Modeling Ecological and Contextual Effects in the Social Sciences

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Longitudinal Structural Equation Modeling

Todd D. Little

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Context

The circumstances in which an event occurs; a setting.

- The set of features that influences the performance or the outcome of a process
- The conditions that are relevant to an event, fact, etc.

- From *contextus* a putting together
- From *contexere* to interweave, braid
- circumstances, times, conditions, situation, ambience, frame of reference, background, framework, relation, connection

Ecology

- The relationship between organisms and their environment.
Image: Overlapping Ecologies of Human Development

**Figure 2.5.** Overlapping Ecologies of Human Development

- Personal Ecology
- Social Ecology
- Physical Ecology
Figure 2.6. Bronfenbrenner’s hierarchy of the Social Ecology
Physical Ecology

Figure 2.7. Widaman’s hierarchy of the Physical Ecology
Personal Ecology

Figure 2.8. Little’s hierarchy of the Personal Ecology
Contexts as Statistical Relationships

Direct effects

▪ Varies at the level of the individual and influences the individual directly

Indirect (mediated) effects

▪ X varies at the level of the individual and influences the individual through its effect on an intervening variable, M

Mediating effects

▪ Distal context influences proximal context which influences the individual

Moderating effects

▪ Interactive influences that change the strength of any of the above effects
▪ Discrete vs. Continuous

Reciprocal effects and feedback loops

▪ Cross-time associations that can express as indirect, mediated/mediating, or moderated/moderating.

Hierarchically nested effects

▪ Larger units of context that can have direct, indirect, mediating, or moderating effects or be mediated and or moderated.
Context and Measurement

"Whatever exists at all exists in some amount. To know it thoroughly involves knowing its quantity as well as its quality"

- E. L. Thorndike (1918)

We should measure persons and contexts well

- Measures should be appropriate for the construct
  - Contexts should be quantified (borrow from sociology, for example)
  - Developmental measures should address change
    - The tragic legacy of test-retest reliability
- Measures and analyses should not be haphazard
  - Avoid: “Hey, this new method is cool, let’s try it on this data?”
  - Question -> Measurement -> Statistical Model
  - Avoid short forms of existing scales (use intentionally missing design)
    - (‘allure of the bloated specific’ idea)
  - Develop or modify to make sure the measurement tool is right
  - Take time to refine and pilot measures (even well-established ones).
Context of Measurement

Homotypic vs. heterotypic expressions across ages
- e.g., Aggression

Surface (proximal) structure vs. deep (ultimate) structure of behavior
- e.g., helping as resource-directed behavior

Typological (subgroups) differences
- Identification issues and procedures
  - Muthen’s m-Plus, Nagin’s Proc Traj, Bergman’s Sleipner

n-adic (dyadic, triadic, etc.) overlay on all of the various modeling approaches
- e.g., SRM, APIM, Siena

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A) Establishing comparability of different measures of the same construct over time: No bias

B) Establishing comparability of different measures of the same construct over time: Bias corrected

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Context of Change

Interindividual differences vs. Intraindividual differences

- Ergodicity conundrum

Associations (within and between time)

- Covariances and Correlations vs. Regressions
- Direct and Indirect effects
  - Auto-regressive vs. Cross-lagged
    - 1st-order vs. higher-order
- Linear vs. non-linear

Means and Variances

Mediation vs. Moderation vs. Additive Effects

\[ B = f(\text{age}) \text{ vs. } \Delta = f(\text{time}) \]
Appropriate Time and Intervals

Age in years, months, days.

Experiential time: Amount of time something is experienced
- Years of schooling, length of relationship, amount of practice
- Calibrate on beginning of event, measure time experienced

Episodic time: Time of onset of a life event
- Toilet trained, driver license, puberty, birth of child, retirement
- Early onset, on-time, late onset: used to classify or calibrate.
- Time since onset or time from normative or expected occurrence.

Measurement Intervals (rate and span)
- How fast is the developmental process?
- Intervals must be equal to or less than expected processes of change
- Measurement occasions must span the expected period of change
- Cyclical processes
  - *E.g., schooling studies at yearly intervals vs. half-year intervals*
Transforming to Episodic Time

<table>
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<tr>
<th>Pattern</th>
<th>Wave 1</th>
<th>Wave 2</th>
<th>Wave 3</th>
<th>Wave 4</th>
<th>Wave 5</th>
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Transforming to Accelerated Longitudinal

<table>
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<th>0 Mos</th>
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Full span of the ages covered

Validity Threats in Longitudinal Work

Threats to Validity

- **Maturation**
  - *In pre-post experiment effects may be due to maturation not the treatment*
  - *Most longitudinal studies, maturation is the focus.*

- **Regression to the mean**
  - *Only applicable with measurement error*

- **Instrumentation effects (factorial invariance)**

- **Test-retest effects (ugh)**

- **Selection Effects**
  - *Sample Selectivity vs. Selective Attrition*

Age, Cohort, and Time of Measurement are confounded

- Sequential designs attempt to unconfound these.
The Sequential Designs

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Cohort-Sequential

Time-Sequential

Cross-Sequential
Temporal Design

Changes (and causes) take time to Unfold

The ability to detect the effect depends on the measurement interval

The ability to model the shape of the effect requires adequate sampling of time intervals.

The ability to model the optimal effect requires knowing the shape in order to pick the optimal (peak) interval.

Lag within Occasion: the Lag as Moderator Model
Types of Change Effects

A) Step Functional

B) Linear Increase

C) Cumulative Ogive

D) Quick & Dissipates

E) Uniform Raise & Fall

F) Quick & Tapers
Lag as Moderator (LAM) Models

One possible way to address the issue of lag choice is to treat lag as a moderator.

Following this approach lag is treated as a continuous variable that can vary across individuals.
Variable Actual Assessments

$X_1$, $X_2$, $X_3$, $X_4$, $X_5$, $X_6$, $X_7$, $X_8$, $X_9$, $X_i$, $X_j$, $X_n$.

$Y_1$, $Y_2$, $Y_3$, $Y_4$, $Y_5$, $Y_6$, $Y_7$, $Y_8$, $Y_i$, $Y_j$, $Y_n$.

$T_1$, $T_{\text{min}}$, $T_2$, $T_{\text{max}}$.
Multiple Regression LAM model

\[
\hat{Y}_i = b_0 + b_1 X_i + b_2 Lag_i + b_3 X_i \times Lag_i
\]

\(X_i\) is the focal predictor of outcome \(Y_i\)

\(Lag_i\) can vary across persons

\(b_1\) describes the effect of \(X_i\) on \(Y_i\) when \(Lag_i\) is zero

\(b_2\) describes the effect of \(Lag_i\) on \(Y_i\) when \(X_i\) is zero

\(b_3\) describes change in the \(X_i \rightarrow Y_i\) relationship as a function of \(Lag_i\)

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An Empirical Example

Data are from the Early Head Start (EHS) Research and Evaluation study ($N = 1,823$)

Data were collected at Time 1 when the focal children were approximately 14 months of age and again at Time 2 when the children were approximately 24 months of age.

The average lag between Time 1 and Time 2 observations was 10.3 months with values ranging from 3.0 to 17.3 months.

Measures:

- The Home Observation for the Measurement of the Environment (HOME) assessed the quality of stimulation in the home at Time 1.
- The Mental Development Index (MDI) from the Bayley Scales of Infant Development measured developmental status of children at Time 2.
HOME predicting MDI

$$MDI_{T2} = b_0 + b_1 HOME_{T1} + b_2 Lag + b_3 (HOME_{T1} \times Lag)$$
Implications of LAM Models

Lag is embraced

- LAM models allow us to model, not ignore, interactions

Selecting Lag is critical

- Sampling only a single lag may limit generalizability

Theory Building

- LAM models may yield a better understanding of relationships and richer theory regarding those relationships
Randomly Distributed Assessment

\[ X_1 \quad Y_1 \quad Y_1 \quad Y_1 \quad Y_1 \quad Y_1 \]
\[ X_2 \quad Y_2 \quad Y_2 \quad Y_2 \quad Y_2 \quad Y_2 \]
\[ X_3 \quad Y_3 \quad Y_3 \quad Y_3 \quad Y_3 \quad Y_3 \]
\[ X_4 \quad Y_4 \quad Y_4 \quad Y_4 \quad Y_4 \quad Y_4 \]
\[ X_5 \quad Y_5 \quad Y_5 \quad Y_5 \quad Y_5 \quad Y_5 \]
\[ X_6 \quad Y_6 \quad Y_6 \quad Y_6 \quad Y_6 \quad Y_6 \]
\[ X_7 \quad Y_7 \quad Y_7 \quad Y_7 \quad Y_7 \quad Y_7 \]
\[ X_8 \quad Y_8 \quad Y_8 \quad Y_8 \quad Y_8 \quad Y_8 \]
\[ X_9 \quad Y_9 \quad Y_9 \quad Y_9 \quad Y_9 \quad Y_9 \]
\[ \vdots \]
\[ X_n \quad Y_n \quad Y_n \quad Y_n \quad Y_n \quad Y_n \]

\[ T_1 \quad T_{\text{begin}} \quad T_{\text{mid}} \quad T_{\text{end}} \]
Multilevel Structures

- Observations at one level are nested within observations at another and so on.
- Number of levels theoretically limitless, bounded by practicality (and software).
  - Random sampling at each level.
- Multilevel vs. multiple-group structures
- Lowest level observations are *not* independent—possible biases in parameter estimates, standard errors, and test of model fit.
  - Goal is to model *both* within- and between-cluster relationship.
- Examples:
  - Students within classrooms
  - Times of measurement within persons
Modeling Data

• Finding meaning in the massively multivariate world
  • Open system versus closed system
  • Verisimilitude versus Causality
  • Justification and Social Justice

• Optimizing the relations between theory and data
  • Having a dialog between theory and data
    • I am the driver, data are my co-pilot
  • Never let data get in the way of good theory
  • Never let theory get in the way of good data
  • Data are my focus group
### Characteristics of Good Models

<table>
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<tr>
<th>I DO SEEK</th>
<th>DEPICT</th>
<th>LEAP</th>
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<tr>
<td>Intuition</td>
<td>Describe</td>
<td><strong>Logical and internally consistent</strong></td>
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<tr>
<td>Design</td>
<td>Explain</td>
<td><strong>Empirically testable (falsifiable)</strong></td>
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<tr>
<td>Operationalization</td>
<td>Predict</td>
<td><strong>Accounts for extant findings</strong></td>
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<td>Specification</td>
<td>Improve</td>
<td><strong>Parsimonious (sufficient verisimilitude)</strong></td>
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Wesearch Instead of Mesearch

Content Experts

Savvy both Theoretically and Methodologically

Methodologists

=>

Unequivicelly Better Research and Socially Just Policy and Practice
In my model, who's the fairest of them all?
GIGO, FUDSI, P-Hacking, Harking, Larking, >50 Shades of Grey, SOL

Error Types I, II, III, IV, S, M … ?

Data
- Design Error
- Measurement Practice Error
- L.O.V.E.
- Psuedo-Hobbsian Researcher Error
- Mesearch Error

Model
- Purpose Error
- Missing Data Model Error
- Parsimony Error
- Mesearch Error

Output
- Reviewer Error
- Commission Errors
- Omission Errors
- Nepotism Error
- Special Interest Error
- Quixotic Empiricism Error
- Mesearch Error
- Massively Multivariate World

Little, Widaman, Levy, Rodgers & Hancock, in press
Design and Measurement Issues

▪ Not all “advances” in developmental research are analysis based: we need to (re)start with the basics!
▪ The Ubiquity of Error
▪ Measurement, Measurement, Measurement
▪ My sources, each of which highlights design and measurement:

[Image of book covers]
(re) focus on Measurement

- Rethink Likert scales
  - Our great-great-great academic progenitors used them!
- Take advantage of touch screen technology and software
  - Using “rulers” and “sliders” is now easy and efficient
- Develop measures/procedures that are sensitive to change
  - Retrospective Pretest Posttest Design
  - Direct change Assessment

"Whatever exists at all exists in some amount. To know it thoroughly involves knowing its quantity as well as its quality"

- E. L. Thorndike (1918)
Retrospective Pre-post Design

I am curious about science.

Strongly Disagree

Strongly Agree

Before the program

At this time
Visual Analog Scaling

I am curious about technology.
Recommended readings


- Duh.


- Introduction to special issue, but first part identifies basic issues in longitudinal modeling and then points you to the innovations covered in the special issue.


- Provides a broad summary of the three classes of techniques


- Introduction to our book that points you to a lot of really great chapters covering many of these issues in detail
Recommended readings


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