ROC Done Right? Part 3
DIBELS® Benchmark Goals

Part 3 Overview

- Importance of evaluating screening tools in an educational context.
- Two commonly used metrics, Sensitivity and Specificity, are problematic in an educational context because they assume:
  - A true, dichotomous outcome.
  - A gold standard of the outcome that is generally agreed upon.
  - No intervening active ingredient between screening and outcome.
- Additional problems of Sensitivity and Specificity:
  - They depend on the choice of cutpoint. (ROC curves address the problem of different cutpoints, but ROC curves don’t address the other problems of sensitivity and specificity).
  - They are affected by differences in base rate.
  - They are affected by differences in Tier 1 instruction and Tier 2 and Tier 3 interventions.
- Our recommendation:
  - Use likelihood or odds of achieving important educational outcomes to evaluate screening assessments.

Sample from mClass Data System

- Data were gathered from 8890 schools in 1226 districts across 50 states for students who were in first grade in the 2004-2005 academic year and were followed longitudinally into their second grade year in the 2005-2006 academic year.
- All data were collected using the Palm® version of DIBELS.
- Participating school districts received training on DIBELS and the Palm during implementation.
- All data were collected using district procedures, with district trained and supervised data collectors.

Descriptive Stats for mClass Samples

<table>
<thead>
<tr>
<th></th>
<th>Full mClass Sample</th>
<th>500 random sub-sample</th>
<th>137 district sub-sample</th>
<th>District 1</th>
<th>District 2</th>
<th>137 district sample</th>
<th>District 1</th>
<th>District 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>58811</td>
<td>500</td>
<td>46154</td>
<td>490</td>
<td>466</td>
<td>46154</td>
<td>490</td>
<td>466</td>
</tr>
<tr>
<td>ORF Gr 2 EOY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>91.93</td>
<td>91.85</td>
<td>91.09</td>
<td>61.87</td>
<td>84.16</td>
<td>90.92</td>
<td>71.56</td>
<td>79.08</td>
</tr>
<tr>
<td>std</td>
<td>37.11</td>
<td>37.26</td>
<td>37.51</td>
<td>35.58</td>
<td>34.32</td>
<td>38.30</td>
<td>35.59</td>
<td>34.32</td>
</tr>
<tr>
<td>NWF Gr 1 EOY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>62.87</td>
<td>62.80</td>
<td>62.04</td>
<td>46.10</td>
<td>52.29</td>
<td>62.03</td>
<td>46.11</td>
<td>52.30</td>
</tr>
<tr>
<td>std</td>
<td>30.56</td>
<td>29.64</td>
<td>31.05</td>
<td>29.56</td>
<td>26.04</td>
<td>31.05</td>
<td>29.54</td>
<td>26.06</td>
</tr>
<tr>
<td>correlation</td>
<td>.65</td>
<td>.65</td>
<td>.65</td>
<td>.59</td>
<td>.62</td>
<td>.68</td>
<td>.64</td>
<td>.61</td>
</tr>
</tbody>
</table>

- 500 random sample from the full data set is for illustrative purposes.
- 137 district sample has complete data for at least 100 students in each district.
- A Monte Carlo study was conducted to model the 137 districts in the mClass sample with bivariate normal random data with (a) the same correlation as the full mClass sample, (b) the same NWF mean, NWF standard deviation, and ORF standard deviation as each district, (c) but with the ORF district mean set to be the same number of standard deviation units from the full mClass sample mean as the NWF district mean.
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- Importance of evaluating screening tools in an educational context.
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  - A true, dichotomous outcome.
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Purpose of Screening Tools in Education

- To quickly identify the likelihood that a student will need additional help to prevent a later academic difficulty.
- To specify important and meaningful goals—a point at which we change the odds to being in favor of an individual’s meeting subsequent goals.
- Key Point: Outcomes are unknown and are likely not even present at the time of the screening. Instead, outcomes eventuate or come into being as a result of the differentiated instruction and intervention provided as a direct result of the screening information.
- For Example: If a child screens as at high risk on a measure of early literacy skills in Kindergarten, we know they are likely to need additional instructional support to be successful. The eventual outcome, their reading skills in first grade, for example, is a direct result of the differentiated instruction and intervention that are provided.

We need to critically evaluate our screening tools for educational decisions

- We need to evaluate the:
  - Reliability of the measures,
  - Validity of the measures,
  - Decision utility of the measures,
  - Consequential validity of the measures.
- Sensitivity and Specificity indices may not be the best metrics to evaluate educational screening measures.
- Sensitivity and specificity were developed for and are most appropriate when:
  - There is a true, dichotomous outcome.
  - There is a gold standard of the outcome that is generally agreed upon.
  - There is no intervening active ingredient. Only when there is no intervening active ingredient are the constructs of “False Positive” and “False Negative” even meaningful.
  - For example, a screening test for tuberculosis.

For Example, Screening for Tuberculosis

<table>
<thead>
<tr>
<th>Screening Decision:</th>
<th>Positive TB</th>
<th>Negative TB</th>
</tr>
</thead>
<tbody>
<tr>
<td>True State (Outcome): Negative for tuberculosis</td>
<td>FP: False Positive</td>
<td>TN: True Negative</td>
</tr>
<tr>
<td>True State (Outcome): Positive for tuberculosis</td>
<td>TP: True Positive</td>
<td>FN: False Negative</td>
</tr>
</tbody>
</table>

- **Sensitivity**: Of individuals **who truly have tuberculosis**, what proportion are identified as having tuberculosis by the screening test? \[ \frac{TP}{TP + FN} \]
- **Specificity**: Of individuals **who truly do not have tuberculosis**, what proportion are identified as not having tuberculosis on the screening test? \[ \frac{TN}{FP + TN} \]
Screening for Tuberculosis, Sensitivity and Specificity Make Sense

- There is a true state, and it is a dichotomous one (TB/not TB) not one of degree (a patient doesn’t have a little bit of TB).
- A gold standard of the true state is generally agreed upon. We are able to know with reasonable certainty whether the person has TB or not.

Sensitivity and Specificity are used to evaluate the accuracy of the screening tool before treatment or action takes place. There is no active ingredient or treatment between screening and gold standard identification of the true state.

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  - Use likelihood or odds of achieving important educational outcomes to evaluate screening assessments.

In an Educational Context, We Need More Sense Than Sensitivity

- To evaluate screening tools in education, our recommendation is to use the likelihood of achieving important educational outcomes because:
  - The outcome is continuous.
  - There is no general agreement on a specific assessment or cutpoint on the assessment that discriminates adequate and not adequate skills.
  - And especially because there is intervening instruction and intervention occurring between the screening assessment and the outcome. When there is intervening instruction and intervention, the constructs of “False Positive” and “False Negative” are not meaningful.

Screening for Adequate Reading Skills

<table>
<thead>
<tr>
<th>True State (Outcome):</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adequate Reading skills (Negative for reading difficulty)</td>
</tr>
<tr>
<td>Uncertain Reading skills (We don’t agree if adequate or not)</td>
</tr>
<tr>
<td>Poor Reading Skills (Positive for Reading Difficulty)</td>
</tr>
<tr>
<td>Screenig Decision:</td>
</tr>
<tr>
<td>High Risk</td>
</tr>
<tr>
<td>$n_{11}$</td>
</tr>
<tr>
<td>$n_{21}$</td>
</tr>
<tr>
<td>$n_{31}$</td>
</tr>
</tbody>
</table>

- **Low Risk Likelihood or Odds**: Of individuals who are identified as low risk on the screening test, what proportion achieve adequate reading skills on the outcome assessment? $\frac{n_{13}}{n_{13} + n_{23} + n_{33}}$
- **Some Risk Likelihood or Odds**: Of individuals who are identified as some risk on the screening test, what proportion achieve adequate reading skills on the outcome assessment? $\frac{n_{12}}{n_{12} + n_{22} + n_{32}}$
- **High Risk Likelihood or Odds**: Of individuals who are identified as high risk on the screening test, what proportion achieve adequate reading skills on the outcome assessment? $\frac{n_{11}}{n_{11} + n_{21} + n_{31}}$
For Example, DIBELS Assessment

First Grade End of Year NWF Initial Assessment:
High Risk  Some Risk  Low Risk

Second End of Year ORF Outcome:
Low Risk Reading Fluency
Some Risk Reading Fluency
High Risk Reading Fluency

• **Low Risk Likelihood or Odds**: Of students who are Low Risk on DIBELS NWF at end of first grade, 85% are Low Risk on end of second grade ORF.

• **Some Risk Likelihood or Odds**: Of students who are Some Risk on DIBELS NWF at end of first, 50% are Low Risk on end of second grade ORF. We just don’t know if they are on track or not.

• **High Risk Likelihood or Odds**: Of students who are High Risk on DIBELS NWF at end of first, 24% are Low Risk on end of second grade ORF.

Note: Odds based on Full WG sample, \(n = 5881\). Scatterplot based on a random sub-sample of WG sample, \(n = 500\).

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We can impose a 2-by-2 Model on Reading Assessment, but it Doesn’t Really Fit

DIBELS Alphabetic Principle:
High Risk  Not High Risk

Second End ORF Outcome:
Not High Risk
High Risk

• **Sensitivity**: Of students who truly have poor reading, what proportion are identified as having poor reading by DIBELS?

• **Specificity**: Of students who truly do not have poor reading, what proportion are identified as not having poor reading on DIBELS?

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Any Two, High Quality Reading Criterion Tests Have a Zone of Disagreement

Between G3 ORF of 80 and 110, the odds are 59% the student will rank “adequate” on the FL State Assessment.


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Any Two High-Quality Reading Criterion Tests Have a Zone of Disagreement

The best reading assessments correlate in the range .60 to .80, consistent with the correlation of ORF and most other reading assessments.

This means there will always be a zone of disagreement between any two criterion measures. How do we determine which assessment is the true gold standard of reading outcomes?

How do we define at-risk reading outcomes?

<table>
<thead>
<tr>
<th>Study</th>
<th>Outcome Criterion</th>
<th>Outcome Test</th>
<th>Time of Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foorman et al. (1998)</td>
<td>&lt;25th Percentile</td>
<td>WJR Broad Reading</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>—</td>
<td>Not specified</td>
<td>WJR Broad Reading</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>—</td>
<td>&lt;30th Percentile</td>
<td>WJR Broad Reading</td>
<td>Spring of 2nd</td>
</tr>
<tr>
<td>O'Connor &amp; Jenkins (1999)</td>
<td>&lt;8th Percentile</td>
<td>WRMT BRS</td>
<td>1st</td>
</tr>
<tr>
<td>Speece et al. (2003)</td>
<td>&lt;25th Percentile</td>
<td>WJR Word Attack</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>—</td>
<td>&lt;25th Percentile</td>
<td>CBM ORF</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>Schatschneider (2006)</td>
<td>&lt;25th Percentile</td>
<td>SAT-10 RC</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>—</td>
<td>&lt;25th Percentile</td>
<td>SAT-10 RC</td>
<td>Spring of 2nd</td>
</tr>
<tr>
<td>—</td>
<td>Level 3</td>
<td>FCAT RC</td>
<td>Spring of 3rd</td>
</tr>
<tr>
<td>Good et al. (2001)</td>
<td>&lt;40 WRC</td>
<td>CBM ORF</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>—</td>
<td>&lt;50 WRC</td>
<td>CBM ORF</td>
<td>Spring of 2nd</td>
</tr>
<tr>
<td>—</td>
<td>&quot;Does not meet expectations&quot;</td>
<td>OSA</td>
<td>Spring of 3rd</td>
</tr>
<tr>
<td>Speece &amp; Case (2001)</td>
<td>DD (-1 SD on slope &amp; level)</td>
<td>CBM ORF</td>
<td>Not specified</td>
</tr>
<tr>
<td>Speece (2005)</td>
<td>&lt;40 WRC &amp; -1 SD slope</td>
<td>CBM ORF</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>Compton et al. (2006)</td>
<td>&lt;85 SS</td>
<td>Broad Reading Composite</td>
<td>Spring of 2nd</td>
</tr>
<tr>
<td>—</td>
<td>&lt;85 SS</td>
<td>Component Reading</td>
<td>Spring of 2nd</td>
</tr>
<tr>
<td>Good et al. (in-press)</td>
<td>&lt;40 WRC</td>
<td>DIBELS ORF</td>
<td>Spring of 1st</td>
</tr>
<tr>
<td>Stage &amp; Jacobsen (2001)</td>
<td>&quot;Below proficiency&quot;</td>
<td>WASL RC</td>
<td>Not specified</td>
</tr>
<tr>
<td>McGintey &amp; Hinson (2004)</td>
<td>&quot;Below proficiency&quot;</td>
<td>MEAP</td>
<td>Not specified</td>
</tr>
</tbody>
</table>


Educational Assessment is a Three-by-three World

First Grade End of Year NWF Initial Assessment:
High Risk Some Risk Low Risk

Second End of Year ORF Outcome:
Low Risk Reading Fluency

Some Risk Reading Fluency

High Risk Reading Fluency

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Using Sensitivity or Specificity to Evaluate or Compare Screening Tools is Meaningless

- It is meaningless to compare sensitivity indices on different tests (Swets, 1988) because:
  - Sensitivity depends on the cutpoint for risk that is selected. As we increase the cutpoint, sensitivity increases,
  - But, there is a trade-off. As we increase the cutpoint, the specificity decreases.
  - Area under the Receiver Operator Characteristic (ROC) Curve is the only general index of the accuracy of a screening measure that is independent of the cutpoint selected.
  - However, the ROC curve also depends on having a gold standard of the outcome criterion. For tuberculosis, this is not a problem. For reading skills in an educational context, as we have seen, this is a significant problem.
- At the very least, we need separate ROC curves for high risk outcomes and low risk outcomes.

ROC Curve for Second Grade, End of Year

**ORF Low Risk Outcome**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>.95</td>
<td>.44</td>
</tr>
</tbody>
</table>

Area Under the Curve = .80

Full WG Sample, n = 58811

**ORF High Risk Outcome**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>.62</td>
<td>.82</td>
</tr>
</tbody>
</table>

Area Under the Curve = .82

Full WG Sample, n = 58811

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The Problem of Differences in Baserates

Differences in baserate only do not change the nature of the underlying relation between the screener and the outcome.

- In a context with a greater (lesser) baserate of reading difficulty, more (less) students will be positive on the screener and more (less) students also will be positive on the outcome.
- The underlying relation between screener and outcome would remain the same, and students would move diagonally on the scatterplot.

Estimating Baserate

- In a setting like screening for tuberculosis, because the condition is truly present or absent at the time of screening and the outcome measure occurs before action or treatment,
  - Baserate is best estimated as the percent with a positive outcome on the criterion measure.
- In an educational setting, because the condition does not become present or absent until the outcome assessment and because the outcome is a joint result of initial skills and the instructional context,
  - Baserate is best estimated as the percent with a positive decision on the screening measure.

Relation of Baserate to Decision Metrics

- Screening decision baserate appears to be related to sensitivity and specificity in the mClass 137 district sample.
- A Monte Carlo study was conducted to examine the relation further. The 137 districts in the mClass sample were modeled with bivariate normal random data with identical differences in decision baserate but with no differences in instructional effectiveness.

<table>
<thead>
<tr>
<th>Correlation of index with screening decision baserate</th>
<th>mClass</th>
<th>Monte Carlo</th>
</tr>
</thead>
<tbody>
<tr>
<td>LRD-LRO Sensitivity</td>
<td>.79</td>
<td>.83</td>
</tr>
<tr>
<td>LRD-LRO Specificity</td>
<td>-.93</td>
<td>-.95</td>
</tr>
<tr>
<td>LRO ROC Area Under the Curve (AUC)</td>
<td>-.41</td>
<td>-.12</td>
</tr>
<tr>
<td>LRD-LRO Positive Predictive Power</td>
<td>.40</td>
<td>.90</td>
</tr>
<tr>
<td>LRD-LRO Negative Predictive Power</td>
<td>-.21</td>
<td>-.80</td>
</tr>
<tr>
<td>LRD-LRO Classification Accuracy</td>
<td>-.20</td>
<td>.04</td>
</tr>
<tr>
<td>High Risk Decision Odds of Low Risk Outcome</td>
<td>-.10</td>
<td>-.74</td>
</tr>
<tr>
<td>Some Risk Decision Odds of Low Risk Outcome</td>
<td>-.13</td>
<td>-.79</td>
</tr>
<tr>
<td>Low Risk Decision Odds of Low Risk Outcome</td>
<td>-.21</td>
<td>-.80</td>
</tr>
</tbody>
</table>

Although most indices are expected to be affected by intervening instruction, these metrics are likely to be the most sensitive to differences in Tier 1 instruction and Tier 2 and Tier 3 intervention.

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Educational Decision Making Also Has the Problem of Differential Tier 1 Effectiveness

Less Effective Tier 1 Instruction:
As more students who screened low risk do not achieve the outcome, specificity and sensitivity decrease.

More Effective Tier 1 Instruction:
As more students who screened low risk achieve the outcome, specificity and sensitivity increase.

The Big Ideas

• Differences in baserate only do not change the nature of the underlying relation between the screener and the outcome.
• Differences in the effectiveness of Tier 1 instruction and Tier 2 & 3 intervention change the underlying relation between screener and outcome.
• Increasing the effectiveness of Tier 1 instruction increases measures of sensitivity and specificity.
• Increasing the effectiveness of Tier 2 & 3 intervention decreases measures of sensitivity and specificity.
• Increasing the effectiveness of the schoolwide system (Tier 1, 2, and 3 support) results in chaotic, unpredictable, and uninterpretable changes in measures of sensitivity and specificity.

The Big Ideas

Sensitivity & Specificity Logic Doesn’t Work

Sample District 1

- Decision Baserate: 0.82
- True Negative: 45
- False Negative: 45
- True Positive: 349
- False Positive: 51
- Sensitivity: 0.89
- Specificity: 0.47
- Negative Predictive Power: 0.50
- Positive Predictive Power: 0.87
- Accurate Classification: 0.80

- Consider Sample District 1.
- Are we really comfortable saying these students are “True Positives”? Or are they failures of our Tier 2 and Tier 3 intervention?
Sensitivity & Specificity Logic Doesn't Work

Sample District 2
Decision Baserate 0.81
True Negative 82
False Negative 7
True Positive 223
False Positive 154
Sensitivity 0.97
Specificity 0.35
Negative Predictive Power 0.92
Positive Predictive Power 0.59
Accurate Classification 0.65

• In Sample District 2, students with similar initial skills are achieving adequate reading skills. Does this mean they are “False Positives”? Or are they successes of our Tier 2 and Tier 3 intervention?

• Consider Sample District 1 again.
• Do we really want to consider these students to be “False Negatives”? Or are they failures of our Tier 1 instruction?

• A fundamental problem is that outcomes are not set, fixed, immutable, “true” at the time of screening. Instead, outcomes are achieved by instruction and intervention.

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Design Specifications of DIBELS Cutpoints

- **Primary Specification**: Low Risk Decision on initial DIBELS assessment should result in the favorable likelihood, or odds, (85% +/- 5%) of achieving subsequent reading health outcomes. In other words, a zone where we are reasonably confident the student has adequate skills.
- **Some Risk Decision** on initial DIBELS assessment should result in 50 – 50 odds (50% +/- 5%) of achieving subsequent reading health outcomes. In other words, a zone of uncertainty where we don’t know if the student is on track or not.
- **High Risk Decision** on initial DIBELS assessment should result in low odds (15% +/- 5%) of achieving subsequent reading health outcomes – unless intensive intervention is implemented. In other words, a zone where we are reasonably confident the student does not have adequate skills.

Linking Screening Decisions to Instruction:
The Purpose is to Improve Outcomes

- Likelihood or odds are a proxy for what it would take to change outcomes. What would it take to ruin the prediction?
- **Low Risk**: odds are in favor of achieving subsequent outcomes.
  - Likely to be easier to teach.
  - Likely to need good Tier 1 instruction (no guarantees!).
- **Some Risk**: means we don’t know the likely outcome. If we do nothing special, the odds are 50 – 50. Maybe we should do something to improve the odds?
  - Likely to be harder to teach.
  - Likely to require more resources for success.
  - Likely to require more effective, intensive instruction.
  - Likely to need additional Tier 2 support.
- **High Risk**: means the odds are against achieving adequate outcomes – unless we provide intensive intervention.
  - Likely to be much harder to teach.
  - Likely to require even more resources for success.
  - Likely to require more extremely careful, effective, intensive intervention.
  - Likely to need effective Tier 3 intervention.

High Risk, Some Risk, and Low Risk Decisions

First Grade End of Year NWF Initial Assessment:
High Risk  Some Risk  Low Risk

Second End of Year ORF Outcome:
Low Risk Reading Fluency
Some Risk Reading Fluency
High Risk Reading Fluency

- High risk, some risk, and low risk likelihood of outcomes (odds) vary with instructional context in interpretable ways.

Sample District 1

- If fewer students with a low risk screening decision achieve the outcome than expected, we would want to examine instruction.
- If fewer students with a high risk or some risk screening decision achieve the outcome than expected, we would want to examine interventions.
Educational Context is Fundamentally Different from Screening for TB

- Sensitivity and specificity may not make sense as primary evaluation metrics in an educational context:
  - The outcome is not a true dichotomous state that is present or absent. Reading skills are a continuum. There are a group of students we have reasonable agreement are on track for reading; a group of students we have reasonable agreement are not on track for reading; and a group of students whose reading status is uncertain:
    - (a) we can’t agree on a point that separates ok and not ok.
    - (b) a student who is above any point on one test may not be above the corresponding point on a different measure.
    - (c) students close to any point may be more similar than different.
  - There is not a gold standard for determining the true state. The true state is a value judgment that depends on measurement, social, and political context.
  - The true state does not exist at the time of screening, but becomes as a result of the effectiveness of instruction and intervention.
  - Whether the true state eventuates depends on the instructional context. The linkage/relation between screening (initial assessment) and outcome depends on the instructional context.
  - Treatment/action is or should be differentiated based upon student need.
  - False negatives should be minimized. False negatives are less desirable than false positives. We don’t want to miss an opportunity to provide instruction to a student that helps put the odds in their favor of becoming a reader.

ROC Done Right

- Sensitivity and Specificity are fatally flawed as a means of evaluating an educational screening measure.
- ROC and area under the curve are interesting pieces of information to consider in evaluating the functioning of a screening measure in an educational context, but they may not be desirable as the primary consideration.
- A more desirable primary consideration may be the likelihood or odds, given initial skill level, of achieving an outcome where there is reasonable agreement the student has adequate reading skills.
- Screening Decision Baserate may affect all of the decision metrics.
- Evaluations or comparisons of instructional effectiveness may be most defensible when decision baserates are comparable or considered.