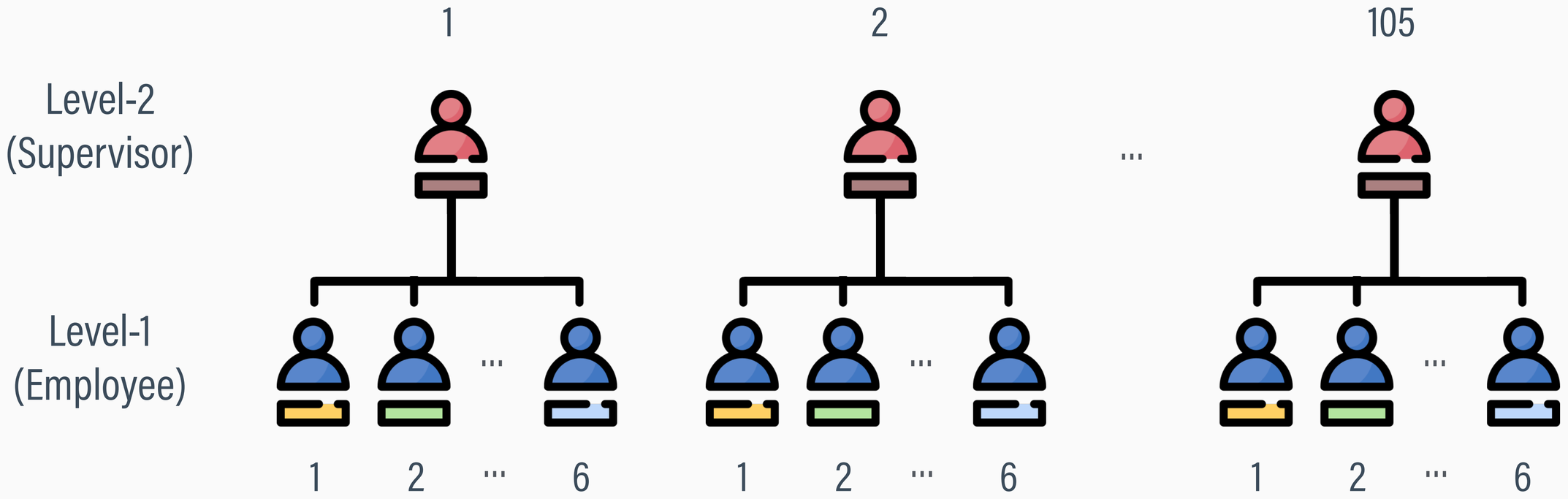
MODULE 6

INTERACTION EFFECTS

ORGANIZATIONAL APPLICATION

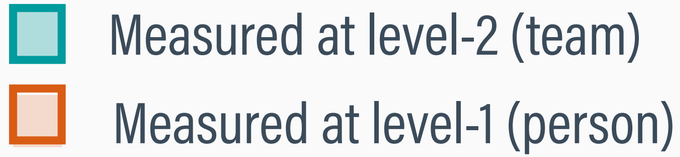
- n_j = 6 employees at level-1 nested within J = 105 teams or workgroups at level-2 (N = 630 data records in total)



VARIABLE INFORMATION

Variable	Definition	Level	Scale
Team	Team-level (level-2) identifier	2	Integers (1 to 105)
Empower	Employee empowerment	1	Numeric (14 to 42)
LMX	Leader–member exchange (supervisor–supervisee relationship quality)	1	Numeric (0 to 17)
Male	Male dummy code	1	Female = 0, Male = 1
Climate	Leadership climate	2	Numeric (10 to 33)

CONCEPTUAL MODEL



- The conceptual model includes three level-1 predictors

empowerment = mean + lmx + male + climate + lmx*climate

- The level-1 predictors may require disaggregation
- The effects of the level-1 predictors may vary across level-2 units (slope coefficients could be “random”)

OUTLINE

1. Random Coefficient Model
2. Interaction Effects (Moderation)
3. Moderated Regression Example
4. Conditional Effects (Simple Slopes)

WITHIN-CLUSTER (LEVEL-1) MODEL

- Both the team-specific empowerment mean (β_{0j}) and the leader-member exchange slope (β_{1j}) vary across clusters, but the gender difference (β_2) is constant

$$empower_{ij} = \beta_{0j} + \beta_{1j}(lmx_{ij}^{w}) + \beta_2(male_{ij}) + \varepsilon_{ij}$$

- Assumption: residuals are normal with constant variation across all persons (level-1 units) and teams (level-2 units)

$$\varepsilon_{ij} \sim N(0,\sigma_{\varepsilon}^2)$$

BETWEEN-CLUSTER (LEVEL-2) MODEL

- The empowerment mean for team j (β_{0j}) is the sum of the grand mean (γ_{00}), a pair of level-2 effects (γ_{01} and γ_{02}), and a between-team residual (u_{0j})
- The LMX slope for team j (β_{1j}) is the sum of the mean slope (γ_{10}) and a team-level residual (u_{1j})
- Assumption: random intercept and slope residuals are bivariate normal *and correlated*

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{lmx}_j^b) + \gamma_{02}(\text{climate}_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + u_{1j}$$

$$\beta_2 = \gamma_{20}$$

$$\begin{pmatrix} u_{0j} \\ u_{1j} \end{pmatrix} \sim N(0, \Sigma_u) \qquad \Sigma_u = \begin{pmatrix} \sigma^2_{u0} & \sigma_{u0u1} \\ \sigma_{u1u0} & \sigma^2_{u1} \end{pmatrix}$$

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$\text{empower}_{ij} = \gamma_{00} + \gamma_{10}(\text{lmx}^{w}_{ij}) + \gamma_{20}(\text{male}_{ij})$$
$$+ \gamma_{01}(\text{lmx}^{b}_{j}) + \gamma_{02}(\text{climate}_{j}) + u_{0j} + (u_{1j})(\text{lmx}^{w}_{ij}) + \varepsilon_{ij}$$

Standard(ish) regression notation (Scott, Shrout, & Weinberg, 2013)

$$\text{empower}_{ij} = \beta_0 + \beta_1(\text{lmx}^{w}_{ij}) + \beta_3(\text{male}_{ij})$$
$$+ \beta_4(\text{lmx}^{b}_{j}) + \beta_5(\text{climate}_{j}) + u_{0j} + (u_{1j})(\text{lmx}^{w}_{ij}) + \varepsilon_{ij}$$

Consider the within-team association between LMX and empowerment. What effect(s) being controlled for? Consider the between-team association between climate and empowerment. What effect(s) being controlled for?

BLIMP SCRIPT 6.1

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;    # automatic dummy coding with lowest group as the reference
CLUSTERID: Team;
CENTER: groupmean = LMX; grandmean = Male LMX.mean Climate;
MODEL: Empower ~ intercept LMX Male LMX.mean Climate | intercept LMX;
BURN: 10000;
ITERATIONS: 20000;
SEED: 90291;
```

RBLIMP SCRIPT 6 (MODEL 1)

```
model1 <- rblimp(
        data = Employee,
        nominal = 'Male',   # automatic dummy coding with lowest group as the reference
        clusterid = 'Team',
        center = 'groupmean = LMX; grandmean = Male LMX.mean Climate',
        model = 'Empower ~ intercept LMX Male LMX.mean Climate | intercept LMX',
        seed = 90291,
        burn = 10000,
        iter = 20000)
output(model1)
posterior_plot(model1, 'Empower')
```

PSR DIAGNOSTIC OUTPUT

Quality control check: PSR diagnostics all < 1.05 well before the end of the burn-in period

BURN-IN POTENTIAL SCALE REDUCTION (PSR) OUTPUT:

NOTE: Split chain PSR is being used. This splits each chain's iterations to create twice as many chains.

Comparing iterations across 2 chains	Highest PSR	Parameter #
251 to 500	1.153	23
501 to 1000	1.119	8
751 to 1500	1.055	8
1001 to 2000	1.087	17
...	...	..
2501 to 5000	1.031	17
2751 to 5500	1.028	17
3001 to 6000	1.055	8
3251 to 6500	1.029	1
3501 to 7000	1.030	1
3751 to 7500	1.018	1
4001 to 8000	1.022	8
4251 to 8500	1.030	8
4501 to 9000	1.033	8
4751 to 9500	1.018	1
5001 to 10000	1.023	1

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

Quality control check: Number of effective MCMC samples diagnostics all > 100

Outcome Variable: Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	1.018	0.556	0.191	2.341	---	---	352.667
L2 : Cov(LMX,Intercept)	-0.185	0.144	-0.483	0.091	---	---	640.151
L2 : Var(LMX)	0.191	0.076	0.074	0.371	---	---	1056.219
Residual Var.	12.294	0.813	10.847	14.028	---	---	4250.904
Coefficients:							
Intercept	28.614	0.232	28.153	29.061	15164.051	0.000	2767.005
LMX	0.633	0.071	0.493	0.773	78.803	0.000	4710.558
Male.1	1.893	0.304	1.298	2.493	38.754	0.000	13091.625
LMX.mean[Team]	-0.173	0.311	-0.870	0.360	0.388	0.533	659.253
Climate	0.292	0.053	0.191	0.398	30.924	0.000	2907.776
...							
Proportion Variance Explained							
by Coefficients	0.289	0.035	0.219	0.357	---	---	2479.671
by Level-2 Random Intercepts	0.049	0.025	0.009	0.108	---	---	334.993
by Level-2 Random Slopes	0.073	0.027	0.028	0.136	---	---	1005.413
by Level-1 Residual Variation	0.585	0.038	0.510	0.661	---	---	2076.889

BLIMP OUTPUT

= level-2 estimate

= level-1 estimate

= combined estimate

```
Outcome Variable:  Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX
```

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
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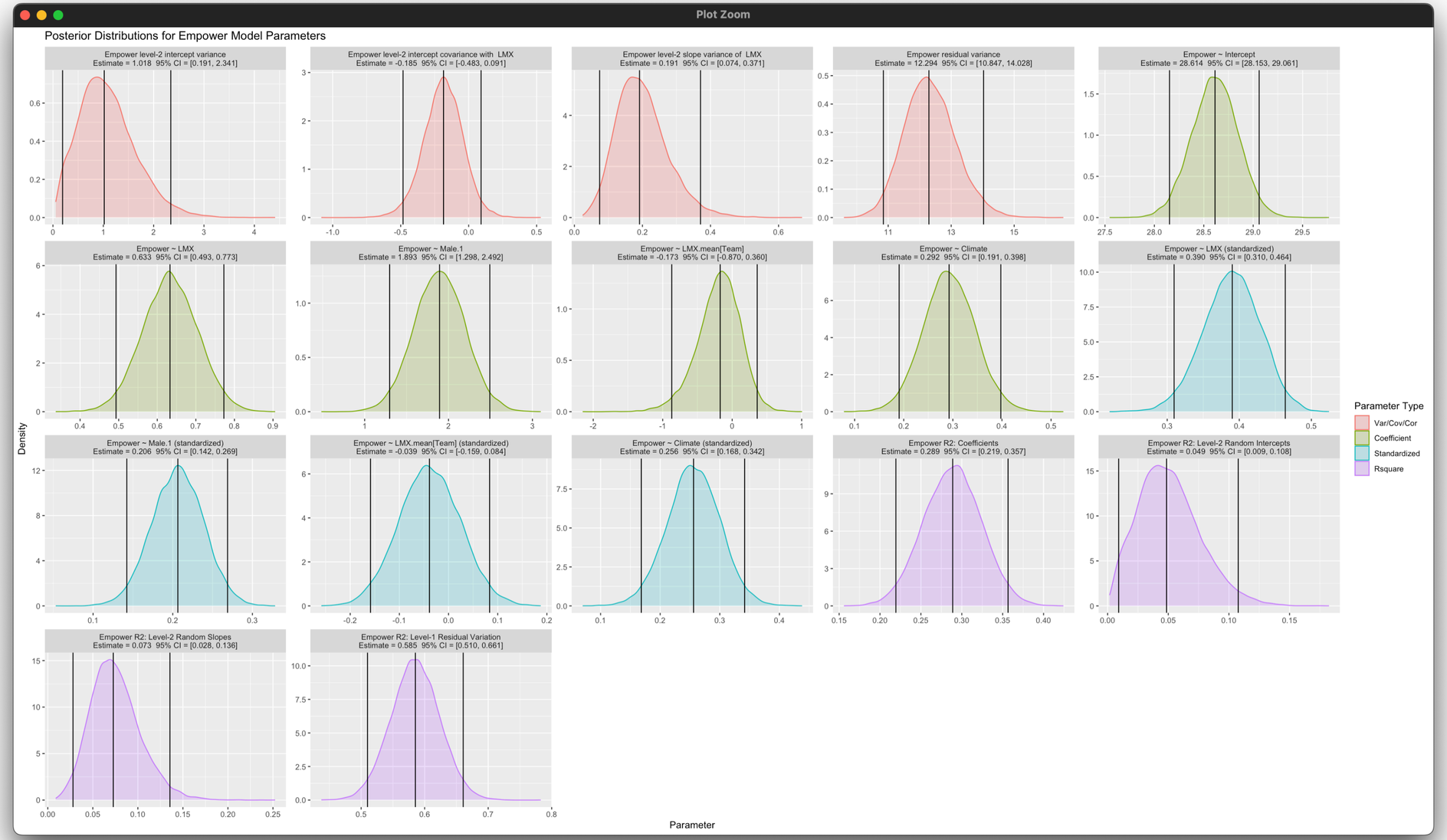
PARAMETER PLOTS (RBLIMP ONLY)



INTERPRETATIONS: FIXED EFFECTS

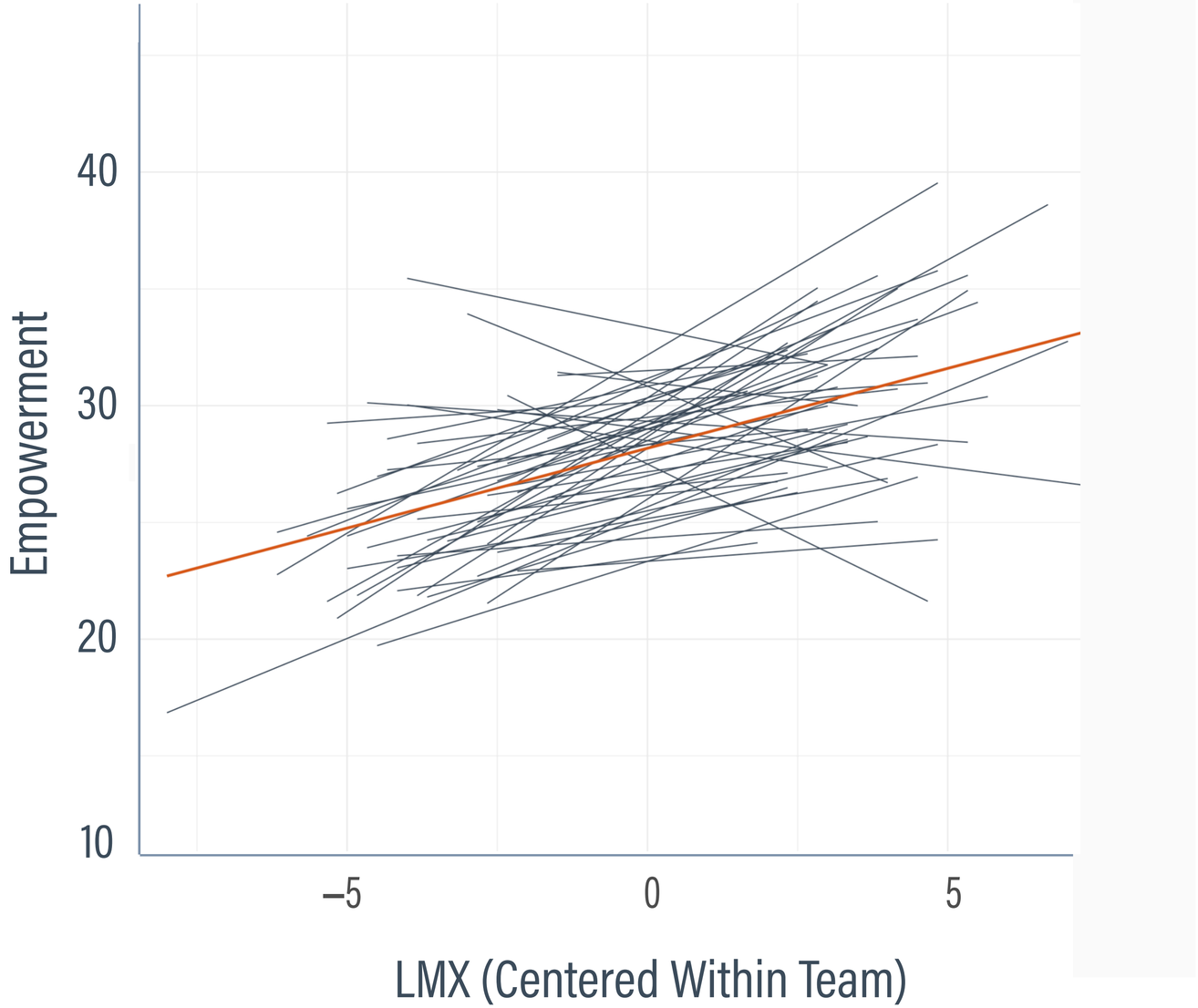
Parameter	Est.	Interpretation
Fixed intercept	28.61	Expected empowerment for a supervisee with zero values on the predictors (the grand mean because all predictors are centered)
LMX (within-team)	0.63	Expected empowerment difference between two people *from the same team* with LMX scores that differ by one point, controlling for gender
Gender (mostly within-team)	1.89	Expected empowerment difference between a male and female *from the same team,* controlling for LMX
LMX (between-team)	–0.17	Expected empowerment mean difference between two teams with average LMX ratings that differ by one point, controlling for team climate
Climate (between-team)	0.29	Expected empowerment mean difference between two teams with climate ratings that differ by one point, controlling for team-average LMX

INTERPRETATIONS: RANDOM EFFECTS

Parameter	Est.	Interpretation
Between-cluster intercept variance (variance of u_{0j} residuals)	1.02	Average squared distance between the team-average predicted and observed empowerment means (residual level-2 mean differences)
Between-cluster slope variance (variance of u_{1j} residuals)	0.19	Average squared distance between the team-specific LMX slopes and the mean slope
Intercept–slope covariance (covariance of u_{0j} and u_{1j} residuals)	–0.19	Negative association where teams with higher empowerment means (intercepts) tend to have lower (less positive) LMX slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	12.29	Average squared distance between a supervisee's observed and predicted empowerment scores (residual within-cluster variation)

RANDOM SLOPE HETEROGENEITY

- The random slope variance (σ^2_{u1} = 0.19) quantifies differences among team-specific LMX slopes
- Visually, the random slope variance is the degree to which team-specific slopes deviate from parallel
- Slope variation can be an outcome!

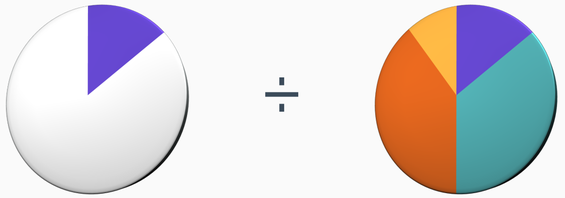


VARIANCE EXPLAINED MEASURES

Explained ÷ Total

Fixed effects of predictors

$$R^2_{predictors} = \frac{\boldsymbol{\beta}^T \boldsymbol{\Sigma}_X \boldsymbol{\beta}}{\sigma^2_Y}$$

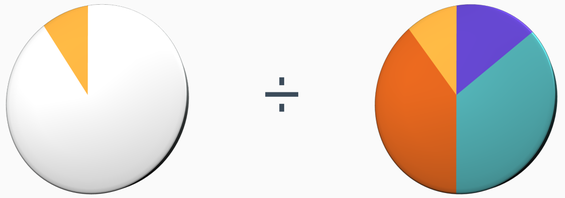


Level-2 random intercept residuals

$$R^2_{slopes} = \frac{tr(\boldsymbol{\Sigma}_u \boldsymbol{\Sigma}_X)}{\sigma^2_Y}$$

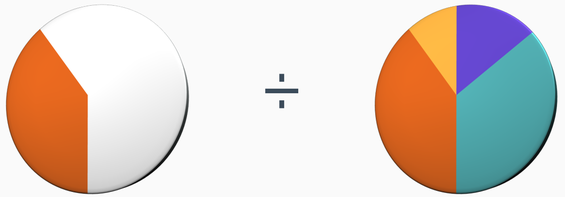
Level-2 random slope residuals

$$R^2_{intercepts} = \frac{\sigma^2_u}{\sigma^2_Y}$$



Level-1 within-cluster residuals

$$R^2_{residual(within)} = \frac{\sigma^2_\varepsilon}{\sigma^2_Y}$$



R^2 EFFECT SIZE MEASURES

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INTERPRETATIONS

- Effect sizes for the level-1 and level-2 residuals are not explained variance, per se, but rather proportions that convey the size of the residual variation

R^2 Effect Size	Est.	Interpretation
Predictors	.29	The level-1 and level-2 predictors explain 29% of the total variation in empowerment
Between-cluster intercept variance (variance of u_{0j} residuals)	.05	Residual between-team variation in the level-2 empowerment means (variance of u_{0j} residuals = 1.02) accounts for 5% of the total variation
Between-cluster slope variance (variance of u_{1j} residuals)	.07	Between-team variation in the random slopes (variance of u_{1j} residuals = 0.19) accounts for 7% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.59	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 12.29) accounts for 59% of the total variation

OUTLINE

1. Random Coefficient Model
2. Interaction Effects (Moderation)
3. Moderated Regression Example
4. Conditional Effects (Simple Slopes)

MODERATION

- Moderation occurs when a focal predictor's influence on the outcome depends on a third (moderator) variable
- For whom does an effect apply?
- We model moderation effects by including the product of two predictors in the regression model (e.g., $Y = X + M + X \times M$)

MODERATED REGRESSION

- β_1 is the influence of the focal predictor *when the moderator equals zero* (i.e., a conditional effect), and β_2 is the effect of the moderator *when the focal predictor equals zero*

$$outcome_i = \beta_0 + \beta_1(focal_i) + \beta_2(moderator_i) + \beta_3(focal_i)(moderator_i) + \varepsilon_{ij}$$

- β_3 is the change in β_1 for a one-unit increase in the moderator

DISAGGREGATION REVISITED

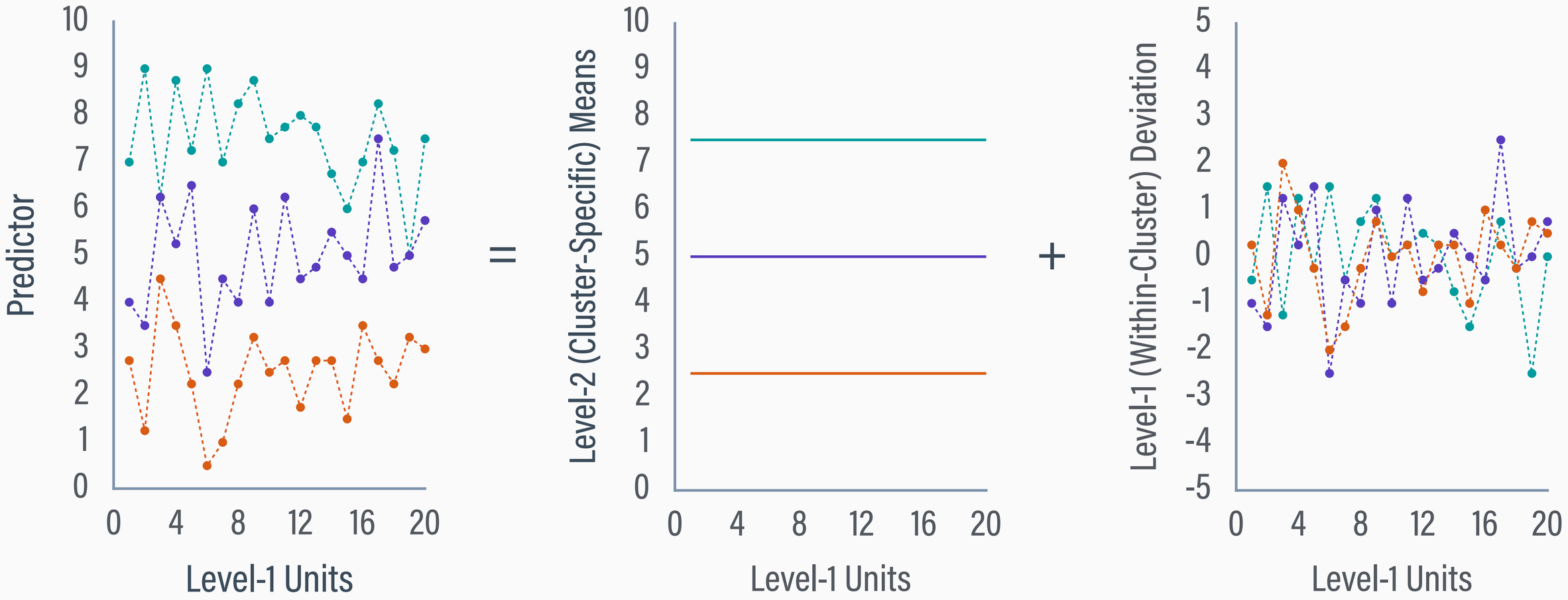
- The literature generally recommends disaggregating level-1 predictor variables into two distinct, uncorrelated variables

$$X_{ij} = X_j^b + X_{ij}^w = \text{cluster mean} + \text{within-cluster deviation}$$

- The level-2 cluster means define a between-cluster variable (X_j^b), and deviations around the level-2 means define a pure within-cluster variable (X_{ij}^w)

DISAGGREGATION GRAPHIC

Score = Level-2 (Between-Cluster) Mean + Level-1 (Within-Cluster) Residual



LEVEL-1 BY LEVEL-1 INTERACTION

- The interaction between a pair of level-1 variables can be disaggregated into four distinct product terms: the cluster means interact, cluster means moderate within-cluster effects, and the within-cluster predictors interact

$$(\text{focal}_{ij})(\text{moderator}_{ij}) = (\text{focal}_{j}^{b} + \text{focal}_{ij}^{w})(\text{moderator}_{j}^{b} + \text{moderator}_{ij}^{w})$$

$$= (\text{focal}_{j}^{b})(\text{moderator}_{j}^{b}) \quad \text{Between-cluster (level-2) product}$$

$$+ (\text{focal}_{j}^{b})(\text{moderator}_{ij}^{w}) \quad \text{Cross-level product}$$

$$+ (\text{focal}_{ij}^{w})(\text{moderator}_{j}^{b}) \quad \text{Cross-level product}$$

$$+ (\text{focal}_{ij}^{w})(\text{moderator}_{ij}^{w}) \quad \text{Within-cluster (level-2) product}$$

LEVEL-1 BY LEVEL-2 INTERACTION

- The interaction between a level-1 predictor and level-2 moderator can be disaggregated into two distinct products

- The cluster means interact, and the level-2 predictor can moderate the influence of the within-cluster predictor

$$(\text{focal}_{ij})(\text{moderator}_j) = (\text{focal}_j^{b} + \text{focal}_{ij}^{w})(\text{moderator}_j)$$

$$= (\text{focal}_j^{b})(\text{moderator}_j) \quad \text{Between-cluster (level-2) product}$$

$$+ (\text{focal}_{ij}^{w})(\text{moderator}_j) \quad \text{Cross-level product}$$

LEVEL-2 BY LEVEL-2 INTERACTION

- The interaction between a pair of level-2 variables produces a single between-cluster product

$$(\text{focal}_j)(\text{moderator}_j)$$

- Both variables have only one source of variation

ORGANIZATIONAL EXAMPLE

- In what contexts or for whom is supervisor relationship quality (LMX) most important?
- Does the effect of LMX on empowerment vary as a function team-level leadership climate?
- Said differently, does team-level climate moderate (enhance or negate) the effect of supervisor relationship quality?

A moderation research question considers whether the effect of LMX on empowerment depends on a team's leadership climate. How many and what type of interaction effects are possible between LMX and climate?

CROSS-LEVEL AND BETWEEN-CLUSTER MODERATION

- The between-level product conveys whether the effect of team-level average LMX depends on the team's climate

- The cross-level product conveys whether the effect of individual within-team LMX depends on the team's climate

$$(lmx_{ij})(climate_j) = (lmx_j^b + lmx_{ij}^w)(climate_j)$$

$$= (lmx_j^b)(climate_j) \quad \text{Between-cluster (level-2) product}$$

$$+ (lmx_{ij}^w)(climate_j) \quad \text{Cross-level product}$$

OUTLINE

1. Random Coefficient Model
2. Interaction Effects (Moderation)
3. Moderated Regression Example
4. Conditional Effects (Simple Slopes)

RANDOM SLOPES AND MODERATION

- β_{1j} represents a single team j's level-1 association between empowerment and leader-member exchange

$$empower_{ij} = \beta_{0j} + \beta_{1j}(lmx^{w}_{ij}) + \beta_{2}(male_{ij}) + \varepsilon_{ij}$$

- The cross-level interaction asks whether the size of a team's β_{1j} slope (within-cluster association) depends on its climate

BETWEEN-CLUSTER (LEVEL-2) MODEL

- γ_{03} is a team-level interaction where climate moderates the effect of team-average LMX

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(lmx_j^b) + \gamma_{02}(climate_j) + \gamma_{03}(lmx_j^b)(climate_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(climate_j) + u_{1j}$$

$$\beta_2 = \gamma_{20}$$

- γ_{11} is a cross-level interaction where climate moderates (predicts) the within-team association β_{1j}

COMBINED-MODEL EQUATION

- Substitute β_{0j} and β_2's equations into the level-1 model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(\text{lmx}_j^b) + \gamma_{02}(\text{climate}_j) + \gamma_{03}(\text{lmx}_j^b)(\text{climate}_j) + u_{0j}$$

$$\beta_2 = \gamma_{20}$$

$$\text{empower}_{ij} = \beta_{0j} + \beta_{1j}(\text{lmx}_{ij}^w) + \beta_2(\text{male}_{ij}) + \varepsilon_{ij}$$

$$\text{empower}_{ij} = \gamma_{00} + \gamma_{01}(\text{lmx}_j^b) + \gamma_{02}(\text{climate}_j) + \gamma_{03}(\text{lmx}_j^b)(\text{climate}_j) + u_{0j} + \beta_{1j}(\text{lmx}_{ij}^w) + \gamma_{20}(\text{male}_{ij}) + \varepsilon_{ij}$$

COMBINED-MODEL EQUATION, CONT.

- Substitute β_{1j}'s equation into the level-1 model and distribute:

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(climate_j) + u_{1j}$$

$$empower_{ij} = \gamma_{00} + \gamma_{01}(lmx_j^b) + \gamma_{02}(climate_j) + \gamma_{03}(lmx_j^b)(climate_j) + u_{0j} + \beta_{1j}(lmx_{ij}^w) + \gamma_{20}(male_{ij}) + \varepsilon_{ij}$$

$$empower_{ij} = \gamma_{00} + \gamma_{01}(lmx_j^b) + \gamma_{02}(climate_j) + \gamma_{03}(lmx_j^b)(climate_j) + u_{0j} + (\gamma_{10} + \gamma_{11}(climate_j) + u_{1j})(lmx_{ij}^w) + \gamma_{20}(male_{ij}) + \varepsilon_{ij}$$

$$empower_{ij} = \gamma_{00} + \gamma_{01}(lmx_j^b) + \gamma_{02}(climate_j) + \gamma_{03}(lmx_j^b)(climate_j) + u_{0j} + \gamma_{10}(lmx_{ij}^w) + \gamma_{11}(climate_j)(lmx_{ij}^w) + (u_{1j})(lmx_{ij}^w) + \gamma_{20}(male_{ij}) + \varepsilon_{ij}$$

COMMON NOTATIONAL SYSTEMS

Use whichever interaction addresses your question. It is not necessary to use both!

Combined-model equation (Raudenbush & Bryk, 2002)

$$\text{empower}_{ij} = \gamma_{00} + \gamma_{01}(\text{lmx}_j^b) + \gamma_{02}(\text{climate}_j) + \gamma_{03}(\text{lmx}_j^b)(\text{climate}_j) + u_{0j}$$
$$+ \gamma_{10}(\text{lmx}_{ij}^w) + \gamma_{11}(\text{climate}_j)(\text{lmx}_{ij}^w) + \gamma_{20}(\text{male}_{ij}) + (u_{1j})(\text{lmx}_{ij}^w) + \varepsilon_{ij}$$

Standard(ish) regression notation (Scott, Shrout, & Weinberg, 2013)

$$\text{empower}_{ij} = \beta_0 + \beta_1(\text{lmx}_{ij}^w) + \beta_2(\text{male}_{ij}) + \beta_3(\text{lmx}_j^b) + \beta_4(\text{climate}_j)$$
$$+ \beta_5(\text{lmx}_{ij}^w)(\text{climate}_j) + \beta_6(\text{lmx}_j^b)(\text{climate}_j) + u_{0j} + (u_{1j})(\text{lmx}_{ij}^w) + \varepsilon_{ij}$$

BLIMP SCRIPT 6.2

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;
CLUSTERID: Team;
CENTER: groupmean = LMX; grandmean = Male LMX.mean Climate;
MODEL: Empower ~ intercept LMX Male LMX.mean Climate
  LMX*Climate LMX.mean*Climate | intercept LMX;  # product terms in the regression model
BURN: 10000;
ITERATIONS: 20000;
SEED: 90291;
```

RBLIMP SCRIPT 6 (MODEL 2)

```
model2 <- rblimp(
        data = Employee,
        nominal = 'Male',
        clusterid = 'Team',
        center = 'groupmean = LMX; grandmean = Male LMX.mean Climate',
        model = 'Empower ~ intercept LMX Male LMX.mean Climate
          LMX*Climate LMX.mean*Climate | intercept LMX',   # product terms in the regression model
        seed = 90291,
        burn = 10000,
        iter = 20000)
output(model2)
posterior_plot(model2, 'Empower')
```

PSR DIAGNOSTIC OUTPUT

Quality control check: PSR diagnostics all < 1.05 well before the end of the burn-in period

BURN-IN POTENTIAL SCALE REDUCTION (PSR) OUTPUT:

NOTE: Split chain PSR is being used. This splits each chain's iterations to create twice as many chains.

Comparing iterations across 2 chains	Highest PSR	Parameter #
251 to 500	1.194	8
501 to 1000	1.180	19
751 to 1500	1.067	2
1001 to 2000	1.043	2
...	...	..
2501 to 5000	1.040	2
2751 to 5500	1.045	2
3001 to 6000	1.041	2
3251 to 6500	1.040	2
3501 to 7000	1.038	2
3751 to 7500	1.019	2
4001 to 8000	1.008	29
4251 to 8500	1.011	2
4501 to 9000	1.005	25
4751 to 9500	1.008	8
5001 to 10000	1.024	1

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

Quality control check: Number of effective MCMC samples diagnostics all > 100

```
Outcome Variable:  Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX
```

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	1.046	0.545	0.223	2.311	---	---	431.694
L2 : Cov(LMX,Intercept)	-0.147	0.129	-0.424	0.084	---	---	999.772
L2 : Var(LMX)	0.152	0.072	0.035	0.321	---	---	776.990
Residual Var.	12.319	0.806	10.848	14.005	---	---	4608.550
Coefficients:							
Intercept	28.624	0.233	28.165	29.086	15080.392	0.000	2520.358
LMX	0.634	0.072	0.494	0.775	77.162	0.000	4463.621
Male.1	1.877	0.303	1.278	2.471	38.308	0.000	13574.742
LMX.mean[Team]	-0.191	0.325	-0.923	0.368	0.430	0.512	603.485
Climate	0.282	0.053	0.178	0.385	28.707	0.000	2912.445
LMX*Climate	0.046	0.016	0.013	0.078	7.718	0.005	6332.701
LMX.mean[Team]*Climate	-0.027	0.069	-0.177	0.100	0.190	0.663	1636.683
...							
Proportion Variance Explained							
by Coefficients	0.302	0.035	0.234	0.372	---	---	2975.744
by Level-2 Random Intercepts	0.050	0.025	0.011	0.106	---	---	422.882
by Level-2 Random Slopes	0.058	0.027	0.013	0.119	---	---	759.626
by Level-1 Residual Variation	0.586	0.037	0.511	0.657	---	---	2054.049

CROSS-LEVEL INTERACTION

= level-2 estimate

= level-1 estimate

= combined estimate

Outcome Variable: Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
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by Level-2 Random Slopes	0.058	0.027	0.013	0.119	---	---	759.626
by Level-1 Residual Variation	0.586	0.037	0.511	0.657	---	---	2054.049

INTERPRETATIONS

- All variables are centered such that 0 equals the mean
- For a team with average climate (climate = 0), the within-cluster slope of empowerment on LMX is 0.63 ($p < .05$)

$$empower_{ij} = 28.62 + \mathbf{0.63}(lmx^{w}_{ij}) + 1.88(male_{ij}) - 0.19(lmx^{b}_{j}) + 0.28(climate_{j}) + \mathbf{0.05}(lmx^{w}_{ij})(climate_{j}) - 0.03(lmx^{b}_{j})(climate_{j}) + u_{0j} + (u_{1j})(lmx^{w}_{ij}) + \varepsilon_{ij}$$

- For every additional one-point increase in climate, the within-cluster slope increases by 0.05 ($p < .05$)

BETWEEN-CLUSTER INTERACTION

= level-2 estimate

= level-1 estimate

= combined estimate

Outcome Variable: Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	1.046	0.545	0.223	2.311	---	---	431.694
L2 : Cov(LMX,Intercept)	-0.147	0.129	-0.424	0.084	---	---	999.772
L2 : Var(LMX)	0.152	0.072	0.035	0.321	---	---	776.990
Residual Var.	12.319	0.806	10.848	14.005	---	---	4608.550
Coefficients:							
Intercept	28.624	0.233	28.165	29.086	15080.392	0.000	2520.358
LMX	0.634	0.072	0.494	0.775	77.162	0.000	4463.621
Male.1	1.877	0.303	1.278	2.471	38.308	0.000	13574.742
LMX.mean[Team]	-0.191	0.325	-0.923	0.368	0.430	0.512	603.485
Climate	0.282	0.053	0.178	0.385	28.707	0.000	2912.445
LMX*Climate	0.046	0.016	0.013	0.078	7.718	0.005	6332.701
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Proportion Variance Explained							
by Coefficients	0.302	0.035	0.234	0.372	---	---	2975.744
by Level-2 Random Intercepts	0.050	0.025	0.011	0.106	---	---	422.882
by Level-2 Random Slopes	0.058	0.027	0.013	0.119	---	---	759.626
by Level-1 Residual Variation	0.586	0.037	0.511	0.657	---	---	2054.049

INTERPRETATIONS

- For a team with average climate (zero), the within-cluster slope of mean empowerment on mean LMX is –0.19 ($p > .05$)

$$empower_{ij} = 28.62 + 0.63(lmx^{w}_{ij}) + 1.88(male_{ij}) - \mathbf{0.19}(lmx^{b}_{j}) + 0.28(climate_{j}) + 0.05(lmx^{w}_{ij})(climate_{j}) - \mathbf{0.03}(lmx^{b}_{j})(climate_{j}) + u_{0j} + (u_{1j})(lmx^{w}_{ij}) + \varepsilon_{ij}$$

- For every additional one-point increase in climate, the between-cluster slope decreases by 0.03 ($p > .05$)

INTERPRETATIONS: FIXED EFFECTS

Parameter	Est.	Interpretation
Fixed intercept	28.62	Expected empowerment for a supervisee with zero values on the predictors (the grand mean because all predictors are centered)
LMX (within-team)	0.63	Expected empowerment difference between two people *from the same team at the climate mean* with LMX scores that differ by one point, controlling for gender
Gender (mostly within-team)	1.88	Expected empowerment difference between a male and female *from the same team,* controlling for LMX and the cross-level interaction
LMX (between-team)	–0.19	Expected empowerment mean difference between two teams at the climate mean with average LMX ratings that differ by one point (conditional effect of LMX)
Climate (between-team)	0.28	Expected empowerment mean difference between two teams at the LMX mean with climate ratings that differ by one point (conditional effect of climate)
LMX (within-team) by Climate	0.05	The amount that the within-team LMX slope changes for every additional one-point increase in team-level climate
LMX (between-team) by Climate	–0.03	The amount that the between-team LMX slope changes for every additional one-point increase in team-level climate

INTERPRETATIONS: RANDOM EFFECTS

Parameter	Est.	Interpretation
Between-cluster intercept variance (variance of u_{0j} residuals)	1.05	Average squared distance between the team-average predicted and observed empowerment means (residual level-2 mean differences)
Between-cluster slope variance (variance of u_{1j} residuals)	0.15	Average squared distance between the team-specific predicted and observed LMX slopes (residual level-2 slope differences)
Intercept–slope covariance (covariance of u_{0j} and u_{1j} residuals)	–0.15	Negative association where teams with higher empowerment means (intercepts) tend to have lower (less positive) LMX slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	12.32	Average squared distance between a supervisee's observed and predicted empowerment scores (residual within-cluster variation)

R^2 EFFECT SIZE MEASURES

Outcome Variable: Empower
Grand Mean Centered: Climate LMX.mean[Team] Male.1
Group Mean Centered: LMX

Parameters	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	1.046	0.545	0.223	2.311	---	---	431.694
L2 : Cov(LMX,Intercept)	-0.147	0.129	-0.424	0.084	---	---	999.772
L2 : Var(LMX)	0.152	0.072	0.035	0.321	---	---	776.990
Residual Var.	12.319	0.806	10.848	14.005	---	---	4608.550
Coefficients:							
Intercept	28.624	0.233	28.165	29.086	15080.392	0.000	2520.358
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LMX.mean[Team]	-0.191	0.325	-0.923	0.368	0.430	0.512	603.485
Climate	0.282	0.053	0.178	0.385	28.707	0.000	2912.445
LMX*Climate	0.046	0.016	0.013	0.078	7.718	0.005	6332.701
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Proportion Variance Explained							
by Coefficients	0.302	0.035	0.234	0.372	---	---	2975.744
by Level-2 Random Intercepts	0.050	0.025	0.011	0.106	---	---	422.882
by Level-2 Random Slopes	0.058	0.027	0.013	0.119	---	---	759.626
by Level-1 Residual Variation	0.586	0.037	0.511	0.657	---	---	2054.049

INTERPRETATIONS

- Effect sizes for the level-1 and level-2 residuals are not explained variance, per se, but rather proportions that convey the size of the residual variation

R^2 Effect Size	Est.	Interpretation
Predictors	.30	The level-1 and level-2 predictors explain 30% of the total variation in empowerment
Between-cluster intercept variance (variance of u_{0j} residuals)	.05	Residual between-team variation in the level-2 empowerment means (variance of u_{0j} residuals = 1.05) accounts for 5% of the total variation
Between-cluster slope variance (variance of u_{1j} residuals)	.06	Between-team variation in the random slopes (variance of u_{1j} residuals = 0.15) accounts for 6% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.59	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 12.29) accounts for 59% of the total variation

MODEL COMPARISON

- The cross-level interaction (climate predicting team-specific LMX slopes) explained/decreased random slope variation and its effect size
- The non-significant between-cluster interaction did not reduce random intercept variation (although it would have, had the effect been salient)

Parameter	Random Slope Model	Moderation Model
Fixed intercept	28.61	28.62
LMX (within-team)	0.63*	0.63*
Male (mostly within-team)	1.89*	1.88*
LMX mean (between-team)	−0.17	−0.19
Climate (between-team)	0.29*	0.28*
LMX (within-team) by climate	—	0.05*
LMX (between-team) by climate	—	−0.03
Residual intercept variance	**1.02**	**1.05**
Residual random slope variance	**0.19**	**0.15**
Residual within-person variance	12.29	12.32
R-square predictors	.29	.30
R-square intercept variance	**.05**	**.05**
R-square slope variance	**.07**	**.06**
R-square within-person variance	.59	.59

OUTLINE

1. Random Coefficient Model
2. Interaction Effects (Moderation)
3. Moderated Regression Example
4. Conditional Effects (Simple Slopes)

CONDITIONAL EFFECTS FOLLOW-UPS

- The within-team LMX slope (the effect of supervisor relationship quality on empowerment) varies across teams with different climate

- The so-called pick-a-point approach to probing interaction effects computes the conditional effect (simple slope) of LMX at different levels of climate (e.g., ± one SD unit from mean)

CONDITIONAL EFFECTS

- Group terms with and without the focal predictor

$$\text{outcome}_i = \beta_0 + \beta_2(\text{moderator}_i) + \beta_1(\text{focal}_i) + \beta_3(\text{focal}_i)(\text{moderator}_i) + \varepsilon_{ij}$$

- Factor out the focal predictor

$$\text{outcome}_i = [\beta_0 + \beta_2(\text{moderator}_i)] + [\beta_1 + \beta_3(\text{moderator}_i)](\text{focal}_i) + \varepsilon_{ij}$$

- Plug in a value of the moderator to compute conditional effects

$$\text{outcome}_i = \text{simple intercept}_i + (\text{simple slope}_i)(\text{focal}_i) + \varepsilon_{ij}$$

CROSS-LEVEL INTERACTION EXAMPLE

1. Collect intercept and slope terms

$$\beta_0 + \beta_4(\text{climate}_j) + u_{0j} \text{ and } \beta_1(\text{lmx}_{ij}^{w}) + \beta_5(\text{lmx}_{ij}^{w})(\text{climate}_j) + (u_{1j})(\text{lmx}_{ij}^{w})$$

2. Set level-2 residuals to 0

$$\beta_0 + \beta_4(\text{climate}_j) \text{ and } \beta_1(\text{lmx}_{ij}^{w}) + \beta_5(\text{lmx}_{ij}^{w})(\text{climate}_j)$$

3. Factor out LMX

$$\beta_0 + \beta_4(\text{climate}_j) \text{ and } [\beta_1 + \beta_5(\text{climate}_j)](\text{lmx}_{ij}^{w})$$

4. Substitute climate scores (e.g., ±1 SD above/below mean is ±4) to get simple intercepts and slopes

$$28.624 + 0.282(+4) \text{ and } [0.634 + 0.046(+4)](\text{lmx}_{ij}^{w})$$

simple intercept = 29.76 and simple slope = 0.82

$$28.624 + 0.282(-4) \text{ and } [0.634 + 0.046(-4)](\text{lmx}_{ij}^{w})$$

simple intercept = 27.49 and simple slope = 0.45

BLIMP SCRIPT 6.3

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;
CLUSTERID: Team;
CENTER: groupmean = LMX; grandmean = Male LMX.mean Climate;
MODEL: Empower ~ intercept LMX Male LMX.mean Climate
  LMX*Climate LMX.mean*Climate | intercept LMX;  # product terms in the regression model
SIMPLE: LMX | Climate;   # simple slopes of LMX at different levels of Climate
BURN: 10000;
ITERATIONS: 20000;
SEED: 90291;
```

RBLIMP SCRIPT 6 (MODEL 3)

```
model3 <- rblimp(
        data = Employee,
        nominal = 'Male',
        clusterid = 'Team',
        center = 'groupmean = LMX; grandmean = Male LMX.mean Climate',
        model = 'Empower ~ intercept LMX Male LMX.mean Climate
          LMX*Climate LMX.mean*Climate | intercept LMX',   # product terms in the regression model
        simple = 'LMX | Climate',   # simple slopes of LMX at different levels of Climate
        seed = 90291,
        burn = 10000,
        iter = 20000)
output(model3)
simple_plot(Empower ~ LMX | Climate, model3)  # conditional effect plot
```

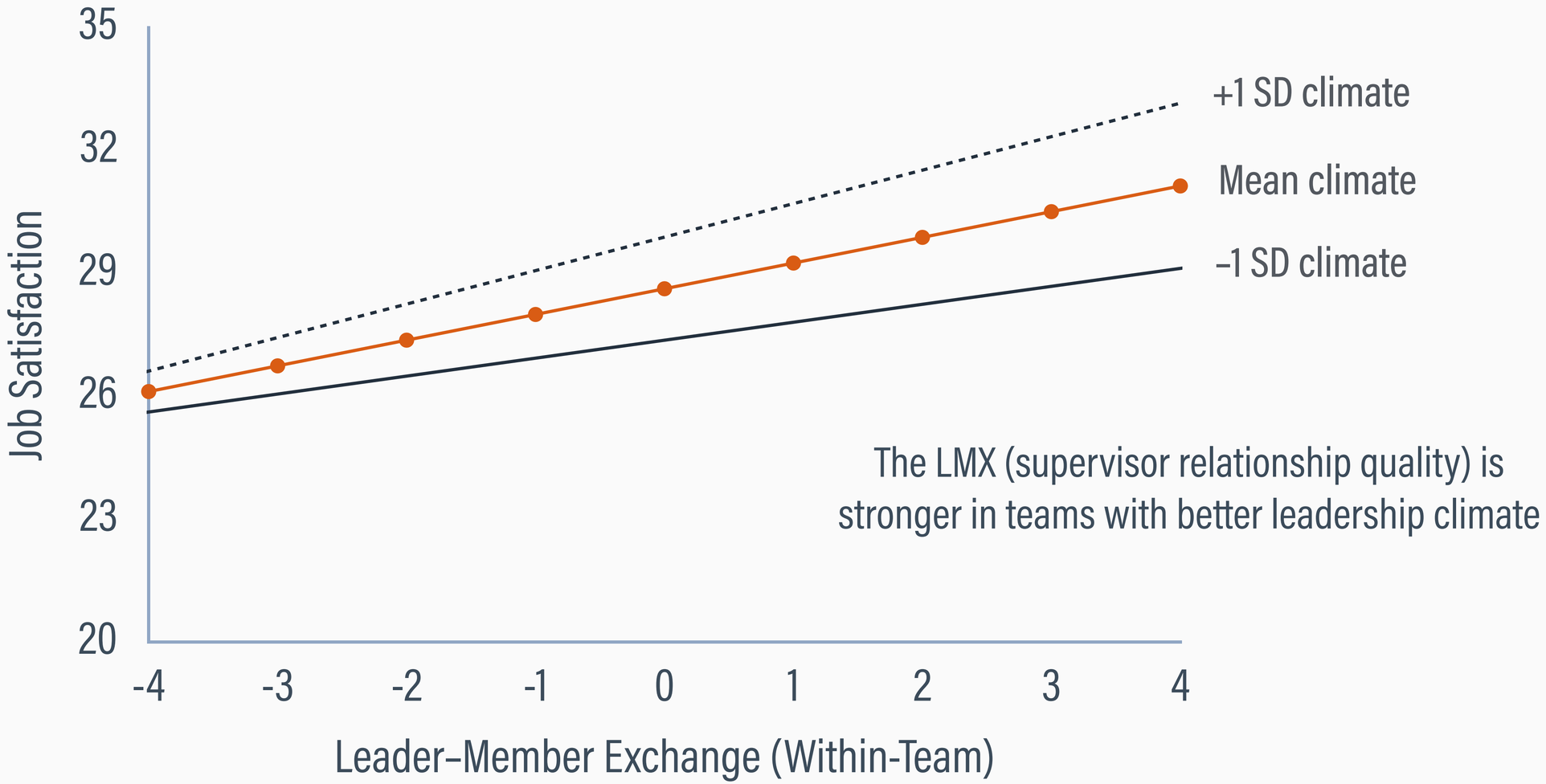
BLIMP OUTPUT

Conditional Effects	Estimate	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
LMX | Climate @ +2 SD							
Intercept	30.900	0.525	29.930	31.984	3469.473	0.000	2831.406
Slope	1.005	0.154	0.709	1.314	42.928	0.000	5572.779
LMX | Climate @ +1 SD							
Intercept	29.761	0.335	29.139	30.449	7882.035	0.000	2533.518
Slope	0.819	0.099	0.630	1.015	69.085	0.000	5004.621
LMX | Climate @ 0							
Intercept	28.624	0.233	28.165	29.086	15080.392	0.000	2520.358
Slope	0.634	0.072	0.494	0.775	77.162	0.000	4463.621
LMX | Climate @ -1 SD							
Intercept	27.488	0.318	26.836	28.082	7465.798	0.000	3251.821
Slope	0.450	0.100	0.248	0.640	20.080	0.000	5672.262
LMX | Climate @ -2 SD							
Intercept	26.351	0.503	25.307	27.284	2742.649	0.000	3587.074
Slope	0.265	0.155	-0.053	0.562	2.854	0.091	6420.419

NOTE: Intercepts are computed by setting all predictors not involved in the conditional effect to zero.

NOTE: Standard deviation units are determined by centering. Group mean centering uses a within-cluster standard deviation, and grand mean centering uses a total standard deviation.

CONDITIONAL EFFECTS GRAPHIC



CONDITIONAL EFFECT PLOTS (RBLIMP ONLY)