Each Model

Factor Structure	Model Type	# Parameters
Correlated Factor	Independent Clusters	87
	BSEM CLs	207
	BSEM RCs	123
Bifactor	Independent Clusters	96
	BSEM CLs	216
	BSEM RCs	133
Higher-order	Independent Clusters	78
	BSEM CLs	198
	BSEM RCs	198

Descriptive Statistics

Facet	Mean (SD)	Reliability Alpha
Self-efficacy	4.02 (0.12)	0.767
Orderliness	3.09 (0.28)	0.837
Dutifulness	3.97 (0.44)	0.669
Achievement-striving	3.85 (0.22)	0.738
Self-discipline	3.44 (0.29)	0.669
Cautiousness	3.23 (0.10)	0.874
Total	3.60 (0.44)	0.898