Multidimensional computer adaptive testing with PROMIS item banks.

Michael Bass, MS, Scott Morris, PhD, Richard Neapolitan, PhD

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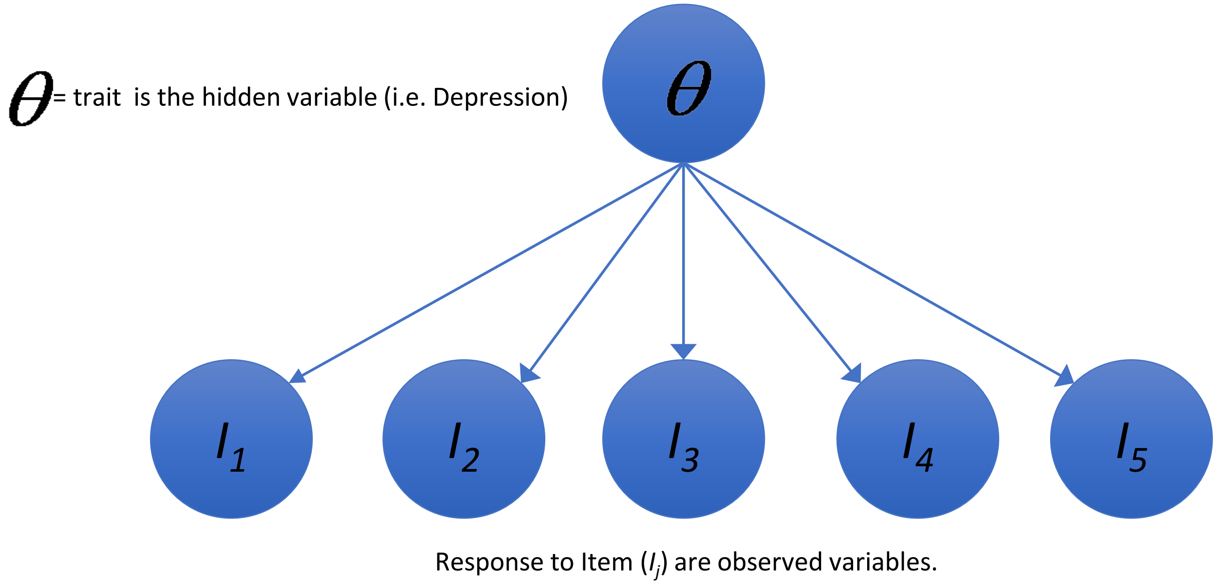
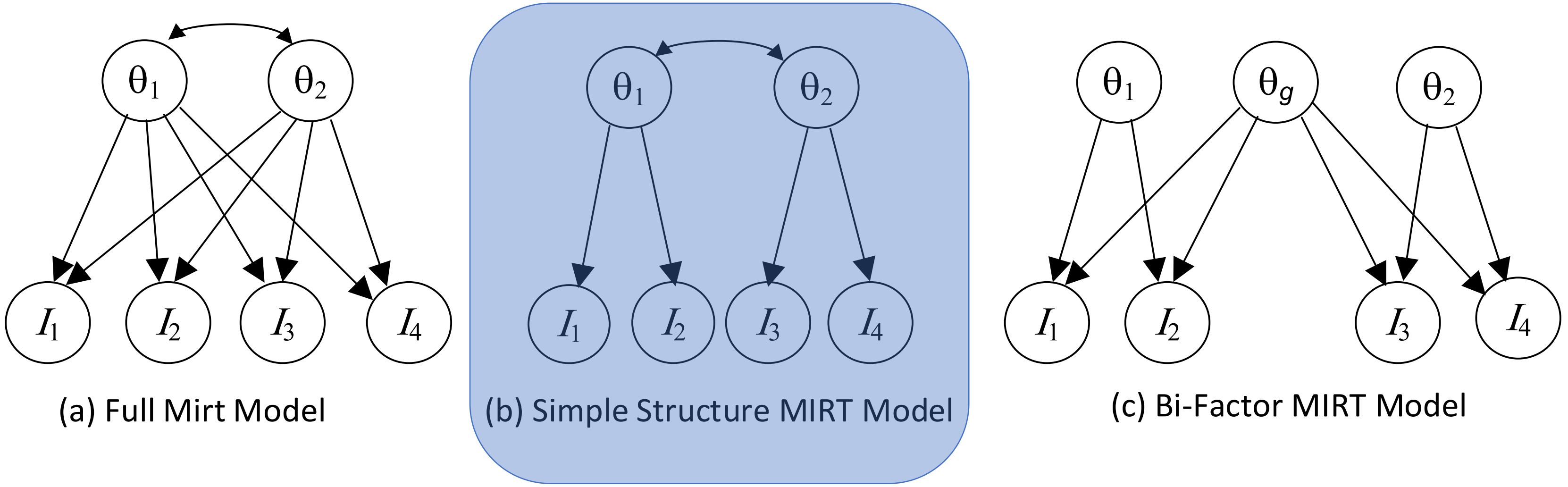
Disclosure

I disclose that neither I nor my partner have relevant financial relationships with commercial interests.

Unidimensional Structural Model for PROMIS Banks



Available Multidimensional IRT models



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Calibrating PROMIS Items

- Wave 1 Sample
- Markov Chain Monte Carlo methods
- IRTPRO

Model Comparison

	# Prm	BIC	Relative Full MIRT
Full MIRT	556	213713.6	
Simple Structure	398	213751.6	38.03
Single Factor	395	217868.0	4154.4
Bi-Factor	474	212713.4	-1000.17

2 Parameter Logistic Model (2PL)

- What is the probability of a test-taker with the ability θ to correctly respond to item $_j$ category $_k$.

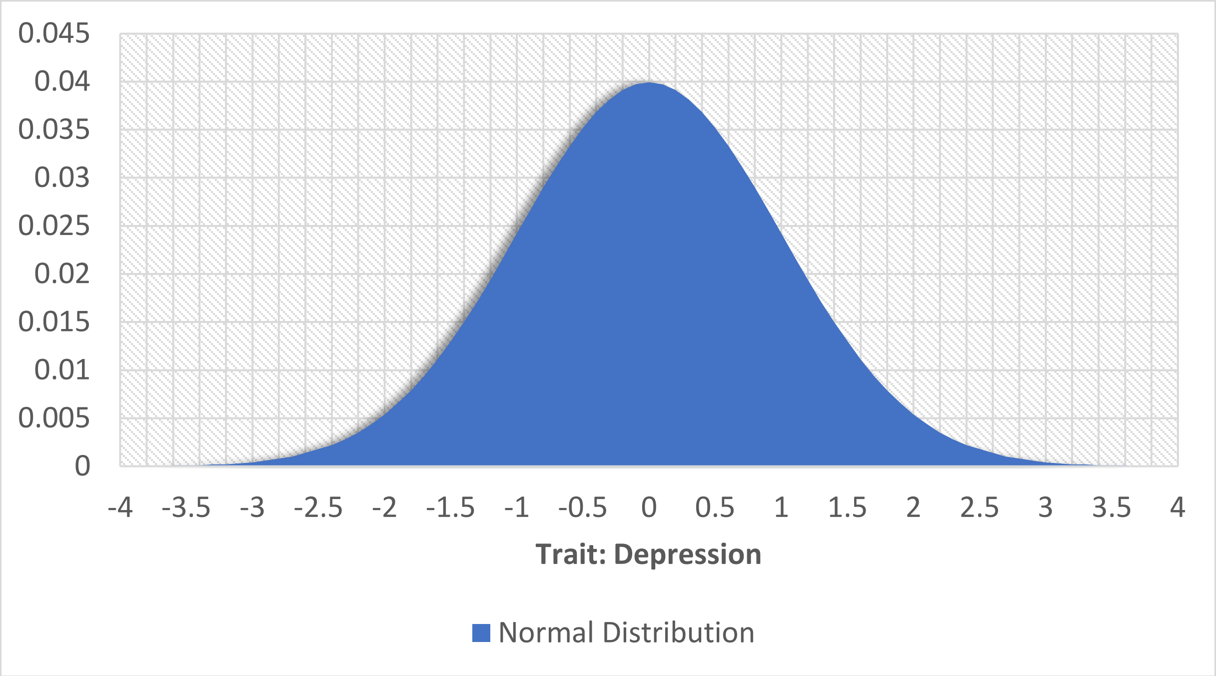
- Unidimensional $$P^*_{\theta jk} = \frac{1}{1+\exp\left[-Da_j(\theta - b_{jk})\right]}$$

- Multidimensional $$P^*_{\theta jk} = \frac{1}{1+\exp\left[-Da_j(\theta - b_{jk})\right]}$$

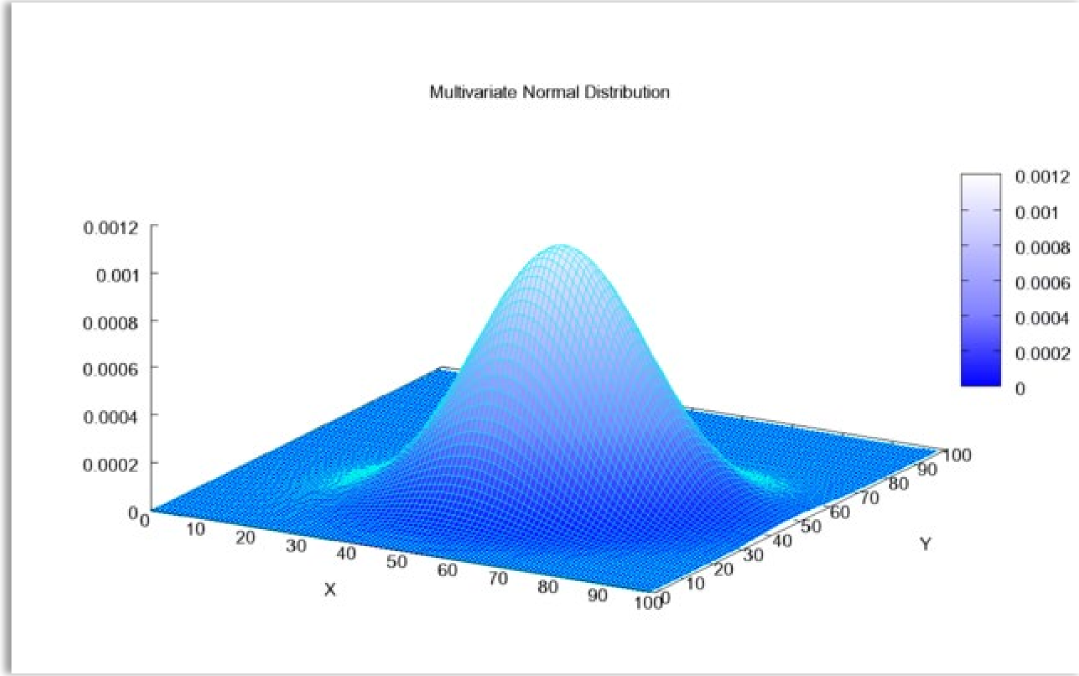
$$\begin{bmatrix} a_j^x & a_j^y & a_j^n \end{bmatrix}$$

$$\begin{bmatrix} \Theta^x - b_{jk} \\ \Theta^y - b_{jk} \\ \Theta^n - b_{jk} \end{bmatrix}$$

Initial Distribution



Unidimensional



Multidimensional

Approach - Simulations

- Monte Carlo simulation designed
- 2 sets of calibrations
  - 1 for generating responses
  - 1 for administering CAT
- True Trait Levels
  - uniformly across trait continuum
  - empirical distribution
    - Clinical and General population
- Administer all items in the banks
- Retrospectively apply stopping rule and outcome criteria

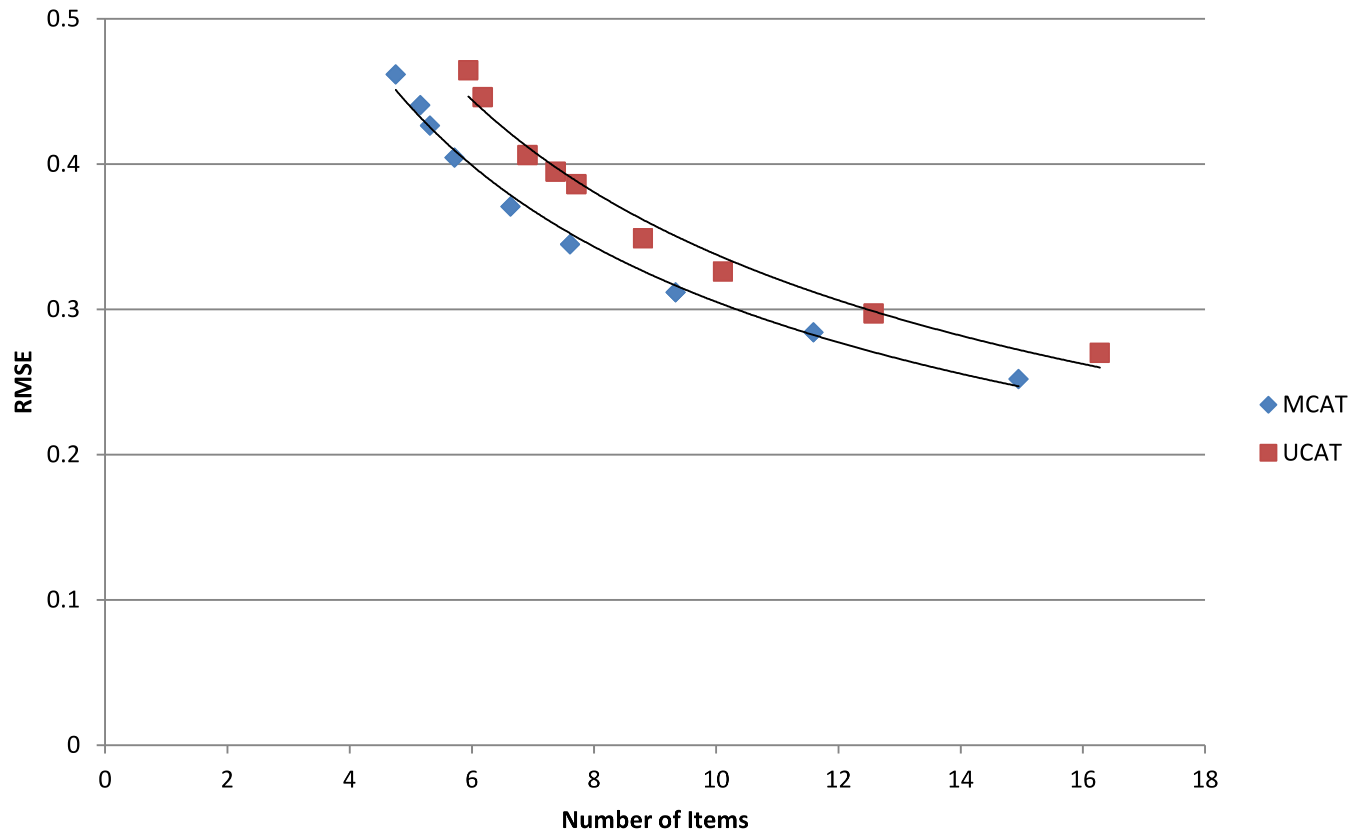
Simulation Outcome Criteria

- Item count to reach the specified standard error (SE)
- Root Mean Square (RMSE)

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}\left[\left(\hat{\theta}_{Anx,i} - \theta_{Anx,i}\right)^2 + \left(\hat{\theta}_{Dep,i} - \theta_{Dep,i}\right)^2\right]}{N}}$$

where $\hat{\theta}_{t,i}$ and $\theta_{t,i}$ represent the EAP estimate and true value of trait *t* for respondent *i*, and *N* is the number of simulated respondents.

RMSE vs Item count



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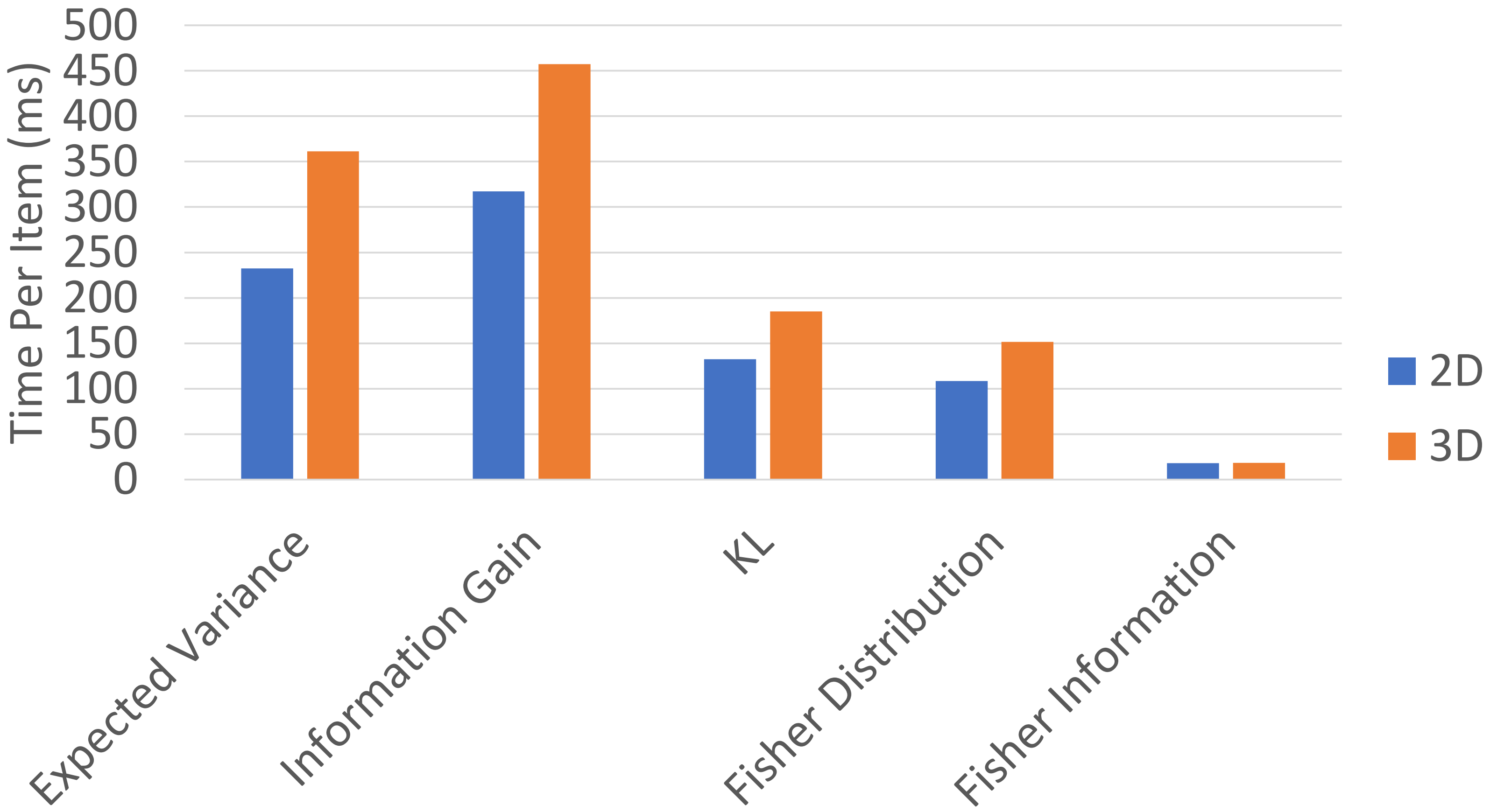
Item Selection - Methods

- Maximize Determinant of *Fisher Information* Matrix
- Maximize Posterior-Weighed Average of FI (*Fisher Distribution*)
- Minimize Sum of Posterior Variance (*Expected Variance*)
- Maximize Kullback-Leibler Information (*KL*)
- Maximize Change in Shannon Entropy (*Information Gain*)

Item Selection - Computation Time



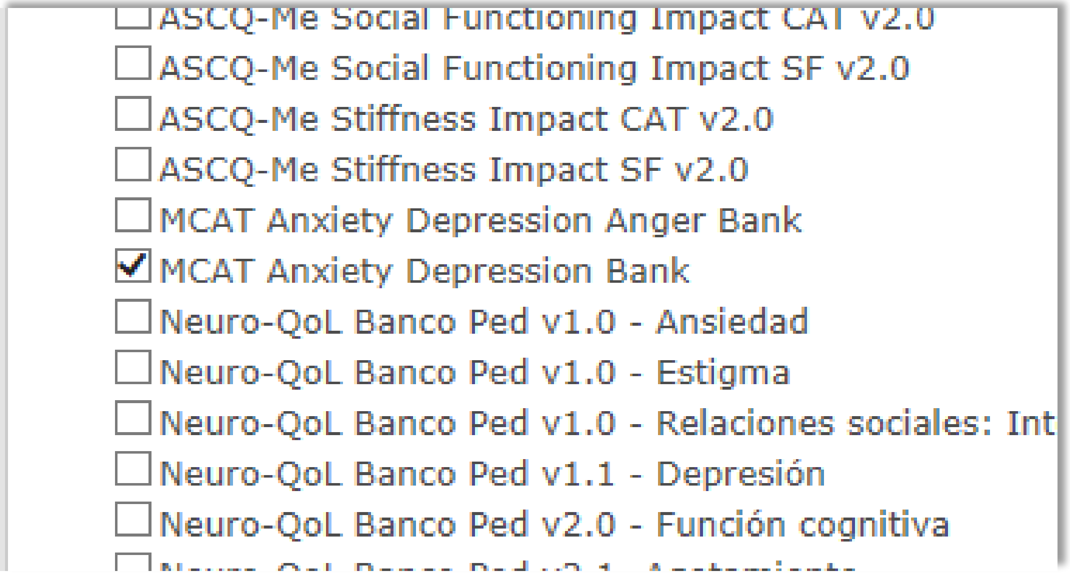
Item Selection - Conclusions

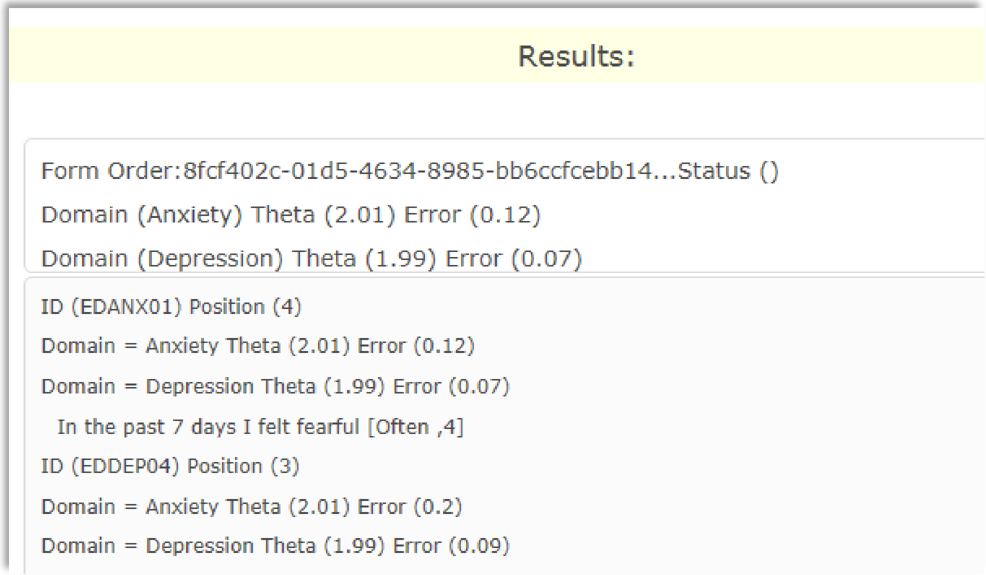
- All item selection methods perform similarly
  - Never more than one additional item (on average)
- Small but consistent differences
  - Fisher Information slightly less efficient
  - KL Information among most efficient
- Small improvements in precision may not justify substantial increase in computational complexity (time to select next item)
  - Likely to become worse with higher dimensionality
- KL Information provided good balance of high efficiency with only modest increase in computation time

Stopping rules

- All variations based on a predictive standard error reduction approach
  - Sum of Variance method
  - Sum of SD method
  - Sum of Variance Above Threshold
- All methods demonstrated gains in efficiency, but
- MCAT more sensitive than UCAT when there is poor item-person mapping

Operationalized MCAT in AC API





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Performance Consideration

Domains	State Size (kb)	DB query (tick intervals)
1	64	9
2	512	1011
3	8192	48775

**Need a mechanism to keep state in memory

Conclusions

- Multidimensionality complicates stopping rules more than item selections methods
- MCAT is more sensitive to item-person mapping. How well do you know your cohort.
- In general, modest efficiency gains but need to consider number of dimensions and the impact on computational performance (i.e. lag)

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Future direction

- On the fly MCAT
  - Domain covariances with unidimensional calibrations
- Stopping rules from educational testing
- Bifactor model (high level of dimensions simplify to 2D computations)

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Questions

Thank you!