NIDA NATIONAL INSTITUTE ON DRUG ABUSE

The Use of Decision Trees for Adaptive Item Selection and Score Estimation

Barth B. Riley
Rodney Funk
Michael L. Dennis
Richard D. Lennox

Matthew Finkelman

Chestnut Health Systems

Tufts UNIVERSITY

Why Not Standard CAT?

- Not all measures or indices conform to an IRT model, which is often the basis of CAT
  - Example: network size
- IRT-based item banks are expensive to develop and maintain, and require specialized skills

Purpose

- Provide an overview of decision tree methods
- Compare the use of decision tree approaches to IRT-based CAT using instruments consisting of dichotomous and polytomous items.

Decision Trees

- A decision tree predicts membership on an outcome based on one or more predictor variables.
- Predictors are used to partition the sample into subsamples that are increasingly homogeneous on the outcome.
- Each subsample is represented by a node in the tree structure.
- The partitioning process is repeated until a stopping rule is met

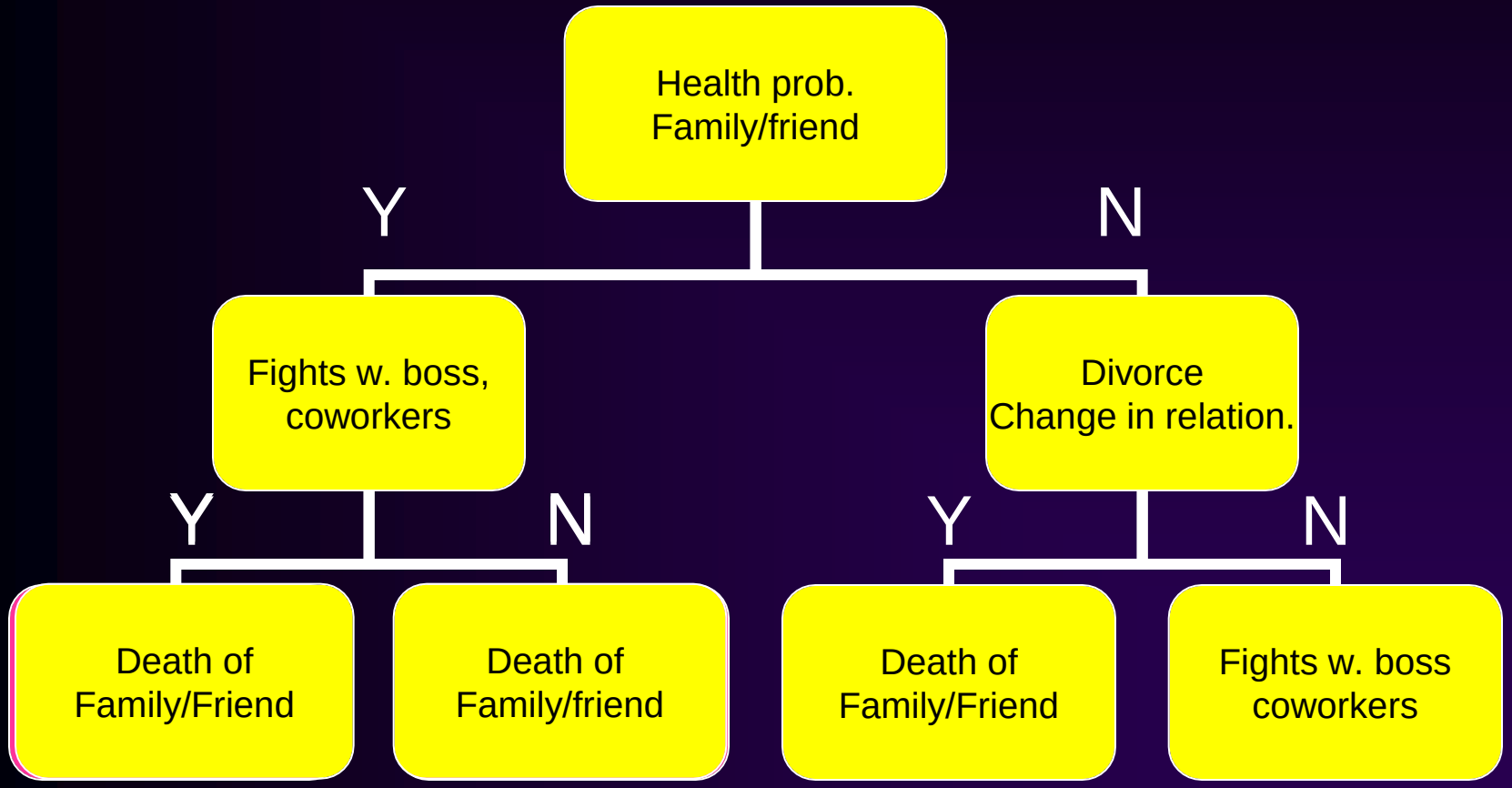
Decision Trees cont.

- Stopping criterion can be based on:
  - Number of levels or depth of the tree
  - A minimum sample size for a given node
- Terminal nodes (nodes at the lowest level of the tree)
  - associated with an estimated probability of being in a particular category on the outcome variable
  - in the case of interval-level outcomes, a mean value on that variable.

Partitioning Algorithms

- Regression trees
  - Similar to ANOVA and discriminant analysis and generally used to predict a continuous outcome
  - Nodes are divided into 2 sub nodes
- CHAID – chi-square automatic interaction detection
  - Used to predict a categorical outcome
  - Nodes can be divided into two or more sub nodes.

Example: Personal Sources of Stress



Decision Tree Pros and Cons

- Pros
  - Does not require assumptions of unidimensionality or local independence
  - Can handle item non-response more easily than CAT
  - Less computationally intensive during administration
  - Can incorporate demographic variables to control "DIF"
- Cons
  - Error propagation: A wrong decision (item) can lead to all subsequent decisions being wrong as well.

Study

- Conducted post-hoc simulations comparing the relative efficiency, and precision of decision trees (using CHAID and CART) vs. IRT-based CAT.
- Measure: Global Appraisal of Individual Needs (GAIN) Substance Problem Scale (16 items)
  - Past-year symptom count (SPSy)
  - Recency of symptom scale (SPSr)

Data Source

- Data from 26,390 participants entering substance abuse treatment
- Dataset was split into two random samples
  - The first sample was used for development of the decision-tree models and for IRT parameter estimation
  - The second sample was used to compare CAT vs. decision-tree efficiency and precision.
- IRT model
  - 2 parameter dichotomous model (SPSy)
  - 2 parameter graded response model (SPSr)

Stop Rule Criterion

- Decision Trees
  - Maximum number of levels (4-10)
  - No nodes w. N < 100 and no new nodes created w. a parent node of N < 200
- CAT
  - Maximum number of items
  - Standard error of measurement < .4475 (measure reliability = .80)

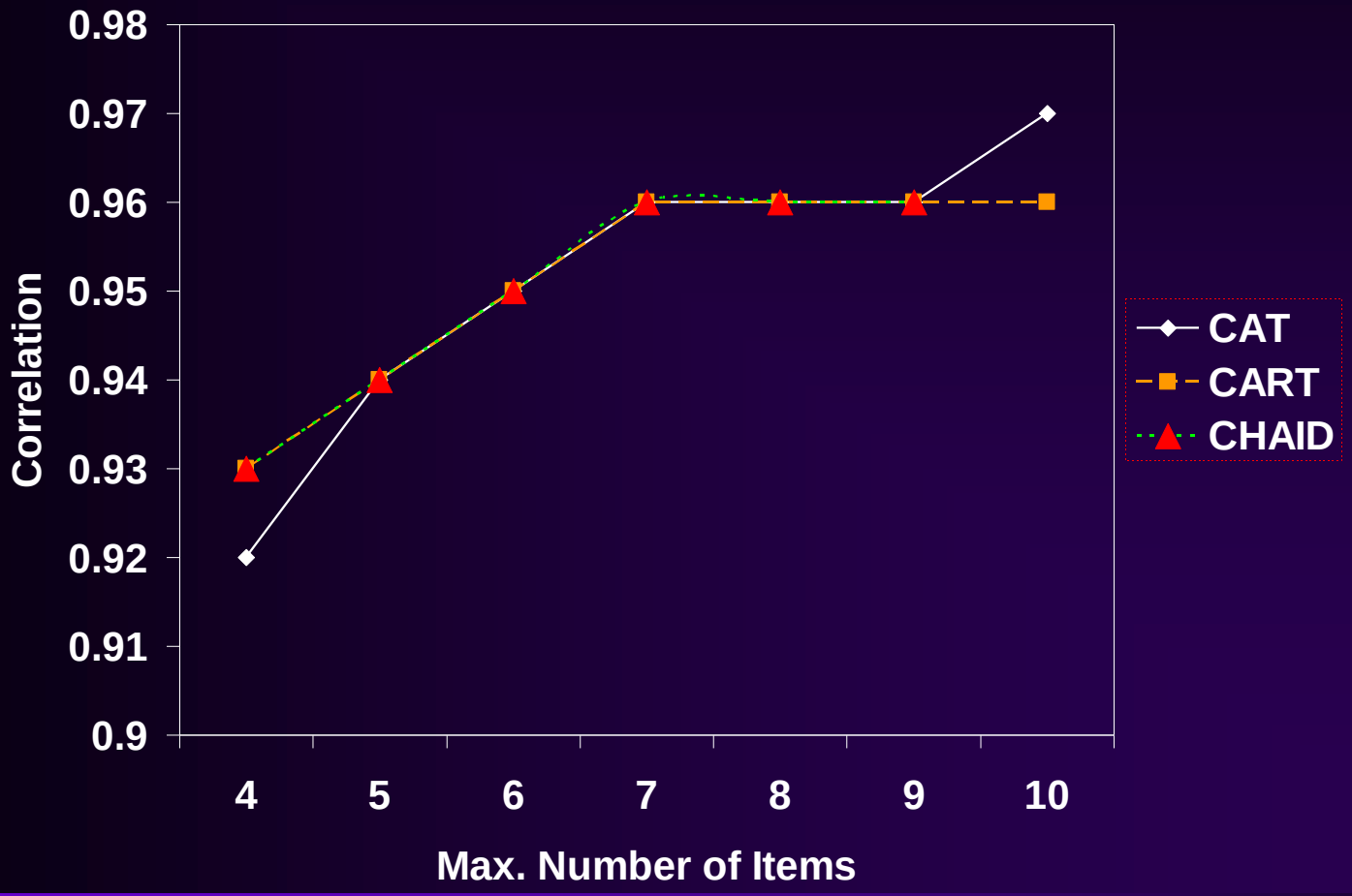
Procedures

- Decision-tree models were developed using SPSS (v. 19).
- Mplus (v. 6) was used to estimate IRT item parameters
- CAT simulations used maximum Fisher's information and were performed using Firestar version 1.33
- Since the decision tree models were used to estimate raw scores, raw score equivalents of IRT measures were used for comparison.

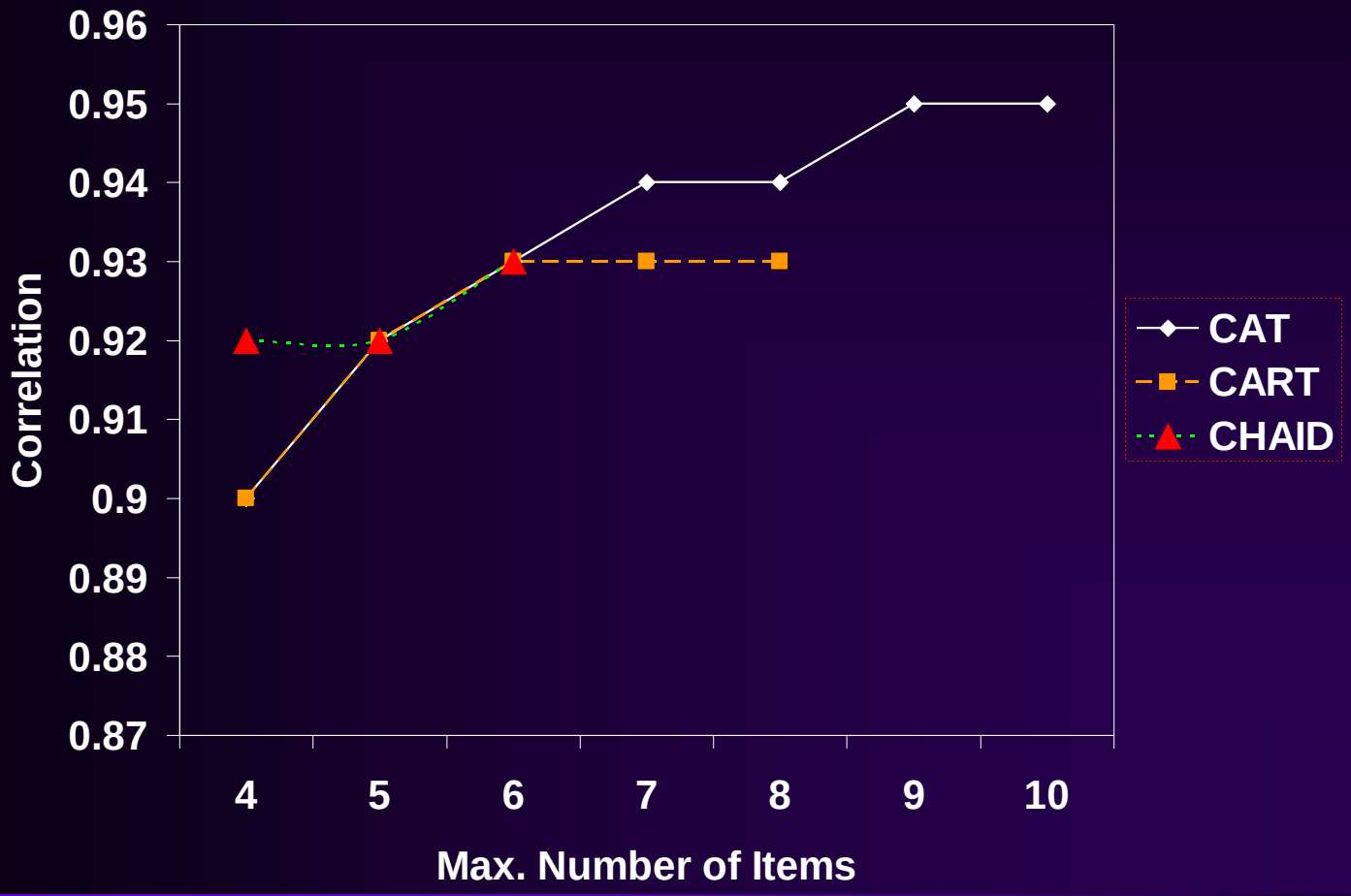
Comparison Criteria

- Correlation w. Total Score (R)
- Efficiency (R^2 x % items saved)
- Bias (Mean CAT/Tree vs. Mean Full)
- Root Mean Squared Error (RMSE) difference between estimated and full scores
- Effect Size (Comparison between persons in outpatient vs. residential treatment)

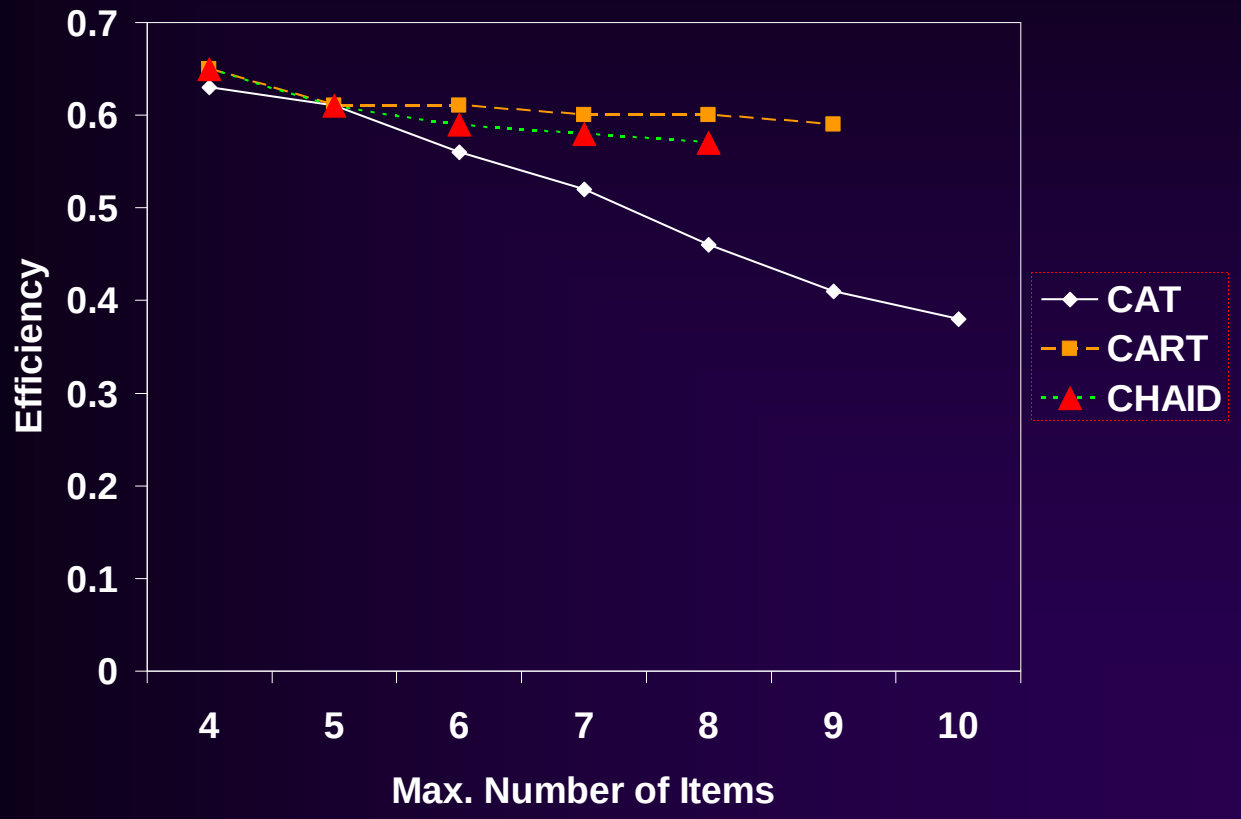
SPSy: Corr. With Total Score



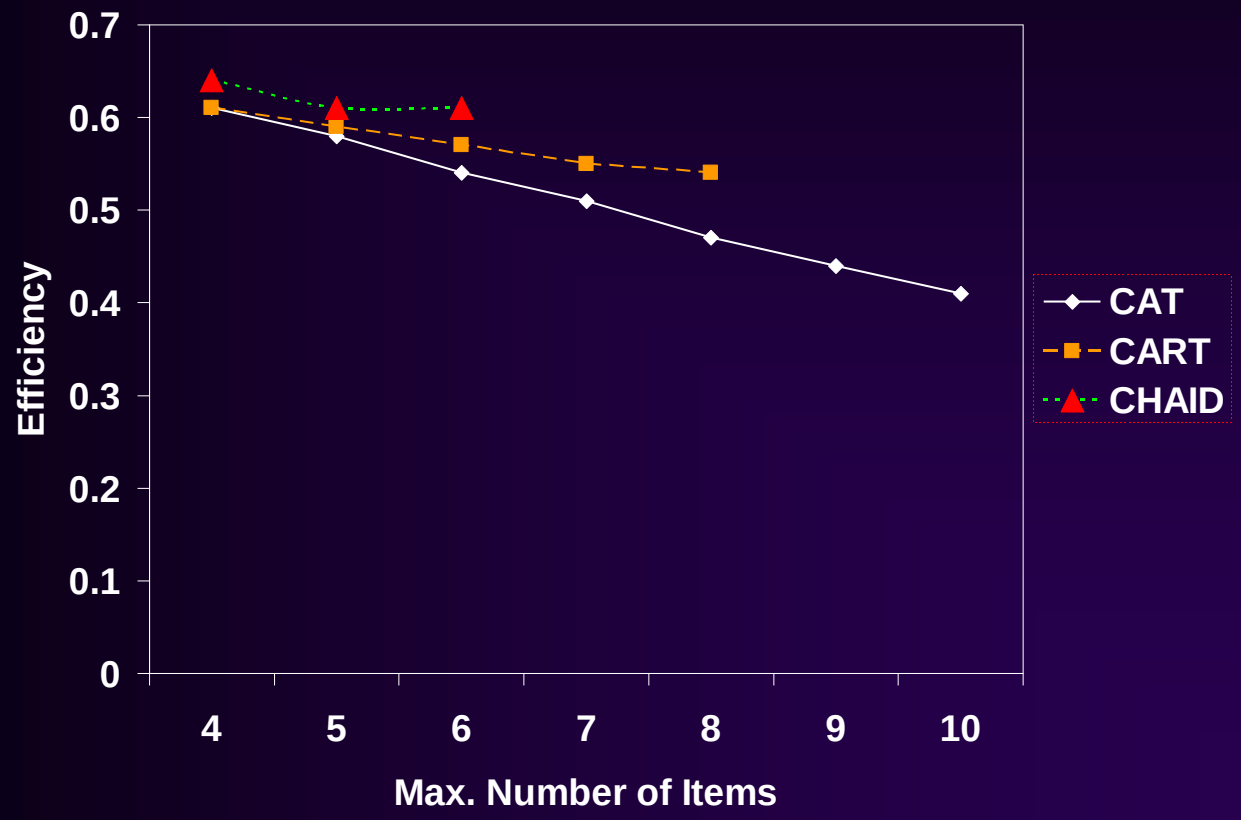
SPSr: Corr. w. Total Score



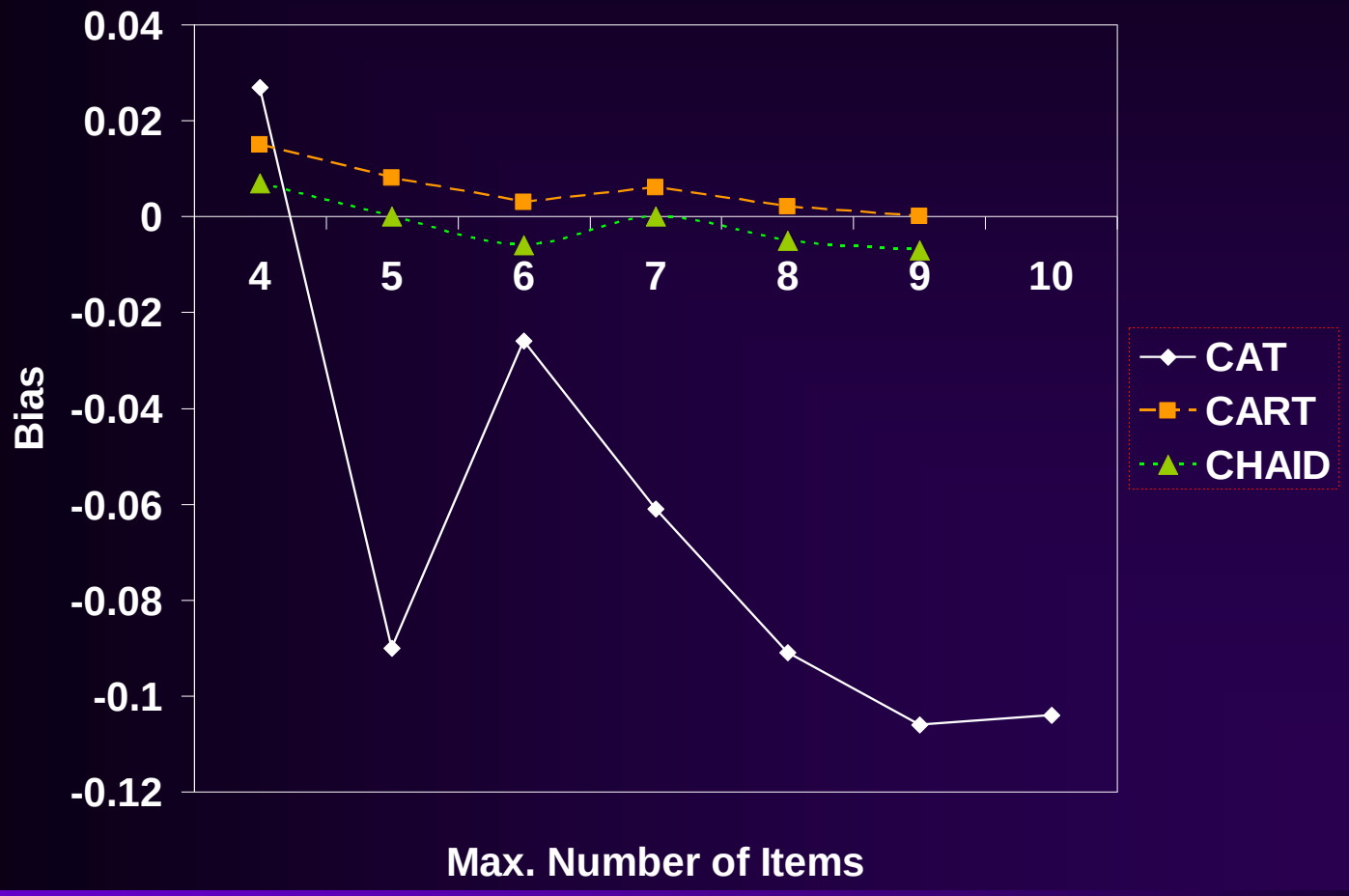
SPSy: Efficiency



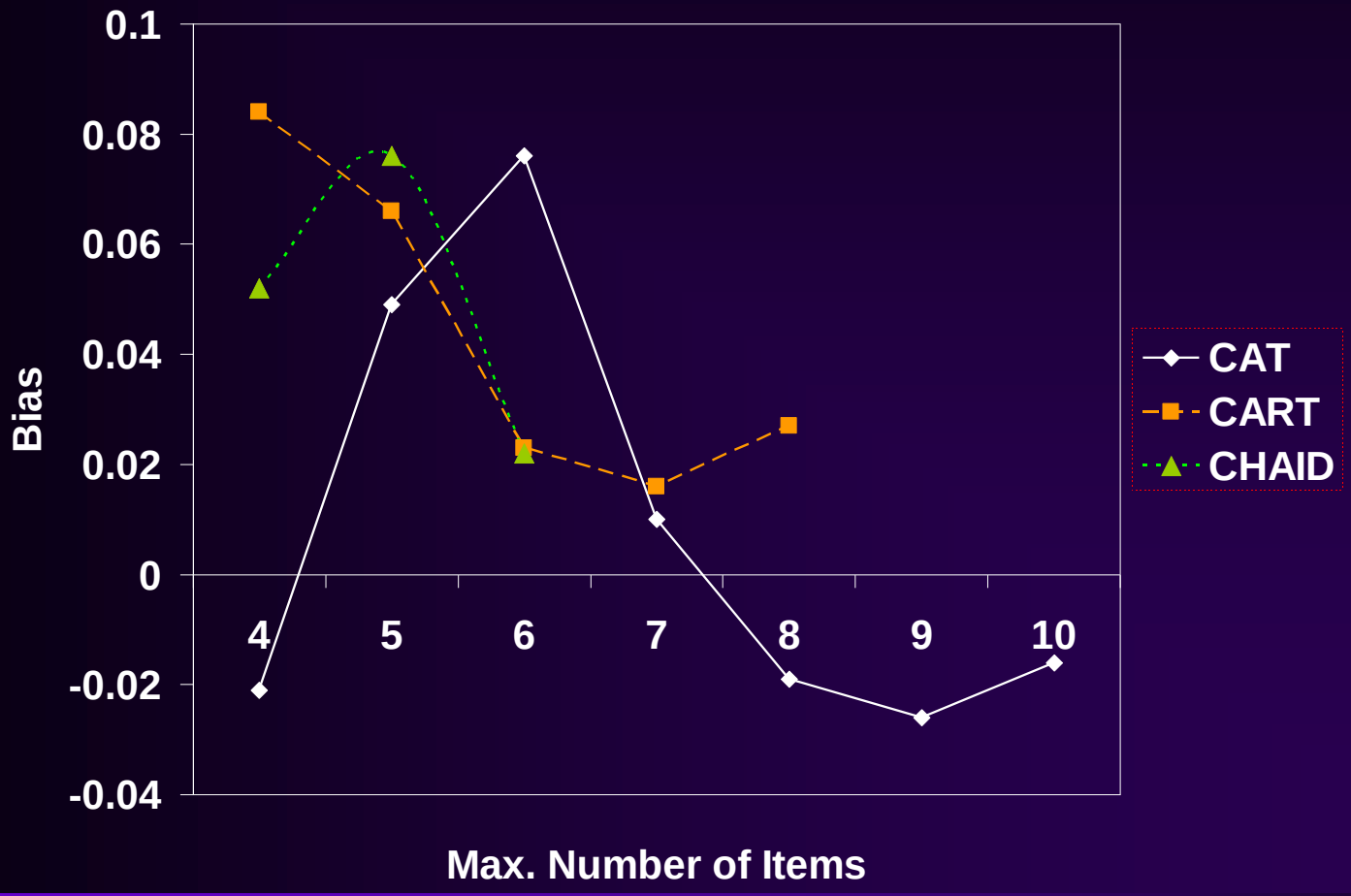
SPSr: Efficiency



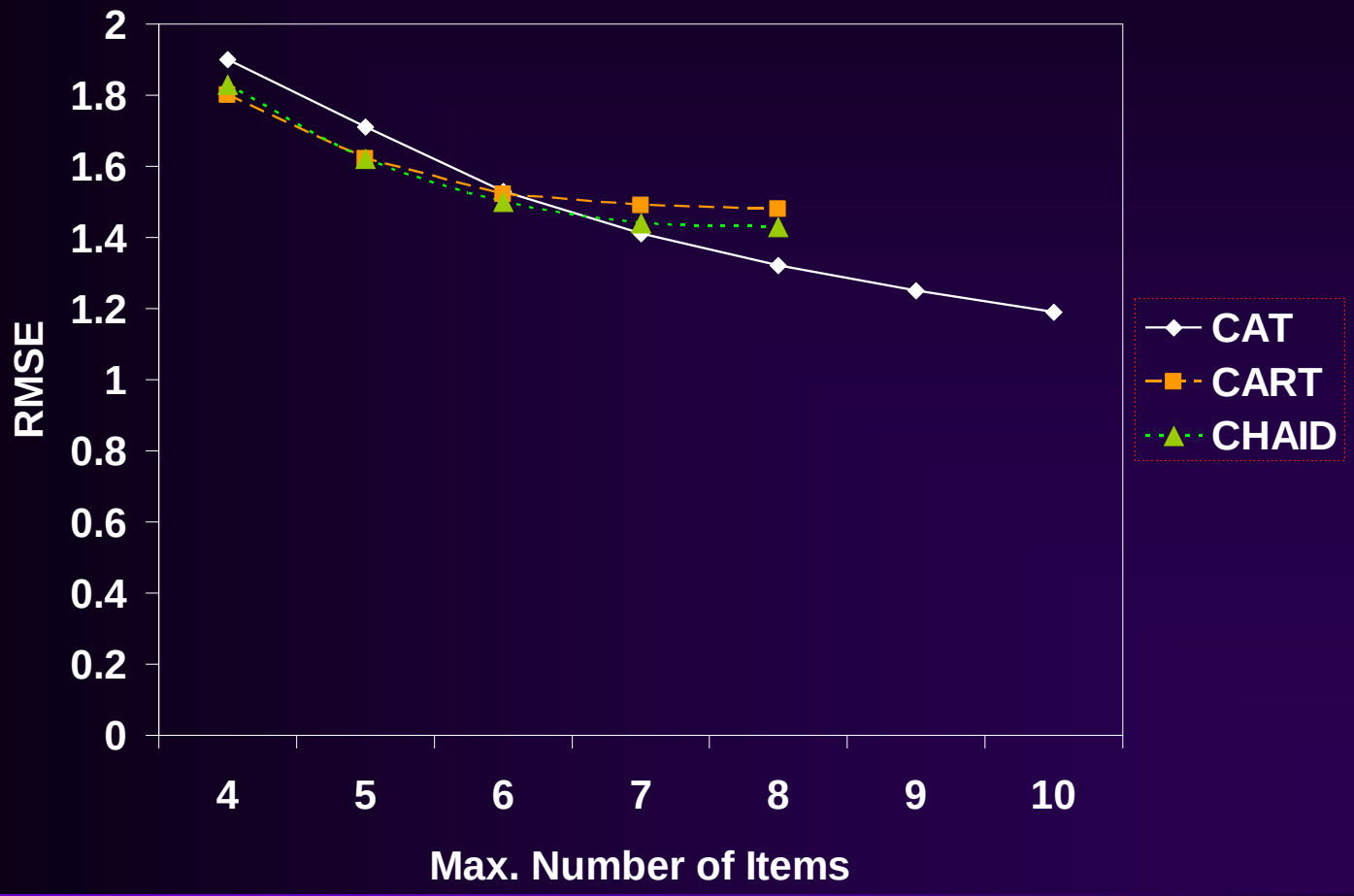
SPSy: Measurement Bias



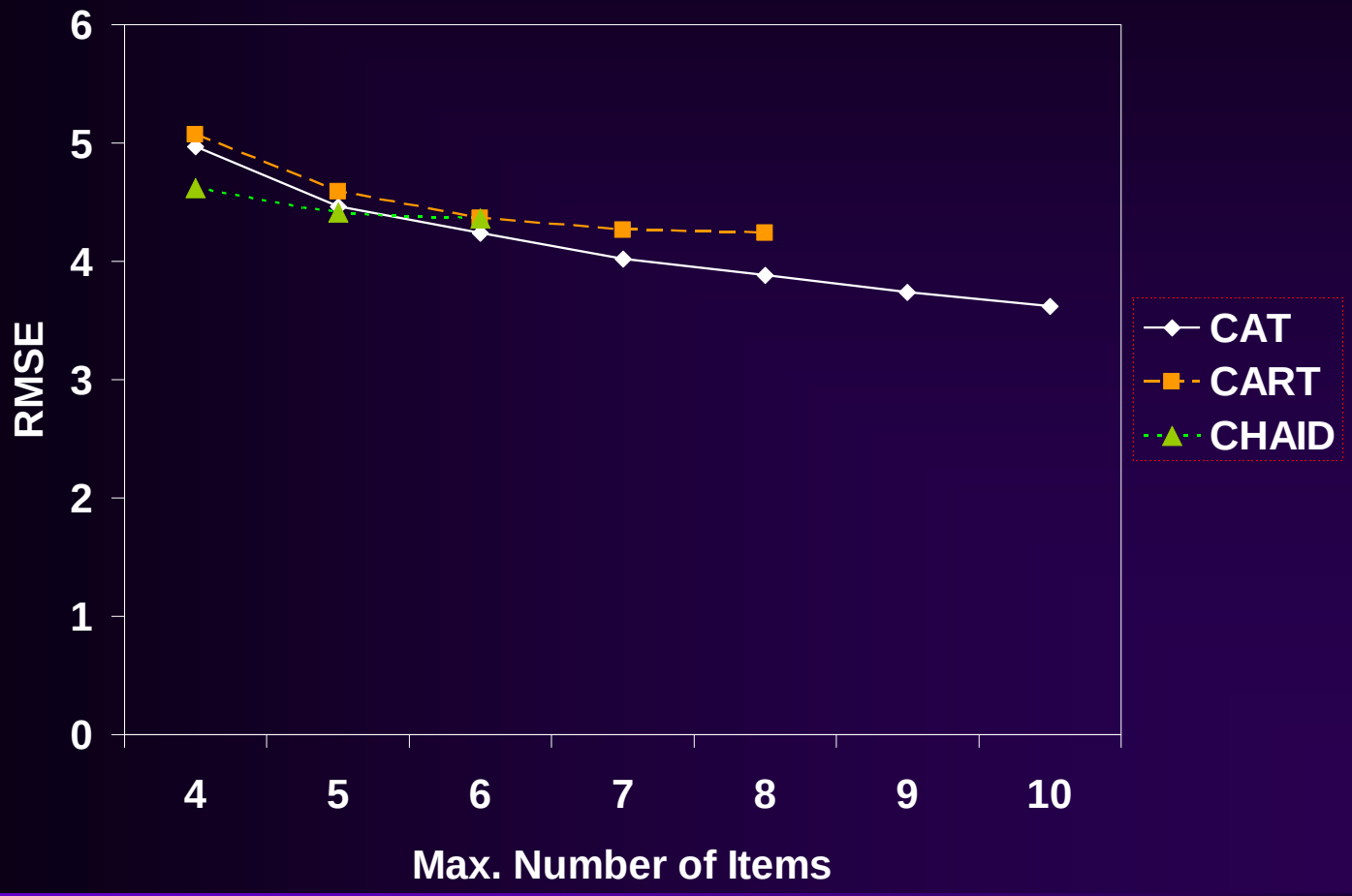
SPSr: Measurement Bias



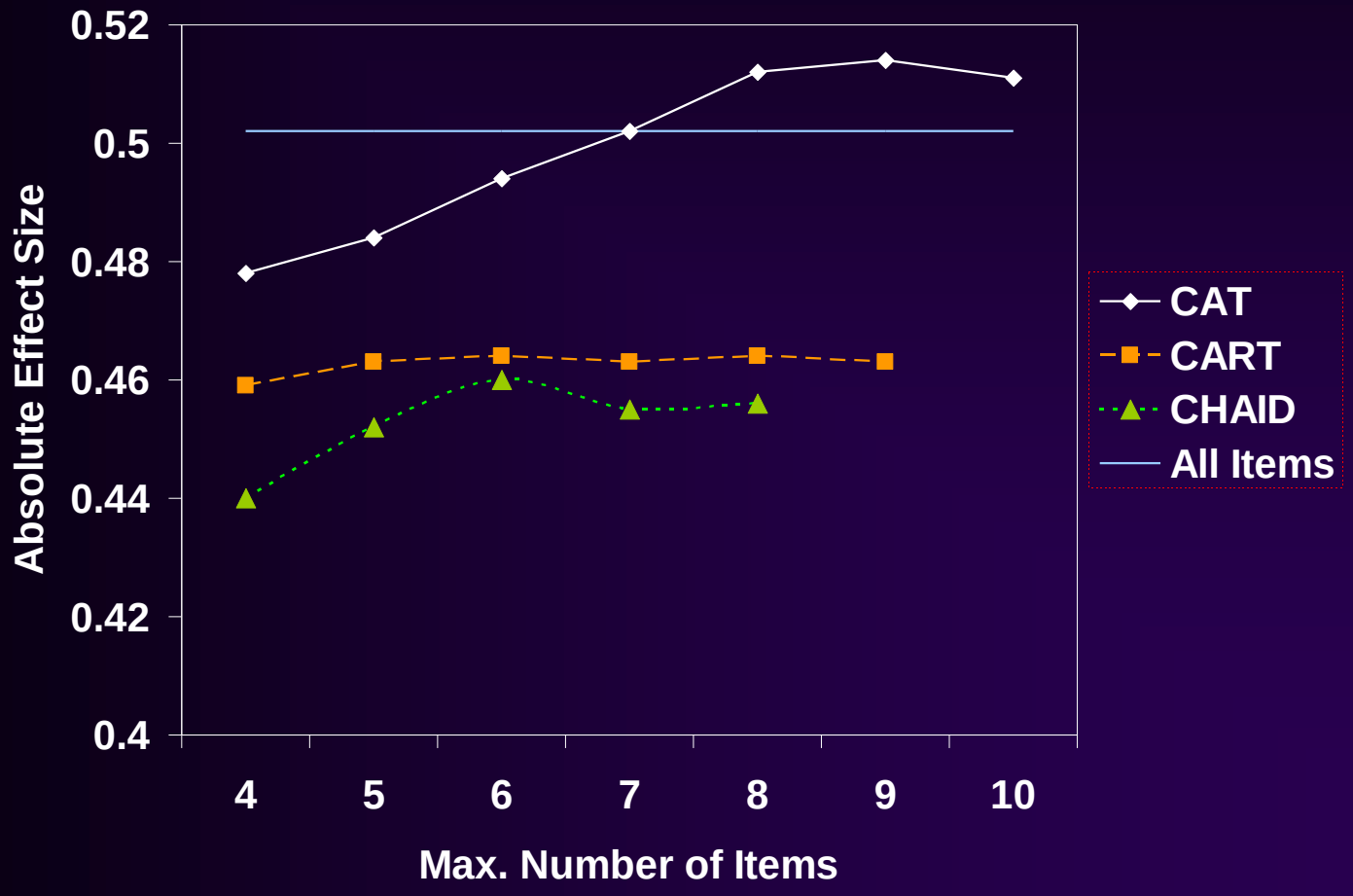
SPSy: RMSE


RMSE
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
4
5
6
7
8
9
10
Max. Number of Items
CAT
CART
CHAID

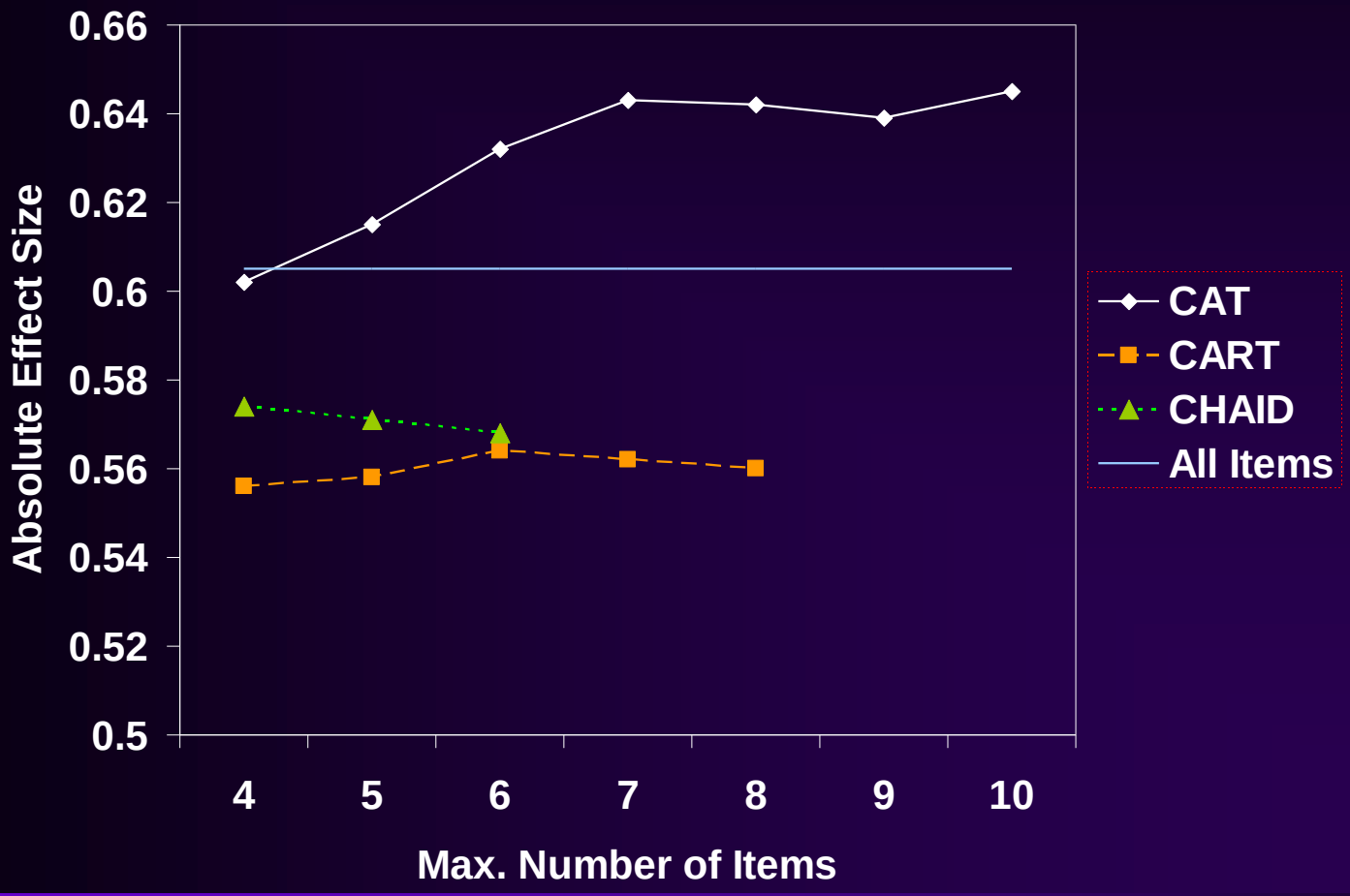
SPSr: RMSE



SPSy: Effect Size



SPSr: Effect Size



Conclusions

- Decision tree methods were more efficient than CAT
  - CART for dichotomous items (SPSy)
  - CHAID for polytomous items (SPSr)
- Score bias was low in all conditions, particularly for decision trees using dichotomous items
- In early stages of administration, decision trees provided slightly higher correlations with the full scale and lower RMSE values.
- But…

Conclusions

- CAT outperformed decision tree methods in later stages of administration.
- CAT also outperformed decision trees with respect to sensitivity to group differences as measured by effect size.

CAT vs. Decision Trees

- CAT selects items based on two criteria:
  - Item location relative to current estimate of theta
  - Item discrimination
- Decision Trees select items that best discriminate between groups defined by the total score.
- CAT is optimal only when trait level is well estimated.
- Findings suggest that combining decision tree followed by CAT item selection may be advantageous.

Thank You!

For further information, contact:

Barth Riley -- bbriley@chestnut.org

For psychometric information on the Global Appraisal of Individual Needs, go to:

http://www.chestnut.org/li/gain/#GAIN%20Working%20Papers