Multilevel Analysis of Time-Series Data in the Context of Behavioral and Psychological Research

Available at: http://faculty.smu.edu/kyler

J. Kyle Roberts

Southern Methodist University
Annette Caldwell Simmons School of Education and Human Development

APA 2010 Annual Meeting
Brief History of the Outcomes Questionnaire

- Developed by Michael Lambert
- The scale we are looking at has 45 items with a total score and three subscale scores.
- There is some debate about the factor structure, but the time-series analysis will include the current factor score regardless of this debate.
- There were an average of 5.8 observations per individual (sd=9.83).
**Problems with Observations**

- Total of 1430 unique IDs.
- More than 1000 have less than 5 observations, and more than 600 have only one observation.
Graphical Exploration of 50 Random Subjects with 10+ Observations
First, Some Data Cleaning

• With the unusually large number of individuals with only 1 observation, it makes sense to run all analyses with multiple cuts from the data.

• Therefore, the following analyses will be performed with:
  1. Whole Dataset
  2. Dataset where all individuals with only 1 observation are removed
  3. Dataset where all individuals with less than 6 observations are removed.
Models Tested

Although we do not know the actual amount of time that elapses between each session for the patients, we do have a variable that shows the total number of sessions at each measurement occasion. This variable, we will call Session

- Model 1 - A simple model with just Session and a random effect for the individual

  \[ y_{ti} = \gamma_{00} + \gamma_{10} \times \text{Session} + u_{0i} + e_{ti} \]

- Model 2 - Adding a random effect for Session

  \[ y_{ti} = \gamma_{00} + (\gamma_{10} + u_{1i}) \times \text{Session} + u_{0i} + e_{ti} \]

- Model 3 - Adding a quadratic term for Session

  \[ y_{ti} = \gamma_{00} + (\gamma_{10} + u_{1i}) \times \text{Session} + \gamma_{20} \times \text{Session}^2 + u_{0i} + e_{ti} \]

- Model 4 - Adding a random effect for the quadratic term

  \[ y_{ti} = \gamma_{00} + (\gamma_{10} + u_{1i}) \times \text{Session} + (\gamma_{20} + u_{2i}) \times \text{Session}^2 + u_{0i} + e_{ti} \]
Whole Dataset - Models 1-4

> anova(m1, m2, m3, m4)

Data: OQdata
Models:
m1: TotalScore ~ Session + (1 | PatientKey)
m2: TotalScore ~ Session + (Session | PatientKey)
m3: TotalScore ~ Session + Session.2 + (Session | PatientKey)
m4: TotalScore ~ Session + Session.2 + (Session + Session.2 | PatientKey)

<table>
<thead>
<tr>
<th>Df</th>
<th>AIC</th>
<th>BIC</th>
<th>logLik</th>
<th>Chisq</th>
<th>Chi Df</th>
<th>Pr(&gt;Chisq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1</td>
<td>4</td>
<td>67135</td>
<td>67163</td>
<td>-33564</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m2</td>
<td>6</td>
<td>66452</td>
<td>66494</td>
<td>-33220</td>
<td>687.075</td>
<td>&lt; 2.2e-16</td>
</tr>
<tr>
<td>m3</td>
<td>7</td>
<td>66439</td>
<td>66488</td>
<td>-33213</td>
<td>15.076</td>
<td>0.0001033</td>
</tr>
<tr>
<td>m4</td>
<td>10</td>
<td>67591</td>
<td>67661</td>
<td>-33786</td>
<td>0.000</td>
<td>1.0000000</td>
</tr>
</tbody>
</table>

It would appear that Model 3 is the strongest model.

\[ y_{ti} = \gamma_0 + (\gamma_{10} + u_{1i}) \times \text{Session} + \gamma_{20} \times \text{Session}^2 + u_{0i} + e_{ti} \]
Results of Model 3 with the Whole Dataset

```r
> summary(m3)

Linear mixed model fit by REML
Formula: TotalScore ~ Session + Session.2 + (Session | PatientKey)
  Data: OQdata
AIC  BIC logLik deviance REMLdev
  66457 66506 -33222 66425 66443
Random effects:
Groups     Name    Variance  Std.Dev.  Corr
PatientKey (Intercept)  416.23390  20.40181
               Session  0.52948   0.72765 -0.264
Residual       146.10511  12.08739
Number of obs: 8031, groups: PatientKey, 1339
Fixed effects:
  Estimate Std. Error t value
(Intercept)   71.8750008 0.6396470  112.37
Session       -0.5840964 0.0434765  -13.43
Session.2     0.0010334 0.0002644    3.91
Correlation of Fixed Effects:
  (Intr)  Sessin
Session   -0.349
Session.2  0.814
```
Dataset with N Obs > 1 - Models 1-4

> anova(m1.1, m1.2, m1.3, m1.4)

Data: minus1samp
Models:
m1.1: TotalScore ~ Session + (1 | PatientKey)
m1.2: TotalScore ~ Session + (Session | PatientKey)
m1.3: TotalScore ~ Session + Session.2 + (Session | PatientKey)
m1.4: TotalScore ~ Session + Session.2 + (Session + Session.2 | PatientKey)

<table>
<thead>
<tr>
<th>Df</th>
<th>AIC</th>
<th>BIC</th>
<th>logLik</th>
<th>Chisq</th>
<th>Chi Df</th>
<th>Pr(&gt;Chisq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m1.1</td>
<td>4</td>
<td>62216</td>
<td>62244</td>
<td>-31104</td>
<td></td>
<td></td>
</tr>
<tr>
<td>m1.2</td>
<td>6</td>
<td>61516</td>
<td>61558</td>
<td>-30752</td>
<td>704.423</td>
<td>2 &lt; 2.2e-16</td>
</tr>
<tr>
<td>m1.3</td>
<td>7</td>
<td>61505</td>
<td>61553</td>
<td>-30745</td>
<td>13.198</td>
<td>1 0.0002803</td>
</tr>
<tr>
<td>m1.4</td>
<td>10</td>
<td>63125</td>
<td>63194</td>
<td>-31552</td>
<td>0.000</td>
<td>3 1.0000000</td>
</tr>
</tbody>
</table>

It would appear that Model 3 is the strongest model here, too, but not by much.

\[ y_{ti} = \gamma_0 + (\gamma_{10} + u_{1i}) \times \text{Session} + \gamma_{20} \times \text{Session}^2 + u_{0i} + e_{ti} \]
Results of Model 3 with N Obs > 1

> summary(m1.3)

Linear mixed model fit by REML
Formula: TotalScore ~ Session + Session.2 + (Session | PatientKey)
   Data: minus1samp

AIC  BIC logLik deviance REMLdev
61522 61571 -30754 61491 61508

Random effects:
  Groups   Name        Variance  Std.Dev.  Corr
  PatientKey (Intercept) 413.15521  20.32622
  Session              0.58622   0.76565 -0.232
  Residual             145.57741  12.06555

Number of obs: 7494, groups: PatientKey, 802

Fixed effects:
  Estimate  Std. Error    t value
(Intercept) 71.9139337  0.7906176  90.96
Session   -0.6268212  0.0469730  -13.34
Session.2   0.0009708  0.0002660   3.65

Correlation of Fixed Effects:
  (Intr) Sessin
Session   -0.352
Session.2  0.310


Dataset with N Obs $>5$ - Models 1-4

> anova(m5.1, m5.2, m5.3, m5.4)

Data: minus5samp
Models:

m5.1: TotalScore ~ Session + (1 | PatientKey)
m5.2: TotalScore ~ Session + (Session | PatientKey)
m5.3: TotalScore ~ Session + Session.2 + (Session | PatientKey)
m5.4: TotalScore ~ Session + Session.2 + (Session + Session.2 | PatientKey)

<table>
<thead>
<tr>
<th></th>
<th>Df</th>
<th>AIC</th>
<th>BIC</th>
<th>logLik</th>
<th>Chisq</th>
<th>Chi Df</th>
<th>Pr(&gt;Chisq)</th>
</tr>
</thead>
<tbody>
<tr>
<td>m5.1</td>
<td>4</td>
<td>51682</td>
<td>51709</td>
<td>-25837</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m5.2</td>
<td>6</td>
<td>51027</td>
<td>51068</td>
<td>-25508</td>
<td>659.017</td>
<td>2</td>
<td>&lt; 2.2e-16</td>
</tr>
<tr>
<td>m5.3</td>
<td>7</td>
<td>51018</td>
<td>51065</td>
<td>-25502</td>
<td>11.744</td>
<td>1</td>
<td>0.0006104</td>
</tr>
<tr>
<td>m5.4</td>
<td>10</td>
<td>50841</td>
<td>50909</td>
<td>-25411</td>
<td>182.272</td>
<td>3</td>
<td>&lt; 2.2e-16</td>
</tr>
</tbody>
</table>

With this dataset, we see that the fourth model really has the best fit.

\[ y_{ti} = \gamma_0 + (\gamma_1 + u_{1i}) \times \text{Session} + (\gamma_2 + u_{2i}) \times \text{Session}^2 + u_{0i} + e_{ti} \]
Results of Model 4 with N Obs > 5

> summary(m5.4)

Linear mixed model fit by REML
Formula: TotalScore ~ Session + Session.2 + (Session + Session.2 | PatientKey)
   Data: minus5samp
   AIC   BIC  logLik deviance REMLdev
50857 50925 -25419 50821 50837
Random effects:
 Groups     Name     Variance   Std.Dev.  Corr
PatientKey (Intercept) 4.0557e+02 20.1388469
           Session 1.0283e+00 1.0140331 -0.257
           Session.2 5.8124e-05 0.0076239 0.162 -0.978
Residual      1.4205e+02 11.9184631
Number of obs: 6269, groups: PatientKey, 399
Fixed effects:

                  Estimate  Std. Error   t value
(Intercept)    73.2202286 1.0862152 67.41
Session       -0.7783150 0.0674767 -11.53
Session.2    0.0058752 0.0006186 9.50

Correlation of Fixed Effects:
   (Intr) Sessin
Session   -0.367