Visualizing Multilevel Models

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3 Mar 2023 10:17:49

Introduction

An evolving set of notes on visualizing results from multilevel models.

The examples below use the `simulated_multilevel_data.dta` file from *Multilevel Thinking*. Here is a direct link to download the data.

Setup

I am not terrifically fond of Stata's default `s2color` graph scheme. Therefore I make use of the `michigan` graph scheme available at: https://agrogan1.github.io/Stata/michigan-graph-scheme/

```
. set scheme michigan
```

Stata's `s1color` scheme would also would be an option as would be Asjad Naqvi's incredible `schemepack`: https://github.com/asjadnaqvi/stata-schemepack

Get Data

```
. use "https://github.com/agrogan1/multilevel-thinking/raw/main/simulate-and-analyze-m
> ultilevel-data/simulated_multilevel_data.dta", clear
```

Scatterplots

```
. twoway scatter outcome warmth

. graph export myscatter.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/myscatter.png saved as
    PNG format
```

Simple Linear Fit

```
. twoway lfit outcome warmth

. graph export mylinear.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/mylinear.png saved as
    PNG format
```

Linear Fit With Confidence Interval

```
. twoway lfitci outcome warmth

. graph export mylfitci.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/mylfitci.png saved as
```

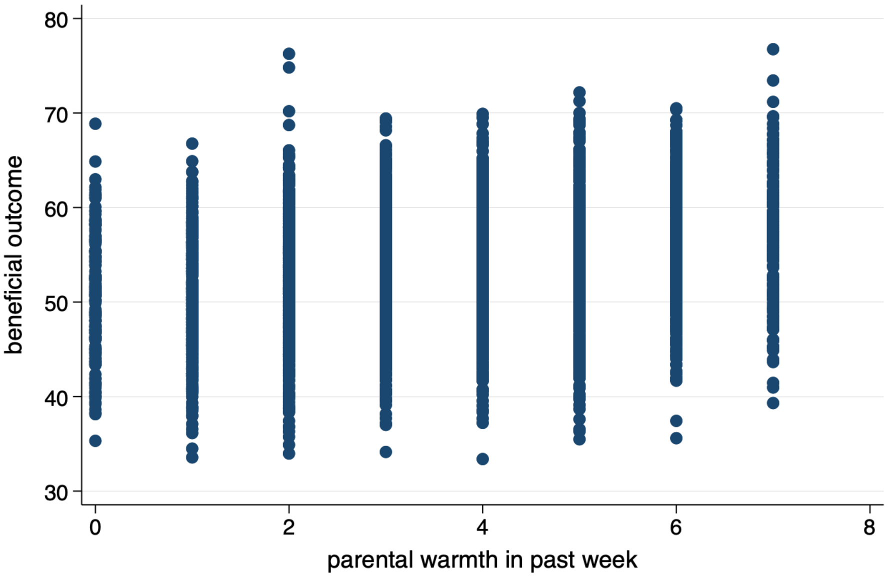


Figure 1: Scatterplot

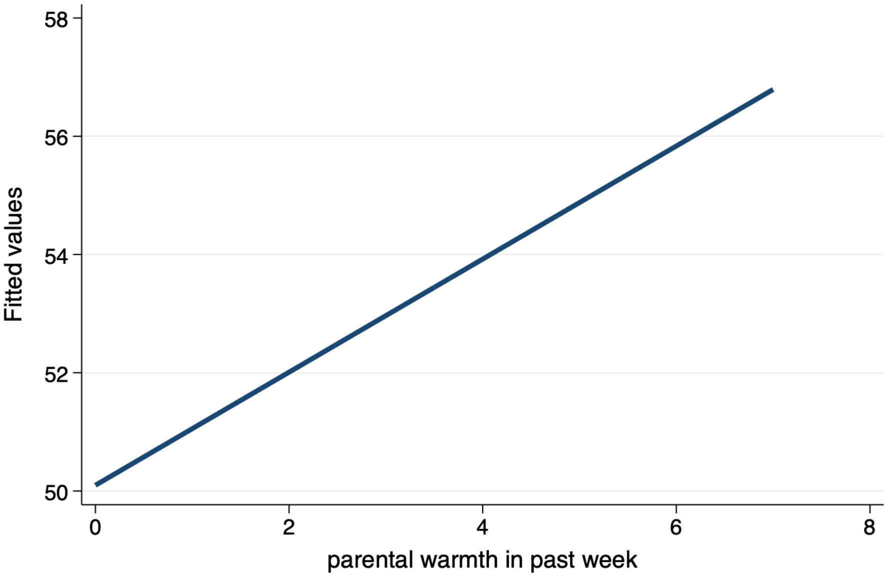


Figure 2: Linear Fit

```
    PNG format
```

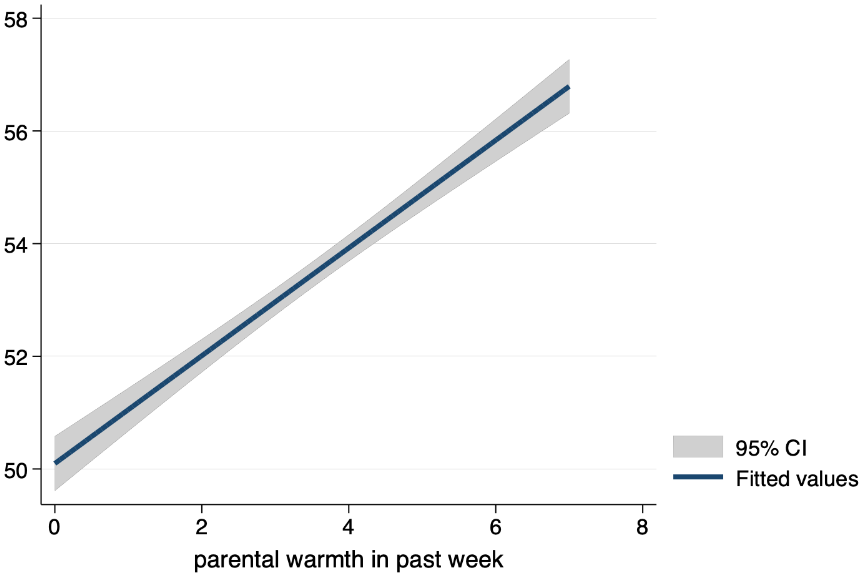


Figure 3: Linear Fit With Confidence Interval

Combine Scatterplot and Linear Fit

```
. twoway (scatter outcome warmth) (lfit outcome warmth)

. graph export myscatterlinear.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/myscatterlinear.png
    saved as PNG format
```

Spaghetti Plots (`spagplot`)

```
. spagplot outcome warmth, id(country)

. graph export myspaghetti.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/myspaghetti.png saved
    as PNG format
```

Small Multiples

I use the `aspect` option to adjust the *aspect ratio* of the graph for better visual presentation. I also use the `mcolor(%30)` option to create some transparency in the dots of the scatterplot, which helps the presentation of these small multiples. The `mcolor(%30)` option could be useful in the other graphs in this tutorial as well.

```
. twoway (scatter outcome warmth, mcolor(%30)) (lfit outcome warmth), by(country) aspe
> ct(1)

. graph export mysmallmultiples.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/mysmallmultiples.png
    saved as PNG format
```

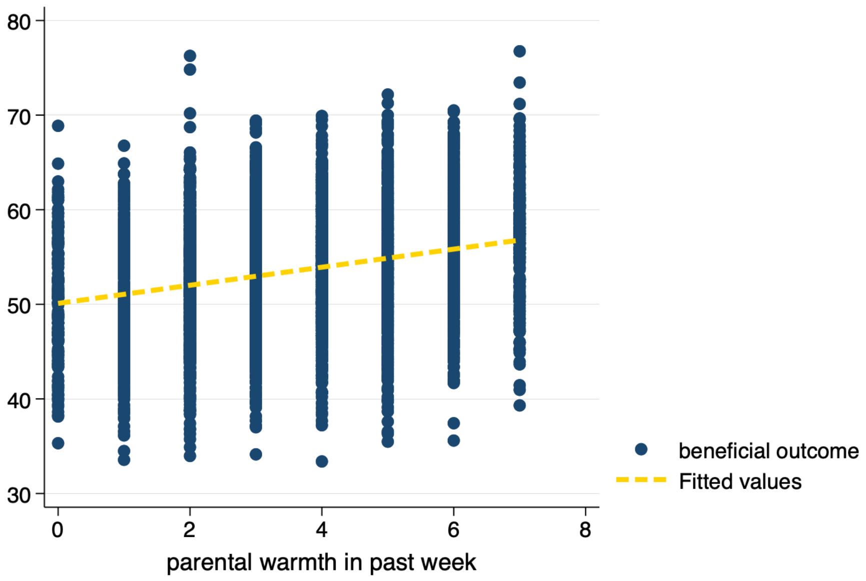


Figure 4: Scatterplot and Linear Fit

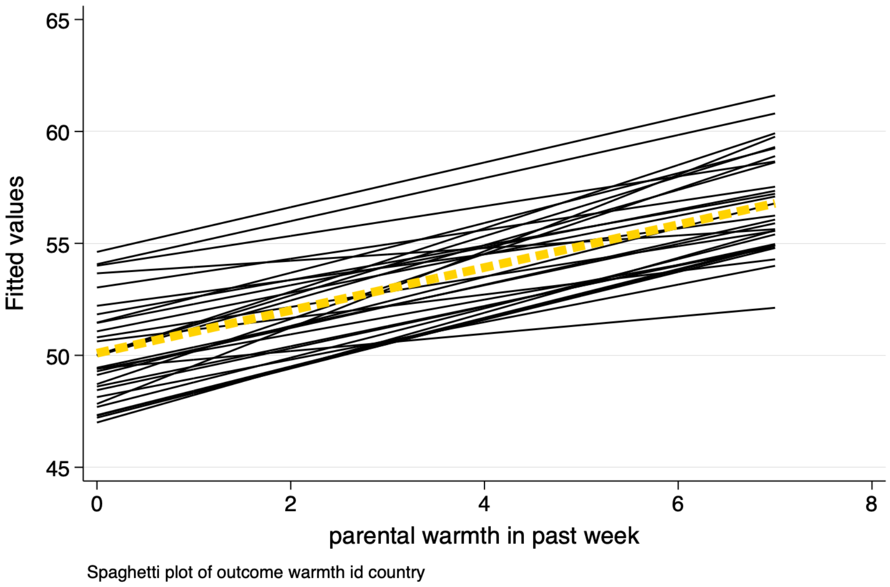


Figure 5: Spaghetti Plot

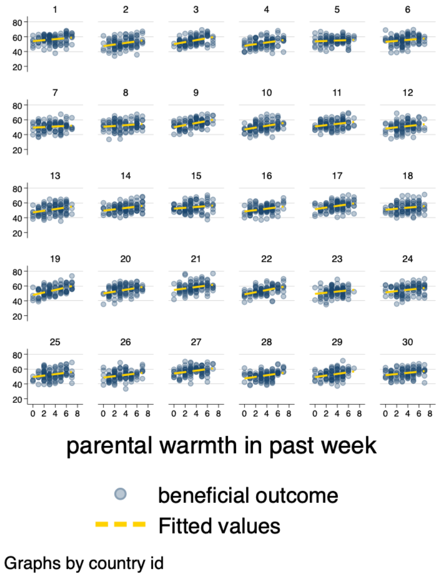


Figure 6: Small Multiples

Multivariate (Predicted) Relationships

A sometimes unacknowledged point is that graphs–unless we take steps to correct this–reflect *unadjusted*, or *bivariate* associations. We may sometimes wish to develop a graphs that reflect the *adjusted* or *predicted* estimates from our models.

In multilevel models, *prediction* is a complex question. The procedures below outline graphs that incorporate predictions using the variables, but do not include predictions that incorporate the random effects. (This will be added!)

Using Predicted Values

Estimate The Model

```
. mixed outcome warmth physical_punishment i.group || country: // estimate MLM

Performing EM optimization:

Performing gradient-based optimization:

Iteration 0:   log likelihood = -9668.0859
Iteration 1:   log likelihood = -9668.0859

Computing standard errors:

Mixed-effects ML regression                     Number of obs     =      3,000
Group variable: country                         Number of groups  =         30
                                                Obs per group:
                                                              min =        100
                                                              avg =      100.0
                                                              max =        100
                                                Wald chi2(3)      =     401.00
Log likelihood = -9668.0859                     Prob > chi2       =     0.0000

------------------------------------------------------------------------------------
            outcome | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
--------------------+---------------------------------------------------------------
             warmth |    .961837   .0581809    16.53   0.000     .8478046    1.075869
physical_punishment |  -.8457672   .0798128   -10.60   0.000    -1.002197   -.6893369
            2.group |   1.084409   .2200548     4.93   0.000     .6531099    1.515709
              _cons |   51.64797   .4645466   111.18   0.000     50.73748    52.55847
------------------------------------------------------------------------------------
```

```
------------------------------------------------------------------------------
  Random-effects parameters  |   Estimate   Std. err.     [95% conf. interval]
-----------------------------+------------------------------------------------
country: Identity            |
                  var(_cons) |      3.403   .9717558      1.944438    5.955659
-----------------------------+------------------------------------------------
               var(Residual) |   36.01911   .9346952      34.23295    37.89847
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 200.29        Prob >= chibar2 = 0.0000
```

Generate Predicted Values

```
. predict outcome_hat // predict yhat
(option xb assumed)
```

Graph With twoway Syntax

```
. twoway (scatter outcome_hat warmth) (lfit outcome_hat warmth)

. graph export mypredictedvalues.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/mypredictedvalues.png
    saved as PNG format
```

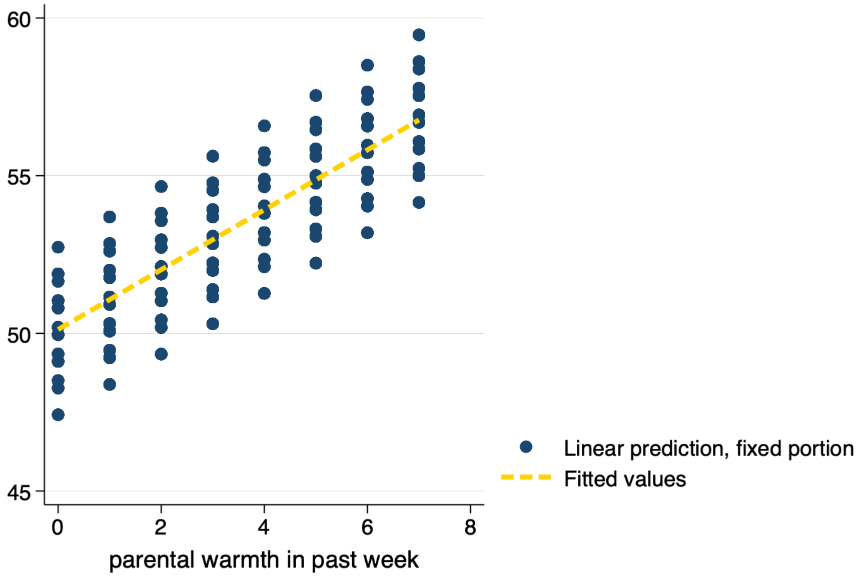


Figure 7: Predicted Values From predict

Spaghetti Plot With Predicted Values

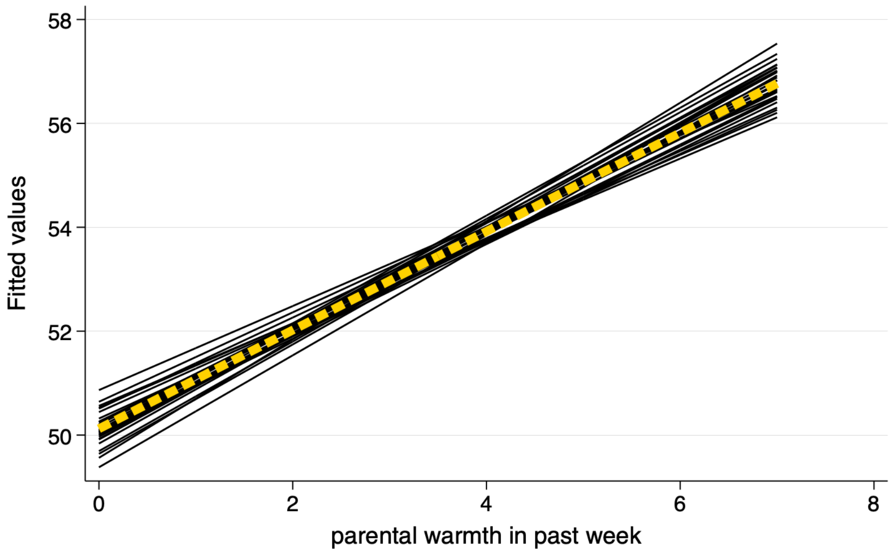
```
. spagplot outcome_hat warmth, id(country)

. graph export myspaghetti2.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/myspaghetti2.png saved
    as PNG format
```

margins and marginsplot

Estimate The Model

```
. mixed outcome warmth physical_punishment i.group || country: // estimate MLM
```



Spaghetti plot of outcome_hat warmth id country

Figure 8: Spaghetti Plot With Predicted Values

```
Performing EM optimization:

Performing gradient-based optimization:

Iteration 0:   log likelihood = -9668.0859
Iteration 1:   log likelihood = -9668.0859

Computing standard errors:

Mixed-effects ML regression                     Number of obs     =      3,000
Group variable: country                         Number of groups  =         30
                                                Obs per group:
                                                              min =        100
                                                              avg =      100.0
                                                              max =        100
                                                Wald chi2(3)      =     401.00
Log likelihood = -9668.0859                     Prob > chi2       =     0.0000

------------------------------------------------------------------------------------
           outcome | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------------+----------------------------------------------------------------
            warmth |    .961837   .0581809    16.53   0.000     .8478046    1.075869
physical_punishment |  -.8457672   .0798128   -10.60   0.000    -1.002197   -.6893369
           2.group |   1.084409   .2200548     4.93   0.000     .6531099    1.515709
             _cons |   51.64797   .4645466   111.18   0.000     50.73748    52.55847
------------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects parameters  |   Estimate   Std. err.     [95% conf. interval]
-----------------------------+------------------------------------------------
country: Identity            |
                  var(_cons) |      3.403   .9717558      1.944438    5.955659
-----------------------------+------------------------------------------------
               var(Residual) |   36.01911   .9346952      34.23295    37.89847
------------------------------------------------------------------------------
LR test vs. linear model: chibar2(01) = 200.29        Prob >= chibar2 = 0.0000
```

Generate Predicted Values *At Specified Values* With margins

```
. margins group, at(warmth = (1 2 3 4 5 6 7)) // predictive *margins*

Predictive margins                                       Number of obs = 3,000

Expression: Linear prediction, fixed portion, predict()
```

```
1._at: warmth = 1
2._at: warmth = 2
3._at: warmth = 3
4._at: warmth = 4
5._at: warmth = 5
6._at: warmth = 6
7._at: warmth = 7

------------------------------------------------------------------------------
             |            Delta-method
             |     Margin   std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   _at#group |
        1 1  |    50.4999   .3983539   126.77   0.000     49.71914    51.28066
        1 2  |   51.58431   .3994365   129.14   0.000     50.80143    52.36719
        2 1  |   51.46174   .3809288   135.10   0.000     50.71513    52.20834
        2 2  |   52.54615     .38173   137.65   0.000     51.79797    53.29432
        3 1  |   52.42357    .371884   140.97   0.000      51.6947    53.15245
        3 2  |   53.50798   .3723656   143.70   0.000     52.77816    54.23781
        4 1  |   53.38541   .3718315   143.57   0.000     52.65664    54.11419
        4 2  |   54.46982   .3719738   146.43   0.000     53.74077    55.19888
        5 1  |   54.34725   .3807751   142.73   0.000     53.60094    55.09355
        5 2  |   55.43166   .3805823   145.65   0.000     54.68573    56.17759
        6 1  |   55.30909    .398109   138.93   0.000     54.52881    56.08937
        6 2  |    56.3935    .397607   141.83   0.000      55.6142    57.17279
        7 1  |   56.27092   .4228024   133.09   0.000     55.44225     57.0996
        7 2  |   57.35533   .4220306   135.90   0.000     56.52817     58.1825
------------------------------------------------------------------------------
```

Graph With marginsplot

```
. marginsplot // plot of predicted values
Variables that uniquely identify margins: warmth group

. graph export mymarginsplot.png, width(1500) replace
file /Users/agrogan/Desktop/GitHub/multilevel/visualizing-MLM/mymarginsplot.png
    saved as PNG format
```

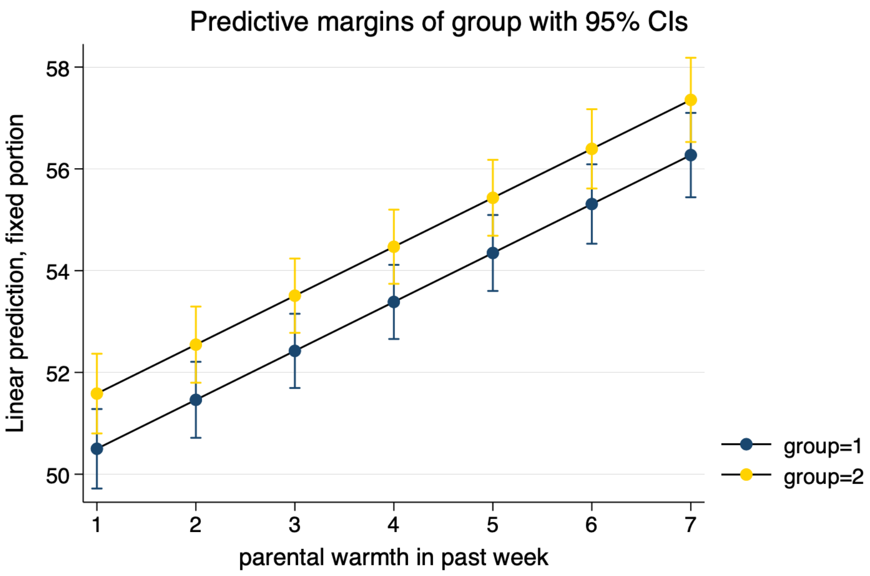


Figure 9: Predicted Values From margins and marginsplot

Curvilinear and Linear Fits

Random Effects