Using Differential Step Functioning (DSF) to Refine the Analysis of DIF in Polytomous Items

Karina Alvarez, Randall D. Penfield

Introduction

- Differential Step Functioning (DSF) examines between-group differences in measurement properties at each step of a polytomous response item.
- Advantages for using DSF over omnibus measures of Differential Item Functioning (DIF) include:
  - DSF tests can be more powerful than omnibus measures when the sign and/or magnitude of the DSF effect varies across steps
  - DSF allows analysts to find and isolate the precise step responsible for an observed DSF effect

Objectives

This study aims to:

- Compare and contrast the logistic regression and cumulative log-odds ratio approaches for measuring DSF
- Apply these approaches to real achievement data
- Identify/interpret existing DSF effects

Methods

- Logistic regression and cumulative log-odds ratio approaches for measuring DSF were applied to 30 polytomous math items of the School Achievement Indicators Program (SAIP), a nationally administered Canadian achievement test.
- Of the 7,519 participants, 4,652 (61.9%) were administered the English version of the SAIP and 2,867 (35.1%) were administered the French version.

Interpreting DSF Magnitude

Measures of DSF using the cumulative log-odds ratio approach ($\hat{\lambda}_j$) and logistic regression ($\hat{\beta}_2$) can be interpreted using the following classification scheme:

- Small DSF effects correspond to DSF measures less than 0.43.
- Medium DSF effects correspond to DSF measures between 0.43 and 0.64.
- Large DSF effects correspond to DSF measures greater than 0.64.

DSF Taxonomy

	Pervasive	*Non-Pervasive*
Constant	All steps display a DSF effect equal in magnitude and sign	Only one or a few steps display a DSF effect equal in magnitude and sign across affected steps
Convergent	All steps display a DSF effects having the same sign, but different magnitudes	Only a few steps display a DSF effects having the same sign, but different magnitudes
Divergent	All steps display a DSF effect, but the signs vary across steps	Only a few steps display a DSF effect and the signs vary across steps

Results

Affected steps, DSF measures, magnitude, and direction

Item/Step	$\hat{\lambda}_j$ (SE)	$\hat{\beta}_2$	Magnitude of DSF Effect	Direction of DSF Effect
Item 5 Step 3	0.421(0.169)	0.463	Small to medium	+
Item 6 Step 2	0.735(0.138)	0.701	Large	+
Item 6 Step 4	1.252(0.503)	0.911	Large	+
Item 7 Step 2	0.522(0.069)	0.525	Medium	+
Item 7 Step 4	1.905(0.506)	1.264	Large	+
Item 10 Step 1	-0.426(0.221)	-0.451	Small to medium	-
Item 11 Step 2	0.572(0.055)	0.576	Medium	+
Item 12 Step 4	0.481(0.140)	0.450	Medium	+
Item 13 Step 4	0.694(0.125)	0.675	Large	+
Item 14 Step 4	0.490(0.061)	0.486	Medium	+
Item 15 Step 1	0.769(0.705)	0.718	Large	+
Item 15 Step 2	1.023(0.590)	1.071	Large	+
Item 15 Step 3	0.897(0.425)	0.877	Large	+
Item 16 Step 1	-1.123(0.055)	1.119	Large	-
Item 16 Step 4	1.315(0.280)	1.250	Large	+
Item 26 Step 1	-0.460(0.066)	-0.453	Medium	-
Item 26 Step 2	-0.452(0.066)	-0.446	Medium	-
Item 26 Step 3	-0.586(0.068)	-0.578	Medium	-
Item 30 Step 1	1.306(0.234)	1.311	Large	+
Item 30 Step 2	1.168(0.169)	1.175	Large	+
Item 30 Step 3	0.849(0.141)	0.866	Large	+

Summary of affected items and interpretation

Item	Step 1	Step 2	Step 3	Step 4	DSF form	Interpretation
5	No DSF	No DSF	M+	No DSF	Non-pervasive	Step-level effect
6	L+	L+	-	-	Constant pervasive	Item-level effect
7	M+	L+	-	-	Constant pervasive	Item-level effect
10	M-	No DSF	No DSF	No DSF	Non-pervasive	Step-level effect
11	M+	No DSF	-	-	Non-pervasive	Step-level effect
12	No DSF	No DSF	No DSF	M+	Non-pervasive	Step-level effect
13	No DSF	No DSF	No DSF	L+	Non-pervasive	Step-level effect
14	No DSF	No DSF	No DSF	M+	Non-pervasive	Step-level effect
15	L+	L+	L+	No DSF	Constant pervasive	Item-level effect
16	L-	No DSF	No DSF	L+	Divergent	Step-level effects
26	M-	M-	M-	No DSF	Constant pervasive	Item-level effect
30	L+	L+	L+	No DSF	Constant Pervasive	Item-level effect

- M- represents a medium negative DSF effect
- M+ represents a medium positive DSF effect
- L- represents a large negative DSF effect
- L+ represents a large positive DSF effect

Summary of Results

- Both the cumulative log-odds ratio and logistic regression obtained very similar results.
- Of the 30 items, 12 demonstrated evidence of DSF.
- There were 6 items that demonstrated non-pervasive DSF where only one step was affected, thus indicating a step-level effect.
- There are 5 items that demonstrated pervasive DSF where all or most steps evidenced a DSF effect in the same direction, thus indicating an item-level effect.
- There was 1 item that demonstrated divergent DSF, where one step was found to favor one group, while another step was found to favor the other group.

Implications

- Implementing a DSF approach for polytomous items rather than using an omnibus measure of DIF can provide additional useful information.
- Distinctive patterns of DSF observed among various items can lead to a better interpretation of the causes of DIF.
- Using a DSF approach with polytomous items is a promising way to help improve the validity of educational and psychological test scores.

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