Determining Optimal Design Features in an Accelerated Longitudinal Study: Monte Carlo Evidence and Useful Recommendations

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Introduction

An accelerated design, also known as a cohort-sequential design (CSD), provides a useful alternative to purely longitudinal and purely cross-sectional designs, in that it can capture both inter- and intra-individual change as well as the predictors of this change (Baer & Schmitz, 2000). The basic premise of this method is that making a limited number of repeated measurements of cross-sectional groups provides the experimenter with a set of temporally overlapping measurements of adjacent age groups or cohorts. This approach allows an approximation of the "true" longitudinal development of a construct to be obtained. To the extent that the sub-groups have the same trajectory, trends can be tested over the age span of all the individuals in a study, not just within groups (Bell, 1954).

Few studies have been carried out to test the true effectiveness of this method. There are several design features that should be examined before conducting an analysis with these data. Sufficiency of overlap between cohorts is a very important design feature to consider. Another consideration is that matching cohorts requires relatively large sample sizes. In general, measurement error introduced by linking sub-populations must be offset by samples typically larger than those used in traditional longitudinal designs, although there is no apparent standard for how much larger the sample size should be in a CSD.

The focus of the current research is to investigate the impact of various levels of sample size per cohort, number of measurement occasions for each cohort, and level of growth on the statistical power of the multiple-group latent growth curve model (MG-LGM) approach to analyzing data that results from a cohort sequential design. The study utilizes Monte Carlo techniques to simulate data from a cohort-sequential design and to analyze it under the MG-LGM. The power of MG-LGM to find the specified effects under the various conditions is the focal point of the current research. It is always important for those planning a study to know not only about the power of a statistical methodology they plan to use under the intended design features, but also the error rates, bias, and estimation errors associated with the method.

Purpose of the Study

- To investigate the use of a multiple-group latent growth model (MG-LGM) as an approach to analyzing data from a cohort-sequential design (CSD).
- The data simulated here is intended to emulate school data (grades 1 through 8).

Method

- Mplus version 3.14 (Muthen & Muthen, 2004) was used to carry out the data simulation and model estimation portions of this study.
- There are a total of N = 9,000 samples of data (500 per cell) that have been simulated, varying on three dimensions.
  - Sample size per cohort: 20, 30, and 40
  - Number of measurement occasions: 3, 4, and 5
  - Effect size: small and null

- Each of the 9000 datasets was generated based on an eight-occasion linear mixed model to approximate a true longitudinal design (measurements within subjects).
  \[y_{i} = \beta_0 + \beta_1 \text{Time}_{i} + \epsilon_{i}
\]
  \[\beta_1 = \gamma_1 + u_1
\]
  \[\beta_0 = \gamma_0 + u_0
\]
- All 8 time points are simulated. Subjects are randomly assigned to a cohort. Data not intended to be seen is dropped.

Results

- ‘Not positive definite psi matrix’ errors •154 out of 4,500 (3.4%) • More problems at lower sample size per cohort and lower number of measurement occasions
- Negative bias found in 14 cells Negative bias found in 14 cells • Highest bias observed = 0.0017
- Power ranged from .55 to .92 • Increased with higher sample size per cohort and more measurement occasions
- Type I error: No clear pattern was observed • Most fall within the range of .04 to .06, just as in Fan’s (2003) Monte Carlo study of LGM.
• Sample size per cohort or number of measurement occasions did not systematically affect the ability of the MG-LGM to correctly fail to reject the null

Conclusions

- ‘Not positive definite psi matrix’ errors
  • The matrix that contains the intercept variance, slope variance and covariance (Psi) has a determinant of zero, or is not uniquely defined.
  • Often happens due to negative variance estimates • 18 out of 154 (11.7%) due to negative variance estimates
  • Low intercept variances and high covariances seem to be associated with estimation errors
  • Most occur in the 3 measurement occasion condition and with lower sample sizes per cohort
  • Increasing the number of subjects per cohort or increasing the number of measurement occasions leads to a decrease in estimation errors
  • Increasing cohort size and number of measurements leads to an increase in power
  • 30 is the minimum cohort sample size needed to achieve sufficient power
  • Under three measurement occasions, at least 40 per cohort are needed
  • Increasing the number of subjects per cohort and the number of measurement occasions both led to increases in power and decreases in estimation errors
  • Researchers should generally strive to observe more subjects per cohort to keep the efficiency of the CSD intact.

References


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