Using Effect Size Measures to Estimate and Report Achievement Gaps

Joseph Stevens
Daniel Anderson
Joseph Nese
and
Gerald Tindal
University of Oregon

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Presentation Purpose

- Describe methods:
  - For estimating achievement gaps
  - To more effectively interpret and report gaps including both common and rarely used methods to estimate effect size (ES)
- Demonstrate these methods using:
  - Operational state accountability data from several states in math and reading
  - Achievement differences between several student subgroups
  - Longitudinal academic growth data

(Contact information and acknowledgements at end)

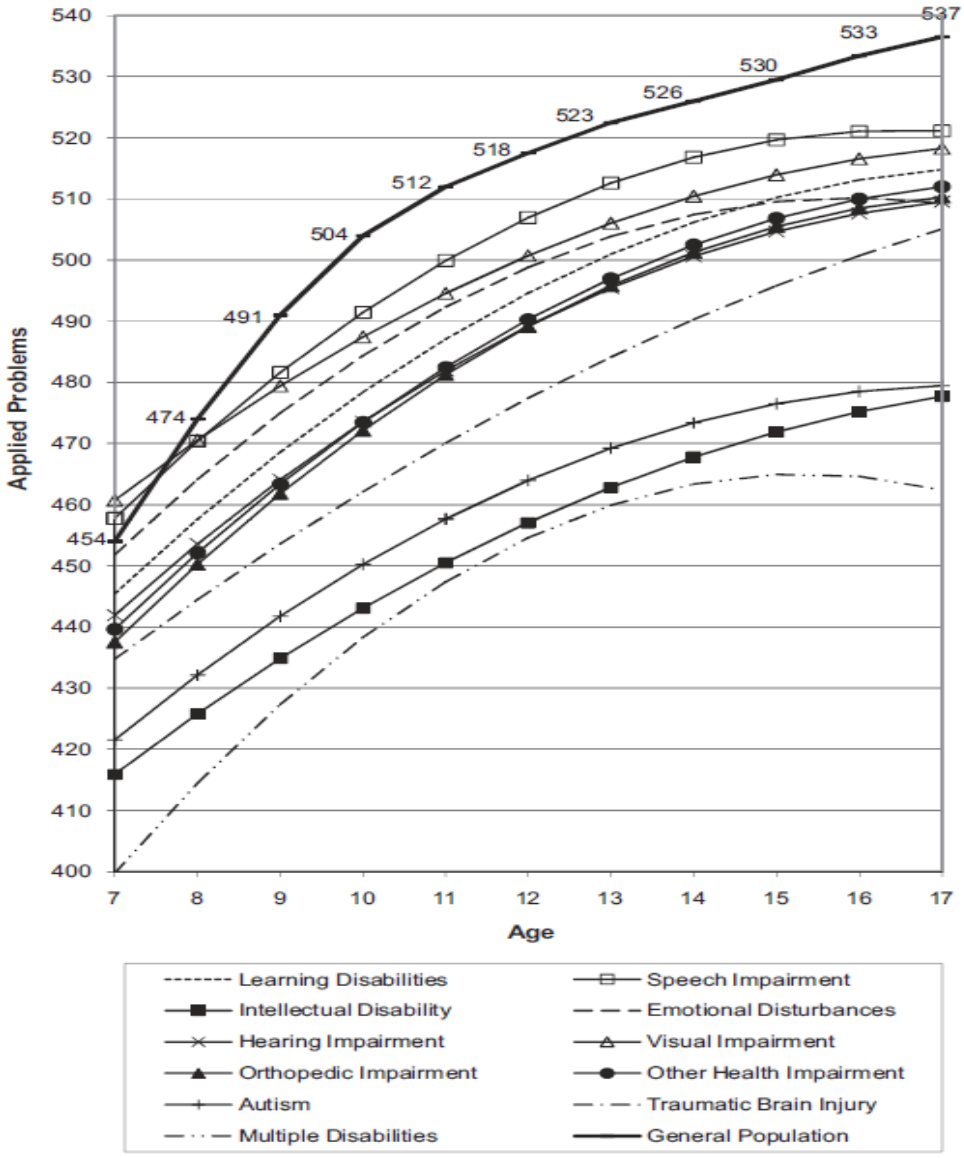
Presentation available at: http://pages.uoregon.edu/stevensj/NCME.pdf

Current Practice

- Substantial room for improvement in the way assessment and accountability information about student achievement and gaps between student subgroups is reported and interpreted
- Many researchers, state and local analysts of accountability data, and policymakers:
  - Interpret group differences by visual inspection and other subjective methods
  - Do not consider where in the distribution the comparison is made, characteristics of the outcome scale, or distribution issues that can substantially impact conclusions about growth and/or gaps

http://pages.uoregon.edu/stevensj/NCME.pdf

Example of a Recently Published Study Using Visual Inspection of Results



Research and Reporting on Student Achievement Gaps

- As part of NCLB, one of the most common methods for reporting achievement gaps is the difference in percent proficient between two groups (P-P)
- Several shortcomings of this approach however:
  - Group differences often evaluated only at one point in distribution (proficiency cutpoint or sample mean)
  - Because P-P ordinal, units may be different at different locations on the scale; thus size of gaps may be due to differences in units rather than performance
  - Methods may require normally distributed data for both groups; thus size of gap may depend on differences in shape of score distributions

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Characteristics of Good Metrics for Comparing Differences Over Time or Between Groups

- Objectivity - comparisons should not be based on visual inspection or subjective interpretation of data
- Metric should clearly represent the magnitude and direction of the difference of interest
- Scale independence - size of difference should not be influenced by units of the particular scale
- Sample size invariance - size of difference should not be influenced by *N* size of groups or study
- Common scale – difference should be expressed on a scale that is common across comparisons or studies

Empirical Examples Presented Here

- In interests of time, no discussion of details on samples and instruments in this presentation
  - Data presented based on NCAASE work examining four state accountability systems over time (see website)
  - See Schulte et al. and/or Stevens et al. (see references at end) for details on state databases and state assessment instruments behind some of the examples presented here

The Standardized Mean Difference: Cohen's *d*

(note additional variations like Hedges' *g* not discussed here)

$$\text{Cohen's } d = \frac{\bar{X}_1 - \bar{X}_2}{s_{pooled}}$$

Where:

$$s_{pooled} = \sqrt{\frac{s_1^2(n_1 - 1) + s_2^2(n_2 - 1)}{n_1 + n_2 - 2}}$$

Examples of ES gap and ES for change over time

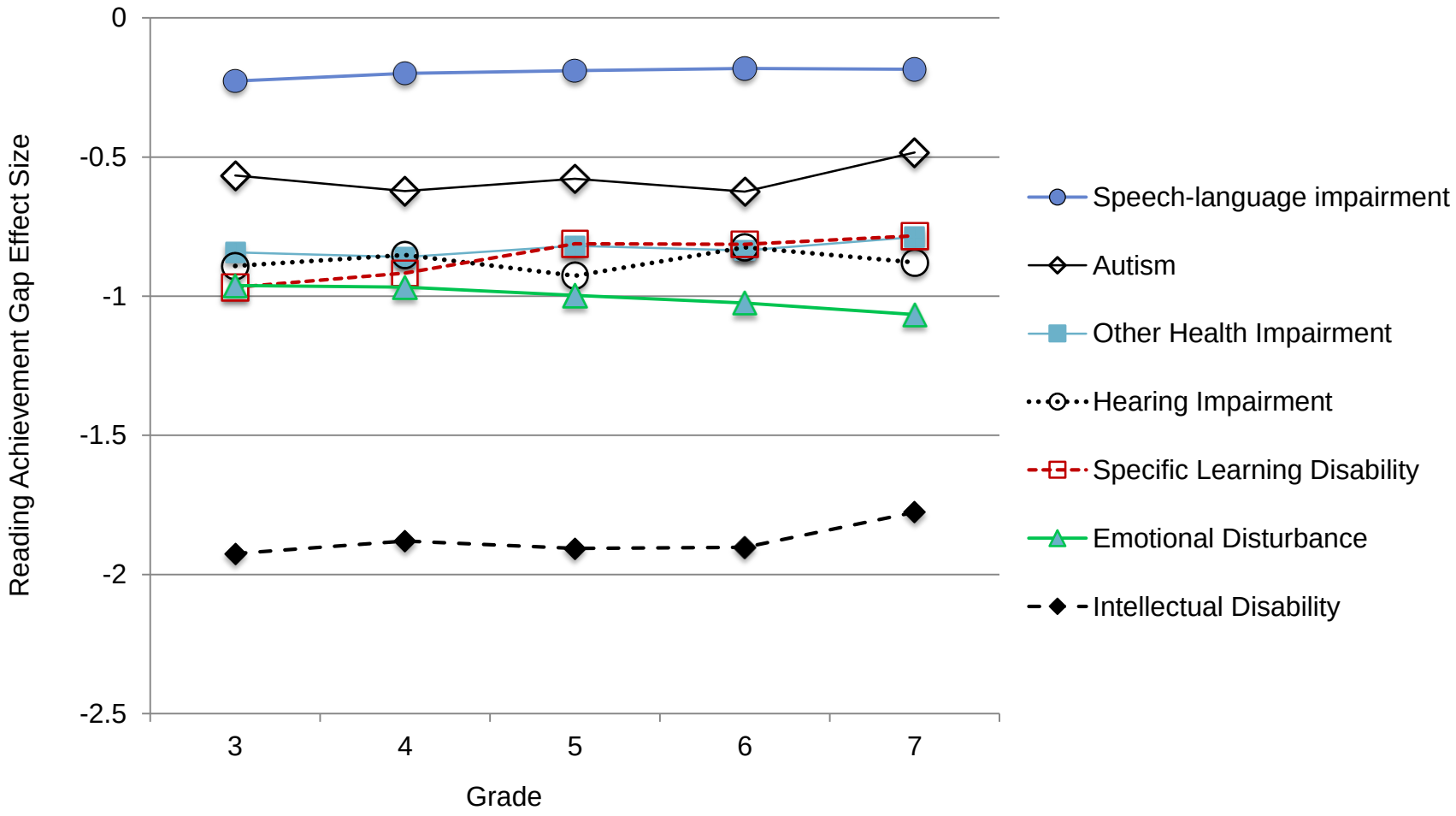
- Bloom, Hill, Black, & Lipsey, 2008:
  - Achievement gap:

    Same as Cohen's d on previous slide except that SD used is the standard deviation of all participants in that grade/occasion (no longer pooling of just the two groups of interest but estimate of population value of the outcome)

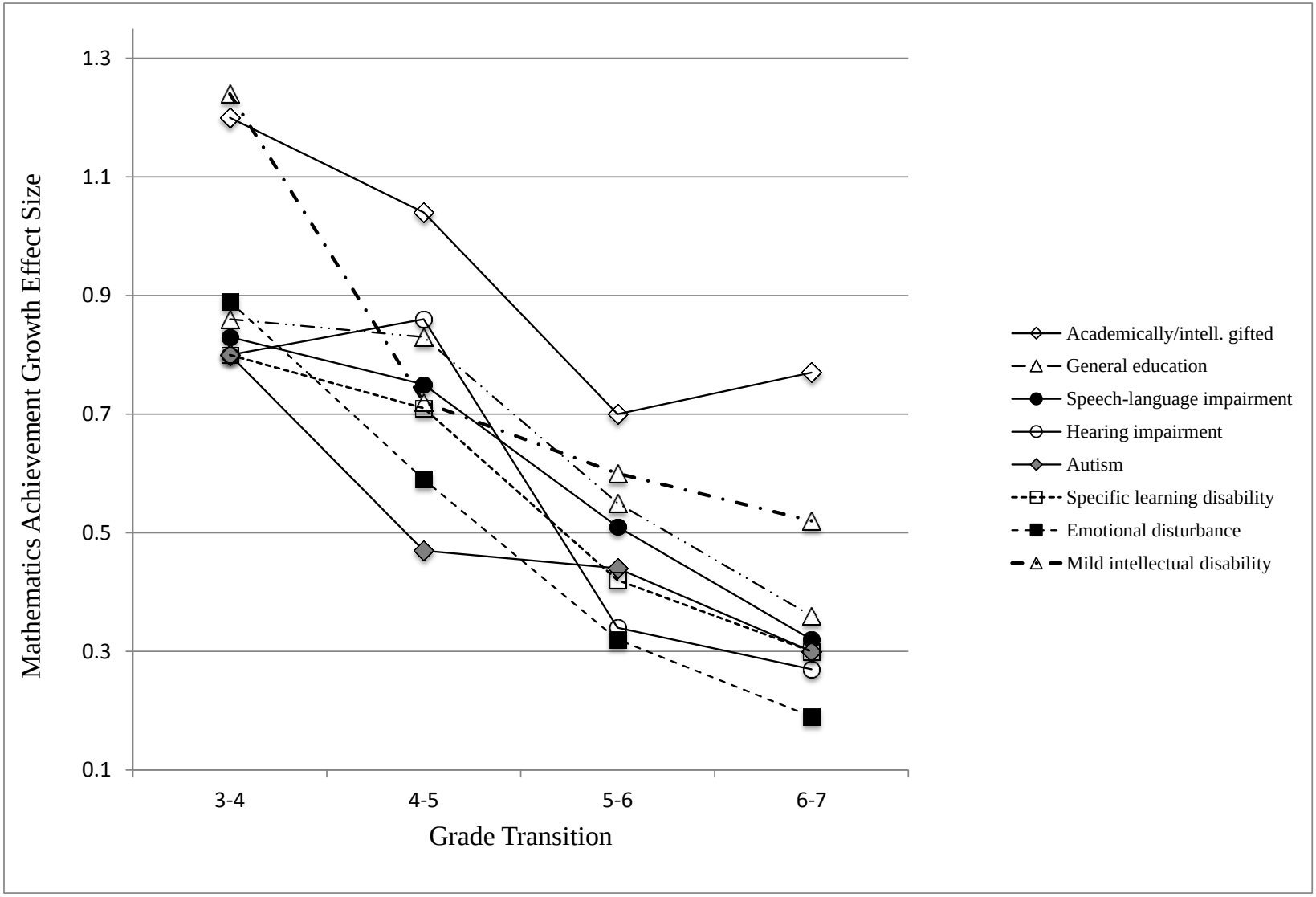
  - Change over time:

    Year-to-year "transition" ESs by examining the mean difference in a group from one year to the next in ratio to the pooled standard deviation for the two years for the group of interest
- Illustrated on next slides

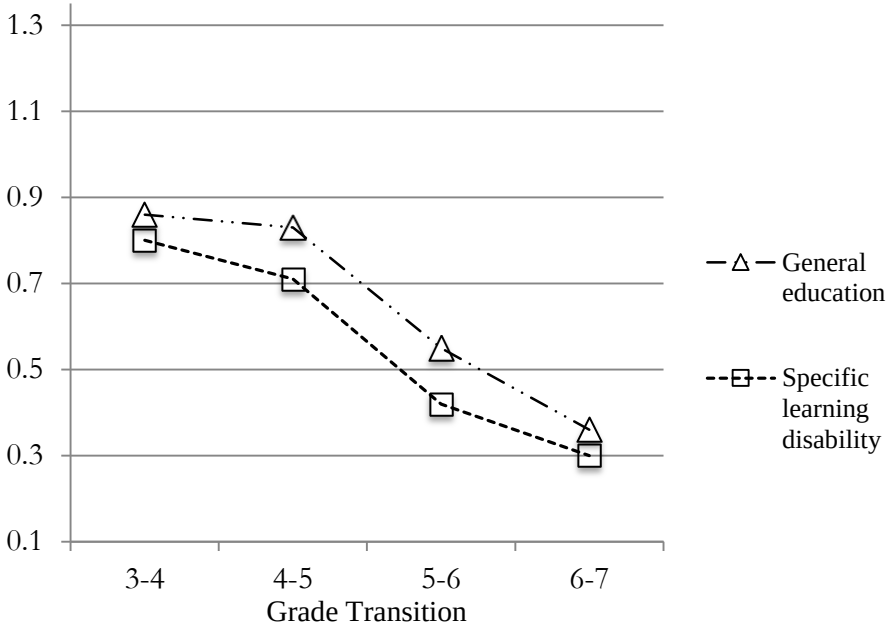
Reading Achievement Gap ES between SWD Groups (compared to regular education students)



ES for Change Over Time by Group



ES for Change Over Time by Group: Calculations

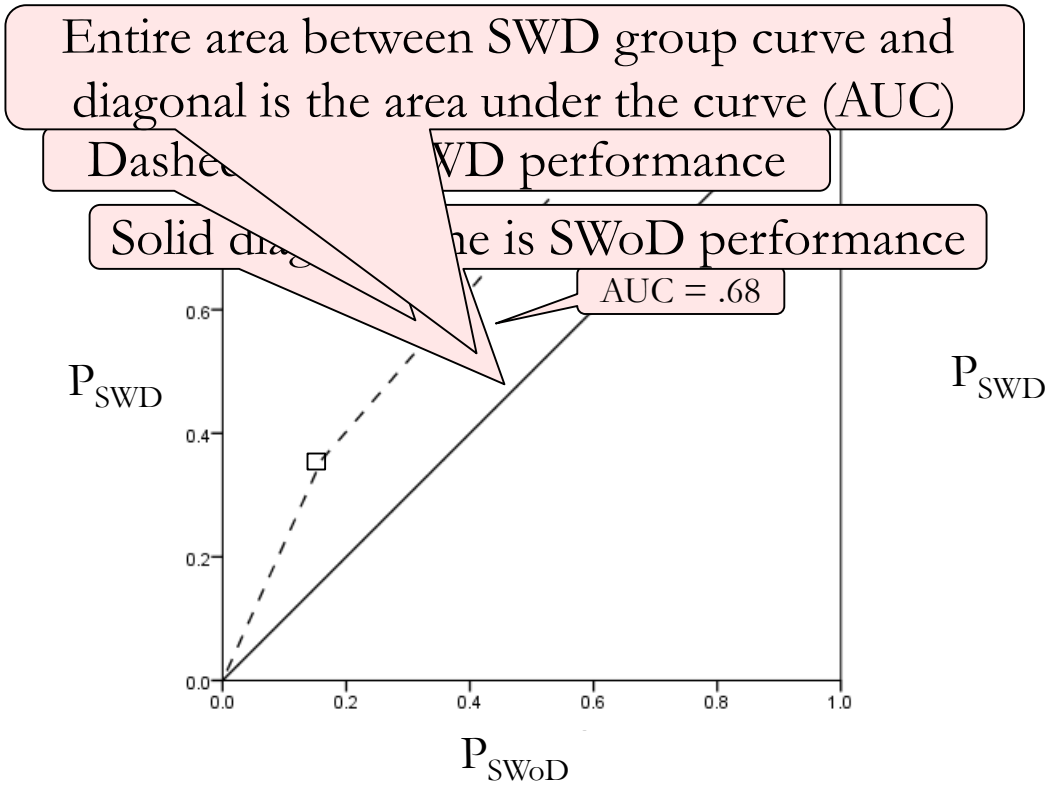


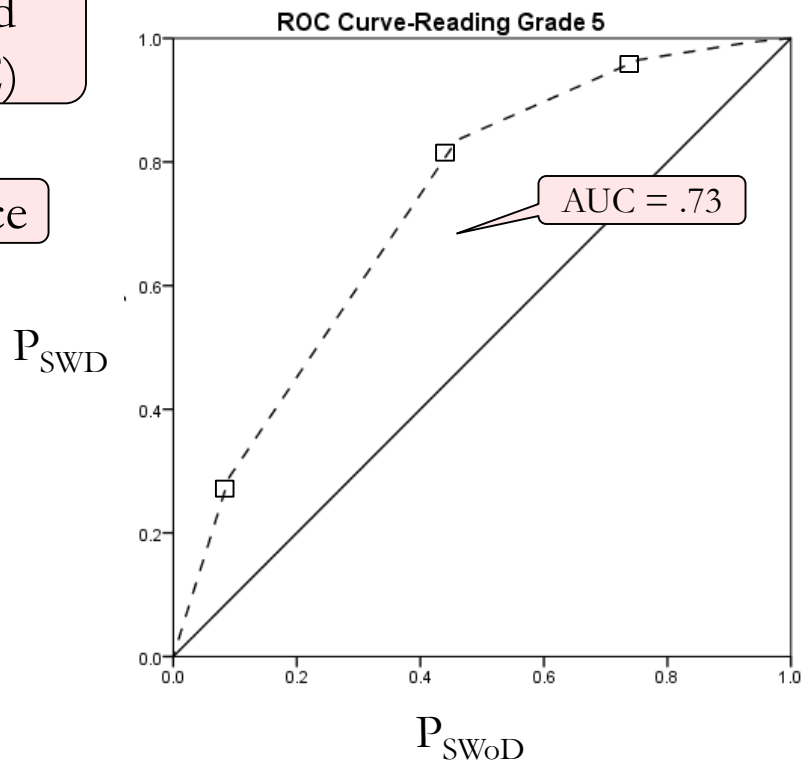
	General Education					Specific Learning Disabilities			
Grade	Mean	SD	$\overline{X}_{t+1} - \overline{X}_t$	Transition ES		Mean	SD	$\overline{X}_{t+1} - \overline{X}_t$	Transition ES
3	251.17	6.90				247.03	6.80		
4	257.04	7.61	5.87	0.810		252.23	7.08	5.20	0.750
5	263.06	7.92	6.02	0.776		257.22	8.07	4.99	0.657
6	267.16	8.34	4.10	0.504		260.28	8.44	3.06	0.371
7	269.98	9.95	2.82	0.308		262.44	9.11	2.16	0.246
		Mean:	**4.70**	**0.599**				**3.85**	**0.506**

Achievement Gaps as Areas Between Score Distributions

- As noted above, a limitation of traditional measures is they only compare groups at the mean or at the proficiency cutpoint, possibly overlooking important group differences lower or higher on the score scale
- Alternative ES measures use whole score distribution and some also accommodate ordinal scales (e.g., proficiency categories; see Ho & Reardon, 2012):
  - Area under the curve (AUC) in Receiver Operating Curve (ROC) analysis
  - V statistic, $V = \sqrt{2}\ (\Phi^{-1})(P_a > P_b)$
- Because of time constraints, we only report a few examples of these analyses

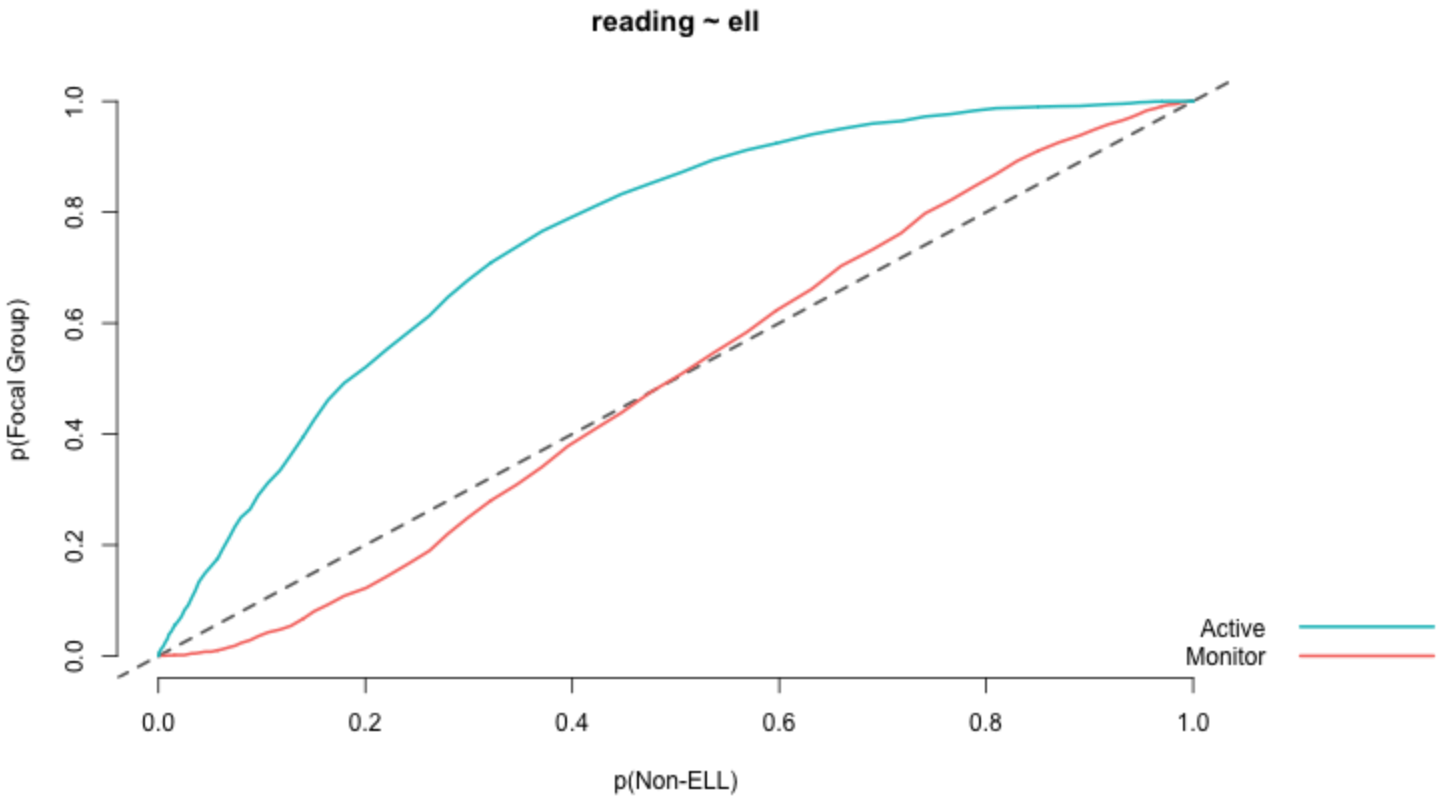
Achievement Gap for SWD vs. SWoD in Oregon Reading in Grade 3 (on left) and Grade 5 (on right)





Whole Distribution Comparisons of Achievement for ELL and Former ELL (monitor) students

(Non-ELL students on Diagonal)



esvis R package (Anderson, see appendix)

ES for Growth

- In addition to Bloom's "transition" ES described earlier, can estimate model-based growth ES using HLM or SEM methods
- There are several growth effect size calculations and variations discussed in literature:

$$\pi_{10} / \mathrm{SD}_{\mathrm{outcome}}$$

  - Note that choice of SD depends on purpose, SD at wave 1 (baseline) is one common choice, but note that SD's may vary over occasions; SD at last occasion or SD pooled over occasions also can be used
  - Also note that ES formulas for estimating power in SEM and HLM, e.g., $\pi_{10} / (\tau_{11}^{1/2})$, are not appropriate as a measure of ES (see Feingold, 2009)

ES for Growth

- Growth rate same at any occasion in a linear model
- In a quadratic model, growth rate differs depending on centering of time (e.g., initial, average, ending) or analytic interest in a particular occasion
- Quadratic growth rate (QGR):

$$\text{QGR} = \pi_{10} + 2(\pi_{20})(\text{time})$$

- Quadratic ES:

$$\text{QGR} / \text{SD}_{\text{outcome}}$$

- Also note differences between unconditional and conditional ES in growth models (latter in contrast to traditional meta-analysis)

Linear Growth Models

Model	π_{10}	Growth Rate	ES Grade 3 SD	ES Grade 5 SD	
Uncond. linear	4.762	4.762	0.690	0.602	*
Cond. linear	5.005	5.005	0.725	0.632	

* Note that calculation of the "power" formula for growth ES results in an overestimate:

$\pi_{10} / \tau_{11}^{1/2} = 4.762/\sqrt{1.272} = 4.222$

Quadratic Growth Models

Model	π_{10}	π_{20}	Growth Rate Grade 3	Growth Rate Grade 5	Growth Rate Grade 7	ES-Grade 3 SD Grade 3	ES-Grade 3 SD Grade 5	ES-Grade 3 SD Grade 7	ES-Grade 5 SD Grade 3	ES-Grade 5 SD Grade 5	ES-Grade 5 SD Grade 7
Uncond. Quadratic	6.925	-0.546	6.924	4.741	2.558	1.004	0.687	0.371	0.875	0.599	0.323
Cond. Quadratic	7.051	-0.518	7.051	4.978	2.905	1.022	0.721	0.421	0.891	0.629	0.367

Conclusions

- Subjective methods like visual inspection to be avoided
- Critically important to apply more sophisticated comparisons than P-P to characterize achievement growth and/or gaps
- Take purpose of estimating gaps or characterizing growth into account in choosing the best metric or calculation
- Consider performance at multiple points in distribution
- Consider scale and distributional characteristics
- Clearly report method/formula for calculating ES and be specific about what SD is used in denominator

Contact Information:

Joseph Stevens, Ph.D.
College of Education
5267 University of Oregon
Eugene, OR 97403
(541) 346-2445
stevensj@uoregon.edu

Presentation available at: http://pages.uoregon.edu/stevensj/NCME.pdf

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Selected References

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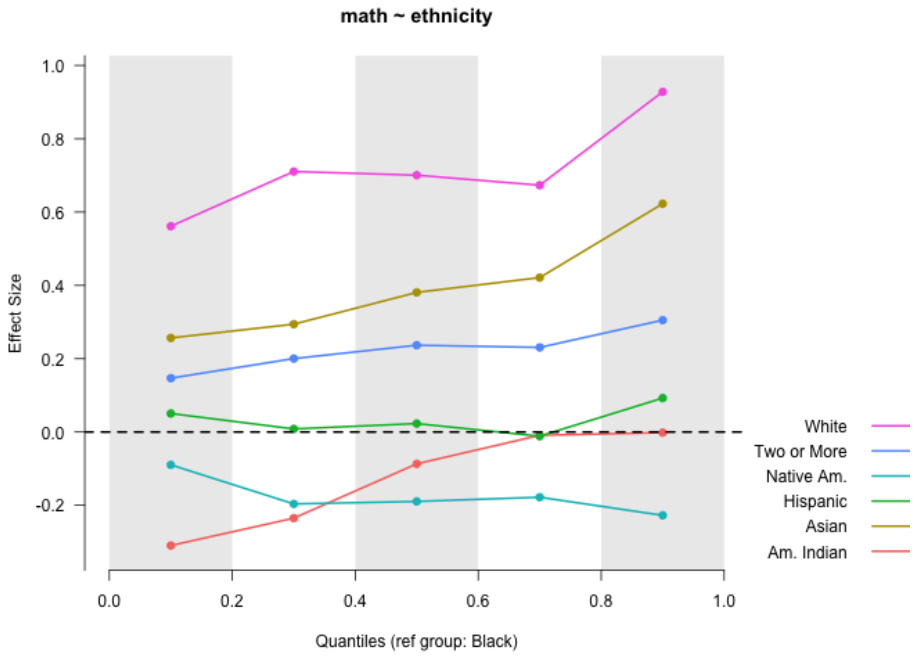
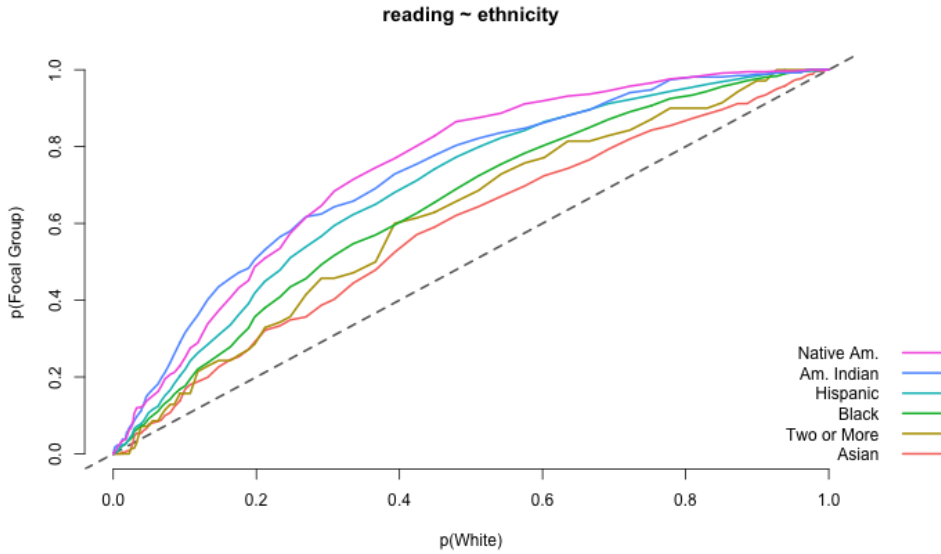
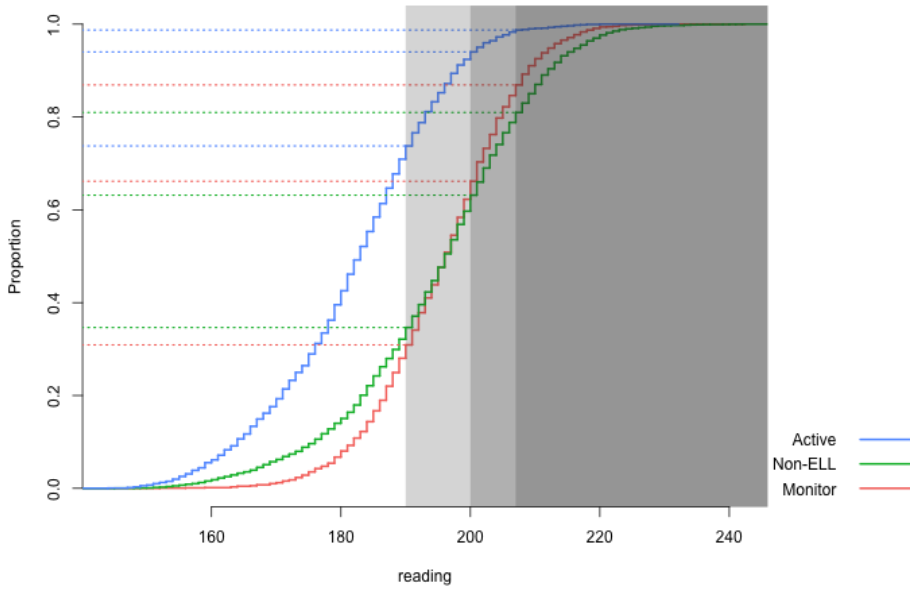
Stevens, J. J., Schulte, A. C., Elliott, S. N., Nese, J. F. T., & Tindal, G. (2015). Mathematics achievement growth of students with and without disabilities on a statewide achievement test. *Journal of School Psychology, 53*, 45-62.

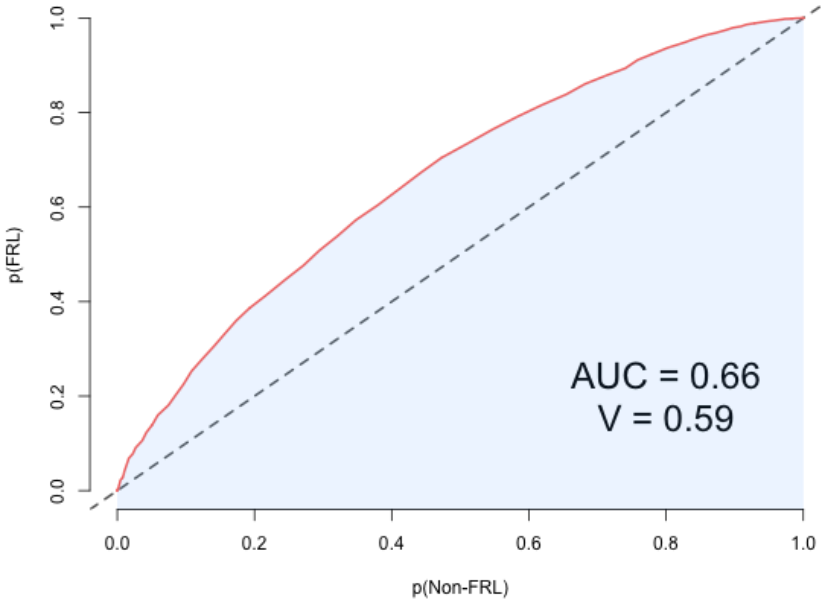
Appendix

Group Comparisons and ES Measures Available From esvis Package









esvis R package (Anderson)

- Plots
  - PP, ECDF, Quantile-binned ES
- Effect sizes
  - Cohen's *d* & Hedges' *g*
  - PAC and TPAC
  - AUC and *V*
- Still under active development
  - Release to CRAN planned for summer

- Install from github

```
install.packages("devtools")
devtools::install_github(
"DJAnderson07/esvis")
```

- Consistent syntax

```
pp_plot(outcome ~ group,
    dataset)
ecdf_plot(outcome ~ group,
    dataset)
binned_plot(outcome ~ group,
    dataset)
coh_d(outcome ~ group,
    dataset)
```