Models for intrapersonal educational research

Jyväskylä Method Festival, 30 May 2017

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The Learning Every Lesson (LEL) study

* Schools in two Local Education Authorities in South East England (June 2007 - April 2008)
* 353 students in 16 classrooms in 11 schools took part
* One-hour introduction to study in classrooms
* 323 students had completed more than a third of the PDA items each learning episode: 4,972 PDA responses ($M_{\text{lessons}} = 15.4; SD = 4.7; \text{Range} = 2-34$)
* 117 students in Year 5 and 206 in Year 6,
* Mean age 10.5 (SD = .63),
* 147 boys and 176 girls

Heuristic theoretical framework for intrapersonal beliefs:
Sources of motivation

<table>
<thead>
<tr>
<th>Intrinsic motivation</th>
<th>Extrinsic motivation</th>
<th>Task difficulty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort exertion</td>
<td>Help-seeking</td>
<td>Competence evaluation</td>
</tr>
<tr>
<td></td>
<td>(teachers and peers)</td>
<td>Positive affect</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Negative affect</td>
</tr>
</tbody>
</table>

PDA questionnaire

* Students were asked to report each of their “learning episodes” or at least once per lesson, during one week
Quality of intrapersonal constructs

<table>
<thead>
<tr>
<th>Construct</th>
<th>$Mg^a$</th>
<th>$SDg^a$</th>
<th>$\alpha$ student-level$^b$</th>
<th>ICC(1)$^c$</th>
<th>ICC(2)$^d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic motivation</td>
<td>0.85</td>
<td>0.09</td>
<td>0.88</td>
<td>0.39</td>
<td>0.91</td>
</tr>
<tr>
<td>Extrinsic motivation</td>
<td>0.87</td>
<td>0.11</td>
<td>0.88</td>
<td>0.48</td>
<td>0.93</td>
</tr>
<tr>
<td>Difficulty</td>
<td>0</td>
<td>0</td>
<td>0.21</td>
<td>0.29</td>
<td>0.86</td>
</tr>
<tr>
<td>Effort</td>
<td>0</td>
<td>0</td>
<td>0.30</td>
<td>0.32</td>
<td>0.88</td>
</tr>
<tr>
<td>Help-seeking: teacher</td>
<td>0.74</td>
<td>0.09</td>
<td>0.86</td>
<td>0.32</td>
<td>0.88</td>
</tr>
<tr>
<td>Help-seeking: peers</td>
<td>0.82</td>
<td>0.11</td>
<td>0.93</td>
<td>0.31</td>
<td>0.87</td>
</tr>
<tr>
<td>Competence evaluation</td>
<td>0.70</td>
<td>0.18</td>
<td>0.84</td>
<td>0.25</td>
<td>0.83</td>
</tr>
<tr>
<td>Positive affect</td>
<td>0.54</td>
<td>0.18</td>
<td>0.48</td>
<td>0.42</td>
<td>0.92</td>
</tr>
<tr>
<td>Negative affect</td>
<td>0.72</td>
<td>0.13</td>
<td>0.77</td>
<td>0.36</td>
<td>0.90</td>
</tr>
</tbody>
</table>

$^a$ = the average and standard deviation of the internal consistency when estimated in cross-sections defined by learning experience within each day, $^b$ = the internal consistency of the items in each construct aggregated at the student level, $^c$ = the intraclass correlation, $^d$ = the reliability of the level-2 aggregate, also referred to as the Spearman-Brown reliability.

Research questions

(1) Does task difficulty differentially predict effort exertion?
(2) Does academic performance predict effort exertion?
(3) Does academic performance moderate the relationship between task difficulty and effort exertion?


We specify multilevel structural equation models (MSEM) with manifest variables, for the Mplus-demo.
Models

- **msem0**: variance component model
  \[ \text{eff}_i = b_0 + u_i + e_{0i} \]

- **msem1**: fixed effect of task difficulty
  \[ \text{eff}_i = b_0 + b_{\text{diff}} \text{CWC}_{ti} + u_i + e_{0i} \]

- **msem2**: random effect of task difficulty
  \[ \begin{bmatrix} u_{0i} \\ u_{i} \end{bmatrix} = \begin{bmatrix} \sigma_{u0}^2 \\ \sigma_{u1}^2 \sigma_{u1}^2 \end{bmatrix} \]

- **msem3**: fixed effect of academic performance
  \[ \text{eff}_i = b_0 + b_{\text{diff}} \text{CWC}_{ti} + b_{\text{ACAPERF}} \text{GMC}_{ti} + u_i + u_{i,\text{diff}} \text{CWC}_{ti} + e_{0i} \]
  with random effects as in msem2

- **msem4**: moderation effect (cross-level interaction) of academic performance \(\times\) task difficulty
  \[ \text{eff}_i = b_0 + b_{\text{diff}} \text{CWC}_{ti} + b_{\text{ACAPERF}} \text{GMC}_{ti} + u_i + u_{i,\text{diff}} \text{CWC}_{ti} + b_{\text{ACAPERF-\text{diff}}} \text{CWC}_{ti} \times u_{i,\text{diff}} \text{CWC}_{ti} + e_{0i} \]
  with random effects as in msem2

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**Variability in intrapersonal correlations** (see workshop.xls, page “intrapersonal correlations”)

- **Effort exertion \(\times\) task difficulty**
- **Competence belief \(\times\) task difficulty**
- **Competence belief \(\times\) effort exertion**

* Variability in intrapersonal regression lines

* Negative correlation: the more difficult the task, the less effort was exerted
* Positive correlation: the more difficult the task, the more effort was exerted
* Negative correlation: higher competence at easier task
* Positive correlation: higher competence at more difficult task
* Negative correlation: higher competence when exerting less effort
* Positive correlation: higher competence when exerting more effort
Msem0: variance component model

\[ \text{eff}_u = b_0 + u_{0i} + e_{0u} \]

**ANALYSIS:** TYPE = TWOLEVEL;

**MODEL:**
%WITHIN%
\[ \text{effort} ; \]
%BETWEEN%
\[ \text{effort} ; \]

<table>
<thead>
<tr>
<th>Estimate</th>
<th>S.E.</th>
<th>Est./S.E.</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ b_{eff} ]</td>
<td>[ 0.241*** ]</td>
<td>[ 3.264*** ]</td>
<td>[ 0.000 ]</td>
</tr>
</tbody>
</table>

**Within Level**

Variance

| EFFORT | 0.598 | 0.026 | 22.804 | 0.000 |

**Between Level**

Means

| EFFORT | 3.264 | 0.031 | 105.431 | 0.000 |

Variances

| EFFORT | 0.241 | 0.028 | 8.753 | 0.000 |

Sample students (M and SD)

**MODEL RESULTS**

Two-Tailed

<table>
<thead>
<tr>
<th>Estimate</th>
<th>S.E.</th>
<th>Est./S.E.</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ b_{0} ]</td>
<td>[ 0.003 ]</td>
<td>[ 0.021 ]</td>
<td>[ 0.121 ]</td>
</tr>
</tbody>
</table>

**Within Level**

Residual Variances

| EFFORT | 0.598 | 0.026 | 22.806 | 0.000 |

**Between Level**

Means

| EFFORT | 3.264 | 0.031 | 105.430 | 0.000 |

Variances

| EFFORT | 0.241 | 0.028 | 8.753 | 0.000 |


Task difficulty was centered within clusters (\( x_j - \bar{x}_j \). Enders & Tofighi, 2007).

* Regressing effort exertion on task difficulty

\[ \text{eff} = b + b \text{diff} + u + u \text{diff} + e \]

\[ \begin{bmatrix}
    u_{0i} \\
    u_{1i}
\end{bmatrix} = \begin{bmatrix}
    \sigma^2_0 \\
    \sigma^2_{0i} \\
    \sigma^2_{1i} \\
    \sigma^2_{i}
\end{bmatrix} \]

\[ \begin{align*}
    b_0 & = 0.539 \\
    \text{S.E.} & = 0.025 \\
    \text{Est./S.E.} & = 21.873 \\
    \text{P-Value} & = 0.000
\end{align*} \]

\[ \begin{align*}
    b_1 & = -0.034 \\
    \text{S.E.} & = 0.014 \\
    \text{Est./S.E.} & = -2.432 \\
    \text{P-Value} & = 0.015
\end{align*} \]

\[ \begin{align*}
    \text{Means} & = \begin{bmatrix}
        3.266 \\
        0.016
    \end{bmatrix} \\
    \text{S.E.} & = \begin{bmatrix}
        0.031 \\
        0.021
    \end{bmatrix} \\
    \text{Est./S.E.} & = \begin{bmatrix}
        106.076 \\
        0.768
    \end{bmatrix} \\
    \text{P-Value} & = \begin{bmatrix}
        0.000 \\
        0.443
    \end{bmatrix}
\end{align*} \]

\[ \begin{align*}
    \text{Variances} & = \begin{bmatrix}
        0.245 \\
        0.068
    \end{bmatrix} \\
    \text{S.E.} & = \begin{bmatrix}
        0.028 \\
        0.011
    \end{bmatrix} \\
    \text{Est./S.E.} & = \begin{bmatrix}
        8.903 \\
        6.390
    \end{bmatrix} \\
    \text{P-Value} & = \begin{bmatrix}
        0.000 \\
        0.000
    \end{bmatrix}
\end{align*} \]

\[ \begin{align*}
    \text{Msem2.inp} & = \text{ANALYSIS: TYPE = TWOLEVEL RANDOM ;} \\
    \text{ALGORITHM=INTEGRATION ;} \\
    \text{INTEGRATION = 10 ;} \\
    \text{GHFIML=OFF;} \\
    \text{Msem2.out} & = \text{MODEL RESULTS} \\
    \text{Two-Tailed} \\
    \text{Estimate} & \text{ S.E.} \text{ Est./S.E.} \text{ P-Value}
\end{align*} \]

\[ \begin{align*}
    \text{Within Level} \\
    \text{Residual Variances} & = \begin{bmatrix}
        \sigma^2_0 \\
        \sigma^2_{0i} \\
        \sigma^2_{1i} \\
        \sigma^2_{i}
\end{bmatrix} \\
    \text{Between Level} & = \begin{bmatrix}
        \sigma^2_0 \\
        \sigma^2_{0i} \\
        \sigma^2_{1i} \\
        \sigma^2_{i}
\end{bmatrix} \\
    \text{Intercept –slope covariance significant, a higher average effort exertion was related to a less steep effort-on-difficulty slope (r = -0.36).}
\end{align*} \]
\[ \text{eff} = b + b_{\text{diff}} + u + u_{\text{diff}} + e \]

\[
\begin{bmatrix}
  u_{0i} \\
  u_{1i}
\end{bmatrix} = \begin{bmatrix}
  \sigma^2_u \\
  \sigma^2_{u0} & \sigma^2_{u1}
\end{bmatrix}
\]

\[ u_{0i} \]
\[ u_{1i} \]
\[ b_{\text{eff}} \]
\[ 3.266^{***} \]
\[ b_{\text{diff}} \]
\[ -0.040^{***} \]
\[ u_{\text{diff}} \]
\[ 0.068^{***} \]
\[ 0.539^{***} \]
\[ \text{eff} \]
\[ u_{1} \]
\[ \text{diff}_{\text{cwc}} \]

\[ \text{Performance was grand-mean centered (i.e., } x_j = \bar{x} \text{; Enders & Tofighi, 2007).} \]
msem4 includes moderation / cross-level interaction effect

\[ \text{eff} = b_0 + b_{\text{diff_cwc}} + b_{\text{ACAPERF}} + u_i + u_i \text{diff_cwc} + b_{\text{ACAPERF}} \times u_i \text{diff_cwc} + e_i \]

Full models possible with latent constructs (Malmberg et al., 2013)

Table 3. Situation-specific effort exertion prediction by task difficulty, personal characteristics and self-beliefs.

<table>
<thead>
<tr>
<th>Fixed effects</th>
<th>Model 1</th>
<th>B</th>
<th>SE</th>
<th>p</th>
<th>Model 2</th>
<th>B</th>
<th>SE</th>
<th>p</th>
<th>Model 3</th>
<th>B</th>
<th>SE</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept (b_0)</td>
<td>3.266</td>
<td>0.031</td>
<td>***</td>
<td></td>
<td>3.266</td>
<td>0.031</td>
<td>***</td>
<td></td>
<td>3.266</td>
<td>0.031</td>
<td>***</td>
<td></td>
</tr>
<tr>
<td>Situation-specific: Task difficulty</td>
<td>0.016</td>
<td>0.021</td>
<td></td>
<td>***</td>
<td>0.016</td>
<td>0.021</td>
<td></td>
<td>***</td>
<td>0.016</td>
<td>0.021</td>
<td></td>
<td>***</td>
</tr>
<tr>
<td>Age</td>
<td>-0.043</td>
<td>0.047</td>
<td></td>
<td></td>
<td>0.017</td>
<td>0.046</td>
<td></td>
<td></td>
<td>0.017</td>
<td>0.046</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender (0 = boy, 1 = girl)</td>
<td>0.257</td>
<td>0.059</td>
<td>***</td>
<td></td>
<td>0.067</td>
<td>0.067</td>
<td></td>
<td></td>
<td>0.067</td>
<td>0.067</td>
<td></td>
<td></td>
</tr>
<tr>
<td>School performance</td>
<td>0.115</td>
<td>0.046</td>
<td></td>
<td>*</td>
<td>-0.061</td>
<td>0.079</td>
<td></td>
<td></td>
<td>-0.061</td>
<td>0.079</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Person-specific Agency: ability</td>
<td>0.465</td>
<td>0.091</td>
<td>***</td>
<td></td>
<td>0.093</td>
<td>0.076</td>
<td></td>
<td></td>
<td>0.093</td>
<td>0.076</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perceived difficulty</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Random effects

| Effort exertion intercept (u_{i0}) | 0.245       | 0.028 | ***    |       | 0.224       | 0.026 | ***    |       | 0.176       | 0.027 | ***    |       |
| Task difficulty slope (u_{i1})      | 0.068       | 0.011 | ***    |       | 0.069       | 0.011 | ***    |       | 0.070       | 0.011 | ***    |       |
| Effort exertion \times task difficulty (u_{i10}) | -0.034     | 0.014 |       | *      | -0.040      | 0.014 |       |       | -0.046      | 0.014 |       |       |
| Residual (e_{0i})                   | 0.539       | 0.025 | ***    |       | 0.539       | 0.025 | ***    |       | 0.539       | 0.025 | ***    |       |

R^2 between: 0.086 0.282
R^2 within: 0.099 0.099

Residual Variances

| Effort exertion | 0.538       | 0.025 | ***    |       | 0.538       | 0.025 | ***    |       | 0.538       | 0.025 | ***    |       |
| Task difficulty  | 0.059       | 0.024 |       |       | 0.059       | 0.024 |       |       | 0.059       | 0.024 |       |       |
| School performance | 0.078       | 0.038 |       |       | 0.078       | 0.038 |       |       | 0.078       | 0.038 |       |       |

Higher performers exert more effort at more difficult tasks

Cross-level interaction: task difficulty \( (i) \times \) school performance \( (i) \) on effort exertion

Figure 1. Situation-average task difficulty \( (i) \times \) school performance \( (i) \) as predictor of effort exertion.
Thank you!