

Policy Relevant Visualization and Analysis of LDS Data With Open Source Tools

Jared Knowles

Policy Research Advisor
Wisconsin Department of Public Instruction

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Outline

- 1 What is Policy Relevant Analysis?
 - Defining Terms
 - The Problem
- 2 Extracting Meaning from Data
 - Why is Data Analysis So Important?
 - Barriers to Data Analysis
 - What is the solution?
- 3 Introduction to R
 - What is R?
 - What can R do?
- 4 R Examples
 - Getting StaRted
 - Advanced Extensions of R
- 5 Policy Analysis Tools
 - Statistical Modeling
 - Linear Model Example
- 6 Putting It Together to Collaborate
 - Same Data, Similar Analyses
 - Coordinating and Social Coding
- 7 Conclusion

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Defining Terms

Policy relevant analysis is answering questions that inform policy in a timely fashion and presenting results in an accessible and engaging fashion.

The Big Questions

- States and LEAs have an abundance of data, but how do we extract meaning from it?
- Can we do data analysis fast enough to inform decisions and improve outcomes?
- Can we produce analyses that are approachable to policy makers and the public so that they galvanize change?
- Can we do these things in a time of reduced staffing, decreased budgets, and a shortage of time?
- Can we do analyses under constraints that remain rigorous and valid and provide accurate information?

Example

The state chief school officer asks:

“Do our state bilingual-bicultural programs provide any benefit to our students? Should we focus on ESL more or keep our BLBC programs?”

Options?

Option

- Contract with university faculty

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- Contract with university faculty
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Caveats

- This will take months. Budget proposal is due in three weeks. Costly.

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Or Ask Jen



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Not Enough Jen's



How do we do more?

What tools exist to help us turn data into usable information that informs decisions?

Policy Research

Summary

An approximate answer to the right problem is worth a good deal more than an exact answer to an approximate problem.

John Tukey

Policy Relevant Research is FAST



Policy Relevant Research is FOCUSED



Policy Relevant Research is APPROXIMATE



Policy Research

Policy research is...

- Fast
- Narrowly focused
- Approximate
- Fast

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- Focused on precision
- Peer-reviewed

Policy Research Is Not...

- A visualization and summary statistics
- Descriptive statistics organized with some text
- Ignorant of policy limitations and context

But it also is not:

- Focused on purely causal relationships
- Overly concerned with precision of estimates
- Irrefutable

Examples from One State

In Wisconsin we have done a few analyses that have helped us make decisions.

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- An analysis of feeder patterns for teacher supply from teacher prep programs

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Gathering More Data

- States and districts collect hundreds of attributes about millions of students
- Data is collected before children reach school age and after they have moved to a college or a career
- Patterns may inform how choices in policy will affect the population
- Lessons learned can help us build simulations to weigh policy outcomes before making decisions—decision support

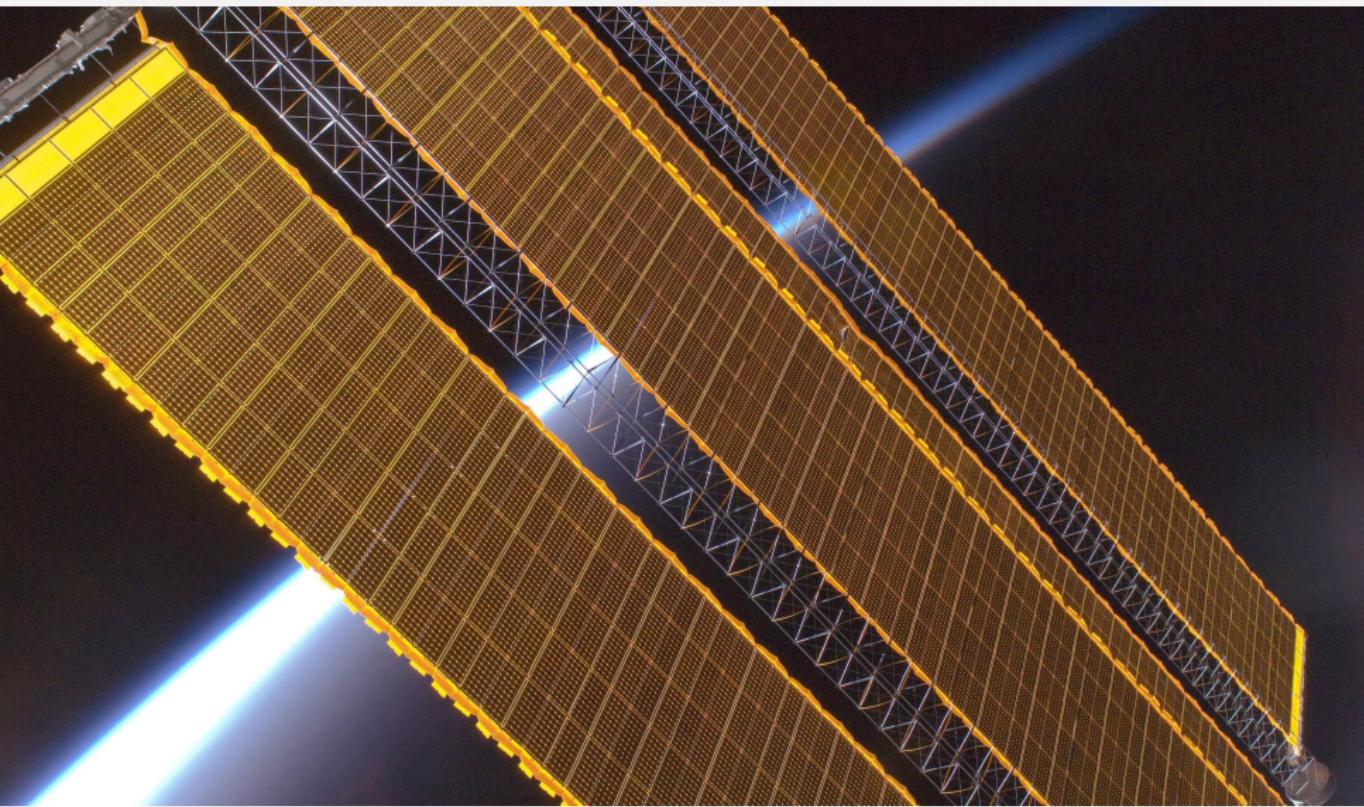
Data is like ore



Analysis concentrates its value



And it can be used to produce something



How?

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Institutional Frustrations

We just need to get our jobs done. We need to do them efficiently, but also transparently and in a reproducible manner. This is currently costly in time, money, and management resources.



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- Acquiring proprietary tools from vendors takes agreements, legal documents, and lag time
- Sharing data with external researchers requires legal agreements, levels of management approval, and planning time to specify narrow scope



Institutional Frustrations

- Analyses are often done in proprietary tool sets, poorly documented, and unable to be reproduced with updated data later



Analyses Don't Get Used

Often when we do an in house analysis it does not get used to support decisions.

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Incoherence

age draw further modifications of the unit printed on page N. — at the left a



FIG. 1.

Or we do the wrong analysis

Sometimes analyses are done at the whim of an analyst or two and not tied to the needs of decision makers or stakeholders

Irrelevant



UNSERE GÄRTEN

GOLF KILLS

www.wien.at



Gartenbezirk 7



Wiesen



Munden



Munden



LICHTTELEFON
797 75-8033



Example

The state chief school officer asks:

“Do our state bilingual-bicultural programs provide any benefit to our students? Should we focus on ESL more or keep our BLBC programs?”

Instead we answer:

- Our ELL students are doing better than last year.
- National research is inconclusive on these programs.
- Our data shows participation is up in BLBC programs.
- We found a researcher to help with this in six months.

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Open Source Tools

A wide-angle photograph of a lush green hillside under a bright blue sky filled with fluffy white clouds.

R

R

```

66 vars<-c("linkdensity", "sd_degreedist", "apl", "diameter", "mean_diameter", "sd_diameter", "mean.cons_omnivory", "skew.cons_trophiclevel",
67 for(o.var in vars){
68   newrow<-new.omnivary.row(c(o.var, alpha=alpha)
69   slopes<-rbind(slopes, newrow)
70 }
71
72
73 #write.table(slopes, file="removal_group.slopes.csv", sep=",", row.names=F)
74 write.table(slopes, file="removal_sp.slopes.csv", sep=",", row.names=F)
75
76
77 dfitfb<-rep(NA, 6)
78
79 vars<-c("linkdensity", "sd_degreedist", "apl", "diameter", "mean_diameter", "sd_diameter", "mean.cons_omnivory", "skew.cons_tropiclevel",
80 for(o.var in vars){
81   dfd<-dfc$subset(removal_data, removal_datayear==2008)
82   lm<-lm(dfc[[o.var]] ~ IC[,o.difchange])
83   o.dfc<-subset(removal_data, removal_datayear==2009)
84   lm<-lm(dfc[[o.var]] ~ IC[,o.difchange])
85   o.dfc<-subset(removal_data, removal_datayear==2010)
86   lm<-lm(dfc[[o.var]] ~ IC[,o.difchange])
87
88   difs<-slope_compare(lm1, lm2, tailed=1)
89   names(diftfb)<-c("var", names(difs))
90   difftfb<-rbind(diftfb, c(o.var, difs))
91 }
92
93 difftfb<-diftfb[1,]
94 write.table(diftfb, file="removal_slope_change.csv", sep=",", row.names=F)
95
96

```

```

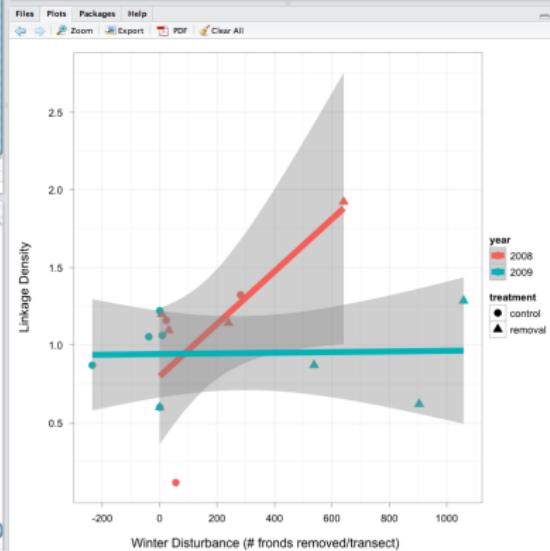
93 #graphing
94 library(ggplot2)
95 #tiff("removal_slopes.tiff", units="px", width=2000, height=1400, res=300)
96
97 gplot<-c1change, richness, data-removal_data, colour-year, shape-treatment, group-year, xlab="\\nWinter Disturbance (# fronds removed/transc
98 scale_lineetype("Year")-scale.colour,grey("Year"), start=0, end=0.5)-stat_smooth(method="lm", size=2, fill="grey55")-
99 scale.colour,grey("Year", start=0, end=0.5)-scale.colour,brewer("Year", palette="Set1")
100
101 gplot
102 #dev.off()
103
104 gplot<-c1change, linkdensity, data-removal_data, colour-year, shape-treatment, group-year, xlab="\\nWinter Disturbance (# Fronds removed/transc
105 gplot<-c1change, sd_degreeist, data-removal_data, colour-year, shape-treatment, group-year, size=5)+theme_bw() + stat_smooth(method="lm")
106 gplot
107
```

```
[1] "linkdensity"
[2] "sd_degreestd"
[3] "opl"
[4] "diameter"
[5] "mean_diameter"
[6] "sd_diameter"
[7] "mean_cons_omnivory"
[8] "skew_cons_trophiclevel"
[9] "mean_cons_trophiclevel"
[10] "power_exp"
[11] "prey_richness"
[12] "consumer_richness"
[13] "algae_richness"
[14] "sessile_invert_richness"
[15] "mobile_species_richness"
[16] "proportion_fruit" function "slope_compare"
> opl <- tchamp(linkdensity, datremoval_dots, colour=year, shape=treatment, group=year, xlab="v0#Inter Disturbance (# fronds removed/seedling)", ylab="Linkage Density", size=15) tchamp.hm(qplot.size=15) tchamp.smooth(method="lo", size=4)
```

```

worse<-c("lwdensity", "lndensity", "apl", "diameter", "mean_diameter", "sd.diameter", "mean.co
for(a.var in vars){
  a.df<-subset(removal_data, removal.dateyear>=2008)
  lnt<-lm(a.df[,a.var]-Ic~tfa$dfChange)
  a.df<-subset(removal_data, removal.dateyear>=2009)
  lnt<-lm(a.df[,a.var]-Ic~tfa$dfChange)
  dfss<- slope.compare(lm1, lm2, tolled=1)
  names(dfss)  
names(lnt$fb)<-c("var", names(dfss))
  dfltab<-bind(dfltab, c(a.var, dfss))
}
dfltab<-dfltab[1,]
write.table(dfltab, file="removal_slope_change.csv", sep=",", row.names=F)
g
#Graphing
library(ggplot2)
tiff("filenames/removal_slopes.tiff", units="px", width=2000, height=1400, res=300)
gplot1<-change_richness, richness, data=removal_data, colour=year, shape=treatment, group=year, xlab="\"Winter Disturb
scale_line_type("Year")+scale_colour_grey("Year", start=0, end=0.5)+scale_shape("Year", start=1, end=0.5)+scale_color_brewer("Year", palette="Set1")

```



R As Part of the Solution

Objections to Data Analysis

- Costly
- Slow and Time Consuming
- Technical and complex
- Opaque and not actionable

The R Solution

- R is free and open source
- R allows reproducible and sharable analysis across researchers
- R can be scripted to do common tasks
- R is a lingua franca that standardizes common tasks

Caveats

But wait...? Isn't R?

Confusing?



Full of Bugs?



Inefficient?



The Truth

- The short answer is no.

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- R has some quirks, but all software does.
- And, R can be amazingly more efficient through collaboration and sharing of code and tools.

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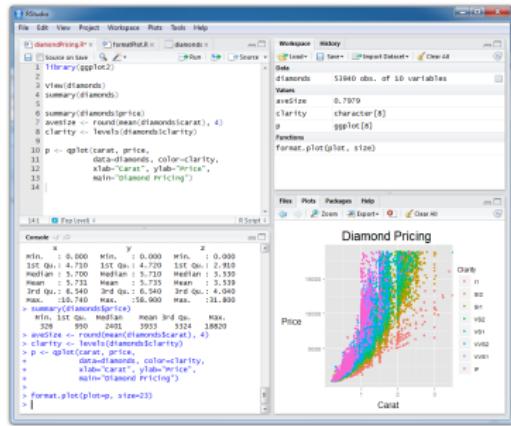
- R is an Open Source (and freely available) environment for statistical computing and graphics
- Available for Windows, Mac OS X, and Linux
- R is being actively developed with two major releases per year
- R can be extended with 'packages' that contain data, code, and documentation to add new functionality
 - 'SGP package' to calculate Student Growth Percentiles
 - 'googleVis' package to build Google Visualizations easily out of data
 - 'ggplot2' package to build attractive custom data visualizations

More Support for R

- R is a common tool among data experts at major universities
- No need to go through procurement, R can be installed in any environment on any machine and used with no licensing or agreements needed
- R source code is very readable to increase transparency of analyses
- R code is easily borrowed from and shared with others
- R is incredibly flexible and can be adapted to specific local needs
- R is under active development, improving greatly, and supported strongly by both professional and academic developers
- R is top of the line best in class statistics software maintained by professional statisticians and supported by an active user community

Using R

- R can be used with an excellent Integrated Development Environment
- RStudio makes many of the basic tasks in R much easier like
 - Importing data
 - Previewing plots
 - Version control
 - Collaboration
- Greatly increases ease of use



Pros and Cons of R

Pros of R

- Open source and freely available on all platforms
- Scripting for reproducible and transparent analyses
- Extensible to fit skills, needs, and cutting edge techniques
- Excellent graphical and output capabilities

Cons

- Steep learning curve and command line interface
- Requires specific inputs to get desired results
- Unforgiving of misspecification of inputs
- Data input can be tricky at first

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- Easy to understand how calculation is done protecting against discontinuity if staff turnover
- Other reports and data analyses are being standardized—quality checks on LDS data, etc.
- More time to do policy research, more transparent data analyses that can be reproduced, accumulation of a knowledge base

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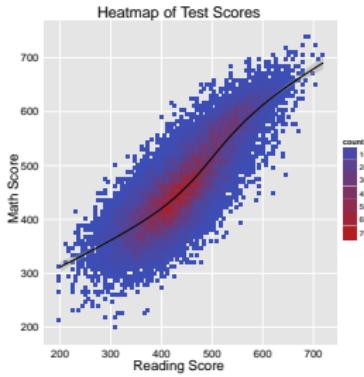
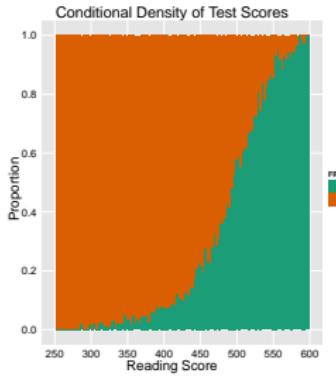
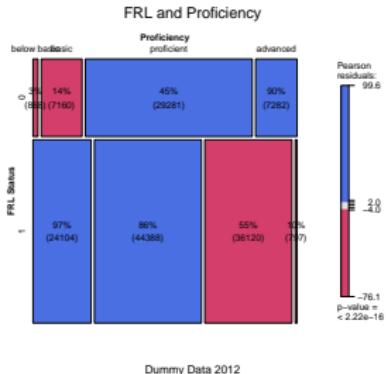
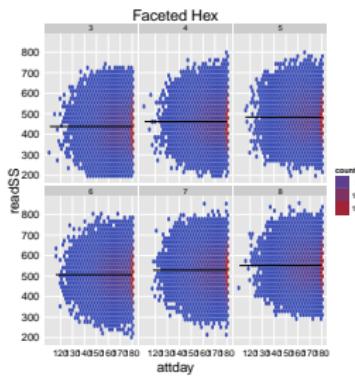
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Visualization

One of the major strengths of R is its ability to create informative and compelling visualizations of data.

Examples of R Figures



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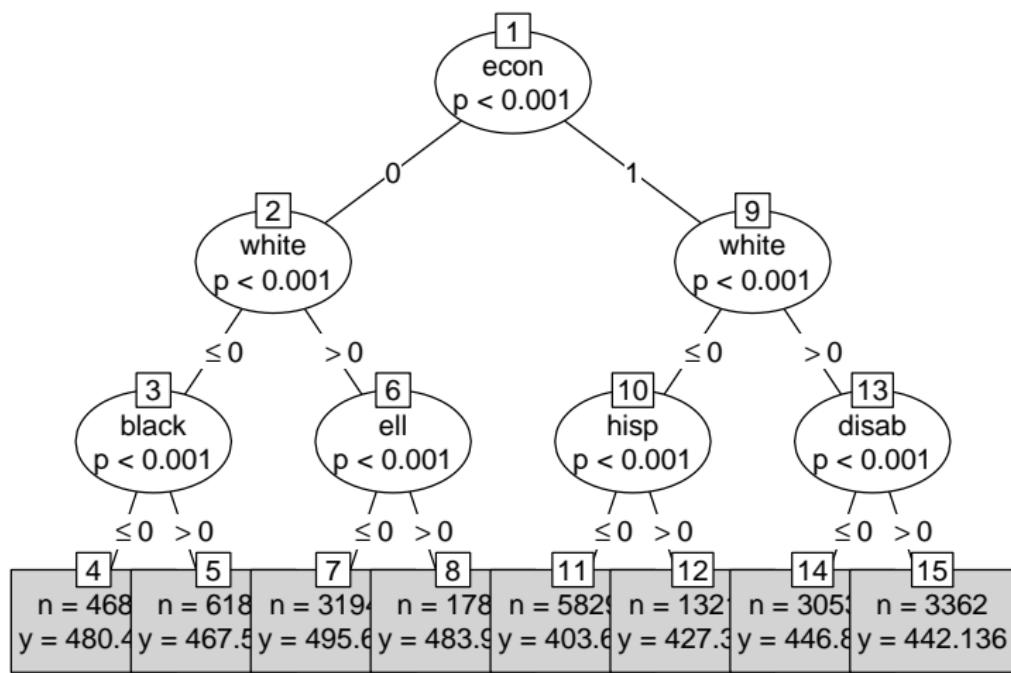
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Inference Trees

Splitting Categorical Data



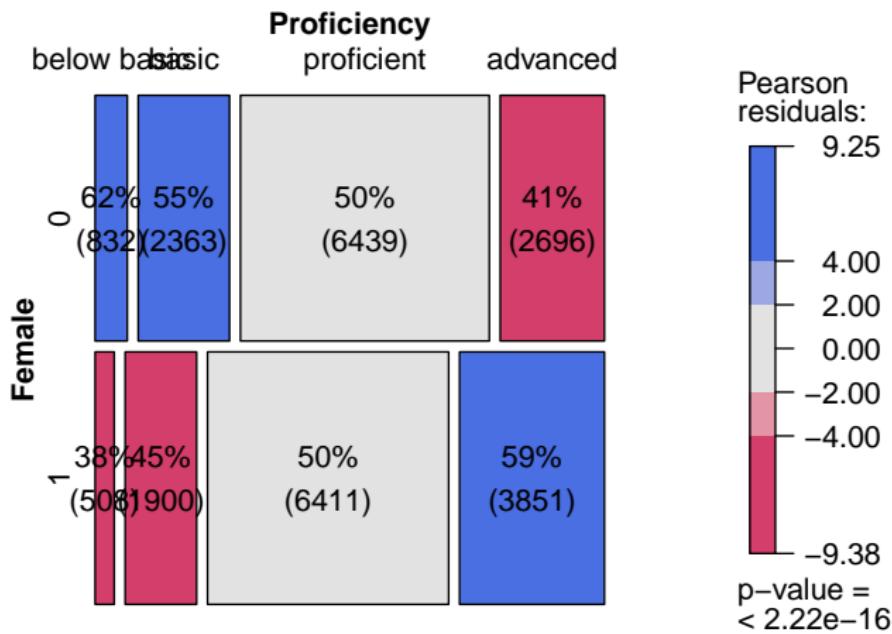
Easy Code for Plot

Code to make this plot:

```
> z1<-ctree(readSS~black+hisp+asian+indian+white+ell+disab+econ  
+           +attday,data=subset(student_long,year=='2000',grade=5),  
+           controls=bonf)  
> plot(z1,type='simple',main="Splitting Categorical Data")
```

Visual Crosstabs

Gender and Proficiency

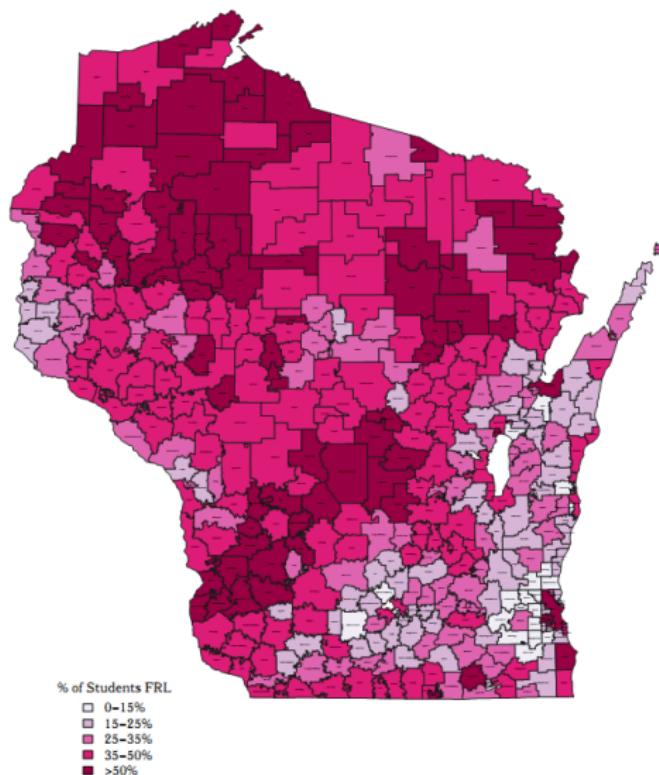


R Code

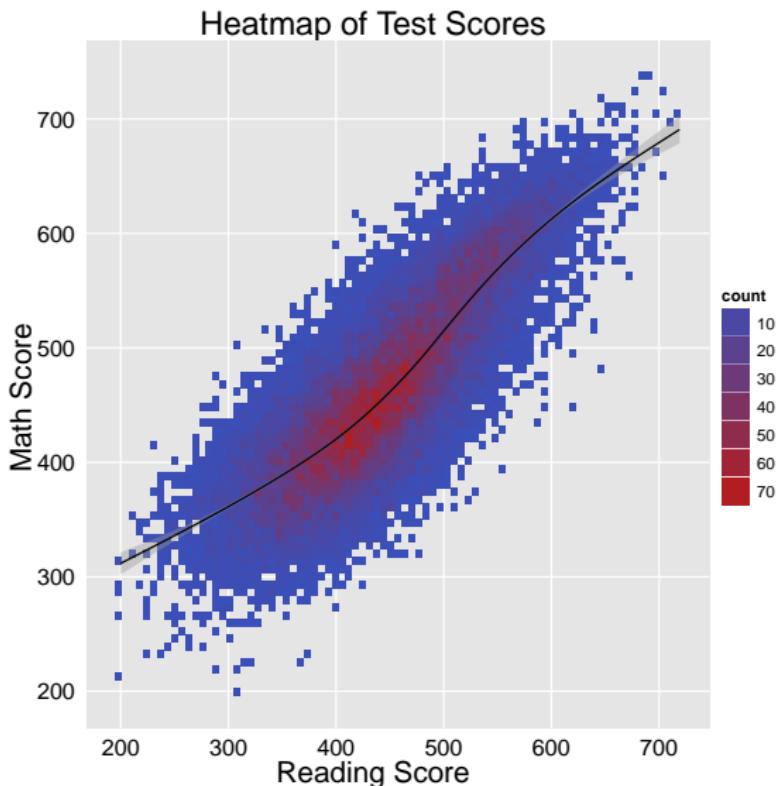
Code for this plot that uses 'mosaictabs' function from the LDS_TOOLS package

```
> plotsub<-subset(student_long,year=='2001' & grade==6)
> varnames<-c('Female','Proficiency')
> mosaictabs.label(plotsub,plotsub$female,plotsub$proflvl,
+                   varnames,'Gender and Proficiency','Dummy Data 2012')
```

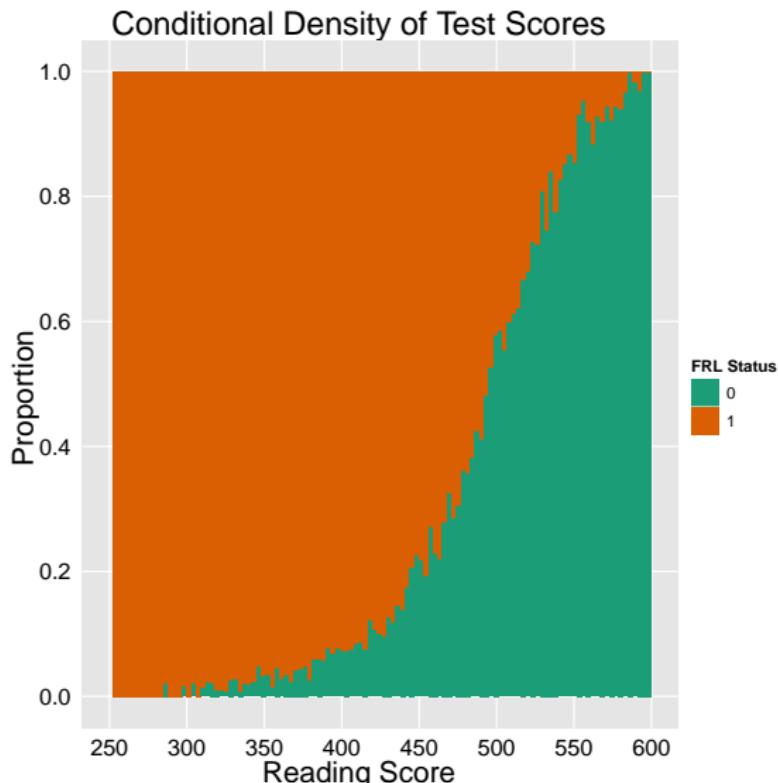
Maps



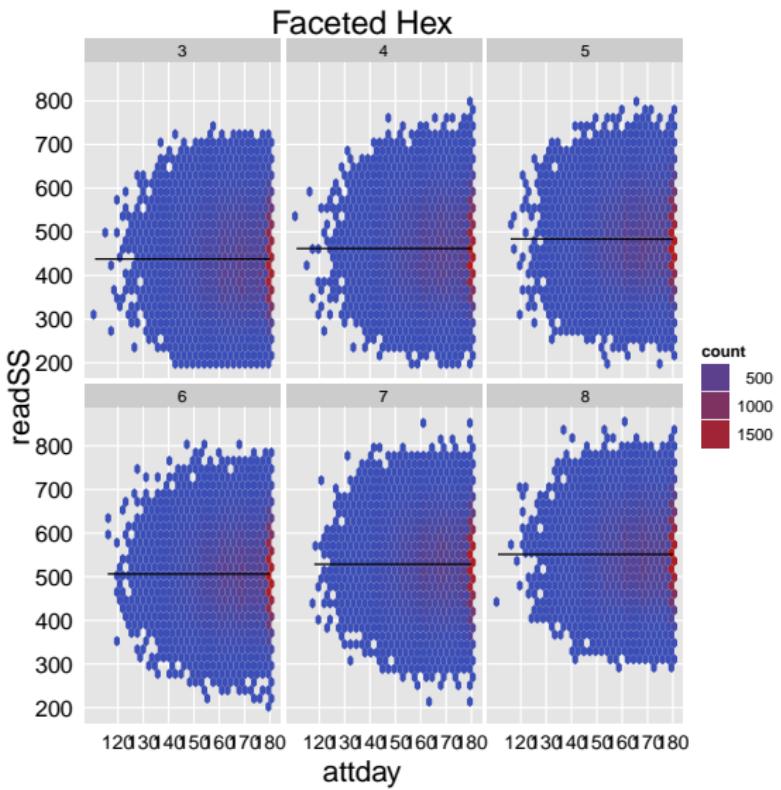
Heatmap



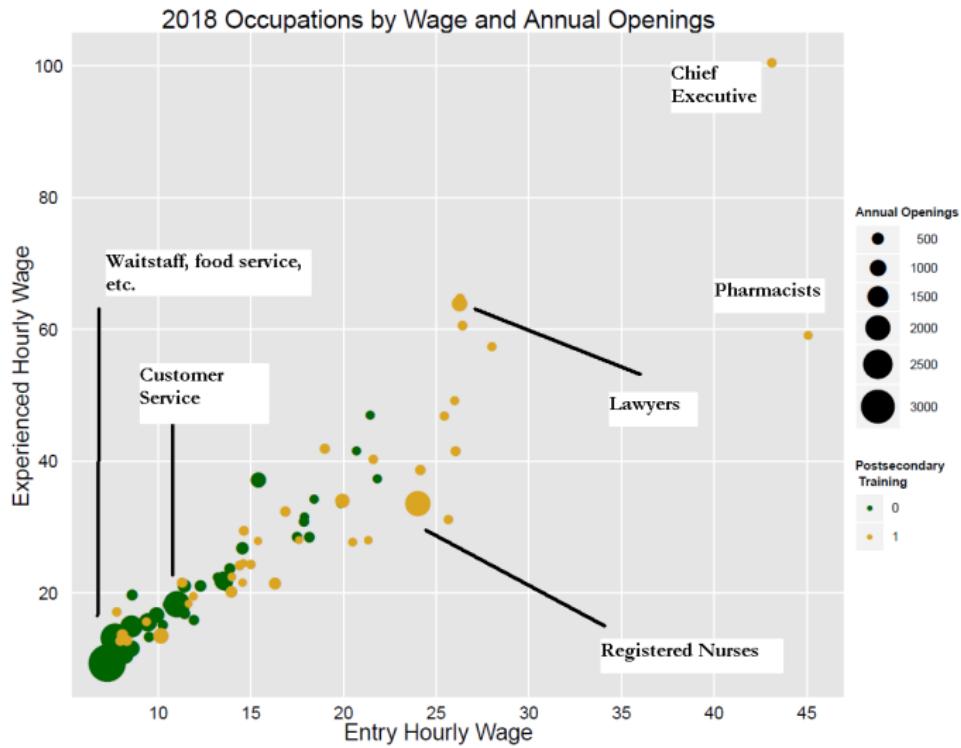
Conditional Density



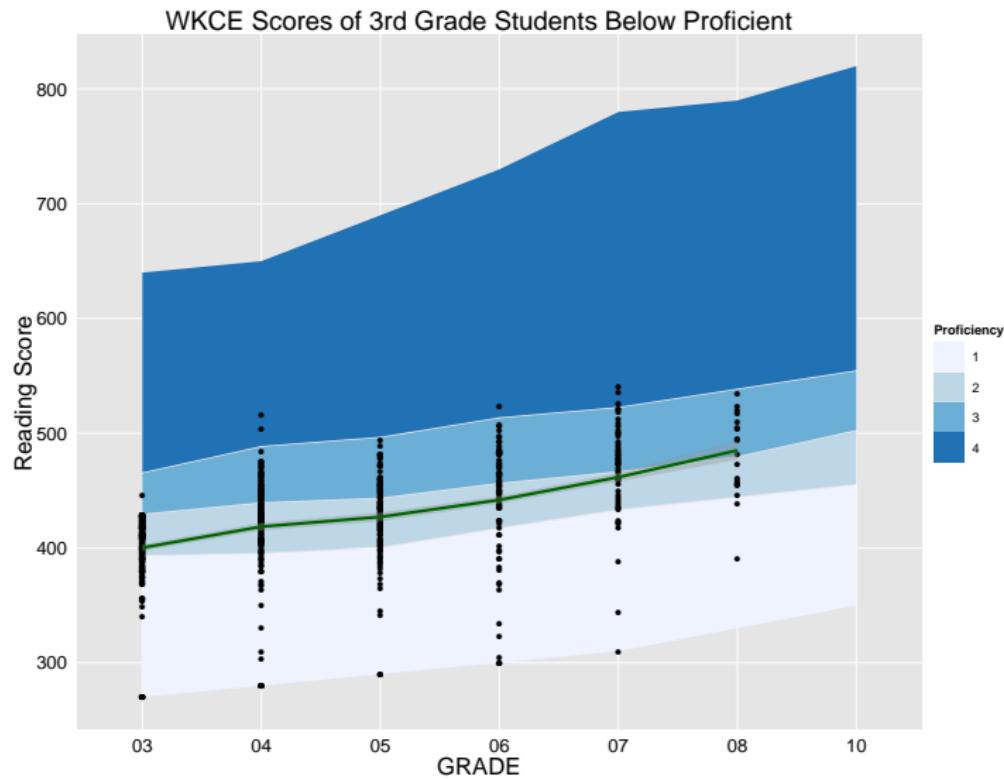
Faceted Hex



Polished Scatter

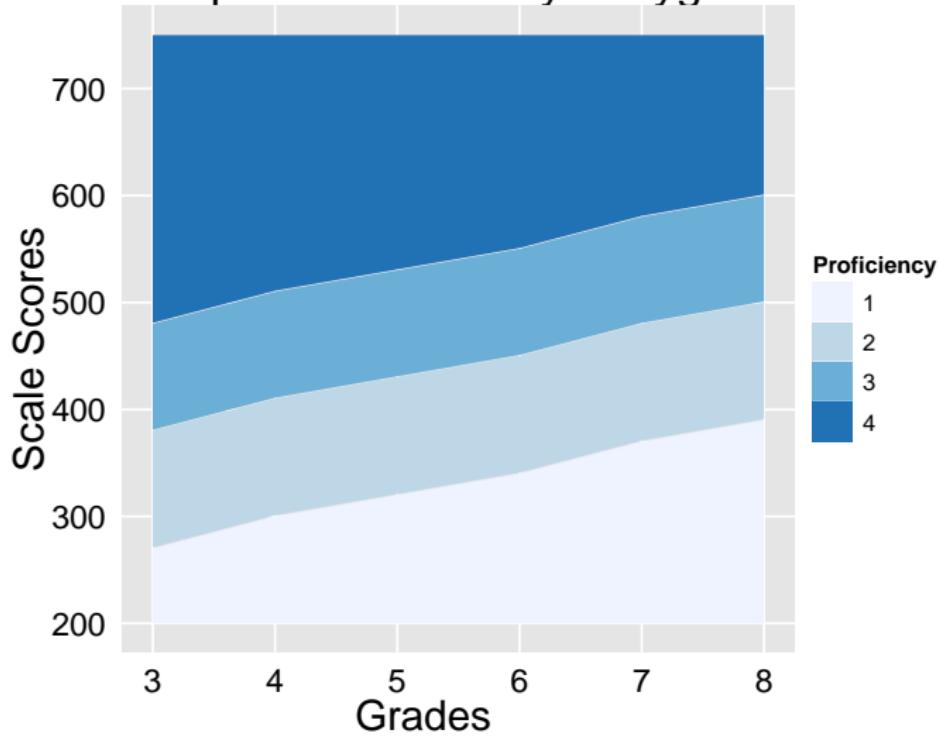


Longitudinal Data



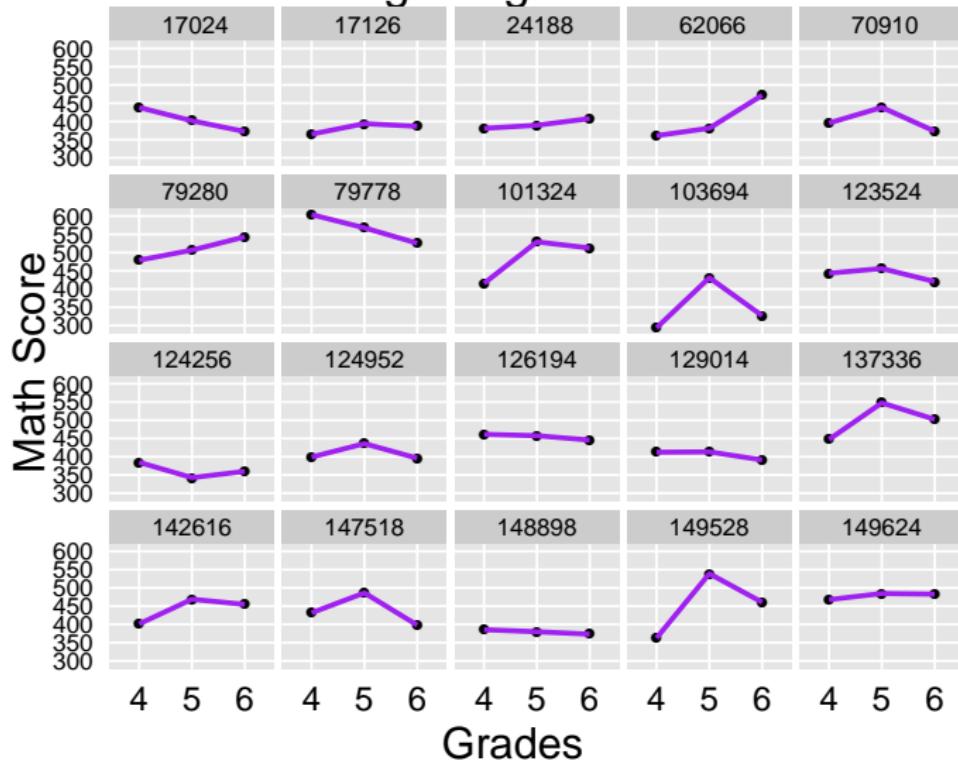
Proficiency Polygon

Example of Proficiency Polygon

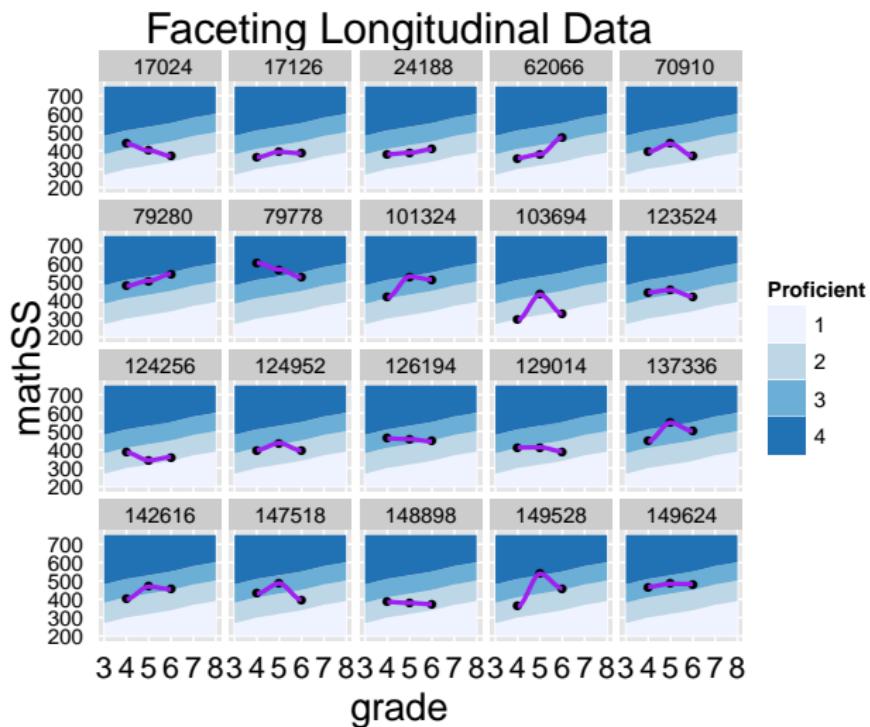


Individual Growth Trajectories

Faceting Longitudinal Data

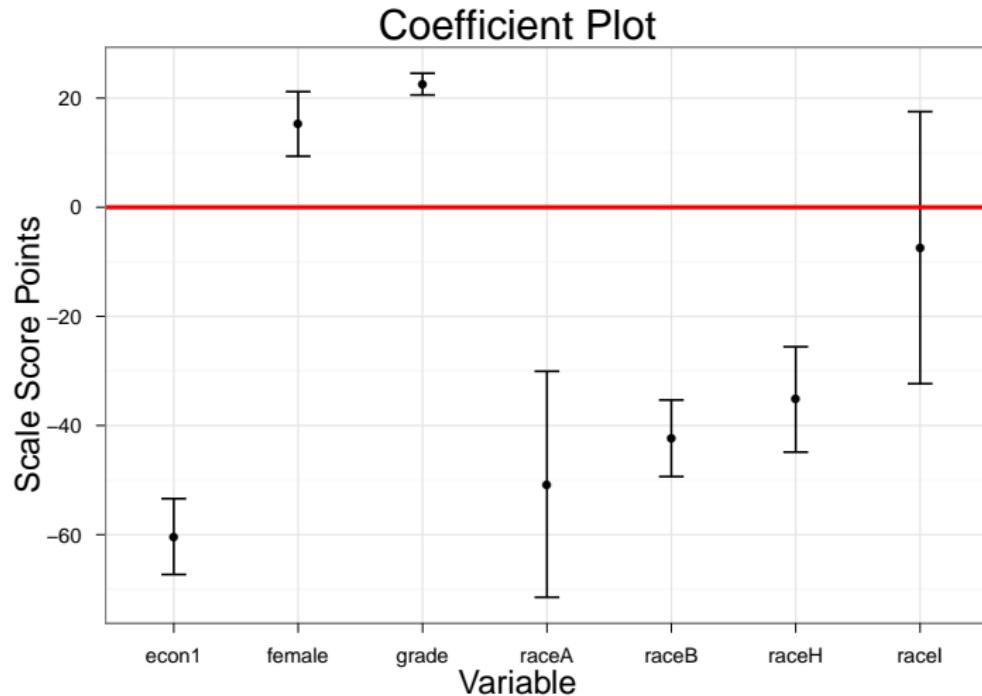


Individual Growth Trajectories

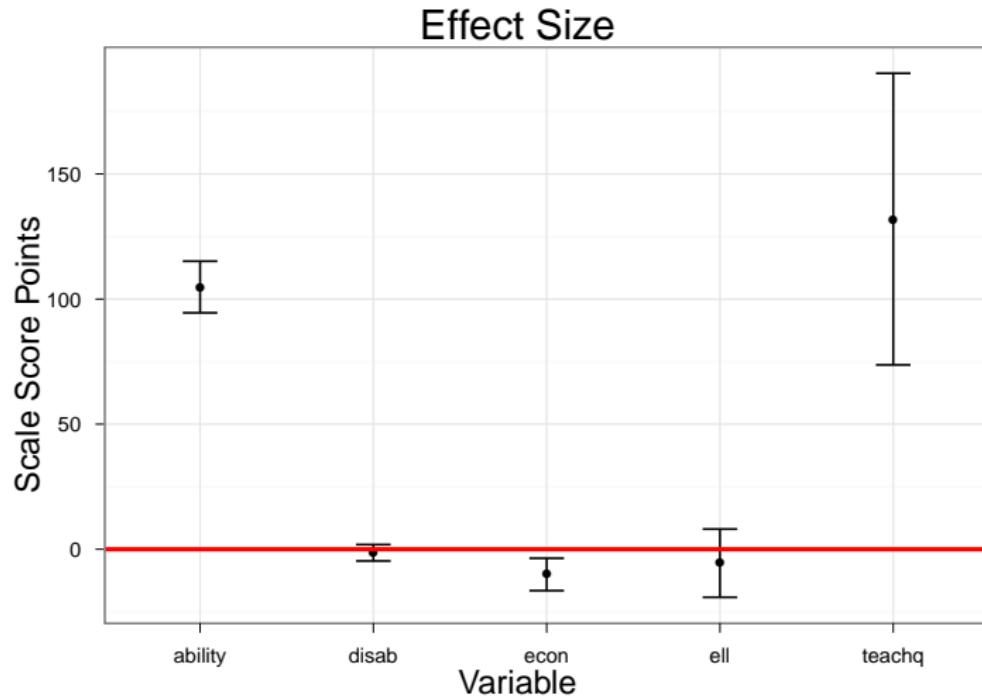


```
| null device  
|       1
```

Communicate Statistical Models



Communicate Statistical Models II



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The Command Line

- R can be tricky because it uses command lines.
- This is powerful, but requires a learning curve.
- Some simple calculations can give a feel for how R works

```
> 2+2
```

```
| [1] 4
```

```
> 7*4
```

```
| [1] 28
```

```
> exp(3)
```

```
| [1] 20.08554
```

```
> pi
```

```
| [1] 3.141593
```

Deconstruct R Commands

```
> summary(student_long[,28:30])
```

```
      readSS          mathSS
Min.   :200.0   Min.   :200.0
1st Qu.:430.9   1st Qu.:420.8
Median :494.4   Median :481.2
Mean   :494.9   Mean   :483.7
3rd Qu.:558.4   3rd Qu.:543.8
Max.   :850.4   Max.   :857.5
      proflvl
below basic: 35927
basic       : 85983
proficient :198393
advanced    :129697
```

- **summary** is the function
- **student_long** is the data object

Crosstabs

Let's test for balance among some categories of students

```
> with(subset(student_long,year=='2001'
+                 & grade==3),table(female,race))
```

| | | race | | | | |
|--------|------|------|------|-----|-----|---|
| female | | W | B | H | I | A |
| 0 | 5570 | 5081 | 1365 | 107 | 224 | |
| 1 | 5653 | 5252 | 1394 | 116 | 238 | |

```
> #As proportions
> with(subset(student_long,year=='2001'
+                 & grade==3),round(prop.table
+                 (table(female,race))*100),4)
```

| | | race | | | | |
|--------|----|------|---|---|---|---|
| female | | W | B | H | I | A |
| 0 | 22 | 20 | 5 | 0 | 1 | |
| 1 | 23 | 21 | 6 | 0 | 1 | |

Crosstabs

We can even output the results of R commands into a print-ready format.
As we have below.

| | W | B | H | I | A |
|---|-------|-------|------|------|------|
| 0 | 22.00 | 20.00 | 5.00 | 0.00 | 1.00 |
| 1 | 23.00 | 21.00 | 6.00 | 0.00 | 1.00 |

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Doing More than the Basics

- R can routinize basic functions like tables, crosstabs, and visualization of data
- R can also be extended to do more advanced analyses like multilevel modeling, spatial error modeling, Bayesian data analysis, forecasting, and simulation
- R can do advanced graphical functions as well
- R can even be expanded to incorporate additional programming languages like Python, C++, and Java

The downside of this is that these functions can have a steep learning curve.

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ANOVA

We can also do statistical tests using both Bayesian and Frequentist methods.

```
> novat1<-aov(readSS~female*race+econ,data=novaset)
> summary(novat1)
```

| | Df | Sum Sq | Mean Sq | F value |
|-------------|-------|----------|----------|----------|
| female | 1 | 2176464 | 2176464 | 763.682 |
| race | 4 | 33929701 | 8482425 | 2976.331 |
| econ | 1 | 20785160 | 20785160 | 7293.140 |
| female:race | 4 | 50009 | 12502 | 4.387 |
| Residuals | 24989 | 71217664 | 2850 | |

| | Pr(>F) |
|-------------|-------------|
| female | < 2e-16 *** |
| race | < 2e-16 *** |
| econ | < 2e-16 *** |
| female:race | 0.00152 ** |
| Residuals | |

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1



Pretty Output

We can also do print-ready model outputs with R's extensible formatting

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|-------------|-------|-------------|-------------|---------|--------|
| female | 1 | 2176463.53 | 2176463.53 | 763.68 | 0.0000 |
| race | 4 | 33929701.29 | 8482425.32 | 2976.33 | 0.0000 |
| econ | 1 | 20785160.43 | 20785160.43 | 7293.14 | 0.0000 |
| female:race | 4 | 50008.56 | 12502.14 | 4.39 | 0.0015 |
| Residuals | 24989 | 71217663.75 | 2849.96 | | |

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A simple OLS Model I

```
> mod1<-lm(readSS~female*race*econ+grade*year,data=student_long)
> summary(mod1)
```

Call:

```
lm(formula = readSS ~ female * race * econ + grade * year, data = stu
```

Residuals:

| Min | 1Q | Median | 3Q | Max |
|----------|---------|--------|--------|---------|
| -284.566 | -34.219 | 0.104 | 34.321 | 246.441 |

Coefficients:

| | Estimate | Std. Error | t value |
|-------------|-----------|------------|---------|
| (Intercept) | 383.11107 | 0.49828 | 768.865 |
| female | 14.24756 | 0.32404 | 43.969 |
| raceB | -37.21069 | 0.57997 | -64.160 |
| raceH | -41.01409 | 0.78264 | -52.405 |
| raceI | 2.48529 | 2.15941 | 1.151 |
| raceA | 0.45644 | 1.38578 | 0.329 |

A simple OLS Model II

| | | | |
|--------------------|-----------|---------|----------|
| econ1 | -54.71664 | 0.32522 | -168.246 |
| grade | 20.81004 | 0.07791 | 267.111 |
| year2001 | -3.48643 | 0.63452 | -5.495 |
| year2002 | 134.55881 | 0.63452 | 212.065 |
| female:raceB | -0.88573 | 0.82287 | -1.076 |
| female:raceH | 4.46915 | 1.09121 | 4.096 |
| female:raceI | 4.72824 | 2.88579 | 1.638 |
| female:raceA | -0.04431 | 1.93005 | -0.023 |
| female:econ1 | -3.22112 | 0.45766 | -7.038 |
| raceB:econ1 | -11.97227 | 0.64901 | -18.447 |
| raceH:econ1 | 6.46426 | 0.89487 | 7.224 |
| raceI:econ1 | -25.56913 | 2.62396 | -9.744 |
| raceA:econ1 | -23.59874 | 1.72464 | -13.683 |
| grade:year2001 | 9.50620 | 0.11018 | 86.281 |
| grade:year2002 | -3.95024 | 0.11018 | -35.853 |
| female:raceB:econ1 | -0.29569 | 0.91935 | -0.322 |
| female:raceH:econ1 | -2.03755 | 1.25022 | -1.630 |
| female:raceI:econ1 | 1.70605 | 3.57366 | 0.477 |
| female:raceA:econ1 | -2.64903 | 2.39991 | -1.104 |

A simple OLS Model III

| | Pr(> t) |
|--------------|--------------|
| (Intercept) | < 2e-16 *** |
| female | < 2e-16 *** |
| raceB | < 2e-16 *** |
| raceH | < 2e-16 *** |
| raceI | 0.250 |
| raceA | 0.742 |
| econ1 | < 2e-16 *** |
| grade | < 2e-16 *** |
| year2001 | 3.92e-08 *** |
| year2002 | < 2e-16 *** |
| female:raceB | 0.282 |
| female:raceH | 4.21e-05 *** |
| female:raceI | 0.101 |
| female:raceA | 0.982 |
| female:econ1 | 1.95e-12 *** |
| raceB:econ1 | < 2e-16 *** |
| raceH:econ1 | 5.07e-13 *** |
| raceI:econ1 | < 2e-16 *** |

A simple OLS Model IV

```
raceA:econ1      < 2e-16 ***
grade:year2001    < 2e-16 ***
grade:year2002    < 2e-16 ***
female:raceB:econ1   0.748
female:raceH:econ1   0.103
female:raceI:econ1   0.633
female:raceA:econ1   0.270
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

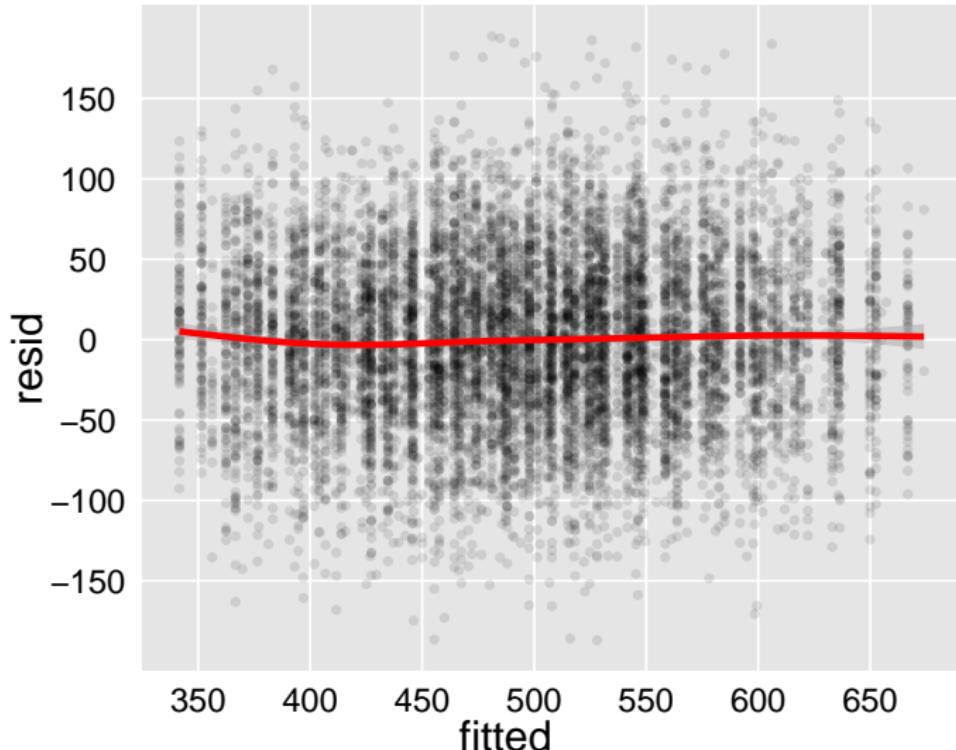
Residual standard error: 51.53 on 449975 degrees of freedom

Multiple R-squared: 0.6742, Adjusted R-squared: 0.6742

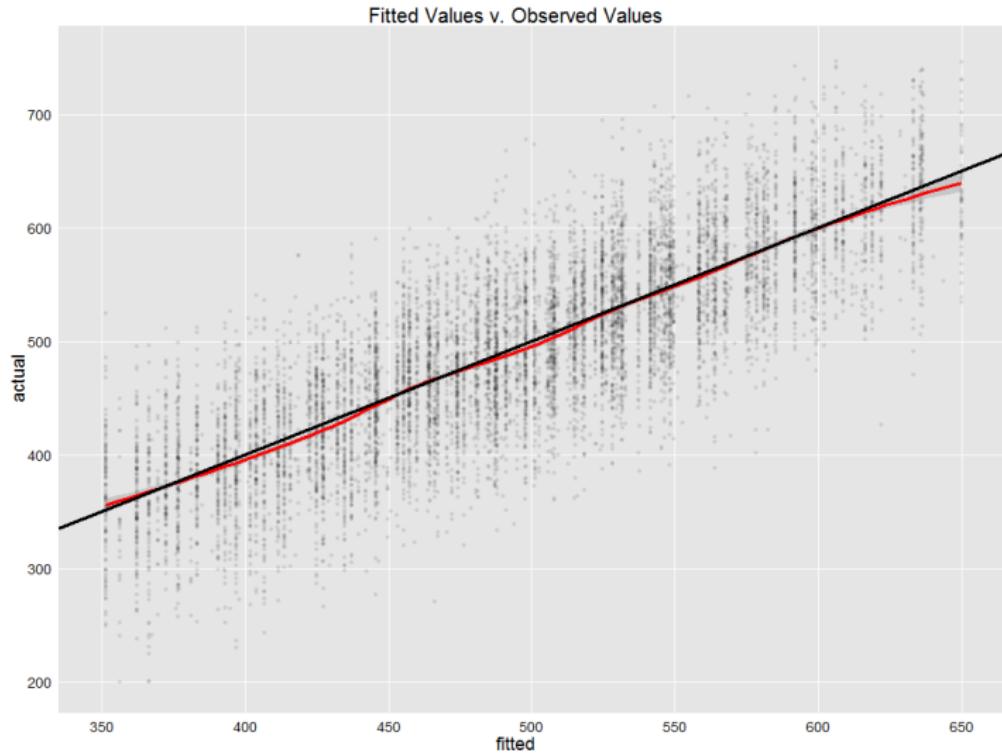
F-statistic: 3.88e+04 on 24 and 449975 DF, p-value: < 2.2e-16

Model Evaluation

Residuals vs. Observed Values

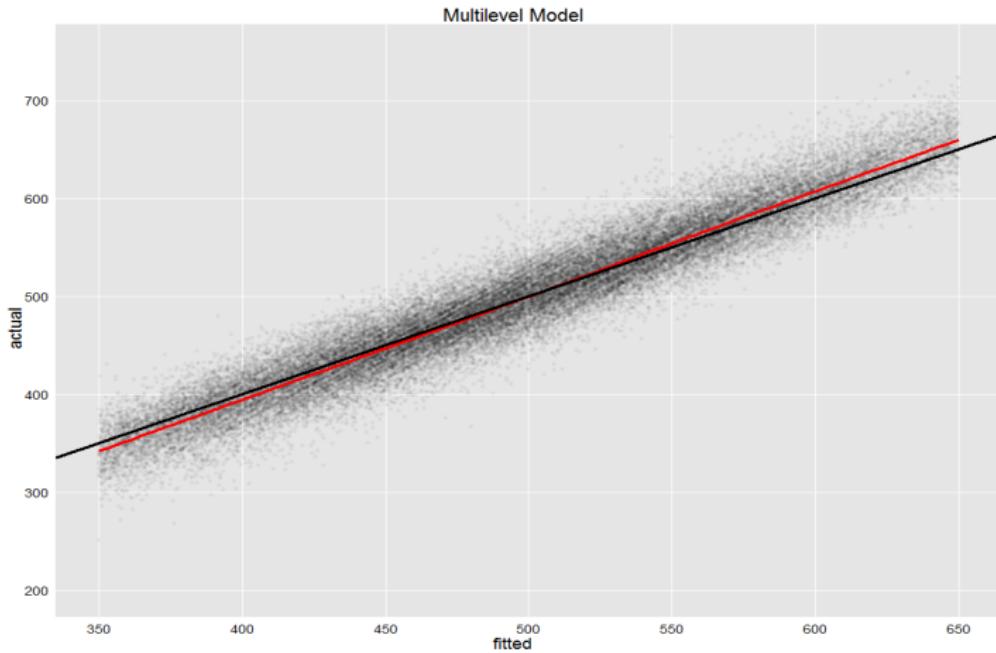


Model Evaluation Part 2



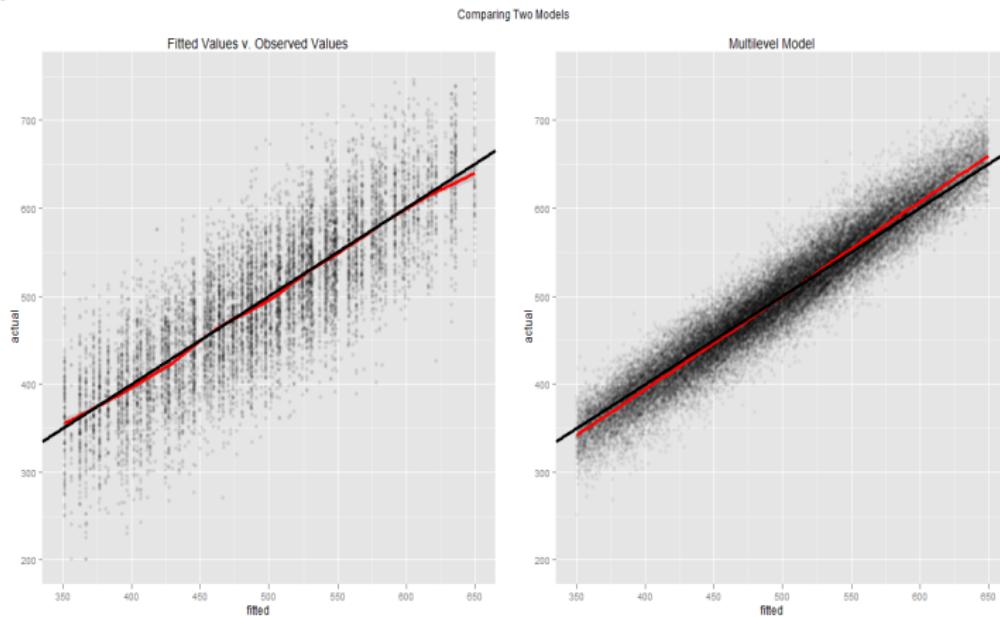
Better Fitting

Using advanced techniques we can greatly improve our model fit over the OLS model.



Compare OLS and Mixed Effects

A simple mixed-effects model estimated with an R package can outperform the simple OLS without much additional effort



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Some stuff

The advantage of R comes when we specialize to develop **advanced tools** that are compatible across our **very similar datasets**.

Collaborative Development



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Leverage Similar Data

Why can we do this?

- We all share similar data with similar attributes and similar reporting needs
- Standardizing on our analysis language makes applying analysis from one place to another easy due to data similarities
- **Build it. Share it. Use it.**

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GitHub

GitHub provides an excellent way to do this.



LDS_TOOLS

https://github.com/jknowles/LDS_TOOLS

- Uses the '**git**' version control system to track collaborative coding on the same source document
- Free and open source coding environment that plays well with RStudio
- No need to contribute, provides easy way to access work of others

Open Source Analysis Code

- LDS_TOOLS is a fledgling effort to open source many of the graphics and analyses from earlier in this presentation
- Make R code and \LaTeX code available to be applied to other SEA and LEA data
- Packaged with a dummy dataset representing common educational data attributes for testing and sharing
- Share visualization techniques, statistical models, and even full reports
- Plug and play—change the variables to match your data and produce the same visualization, report, analysis

LDS_TOOLS Available Now

You can visit online at: https://github.com/jknowles/LDS_TOOLS

Available Tools:

- Improved mosaic plots
- Gantt charts for project planning
- Proficiency polygons for assessments
- Convenience functions for education data

Planned Tools:

- Easy to make maps
- Data mining and statistical modeling routines
- Pre-built data quality reports
- Summary reports for NSC, Assessment, and Enrollment data

Who can get involved?

Current staff can use these tools, and even contribute to them

- Analysts with a couple of days to learn basic R skills
- Anyone with programming skills
- University partners
- The R Community

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Questions?



Questions?

Contact Information

For more information:

Jared Knowles
Wisconsin Department of Public Instruction
jared.knowles@dpi.wi.gov
https://github.com/jknowles/LDS_TOOLS

Example

This entire presentation was created with R, \LaTeX and is available online at GitHub to be edited, modified, and reused.

<https://github.com/jknowles/mis-presentation>

Tools

- **R** (<http://cran.r-project.org/>)
 - An open source statistics package that is freely available for all platforms.
- **RStudio** (<http://www.rstudio.org/>)
 - An enhanced front-end for R. An Integrated Development Environment (IDE) for statistical programming.
- **Quantum GIS** (<http://www.qgis.org/>)
 - A GIS package that provides most of the functionality of ArcGIS but is freely available.
- **GeoDa** (<http://geodacenter.asu.edu/>)
 - A geo-spatial statistics package for analyzing clustering and spatial correlation of datasets.
- **LATEX** (<http://www.latex-project.org/>)
 - A typesetting and document building tool that integrates with R.

Tutorials

- R Reference (<http://www.statmethods.net/>)
- First R Commands to Learn
(<https://github.com/hadley/devtools/wiki/vocabulary>)
- Beginning with \LaTeX (<http://en.wikibooks.org/wiki/\LaTeX>)
- Quantum GIS Guide
(<http://qgis.org/en/documentation/manuals.html>)
- R Graph Gallery (<http://addictedtor.free.fr/graphiques/>)