

# **Multilevel Multilingual**

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# 1 Multilevel Models in Stata, R and Julia

## 1.1 Introduction

Below, I describe the use of [Stata](#), [R](#), and [Julia](#) to estimate multilevel models. Because this document is built by [Quarto](#), I describe calling these programs from within a [Quarto](#) environment. However, each piece of software could be used individually and separately.

## 1.2 The Data

The examples below use the `simulated_multilevel_data.dta` file from [Multilevel Thinking](#). Here is a [direct link](#) to download the data.

Table 1.1: Sample of Simulated Multilevel Data

country	HDI	family	id	group	physical_punishment	warmth	outcome
1	69	1	1.1	2	2	3	59.18
1	69	2	1.2	2	4	0	61.54
1	69	3	1.3	1	4	4	51.87
1	69	4	1.4	2	0	6	51.71
1	69	5	1.5	2	3	2	55.88
1	69	6	1.6	1	5	3	60.78

## 1.3 The Equation

$$\text{outcome}_{ij} = \beta_0 + \beta_1 \text{warmth}_{ij} + \beta_2 \text{physical punishment}_{ij} + \beta_3 \text{group}_{ij} + \beta_4 \text{HDI}_{ij} + u_{0j} + u_{1j} \times \text{warmth}_{ij} + e_{ij} \quad (1.1)$$

## 1.4 Setup

### 1.4.1 Stata

I need to use the library `Statamarkdown` to call Stata, or I could run Stata on its own

```
library(Statamarkdown)
```

### 1.4.2 R

In R, I use the library `lme4` to run multilevel models.

```
library(lme4)
```

### 1.4.3 Julia

I need to call Julia from R.

```
library(JuliaCall)

julia_setup(JULIA_HOME = "/Applications/Julia-1.8.app/Contents/Resources/julia/bin")
```

## 1.5 Get Data & Run Models

To explain statistical syntax for each software, I consider the more general case of a multilevel model with dependent variable **y**, independent variables **x** and **z**, clustering variable **group**, and a random slope for **x**. *i* is the index for the person, while *j* is the index for the **group**.

$$y = \beta_0 + \beta_1 x_{ij} + \beta_2 z_{ij} + u_{0j} + u_{1j} \times x_{ij} + e_{ij} \quad (1.2)$$

### 1.5.1 Stata

In Stata `mixed`, the syntax for a multilevel model of the form described in Equation 1.2 is:

```
mixed y x || group: x
```

### 1.5.1.1 Get The Data

#### 💡 Tip For Running Stata From Quarto

Because I am running Stata from inside a Quarto document, and running Stata in multiple chunks, I need to use the `collectcode=TRUE` option in the first Stata chunk. i.e. my Quarto chunk needs to begin with “`{stata, collectcode=TRUE}`”  
See Doug Hemken’s excellent documentation on Statamarkdown [here](#).

```
use simulated_multilevel_data.dta
```

### 1.5.1.2 Graph

```
twoway scatter outcome warmth, xtitle("warmth") ytitle("outcome") title("Outcome by Parent  
quietly graph export scatter.png, replace
```

```
> arental Warmth")
```

### 1.5.1.3 Run The Model

```
mixed outcome warmth physical_punishment group HDI || country: warmth
```

Performing EM optimization ...

Performing gradient-based optimization:

Iteration 0: Log likelihood = -9668.198

Iteration 1: Log likelihood = -9667.9551

Iteration 2: Log likelihood = -9667.9534

Iteration 3: Log likelihood = -9667.9533

Iteration 4: Log likelihood = -9667.9532

Computing standard errors ...

Mixed-effects ML regression

Group variable: country

Number of obs = 3,000

Number of groups = 30

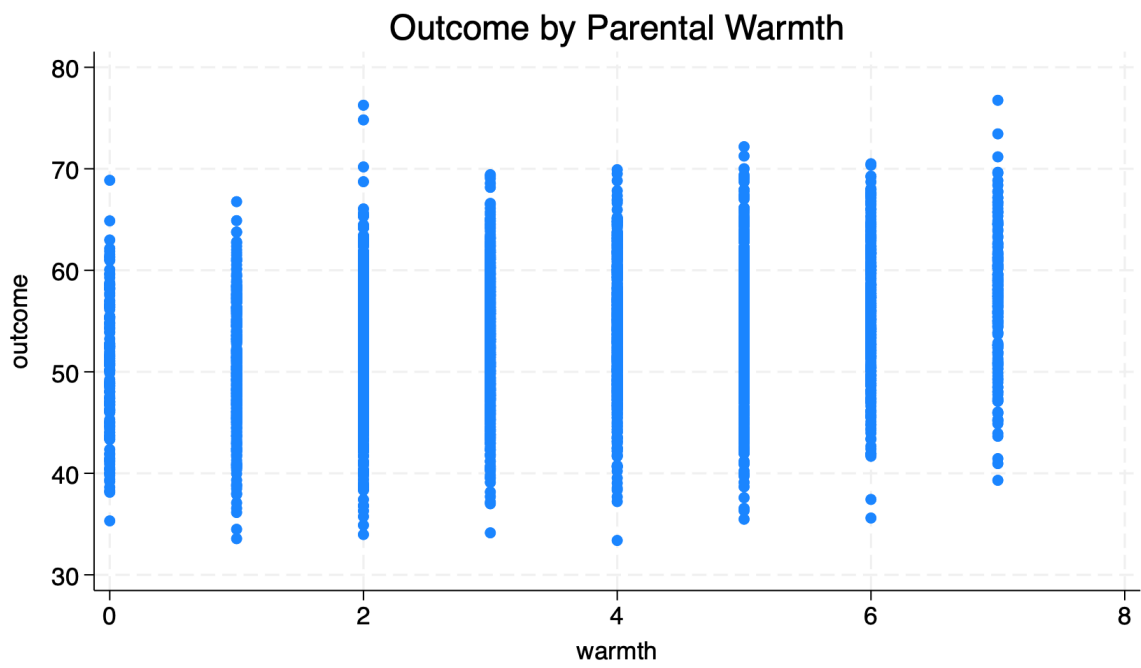


Figure 1.1: Outcome by Parental Warmth



```

Obs per group:
      min =    100
      avg =  100.0
      max =    100
Wald chi2(4)      = 401.26
Prob > chi2       = 0.0000

Log likelihood = -9667.9532
-----
      outcome | Coefficient  Std. err.      z    P>|z|    [95% conf. interval]
-----+-----
      warmth |   .9616447   .0581825   16.53   0.000    .8476091    1.07568
physical_punishment |  -.8453802   .0798155  -10.59   0.000   -1.001816   -.6889448
      group |   1.084344   .2200539    4.93   0.000    .6530461    1.515642
      HDI |   .010557   .0204522    0.52   0.606   -.0295286    .0506426
      _cons |  49.87963   1.436612   34.72   0.000   47.06392   52.69534
-----

Random-effects parameters | Estimate  Std. err.    [95% conf. interval]
-----+-----
country: Independent |
      var(warmth) |   1.83e-06   .0000173    1.76e-14    190.9774
      var(_cons) |   3.370262   .9633726    1.924651    5.901676
-----+-----
      var(Residual) |   36.01906   .9346936    34.23291    37.89842
-----

LR test vs. linear model: chi2(2) = 198.01          Prob > chi2 = 0.0000

```

Note: LR test is conservative and provided only for reference.

## 1.5.2 R

In R `lme4`, the general syntax for a multilevel model of the form described in Equation [1.2](#) is:

```
lmer(y ~ x + z + (1 + x || group), data = ...)
```

### 1.5.2.1 Get The Data

```
library(haven)

df <- read_dta("simulated_multilevel_data.dta")
```

### 1.5.2.2 Graph

```
library(ggplot2)

ggplot(df,
       aes(x = warmth,
           y = outcome)) +
  geom_point() +
  labs(title = "Outcome by Parental Warmth")
```

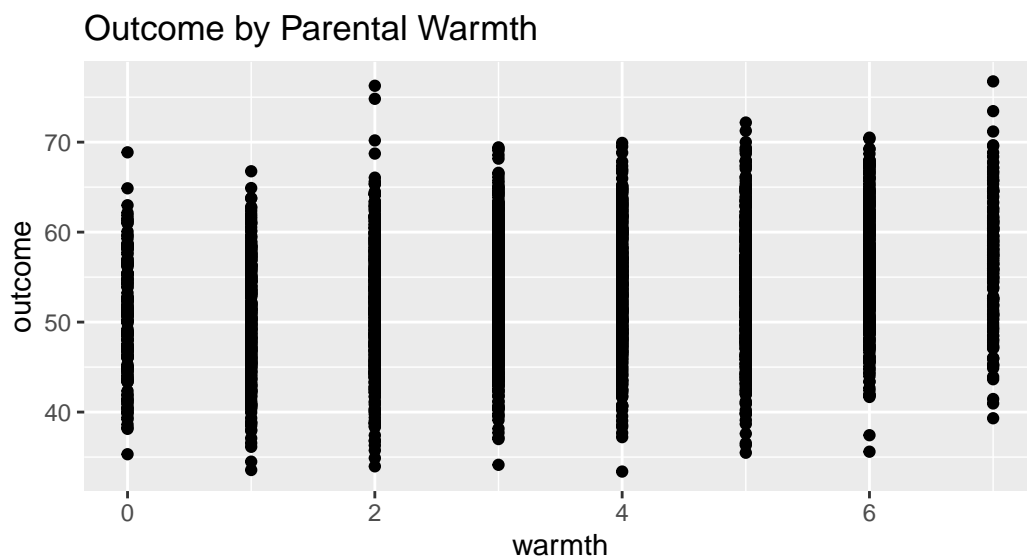


Figure 1.2: Outcome by Parental Warmth

### 1.5.2.3 Run The Model

```
fit1 <- lmer(outcome ~ warmth + physical_punishment +  
             group + HDI +  
             (1 + warmth || country),  
             data = df)  
  
summary(fit1)
```

Linear mixed model fit by REML ['lmerMod']

Formula: outcome ~ warmth + physical\_punishment + group + HDI + ((1 |  
country) + (0 + warmth | country))

Data: df

REML criterion at convergence: 19350.3

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.4496	-0.6807	0.0016	0.6864	3.1792

Random effects:

Groups	Name	Variance	Std.Dev.
country	(Intercept)	3.611568	1.90041
country.1	warmth	0.001876	0.04331
Residual		36.049124	6.00409

Number of obs: 3000, groups: country, 30

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	49.88754	1.48203	33.662
warmth	0.96155	0.05875	16.367
physical_punishment	-0.84556	0.07986	-10.588
group	1.08471	0.22017	4.927
HDI	0.01044	0.02116	0.493

Correlation of Fixed Effects:

	(Intr)	warmth	physc_	group
warmth		-0.126		
physcl_pnsh	-0.135	-0.025		
group	-0.218	-0.010	-0.019	
HDI	-0.925	-0.006	0.008	-0.001

### 1.5.3 Julia

In Julia `MixedModels`, the general syntax for a multilevel model of the form described in Equation 1.2 is:

```
fit(MixedModel, @formula(y ~ x + z + (1 + x | group)), data)
```

#### 1.5.3.1 Load The Needed Packages And Load The Data

```
using Tables, MixedModels, StatFiles, DataFrames, CategoricalArrays, DataFramesMeta

df = DataFrame(load("simulated_multilevel_data.dta"))
```

#### 1.5.3.2 Graph

```
using StatsPlots

@df df scatter(:outcome, :warmth,
               title = "Outcome by Parental Warmth",
               ylabel = "outcome",
               xlabel = "parental warmth")
```

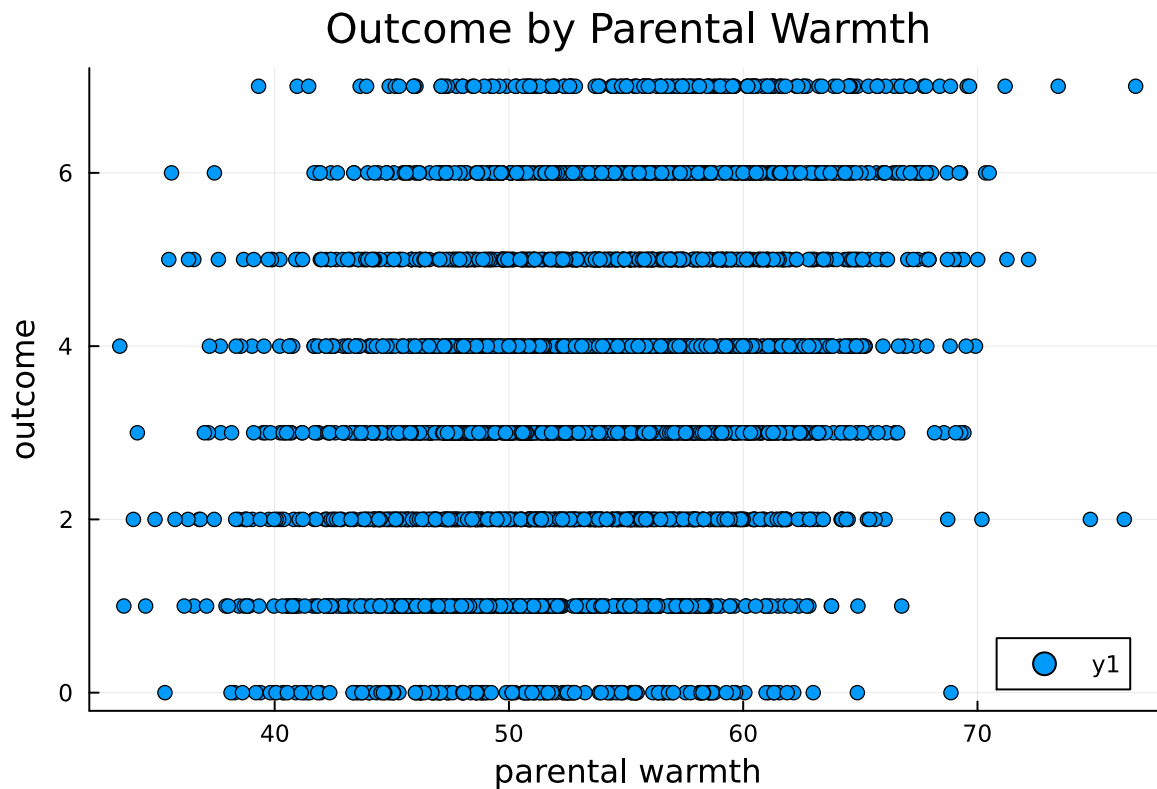


Figure 1.3: Outcome by Parental Warmth

### 1.5.3.3 Change Country To Categorical

```
@transform!(df, :country = categorical(:country))
```

### 1.5.3.4 Run The Model

```
m1 = fit(MixedModel, @formula(outcome ~ warmth + physical_punishment +
    group + HDI +
    (1 + warmth | country)), df)
```

Linear mixed model fit by maximum likelihood

```
outcome ~ 1 + warmth + physical_punishment + group + HDI + (1 + warmth | country)
logLik   -2 logLik     AIC      AICc     BIC
-9667.9392 19335.8783 19353.8783 19353.9385 19407.9357
```

Variance components:

	Column	Variance	Std.Dev.	Corr.
country	(Intercept)	3.2369484	1.7991521	
	warmth	0.0001080	0.0103903	+1.00
Residual		36.0187144	6.0015593	

Number of obs: 3000; levels of grouping factors: 30

Fixed-effects parameters:

	Coef.	Std. Error	z	Pr(> z )
(Intercept)	49.9018	1.43435	34.79	<1e-99
warmth	0.961545	0.0582135	16.52	<1e-60
physical_punishment	-0.845389	0.0798149	-10.59	<1e-25
group	1.08524	0.220055	4.93	<1e-06
HDI	0.0101984	0.0204401	0.50	0.6178

## 2 Cross-Classified Models in Stata, R and Julia

### 2.1 Introduction

A two level multilevel model imagines that *Level 1* units are nested in *Level 2* units. A three level multilevel model imagines that *Level 1* units are nested in *Level 2* units, which are in turn nested in *Level 3*.

A cross-classified model imagines that the nesting is not hierarchical, but rather that there are two sets of clusters or nestings in which individuals may be nested.

In this data, *events* are nested inside *persons* which are in turn nested in *countries*, since in this data, individuals never change countries. However, the use of a cross-classified framework would allow for a situation in which *persons* moved from country to country, and experienced different *events* in different *countries*.

Below, I describe the use of [Stata](#), [R](#), and [Julia](#) to estimate cross-classified models. Because this document is built by [Quarto](#), I describe calling these programs from within a [Quarto](#) environment. However, each piece of software could be used individually and separately.

### 2.2 The Data

The examples below use the `simulated_multilevel_longitudinal_data.dta` file from [Multilevel Thinking](#). Here is a [direct link](#) to download the data.

Table 2.1: Sample of Simulated Multilevel Longitudinal Data

country	HDI	family	id	group	t	physical_punishment	warmth	outcome
1	69	1	1.1	2	1	2	3	59.18
1	69	1	1.1	2	2	2	2	58.29
1	69	1	1.1	2	3	3	3	60.58
1	69	2	1.2	2	1	4	0	61.54
1	69	2	1.2	2	2	4	0	55.96
1	69	2	1.2	2	3	4	2	56.19

## 2.3 The Equation

$$\text{outcome}_{ijt} = \beta_0 + \beta_1 t_{ijt} + \beta_2 \text{warmth}_{ijt} + \beta_3 \text{physical punishment}_{ijt} + \beta_4 \text{group}_{ijt} + \beta_5 \text{HDI}_{ijt} + u_{0j} + v_{0i} + e_{ijt} \quad (2.1)$$

## 2.4 Setup

### 2.4.1 Stata

I need to use the library `Statamarkdown` to call Stata, or I could run Stata on its own

```
library(Statamarkdown)
```

### 2.4.2 R

In R, I use the library `lme4` to run multilevel models.

```
library(lme4)
```

### 2.4.3 Julia

I need to call Julia from R.

```
library(JuliaCall)

julia_setup(JULIA_HOME = "/Applications/Julia-1.8.app/Contents/Resources/julia/bin")
```

## 2.5 Get Data & Run Models

To explain statistical syntax for each software, I consider the more general case of a cross-classified model with dependent variable  $y$ , independent variables  $x$  and  $z$ , clustering variables `country` and `id`.

$$y = \beta_0 + \beta_1 x_{ijt} + \beta_2 z_{ijt} + u_{0j} + v_{0i} + e_{ijt} \quad (2.2)$$



## 2.5.1 Stata

In Stata `mixed`, the syntax for a multilevel model of the form described in Equation 2.2 is:

```
mixed y x || _all: R.group1 || group2:
```

### 2.5.1.1 Get The Data



#### Tip For Running Stata From Quarto

Because I am running Stata from inside a Quarto document, and running Stata in multiple chunks, I need to use the `collectcode=TRUE` option in the first Stata chunk. i.e. my Quarto chunk needs to begin with “`{stata, collectcode=TRUE}`”. See Doug Hemken’s excellent documentation on Statamarkdown [here](#).

```
use simulated_multilevel_longitudinal_data.dta
```

### 2.5.1.2 Run The Model

```
mixed outcome t warmth physical_punishment group HDI || _all: R.country || id:
```

```
variable t not found  
r(111);
```

```
end of do-file  
r(111);
```

## 2.5.2 R

In R `lme4`, the general syntax for a multilevel model of the form described in Equation 2.2 is:

```
lmer(y ~ x + z + (1 | group1) + (1 | group2), data = ...)
```

### 2.5.2.1 Get The Data

```
library(haven)

df <- read_dta("simulated_multilevel_longitudinal_data.dta")
```

### 2.5.2.2 Run The Model

```
fit1 <- lmer(outcome ~ t + warmth + physical_punishment +
             group + HDI +
             (1 | id) +
             (1 | country),
             data = df)

summary(fit1)
```

Linear mixed model fit by REML ['lmerMod']

Formula: outcome ~ t + warmth + physical\_punishment + group + HDI + (1 | id) + (1 | country)

Data: df

REML criterion at convergence: 57088.4

Scaled residuals:

Min	1Q	Median	3Q	Max
-3.4471	-0.6226	0.0081	0.6153	3.1993

Random effects:

Groups	Name	Variance	Std.Dev.
id	(Intercept)	8.864	2.977
country	(Intercept)	3.924	1.981
Residual		26.008	5.100

Number of obs: 9000, groups: id, 3000; country, 30

Fixed effects:

	Estimate	Std. Error	t value
(Intercept)	49.494782	1.471780	33.629
t	0.987964	0.065840	15.005
warmth	0.946259	0.038200	24.771
physical_punishment	-0.926880	0.049970	-18.549

group	0.985786	0.153550	6.420
HDI	0.007543	0.021437	0.352

Correlation of Fixed Effects:

	(Intr)	t	warmth	physc_	group
t	-0.090				
warmth	-0.085	0.008			
physcl_pnsh	-0.085	0.003	-0.019		
group	-0.154	0.000	-0.013	-0.008	
HDI	-0.943	0.000	-0.003	0.003	0.000

### 2.5.3 Julia

In Julia MixedModels, the general syntax for a multilevel model of the form described in Equation 2.2 is:

```
fit(MixedModel, @formula(y ~ x + z + (1 | group1) + (1 | group2)), data)
```

#### 2.5.3.1 Load The Needed Packages And Load The Data

```
using Tables, MixedModels, StatFiles, DataFrames, CategoricalArrays, DataFramesMeta

df = DataFrame(load("simulated_multilevel_longitudinal_data.dta"))
```

#### 2.5.3.2 Change Country To Categorical

```
@transform!(df, :country = categorical(:country))
```

#### 2.5.3.3 Run The Model

```
m1 = fit(MixedModel, @formula(outcome ~ t + warmth + physical_punishment +
                             group + HDI +
                             (1 | id) +
                             (1 | country)), df)
```

Linear mixed model fit by maximum likelihood

outcome ~ 1 + t + warmth + physical\_punishment + group + HDI + (1 | id) + (1 | country)

logLik	-2 logLik	AIC	AICc	BIC
-28533.9968	57067.9935	57085.9935	57086.0136	57149.9384

Variance components:

	Column	Variance	Std.Dev.
id	(Intercept)	8.85264	2.97534
country	(Intercept)	3.65030	1.91058
Residual		26.00093	5.09911

Number of obs: 9000; levels of grouping factors: 3000, 30

Fixed-effects parameters:

	Coef.	Std. Error	z	Pr(> z )
(Intercept)	49.4945	1.42422	34.75	<1e-99
t	0.987965	0.0658315	15.01	<1e-50
warmth	0.946255	0.0381869	24.78	<1e-99
physical_punishment	-0.926774	0.0499549	-18.55	<1e-76
group	0.985819	0.153487	6.42	<1e-09
HDI	0.00754357	0.0207101	0.36	0.7157