Biostatistics 140.656, 2018-19
Lab 2 Solution

Topics:

- Centering within multilevel models with two levels
- Visualization of total, between, within, and contextual effects
- Interpretation of contextual effects

Learning Objectives:

Students who successfully complete this lab will be able to:

- Construct graphical displays of 2-level multilevel data where the focus is on a level-1 outcome and a level-1 covariate.
- Simulate 2-level multilevel data with specific between, within and contextual effects
- Fit linear mixed models and interpret contextual effects within these models.

Scientific Background:

Suppose you are an obstetrician interested in women's satisfaction with their labor and childbirth experiences. You have access to patient information from three local hospitals: Greater Baltimore Medical Center (GBMC, Hospital 1), Mercy Medical Center (Hospital 2) and Johns Hopkins Hospital (Hospital 3).

You were able to obtain a random sample of 30 nulliparous women (women having their first child) from each hospital and for each woman you have measures of:

- casemix: score for how complicated the birth is likely to be; higher scores mean the birth is expected to be more complicated based on pre-existing conditions, prenatal care, and socioeconomic status
- patient satisfaction score (Y): scores for patient satisfaction with labor and childbirth experiences; higher scores indicate greater satisfaction with the birth experience

Your goals are as follows:

1. Quantify the relationship between patient satisfaction and casemix within a hospital
2. Determine how the hospital mean patient satisfaction changes with hospital mean casemix
3. Determine if the context of the hospital matters; i.e. do women of the same casemix benefit from attending GBMC (whose casemix is lower on average) verses Mercy or Hopkins.

These goals can be addressed by the following mixed model where Y_{ij} is the patient satisfaction score and X_{ij} is the casemix for woman *j* from hospital *i*.

$$Y_{ij} = \beta_0 + b_{0i} + \beta_1\left(X_{ij} - \bar{X}_{i.}\right) + \beta_2\bar{X}_{i.} + \varepsilon_{ij}, b_{0i} \sim N(0, \tau^2), \varepsilon_{ij} \sim N(0, \sigma^2)$$

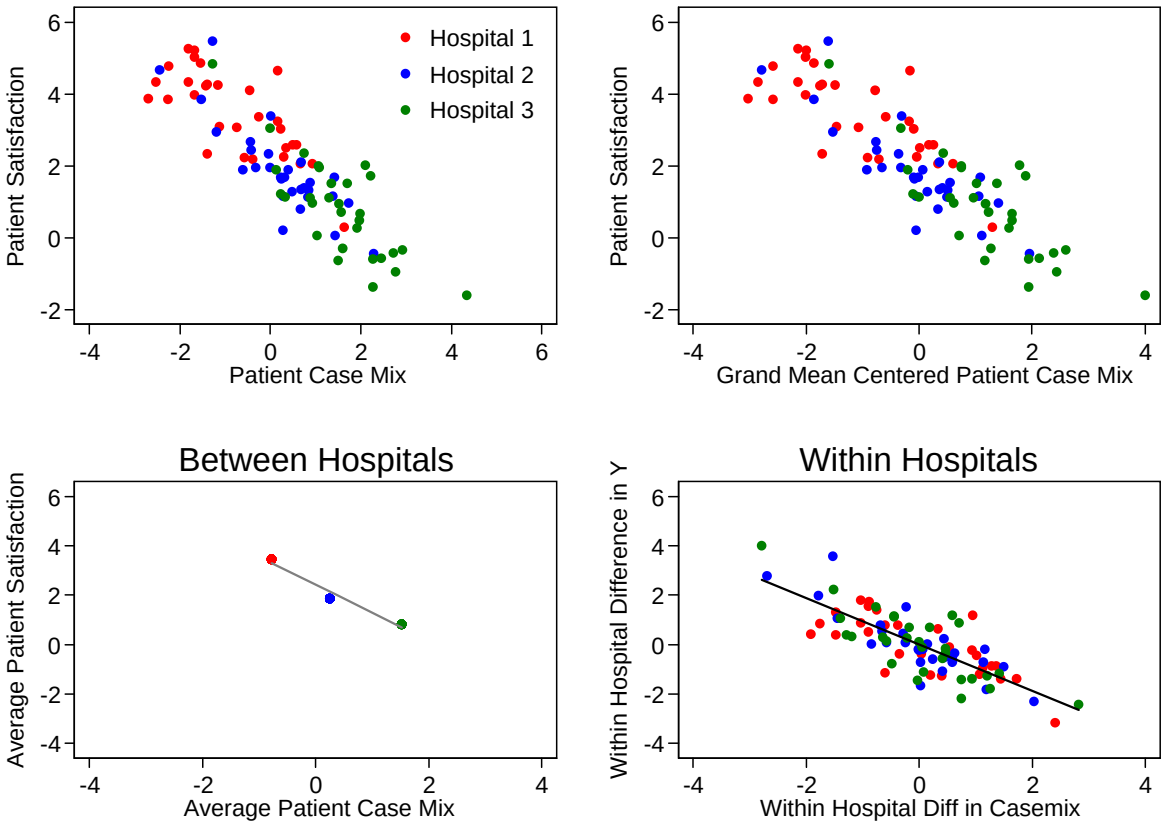
No contextual effects: beta_1 = beta_2 --> y_ij = beta_0 + b_0i + beta1(x_ij)

Lab Exercise:

1. Simulated world 1: No contextual effect ($\beta_1 = \beta_2$).

   Run the lab2 do-file or R script.

   Consider the graphical display of the data produced by the do-file or R script and answer the following questions:



   a. Which hospital has lowest average casemix?

      ANSWER: GBMC (Hospital 1) has the lowest average casemix (scores are negative, meaning less complications).

   b. Which hospital has highest average patient satisfaction?

      ANSWER: GBMC (Hospital 1) had the highest patient satisfaction (highest patient satisfaction scores).

   c. What patterns in the data support the claim that the between cluster and within cluster associations between patient satisfaction and casemix are the same?

ANSWER: If you compare the plots for the between hospital and within hospital association (lower left and lower right, respectively), the slopes are roughly the same. This pattern supports the claim that the between cluster and within cluster associations between patient satisfaction and casemix are the same.

d. Relative to grand mean centering the casemix variable, what is the advantage of hospital mean centering the casemix variable?

ANSWER: The advantage of hospital mean centering the casemix variable is that we can examine ONLY the within hospital association between patient satisfaction and casemix. In the grand-mean centering approach, we have both between hospital and within hospital effects.

Consider the results of the linear mixed model and answer the following questions:

```
. mixed Y mean_casemix centered_casemix || hospid:

Computing standard errors:

Mixed-effects ML regression                     Number of obs      =        90
Group variable: hospid                          Number of groups   =         3

                                                Obs per group: min =        30
                                                               avg =      30.0
                                                               max =        30


                                                Wald chi2(2)       =    237.26
Log likelihood = -106.83456                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
mean_casemix |  -1.135602   .1178279    -9.64   0.000     -1.36654   -.9046632
centered_c~x |  -.9403593   .0782631   -12.02   0.000    -1.093752   -.7869665
       _cons |   2.423696   .1172481    20.67   0.000     2.193894    2.653499
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
hospid: Identity             |
                  var(_cons) |   .0162329   .0302032      .0004233    .6225239
-----------------------------+------------------------------------------------
               var(Residual) |   .6168227   .0935224       .458249    .8302697
------------------------------------------------------------------------------
LR test vs. linear regression: chibar2(01) =     0.59 Prob >= chibar2 = 0.2208
```

a. Interpret the estimated value of β_1

ANSWER: This is the estimated value of the within cluster effect. The expected difference in patient satisfaction between two women from the same hospital but who differ in casemix score by one unit is -0.94 (95% CI: -1.09, -0.79).

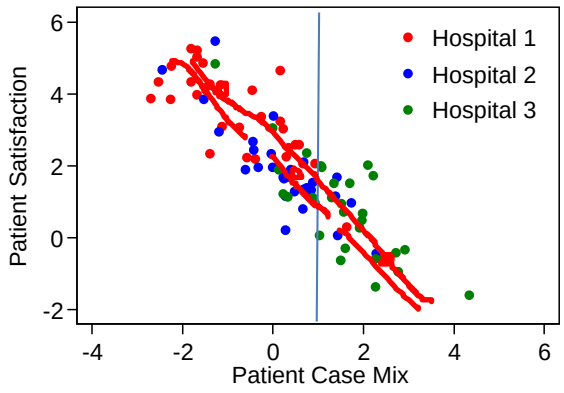
b. Interpret the estimated value of β_2

ANSWER: This is the estimated value of the between cluster effect. The expected difference in mean patient satisfaction between two hospitals that differ in average casemix score by one unit is -1.14 (95% CI: -1.37, -0.90).

c. Estimate and interpret the contextual effect

ANSWER: The contextual effect can be estimated by taking the difference between β_2 and β_1 (-1.14 - (-0.90) = -0.20). The difference in expected patient satisfaction comparing two women who have the same value of casemix but who come from hospitals that differ by one unit in mean casemix.

In the figure below, the light blue line is at casemix = 1. The contextual effect is the difference in the expected patient satisfaction score for women with casemix = 1 but who attend hospitals that differ in their average patient casemix. You can see from the figure below, that there is little distinction between hospitals in the patient satisfaction scores among women with the same casemix. This is visual evidence of NO contextual effect.



2. Positive contextual effect.

In your group, discuss what it would mean within the context of this problem to have a positive contextual effect.

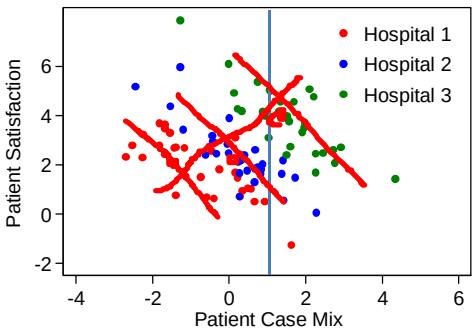
ANSWER: A positive contextual effect would mean that among women with the same casemix score, those who receive care at hospitals with higher average casemix would have higher average patient satisfaction scores.

Modify the lab2 do-file or R script to simulate a positive contextual effect, i.e. provide new values of β_1 and β_2. Simulate a single study with the positive contextual effect. Review the graphical displays and model fits for this single simulated study.

ANSWER: Let's fix the variance components and the within hospital association between patient satisfaction and casemix. In order to generate a positive contextual effect, you would need to change the between effect such that $\beta_2 > \beta_1$.

Below I modified the simulation so that $\beta_2 = 1$ (everything else within the lab2.do file stayed the same).

Notice in the figure below that now when we consider women with casemix score = 1, the expected patient satisfaction score for women at Hospital 3 would be larger than the expected patient satisfaction score for women at Hospital 2 and 1. That is, delivering at Hospital 3 is value added for women with the same casemix.



positive contextual effect

Provide the estimate of and interpretation of the positive contextual effect from your single simulated study.

ANSWER: From the fit of the model (pasted below), when comparing two women with the same casemix score but whom are delivering children at hospitals that differ by 1 unit in the hospital average casemix score, the expected patient satisfaction of the woman delivering at the hospital with higher average casemix score is 1.8 points greater than the other woman's expected patient satisfaction.


```
. mixed Y mean_casemix centered_casemix || hospid:

Computing standard errors:

Mixed-effects ML regression                     Number of obs      =        90
Group variable: hospid                          Number of groups   =         3

                                                Obs per group: min =        30
                                                               avg =      30.0
                                                               max =        30


                                                Wald chi2(2)       =    198.19
Log likelihood = -106.83457                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
mean_casemix |   .8643984   .1178279     7.34   0.000       .63346    1.095337
centered_casemix |  -.9403593   .0782631   -12.02   0.000    -1.093752   -.7869665
       _cons |   2.423696   .1172481    20.67   0.000     2.193894    2.653499
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
hospid: Identity             |
                  var(_cons) |   .0162329   .0302032      .0004233     .622524
-----------------------------+------------------------------------------------
               var(Residual) |   .6168227   .0935224       .458249    .8302697
------------------------------------------------------------------------------
LR test vs. linear regression: chibar2(01) =     0.59 Prob >= chibar2 = 0.2208

. lincom mean_casemix - centered_casemix

 ( 1)  [Y]mean_casemix - [Y]centered_casemix = 0

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |   1.804758   .1414515    12.76   0.000     1.527518    2.081997
------------------------------------------------------------------------------
```

3. Negative contextual effect.

   In your group, discuss what it would mean within the context of this problem to have a negative contextual effect.

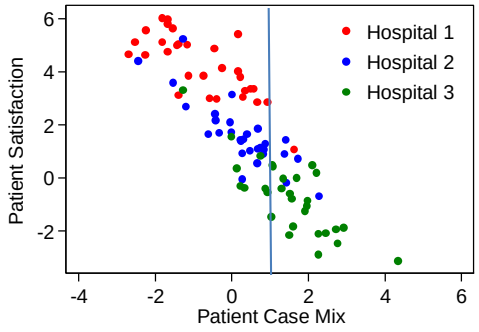
   ANSWER: A negative contextual effect would indicate that when comparing women of the same casemix score but whom are attending different hospitals, the expected patient satisfaction for the women decreases as the hospital average casemix increases.

Modify the lab2 do-file or R script to simulate a negative contextual effect, i.e. provide new values of β_1 and β_2. Simulate a single study with the negative contextual effect. Review the graphical displays for this single simulated study.

ANSWER: Let's fix the variance components and the within hospital association between patient satisfaction and casemix. In order to generate a negative contextual effect, you would need to change the between effect such that $\beta_2 < \beta_1$.

Below I modified the simulation so that β_2 = -2 (everything else within the lab2.do file stayed the same).

Notice in the figure below that now when we consider women with casemix score = 1, the expected patient satisfaction score for women at Hospital 3 is smaller than the expected patient satisfaction score for women at Hospital 2 and 1. That is, delivering at Hospital 3 is "value removed" for women with the same casemix.



Provide the estimate of and interpretation of the positive contextual effect from your single simulated study.

ANSWER: From the fit of the model (pasted below), the expected patient satisfaction score among women with the same casemix but whom attend different hospitals decreases by 1.20 points per additional point difference in the hospital average casemix.


```
Mixed-effects ML regression                     Number of obs      =        90
Group variable: hospid                          Number of groups   =         3

                                                Obs per group: min =        30
                                                               avg =      30.0
                                                               max =        30


                                                Wald chi2(2)       =    472.88
Log likelihood = -106.83457                     Prob > chi2        =    0.0000

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
mean_casemix |  -2.135602   .1178279   -18.12   0.000     -2.36654   -1.904663
centered_case~ |  -.9403593   .0782631   -12.02   0.000    -1.093752   -.7869665
       _cons |   2.423696   .1172481    20.67   0.000     2.193894    2.653499
------------------------------------------------------------------------------

------------------------------------------------------------------------------
  Random-effects Parameters  |   Estimate   Std. Err.     [95% Conf. Interval]
-----------------------------+------------------------------------------------
hospid: Identity             |
                  var(_cons) |   .0162329   .0302032      .0004233    .6225239
-----------------------------+------------------------------------------------
               var(Residual) |   .6168227   .0935224       .458249    .8302697
------------------------------------------------------------------------------
LR test vs. linear regression: chibar2(01) =     0.59 Prob >= chibar2 = 0.2208

. lincom mean_casemix - centered_casemix

 ( 1)  [Y]mean_casemix - [Y]centered_casemix = 0

------------------------------------------------------------------------------
           Y |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         (1) |  -1.195242   .1414515    -8.45   0.000    -1.472482   -.9180025
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```