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Evaluating (Mixture) Multigroup SEM with Exploratory Measurement Models

Jennifer Dang Guay, Yves Rosseel, Kim De Roover

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Instituto Canario de Igualdad
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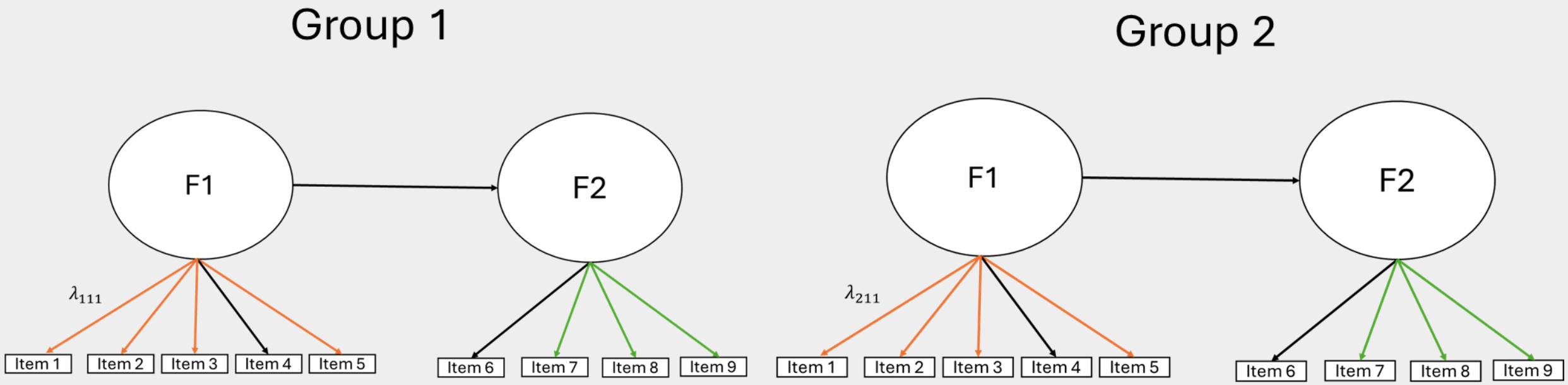
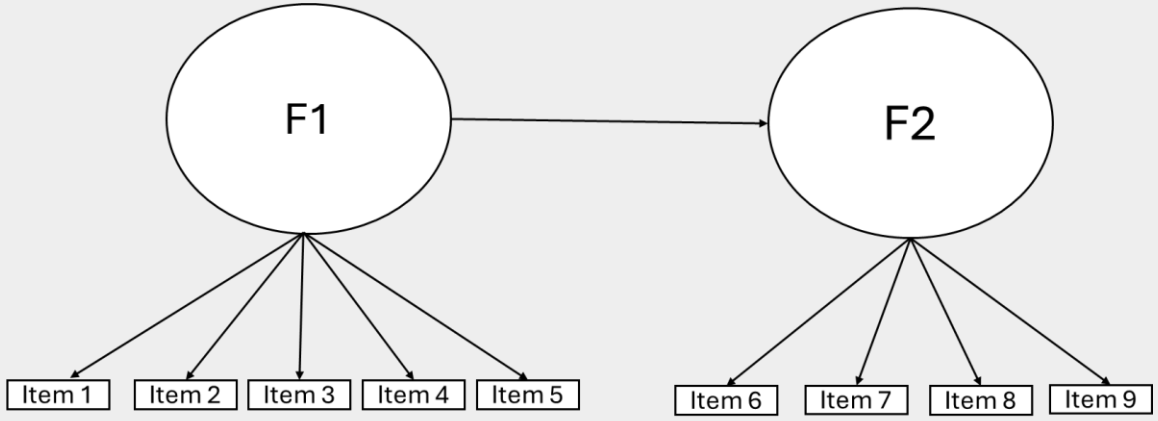
(Partial) metric invariance

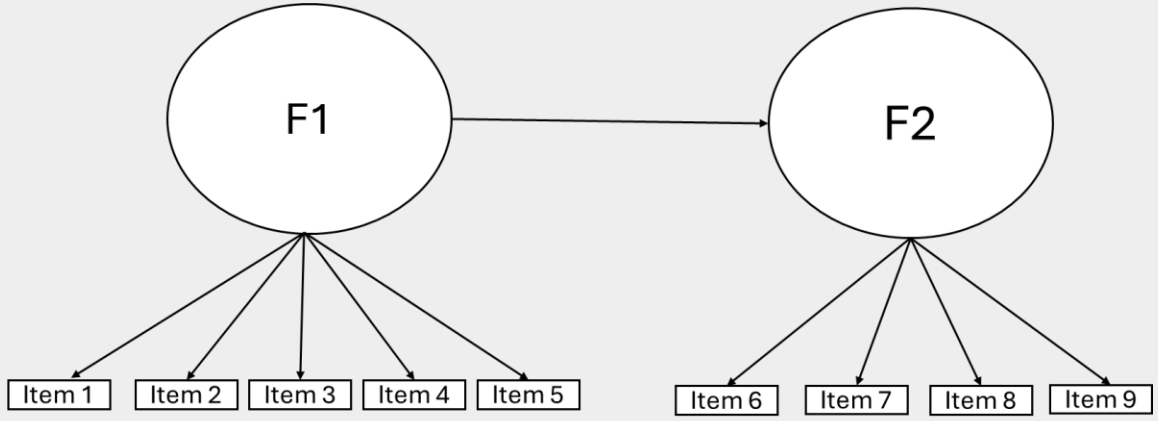


MG-SEM with a CFA-based MM is too restrictive

Group 1

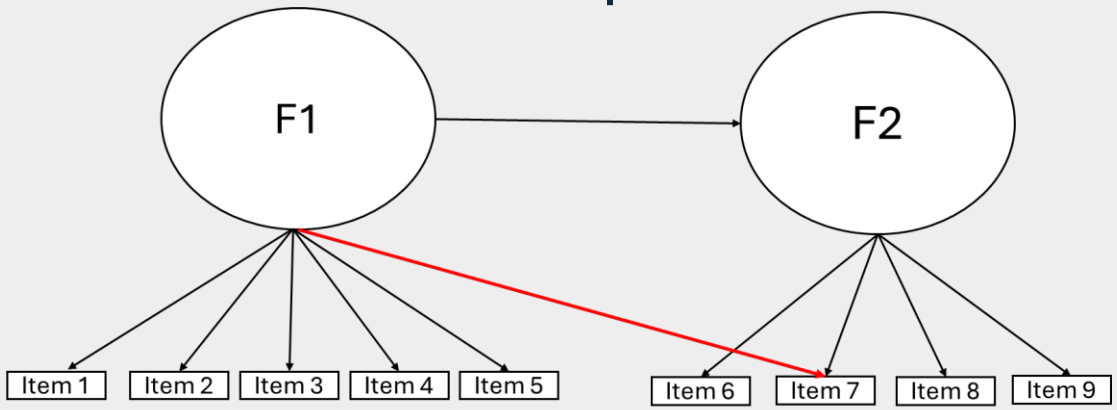


Group 2

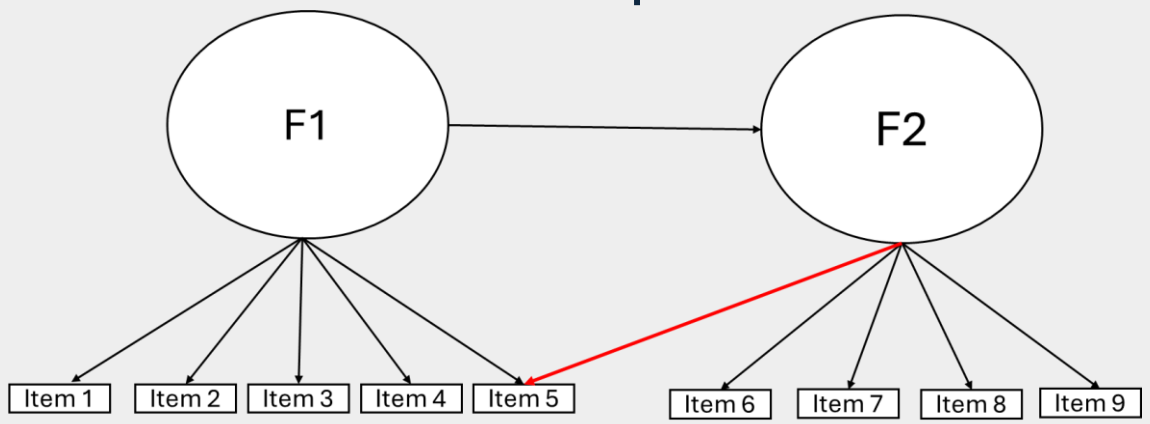


… which makes it harder to find loading differences

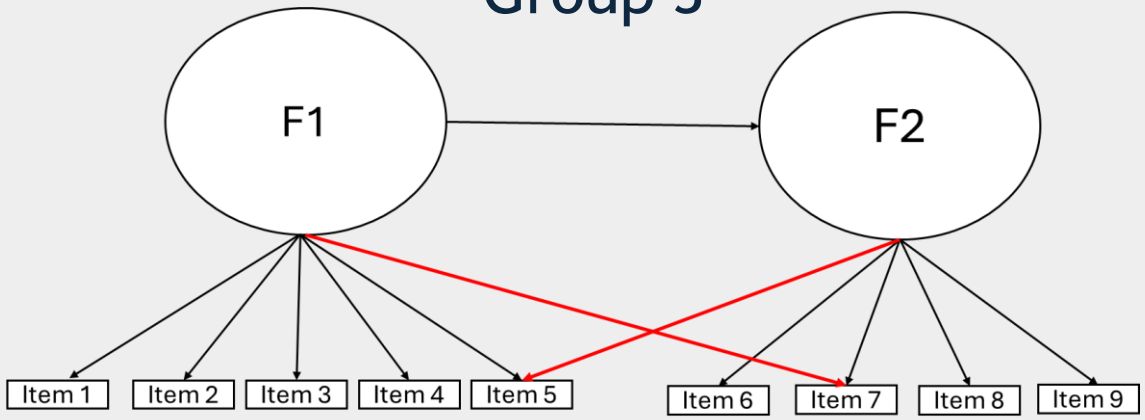
Group 1



Group 2

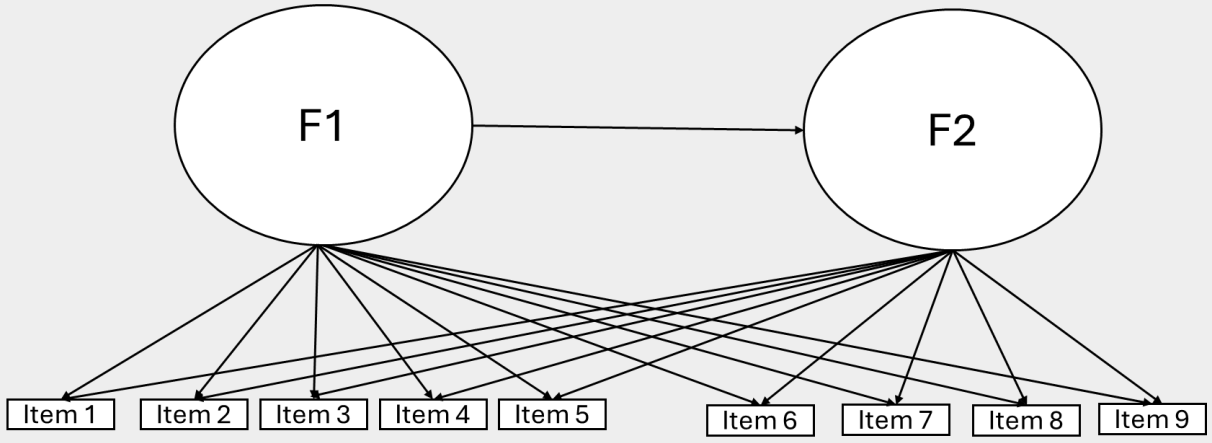


Group 3

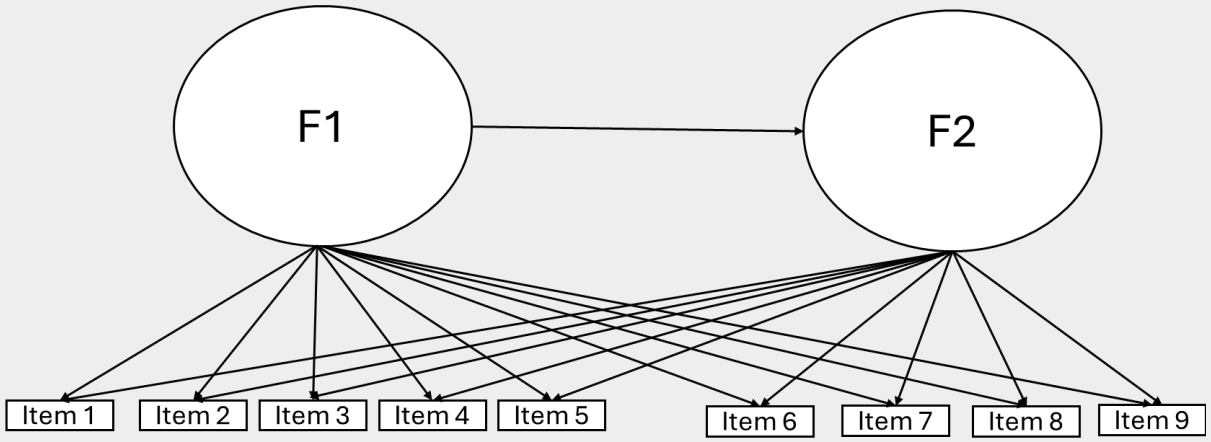


MG-ESEM with an EFA-based MM is a popular alternative

Group 1



Group 2



Rotation in MG-ESEM: Helps identify loading differences

- The group-specific loadings have **rotational freedom**
- Rotating them leads to different loading solutions
- Ideally rotate to find loading differences easily

Simple structure rotation per group: **OVERESTIMATED** loading differences

Group 1

	F1	F2
Item 1	**0.72**	-0.01
Item 2	**0.59**	-0.01
Item 3	**0.29**	0.00
Item 4	**0.59**	0.19
Item 5	**0.56**	-0.01
Item 6	0.00	**0.58**
Item 7	0.00	**0.64**
Item 8	0.00	**0.49**
Item 9	0.00	**0.37**

Group 2

	F1	F2
Item 1	**0.76**	-0.01
Item 2	**0.62**	-0.01
Item 3	**0.31**	-0.00
Item 4	**0.62**	**0.30**
Item 5	**0.59**	-0.01
Item 6	0.00	**0.90**
Item 7	0.00	**0.99**
Item 8	0.00	**0.77**
Item 9	0.00	**0.57**

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Rotation should not only pursue SIMPLE STRUCTURE but also AGREEMENT between groups
(De Roover & Vermunt, 2019)

Novel MG-EFA-based methods for pursuing agreement

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Multigroup alignment (**MG-A;** Asparouhov & Muthén, 2014)

- Pursues agreement *after* a simple structure rotation per group
- By rescaling factor variances

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Multigroup factor rotation (**MG-FR**; De Roover & Vermunt, 2019)

- Pursues agreement *while* rotating and rescaling factor variances

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Multigroup factor rotation (**MG-FR**; De Roover & Vermunt, 2019)

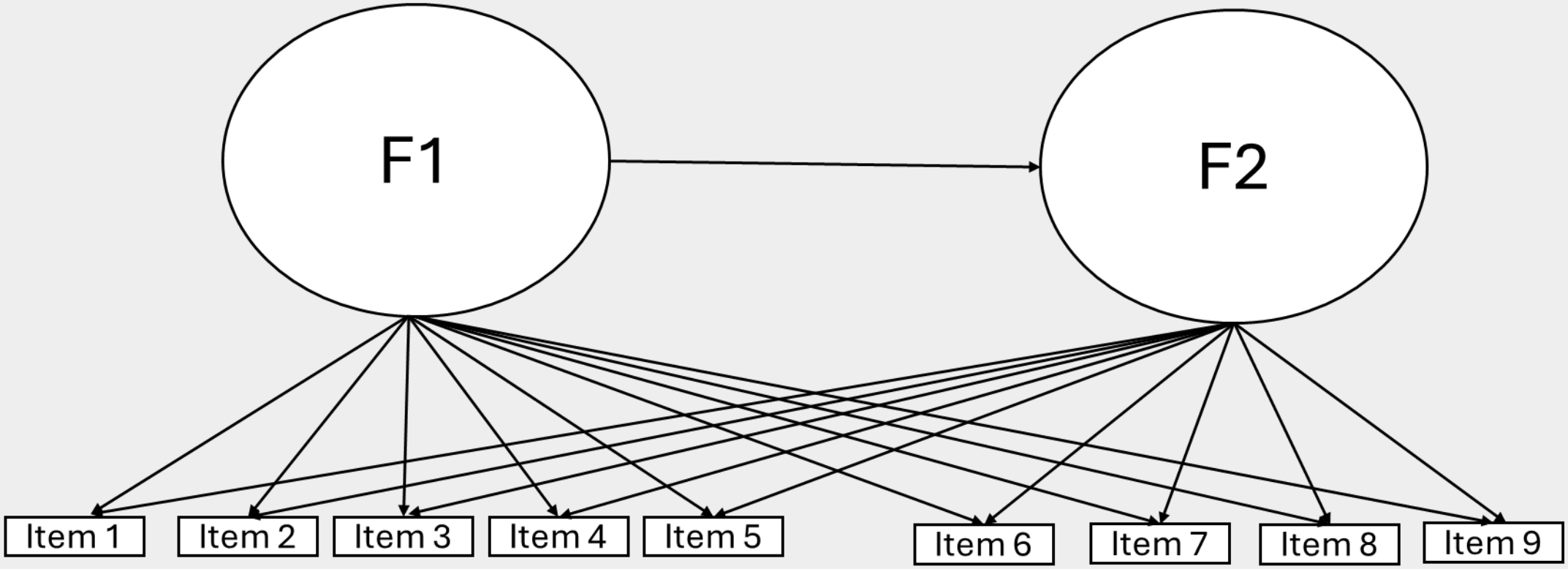
- Pursues agreement *while* rotating and rescaling factor variances
- Rotation criterion: weighted combination of a simple structure criterion R_g^{SS} and an agreement criterion (R^A)

$$R^{MG} = wR^A + (1-w)\sum_{g=1}^{G} R_g^{SS}$$

Aims

Examine the performance of MG-A and MG-FR to recover loadings and structural relations

2-step MG-ESEM based on the local structural-after-measurement approach (Rosseel & Loh, 2024)



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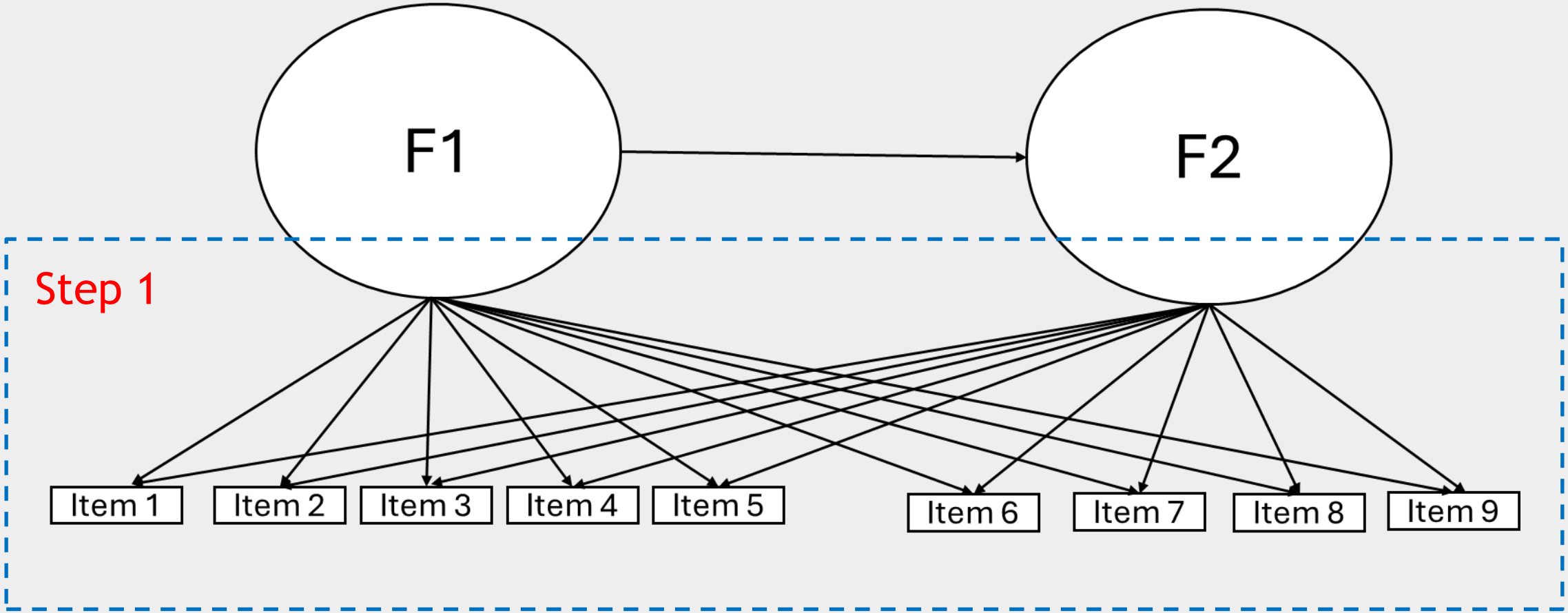

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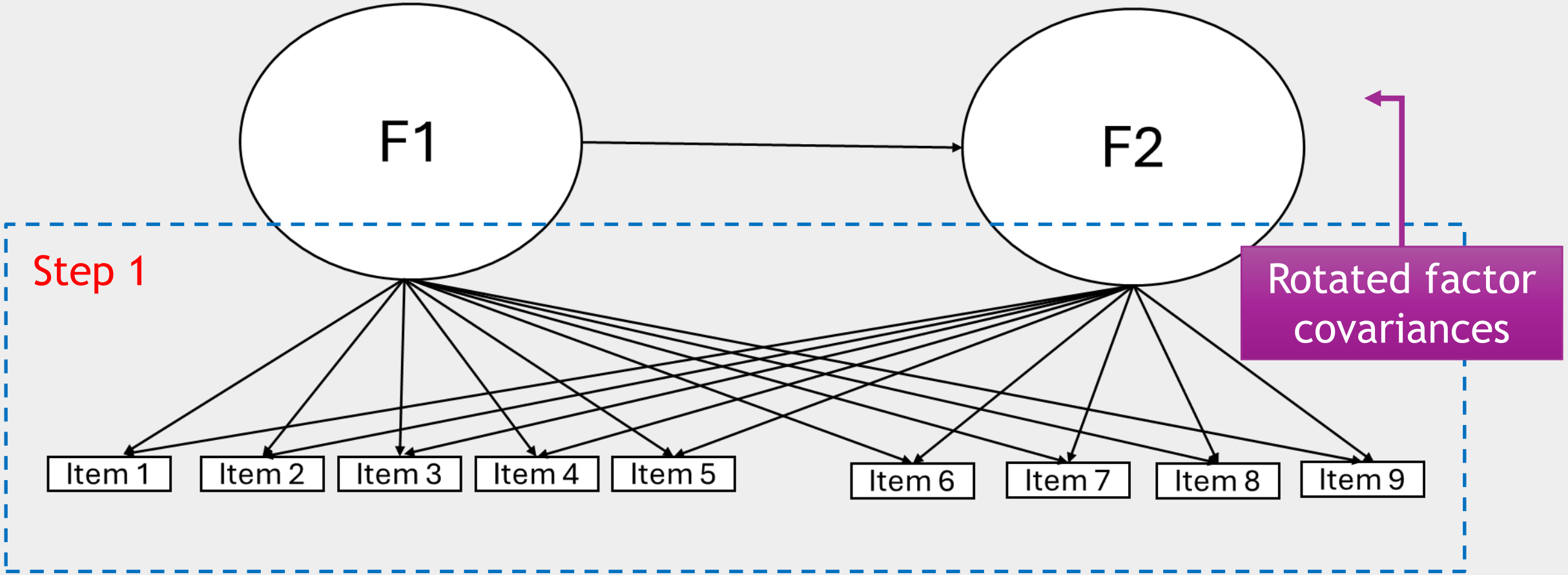

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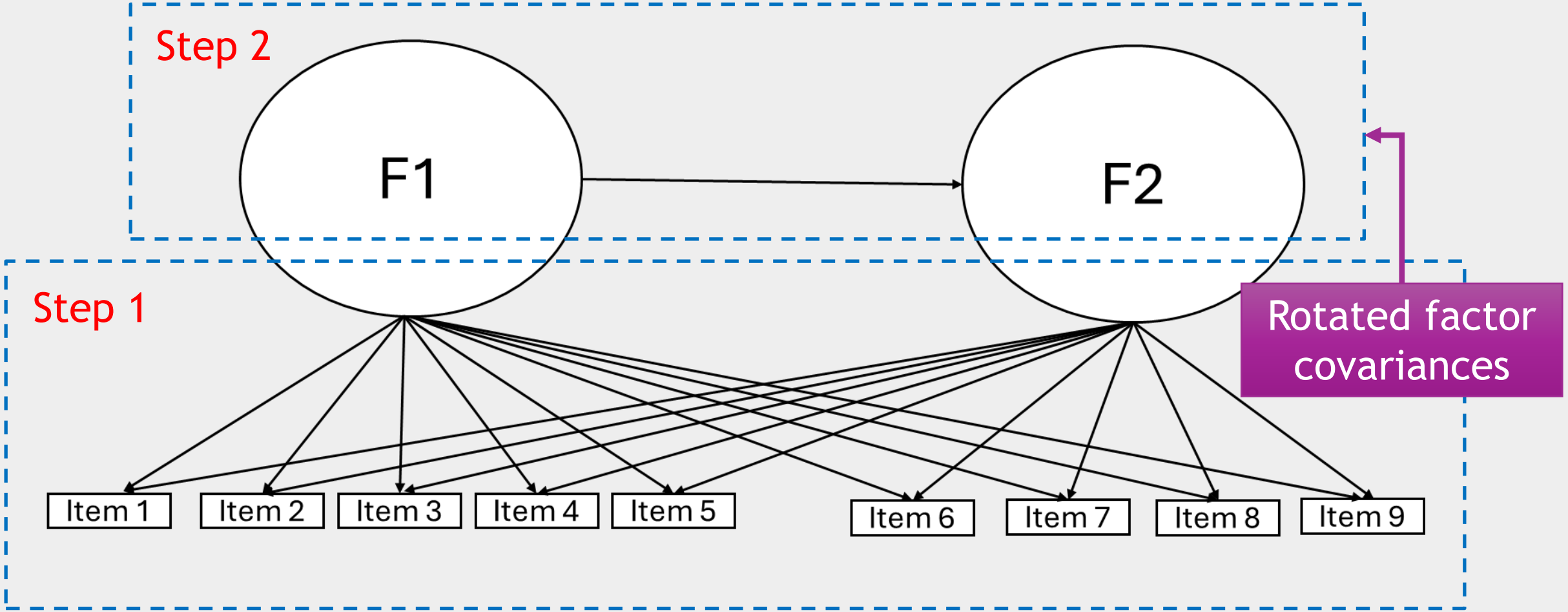

Models

- MG-CFA (benchmark)
  - Correctly specified or misspecified (e.g., overlooking crossloadings)
- MG-EFA (benchmark)
  - Simple structure criteria: Geomin, Oblimin, Target
- MG-A
  - Simple structure criteria: Geomin, Oblimin, Target
  - Software: *Mplus*
- MG-FR
  - Simple structure criteria : Geomin, Oblimin, Target
  - Agreement criterion weights: 0.1, 0.5
  - Software: *Latent Gold*

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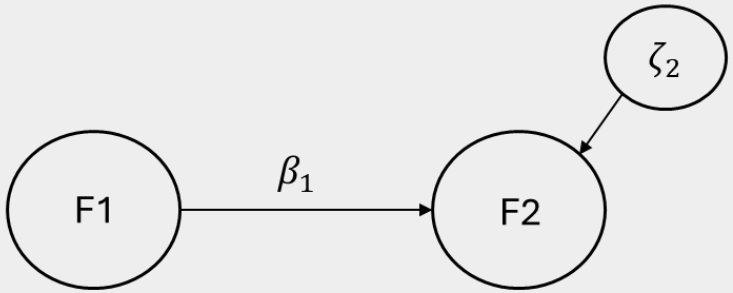
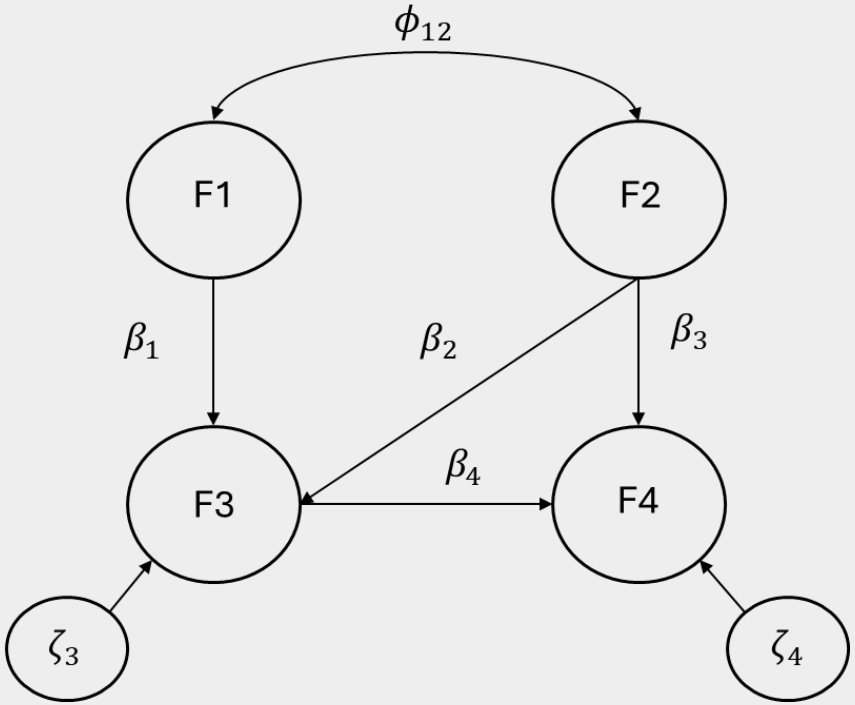
Simulation Design

- Simulated data with a marker variable per factor
- Structural models:

Number of factors = 2



Number of factors = 4



Simulation Design

- Manipulated conditions:

Manipulated Conditions	
Number of groups	2, 4, 6
Number of observations per group	100, 300, 500
Number of factors	2, 4
Average regression parameter	0.2, 0.4
Type and size of loading differences	Primary loading shift, Primary loading decrease of 0.2, Primary loading decrease of 0.4, Crossloading of 0.2, Crossloading of 0.4
Invariant crossloadings of 0.3	Yes, no

Primary loading shifts

Group 1 loadings		Group 2 loadings	
F1	F2	F1	F2
1	0	**1**	0
0	√.60	√.60	0
√.60	0	√.60	0
√.60	0	0	√.60
√.60	0	√.60	0
0	**1**	0	**1**
0	√.60	0	√.60
0	√.60	0	√.60
0	√.60	0	√.60
0	√.60	0	√.60

Primary loading decreases

Group 1 loadings		Group 2 loadings	
F1	F2	F1	F2
1	0	**1**	0
√.60-0.4	0	√.60	0
√.60	0	√.60	0
√.60	0	√.60-0.4	0
√.60	0	√.60	0
0	**1**	0	**1**
0	√.60-0.4	0	√.60
0	√.60	0	√.60
0	√.60	0	√.60-0.4
0	√.60	0	√.60

Crossloadings

Group 1 loadings		Group 2 loadings	
F1	F2	F1	F2
1	0	**1**	0
√.60	CL .4	√.60	0
√.60	0	√.60	0
√.60	0	√.60	CL .4
√.60	0	√.60	0
0	**1**	0	**1**
CL .4	√.60	0	√.60
0	√.60	0	√.60
0	√.60	CL.4	√.60
0	√.60	0	√.60

Invariant Crossloadings of .3

Group 1 loadings		Group 2 loadings	
F1	F2	F1	F2
1	0	**1**	0
0	√.60	√.60	0
√.60	CL .3	√.60	CL .3
√.60	0	0	√.60
√.60	0	√.60	0
0	**1**	0	**1**
0	√.60	0	√.60
CL .3	√.60	CL .3	√.60
0	√.60	0	√.60
0	√.60	0	√.60

Results

Table of interactions: RMSE of **LOADINGS**

Type and size of loading differences	Invariant Crossloadings	Models					
		MG-CFA Mis-specified	MG-CFA Correct	MG-EFA	MG-A	MG-FR $w = 0.1$	MG-FR $w = 0.5$
Primary loading shift	No	0.161	0.033	0.056	0.061	0.070	0.116
	Yes	0.190	0.036	0.058	0.064	0.069	0.119
Primary loading decrease .4	No	-	0.032	0.056	0.056	0.051	0.056
	Yes	0.095	0.036	0.059	0.060	0.053	0.055
Crossloading .4	No	0.122	0.037	0.058	0.058	0.053	0.056
	Yes	0.160	0.041	0.065	0.067	0.057	0.058

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Table of interactions: RMSE of STRUCTURAL RELATIONS

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		MG-CFA Mis-specified	MG-CFA Correct	MG-EFA	MG-A	MG-FR w = 0.1	MG-FR w = 0.5
Primary loading shift	No	0.082	0.072	0.077	0.078	0.093	0.215
	Yes	0.166	0.072	0.077	0.081	0.093	0.209
Primary loading decrease .4	No	-	0.073	0.078	0.073	0.071	0.093
	Yes	0.136	0.075	0.081	0.077	0.071	0.086
Crossloading .4	No	0.142	0.073	0.077	0.073	0.070	0.084
	Yes	0.250	0.074	0.089	0.095	0.078	0.086

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Conclusions

- MG-CFA can lead to misspecifications and biased structural relations
- MG-EFA-based methods help to better recover factor loadings and structural relations
- MG-A does not differ substantially from MG-EFA
- MG-FR improved the recovery over MG-EFA for most types of loading differences, except primary loading shifts

➢Use MG-FR (in most cases) to resolve the rotational freedom in MG-ESEM

Many group comparisons: **Mixture** MG-ESEM

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- Can clustering be improved when using an EFA-based MM?
  - Extend MG-ESEM to include clustering in the second step
  - ➢ MMG-ESEM

Many group comparisons: **Mixture** MG-ESEM

- Can clustering be improved when using an EFA-based MM?
  - Extend MG-ESEM to include clustering in the second step
  - ➢ MMG-ESEM
- **CHALLENGES:**
  - choice of simple structure criterion and weight for the agreement part of MG-FR

References

- Asparouhov, T., & Muthén, B. (2014). Multiple-Group Factor Analysis Alignment. *Structural Equation Modeling: A Multidisciplinary Journal*, *21*(4), 495–508. https://doi.org/10.1080/10705511.2014.919210
- De Roover, K., & Vermunt, J. K. (2019). On the Exploratory Road to Unraveling Factor Loading Non-invariance: A New Multigroup Rotation Approach. *Structural Equation Modeling: A Multidisciplinary Journal*, *26*(6), 905–923. https://doi.org/10.1080/10705511.2019.1590778
- Rosseel, Y., & Loh, W. W. (2022). A structural after measurement approach to structural equation modeling. *Psychological Methods*. https://doi.org/10.1037/met0000503

Thank you!

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