Tutorial

Classical Test Theory
Item Response Theory
Computer Adaptive Testing
Automatic Item Generation
Automatic Essay Grading

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Basics

- Test = collection of questions (items)
- Examinee = person taking the test
- Ability = examinee's level of attainment of a skill

CTT – Classical Test Theory

- Examinee and test characteristics not separable
  - Ability = true score (expected value of performance on test)
  - Item difficulty = proportion of examinees in a group of interest who answer the item correctly
  - Taking a “hard” test, examinee will appear to have low ability
  - Taking an “easy” test, examinee will appear to have higher ability

CTT – Classical Test Theory (2)

- **Item characteristics are group-dependent**
  - Preparing test for a “different” population is hard
- **Examinee scores are test-dependent**
  - Contain different amount of error
- **Reliability = correlation between test scores on parallel forms of test**
  - Parallel forms – do they exist?
- **Theory is test oriented, not item oriented**
  - No predictions can be made about item perf.

Requirements for a new theory

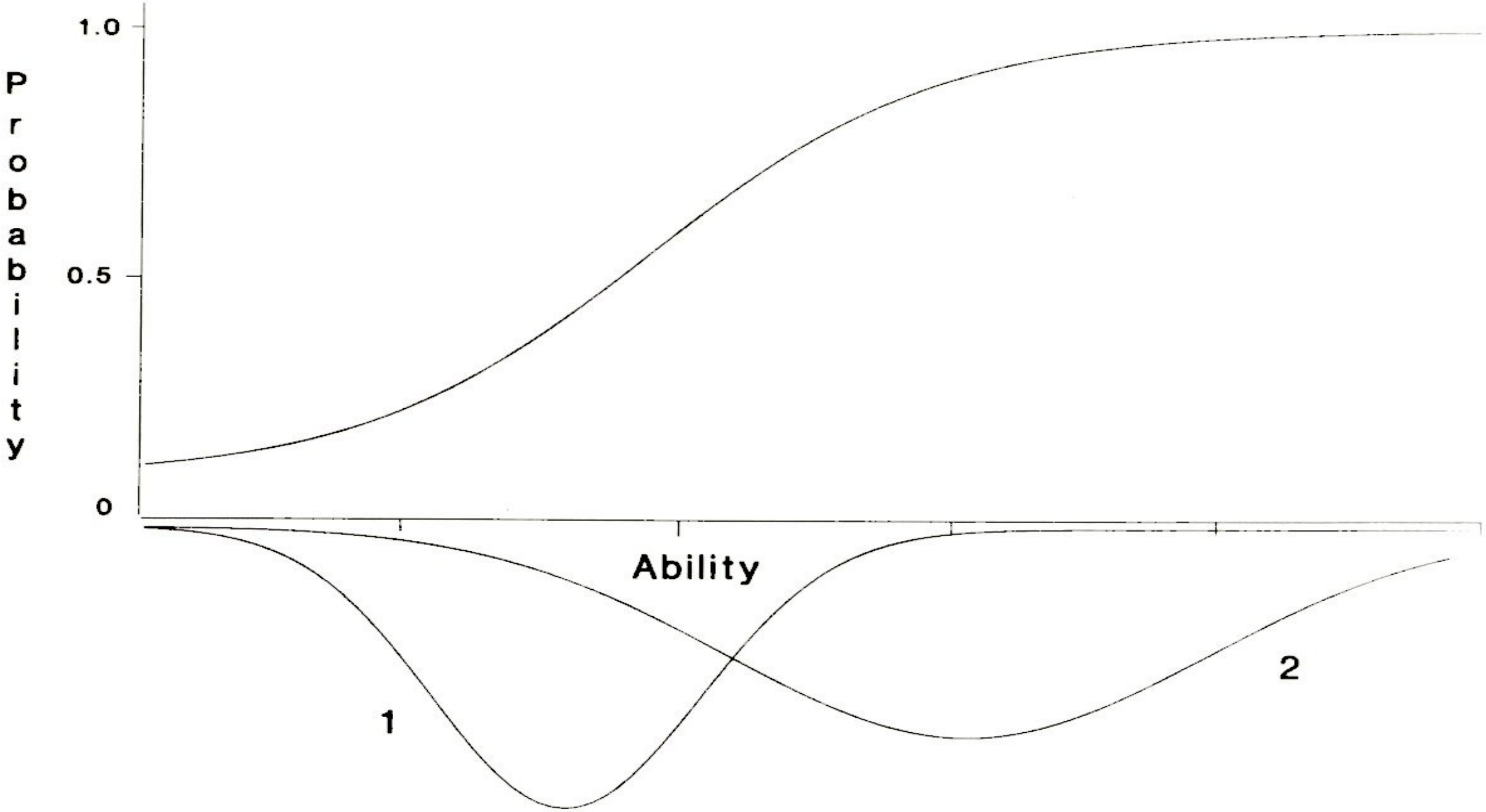
- Item characteristics that are not group-dependent
- Scores that are not test-dependent
- Model of items, not test
- Reliability not defined by parallel forms
- Measure of precision for each ability score

IRT – Item Response Theory

- Postulates:
  - Performance of an examinee can be predicted by a sef of factors (abilities)
  - Relationship between examinees' item performance can be described by monotonically increasing function (Item characteristic curve – ICC)
- IRT models are falsifiable
  - Need to assess the fit of the model to the data.

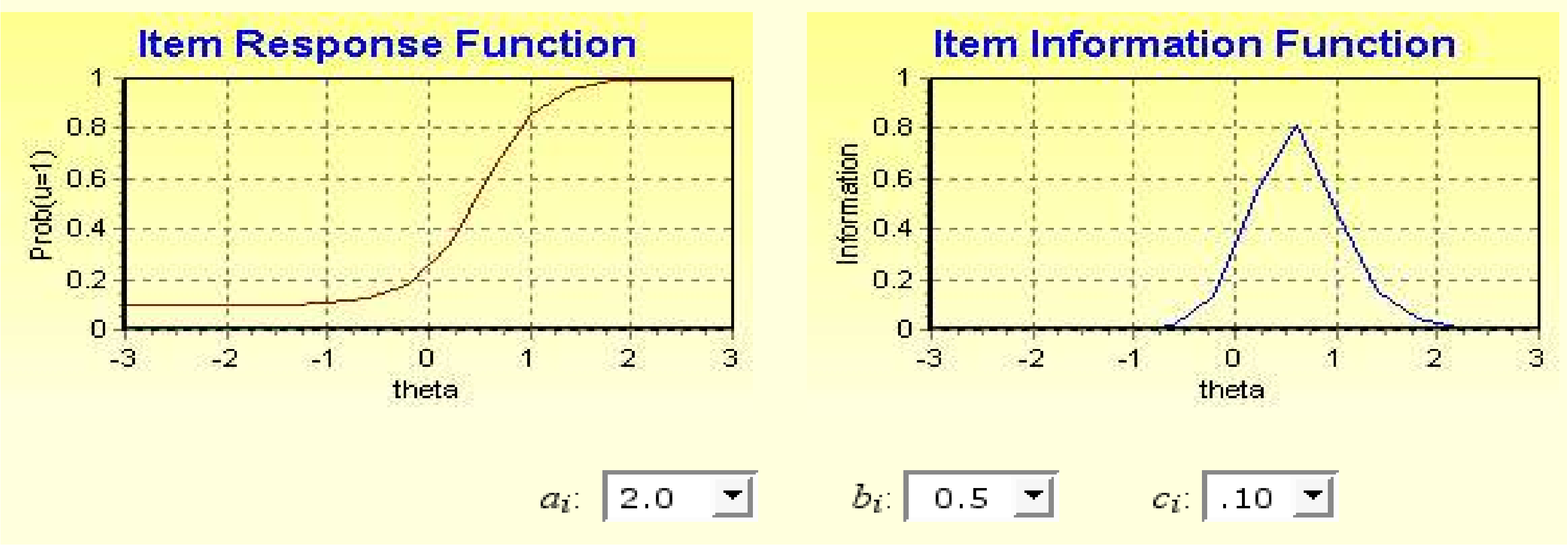
IRT – Item Response Theory (2)

- Item and ability parameters are **invariant**



$$P_i(\theta) = c_i + \frac{(1 - c_i)}{1 + e^{-Da_i(\theta - b_i)}}$$

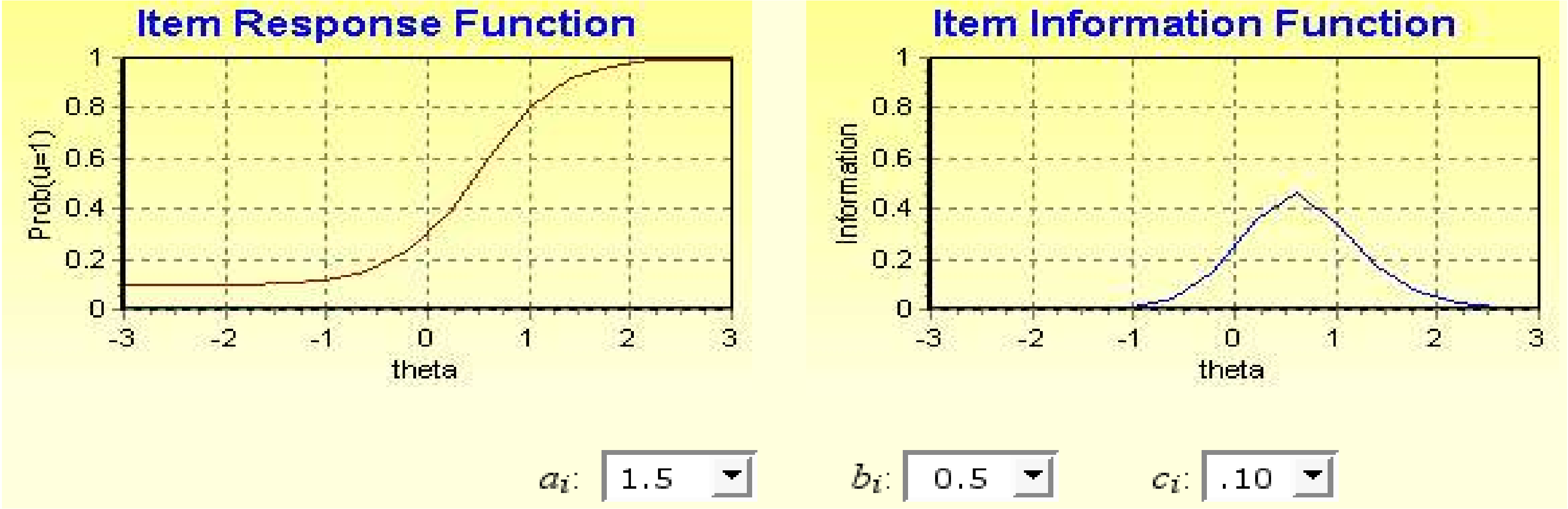
$$I_i(\theta) = \frac{P_i'(\theta)^2}{P_i(\theta)\,(1 - P_i(\theta))}$$



Item Response Function

Item Information Function

a_i: 2.0 b_i: 0.5 c_i: .10

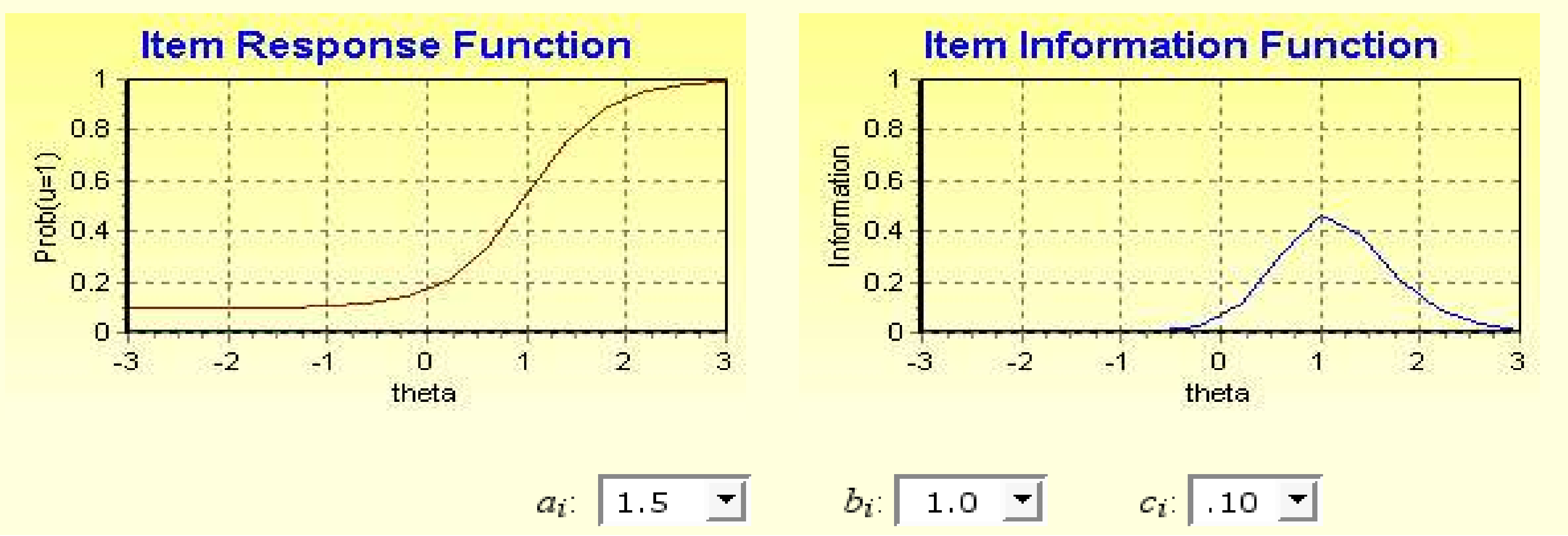


Item Response Function

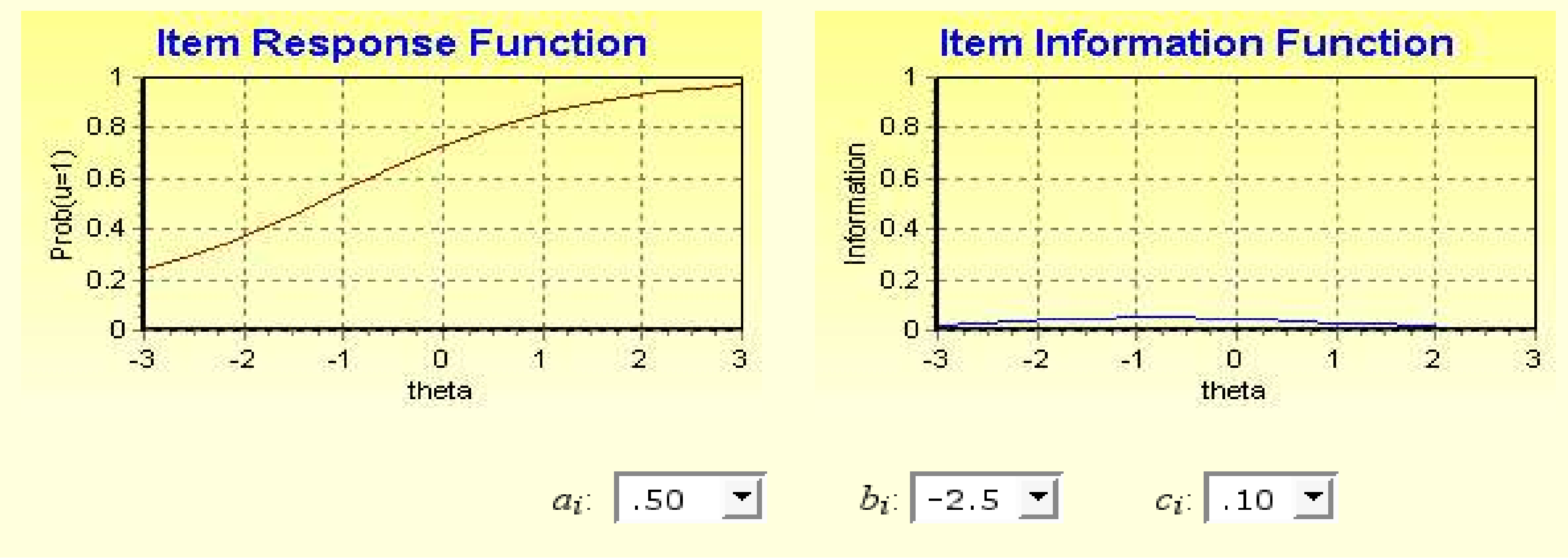
Item Information Function

a_i: 1.5 b_i: 0.5 c_i: .10

$$I_i(\theta) = \frac{2.89\, a_i^2 \,(1 - c_i)}{[c_i + e^{1.7a_i(\theta - b_i)}]\;[1 + e^{-1.7a_i(\theta - b_i)}]^2}$$

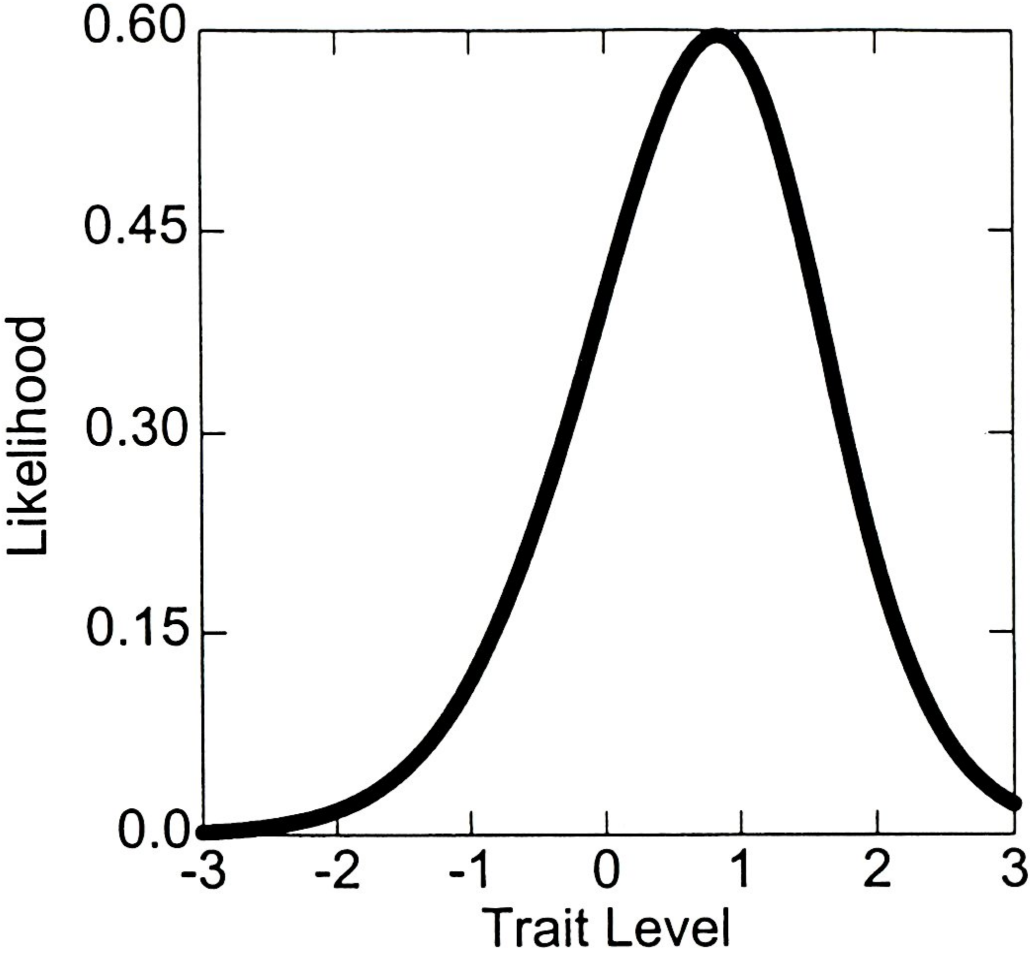


a_i: 1.5 ▾ b_i: 1.0 ▾ c_i: .10 ▾



a_i: .50 ▾ b_i: -2.5 ▾ c_i: .10 ▾

$$L(u_1, u_2, \ldots, u_n \mid \theta) = \prod_{j=1}^{n} P_j^{u_j} Q_j^{1-u_j}$$



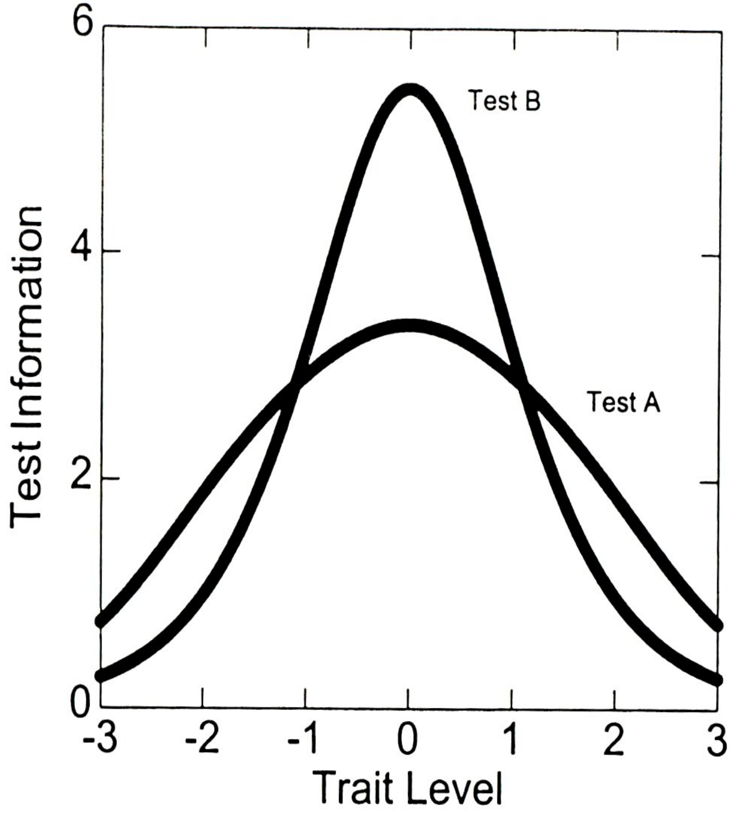


FIG. 7.3. Test information curves for example tests A and B.

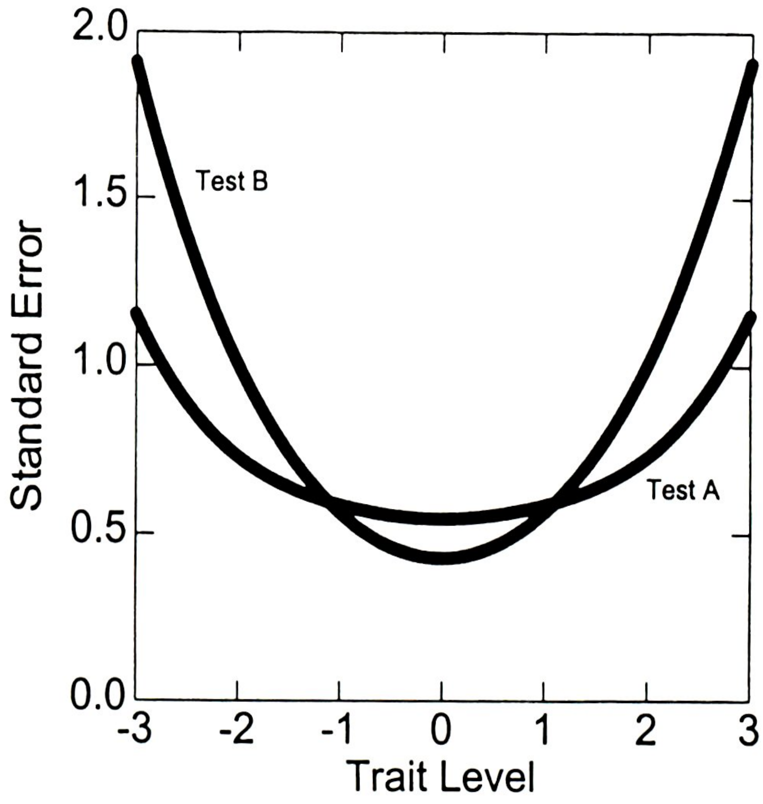


FIG. 7.4. Standard error curves for example tests A and B.

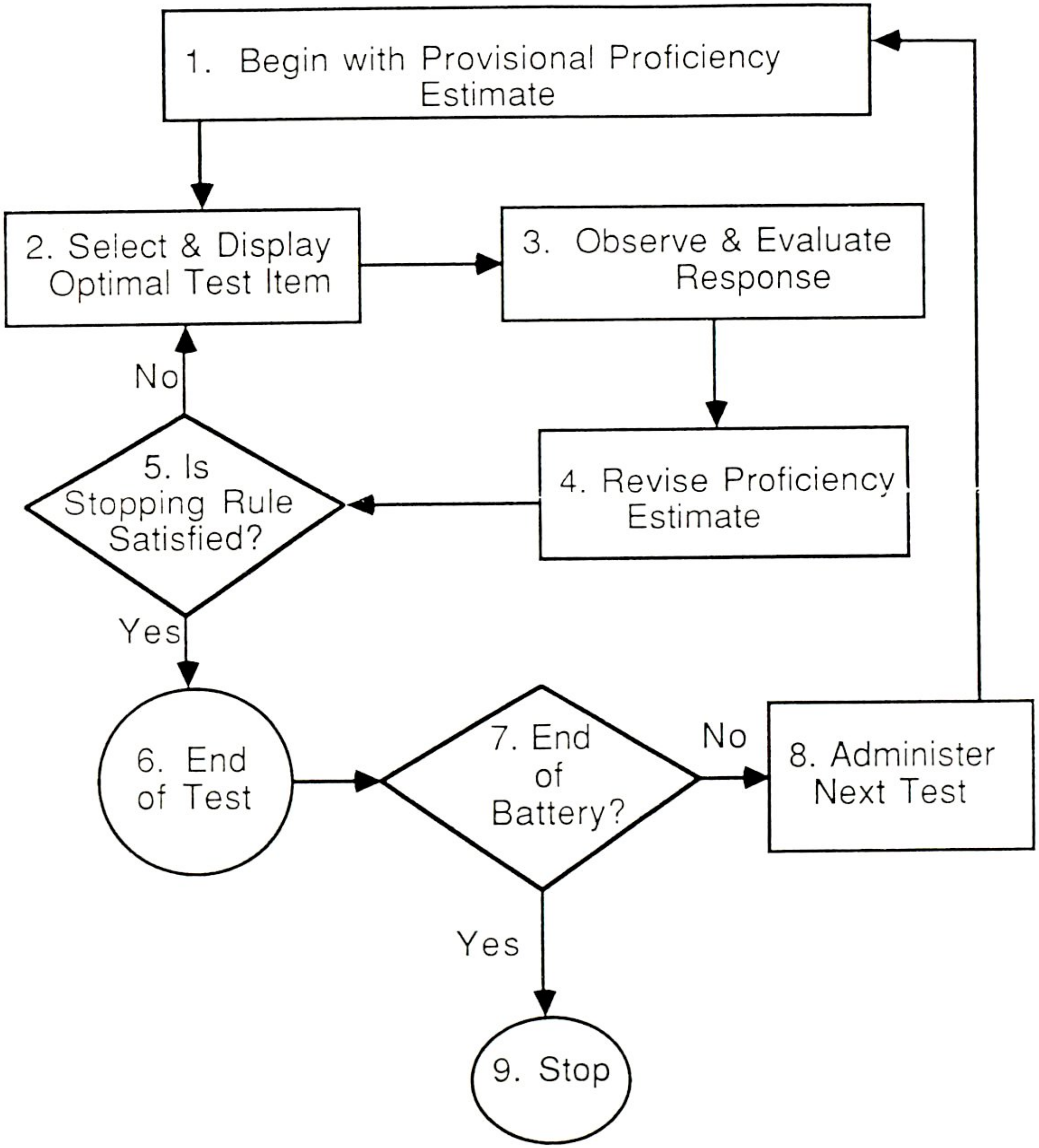
IRT – References

- **Hambleton, R. K., Swaminathan, H., Rogers, H. J., (1991).**
  - Fundamentals of Item Response Theory
- **Embretson, S. E., Reise, S. P. (2000).**
  - *Item Response Theory for Psychologists*.
- **Baker, F. B., Kim, S.-H. (2004).**
  - *Item response theory: Parameter estimation techniques. Second Edition, Revised and Expanded*.

CAT – Computer Adaptive Testing

- Individual vs. Group testing
- Improving entire measurement process:
  - Improved test security
  - Each indiviual stays busy productively
  - The test can be scored immediately
  - Unobtrusive pretesting

Adaptive Test Logic


1. Begin with Provisional Proficiency Estimate
2. Select & Display Optimal Test Item
3. Observe & Evaluate Response
4. Revise Proficiency Estimate
5. Is Stopping Rule Satisfied?
No
Yes
6. End of Test
7. End of Battery?
No
8. Administer Next Test
Yes
9. Stop

CAT – Key questions

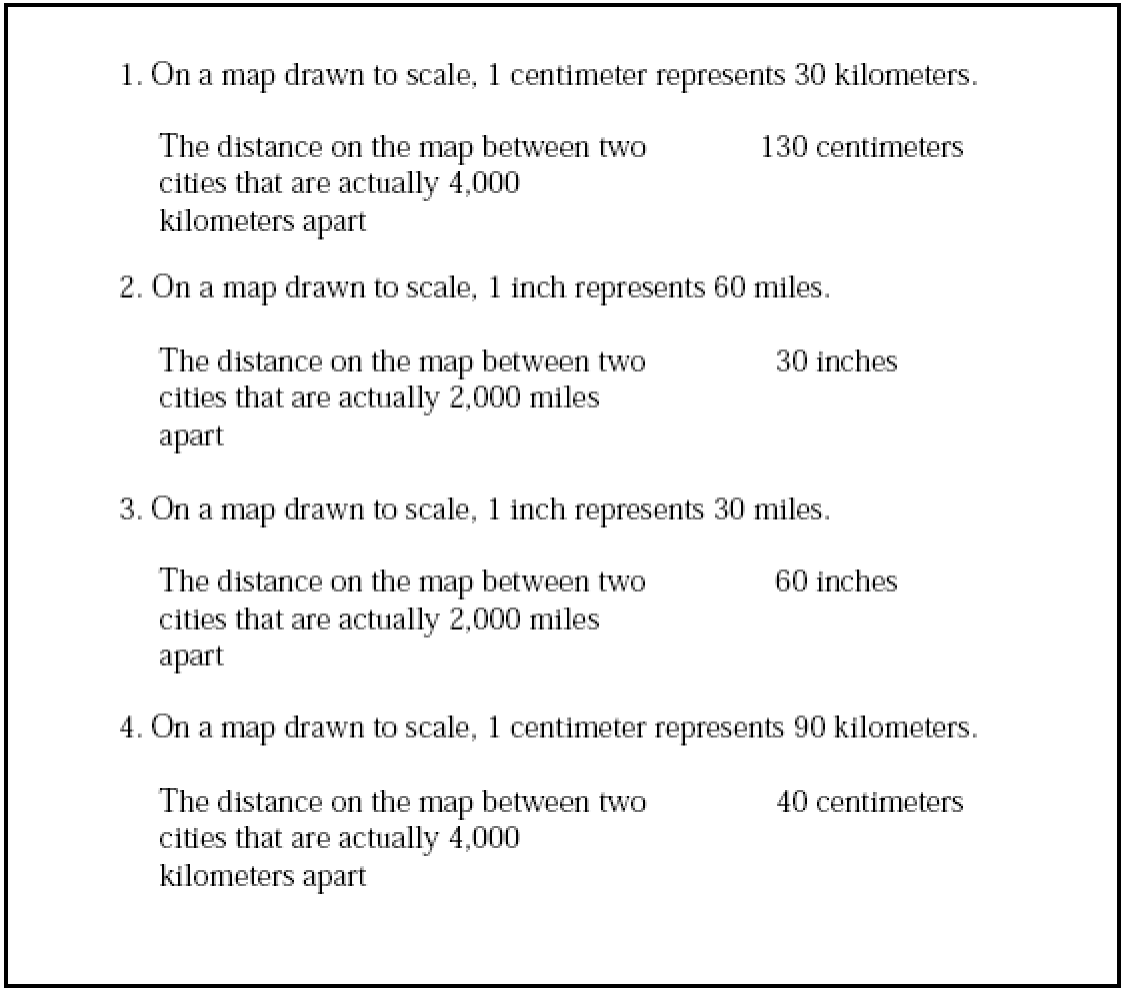
- How to START
  - Medium difficulty item?
- How to CONTINUE
  - Item exposure control
  - Stratification
- How to STOP

CAT – References

- **Wainer, H., (Ed.) (2000).**
  - *Computerized adaptive testing: A primer (2nd Edition).*
- **Sands, W. A., Waters, B. K., McBride, J. R., (Eds.). (1997).**
  - *Computerized adaptive testing: From inquiry to operation.*
- **van der Linden, W. J., Glas, C. A. W., (Eds.). (2000)**
  - *Computerized Adaptive Testing – Theory and Practice*

AIG – Automatic Item Generation

- Item models used to generate new items:



1. On a map drawn to scale, 1 centimeter represents 30 kilometers.

   The distance on the map between two cities that are actually 4,000 kilometers apart — 130 centimeters

2. On a map drawn to scale, 1 inch represents 60 miles.

   The distance on the map between two cities that are actually 2,000 miles apart — 30 inches

3. On a map drawn to scale, 1 inch represents 30 miles.

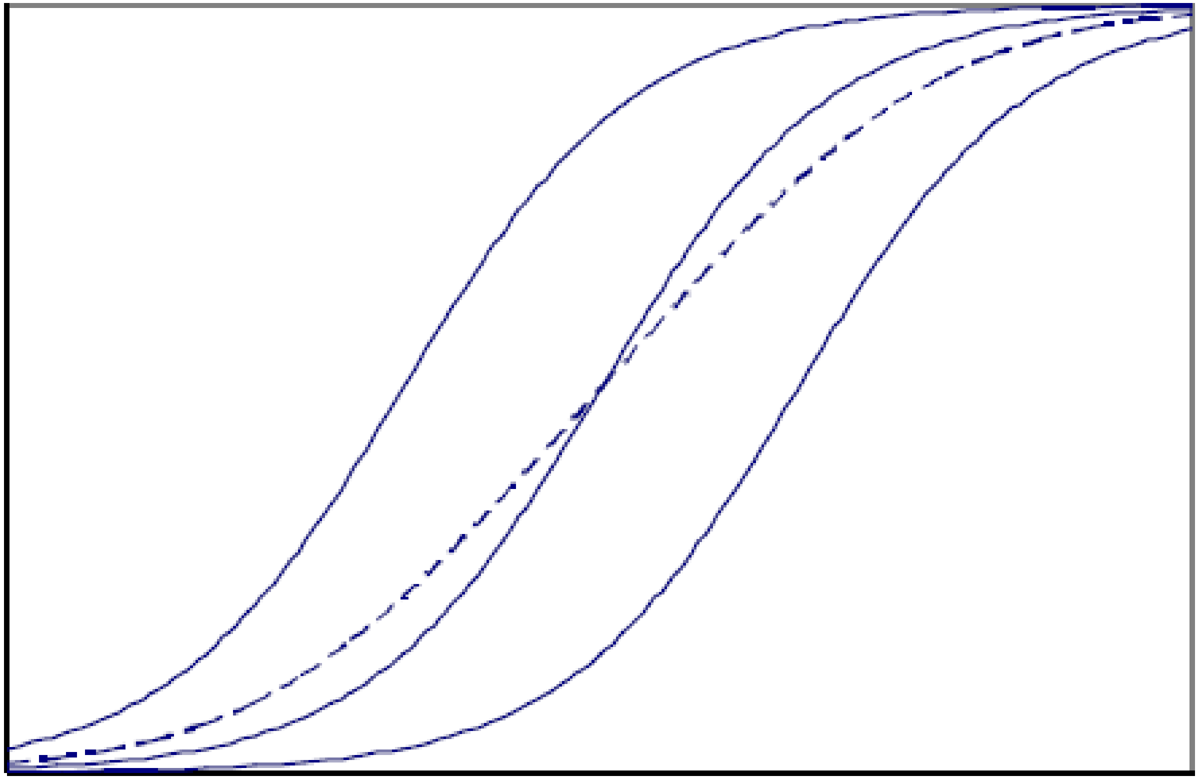
   The distance on the map between two cities that are actually 2,000 miles apart — 60 inches

4. On a map drawn to scale, 1 centimeter represents 90 kilometers.

   The distance on the map between two cities that are actually 4,000 kilometers apart — 40 centimeters

AIG – Item model calibration

- Expected response function:



Graph of expected response function (dashed curve) against three item characteristic curves at three levels of difficulty.

AIG – References

- **Bejar, I. I., Lawless, R., Morley, M. E., Wagner, M. E., Bennett, R. E., Revuelta, J. (2003).**
  - *A feasibility study of on-the-fly item generation in adaptive testing.*
- **Deane, P., Sheehan, K. (2003).**
  - *Automatic item generation via frame semantics: Natural language generation of math word problems.*

AEG – Automatic Essay Grading

- Essay / short free-text response
- Statistical and NLP techniques
- **Electronic Essay Rater (E-Rater)**
  - Syntactic structure, vocabulary use
  - Grades writing skills on six-point scale (performance: 87 - 94 %)
- **Conceptual Rater (C-Rater)**
  - Assessment of short-answer to content-based questions (performance: 80%)

AEG – References

- **Valenti, S., Neri, F., Cucchiarelli, A. (2003).**
  - *An overview of current research on automated essay grading.*
- **Burstein, J. C., Kaplan, R. M., Wolff, S., Lu, C. (1996).**
  - *Using Lexical Semantic Techniques to Classify Free Responses.*