Item Response Demands, Predicting Item Difficulty, and Validity of Inferences from Test Scores

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Overview

- Goals of the studies
- Literature review
- Results from studies 1, 2, and 3
- Attempt to manipulate item difficulty
- Relevance to item specification, writer training, forms assembly
- In the paper: item-ALD alignment and interpretation validity
Goals of the studies

- Investigate hypothesized content, cognitive, and linguistic item response demands that may predict item difficulty in K-12 achievement tests
- Provide empirical support for significant predictors
- Try to manipulate item difficulty
Item response demands

- Content area, cognitive, and linguistic knowledge and skills required by test items
  - Examinees must recognize, understand, and process to respond to items
- Operationalized as item features
  - E.g., prompts in stem, response options
- May represent proxies for the cognitive processing that examinees activate during testing
  - As indicated in cognitive lab studies (e.g., Ferrara et al., 2004) and IDM studies
Literature review

- 24 studies, 1981-2017
  - More to add
- (a) Reading, literacy, and verbal reasoning; and (b) mathematics and quantitative reasoning
  - Science, insurance certification
- PISA, GRE, state assessments, adult literacy; other
- Mostly OLS; some CART and LLTM
Literature review (cont.)

- **R-squares: predicting p-values, IRT locations**
  - Reading, etc.: .11-.94, .17-.89
  - Mathematics, etc.: .03-.62, .36-.90
  - Overall: 13 of the 24 studies, GT .50; nine more GT .20
Literature review (cont.)

- Content, Cognitive, and Linguistic demands
  - Also, Item Design, Stimulus demands
- Wide array of content areas, ages and grade levels, testing programs, item response demands
- So far, we find minimal replication of findings on item response demands across these studies
- R-squares indicate lots of practically useful information about item response demands that we can use to manage item difficulty
Table 2. Significant Item Response Demands from the Literature Review

<table>
<thead>
<tr>
<th>Item Design Demands</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item/response type, item surface features (e.g., equation in the stem)</td>
<td>Sheehan &amp; Mislevy (1994)</td>
</tr>
<tr>
<td>Process variables: literacy (type info requested, type of match); mathematics (operation specificity)</td>
<td>Mosenthal (1998), Kirsch (2001)</td>
</tr>
<tr>
<td>Amount of reasoning required to confirm correct response</td>
<td>Gorin &amp; Embretson (2006)</td>
</tr>
<tr>
<td>Judgment of item difficulty</td>
<td>Sheehan &amp; Mislevy (1994)</td>
</tr>
</tbody>
</table>
Our three studies

- State and national assessment programs
  - Multiple content areas, schooling levels
- Typical coder training, agreement rates, consensus decision process
- Classification and regression tree (CART) analysis
Results studies 1 and 2

Item Type and Maximum Points demands included

Table 3. Importance Statistics and R-squares for Studies 1 and 2: Empirical Evidence for Item Response Demands

<table>
<thead>
<tr>
<th>Item Design Demands$^1$</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item Type$^2$</td>
<td>100</td>
<td>97</td>
</tr>
<tr>
<td>Maximum Points$^2$</td>
<td>NA</td>
<td>100</td>
</tr>
</tbody>
</table>

Conditional Random Forest R-squares (for analyses including all variables in this table)

<table>
<thead>
<tr>
<th></th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional Random Forest R-squares</td>
<td>0.46</td>
<td>0.23</td>
</tr>
<tr>
<td></td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td>0.21</td>
<td>0.20</td>
</tr>
<tr>
<td></td>
<td>0.23</td>
<td>0.05</td>
</tr>
</tbody>
</table>
### Results studies 1 and 2 (cont.)

**Item Type and Maximum Points demands excluded**

Table 3. Importance Statistics and R-squares for Studies 1 and 2: Empirical Evidence for Item Response Demands

<table>
<thead>
<tr>
<th></th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Language Arts</td>
<td>Mathematics</td>
</tr>
<tr>
<td>Study 1</td>
<td>0.44</td>
<td>0.07</td>
</tr>
</tbody>
</table>

Conditional Random Forest R-squares$^3$ (for content, cognitive, and linguistic demands only)
# Results study 3

## Table 4a. Importance Statistics Study 3: Empirical Evidence for Important Item Response Demands, English Language Arts

<table>
<thead>
<tr>
<th>Grade</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional Random Forest R-square</td>
<td>.05</td>
<td>.12</td>
<td>.17</td>
<td>.32</td>
<td>.37</td>
<td>.20</td>
<td>.14</td>
<td>.00</td>
<td>.10</td>
<td>.16</td>
</tr>
</tbody>
</table>

## Table 4b. Importance Statistics Study 3: Empirical Evidence for Important Item Response Demands, Mathematics

<table>
<thead>
<tr>
<th>Grade/Content Area</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Algebra 1</th>
<th>Algebra 2</th>
<th>Geom.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conditional Random Forest R-square</td>
<td>.40</td>
<td>.50</td>
<td>.39</td>
<td>.33</td>
<td>.44</td>
<td>.47</td>
<td>.47</td>
<td>.33</td>
<td>.36</td>
<td>.37</td>
</tr>
</tbody>
</table>
Significant response demands

**Study 1 (high school tests)**
- Language Arts, Social Studies
  - Standard/Objective, Indicator, Question Type

**Study 2 (performance tasks)**
- Grade 4 social studies, grade 5 science
  - Question Type, Relational Complexity, DOK, Linguistic Demands (e.g., Grammatical Density, Vocabulary Density)
Study 3 (grades 3 to high school)

**ELA**
- Item Design demands, Reading Selection demands including text complexity, Standard/Objective, Command of Textual Evidence (2 grades), Processing Demands (4 grades)

**Mathematics**
- Item Design demands, Evidence Statement
- No Stimulus or Linguistic demands
Conclusions

- Our studies and literature review indicate many useful item response demands
  - For understanding and becoming more explicit about the KSAs we require of examinees
    - In addition to the stated assessment targets
  - For targeting difficulty levels—and aligning items and ALDs
Conclusions (cont.)

- IDM studies too diverse to find replications of evidence for specific response demands
  - Some exceptions
- K-12 achievement tests in particular
  - Broadly defined constructs, range of item types, developed under challenging time constraints
  - IDM research on an array of content areas, grades, item types, response demands
  - Content area, examinee groups matter
  - Many disappointing R-squares
Conclusions (cont.)

- Manipulating item demands systematically to align with difficulty level targets and achievement levels
  - Not a typical thing for item writers
  - Not typically specified
- A next step
Thank you

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