Science is an attempt to exploit this contact between our minds and the world, and science is also motivated by the limitations that result from our relations to the world; we need science because much of the world is not accessible to ordinary observation. Science works by taking theoretical ideas and trying to find ways to expose them to observation. The scientific strategy is to construe ideas, to embed them in surrounding conceptual frameworks, and to develop them, in such a way that this exposure is possible even in the case of the most general and ambitious hypotheses about the universe. (Godfrey-Smith, 2003, p. 161)

Thinking about the Latent Variable from Three Perspectives

• Mathematical model (e.g., SEM, MLM, IRT)
• Theoretical model
  • Classical test theory (i.e., true-score, reliability)
  • Psychological concepts (e.g., g-intelligence, traits)
  • Construct validity – nomological (stochastological*) networks
• Philosophical connections
  • Levels/units of analysis
    • Particles, molecules, cells, organ tissues, brain/nervous system, cognition, personality, social interaction, and culture.
  • Empiricism/positivism, operationalism, naturalism, realism
Kinds of Mathematical Latent Variables

1. Principal component (not a latent variable)
2. Common factor model
3. Reflective measurement
4. Formative measurement
5. Various SEM (higher-order, bi-factor, MTMM)
6. Latent-class and latent profile analysis
7. IRT
8. Latent variables in longitudinal data (e.g., change)
9. Latent variables in MLM (random and contextual variables)
10. Network analysis of personality (Borsboom et al.)
Common Factor Model

\[ \hat{\rho}_{X_iX_i} = \frac{\left( \sum \hat{\lambda}_i \right)^2 \hat{\phi}}{\left( \sum \hat{\lambda}_i \right)^2 \hat{\phi} + \sum \hat{\theta}_{ii}} \]

In Kline (Raykov, 1997, 2004)

Reliability of Effort = .896

Note arrows going from latent variables to indicators: Reflective measurement with effect indicators
Formative Measurement

Note arrows going from indicators to latent variable

These indicators are referred to as “causal indicators”

Other Examples of LVs with Causal Indicators

1. Social Interaction
   • Time spent with family, with friends, with coworkers

2. Quality of Life
   • Health, happiness, economic status

3. SES
   • Education, income, occupational prestige

4. Exposure to discrimination
   • Race, sex, age, disabilities

5. Stress
   • Job loss, divorce, death in family, injury
Deciding to Use Formative Measurement

- Causal indicators not necessarily correlated with other indicators (implications for CTT and Cronbach’s alpha)
- Effect/reflective indicator can be deleted without changing meaning of LV, removing a causal indicator can change meaning
- Imagine a shift in the latent variable: does it lead to a shift in all indicators? (if yes, then effect/reflective indicators)
- Alternatively, a shift if one causal indicator would lead to a shift in the latent variable
- Vanishing Tetrad test (Bollen)
Formative Measurement

$\chi^2_{(2)} = 6.638, p < .05, \text{RMSEA} = .083, \text{CFI} = .960$
## Formative Measurement

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>S.E.</th>
<th>Est./S.E.</th>
<th>Two-Tailed P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POS BY</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GRADE</td>
<td>0.378</td>
<td>0.062</td>
<td>6.056</td>
<td>0.000</td>
</tr>
<tr>
<td>DEP1B</td>
<td>-0.707</td>
<td>0.082</td>
<td>-8.670</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>POS ON</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ES</td>
<td>0.050</td>
<td>0.070</td>
<td>0.719</td>
<td>0.472</td>
</tr>
<tr>
<td>ENJOYU1B</td>
<td>0.617</td>
<td>0.085</td>
<td>7.292</td>
<td>0.000</td>
</tr>
<tr>
<td>HARM1B</td>
<td>-0.133</td>
<td>0.066</td>
<td>-2.009</td>
<td>0.045</td>
</tr>
<tr>
<td><strong>ES WITH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENJOYU1B</td>
<td>0.286</td>
<td>0.050</td>
<td>5.679</td>
<td>0.000</td>
</tr>
<tr>
<td>HARM1B</td>
<td>-0.060</td>
<td>0.055</td>
<td>-1.092</td>
<td>0.275</td>
</tr>
<tr>
<td>ENJOYU1B WITH HARM1B</td>
<td>-0.174</td>
<td>0.053</td>
<td>-3.282</td>
<td>0.001</td>
</tr>
</tbody>
</table>
MLM of Diary Data – SEM Approach

Notice the variation in the intercepts and the slopes
MLM of Diary Data – SEM Approach

**WITHIN**

- **Weekly Drink**
  - Slope
  - **Depress**

**BETWEEN**

- **Intercept**
  - \( \gamma_{00} = 5.386 \)
  - \( \tau_{00} = 32.614 \)

- **Slope**
  - \( \gamma_{01} = -0.054 \) n.s.
  - \( \gamma_{10} = 0.022^* \)
  - \( \tau_{10} = 0.189 \)
  - \( \tau_{11} = 0.007^{**} \)

- **Trait drinking**

\( \sigma_t^2 = 17.720 \)
Latent Growth Modeling

\[ M = -0.119 \]

\[ M = 5.238 \]
LGM vs. MLM of Longitudinal Data

LGM

M = 5.238

MLM

Time (linear)

Slope

Drink

WITHIN

BETWEEN

Mean = 5.236
Var = 31.765

Mean = -0.118
Var = 0.782

-0.139
Principal Components Analysis

Figure 6.3 Conceptual representation of principal components analysis for 6 indicators and 2 composites (components).