Using Item Response Theory (IRT)-Based Instruments and Computerized Adaptive Testing (CAT) for Assessment of Health

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Why is Toolbox Project Considering IRT?

- Some things being measured can be expressed as a range of function on a definable continuum
- That continuum can be characterized more or less equally by any number of questions or items
- Those items can be ordered from low to high, or easy to difficult
- IRT provides a way to organize the information so that a precise score can be obtained from just a few items
- Accuracy is nice; brevity is essential

Item Response Theory (IRT)

- Unlike classical test theory, IRT describes the association between where a respondent falls on a given concept or trait (θ) and the probability of a particular response to an item
- Reliability is not a property of a "test," it varies across the measurement continuum
- Scores obtained can be treated as independent of the exact questions asked
- An IRT approach can be useful for examining
  - Item-level properties of an instrument ("item bank")
  - Information provided by administered items (or groups of items) across θ
- This adds up to FLEXIBILITY for the researcher
IRT Models

- IRT models differ with respect to the number of item parameters that are estimated. (3PL, 2PL, 1PL, Rasch)
- Polytomous models are used to describe items with 3+ response options, while dichotomous models address items with binary responses.
- Assumptions
  - unidimensionality
  - the instrument measures one dominant construct
  - local independence
  - the likelihood of answering an item in one direction is unrelated to the probability of answering another item in the same direction, at constant $\theta$

IRT Parameters

- A person’s trait level and their likelihood of responding to an item can be described in terms of several parameters.
- The point at which a participant has 50% likelihood of responding in the keyed direction
  - $b$, or difficulty
  - Its ability to distinguish low trait from high trait individuals
  - $\alpha$, or discrimination
  - The likelihood of low attribute participants responding in the keyed direction
  - $c$, or guessing

Clinical and Health Services Research Applications of IRT

- Efficient collection of health outcomes data in clinical trials
  - Comparing health interventions and strategies
  - Comparing pharmaceutical treatments
- Monitoring the health outcomes of populations
  - Health plan members
  - Medicare beneficiaries
  - US general population
- Publicly available, adaptable and sustainable
  - Online common item repository
  - Online CAT and short form delivery
Advantages of Short-Forms Developed from Item Banks

- Flexibility in length and content
  - Select items matched to clinical features and severity in the target population
  - Select items known to provide the most information
  - Any form selected or created produces scores on a common metric

Three Diseases, Three Questionnaires, One Metric

Interpretation Aids

**PRO Bank Person Score**

- **Low**
- **High**

**Item Location**

People and Items Distributed on the Same Metric: Fatigue

- People with more fatigue
- People with less fatigue
- Items more likely to be endorsed
- Items less likely to be endorsed

## Interpretation Aids

**PRO Bank Person Score**

- **Low**
- **High**

**Item Location**
This person’s fatigue score is 60, significantly worse than average (50). People who score 60 on fatigue tend to answer questions as follows:

...“I have been too tired to climb one flight of stairs: VERY MUCH
...“I have had enough energy to go out with my family: A LITTLE BIT

Interpretation Aids: Fatigue example

Fatigue Score=40

This person’s fatigue score is 40, significantly better than average (50). People who score 40 on fatigue tend to answer questions as follows:

...“I have been too tired to climb one flight of stairs: SOMEWHAT
...“I have had enough energy to go out with my family: VERY MUCH

Click here if you would like to see this person’s individual answers.
Computerized Adaptive Testing (CAT)

- Estimates location (severity; capability) of a person on a domain (concept) by selecting questions based on that person's prior answers.
- Iteratively estimates a person's standing on the domain (e.g., depressive symptoms) and administers only the most informative items, achieving precision with a minimum possible number of questions.

Beginning of CAT:
PROMIS Depression Bank

I felt depressed
1. Never
2. Rarely
3. Sometimes
4. Often
5. Always

Next Best Item: I felt like a failure

T-Score = 50 SE = 10

T-Score = 52 SE = 4

Best Item I felt depressed

T-Score Information

Posterior Distribution

Items Administered

T-Score

012345678

20 30 40 50 60 70 80

Max at T-Score=56

T-Score = 50
SE = 10

Items Administered

T-Score

012345678

20 30 40 50 60 70 80

Max at T-Score=57

T-Score = 52
SE = 4

Items Administered
I felt like a failure
- Never
- Rarely
- Sometimes
- Often
- Always

T-Score = 53
SE = 3

Items Administered
T-Score
0 1 2 3 4 5 6 7 8
20 30 40 50 60 70 80
Items: 15, 10

T-Score: 53
SEM: 3

Item 1

I felt worthless
- Never
- Rarely
- Sometimes
- Often
- Always

T-Score = 55
SE = 2

Items Administered
T-Score
0 1 2 3 4 5 6 7 8
20 30 40 50 60 70 80
Items: 15, 10, 1

T-Score: 55
SEM: 2

Item 3

I felt helpless
- Never
- Rarely
- Sometimes
- Often
- Always

T-Score = 56
SE = 2

Items Administered
T-Score
0 1 2 3 4 5 6 7 8
20 30 40 50 60 70 80
Items: 15, 10, 1, 3

T-Score: 56
SEM: 2

Item 21
I felt hopeless
1. Never
2. Rarely
3. Sometimes
4. Often
5. Always

- T-Score: 55
- SE: 2

Next Best Item: nothing to look for

I felt unhappy
1. Never
2. Rarely
3. Sometimes
4. Often
5. Always

- T-Score: 54
- SE: 2

Next Best Item: life was empty

Comparison of Measurement Precision
Full-length Item Bank vs. CAT vs. Short-form
Conclusion

Item Response Theory (IRT) models enable reliable and precise measurement

- Fewer items needed for equal precision
  - Making assessment briefer

- More precision gained by adding items
  - Reducing error and sample size requirements

- Error is understood at the individual level
  - Enabling practical individual assessment

NIH Toolbox
Assessment of Neurological and Behavioral Function

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For more information, please visit www.nihtoolbox.org

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