Centering lower-level interactions in multilevel models

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Longitudinal diary study on sexual behavior in Flanders

- Info on 66 heterosexual couples
  - Here, we only focus on men's data
- Daily measures during 3 weeks:
  - Daily morning reports on sexual and intimate behavior: amount of intimate acts (kissing, cuddling and caressing) measured on a 7-point scale
  - Daily evening reports on positive relationship feelings: average score of 9 items (happy, satisfied, understood, . . .) measured on a 7-point scale

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Question: What is the contribution of intimacy to next-day positive relationship feelings?

Standard multilevel modeling

In our example:

- X_{ij}: daily measurement of intimacy of individual j at time i
- Y_{ij}: next day's positive relational feelings

Standard analysis by a multilevel model with random intercept b_j:

$$E(Y_{ij}|X_{ij}, b_j) = \gamma_0 + \gamma X_{ij} + b_j \tag{1}$$

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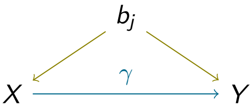

Unfortunately, there may be upper level endogeneity!

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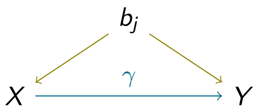

(1) assumes that b_j and X_{ij} are independent
$\Rightarrow$ biased estimator for γ under upper-level endogeneity!

Centring of lower level effects

A solution to the upper-level endogeneity problem is to separate within- from between-effects:

$$E(Y_{ij} \mid X_{ij}, u_j) = \gamma_0 + \gamma_W X_{ij}^c + \gamma_B \overline{X}_j + b_j \tag{2}$$

$$\text{with } \overline{X}_j = \tfrac{1}{n_j} \textstyle\sum_{i=1}^{n_j} X_{ij} \text{ and } X_{ij}^c = X_{ij} - \overline{X}_j$$

- γ_W captures the within-subject effect
- γ_B captures the between-subject effect

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- The OLS-estimator for γ_W will converge to (in balanced designs):

$$\hat{\gamma}_W = \frac{\mathrm{cov}(Y_{ij}, X_{ij} - \overline{X}_j)}{\mathrm{var}(X_{ij} - \overline{X}_j)} \to \gamma \tag{3}$$

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$\Rightarrow$ No bias!

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(note that $\overline{X}_j$ can also be excluded from (2), as $\overline{X}_j \perp\!\!\!\perp X_{ij}^c$)

Revisited: Longitudinal study on sexual behavior in Flanders

New question: Does the effect of intimacy on next-day positive relationship feelings differ according to whether or not the participant has masturbated the previous day?

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$\Rightarrow$ Lower level interaction term!

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- b_j may again be correlated with X, Y and/or Z in case of upper level endogeneity
- The 'naive' model may then again yield biased estimators for the γ's

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$$\overline{X}_j * \overline{Z}_j \qquad\qquad X^c_{ij} * Z^c_{ij}$$

Question: which approach should we take? Do they differ in any way?

The P1C2-approach

- P1C2 model:

$$E(Y_{ij} \mid X_{ij}, Z_{ij}, u_j) = \gamma_0 + \gamma_1 X_{ij}^c + \gamma_2 Z_{ij}^c + \gamma_3 (XZ)_{ij}^c + b_j \quad (5)$$

with $(XZ)_{ij}^c = X_{ij}Z_{ij} - \overline{XZ}_j$ (and $\overline{XZ}_j = \frac{1}{n_j}\sum_{i=1}^{n_j} X_{ij}Z_{ij}$)

$\Rightarrow \hat{\gamma}_1$, $\hat{\gamma}_2$ and $\hat{\gamma}_3$ are unbiased estimators for γ_1, γ_2 and γ_3

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- P1C2+ model:

$$E(Y_{ij} \mid X_{ij}, Z_{ij}, u_j) = \gamma_0 + \gamma_1 X^c_{ij} + \gamma_2 Z^c_{ij} + \gamma_3 (XZ)^c_{ij} + \gamma_4 \overline{X}_j + \gamma_5 \overline{Z}_j + \gamma_6 \overline{XZ}_j + b_j$$

$\Rightarrow$ in balanced designs, the estimated within-effects $\hat{\gamma}_1$, $\hat{\gamma}_2$ and $\hat{\gamma}_3$ are identical in both models

The C1P2-approach

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- C1P2++ model:

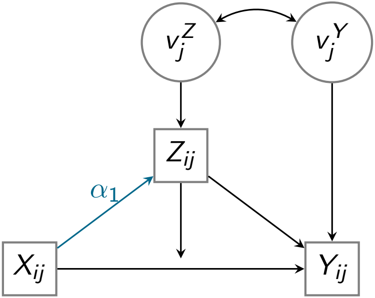
$$E(Y_{ij} \mid X_{ij}, Z_{ij}, u_j) = \gamma_0 + \gamma_1 X^c_{ij} + \gamma_2 Z^c_{ij} + \gamma_3 X^c_{ij} Z^c_{ij} + \gamma_4 \overline{X}_j + \gamma_5 \overline{Z}_j + \gamma_6 \overline{X}_j \overline{Z}_j + \gamma_7 \overline{X}_j Z^c_{ij} + \gamma_8 \overline{Z}_j X^c_{ij} + b_j$$

Example - Results

	Intimacy = X		*Masturbation* = Z		*Interaction* = XZ	
	Estimate	*p*-value	Estimate	*p*-value	Estimate	*p*-value
P1C2	0.079 (0.015)	$<$ .001	-0.151 (0.079)	.057	.-0.075 (0.039)	.054
P1C2+	0.079 (0.015)	$<$ .001	-0.150 (0.079)	.059	.-0.075 (0.039)	.054
C1P2	0.080 (0.015)	$<$ .001	-0.163 (0.080)	.042	.-0.102 (0.050)	.042
C1P2+	0.080 (0.015)	$<$ .001	-0.160 (0.080)	.045	.-0.098 (0.045)	.049
C1P2++	0.080 (0.015)	$<$ .001	-0.167 (0.080)	.037	.-0.096 (0.050)	.056

- Different approaches lead to different estimates
- Different approaches lead to different conclusions (at the 5% significance level)!

Simulation Study - Settings



Simulation	α_1	Distribution of X
Sim 1	0.0	$N(0,1)$
Sim 2	0.0	$B(1,0.5) - 0.5$
Sim 3	-0.2	$B(1,0.5) - 0.5$
Sim 4	-1.5	$B(1,0.5) - 0.5$

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- Bias for interaction effect in C1P2=C1P2+ when Z is a mediator:

$$E(\hat{\gamma}_3) = \gamma_3 \frac{\mathrm{cov}[X_{ij}Z_{ij}, X_{ij}^c Z_{ij}^c]}{\mathrm{var}[X_{ij}^c Z_{ij}^c]} \quad (7)$$

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- No bias for P1C2 = P1C2+ and C1P2++
- Precision of interaction effect estimator is about 30% smaller for P1C2 compared to C1P2++

Conclusions

1. P1C2 yields more precise estimators of the interaction effect compared to the C1P2-approaches

2. In contrast to C1P2, P1C2 is not affected by misspecification or omission of upper level effects (i.e. upper level endogeneity)

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1. P1C2 yields more precise estimators of the interaction effect compared to the C1P2-approaches
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Thank you!

Possible complication when the predictors are NOT centred

- Again consider C1P2 or C1P2+:

$$E(Y_{ij} \mid X_{ij}, Z_{ij}, u_j) = \gamma_0 + \gamma_1 X_{ij}^c + \gamma_2 Z_{ij}^c + \gamma_3 X_{ij}^c Z_{ij}^c + b_j$$

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- Bias in main effects for these approaches:

$$\begin{aligned} E[\hat{\gamma}_1] = \beta_1 + \beta_3 E(\overline{Z}_j) \\ E[\hat{\gamma}_2] = \beta_2 + \beta_3 E(\overline{X}_j) \end{aligned}$$

Results - Simulation Study

	Estimator	$\hat{\gamma}_1$				$\hat{\gamma}_2$				$\hat{\gamma}_3$			
		Estimate (sd_E)	*se*	Coverage	Power	Estimate (sd_E)	*se*	Coverage	Power	Estimate (sd_E)	*se*	Coverage	Power
Sim 1	P1C2	0.101 (0.031)	0.028	0.92	0.93	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.019)	0.020	0.95	1.00
	C1P2	0.101 (0.032)	0.028	0.92	0.92	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.029)	0.029	0.95	0.94
	C1P2++	0.101 (0.031)	0.028	0.93	0.93	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.029)	0.029	0.95	0.94
Sim 2	P1C2	0.103 (0.056)	0.055	0.95	0.46	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.040)	0.039	0.95	0.72
	C1P2	0.103 (0.056)	0.055	0.95	0.47	0.100 (0.027)	0.028	0.96	1.00	-0.099 (0.058)	0.058	0.95	0.41
	C1P2++	0.103 (0.056)	0.056	0.95	0.46	0.150 (0.027)	0.028	0.96	1.00	-0.099 (0.058)	0.058	0.95	0.41
Sim 3	P1C2	0.103 (0.056)	0.055	0.95	0.46	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.040)	0.039	0.95	0.72
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Sim 4	P1C2	0.103 (0.068)	0.069	0.95	0.33	0.150 (0.027)	0.028	0.96	1.00	-0.101 (0.040)	0.039	0.95	0.72
	C1P2	0.103 (0.068)	0.069	0.95	0.33	0.150 (0.027)	0.028	0.96	1.00	**-0.090 (0.055)**	0.055	0.95	0.37
	C1P2++	0.103 (0.068)	0.069	0.96	0.33	0.150 (0.027)	0.028	0.96	1.00	-0.099 (0.055)	0.056	0.96	0.41