April 2013

BNCD Center for Biobehavioral Neurosciences in Communication Disorders

Mabel Rice, Director

Analytical Techniques & Technology Core

Daniel Bontempo, Co-Director/Statistician • Susan Kemper, Director

Multilevel Analyses for Repeated Measures

Multilevel modeling (MLM), also called mixed effects modeling, hierarchical linear modeling (HLM) or random coefficient modeling, is gaining increasing recognition as an advantageous method for handling dependencies in repeated measures data (Cnaan, Laird, & Slasor, 1997; Gueorguieva & Krystal, 2004; Misangyi, LePine, Algina, & Goeddeke, 2006; Nezlek, Schroder-Abe, & Schutz, 2006). Of particular importance to BNCD investigators is that utilization extends to experimental studies (Hoffman & Rovine, 2007) as well as psycholinguistic research (Locker, Hoffman, & Boviard, 2007; Quene & van den Bergh, 2004, 2008). MLM methods are not just for longitudinal studies with follow-up over time.

Repeated measures ANOVA (RM-ANOVA) is being supplanted by MLM for several reasons. First, there is greater flexibility in handling incomplete data (i.e., unbalanced, missing). In repeated RM-ANOVA, if any repeated measure is missing (e.g., a child produces an unscorable response, or an experimental apparatus fails on one or more trials), all the other measures for that subject must be excluded from analysis (list-wise deletion). In addition to undesirable data loss, the result is an unbalanced design (i.e., unequal N across experimental groups), which can further complicate the analysis. With MLM it is possible to include all available data in the model.

Second, the MLM framework offers flexibility concerning residuals. ANOVA offers only one variance-covariance structure for the residuals at each repeated measurement. ANOVA assumes compound-symmetry, i.e., that each repeated measurement has the same residual error, and that the covariance between the residuals of any two measurements is the same (aka, sphericity). When repeated measures comprise multiple trials over a short period of time, this may not be an unreasonable assumption; but when the repeated measures occur over learning or development, the sphericity assumption may be unrealistic. The analysis conclusions (i.e., F-tests) may be biased when violations occur. Either univariate corrections adjusting the degrees of freedom (Greenhouse-Geisser, or Huynh-Feldt) must be used, or a less powerful multivariate (MANOVA) approach is required. In contrast, MLM offers multiple variance-covariance structures, including an “unstructured” where the variance (and associated covariances) of each repeated measure’s residual is freely estimated. This does require additional model parameters, but not only avoids the sphericity assumption, but also opens the repeated residual variances to scientific investigation. In summary, the residual is no longer a nuisance term, but is an important within-person random coefficient in the repeated measures model.

Compound Symmetry

$$\begin{pmatrix} \sigma^2 & \rho & \rho & \ldots\ \rho \\ \rho & \sigma^2 & \rho & \ldots\ \rho \\ \ldots & \ldots & \ldots & \ldots \\ \rho & \rho & \rho & \ldots\ \sigma^2 \end{pmatrix}$$

Unstructured

$$\begin{pmatrix} \sigma^2_1 & \rho_{12} & \rho_{13} & \ldots\ \rho_{1n} \\ \rho_{12} & \sigma^2_2 & \rho_{23} & \ldots\ \rho_{2n} \\ \ldots & \ldots & \ldots & \ldots \\ \rho_{1n} & \rho_{2n} & \rho_{3n} & \ldots\ \sigma^2_n \end{pmatrix}$$

Center investigators can contact Daniel Bontempo (deb193@ku.edu, 785-846-4824) to discuss any multilevel, multivariate, or advanced statistical issues. Call for quick questions, or in-depth consultation by appointment. The ATT Core is also available to assist with grant proposals methods sections, or to conduct advanced analyses of your data.

Third, random coefficients are not limited to the within-person residuals. Repeated measurement dependencies are handled with a between-person random intercept variance parameter. This model parameter expresses the magnitude of individual differences. In lab studies, multilevel random intercept models (for each person/ subject) can be employed to account for within-person dependencies on repeated measures, by separately estimating unexplained between-person and within-person variances. Growth modeling, which extends random intercept models by using a 2nd random between-person coefficient to capture individual differences in change, has seen broad application in longitudinal research. However these models can be used with lab data when the stimuli used in repeated trials are ordered along a continuous dimension (e.g., word neighborhood density). Now, the fuller potential to study between-person differences in within-person change is realized. Further, generalizations of the multilevel model readily provide for multilevel logistic regression; and such models have been utilized with psycholinguistic data (Guo & Zhao, 2000; Quene & van den Bergh, 2008).

The references below might be helpful if you would like more information on multilevel models, or their use in experimental settings:

Cnaan, A., Laird, N. M., & Slasor, P. (1997). Using the General Linear Mixed Model to Analyse Unbalanced Repeated Measures and Longitudinal Data. *Statistics in Medicine, 16* (20), 2349-2380.

Gueorguieva, R., & Krystal, J. H. (2004). Move over Anova - Progress in Analyzing Repeated-Measures Data and Its Reflection in Papers Published in the Archives of General Psychiatry. *Archives of General Psychiatry, 61*(3), 310-317.

Guo, G., & Zhao, H. X. (2000). Multilevel Modeling for Binary Data. *Annual Review of Sociology, 26*, 441-462.

Hoffman, L., & Rovine, M. J. (2007). Multilevel Models for the Experimental Psychologist: Foundations and Illustrative Examples. *Behavior Research Methods, 39*(1), 101-117.

Locker, L., Hoffman, L., & Bovaird, J. A. (2007). On the use of multilevel modeling as an alternative to items analysis in psycholinguistic research. *Behavior Research Methods*, 39 (4), 723-730. doi: 10.3758/bf03192962

Misangyi, V. F., LePine, J. A., Algina, J., & Goeddeke, F. (2006). The Adequacy of Repeated-Measures Regression for Multilevel Research - Comparisons with Repeated-Measures Anova, Multivariate Repeated-Measures Anova, and Multilevel Modeling across Various Multilevel Research Designs. *Organizational Research Methods, 9*(1), 5-28.

Nezlek, J. B., Schroder-Abe, M., & Schutz, A. (2006). Multilevel Analyses in Psychological Research. Advantages and Potential of Multilevel Random Coefficient Modeling. *Psychologische Rundschau, 57* (4), 213-223.

Quene, H., & van den Bergh, H. (2004). On Multi-Level Modeling of Data from Repeated Measures Designs: A Tutorial. *Speech Communication, 43*(1-2), 103-121.

Quene, H., & van den Bergh, H. (2008). Examples of Mixed-Effects Modeling with Crossed Random Effects and with Binomial Data. *Journal of Memory and Language, 59*(4), 413-425.

Potential topics for future ATT Core newsletters are listed below. Additional topics, ideas, or suggestions are very welcome. Please contact Daniel Bontempo with any ideas for making the ATT Core newsletter a more useful resource.

- Plotting raw and model-implied individual trajectories
- Use of linear splines to model non-linearity
- Parameterizing models to control for group baseline differences
- Contrast (ANOVA) vs MLM dummy codings an how to get ANOVA-like contrasts after regression.
- How MLM individual trajectory estimates “borrow strength” form the group mean trajectory
- Crossed-random intercepts and language as fixed effect fallacy,
- Effective use of online supplemental materials
- Median odds ratio (MOR) and individual differences
- Research questions answered by random change-point models,
- Alternatives to assuming normally distributed residuals
- Getting/making/editing SEM diagrams when the package does not provide them
- Reliability and precision of growth rates (slopes)
- Classification and regression tree (CART)
- Various effect size measures

The ATT Core is also available to assist center investigators with methods sections of grant proposals, or to assist with advanced analyses. If you are planning a grant submission and would like to discuss the advantages of, or the language to describe multilevel models in your methodology section, contact Daniel Bontempo (deb193@ku.edu, 785-846-4824) .