Lesson 9: Differential Item Functioning

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Outline

Review - IRT models

- Item Characteristic Curve (ICC)
- Item Response Fuction (IRF)
- Item Information Function (IIF)
- Test Information Function (TIF)
- Likelihood function
- Parameter estimation: JML, CML, MML, Bayesian approaches
- Model fit, item fit, person fit

- 1PL, 2PL, 3PL, 4PL IRT models
- Graded Response Model (GRM)
- Partial Credit Model (PCM)
- Generalized Partial Credit Model (GPCM)
- Rating Scale Model (RSM)
- Nominal Response Model (NRM)

Motivation for differential item functioning (DIF) analysis

Complex validation of Homeostasis Concept Inventory (HCI)

McFarland et al. Development and Validation of the Homeostasis Concept Inventory. *CBE Life Sciences Education*, vol. 16 no. 2 ar35, 2017. doi 10.1187/cbe.16-10-0305

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Is the test fair?

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Differential Item Functioning (DIF) Analysis

- Analytical method to address item fairness
- Ubiquitous in large-scale assessments development
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Methods paper: Importance of DIF Analysis

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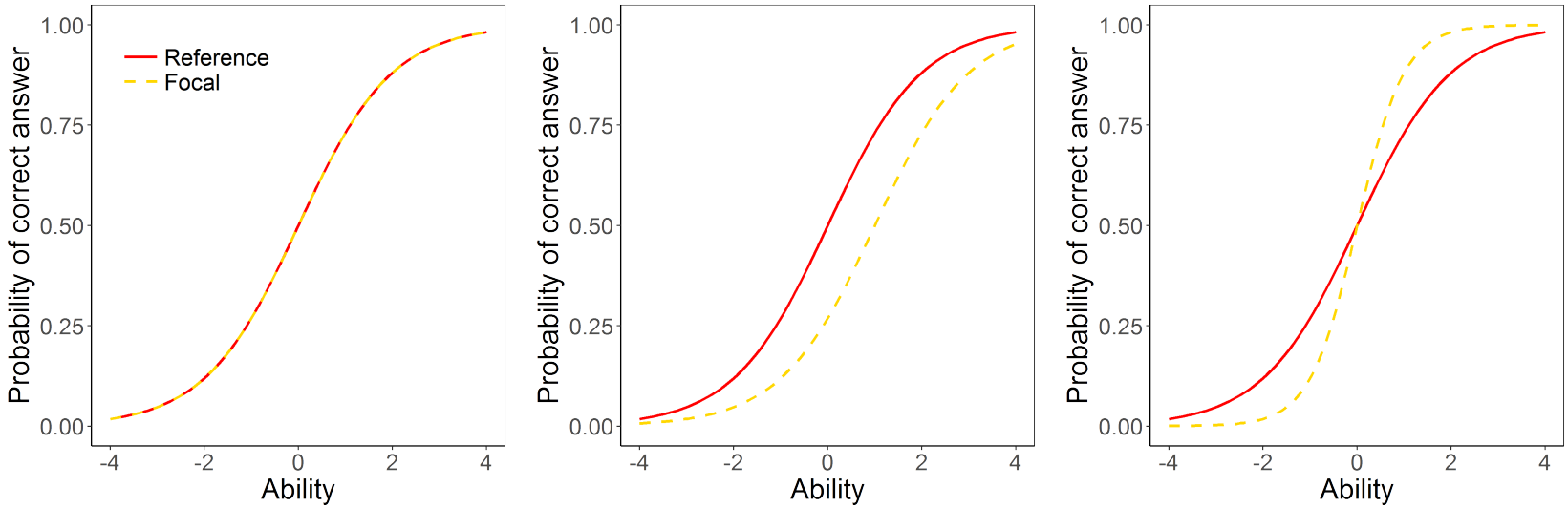
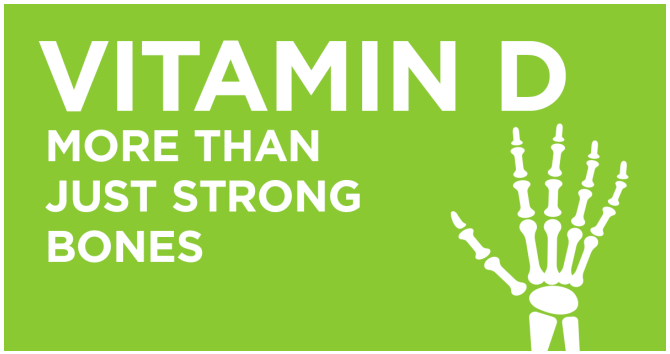
- Two groups referred to as reference and focal (usually minority)
- Two types of DIF - uniform and non-uniform



Example of DIF item

Childhood illnesses (Drabinová & Martinková, 2017)



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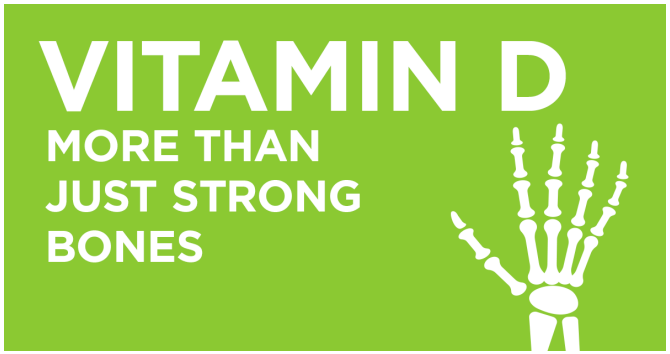

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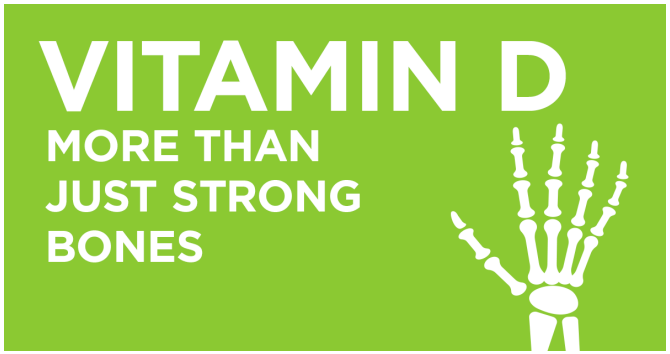

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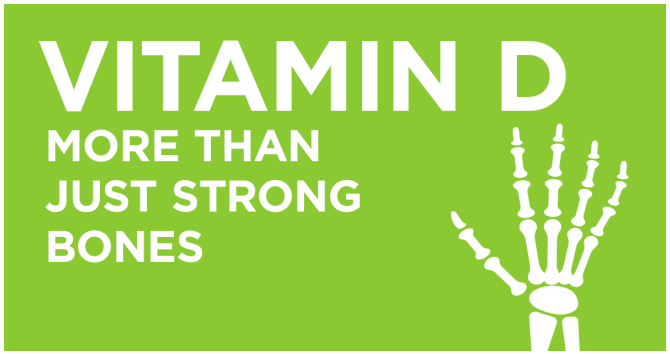

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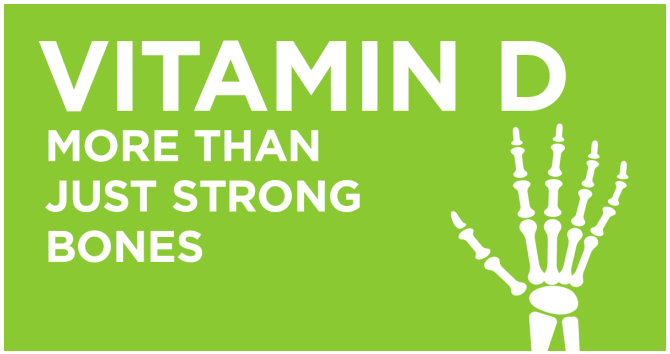

Deficiency of vitamin D in childhood could cause

a. rickets

b. scurvy

c. dwarfism

d. mental retardation

Example of DIF item

Tipping example (Martiniello et al., 2012)

Of the following, which is the closest approximation of a 15 percent tip on a restaurant check of $24.99?

a. $2.50
b. $3.00
c. $3.75
d. $4.50

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Who might have been dissadvantaged?
Terminology: Reference group (R), Focal group (F)

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What is the primary and the secondary latent variable tested in mentioned examples?

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  - Unrelated to content being tested
    - DIF item is considered unfair
    - Item should be reworded or removed
    - Example: Tipping

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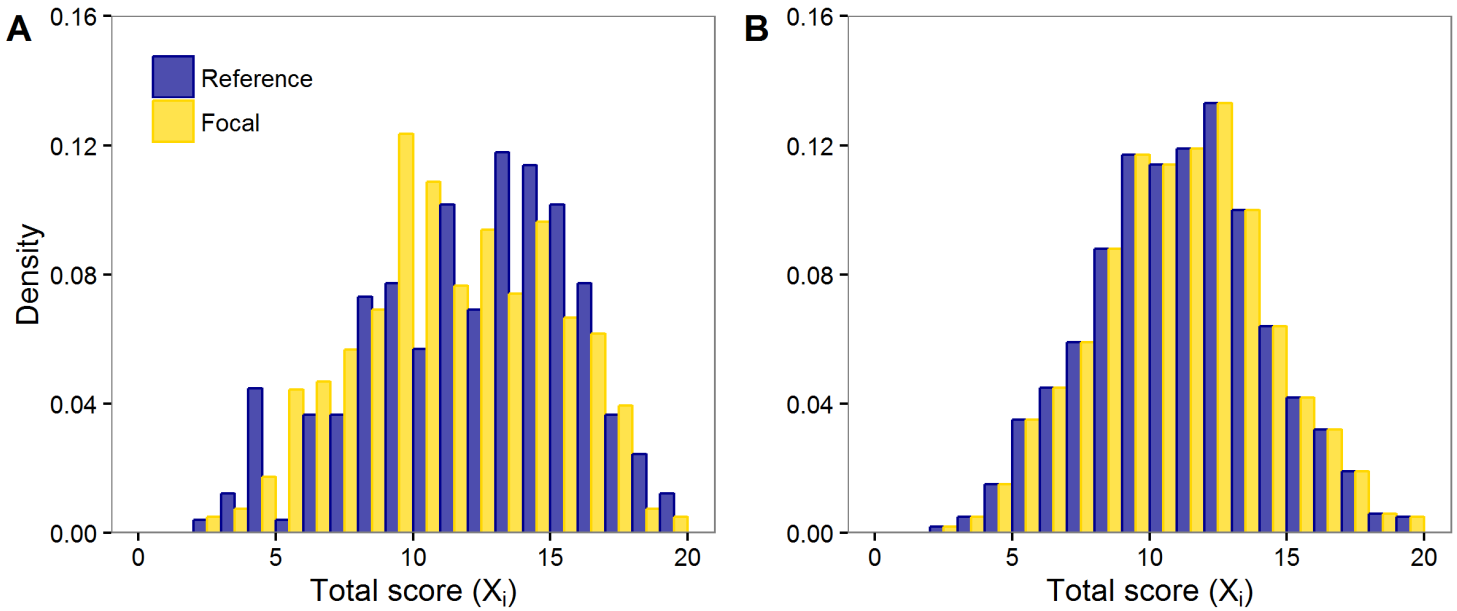
- Content experts must decide on item fairness
- Secondary latent trait causing DIF
  - Unrelated to content being tested
    - DIF item is considered unfair
    - Item should be reworded or removed
    - Example: Tipping
  - Related to content being tested
    - DIF item is not considered unfair
    - Item can inform teaching
    - Example: Item on childhood illnesses as part of Czech Medical School Admission Test in Biology

DIF vs. Difference in total scores

Comparing total scores only can lead to incorrect conclusions about item/test fairness:

- Case study 1: Homeostasis Concept Inventory
  - Significant difference between males and females in total score (Fig A)
- Case study 2: Simulated dataset based on GMAT
  - Identical distributions of total score (Fig B)



Martinková et al. (2017)

DIF vs. Difference in total scores (cont.)

Comparing total scores only can lead to incorrect conclusions about item/test fairness:

- Case study 1: No HCI item detected as DIF

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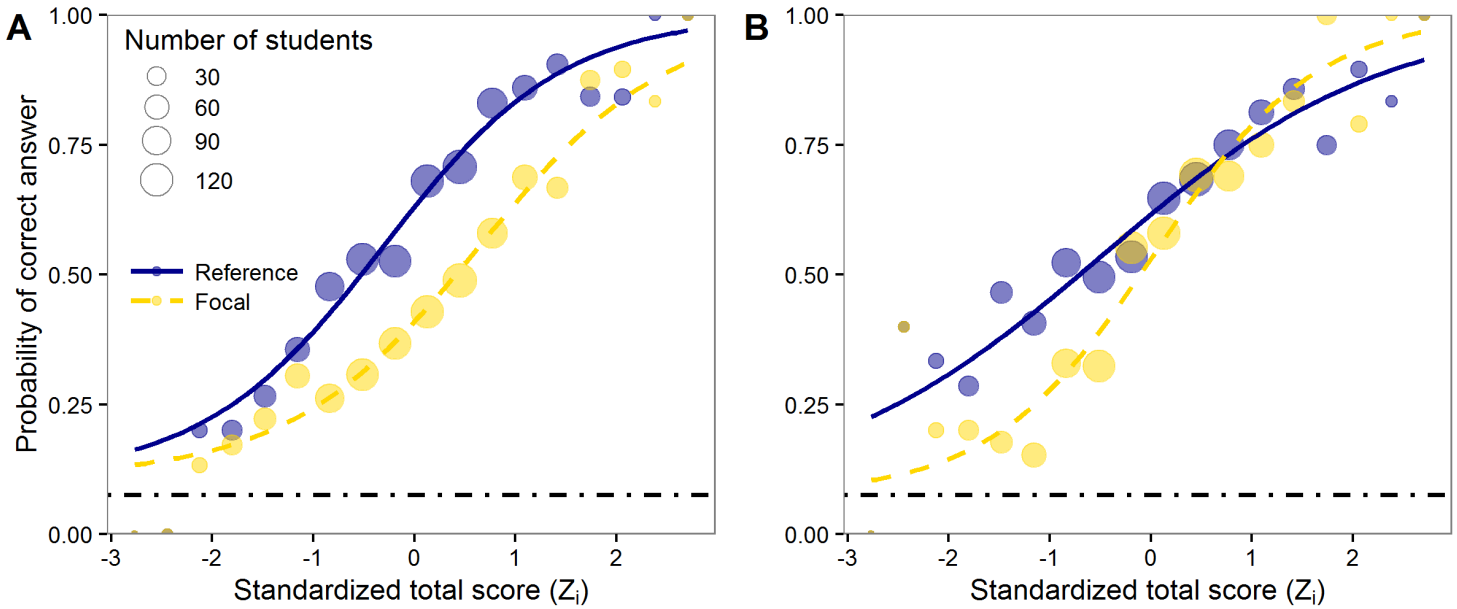
DIF vs. Difference in total scores (cont.)

Comparing total scores only can lead to incorrect conclusions about item/test fairness:

- Case study 1: No HCI item detected as DIF
- Case study 2: DIF detected in two items of simulated dataset
  - Item 1 exhibits uniform DIF (Fig A)
  - Item 2 exhibits non-uniform DIF (Fig B)



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  - Mantel-Haenszel test
  - \+ simple, easily implemented
  - − cannot detect non-uniform DIF
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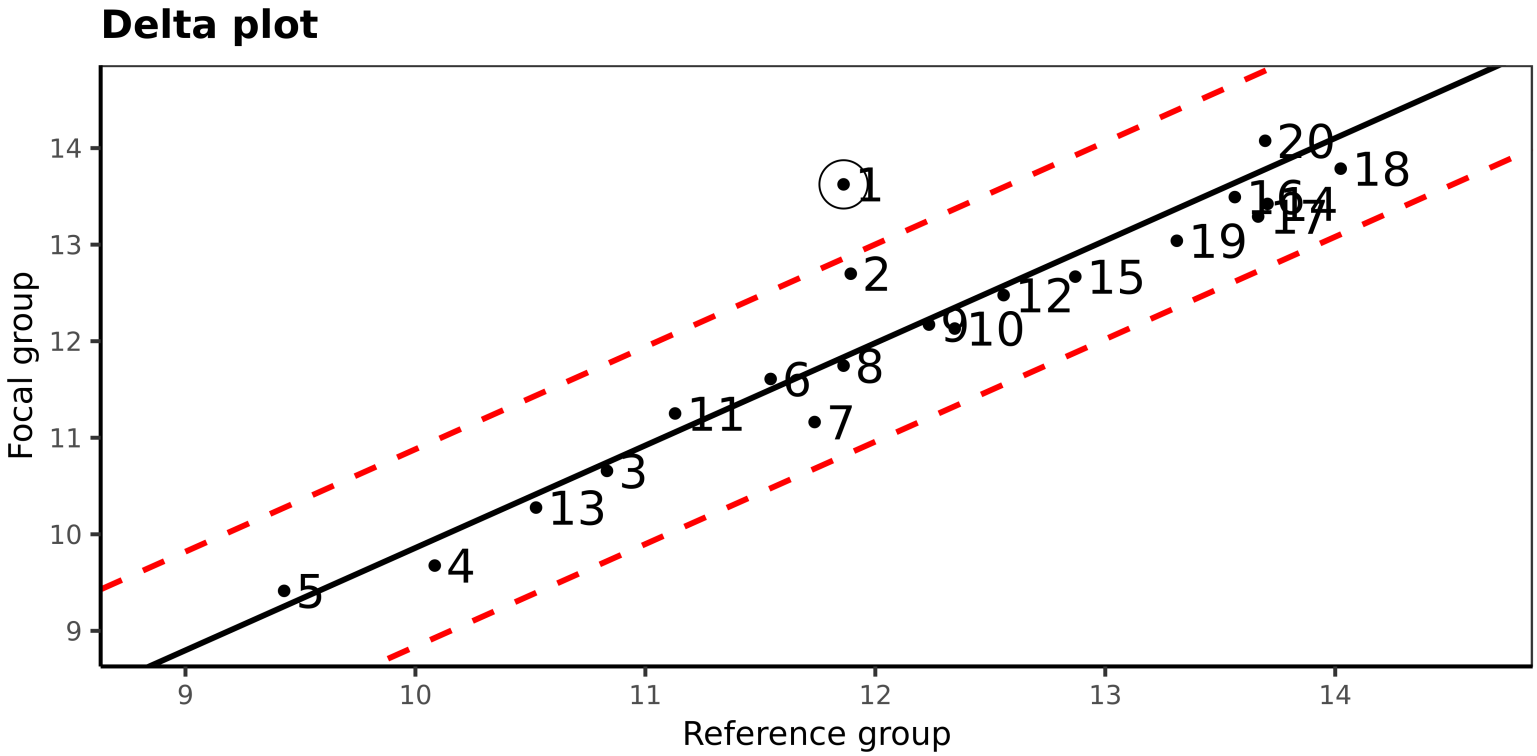
- Based on **latent ability**
  - Item Response Theory models
    (non-linear mixed effect models)
  + detects both forms of DIF, accounts for possibility of guessing/inattention
  – more complex, computationally demanding

Delta plot

- Angoff & Ford (1973)
- compares proportions of correct answers
- displays non-linear transformation of proportions (using quantiles)
- detection threshold
  - fixed to 1.5
  - normal approximation (Magis & Facon, 2012).



Mantel-Haenszel test

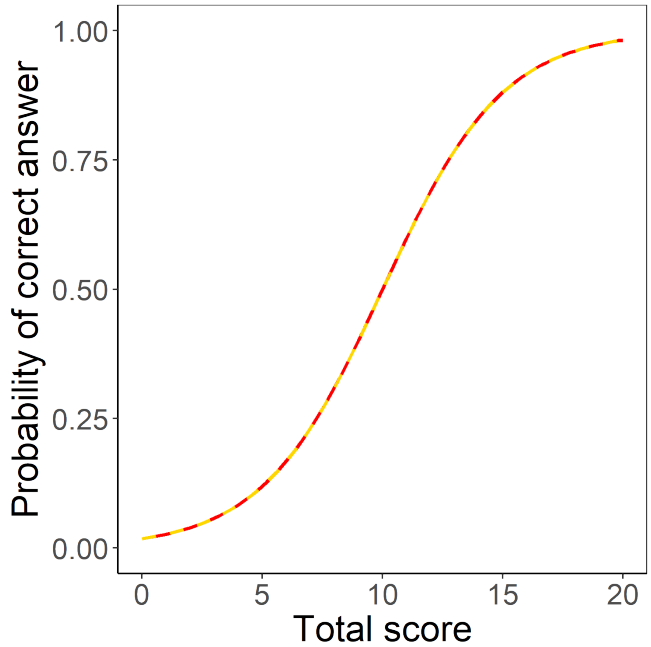
- Test of independence of two binary variables: item score and group membership.
- X^2 test, but incorporating also ability score
- Looking at contingency tabels for each level of total score, adding up

Logistic regression for DIF detection

$$\mathrm{P}(Y_{ij} = 1|X_i, G_i) = \frac{e^{\beta_{0j}+\beta_{1j}X_i}}{1 + e^{\beta_{0j}+\beta_{1j}X_i}}$$

$=$ probability of correct answer of student i to item j

X_i total score, G_i group



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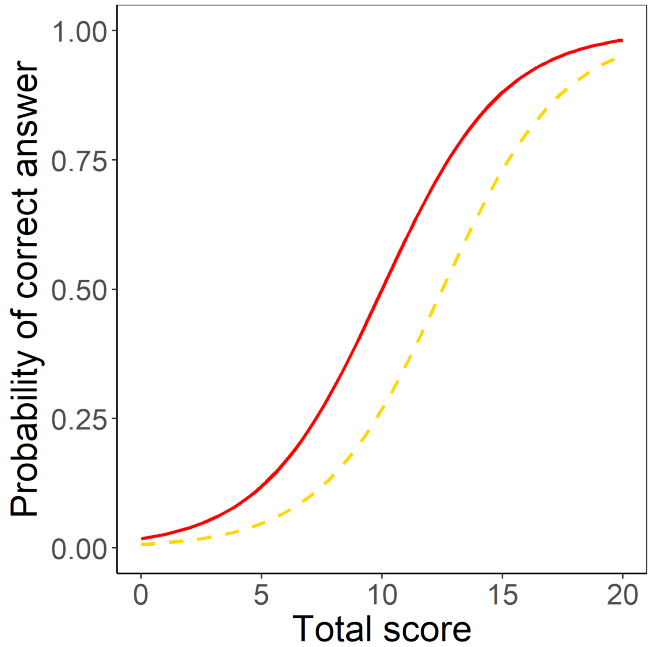

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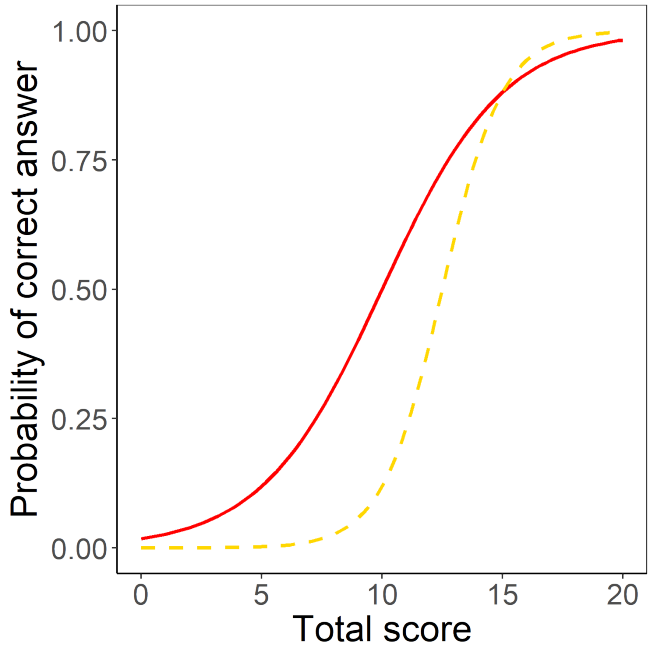

Further Topics

Further DIF detection methods:

- Non-linear regression
- SIBTEST
- IRT-based methods

Further issues in DIF detection:

- Correction for multiple comparisons
- Purification
- DIF Effect size

Conclusion

DIF/DDF analysis should be used routinely in test development

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- to inform teaching

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DIF detection methods

- Delta-Plot
- Mantel-Haenszel test
- Logistic regression
- Further (NLR, SIBTEST, IRT/based methods)

Thank you for your attention!

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References

- McFarland, Price, Wenderoth, Martinková, Cliff, Michael, Modell and Wright (2017). Development and Validation of the Homeostasis Concept Inventory. *CBE Life Sciences Education*, vol. 16 no. 2 ar35. doi 10.1187/cbe.16-10-0305
- Martinková, Drabinová, Liaw, Sanders, McFarland & Price (2017). Checking Equity: Why DIF Analysis should be a Routine Part of Developing Conceptual Assessments. *CBE-Life Sciences Education*, 16(2), rm2. doi 10.1187/cbe.16-10-0307
- Drabinová & Martinková (2017). Detection of Differential Item Functioning with Non-Linear Regression: Non-IRT Approach Accounting for Guessing. *Journal of Educational Measurement*, 54(4), pp. 498-517, 2017. dx.doi.org/10.1111/jedm.12158