Modeling Practice Effects Using a Three-Form Planned Missing Data Design

Terrence D. Jorgensen [1], Mijke Rhemtulla [2], Alexander M. Schoemann [3], Brent McPherson [1], Wei Wu [1], & Todd D. Little [4]

[1] *University of Kansas,* [2] *University of Amsterdam,* [3] *East Carolina University,* [4] *Institute for Measurement, Methodology, Analysis, and Policy at Texas Tech*

Presented 20 May 2014 at Modern Modeling Methods, Storrs, CT

Practice Effects

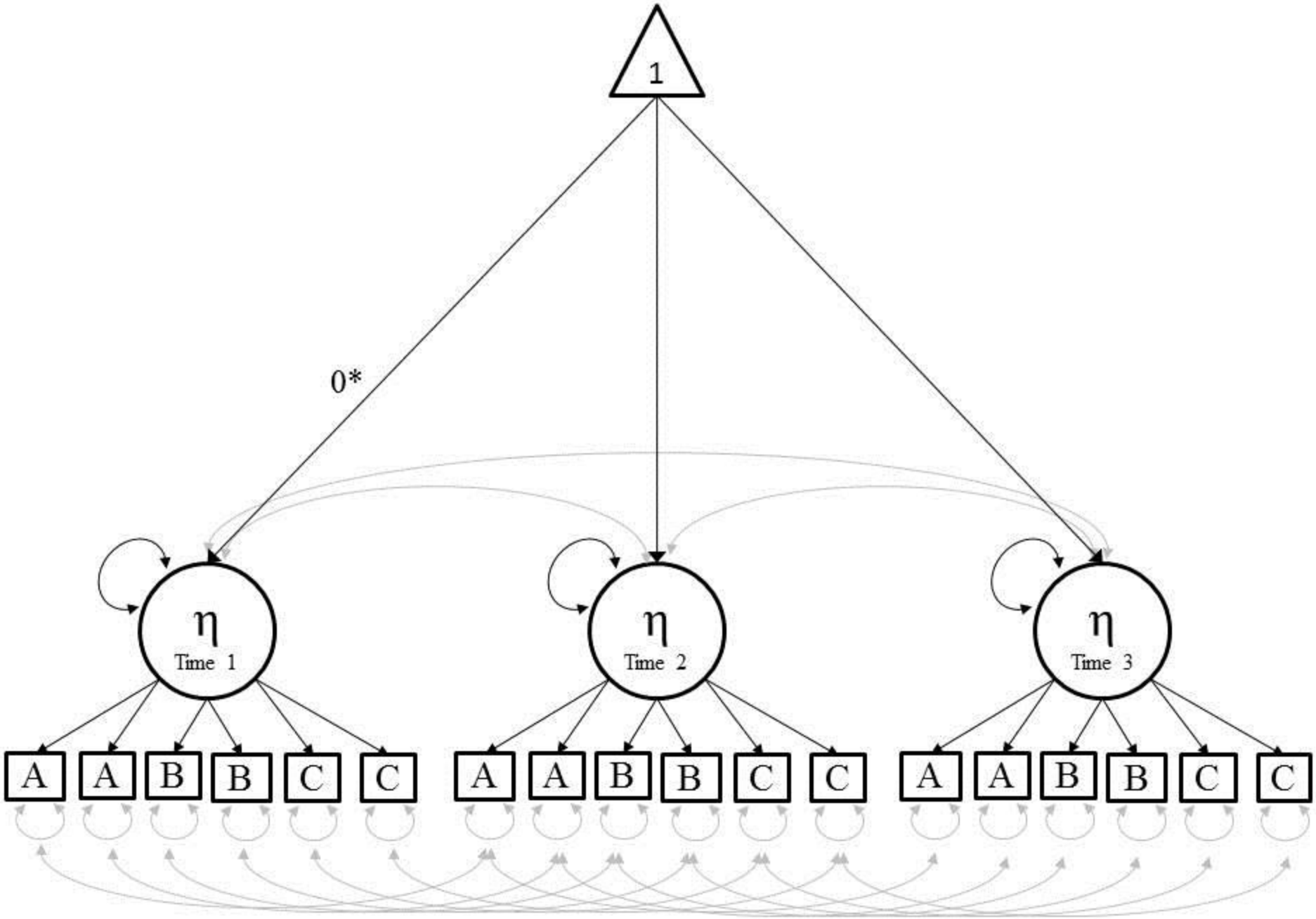
- Can be expected in many contexts when making repeated measurements
  - Development of a skill set or perceptual ability (e.g., cognitive functioning; Salthouse et al., 2004)

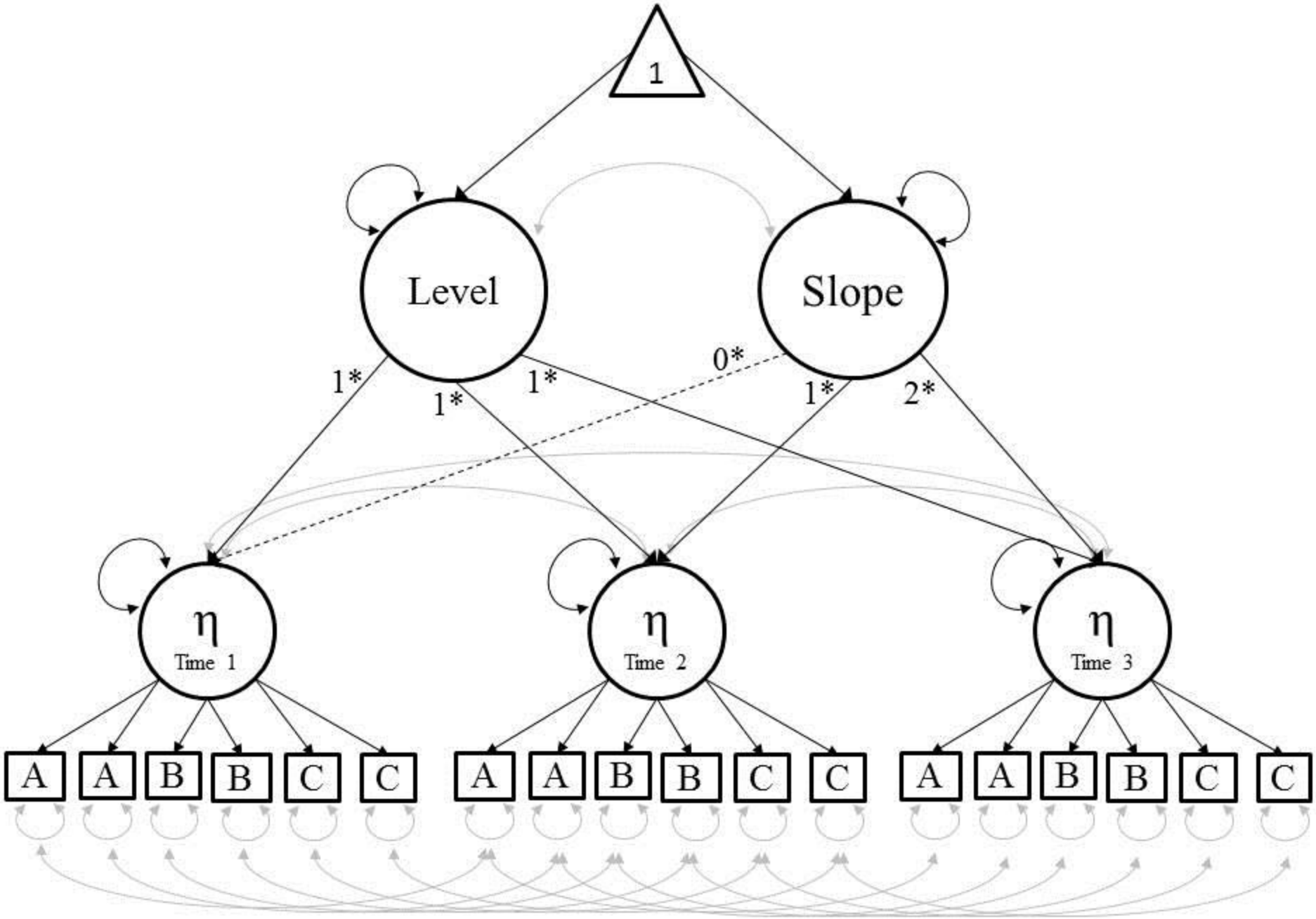
- Cause apparently conflicting effects of age/time
  - Cross-sectional results show declining performance
  - Longitudinal results show improved performance

Practice Effects

- When studying longitudinal development of a skill:
  - Using different tests on each occasion would confound skill development with the test specifics
  - Using the same test would confound skill development with practice

- Can study change using multiple tests on each occasion as indicators of a latent construct
  - Interested in the **latent mean**, not in a particular test


1
0*
η
Time 1
η
Time 2
η
Time 3
A
A
B
B
C
C
A
A
B
B
C
C
A
A
B
B
C
C


1
Level
Slope
1*
1*
1*
0*
1*
2*
η
Time 1
η
Time 2
η
Time 3
A
A
B
B
C
C
A
A
B
B
C
C
A
A
B
B
C
C

Practice Effects in SEM

- If indicators are subject to practice effects, those effects can manifest in the latent means
  - Strong invariance constraints are required to infer changes in the latent mean
- Using a 3-form planned missing data design
  - Participants see only a subset of indicators
  - Indicators seen less often on consecutive occasions
    - Practice effects fade at greater lags (Salthouse et al., 2004)
  - Missing data patterns can be used as predictors of practice effects

Participant	Form	Age	Sex	DV-1 Occupation	DV-2 Genre	DV-3 Volume	Open 1	Open 2	Open 3	Extra 1	Extra 2	Extra 3	Neuro 1	Neuro 2	Neuro 3	Consc 1	Consc 2	Consc 3	Agree 1	Agree 2	Agree 3
1	1	17	F	professor	Classical	loud	4	4	--	1	5	--	1	2	--	4	2	--	3	2	--
2	1	12	F	musician	Funk	soft	1	3	--	2	2	--	5	3	--	4	1	--	2	1	--
3	1	17	M	student	Jazz	soft	2	4	--	5	5	--	2	4	--	5	1	--	4	2	--
4	1	29	M	server	Metal	soft	1	3	--	5	2	--	2	1	--	1	1	--	4	2	--
5	1	17	M	chef	Rock	soft	1	4	--	5	1	--	2	2	--	5	3	--	2	2	--
6	2	11	F	painter	Pop	loud	4	--	4	2	--	1	1	--	5	1	--	5	5	--	3
7	2	19	F	librarian	Alt	loud	1	--	4	4	--	3	4	--	3	4	--	2	4	--	3
8	2	22	F	server	Ska	soft	4	--	2	3	--	3	3	--	3	1	--	2	5	--	5
9	2	18	M	doctor	Punk	loud	1	--	3	2	--	2	2	--	4	4	--	1	3	--	2
10	2	19	F	statistician	Pop	loud	4	--	5	3	--	4	5	--	4	3	--	2	3	--	1
11	3	28	F	chef	Rock	loud	--	3	3	--	5	5	--	5	4	--	3	3	--	2	5
12	3	25	M	nurse	Rock	soft	--	4	5	--	2	2	--	2	5	--	4	5	--	3	5
13	3	19	M	lawyer	Jazz	soft	--	3	4	--	3	2	--	4	5	--	4	5	--	1	2
14	3	18	F	accountant	Metal	soft	--	3	1	--	1	2	--	3	3	--	4	4	--	5	4
15	3	21	F	secretary	Alt	loud	--	4	4	--	1	2	--	1	1	--	5	3	--	4	5

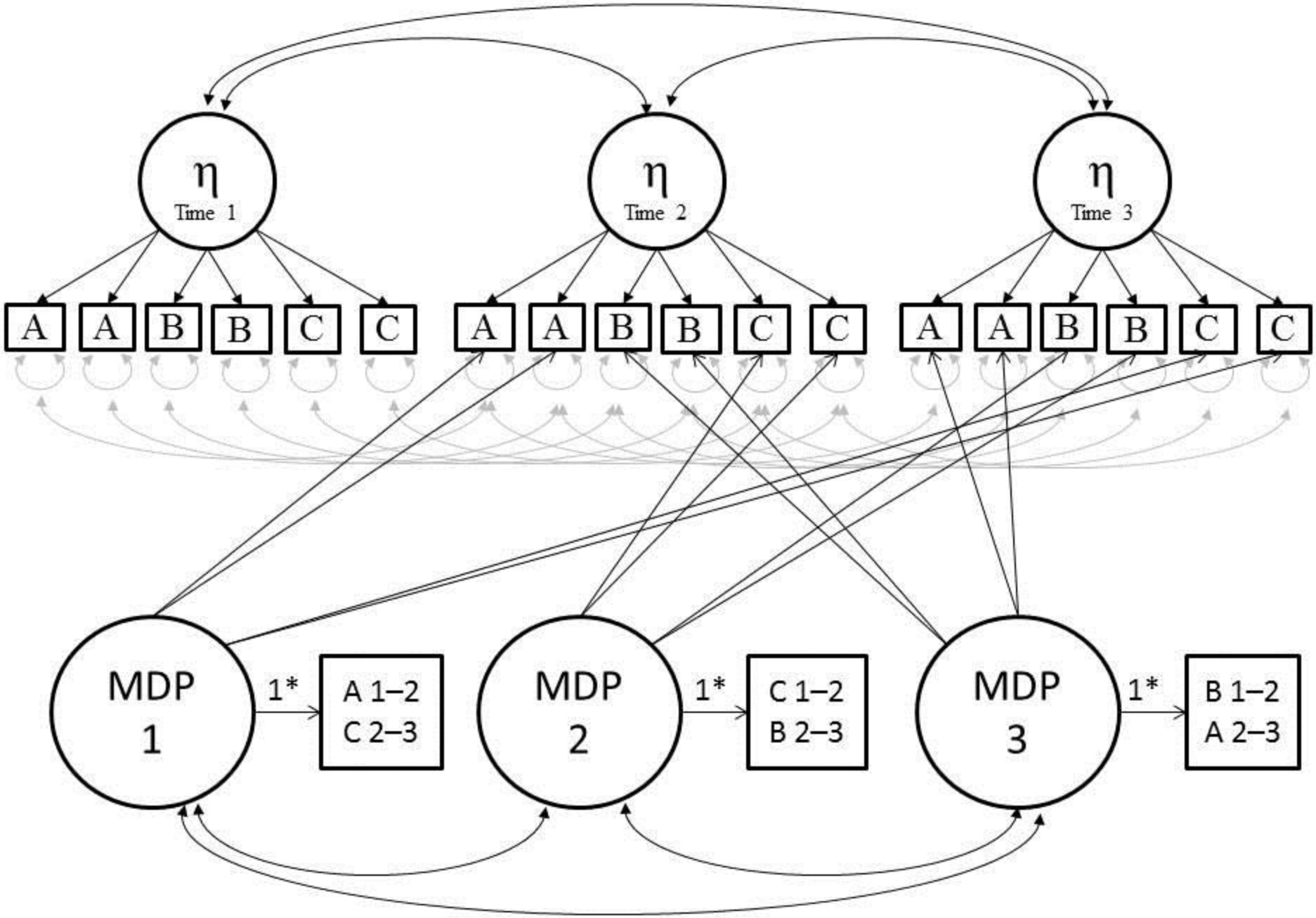
X Block A Block B Block C Block Grey Cells = Planned Missing Data

Missing Data Patterns Across Conditions

Assignment Strategy	Order of Forms	Indicators seen consecutively on: Occasion 2	Occasion 3
Different forms over time	AB–AC–BC	A	C
	AC–BC–AB	C	B
	BC–AB–AC	B	A
Same forms over time	AB–AB–AB	AB	AB
	AC–AC–AC	AC	AC
	BC–BC–BC	BC	BC

Modeling Practice Effects

- Using SEM, 3-form design to study change allows us to separate effects of time from practice
  - Assign different forms over time to minimize variables seen on consecutive occasions
  - Missing data patterns (dummy variables) indicate whether each participant sees an item on consecutive occasions
  - Regressing items on these indicators allows the practice effect to be estimated


η
Time 1
η
Time 2
η
Time 3
A
A
B
B
C
C
A
A
B
B
C
C
A
A
B
B
C
C
MDP
1
1*
A 1–2
C 2–3
MDP
2
1*
C 1–2
B 2–3
MDP
3
1*
B 1–2
A 2–3

Modeling Practice Effects

- Problem:
  - 3 missing data patterns are multicollinear
    - Any dummy variable is a combination of the other two
    - $D_1 = 1 - (D_2 + D_3)$
  - Using only 2 dummy variables (treating the 3rd as a reference group) would not remove practice effects for the third group
- Solution:
  - Add a fourth group (10% from each, or gather new participants) who do not see any items consecutively
  - e.g., reference group sees only Form A, then B, then C

Missing Data Patterns with a 4th (Reference) Group

Groups based on random assignment	Order of Forms	Indicators seen consecutively on: Occasion 2	Occasion 3
Typical groups using a 3-forms design	AB–AC–BC	A	C
	AC–BC–AB	C	B
	BC–AB–AC	B	A
Additional group NO expected practice effects	A – B – C	—	—

Method

- 3-factor CFA (construct measured at 3 times)
  - 6 indicators (2 for each planned-missing form)
- Factor means and variances = 0 & 1
- Factor correlations = 0.5 (lag 1) and 0.25 (lag 2)
- Factor loadings = 0.7
  - Residual variances = $1 - 0.7^2 = 0.51$
- Residual correlations = 0.2 (lag 1) and 0.04 (lag 2)
- Indicator means = 0
  - unless the indicator was seen on the previous occasion
- **Practice effect**: indicator mean increased by 0.1
  - Standard normal variables, so Cohen's $d = 0.1$ (small effect)

2 × 2 × 2 Design

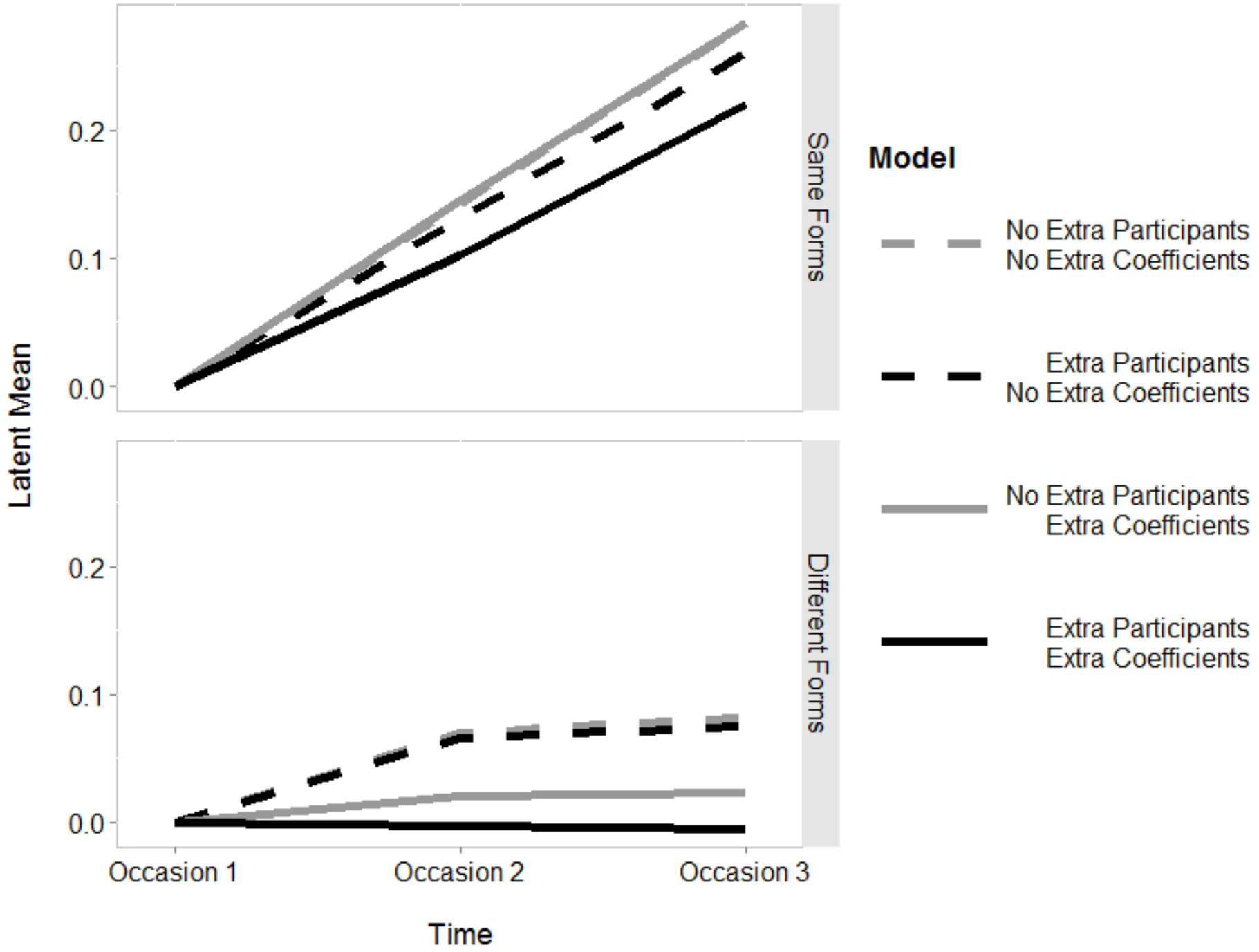
- 2 **assignment methods**
  - Subjects assigned to same or different forms over time
- **Extra coefficients** to estimate practice effect
  - If no, missing-data-pattern indicators excluded from model on next slide (i.e., CFA only)
- **Extra participants** for reference group
  - If no, only 2 of the 3 missing data patterns were used to estimate practice effects; $N = 270$ ($n = 90$ in each group)
  - If yes, additional $n = 30$ participants without practice effect (i.e., they never saw the same indicators twice)
- 1000 replications in each of 8 conditions

Results

- Because the true latent mean = 0 across time, any nonzero estimate indicates contamination

- Only 1 condition with **zero** contamination
  - Different forms, extra participants, extra coefficients
  - Minimal contamination even without extra participants

- Rejection rates for H_0: latent mean = 0
  - Highest for same forms
  - Different forms with extra coefficients: ≤ 6%


Latent Mean
0.2
0.1
0.0
Same Forms
Different Forms
Occasion 1
Occasion 2
Occasion 3
Time
Model
No Extra Participants
No Extra Coefficients
Extra Participants
No Extra Coefficients
No Extra Participants
Extra Coefficients
Extra Participants
Extra Coefficients

Latent Means and Rejection Rates Across Conditions

Assignment Strategy	Extra Coefficients	Extra Participants	Occasion 2 Mean	Occasion 2 Rejection	Occasion 3 Mean	Occasion 3 Rejection
Different forms	No	No	0.07	17%	0.08	15%
		Yes	0.07	15%	0.08	14%
	Yes	No	**0.02**	**6%**	**0.02**	**6%**
		Yes	**0.00**	**6%**	**0.00**	**5%**
Same forms	No	No	0.14	50%	0.28	91%
		Yes	0.13	45%	0.26	89%
	Yes	No	0.15	33%	0.28	74%
		Yes	0.10	15%	0.22	44%

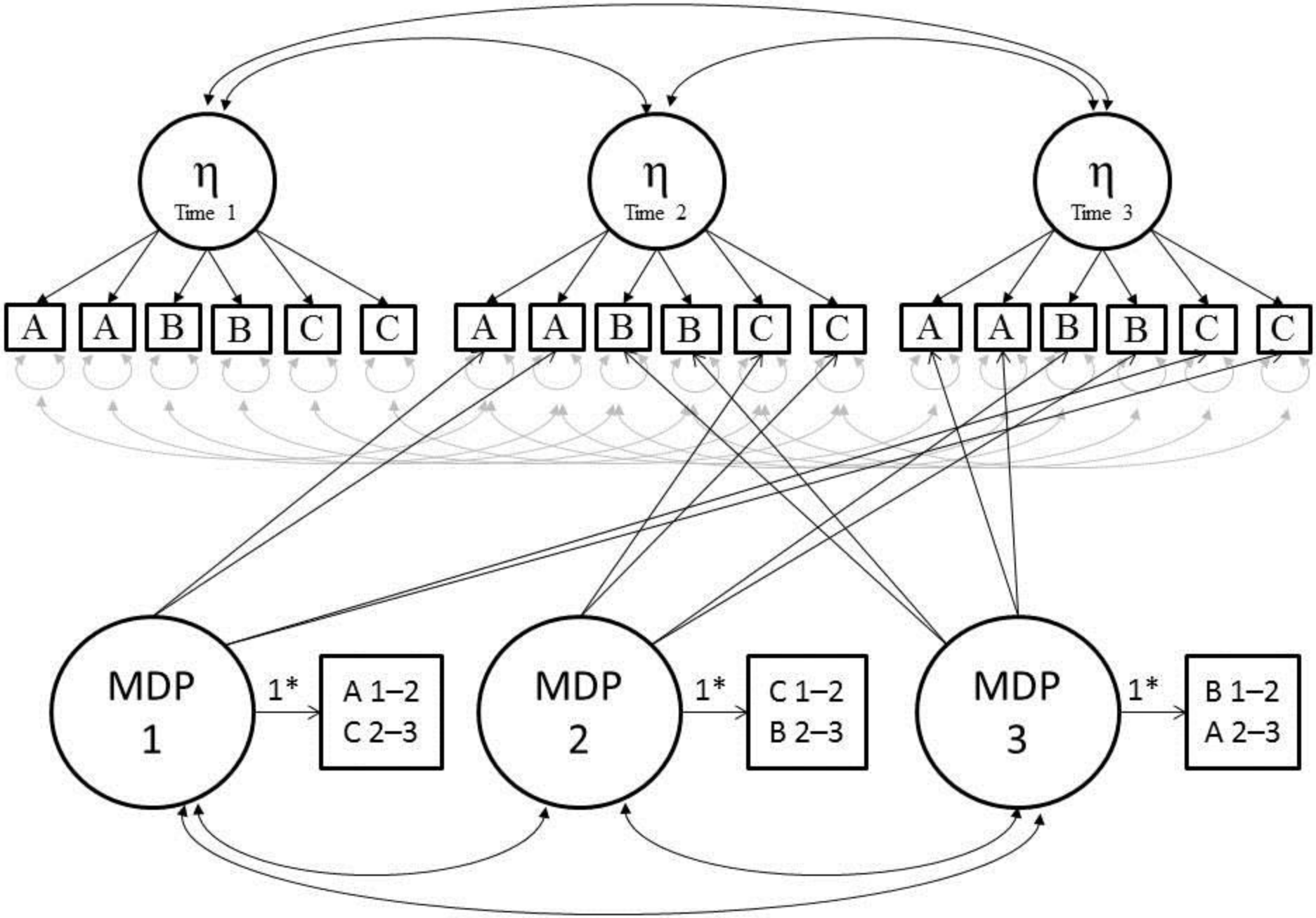
Conclusion

- To prevent practice effects from contaminating estimates of latent means
  - Use a multiform planned missing design
  - Assign participants to different forms over time
  - Estimate practice effects using missing data patterns
  - Include a small reference group with no (or minimal) expected practice effects
    - Excluding the extra reference group **seemed** to work well in this simulation, when the other 2 conditions were satisfied
    - **CAVEAT**: Using extra coefficients *without* extra participants results in **failing** tests of strong invariance

Rates of Passing Tests of Strong Invariance

		Extra Coefficients	
Extra Participants	Criterion	Yes	No
Yes	$\Delta\chi^2(df = 10, \alpha = .05)$	94.8%	93.4%
	ΔCFI < 0.01	99.8%	97.8%
	ΔCFI < 0.002	96.2%	78.0%
No	$\Delta\chi^2(df = 10, \alpha = .05)$	38.4%	94.0%
	ΔCFI < 0.01	72.6%	97.0%
	ΔCFI < 0.002	43.8%	77.4%

Note. Cheung & Rensvold (2002) proposed ΔCFI < 0.01, whereas Meade, Johnson, & Braddy (2008) proposed ΔCFI < 0.002.


η
Time 1
η
Time 2
η
Time 3
A
A
B
B
C
C
A
A
B
B
C
C
A
A
B
B
C
C
MDP
1
1*
A 1–2
C 2–3
MDP
2
1*
C 1–2
B 2–3
MDP
3
1*
B 1–2
A 2–3

Future Research

- Only investigated a small practice effect, with no true change in the latent mean
  - Recover true change when there is true change?
  - Recover true change when effect is more persistent?
  - Strong invariance when practice effects are larger?
  - Vary magnitude of true change and practice effect
- Extend panel model to latent growth curve
  - Recover true slope when practice effects estimated?
  - Infer incorrect functional form (linear/quadratic) when practice effect contaminates latent means?

Acknowledgements

This study was supported by

- Grant NSF 1053160 (Wei Wu & Todd D. Little, co-PIs),
- Center for Research Methods and Data Analysis at the University of Kansas (when Todd D. Little was director; 2009–2013)
  - Todd D. Little is now director of the Institute for Measurement, Methodology, Analysis, and Policy at Texas Tech University
- A Banting postdoctoral fellowship from the Social Sciences and Humanities Research Council of Canada awarded to Mijke Rhemtulla

References

Salthouse, T. A., Schroeder, D. H., & Ferrer, E. (2004). Estimating retest effects in longitudinal assessments of cognitive functioning in adults between 18 and 60 years of age. *Developmental Psychology, 40*(5), 813–822. doi:10.1037/0012-1649.40.5.813

Data were simulated using the R package simsem (http://simsem.org/)

Models were fit using FIML in lavaan 0.5-16 (http://lavaan.ugent.be/)

Pornprasertmanit, S., Miller, P., & Schoemann, A. M. (2013). simsem: SIMulated structural equation modeling (version 0.5-3) [R package]. Available from the Comprehensive R Archive Network: http://cran.r-project.org/

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software, 48*, 1–36. Retrieved from http://www.jstatsoft.org/v48/i02/

Contact Information

I'm happy to share these slides.

tdj@ku.edu

Some of this material is published (as Study 2) as an online advanced copy in the *International Journal of Behavioral Development*

Jorgensen, T. D., Rhemtulla, M., Schoemann, A. M., McPherson, B., Wu, W., & Little T. D. (2014). Optimal assignment methods in three-form planned missing data designs for longitudinal panel studies. *International Journal of Behavioral Development*. doi:10.1177/0165025414531094