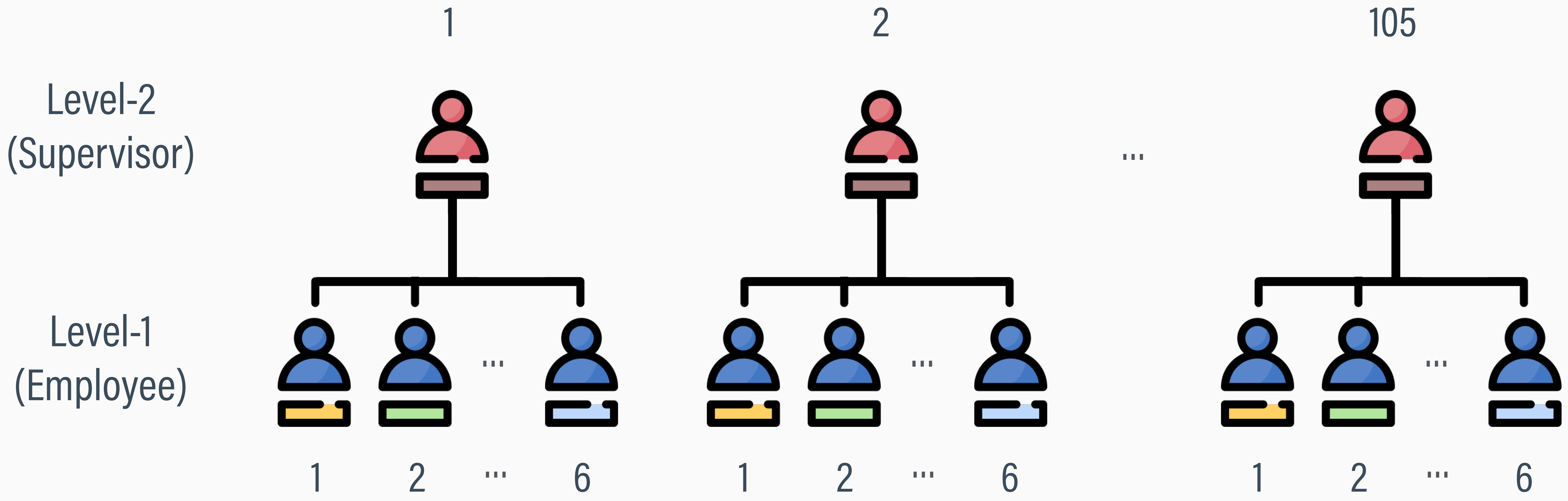
MODULE 5

RANDOM COEFFICIENT MODELS

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)
JobSat	Job satisfaction rating	1	Ordinal (1 to 7)
LMX	Leader–member exchange (supervisor–supervisee relationship quality)	1	Numeric (0 to 17)
Empower	Employee empowerment	1	Numeric (14 to 42)
Male	Male dummy code	1	Female = 0, Male = 1

DATA STRUCTURE

- Stacked (long) data format where each level-2 unit (supervisor) has one row per level-1 (supervisee) observation
- The i subscript indexes level-1 observations, and j indexes level-2 units
- Variables measured at level-2 repeat across all rows within a cluster

Row	i	j	$JobSat_{ij}$	LMX_{ij}	$Climate_j$	
1	1	1	1.0	5.6	7.3	
2	2	1	2.0	4.3	7.3	
…	…	1	…	…	…	Team 1
6	6	1	5.0	7.3	7.3	
7	1	2	7.0	3.9	4.0	
8	2	2	3.0	7.1	4.0	
…	…	2	…	…	…	Team 2
12	6	2	6.0	3.5	4.0	
…	…	…	…	…	…	
625	1	105	2.0	5.4	3.3	
626	2	105	3.0	3.5	3.3	
…	…	105	…	…		Team 105
630	6	105	1.0	7.9	3.3	

RANDOM SLOPE COEFFICIENTS

- Thus far, we have fit random intercept models where the outcome mean (intercept) varied across clusters
- Random slope or random coefficient models allow the influence of a predictor to vary across level-2 units
- Essentially, random slopes are akin to interaction effect where the predictor’s influence varies across level-2 groups

CONCEPTUAL MODEL

Measured at level-2 (team)

Measured at level-1 (person)

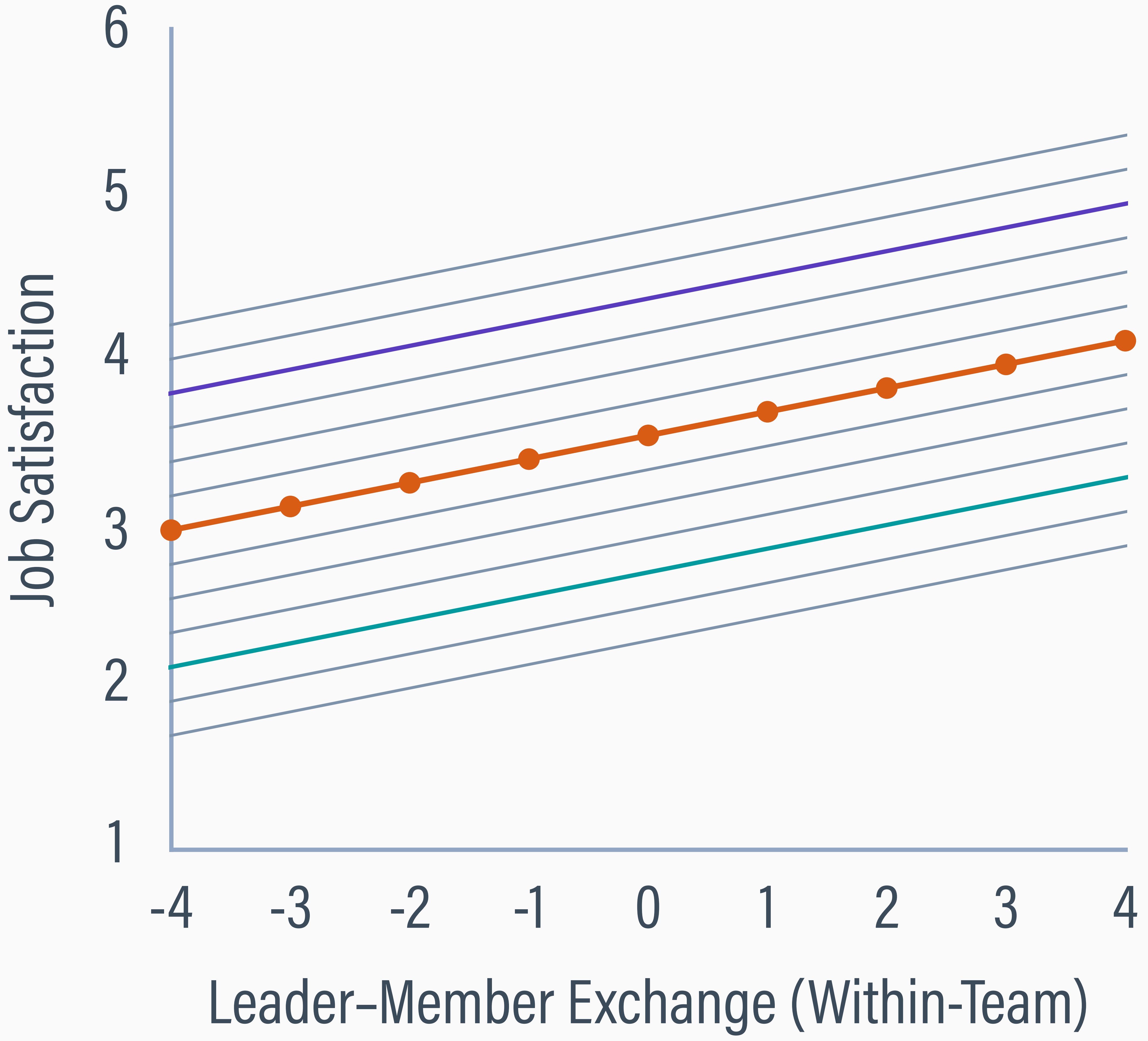
- The conceptual model includes three level-1 predictors

jobsat = mean + lmx + empowerment + gender

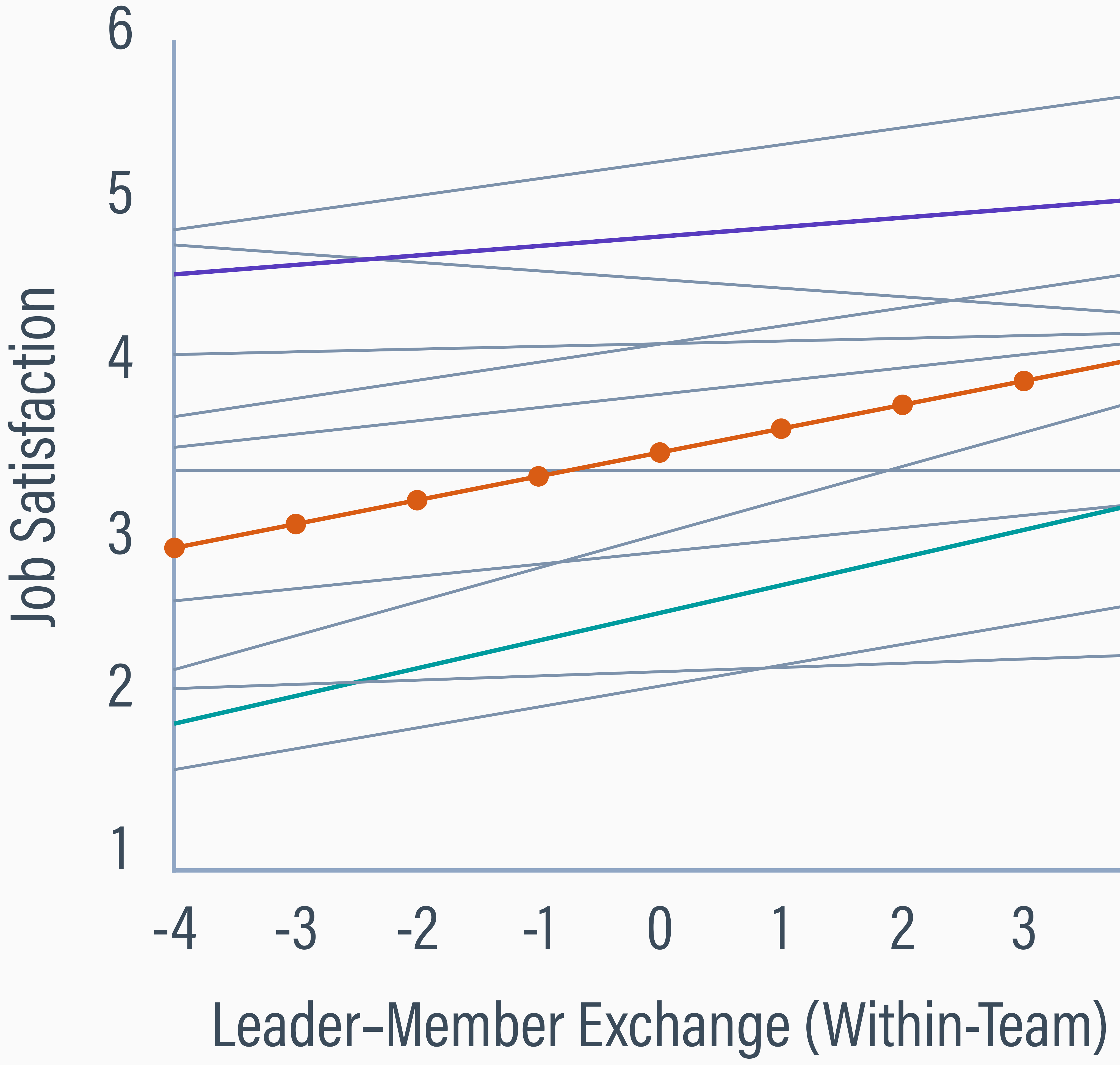
- The level-1 predictors may require disaggregation
- The effects of the level-1 predictors may vary across level-2 units (slope coefficients could be “random”)

MODELING OVERVIEW

Random Intercept Model



Random Slope Model



MODEL-BUILDING STEPS

- The methods literature often recommends a multistep model-building procedure that begins at level-1

1) Estimate ICCs

2) Add predictors measured at level-1

3) Add random coefficients for level-1 predictors

4a) Add cluster means of level-1 predictors

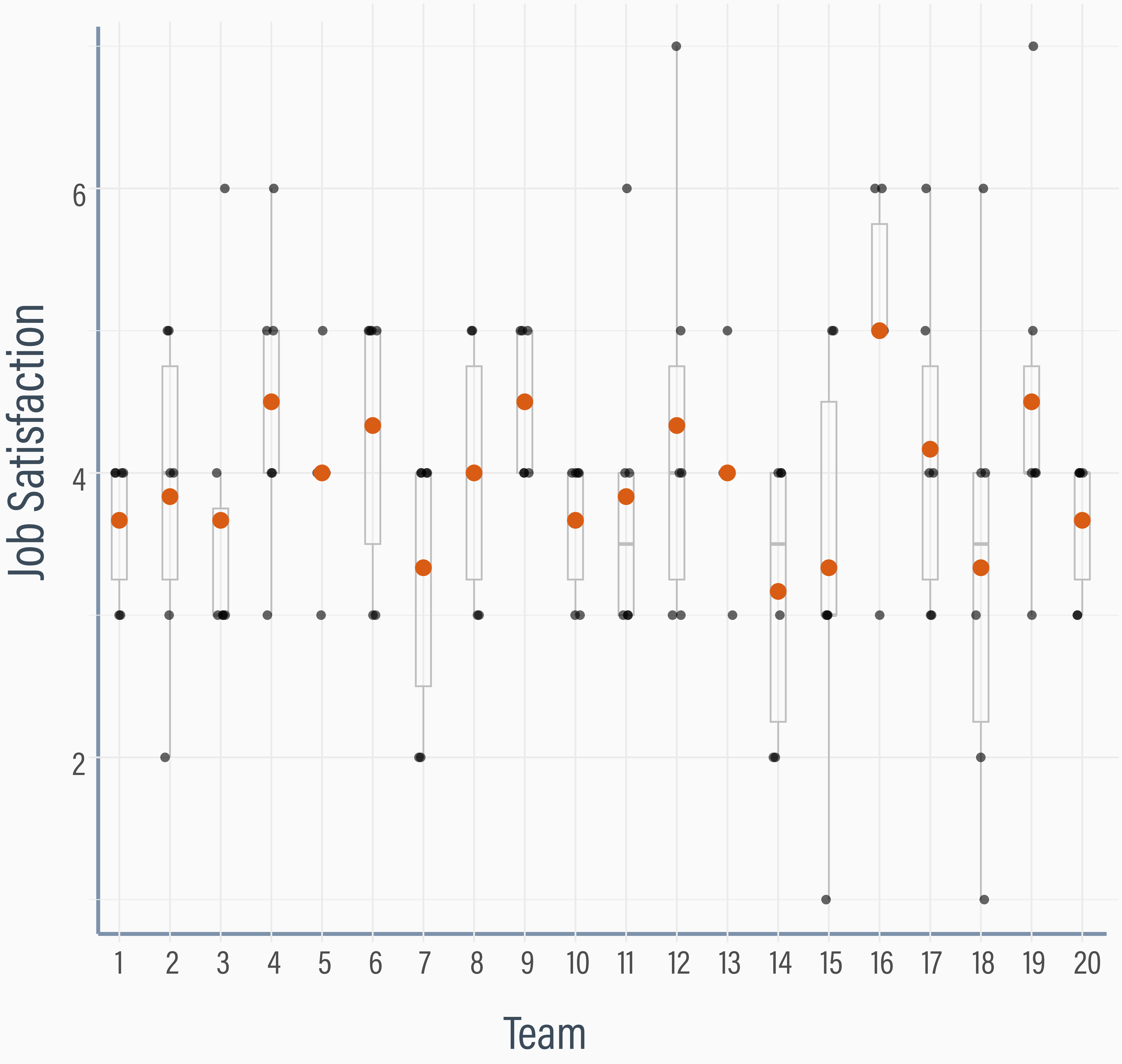
4b) Add predictors measured at level-2

May be combined into a single step

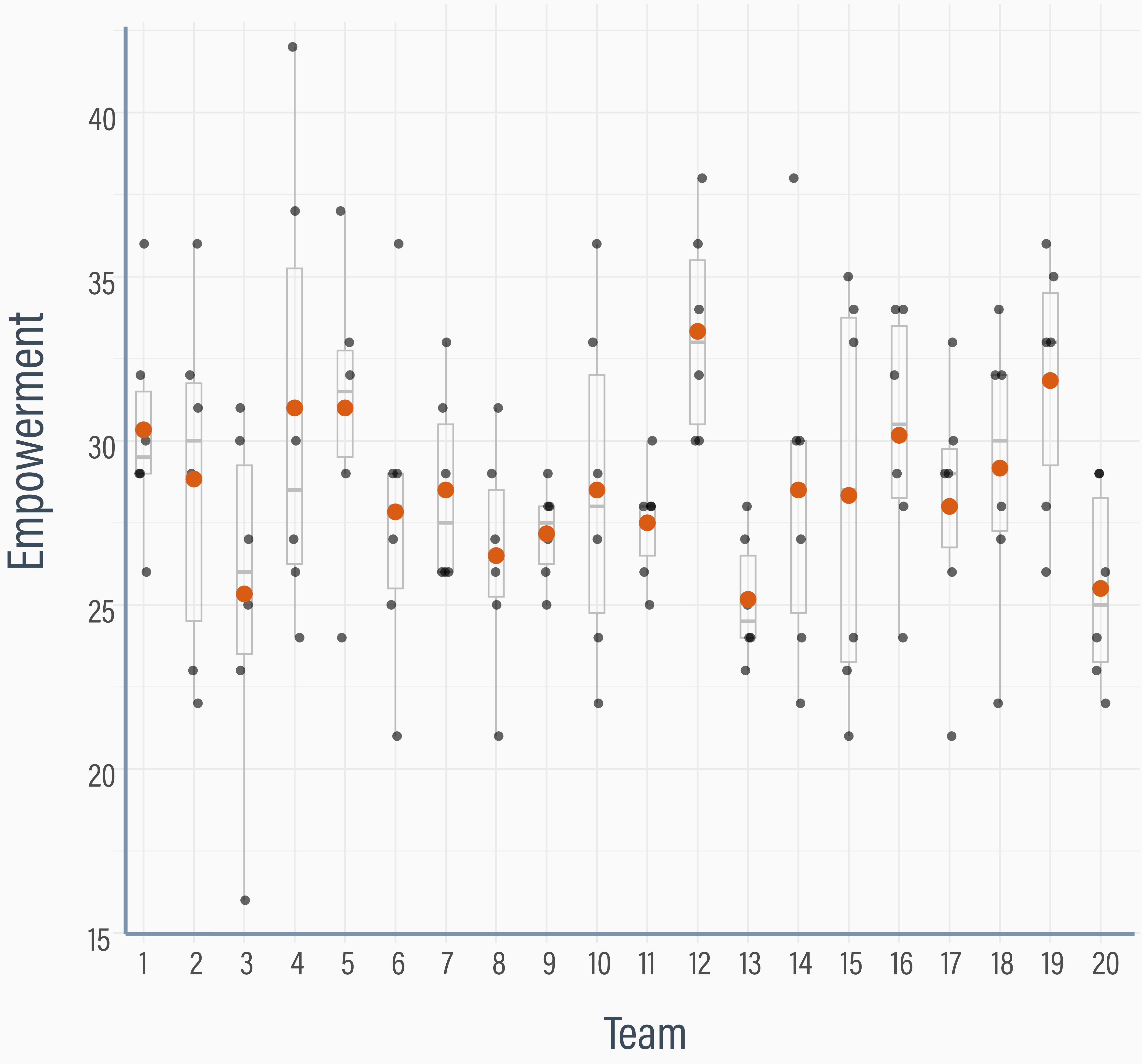
OUTLINE

1. Estimate ICCs
2. Add Within-Cluster Predictors
3. Strategy 1: Evaluate Random Slopes One at a Time
4. Strategy 2: Add All Random Slopes at Once
5. Add Between-Cluster Predictors
6. Latent Variable Specification

BOX PLOTS

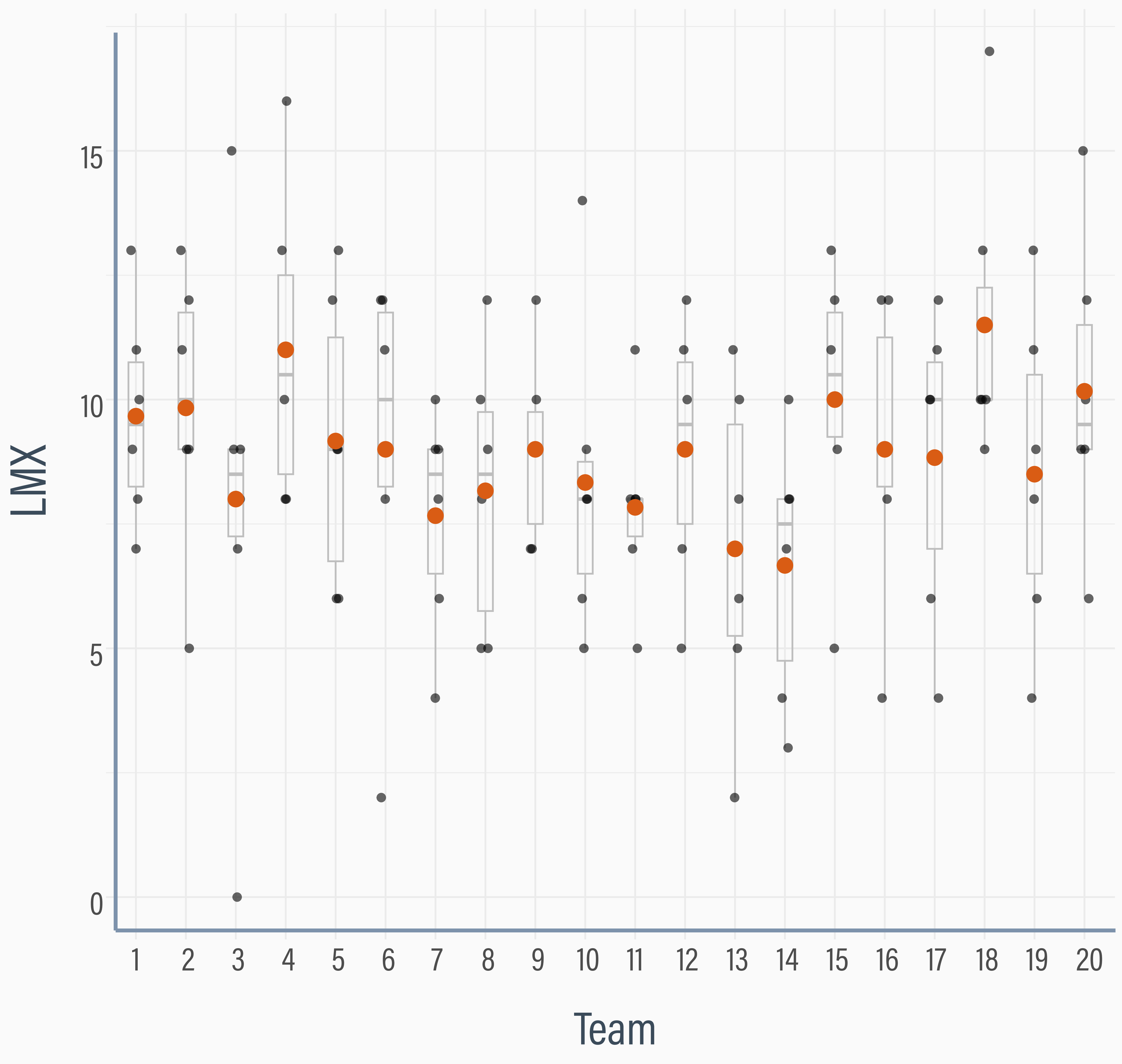


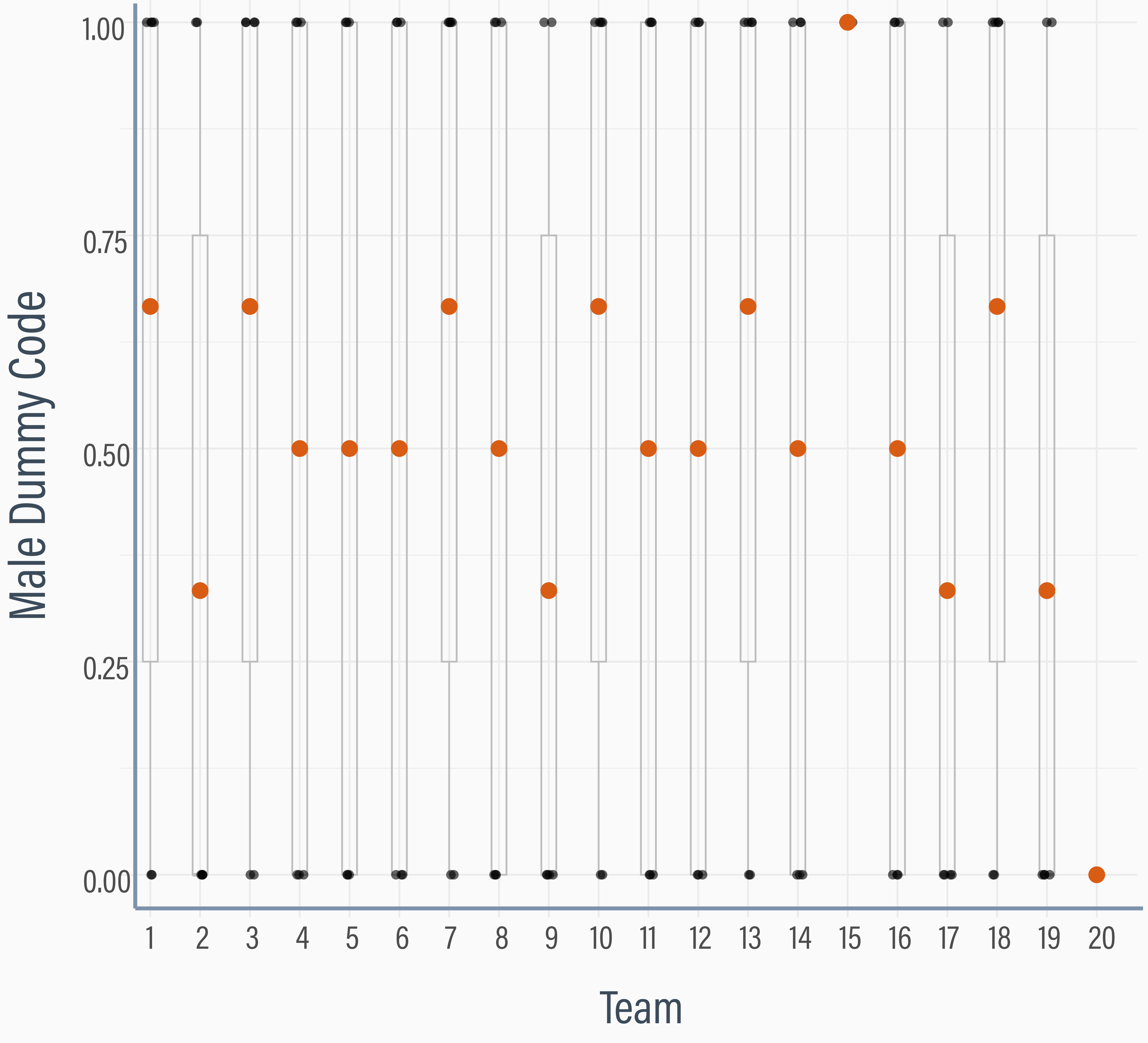
Job Satisfaction
6
4
2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Team



Empowerment
40
35
30
25
20
15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Team

BOX PLOTS, CONTINUED





BLIMP SCRIPT 5.1

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
CLUSTERID: Team;
NOMINAL: Male;    # invokes logistic regression model
MODEL:
{ JobSat LMX Empower Male } ~ intercept | intercept;    # { } applies the same model all all variables
BURN: 20000;
ITERATIONS: 10000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 1)

```
model1 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    model = '{ JobSat LMX Empower Male } ~ intercept | intercept',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model1)
```

BLIMP OUTPUT

= level-2 estimate

= level-1 estimate

Outcome Variable: Empower

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	2.562	0.826	1.254	4.458	---	---	2191.061
Residual Var.	18.098	1.127	16.067	20.441	---	---	9768.133
Coefficients:							
Intercept	28.613	0.232	28.160	29.070	15190.266	0.000	7213.627
Proportion Variance Explained							
by Coefficients	0.000	0.000	0.000	0.000	---	---	nan
by Level-2 Random Intercepts	0.124	0.036	0.062	0.203	---	---	2133.810
by Level-1 Residual Variation	0.876	0.036	0.797	0.938	---	---	2133.810

BLIMP OUTPUT

= level-2 estimate

= level-1 estimate

Outcome Variable: JobSat

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	**0.190**	0.064	0.082	0.332	---	---	1568.277
Residual Var.	**1.416**	0.089	1.254	1.606	---	---	7093.805
Coefficients:							
Intercept	**3.990**	0.064	3.866	4.116	3927.745	0.000	7631.814
Proportion Variance Explained							
by Coefficients	0.000	0.000	0.000	0.000	---	---	nan
by Level-2 Random Intercepts	**0.118**	0.037	0.052	0.195	---	---	1500.756
by Level-1 Residual Variation	**0.882**	0.037	0.805	0.948	---	---	1500.756

BLIMP OUTPUT

= level-2 estimate

= level-1 estimate

Outcome Variable: LMX

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	1.329	0.389	0.685	2.221	---	---	2411.923
Residual Var.	7.904	0.493	7.013	8.938	---	---	10542.820
Coefficients:							
Intercept	9.594	0.160	9.278	9.909	3578.424	0.000	6155.384
Proportion Variance Explained							
by Coefficients	0.000	0.000	0.000	0.000	---	---	nan
by Level-2 Random Intercepts	0.144	0.038	0.077	0.226	---	---	2363.170
by Level-1 Residual Variation	0.856	0.038	0.774	0.923	---	---	2363.170

BLIMP OUTPUT

= level-2 estimate

= level-1 estimate

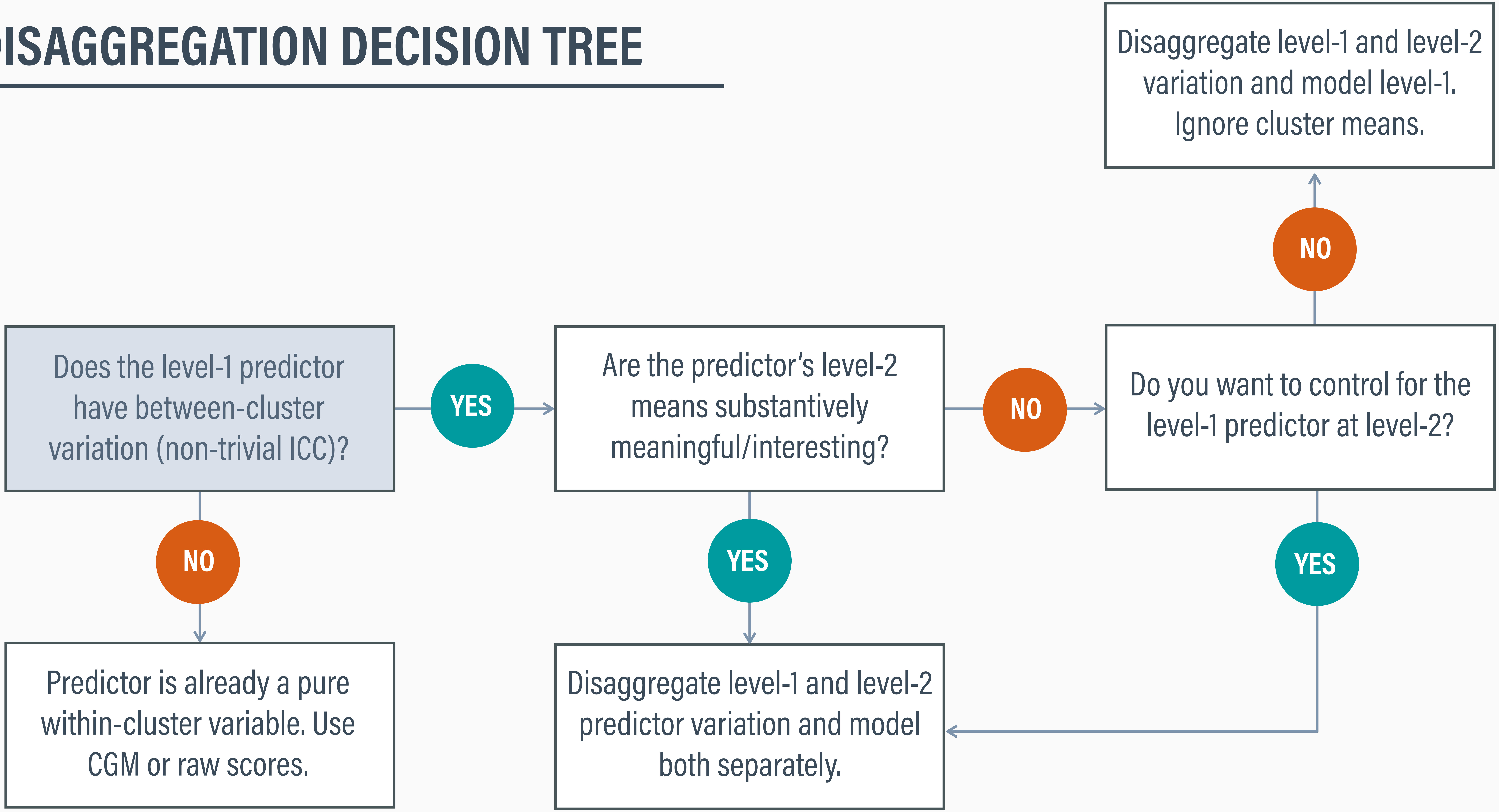
```
Outcome Variable:  Male

Parameters                          Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                ------------------------------------------------------------------------------
Male.1
Variances:
  L2 : Var(Intercept)                0.107      0.099      0.006      0.373        ---        ---    212.741

Coefficients:
  Intercept                         -0.064      0.088     -0.239      0.108      0.537      0.464  13628.593

Odds Ratio:
  Intercept                          0.938      0.083      0.787      1.114        ---        ---  13657.539

Proportion Variance Explained
  by Coefficients                    0.000      0.000      0.000      0.000        ---        ---        nan
  by Level-2 Random Intercepts       0.032      0.027      0.002      0.102        ---        ---    199.871
  by Level-1 Residual Variation      0.968      0.027      0.898      0.998        ---        ---    199.871

                                ------------------------------------------------------------------------------
```

ICC SUMMARY

- The outcome has nontrivial between-person variation in the team-specific means ($ICC_{jobsat} = .12$), so we need MLM
- Two level-1 predictors (LMX and empowerment) have > 10% team-level mean variation ($ICC_{lmx} = .14$ and $ICC_{empower} = .12$)
- Gender variation is comprised of 3% team-level mean variation
- The predictor ICCs suggest the need for disaggregation (there could be unique associations at level-1 and level-2)

The ICC for gender is .03. Gender is dummy coded such that female = 0 and male = 1. In small groups of two or three, discuss the meaning of the team-level gender averages (random intercepts). What does it mean for gender to have a non-zero ICC?

DISAGGREGATION DECISION TREE



SUMMARY, CONTINUED

- The gender dummy code has a relatively low ICC at .03
- Because the within-team sample sizes are small ($n_j = 6$), latent group means will be very noisy
- Estimating latent means from such a small amount of variation can cause convergence issues, and invoking a categorical variable model likely exacerbates the issue
- This variable is a good candidate for grand mean centering

OUTLINE

1. Estimate ICCs
2. Add Within-Cluster Predictors
3. Strategy 1: Evaluate Random Slopes One at a Time
4. Strategy 2: Add All Random Slopes at Once
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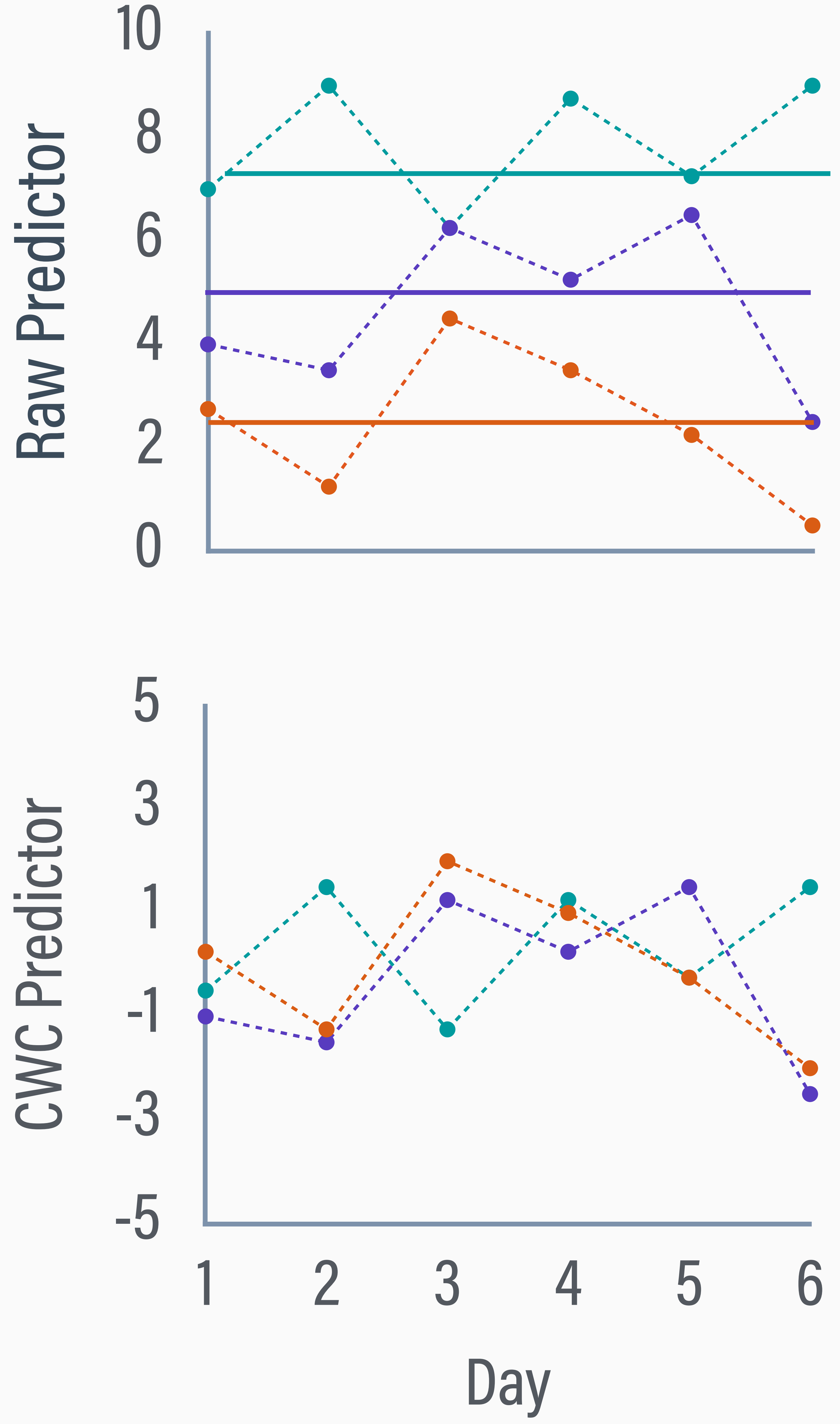
CENTERING WITHIN CLUSTER (CWC)

- Pure within-cluster predictors are created by deviating (centering) each person's score at its level-2 team mean

$$lmx^{w}_{ij} = lmx_{ij} - \mu_{j(lmx)}$$
$$empower^{w}_{ij} = empower_{ij} - \mu_{j(empower)}$$

- The resulting deviation scores contain only within-team (level-1) variation



CENTERING BINARY PREDICTORS

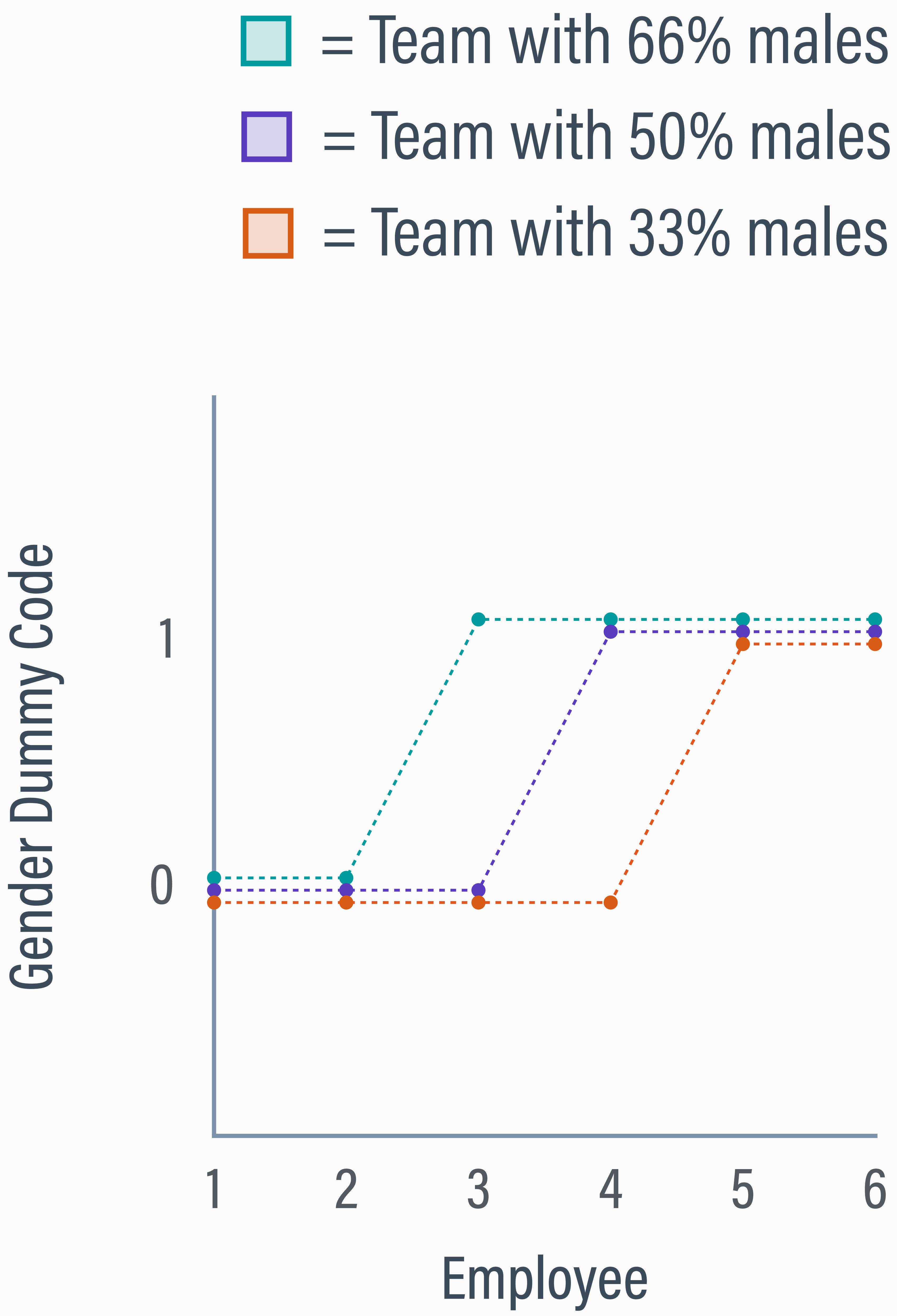
- Binary predictors can also possess cluster-level mean variation, so centering considerations are identical
- It is absolutely appropriate to disaggregate dummy codes into separate within- and between-cluster predictors
- The ICC, not the variable's metric, informs disaggregation

INTERPRETING CLUSTER MEANS

- Cluster means are the proportions of males (1s) in each team (gender composition)

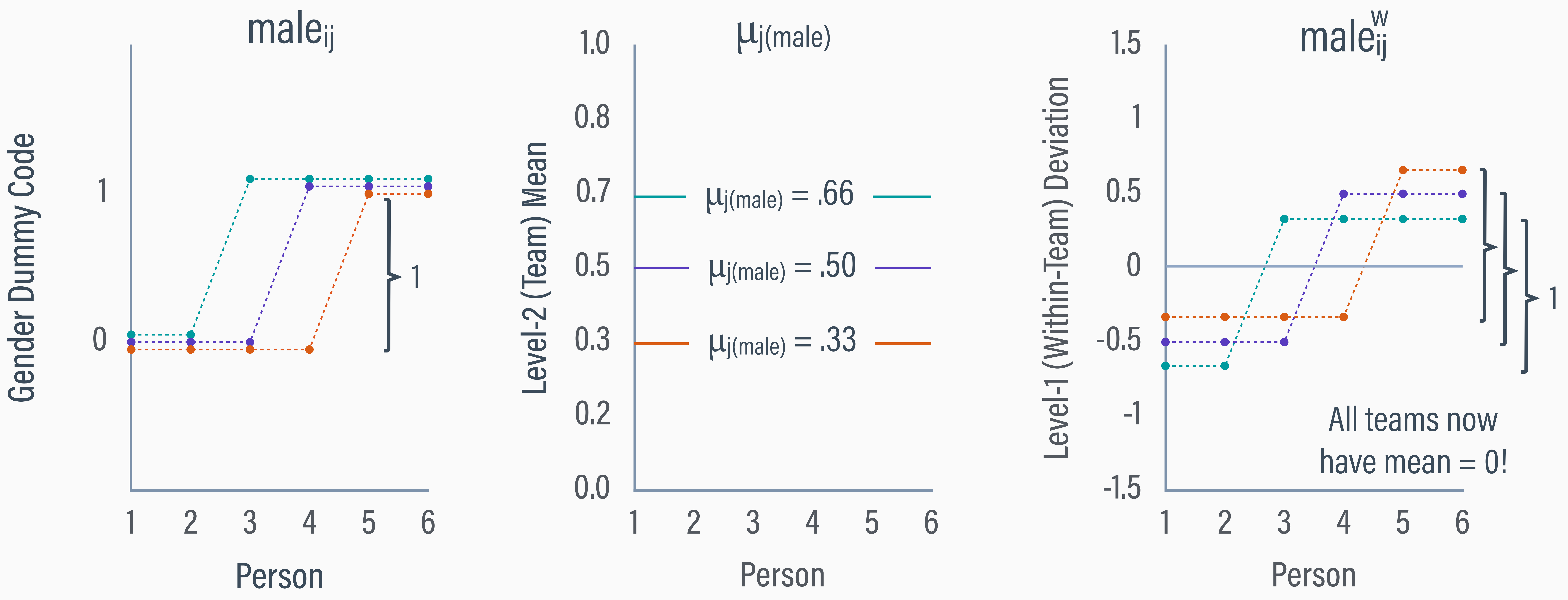
$$male^{w}_{ij} = male_{ij} - \mu_{j(male)}$$

- In this example, $\mu_{j(male)}$ = .33, .50, and .66
- Centering within team removes team-level differences in gender composition



WITHIN-CLUSTER CENTERING A DUMMY CODE

Level-1 Dummy Code – Level-2 Team Mean (Proportion of 1s) = Pure Level-1 (Within-Team) Code



Consider the following disaggregated regression model with disaggregated gender predictor. Provide a brief interpretation of the β_1 and β_2 slope coefficients.

$$
\begin{aligned}
jobsat_{ij} &= \beta_0 + \beta_1(male_{ij}^{w}) + \beta_2(\mu_{j(male)}) + u_{0j} + \varepsilon_{ij} \\
&= 4 + .30(male_{ij}^{w}) + .60(\mu_{j(male)}) + u_{0j} + \varepsilon_{ij}
\end{aligned}
$$

PRACTICAL CONSIDERATIONS

- The bias due to “smushing” level-1 and level-2 slopes into a single slope (no disaggregation) is minimal with small ICCs
- Estimating the level-2 means (latent variables) is challenging when the ICC is small because there isn’t much variation to work with at level-2 (greater chance of convergence failures)
- Level-2 means are very noisy when the ICC is small and the number of observations per cluster is small (lower power)

WITHIN-CLUSTER (LEVEL-1) MODEL

- Job satisfaction rating i for team j is the sum of a level-2 mean (β_{0j}), fixed effects due to within-team predictors (β_1 through β_3), and a within-team residual (ε_{ij})

$$jobsat_{ij} = \beta_{0j} + \beta_1(lmx_{ij}^{w}) + \beta_2(empower_{ij}^{w}) + \beta_3(male_{ij}) + \varepsilon_{ij}$$

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

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

BETWEEN-CLUSTER (LEVEL-2) MODEL

- Slopes are constant across level-2 units, but the job satisfaction mean for team j (β_{0j}) is the sum of the grand mean (γ_{00}) and a between-team residual (u_{0j})
- Assumption: random intercept residuals are normal with constant variation across teams (level-2 units)

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_1 = \gamma_{10}$$
$$\beta_2 = \gamma_{20}$$
$$\beta_3 = \gamma_{30}$$

$$u_{0j} \sim N(0, \sigma_u^2)$$

DECODING THE SUBSCRIPTS

The second subscript numbers the coefficients on the right side starting at 0 (the intercept)

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

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

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

The first subscript tells which level-2 outcome variable these terms are attached to (γ_{00} and u_{0j} belong in β_{0j}'s equation, γ_{10} is attached to β_1)

COMBINED-MODEL EQUATION

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_1 = \gamma_{10}$$
$$\beta_2 = \gamma_{20}$$
$$\beta_3 = \gamma_{30}$$

Substituting the right sides of the level-2 equations …

into their coefficients from the level-1 equation

$$jobsat_{ij} = \beta_{0j} + \beta_1(lmx_{ij}^{w}) + \beta_2(empower_{ij}^{w}) + \beta_3(male_{ij}) + \varepsilon_{ij}$$

gives the combined-model regression equation (Raudenbush & Bryk, 2002)

$$jobsat_{ij} = \overbrace{\gamma_{00} + u_{0j}}^{\text{Leading 0 subscript conveys team-level effects}} + \underbrace{\gamma_{10}(lmx_{ij}^{w}) + \gamma_{20}(empower_{ij}^{w}) + \gamma_{30}(male_{ij})}_{\text{Nonzero subscript conveys within-team effects}} + \varepsilon_{ij}$$

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$jobsat_{ij} = \gamma_{00} + \gamma_{10}(lmx^{w}_{ij}) + \gamma_{20}(empower^{w}_{ij}) + \gamma_{30}(male_{ij}) + u_{0j} + \varepsilon_{ij}$$

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

$$jobsat_{ij} = \beta_{0} + \beta_{1}(lmx^{w}_{ij}) + \beta_{2}(empower^{w}_{ij}) + \beta_{3}(male_{ij}) + u_{0j} + \varepsilon_{ij}$$

BLIMP SCRIPT 5.2

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;   # invokes categorical variable model and automatic dummy coding
CLUSTERID: Team;
CENTER: groupmean = LMX Empower; grandmean = Male;   # centering gender is cosmetic
MODEL: JobSat ~ intercept LMX Empower Male | intercept;
BURN: 20000;
ITERATIONS: 10000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 2)

```
model2 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male',
    model = 'JobSat ~ intercept LMX Empower Male | intercept',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model2)
plot_posterior(model2, 'JobSat')
```

BLIMP OUTPUT

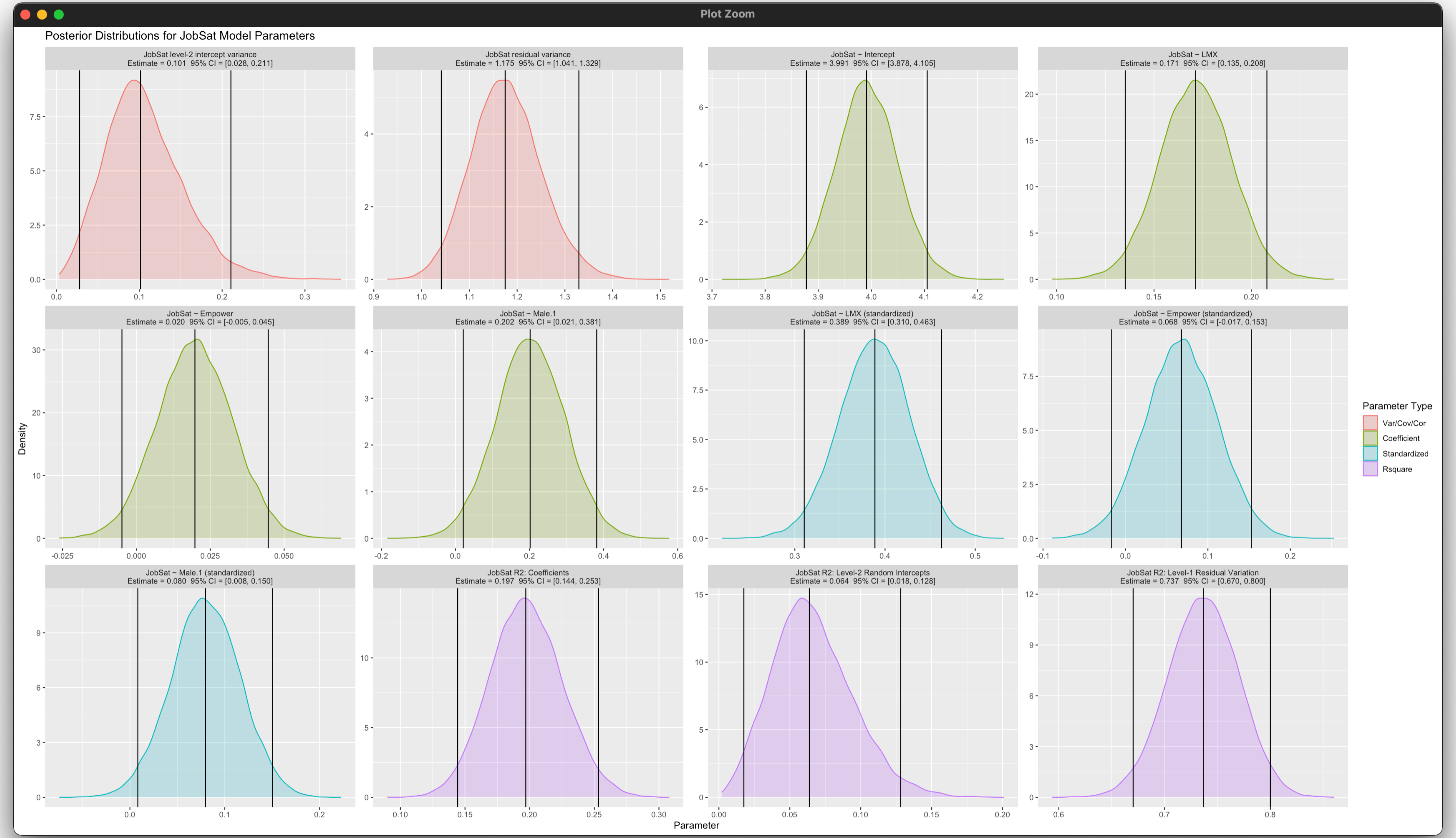
= level-2 estimate
= level-1 estimate
= combined estimate

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX
```

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	0.101	0.047	0.028	0.211	---	---	640.126
Residual Var.	1.175	0.073	1.041	1.329	---	---	6327.593
Coefficients:							
Intercept	3.991	0.058	3.878	4.105	4718.233	0.000	2735.980
LMX	0.171	0.019	0.135	0.208	85.554	0.000	9092.221
Empower	0.020	0.013	-0.005	0.045	2.439	0.118	11341.607
Male.1	0.202	0.092	0.021	0.381	4.778	0.029	17185.784
Standardized Coefficients:							
LMX	0.389	0.039	0.310	0.463	99.108	0.000	6235.514
Empower	0.068	0.043	-0.017	0.153	2.445	0.118	11091.889
Male.1	0.080	0.036	0.008	0.150	4.825	0.028	17139.893
Proportion Variance Explained							
by Coefficients	0.197	0.028	0.144	0.253	---	---	5347.962
by Level-2 Random Intercepts	0.064	0.028	0.018	0.128	---	---	634.331
by Level-1 Residual Variation	0.737	0.033	0.670	0.800	---	---	1782.897

PARAMETER PLOTS (RBLIMP ONLY)



INTERPRETATIONS

Parameter	Est.	Interpretation
Fixed intercept	3.99	Expected job satisfaction for a supervisee with zero values on the predictor (the grand mean because the predictors are centered)
LMX (within-team)	0.17	Expected satisfaction difference between two people *from the same team* with LMX scores that differ by one point, controlling for empowerment and gender
Empower (within-team)	0.02	Expected satisfaction difference between two people *from the same team* with empowerment scores that differ by one point, controlling for LMX and gender
Gender (mostly within-team)	0.20	Expected satisfaction difference between a male and female *from the same team,* controlling for LMX and empowerment
Between-cluster variance (variance of u_{0j} residuals)	0.10	Average squared distance between the job satisfaction means and the grand mean (level-2 mean differences)
Within-cluster residual variance (variance of ε_{ij} residuals)	1.18	Average squared distance between a supervisee's observed and predicted job satisfaction scores (residual within-cluster variation)

VARIANCE EXPLAINED MEASURES

Explained ÷ Total

Fixed effects of predictors

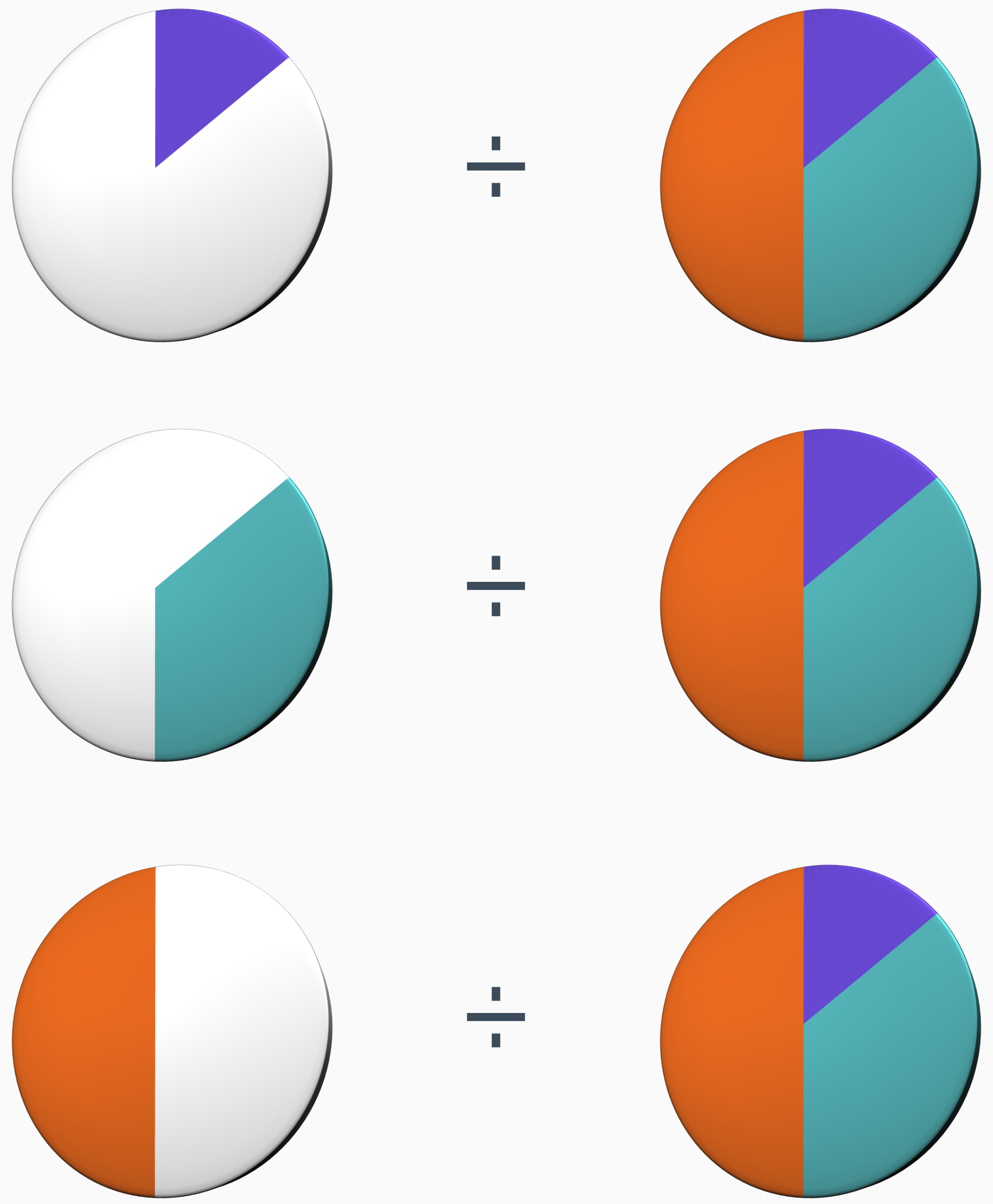
$$R^2_{predictors} = \frac{\boldsymbol{\beta}^T \boldsymbol{\Sigma}_X \boldsymbol{\beta}}{\sigma^2_Y}$$

Level-2 random intercept residuals

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

Level-1 within-cluster residuals

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



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	.20	The level-1 predictors explain 20% of the total variation in job satisfaction
Between-cluster variance (variance of u_{0j} residuals)	.06	Between-team variation in the level-2 residuals (variance of u_{0j} residuals = 0.10) accounts for 6% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.74	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 1.31) accounts for 74% of the total variation

MODEL-BUILDING STEPS

- The methods literature often recommends a multistep model-building procedure that begins at level-1

1) Estimate ICCs
2) Add predictors measured at level-1
3) Add random coefficients for level-1 predictors

4a) Add cluster means of level-1 predictors

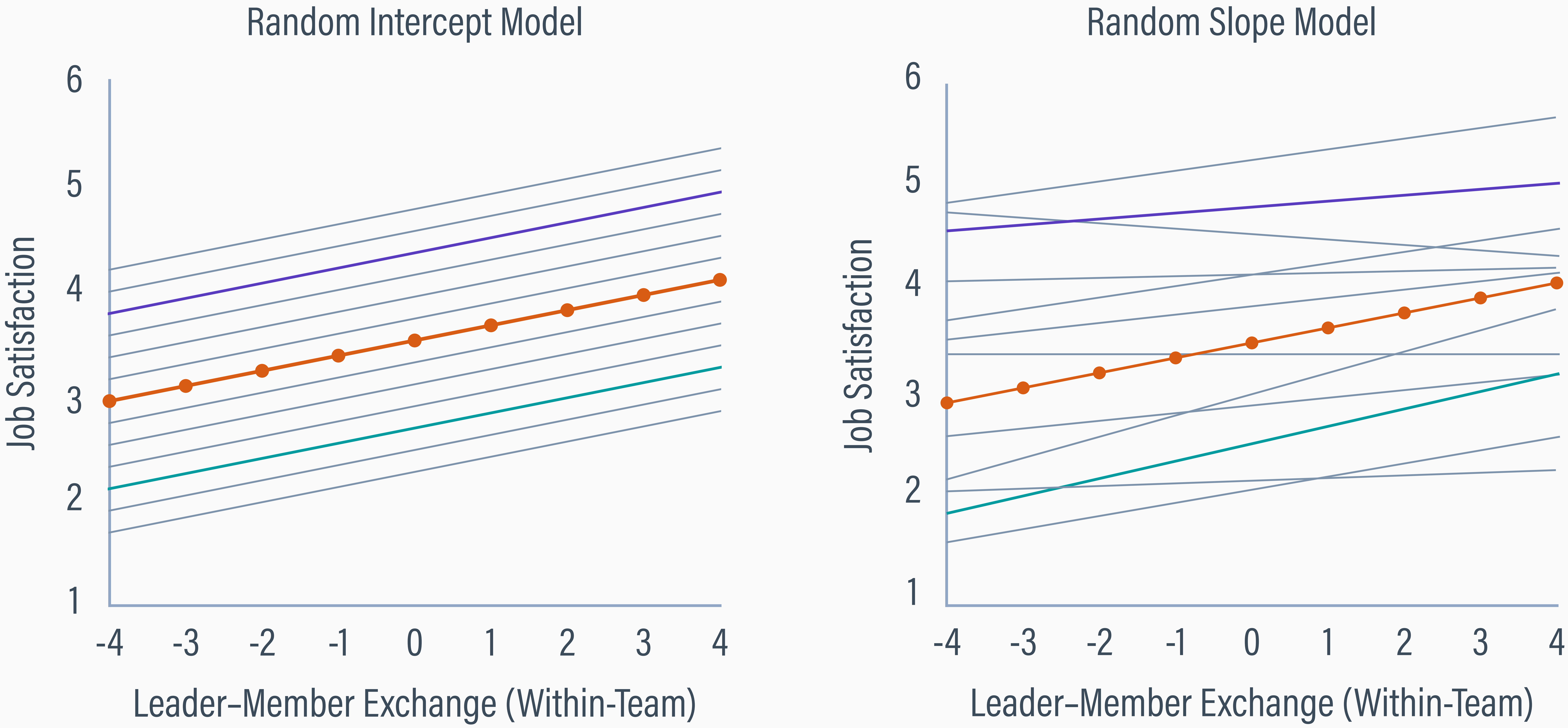
4b) Add predictors measured at level-2

May be combined into a single step

RANDOM SLOPE COEFFICIENTS

- Random slope or random coefficient models allow the influence of a predictor to vary across level-2 units
- The influence of LMX, empowerment, or gender could vary across teams
- e.g., In some teams, the quality of the supervisor–supervisee relationship (LMX) may strongly influence satisfaction, whereas in others, it may not

MODEL COMPARISON



OUTLINE

1. Estimate ICCs
2. Add Within-Cluster Predictors
3. Strategy 1: Evaluate Random Slopes One at a Time
4. Strategy 2: Add All Random Slopes at Once
5. Add Between-Cluster Predictors
6. Latent Variable Specification

PROS AND CONS

Pros

- Provides insight into the univariate R^2 contribution of each predictor (without regard to shared variation with others)
- Starting simple and building in complexity is more likely to produce a model that converges / has support

Cons

- Theory may not guide the sequence
- Each step in the sequence invokes a data-dependent decision about whether to include or discard a random slope
- Different entry orders could produce different results

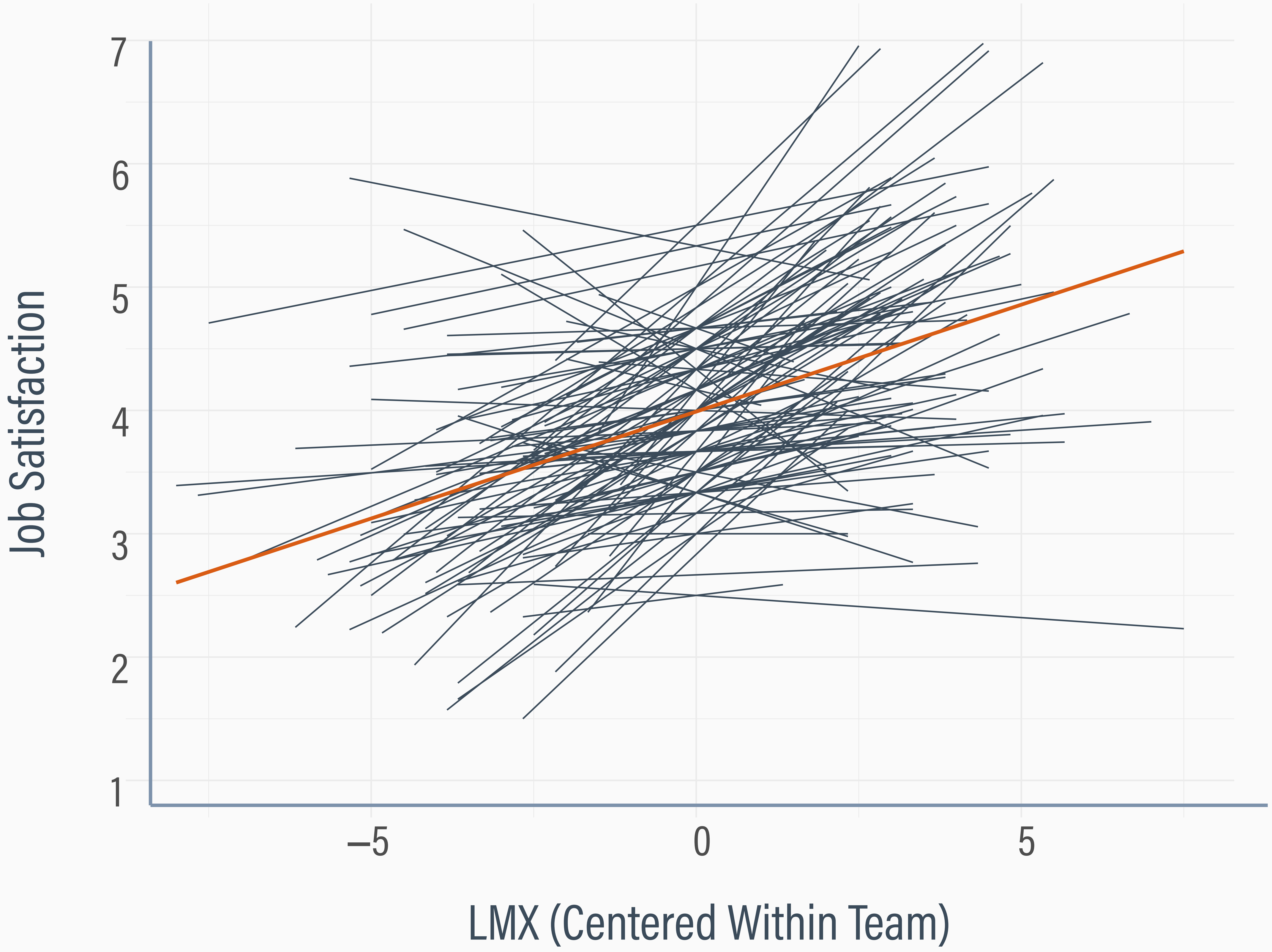
DESCRIPTION OF MODEL-BUILDING

Description of model building steps for a paper:

To evaluate the need for random slopes, we added random coefficients for focal level-1 predictors one at a time. We did not consider random coefficients for covariates. Although this procedure was inherently exploratory, it avoids convergence problems that can when adding unnecessary effects to the model. For each coefficient, we considered three criteria. First, we examined MCMC diagnostics to evaluate whether there were signs of overfitting. This included potential scale reduction factor values that indicated slow convergence or small effective sample size values indicating poor support from the data. Second, we examined the Rights and Sterba (2019) R-square effect size to evaluate whether a random coefficient accounted for a meaningful amount of variation. Finally, we considered an approximate chi-bar significance test for evaluating whether the random slope and its covariance with the random intercepts were different from zero (Snijders & Bosker, 2012, p. 99). After evaluating the random slopes individually, we added coefficients with salient effects to the final model prior to adding level-2 predictors.

TEAM-SPECIFIC LMX SLOPES

The R script for this example includes a function to make this graph.



WITHIN-CLUSTER (LEVEL-1) MODEL

- Both the team-specific job satisfaction mean (β_{0j}) and the leader-member exchange slope vary across clusters (β_{1j}), but the empowerment and gender slopes are constant

$$jobsat_{ij} = \beta_{0j} + \beta_{1j}(lmx^{w}_{ij}) + \beta_2(empower^{w}_{ij}) + \beta_3(male_{ij}) + \varepsilon_{ij}$$

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

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

BETWEEN-CLUSTER (LEVEL-2) MODEL

- The job satisfaction mean for team j (β_{0j}) is the sum of the grand mean (γ_{00}) 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*

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2} = \gamma_{20}$$
$$\beta_{3} = \gamma_{30}$$

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

DECODING THE SUBSCRIPTS

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

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

$$\beta_{2j} = \gamma_{20}$$

$$\beta_{3j} = \gamma_{30}$$

The second subscript numbers the coefficients on the right side starting at 0 (the intercept)

The first subscript tells which level-2 outcome variable these terms are attached to (γ_{00} and u_{0j} belong in β_{0j}'s equation, γ_{10} is attached to β_1)

ILLUSTRATION: POSITIVE SLOPE RESIDUAL

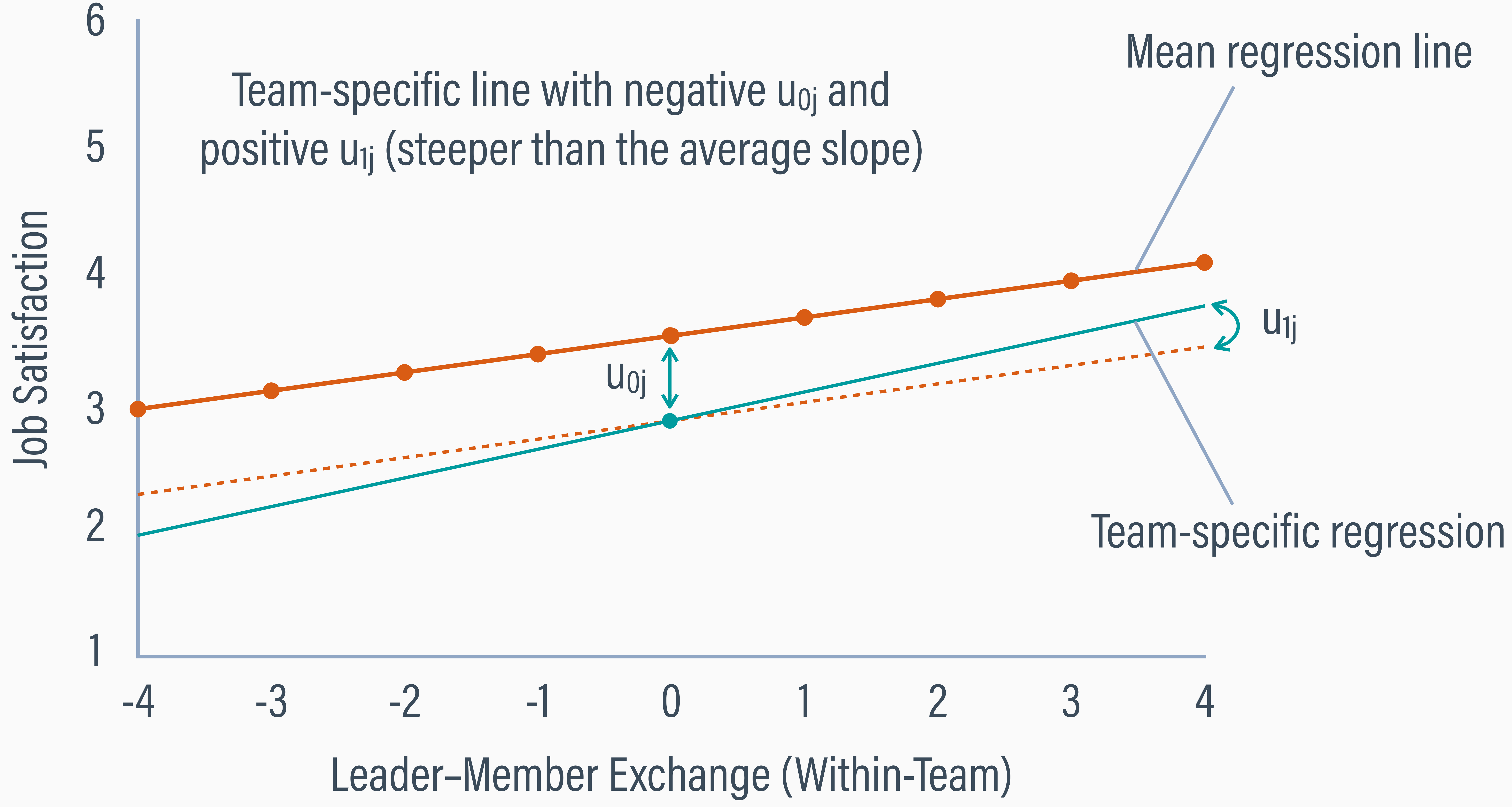
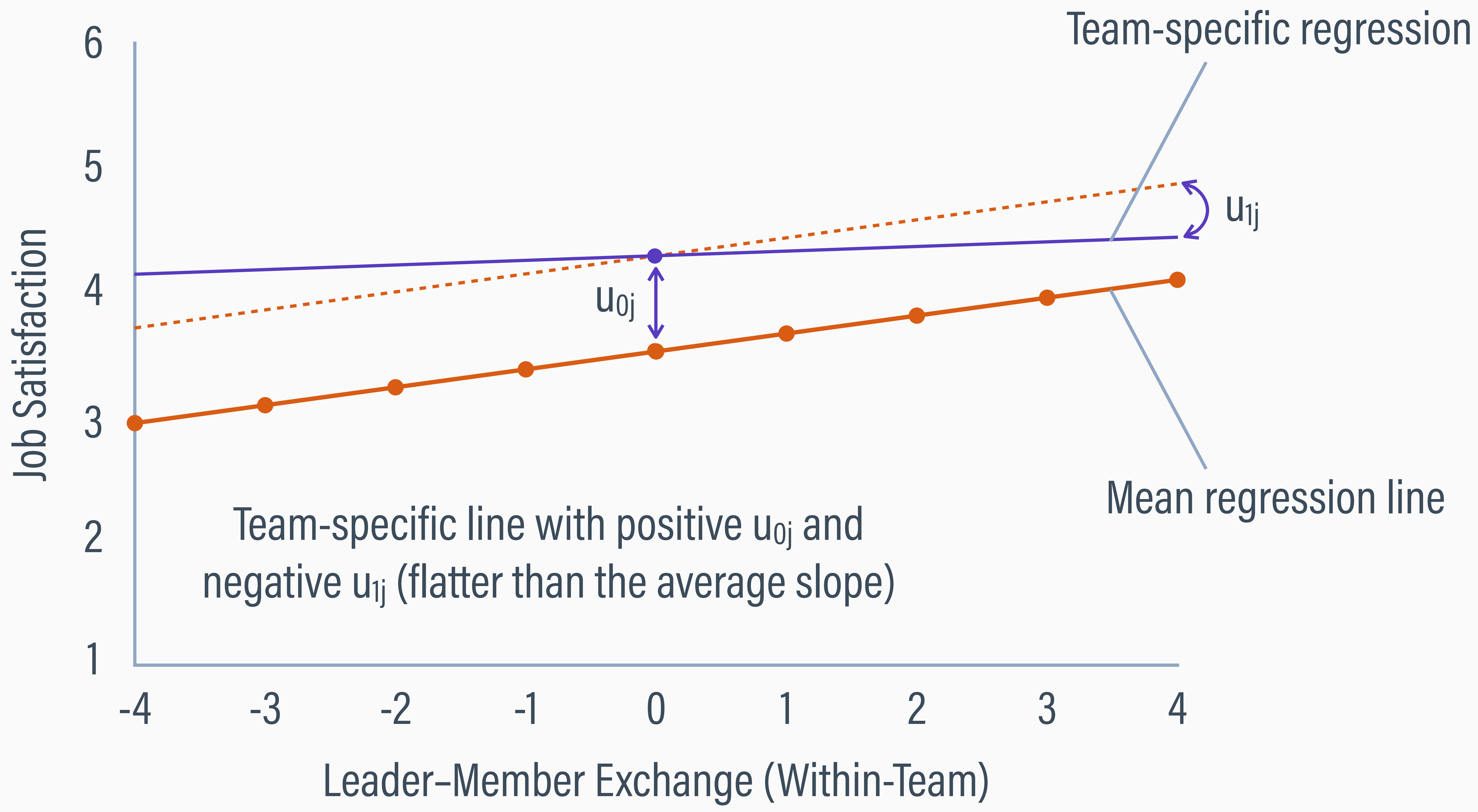


ILLUSTRATION: NEGATIVE SLOPE RESIDUAL



COMBINED-MODEL EQUATION

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_1 = \gamma_{10} + u_{1j}$$

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

$$\beta_3 = \gamma_{30}$$

Substituting the right sides of the level-2 equations ...

into their coefficients from the level-1 equation

$$jobsat_{ij} = \beta_{0j} + \beta_{1j}(lmx^{w}_{ij}) + \beta_2(empower^{w}_{ij}) + \beta_3(male_{ij}) + \varepsilon_{ij}$$

gives the combined-model regression equation (Raudenbush & Bryk, 2002)

Leading 0 subscript conveys team-level effects

$$jobsat_{ij} = \gamma_{00} + u_{0j} + (\gamma_{10} + u_{1j})(lmx^{w}_{ij}) + \gamma_{20}(empower^{w}_{ij}) + \gamma_{30}(male_{ij}) + \varepsilon_{ij}$$

Nonzero subscript conveys within-team effects

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$jobsat_{ij} = \gamma_{00} + \gamma_{10}(lmx^{w}_{ij}) + \gamma_{20}(empower^{w}_{ij}) + \gamma_{30}(male_{ij}) + u_{0j} + (u_{1j})(lmx^{w}_{ij}) + \varepsilon_{ij}$$

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

$$jobsat_{ij} = \beta_{0} + \beta_{1}(lmx^{w}_{ij}) + \beta_{2}(empower^{w}_{ij}) + \beta_{3}(male_{ij}) + u_{0j} + (u_{1j})(lmx^{w}_{ij}) + \varepsilon_{ij}$$

BLIMP SCRIPT 5.3

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;   # invokes categorical variable model
CLUSTERID: Team;
CENTER: groupmean = LMX Empower; grandmean = Male;   # cwc with latent group means
MODEL: JobSat ~ intercept LMX Empower Male | intercept LMX;
BURN: 20000;
ITERATIONS: 10000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 3)

```
model3 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male',
    model = 'JobSat ~ intercept LMX Empower Male | intercept LMX',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model3)
plot_posterior(model3, 'JobSat')
```

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           1.738            25
                          501 to 1000          1.461            24
                          751 to 1500          1.427            24
                         1001 to 2000          1.093            24
                                  ...            ...            ..
                         2501 to 5000          1.029            26
                         2751 to 5500          1.028            31
                         3001 to 6000          1.059            31
                         3251 to 6500          1.044            25
                         3501 to 7000          1.033             2
                         3751 to 7500          1.025            31
                         4001 to 8000          1.028            30
                         4251 to 8500          1.024            31
                         4501 to 9000          1.013            25
                         4751 to 9500          1.031            24
                         5001 to 10000         1.032             2
```

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

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

Outcome Variable: JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	0.109	0.047	0.035	0.217	---	---	**1030.885**
L2 : Cov(LMX,Intercept)	0.009	0.009	-0.009	0.027	---	---	**418.520**
L2 : Var(LMX)	0.005	0.003	0.001	0.014	---	---	**309.126**
Residual Var.	1.144	0.073	1.012	1.297	---	---	4630.627
Coefficients:							
Intercept	3.985	0.059	3.870	4.103	4486.797	0.000	2851.341
LMX	0.172	0.020	0.133	0.211	74.258	0.000	9594.087
Empower	0.020	0.013	-0.005	0.045	2.468	0.116	10897.156
Male.1	0.199	0.094	0.012	0.380	4.437	0.035	16785.705
...							
Proportion Variance Explained							
by Coefficients	0.195	0.030	0.138	0.255	---	---	6812.838
by Level-2 Random Intercepts	0.068	0.028	0.022	0.130	---	---	1004.732
by Level-2 Random Slopes	0.024	0.017	0.004	0.069	---	---	305.036
by Level-1 Residual Variation	0.708	0.037	0.632	0.777	---	---	1407.830

BLIMP OUTPUT

= level-2 estimate
= level-1 estimate
= combined estimate

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX
```

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	0.109	0.047	0.035	0.217	---	---	1030.885
L2 : Cov(LMX,Intercept)	0.009	0.009	-0.009	0.027	---	---	418.520
L2 : Var(LMX)	0.005	0.003	0.001	0.014	---	---	309.126
Residual Var.	1.144	0.073	1.012	1.297	---	---	4630.627
Coefficients:							
Intercept	3.985	0.059	3.870	4.103	4486.797	0.000	2851.341
LMX	0.172	0.020	0.133	0.211	74.258	0.000	9594.087
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...							
Proportion Variance Explained							
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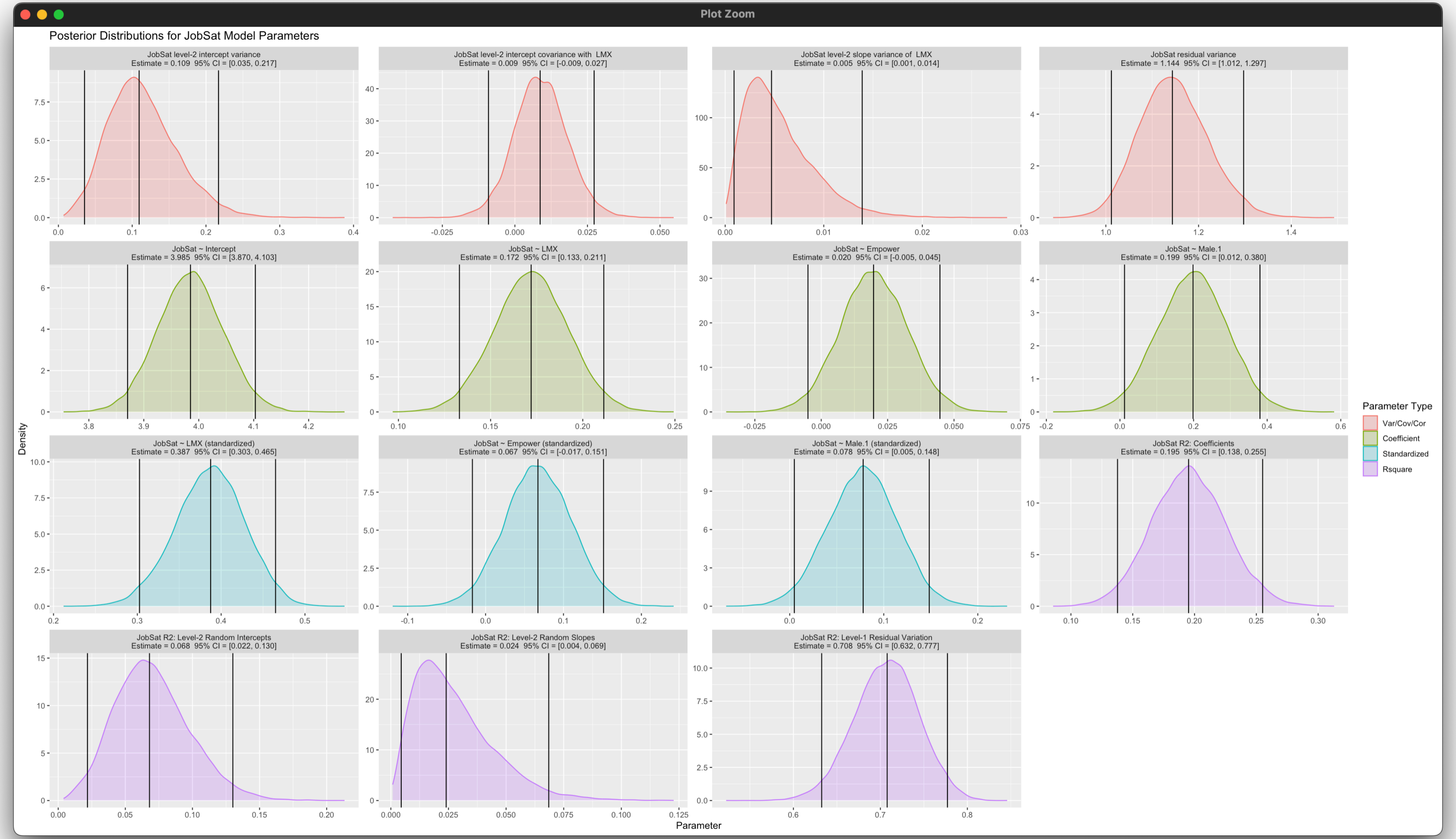
by Level-2 Random Slopes	0.024	0.017	0.004	0.069	---	---	305.036
by Level-1 Residual Variation	0.708	0.037	0.632	0.777	---	---	1407.830

PARAMETER PLOTS (RBLIMP ONLY)

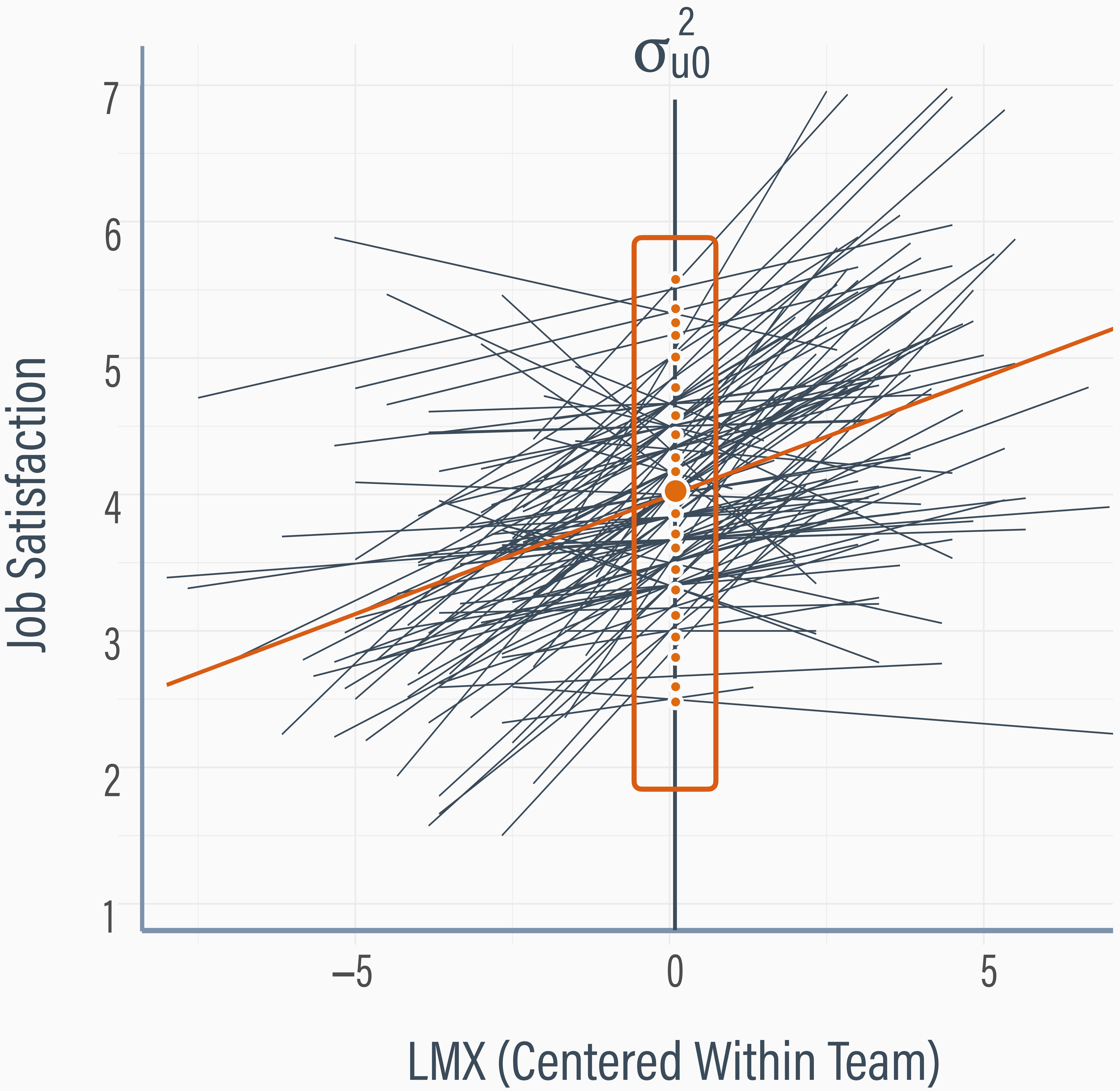


INTERPRETATIONS

Parameter	Est.	Interpretation
Fixed intercept	3.99	Expected job satisfaction for a supervisee with zero values on the predictor (the grand mean because the predictors are centered)
LMX (within-team)	0.17	Expected satisfaction difference between two people *from the same team* with LMX scores that differ by one point, controlling for empowerment and gender
Empower (within-team)	0.02	Expected satisfaction difference between two people *from the same team* with empowerment scores that differ by one point, controlling for LMX and gender
Gender (mostly within-team)	0.20	Expected satisfaction difference between a male and female *from the same team,* controlling for LMX and empowerment
Between-cluster intercept variance (variance of u_{0j} residuals)	0.11	Average squared distance between the job satisfaction means and the grand mean (level-2 mean differences)
Between-cluster slope variance (variance of u_{1j} residuals)	0.005	Average squared distance between the team-specific slopes and the mean slope
Intercept–slope covariance (covariance of u_{0j} and u_{1j} residuals)	0.009	Positive association where teams with higher job satisfaction means (intercepts) also tend to have higher (more positive) LMX slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	1.14	Average squared distance between a supervisee's observed and predicted job satisfaction scores (residual within-cluster variation)

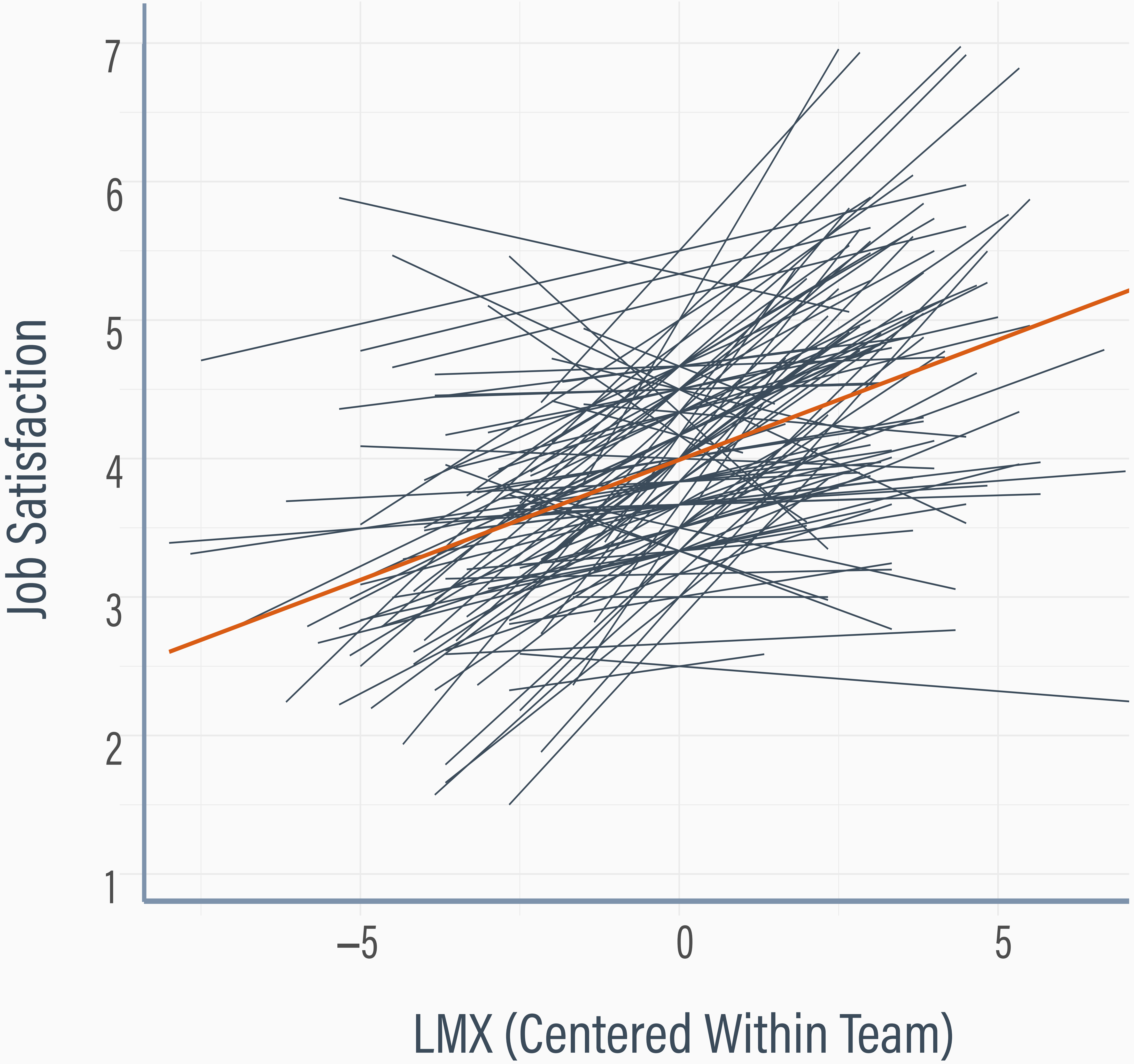
RANDOM INTERCEPT VARIANCE

- The random intercept variance (σ^2_{u0} = 0.11) quantifies differences among team-specific intercepts or means
- Visually, the random intercept variance is the vertical separation of the lines at sleep quality = 0



RANDOM SLOPE VARIANCE

- The random slope variance (σ^2_{u1} = 0.005) quantifies differences among team-specific slopes
- Visually, the random slope variance is the degree to which team-specific slopes deviate from parallel



DO RANDOM SLOPES IMPROVE FIT?

- It is important to include random slopes, but do so judiciously because overfitting impacts convergence and power
- MCMC will show signs of struggle when overfitting, so checking diagnostics is especially important
- Rights and Sterba (2019) effect sizes are useful
- A specialized chi-square test (called a chi-bar test) is necessary when significance testing variances

PREDICTED OUTCOME VARIATION

- Model-predicted total variance = (a) explained variation due to predictors + (b) random intercept residual variation + (c) random slope variation + (d) within-cluster residual variance

$$\mathrm{var}\left(Y_{ij}\right) = \boldsymbol{\beta}^{T}\boldsymbol{\Sigma}_{X}\boldsymbol{\beta} + \mathrm{tr}(\boldsymbol{\Sigma}_{u}\boldsymbol{\Sigma}_{X}) + \mathrm{var}\left(u_{0j}\right) + \mathrm{var}\left(\varepsilon_{ij}\right)$$

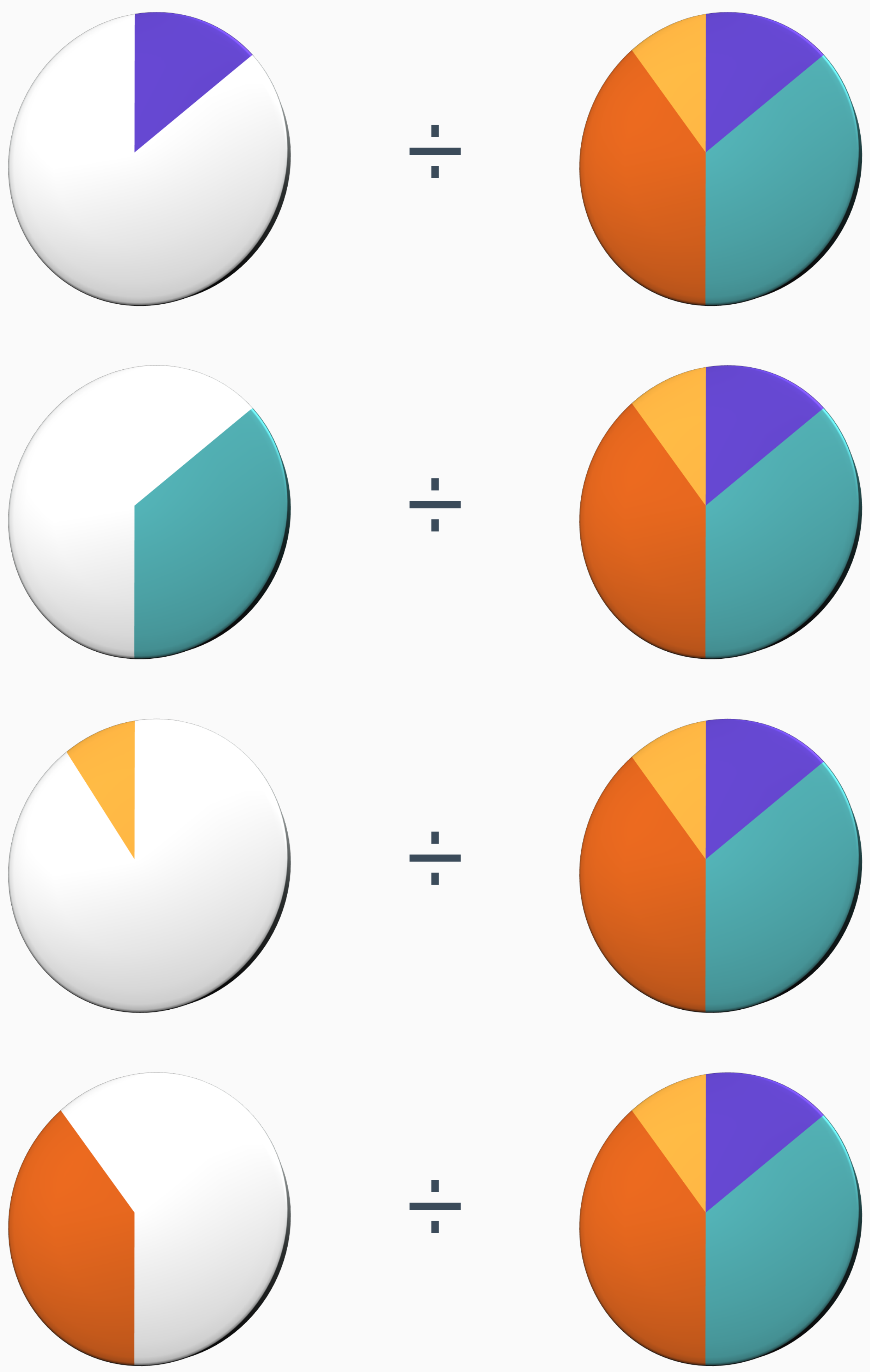
total = explained by predictors + slope residuals + intercept residuals + level-1 residuals

- Total variance is the denominator for R-square effect sizes

VARIANCE EXPLAINED MEASURES

Fixed effects of predictors	$$R^2_{\text{predictors}} = \frac{\boldsymbol{\beta}^{T}\boldsymbol{\Sigma}_X\boldsymbol{\beta}}{\sigma^2_Y}$$	
Level-2 random intercept residuals	$$R^2_{\text{slopes}} = \frac{\text{tr}(\boldsymbol{\Sigma}_u\boldsymbol{\Sigma}_X)}{\sigma^2_Y}$$	
Level-2 random slope residuals	$$R^2_{\text{intercepts}} = \frac{\sigma^2_u}{\sigma^2_Y}$$	
Level-1 within-cluster residuals	$$R^2_{\text{residual(within)}} = \frac{\sigma^2_\varepsilon}{\sigma^2_Y}$$	

Explained ÷ Total



R^2 EFFECT SIZE MEASURES

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                          Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                   --------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)                0.109      0.047      0.035      0.217        ---        ---   1030.885
  L2 : Cov(LMX,Intercept)            0.009      0.009     -0.009      0.027        ---        ---    418.520
  L2 : Var(LMX)                      0.005      0.003      0.001      0.014        ---        ---    309.126
  Residual Var.                      1.144      0.073      1.012      1.297        ---        ---   4630.627

Coefficients:
  Intercept                          3.985      0.059      3.870      4.103   4486.797      0.000   2851.341
  LMX                                0.172      0.020      0.133      0.211     74.258      0.000   9594.087
  Empower                            0.020      0.013     -0.005      0.045      2.468      0.116  10897.156
  Male.1                             0.199      0.094      0.012      0.380      4.437      0.035  16785.705

...

Proportion Variance Explained
  by Coefficients                    0.195      0.030      0.138      0.255        ---        ---   6812.838
  by Level-2 Random Intercepts       0.068      0.028      0.022      0.130        ---        ---   1004.732
  by Level-2 Random Slopes           0.024      0.017      0.004      0.069        ---        ---    305.036
  by Level-1 Residual Variation      0.708      0.037      0.632      0.777        ---        ---   1407.830

                                   --------------------------------------------------------------------------
```

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	.20	The level-1 predictors explain 20% of the total variation in job satisfaction
Between-cluster intercept variance (variance of u_{0j} residuals)	.07	Between-team variation in the level-2 residuals (variance of u_{0j} residuals = 0.11) accounts for 7% of the total variation
Between-cluster slope variance (variance of u_{1j} residuals)	.02	Between-team variation in the random slope residuals (variance of u_{1j} residuals = 0.005) accounts for 2% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.71	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 1.14) accounts for 71% of the total variation

RANDOM SLOPE R^2 BENCHMARKS

- Random slope R^2 values tend to be quite small (values > .10 appear to be uncommon)
- Across data sets from numerous MLM and longitudinal books, random slope R^2 values ranged from .001 to .094 (Enders, Woller, & Keller, 2023)
- The mean R^2 from cross-section applications was about .04, and the mean from longitudinal applications was about .05

NESTED MODEL WALD TEST

- The Wald is the sum of squared standardized differences between the point estimates and the null

$$\chi^2_{MCMC} = (\boldsymbol{\theta} - \boldsymbol{\theta}_0)\mathrm{cov}(\boldsymbol{\theta})^{-1}(\boldsymbol{\theta} - \boldsymbol{\theta}_0)$$

$$= (\text{estimates} - \text{null})(\text{covariance matrix of the estimates})^{-1}(\text{estimates} - \text{null})$$

- When evaluating random slopes, $\boldsymbol{\theta}$ contains both the slope variance and its covariance with the intercepts (which must be zero if the random slope variance is zero)

SIGNIFICANCE TESTING WITH VARIANCES

- Testing whether variances differ from zero is challenging because the null hypothesis (variance = 0) is the lowest possible value (estimates vary on only one side of the null)
- A specialized chi-square distribution (called a chi-bar) is necessary when significance testing slope variances
- The p-value is a weighted average of p-values from chi-square distribution with different degrees of freedom

RBLIMP SCRIPT 5 (MODEL 3)

```
model3 <- rblimp( ...
    model = 'JobSat ~ intercept LMX Empower Male | intercept LMX',
    ...)
output(model3)
chibar_test(model3, raneff = c('LMX'))   # chi-bar test from mlm-functions.R
```

```
Wald Statistic                                  2.819
Number of Parameters Tested (df)                    2
Probability (Chi-Bar Mixture Method)            0.169
Probability (Chi-Bar Binomial Method)           0.108
Probability (Central Chi-Square)                0.244
```

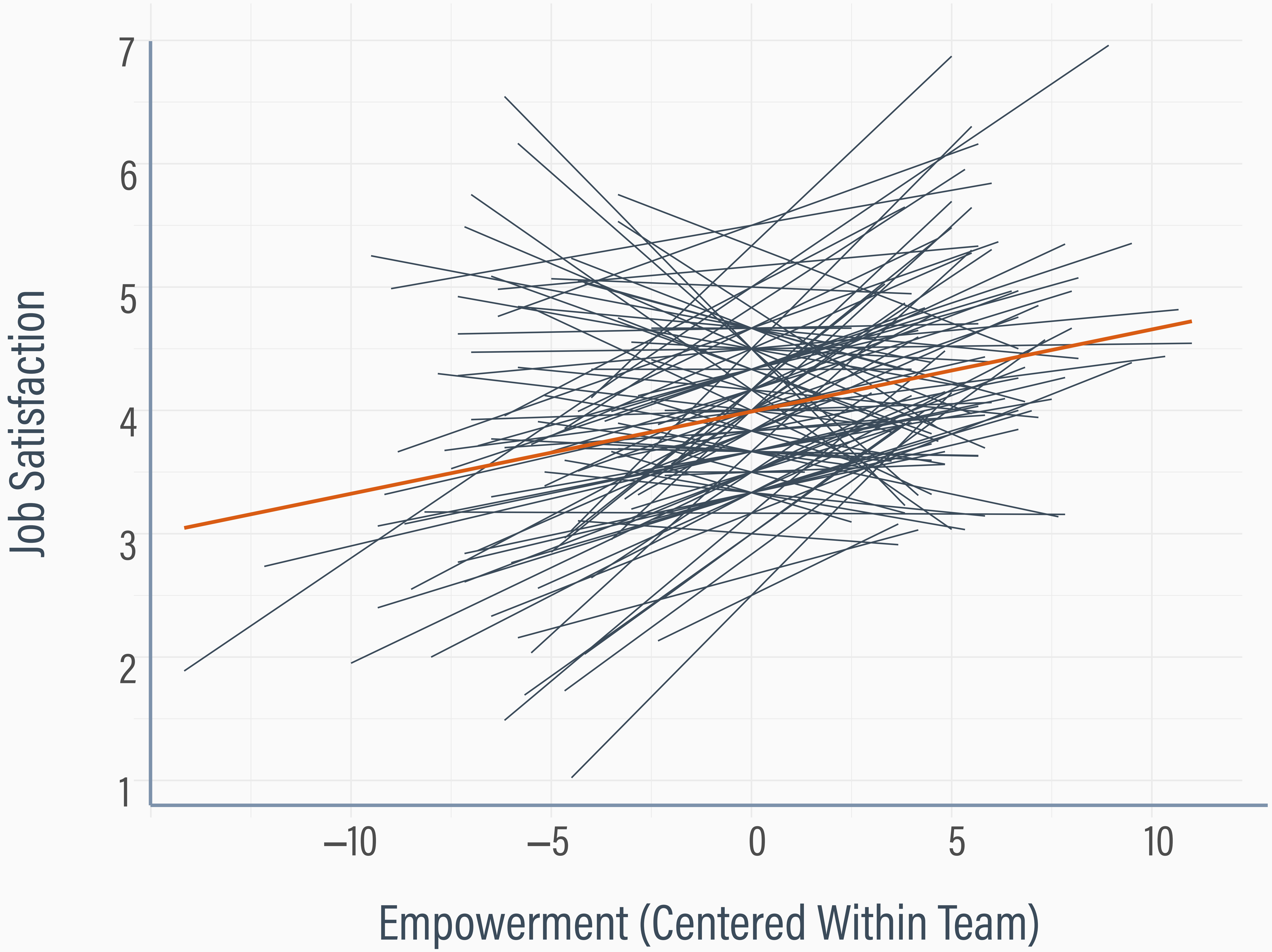
Use these, perhaps in tandem

WALD TEST INTERPRETATION

- The test supports the null hypothesis that the population slope variance and its covariance equal zero
- $\chi^2 = 2.81$, $p = .11$ to $.16$
- Adding the LMX random slope did not improve model fit, with the caveat that the chi-bar test is an approximation

TEAM-SPECIFIC EMPOWERMENT SLOPES

The R script for this example includes a function to make this graph.



WITHIN-CLUSTER (LEVEL-1) MODEL

- Both the team-specific job satisfaction mean (β_{0j}) and the empowerment slope vary across clusters (β_{2j}), but the leader-member exchange and gender slopes are constant

$$jobsat_{ij} = \beta_{0j} + \beta_1(lmx_{ij}^{w}) + \beta_{2j}(empower_{ij}^{w}) + \beta_2(male_{ij}) + \varepsilon_{ij}$$

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

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

BETWEEN-CLUSTER (LEVEL-2) MODEL

- The job satisfaction mean for team j (β_{0j}) is the sum of the grand mean (γ_{00}) and a between-team residual (u_{0j})
- The empowerment slope for team j (β_{2j}) is the sum of the mean slope (γ_{20}) and a team-level residual (u_{2j})
- Assumption: random intercept and slope residuals are bivariate normal and correlated

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

$$\beta_1 = \gamma_{10}$$

$$\beta_2 = \gamma_{20} + u_{2j}$$

$$\beta_3 = \gamma_{30}$$

$$\begin{pmatrix} u_{0j} \\ u_{2j} \end{pmatrix} \sim N(0, \boldsymbol{\Sigma}_u) \quad \boldsymbol{\Sigma}_u = \begin{pmatrix} \sigma^2_{u0} & \sigma_{u0u2} \\ \sigma_{u2u0} & \sigma^2_{u2} \end{pmatrix}$$

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$jobsat_{ij} = \gamma_{00} + \gamma_{10}(lmx^{w}_{ij}) + \gamma_{20}(empower^{w}_{ij}) + \gamma_{30}(male_{ij}) + u_{0j} + (u_{2j})(empower^{w}_{ij}) + \varepsilon_{ij}$$

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

$$jobsat_{ij} = \beta_{0} + \beta_{1}(lmx^{w}_{ij}) + \beta_{2}(empower^{w}_{ij}) + \beta_{3}(male_{ij}) + u_{0j} + (u_{2j})(empower^{w}_{ij}) + \varepsilon_{ij}$$

BLIMP SCRIPT 5.4

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;    # invokes categorical variable model
CLUSTERID: Team;
CENTER: groupmean = LMX Empower; grandmean = Male;    # cwc with latent group means
MODEL: JobSat ~ intercept LMX Empower Male | intercept Empower;
BURN: 20000;
ITERATIONS: 10000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 4)

```
model4 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male',
    model = 'JobSat ~ intercept LMX Empower Male | intercept Empower',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model4)
```

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              1.299           30
                        501 to 1000             1.183           30
                        751 to 1500             1.128           13
                       1001 to 2000             1.085           31
                                ...               ...           ..
                       2501 to 5000             1.079           24
                       2751 to 5500             1.073           24
                       3001 to 6000             1.045           30
                       3251 to 6500             1.050           24
                       3501 to 7000             1.063           24
                       3751 to 7500             1.072           31
                       4001 to 8000             1.018           24
                       4251 to 8500             1.042           30
                       4501 to 9000             1.018           30
                       4751 to 9500             1.021           24
                       5001 to 10000            1.022           24
```

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

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

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                      Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                             ---------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)             0.118      0.047      0.045      0.228        ---        ---    899.675
  L2 : Cov(Empower,Intercept)    -0.011      0.007     -0.026      0.001        ---        ---    535.197
  L2 : Var(Empower)               0.003      0.002      0.001      0.008        ---        ---    335.096
  Residual Var.                   1.118      0.072      0.988      1.267        ---        ---   5029.485

Coefficients:
  Intercept                       4.001      0.060      3.883      4.118   4434.613      0.000   2551.627
  LMX                             0.173      0.019      0.137      0.210     86.221      0.000   9104.124
  Empower                         0.018      0.014     -0.010      0.045      1.629      0.202   8248.654
  Male.1                          0.202      0.093      0.019      0.387      4.721      0.030  15935.151

...

Proportion Variance Explained
  by Coefficients                 0.193      0.029      0.138      0.253        ---        ---   6754.576
  by Level-2 Random Intercepts    0.073      0.027      0.028      0.135        ---        ---    849.843
  by Level-2 Random Slopes        0.039      0.022      0.008      0.093        ---        ---    315.212
  by Level-1 Residual Variation   0.690      0.038      0.614      0.762        ---        ---   1338.607

                             ---------------------------------------------------------------------------
```

BLIMP OUTPUT

= level-2 estimate
= level-1 estimate
= combined estimate

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX
```

Parameters	Median	StdDev	2.5%	97.5%	ChiSq	PValue	N_Eff
Variances:							
L2 : Var(Intercept)	0.118	0.047	0.045	0.228	---	---	899.675
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Residual Var.	1.118	0.072	0.988	1.267	---	---	5029.485
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Intercept	4.001	0.060	3.883	4.118	4434.613	0.000	2551.627
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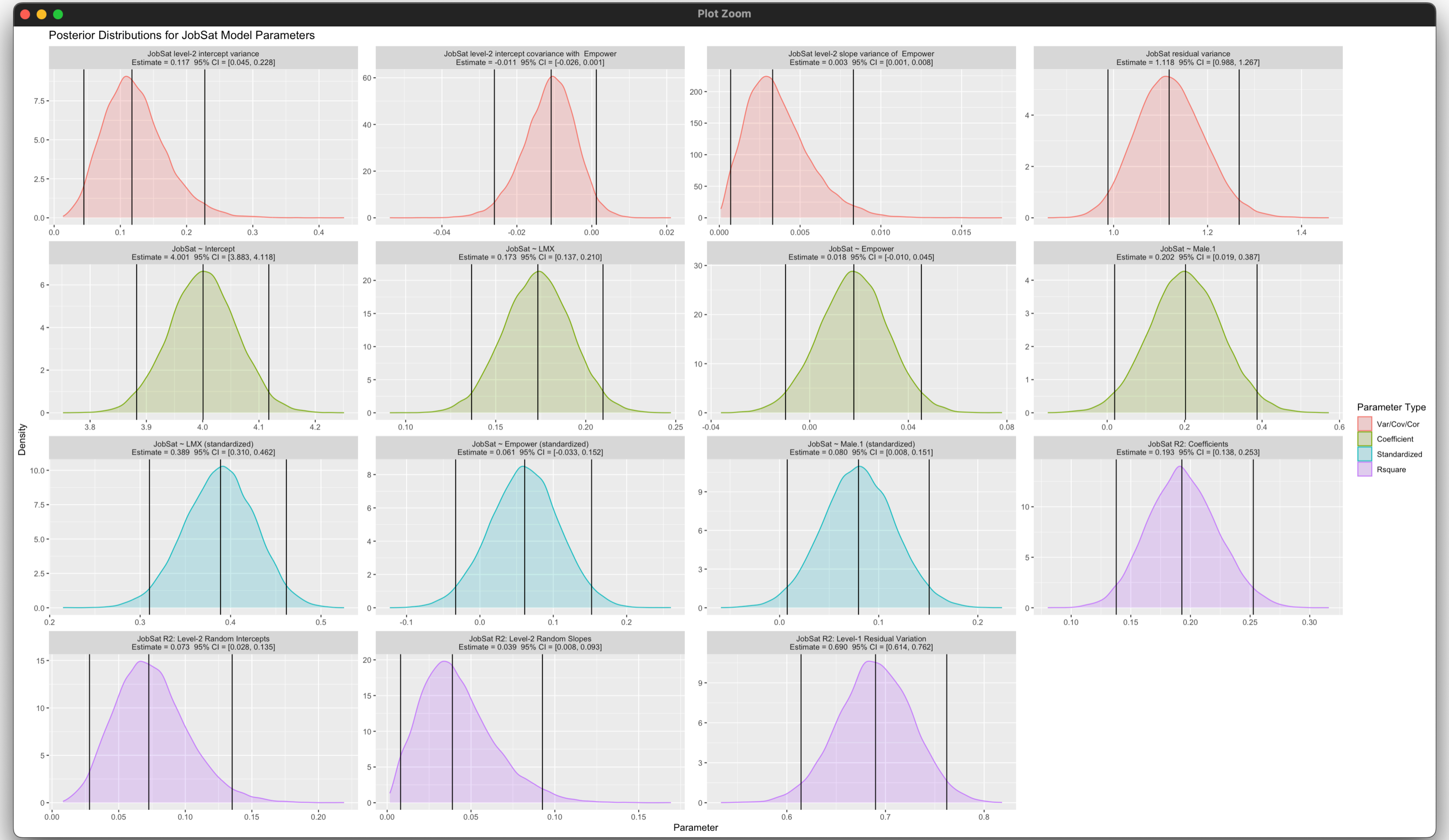
Male.1	0.202	0.093	0.019	0.387	4.721	0.030	15935.151
...							
Proportion Variance Explained							
by Coefficients	0.193	0.029	0.138	0.253	---	---	6754.576
by Level-2 Random Intercepts	0.073	0.027	0.028	0.135	---	---	849.843
by Level-2 Random Slopes	0.039	0.022	0.008	0.093	---	---	315.212
by Level-1 Residual Variation	0.690	0.038	0.614	0.762	---	---	1338.607

PARAMETER PLOTS (RBLIMP ONLY)



INTERPRETATIONS

Parameter	Est.	Interpretation
Fixed intercept	4.01	Expected job satisfaction for a supervisee with zero values on the predictor (the grand mean because the predictors are centered)
LMX (within-team)	0.17	Expected satisfaction difference between two people *from the same team* with LMX scores that differ by one point, controlling for empowerment and gender
Empower (within-team)	0.02	Expected satisfaction difference between two people *from the same team* with empowerment scores that differ by one point, controlling for LMX and gender
Gender (mostly within-team)	0.20	Expected satisfaction difference between a male and female *from the same team,* controlling for LMX and empowerment
Between-cluster intercept variance (variance of u_{0j} residuals)	0.12	Average squared distance between the job satisfaction means and the grand mean (level-2 mean differences)
Between-cluster slope variance (variance of u_{2j} residuals)	0.003	Average squared distance between the team-specific slopes and the mean slope
Intercept–slope covariance (covariance of u_{0j} and u_{2j} residuals)	−0.01	Negative association where teams with higher job satisfaction means (intercepts) tend to have lower (less positive or perhaps negative) empowerment slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	1.14	Average squared distance between a supervisee’s observed and predicted job satisfaction scores (residual within-cluster variation)

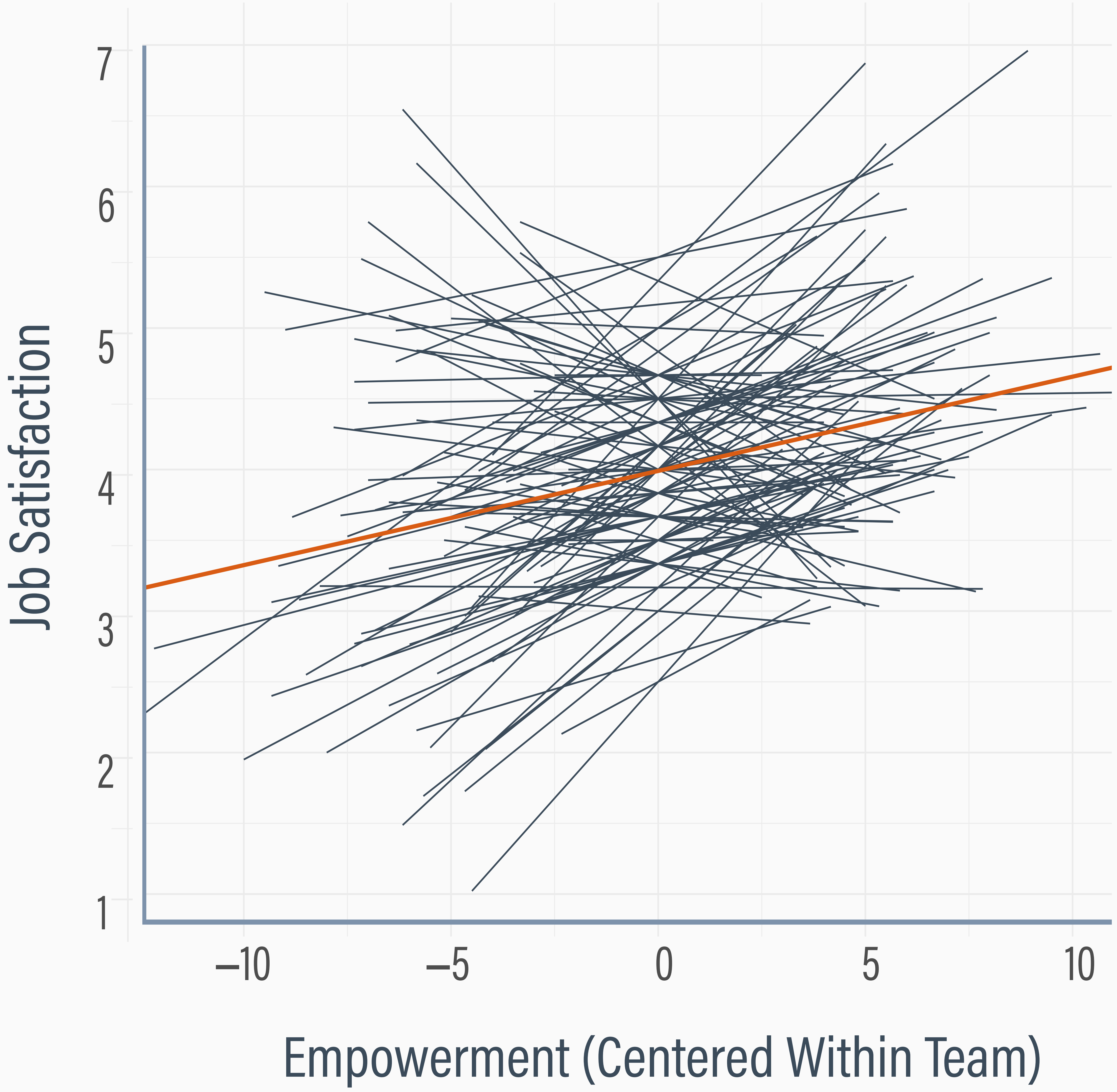
RANDOM INTERCEPT VARIANCE

- The random intercept variance (σ^2_{u0} = 0.12) quantifies differences among team-specific intercepts or means
- Visually, the random intercept variance is the vertical separation of the lines at sleep quality = 0

RANDOM SLOPE VARIANCE

- The random slope variance (σ^2_{u2} = 0.003) quantifies differences among team-specific slopes

- Visually, the random slope variance is the degree to which team-specific slopes deviate from parallel



R^2 EFFECT SIZE MEASURES

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                        Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                               -----------------------------------------------------------------------------

Variances:
  L2 : Var(Intercept)              0.118      0.047      0.045      0.228        ---        ---    899.675
  L2 : Cov(Empower,Intercept)     -0.011      0.007     -0.026      0.001        ---        ---    535.197
  L2 : Var(Empower)                0.003      0.002      0.001      0.008        ---        ---    335.096
  Residual Var.                    1.118      0.072      0.988      1.267        ---        ---   5029.485

Coefficients:
  Intercept                        4.001      0.060      3.883      4.118   4434.613      0.000   2551.627
  LMX                              0.173      0.019      0.137      0.210     86.221      0.000   9104.124
  Empower                          0.018      0.014     -0.010      0.045      1.629      0.202   8248.654
  Male.1                           0.202      0.093      0.019      0.387      4.721      0.030  15935.151

...

Proportion Variance Explained
  by Coefficients                  0.193      0.029      0.138      0.253        ---        ---   6754.576
  by Level-2 Random Intercepts     0.073      0.027      0.028      0.135        ---        ---    849.843
  by Level-2 Random Slopes         0.039      0.022      0.008      0.093        ---        ---    315.212
  by Level-1 Residual Variation    0.690      0.038      0.614      0.762        ---        ---   1338.607

                               -----------------------------------------------------------------------------
```

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	.19	The level-1 predictors explain 19% of the total variation in job satisfaction
Between-cluster intercept variance (variance of u_{0j} residuals)	.07	Between-team variation in the level-2 residuals (variance of u_{0j} residuals = 0.12) accounts for 7% of the total variation
Between-cluster slope variance (variance of u_{1j} residuals)	.04	Between-team variation in the random slope residuals (variance of u_{2j} residuals = 0.003) accounts for 4% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.69	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 1.12) accounts for 69% of the total variation

RBLIMP SCRIPT 5 (MODEL 3)

```
model4 <- rblimp( ...
    model = 'JobSat ~ intercept LMX Empower Male | intercept Empower',
    ...)
output(model4)
chibar_test(model4, raneff = c('Empower'))   # chi-bar test from mlm-functions.R
```

```
Wald Statistic                                  4.437
Number of Parameters Tested (df)                    2
Probability (Chi-Bar Mixture Method)            0.072
Probability (Chi-Bar Binomial Method)           0.045
Probability (Central Chi-Square)                0.109
```

Use these, perhaps in tandem

WALD TEST INTERPRETATION

- The test is ambiguous about the null, as p-values differ across approximations
- $\chi^2 = 4.45$, $p = .045$ to $.072$
- Given the non-trivial random slope effect size ($R^2_{slopes} = .04$) and quality-control diagnostics, I would include this effect

The gender (female = 0, male = 1) slope was about .20, meaning that males reported higher job satisfaction by about .20. The gender slope was constant across all teams, but we could also make its coefficient random. In small groups of two or three, discuss the meaning of a random slope for gender. Had we estimated that effect, what would it have quantified and/or how would it be interpreted?

OUTLINE

PROS AND CONS

Pros

- Reduces the data-dependent model-building decisions
- Easy to implement, fewer modeling steps

Cons

- Convergence failures highly likely as the number of random predictors increases
- May produce overly complex model with unnecessary parameters
- No information about the incremental R^2 contribution of each predictor

WITHIN-CLUSTER (LEVEL-1) MODEL

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

$$jobsat_{ij} = \beta_{0j} + \beta_{1j}(lmx^{w}_{ij}) + \beta_{2j}(empower^{w}_{ij}) + \beta_{3}(male_{ij}) + \varepsilon_{ij}$$

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

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

BETWEEN-CLUSTER (LEVEL-2) MODEL

- The job satisfaction mean for team j (β_{0j}) is the sum of the grand mean (γ_{00}) and a between-team residual (u_{0j})
- The LMX and empowerment slopes for team j (β_{1j} and β_{2j}) are the sum of the mean slopes (γ_{10} and γ_{20}) and team-level residuals (u_{1j} and u_{2j})
- Assumption: random intercept and slope residuals are multivariate normal and correlated

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1j} = \gamma_{10} + u_{1j}$$
$$\beta_{2j} = \gamma_{20} + u_{2j}$$
$$\beta_{3} = \gamma_{30}$$

$$\begin{pmatrix} u_{0j} \\ u_{1j} \\ u_{2j} \end{pmatrix} \sim N(0, \boldsymbol{\Sigma}_u) \quad \boldsymbol{\Sigma}_u = \begin{pmatrix} \sigma^2_{u0} & \sigma_{u0u1} & \sigma_{u0u2} \\ \sigma_{u1u0} & \sigma^2_{u1} & \sigma_{u1u2} \\ \sigma_{u2u0} & \sigma_{u2u1} & \sigma^2_{u2} \end{pmatrix}$$

DECODING THE SUBSCRIPTS

The second subscript numbers the coefficients on the right side starting at 0 (the intercept)

$$\beta_{0j} = \gamma_{00} + u_{0j}$$

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

$$\beta_{2j} = \gamma_{20} + u_{2j}$$

$$\beta_{3j} = \gamma_{30}$$

The first subscript tells which level-2 outcome variable these terms are attached to (γ_{00} and u_{0j} belong in β_{0j}'s equation, γ_{10} is attached to β_1)

COMBINED-MODEL EQUATION

$$\beta_{0j} = \gamma_{00} + u_{0j}$$
$$\beta_{1} = \gamma_{10} + u_{1j}$$
$$\beta_{2} = \gamma_{20} + u_{2j}$$
$$\beta_{3} = \gamma_{30}$$

Substituting the right sides of the level-2 equations ...

into their coefficients from the level-1 equation

$$jobsat_{ij} = \beta_{0j} + \beta_{1j}(lmx^{w}_{ij}) + \beta_{2j}(empower^{w}_{ij}) + \beta_{3}(male_{ij}) + \varepsilon_{ij}$$

gives the combined-model regression equation (Raudenbush & Bryk, 2002)

Leading 0 subscript conveys team-level effects

$$jobsat_{ij} = \overbrace{\gamma_{00} + u_{0j}} + \underbrace{(\gamma_{10} + u_{1j})(lmx^{w}_{ij}) + (\gamma_{20} + u_{2j})(empower^{w}_{ij}) + \gamma_{30}(male_{ij})} + \varepsilon_{ij}$$

Nonzero subscript conveys within-team effects

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$\text{jobsat}_{ij} = \gamma_{00} + \gamma_{10}(\text{lmx}^{w}_{ij}) + \gamma_{20}(\text{empower}^{w}_{ij}) + \gamma_{30}(\text{male}_{ij})$$
$$+ u_{0j} + (u_{1j})(\text{lmx}^{w}_{ij}) + (u_{2j})(\text{empower}^{w}_{ij}) + \varepsilon_{ij}$$

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

$$\text{jobsat}_{ij} = \beta_{0} + \beta_{1}(\text{lmx}^{w}_{ij}) + \beta_{2}(\text{empower}^{w}_{ij}) + \beta_{3}(\text{male}_{ij})$$
$$+ u_{0j} + (u_{1j})(\text{lmx}^{w}_{ij}) + (u_{2j})(\text{empower}^{w}_{ij}) + \varepsilon_{ij}$$

BLIMP SCRIPT 5.5

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;    # invokes categorical variable model
CLUSTERID: Team;
CENTER: groupmean = LMX Empower; grandmean = Male;    # cwc with latent group means
MODEL: JobSat ~ intercept LMX Empower Male | intercept LMX Empower;
BURN: 20000;
ITERATIONS: 10000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 5)

```
model5 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male',
    model = 'JobSat ~ intercept LMX Empower Male | intercept LMX Empower',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model5)
```

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             1.323            27
                          501 to 1000            1.134            33
                          751 to 1500            1.109            28
                         1001 to 2000            1.176            34
                                  ...             ...             ..
                         2501 to 5000            1.046            34
                         2751 to 5500            1.043             3
                         3001 to 6000            1.087             3
                         3251 to 6500            1.054             3
                         3501 to 7000            1.060             3
                         3751 to 7500            1.036             3
                         4001 to 8000            1.040            28
                         4251 to 8500            1.035             3
                         4501 to 9000            1.060             3
                         4751 to 9500            1.046             3
                         5001 to 10000           1.028             3
```

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

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

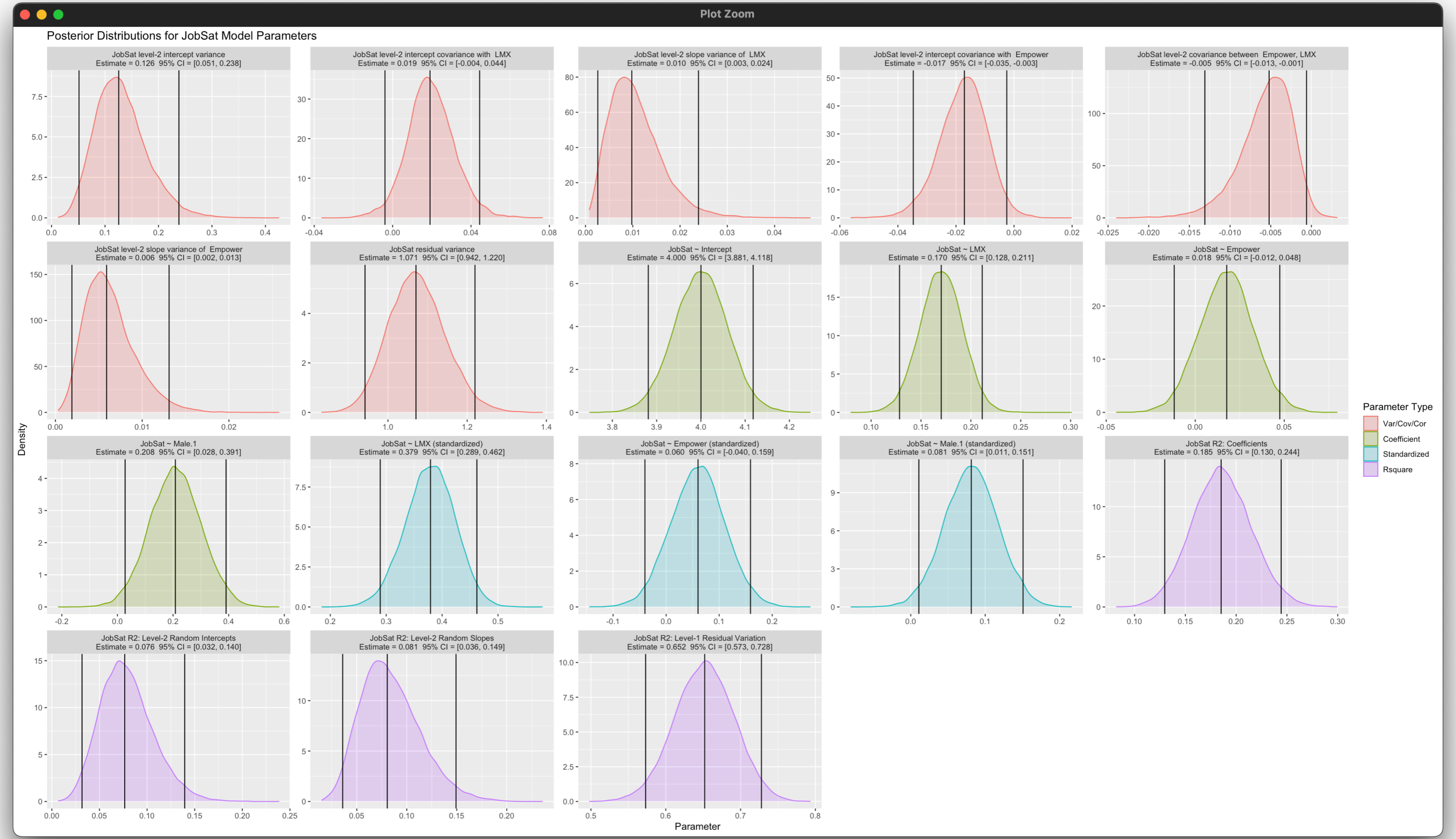
```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                         Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                 ---------------------------------------------------------------------------

Variances:
  L2 : Var(Intercept)               0.126      0.048      0.051      0.238        ---        ---    634.442
  L2 : Cov(LMX,Intercept)           0.019      0.012     -0.004      0.044        ---        ---    307.673
  L2 : Var(LMX)                     0.010      0.006      0.003      0.024        ---        ---    306.059
  L2 : Cov(Empower,Intercept)      -0.017      0.008     -0.035     -0.002        ---        ---    549.230
  L2 : Cov(Empower,LMX)            -0.005      0.003     -0.013     -0.001        ---        ---    380.005
  L2 : Var(Empower)                 0.006      0.003      0.002      0.013        ---        ---    361.246
  Residual Var.                     1.071      0.071      0.942      1.220        ---        ---   5147.409

Coefficients:
  Intercept                         4.000      0.060      3.881      4.118   4395.675      0.000   3081.469
  LMX                               0.170      0.021      0.128      0.211     64.216      0.000   6656.881
  Empower                           0.018      0.015     -0.012      0.048      1.373      0.241   6176.238
  Male.1                            0.208      0.092      0.028      0.391      5.134      0.023  12031.703

...

Proportion Variance Explained
  by Coefficients                   0.185      0.029      0.130      0.244        ---        ---   6178.264
  by Level-2 Random Intercepts      0.076      0.028      0.032      0.140        ---        ---    583.781
  by Level-2 Random Slopes          0.081      0.029      0.036      0.149        ---        ---    313.079
  by Level-1 Residual Variation     0.652      0.039      0.573      0.728        ---        ---   1029.838

                                 ---------------------------------------------------------------------------
```

BLIMP OUTPUT

= level-2 estimate
= level-1 estimate
= combined estimate

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                          Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                  -----------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)                0.126      0.048      0.051      0.238        ---        ---    634.442
  L2 : Cov(LMX,Intercept)            0.019      0.012     -0.004      0.044        ---        ---    307.673
  L2 : Var(LMX)                      0.010      0.006      0.003      0.024        ---        ---    306.059
  L2 : Cov(Empower,Intercept)       -0.017      0.008     -0.035     -0.002        ---        ---    549.230
  L2 : Cov(Empower,LMX)             -0.005      0.003     -0.013     -0.001        ---        ---    380.005
  L2 : Var(Empower)                  0.006      0.003      0.002      0.013        ---        ---    361.246
  Residual Var.                      1.071      0.071      0.942      1.220        ---        ---   5147.409

Coefficients:
  Intercept                          4.000      0.060      3.881      4.118   4395.675      0.000   3081.469
  LMX                                0.170      0.021      0.128      0.211     64.216      0.000   6656.881
  Empower                            0.018      0.015     -0.012      0.048      1.373      0.241   6176.238
  Male.1                             0.208      0.092      0.028      0.391      5.134      0.023  12031.703

...

Proportion Variance Explained
  by Coefficients                    0.185      0.029      0.130      0.244        ---        ---   6178.264
  by Level-2 Random Intercepts       0.076      0.028      0.032      0.140        ---        ---    583.781
  by Level-2 Random Slopes           0.081      0.029      0.036      0.149        ---        ---    313.079
  by Level-1 Residual Variation      0.652      0.039      0.573      0.728        ---        ---   1029.838

                                  -----------------------------------------------------------------------------
```

PARAMETER PLOTS (RBLIMP ONLY)



COEFFICIENT INTERPRETATIONS

Parameter	Est.	Interpretation
Fixed intercept	4.01	Expected job satisfaction for a supervisee with zero values on the predictor (the grand mean because the predictors are centered)
LMX (within-team)	0.17	Expected satisfaction difference between two people *from the same team* with LMX scores that differ by one point, controlling for empowerment and gender
Empower (within-team)	0.02	Expected satisfaction difference between two people *from the same team* with empowerment scores that differ by one point, controlling for LMX and gender
Gender (mostly within-team)	0.21	Expected satisfaction difference between a male and female from the same team, controlling for LMX and empowerment

VARIANCE-COVARIANCE INTERPRETATIONS

Parameter	Est.	Interpretation
Between-cluster intercept variance (variance of u_{0j} residuals)	0.13	Average squared distance between the job satisfaction means and the grand mean (level-2 mean differences)
Between-cluster slope variance (variance of u_{1j} residuals)	0.01	Average squared distance between the team-specific LMX slopes and the mean LMX slope
Between-cluster slope variance (variance of u_{2j} residuals)	0.006	Average squared distance between the team-specific empowerment slopes and the mean empowerment slope
Intercept–slope covariance (covariance of u_{0j} and u_{1j} residuals)	0.02	Positive association where teams with higher job satisfaction means (intercepts) tend to have higher (steeper, more positive) LMX slopes
Intercept–slope covariance (covariance of u_{0j} and u_{2j} residuals)	−0.02	Negative association where teams with higher job satisfaction means (intercepts) tend to have lower (less positive or perhaps negative) empowerment slopes
Slope–slope covariance (covariance of u_{1j} and u_{2j} residuals)	−0.005	Negative association where teams with higher (more positive) LMX slopes tend to have lower (less positive or perhaps negative) empowerment slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	1.07	Average squared distance between a supervisee's observed and predicted job satisfaction scores (residual within-cluster variation)

R^2 EFFECT SIZE MEASURES

Collectively, the pair of random slopes has a relatively large effect size (R^2_{slopes} = .08)

```
Outcome Variable:  JobSat

Grand Mean Centered: Male.1
Group Mean Centered: Empower LMX


Parameters                        Median     StdDev       2.5%      97.5%      ChiSq     PValue     N_Eff
                                ---------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)              0.126      0.048      0.051      0.238        ---        ---   634.442
  L2 : Cov(LMX,Intercept)          0.019      0.012     -0.004      0.044        ---        ---   307.673
  L2 : Var(LMX)                    0.010      0.006      0.003      0.024        ---        ---   306.059
  L2 : Cov(Empower,Intercept)     -0.017      0.008     -0.035     -0.002        ---        ---   549.230
  L2 : Cov(Empower,LMX)           -0.005      0.003     -0.013     -0.001        ---        ---   380.005
  L2 : Var(Empower)                0.006      0.003      0.002      0.013        ---        ---   361.246
  Residual Var.                    1.071      0.071      0.942      1.220        ---        ---  5147.409

Coefficients:
  Intercept                        4.000      0.060      3.881      4.118   4395.675      0.000  3081.469
  LMX                              0.170      0.021      0.128      0.211     64.216      0.000  6656.881
  Empower                          0.018      0.015     -0.012      0.048      1.373      0.241  6176.238
  Male.1                           0.208      0.092      0.028      0.391      5.134      0.023 12031.703

...

Proportion Variance Explained
  by Coefficients                  0.185      0.029      0.130      0.244        ---        ---  6178.264
  by Level-2 Random Intercepts     0.076      0.028      0.032      0.140        ---        ---   583.781
  by Level-2 Random Slopes         0.081      0.029      0.036      0.149        ---        ---   313.079
  by Level-1 Residual Variation    0.652      0.039      0.573      0.728        ---        ---  1029.838

                                ---------------------------------------------------------------------------
```

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	.19	The level-1 predictors explain 19% of the total variation in job satisfaction
Between-cluster intercept variance (variance of u_{0j} residuals)	.08	Between-team variation in the level-2 residuals (variance of u_{0j} residuals = 0.12) accounts for 7% of the total variation
Between-cluster slope variance (variance of u_{1j} residuals)	.08	Between-team variation in the random slope residuals (variance of u_{1j} and u_{2j} residuals collectively) accounts for 8% of the total variation
Within-cluster variance (variance of ε_{ij} residuals)	.65	Within-team variation in the level-1 residuals (variance of ε_{ij} residuals = 1.07) accounts for 65% of the total variation

RBLIMP SCRIPT 5 (MODEL 3)

```
model5 <- rblimp( ...
    model = 'JobSat ~ intercept LMX Empower Male | intercept LMX Empower',
    ...)
output(model5)
chibar_test(model5, raneff = c('LMX','Empower'))   # chi-bar test from mlm-functions.R
```

```
Wald Statistic                                    9.583
Number of Parameters Tested (df)                      5
Probability (Chi-Bar Mixture Method)                 NA
Probability (Chi-Bar Binomial Method)             0.020
Probability (Central Chi-Square)                  0.088
```

Use these, perhaps in tandem

WALD TEST INTERPRETATION

- The test refutes the null hypothesis that all population slope variances and covariances (five parameters) equal zero
- $\chi^2 = 9.58$, $p = .02$
- Adding the pair of random slopes improves model fit, with the caveat that the chi-bar test is an approximation

OUTLINE

1. Estimate ICCs
2. Add Within-Cluster Predictors
3. Strategy 1: Evaluate Random Slopes One at a Time
4. Strategy 2: Add All Random Slopes at Once
5. Add Between-Cluster Predictors
6. Latent Variable Specification

WITHIN-CLUSTER (LEVEL-1) MODEL

- Both the team-specific job satisfaction mean (β_{0j}) and the empowerment slope vary across clusters (β_{2j}), but the leader-member exchange and gender slopes are constant

$$jobsat_{ij} = \beta_{0j} + \beta_1(lmx^{w}_{ij}) + \beta_{2j}(empower^{w}_{ij}) + \beta_2(male_{ij}) + \varepsilon_{ij}$$

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

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

BETWEEN-CLUSTER (LEVEL-2) MODEL

- The job satisfaction mean for team j (β_{0j}) is a function of team-average LMX and empowerment plus a between-team residual (u_{0j})
- The empowerment slope for team j (β_{2j}) is the sum of the mean slope (γ_{20}) and a team-level residual (u_{2j})
- Assumption: random intercept residuals are bivariate normal and correlated

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

$$\beta_1 = \gamma_{10}$$

$$\beta_2 = \gamma_{20} + u_{2j}$$

$$\beta_3 = \gamma_{30}$$

$$\begin{pmatrix} u_{0j} \\ u_{2j} \end{pmatrix} \sim N(0, \boldsymbol{\Sigma}_u) \quad \boldsymbol{\Sigma}_u = \begin{pmatrix} \sigma^2_{u0} & \sigma_{u0u2} \\ \sigma_{u2u0} & \sigma^2_{u2} \end{pmatrix}$$

COMMON NOTATIONAL SYSTEMS

Combined-model equation (Raudenbush & Bryk, 2002)

$$\text{jobsat}_{ij} = \gamma_{00} + \gamma_{10}(\text{lmx}_{ij}^{w}) + \gamma_{20}(\text{empower}_{ij}^{w}) + \gamma_{30}(\text{male}_{ij})$$
$$+ \gamma_{01}(\text{lmx}_{j}^{b}) + \gamma_{02}(\text{empower}_{j}^{b}) + u_{0j} + (u_{2j})(\text{empower}_{ij}^{w}) + \varepsilon_{ij}$$

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

$$\text{jobsat}_{ij} = \beta_0 + \beta_1(\text{lmx}_{ij}^{w}) + \beta_2(\text{empower}_{ij}^{w}) + \beta_3(\text{male}_{ij})$$
$$+ \beta_4(\text{lmx}_{j}^{b}) + \beta_5(\text{empower}_{j}^{b}) + u_{0j} + (u_{2j})(\text{empower}_{ij}^{w}) + \varepsilon_{ij}$$

BLIMP SCRIPT 5.6

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

RBLIMP SCRIPT 5 (MODEL 6)

```
model6 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male LMX.mean Empower.mean',
    model = 'intercept LMX Empower Male LMX.mean Empower.mean | intercept Empower',
    seed = 90291,
    burn = 10000,
    iter = 20000)
output(model6)
```

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             1.912            29
                          501 to 1000            1.102            29
                          751 to 1500            1.387            34
                         1001 to 2000            1.175            34
                                  ...              ...            ..
                         2501 to 5000            1.059            35
                         2751 to 5500            1.053            35
                         3001 to 6000            1.088            35
                         3251 to 6500            1.048            34
                         3501 to 7000            1.060            34
                         3751 to 7500            1.068            28
                         4001 to 8000            1.037            10
                         4251 to 8500            1.029             2
                         4501 to 9000            1.023             1
                         4751 to 9500            1.032            18
                         5001 to 10000           1.038             3
```

EFFECTIVE SAMPLE SIZE DIAGNOSTIC

Quality control check: Number of effective MCMC samples diagnostics **not** all > 100, increase the number of iterations

```
Outcome Variable:  JobSat

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

Parameters                         Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                 --------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)               0.084      0.046      0.014      0.190        ---        ---    288.791
  L2 : Cov(Empower,Intercept)      -0.009      0.007     -0.024      0.002        ---        ---     76.677
  L2 : Var(Empower)                 0.003      0.002      0.000      0.008        ---        ---    100.363
  Residual Var.                     1.117      0.072      0.987      1.270        ---        ---   1303.014

Coefficients:
  Intercept                         3.995      0.064      3.869      4.121   3885.470      0.000   2053.484
  LMX                               0.168      0.019      0.130      0.204     78.051      0.000   6849.160
  Empower                           0.013      0.014     -0.015      0.041      0.844      0.358   5740.524
  Male.1                            0.205      0.092      0.025      0.385      4.946      0.026  15196.444
  LMX.mean[Team]                    0.202      0.125      0.021      0.541      3.053      0.081    237.334
  Empower.mean[Team]                0.189      0.106      0.047      0.474      3.789      0.052    203.254

...

Proportion Variance Explained
  by Coefficients                   0.225      0.034      0.162      0.295        ---        ---   1085.122
  by Level-2 Random Intercepts      0.051      0.027      0.008      0.113        ---        ---    282.645
  by Level-2 Random Slopes          0.037      0.022      0.000      0.087        ---        ---     96.012
  by Level-1 Residual Variation     0.682      0.038      0.606      0.754        ---        ---    553.156

                                 --------------------------------------------------------------------------
```

BLIMP SCRIPT 5.6

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;    # invokes categorical variable model
CLUSTERID: Team;
CENTER: groupmean = LMX Empower; grandmean = Male LMX.mean Empower.mean;
MODEL: JobSat ~ intercept LMX Empower Male LMX.mean Empower.mean | intercept Empower;
BURN: 10000;
ITERATIONS: 30000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 6)

```
model6 <- rblimp(
    data = Employee,
    nominal = 'Male',
    clusterid = 'Team',
    center = 'groupmean = LMX Empower; grandmean = Male LMX.mean Empower.mean',
    model = 'intercept LMX Empower Male LMX.mean Empower.mean | intercept Empower',
    seed = 90291,
    burn = 10000,
    iter = 30000)
output(model6)
```

BLIMP OUTPUT

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

```
Outcome Variable:  JobSat

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

Parameters                           Median     StdDev       2.5%      97.5%      ChiSq     PValue      N_Eff
                                -----------------------------------------------------------------------------
Variances:
  L2 : Var(Intercept)                 0.084      0.046      0.014      0.192        ---        ---    372.982
  L2 : Cov(Empower,Intercept)        -0.009      0.007     -0.024      0.002        ---        ---    195.594
  L2 : Var(Empower)                   0.003      0.002      0.000      0.008        ---        ---    157.077
  Residual Var.                       1.116      0.072      0.987      1.270        ---        ---   3159.871

Coefficients:
  Intercept                           3.995      0.064      3.870      4.121   3908.187      0.000   3387.670
  LMX                                 0.168      0.019      0.131      0.205     78.759      0.000  10859.531
  Empower                             0.013      0.014     -0.015      0.041      0.851      0.356   8238.233
  Male.1                              0.205      0.092      0.024      0.385      4.913      0.027  21706.381
  LMX.mean[Team]                      0.201      0.131      0.014      0.545      2.750      0.097    375.083
  Empower.mean[Team]                  0.188      0.107      0.043      0.469      3.596      0.058    344.974

...

Proportion Variance Explained
  by Coefficients                     0.225      0.034      0.162      0.295        ---        ---   1505.422
  by Level-2 Random Intercepts        0.051      0.027      0.009      0.114        ---        ---    362.076
  by Level-2 Random Slopes            0.037      0.022      0.001      0.087        ---        ---    151.893
  by Level-1 Residual Variation       0.682      0.038      0.606      0.754        ---        ---   1343.492

                                -----------------------------------------------------------------------------
```

BLIMP OUTPUT

= level-2 estimate
= level-1 estimate
= combined estimate

```
Outcome Variable:  JobSat

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


Parameters                        Median    StdDev      2.5%     97.5%     ChiSq    PValue     N_Eff
                                 ------------------------------------------------------------------------------

Variances:
  L2 : Var(Intercept)              0.084     0.046     0.014     0.192       ---       ---   372.982
  L2 : Cov(Empower,Intercept)     -0.009     0.007    -0.024     0.002       ---       ---   195.594
  L2 : Var(Empower)                0.003     0.002     0.000     0.008       ---       ---   157.077
  Residual Var.                    1.116     0.072     0.987     1.270       ---       ---  3159.871

Coefficients:
  Intercept                        3.995     0.064     3.870     4.121  3908.187     0.000  3387.670
  LMX                              0.168     0.019     0.131     0.205    78.759     0.000 10859.531
  Empower                          0.013     0.014    -0.015     0.041     0.851     0.356  8238.233
  Male.1                           0.205     0.092     0.024     0.385     4.913     0.027 21706.381
  LMX.mean[Team]                   0.201     0.131     0.014     0.545     2.750     0.097   375.083
  Empower.mean[Team]               0.188     0.107     0.043     0.469     3.596     0.058   344.974

...

Proportion Variance Explained
  by Coefficients                  0.225     0.034     0.162     0.295       ---       ---  1505.422
  by Level-2 Random Intercepts     0.051     0.027     0.009     0.114       ---       ---   362.076
  by Level-2 Random Slopes         0.037     0.022     0.001     0.087       ---       ---   151.893
  by Level-1 Residual Variation    0.682     0.038     0.606     0.754       ---       ---  1343.492

                                 ------------------------------------------------------------------------------
```

INTERPRETATIONS

Parameter	Est.	Interpretation
Fixed intercept	4.00	Expected job satisfaction for a supervisee with zero values on the predictor (the grand mean because the predictors are centered)
LMX (within-team)	0.17	Expected satisfaction difference between two people *from the same team* with LMX scores that differ by one point, controlling for empowerment and gender
Empower (within-team)	0.01	Expected satisfaction difference between two people *from the same team* with empowerment scores that differ by one point, controlling for LMX and gender
Gender (mostly within-team)	0.21	Expected satisfaction difference between a male and female *from the same team,* controlling for LMX and empowerment
LMX (between-team)	0.20	Expected satisfaction mean difference between two teams with average LMX ratings that differ by one point, controlling for average empowerment and gender
Empower (between-team)	0.19	Expected satisfaction mean difference between two teams with average empowerment ratings that differ by one point, controlling for average LMX and gender

INTERPRETATIONS, CONTINUED

Parameter	Est.	Interpretation
Between-cluster intercept variance (variance of u_{0j} residuals)	0.08	Average squared distance between the job satisfaction means and their predicted values (residual level-2 mean differences)
Between-cluster slope variance (variance of u_{2j} residuals)	0.003	Average squared distance between the team-specific slopes and the mean slope
Intercept–slope covariance (covariance of u_{0j} and u_{2j} residuals)	−0.01	Positive association where teams with higher job satisfaction means (intercepts) tend to have lower (less positive or perhaps negative) slopes
Within-cluster residual variance (variance of ε_{ij} residuals)	1.12	Average squared distance between a supervisee's observed and predicted job satisfaction scores (residual within-cluster variation)

OUTLINE

1. Estimate ICCs
2. Add Within-Cluster Predictors
3. Strategy 1: Evaluate Random Slopes One at a Time
4. Strategy 2: Add All Random Slopes at Once
5. Strategy 3: Add Random Slopes in a Sequence
6. Add Between-Cluster Predictors
7. Latent Variable Specification

BLIMP SCRIPT 5.7

```
DATA: EmployeeSatisfaction.dat;
VARIABLES: Employee Team Turnover Male Empower LMX JobSat Climate TeamPerf;
NOMINAL: Male;
CLUSTERID: Team;
LATENT: Team = beta0j beta2j;    # define random intercept and slope
CENTER: groupmean = LMX Empower; grandmean = Male LMX.mean Empower.mean;
MODEL:
beta0j ~ intercept LMX.mean Empower.mean;
beta2j ~ intercept;
beta0j ~~ beta2j;    # correlate random intercepts and slopes
JobSat ~ intercept@beta0j LMX Empower@beta2j Male;
BURN: 20000;
ITERATIONS: 30000;
SEED: 90291;
```

RBLIMP SCRIPT 5 (MODEL 7)

```
model7 <- rblimp(
        data = Employee,
        nominal = 'Male',
        clusterid = 'Team',
        latent = 'Team = beta0j beta2j',
        center = 'groupmean = LMX Empower; grandmean = Male LMX.mean Empower.mean',
        model = '
          beta0j ~ intercept LMX.mean Empower.mean;
          beta2j ~ intercept;
          beta0j ~~ beta2j;
          JobSat ~ intercept@beta0j LMX Empower@beta2j Male',
        seed = 90291,
        burn = 20000,
        iter = 30000)
output(model7)
```