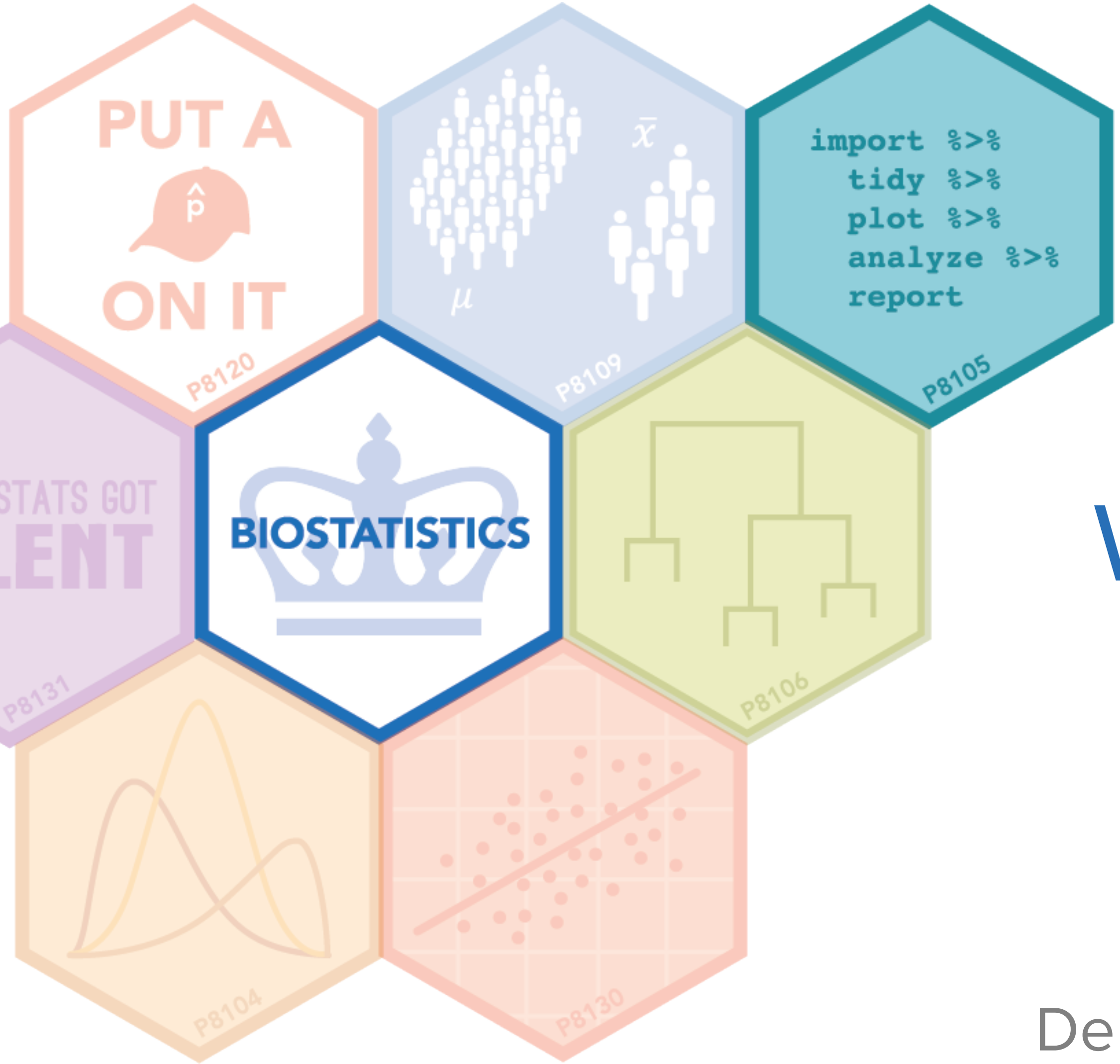


```
import %>%
  tidy %>%
  plot %>%
  analyze %>%
  report
```

WRITING WITH DATA

Jeff Goldsmith, PhD

Department of Biostatistics

Writing is important

- You're going to spend a lot of your time communicating in writing
  - With collaborators, a general public, future you
  - About data cleaning, analyses, results
  - In formal reports, brief summaries, replies to questions

- Time to get good

Tools

- Code is necessary but not sufficient
- Use tools that combine your code and text
- Greatly facilitates reproducibility, which is a big concept
  - In short, someone you don't know or work with should be able to reproduce each step of your analysis
  - As a part of this, they should understand why you did what you did
  - (Again, this someone is often future you)

- We'll use R Markdown to write reproducible reports

General tips

- Know your audience
  - Are they statistically knowledgeable?
  - How many details do they want / need?

- Say exactly what you did
  - Don't leave any thing important out
  - Not the same as a step-by-step list of what you typed into R

General structure

- Introduction / overview
- Data and methods
  - File names
  - Summary statistics
  - Exploratory analysis
  - Formal analysis
- Results
- Discussion

- Some version of these exist in almost everything I write
- Sometimes these are long, sometimes they’re a sentence

Introduction

- What is the context for this problem?
- What kind of data were gathered?
- What do you hope to learn?

Data

- Importing, tidying, and editing
  - Loading data
  - Reorganizing into usable form
  - Identifying missing values
  - Recoding and creating variables
- Summary statistics
  - Sample size
  - Means or proportions of major variables

Methods / “models”

- Exploratory analyses
  - Visualizations
  - Numerical summaries

- Formal analyses
  - Model components
  - Model strategy
  - Formal comparisons of interest, tests, significance levels

Results

- What did you find in exploratory analyses (any missing values? data distributions? notable features?)
- What happened in your modeling?
- What is your final model, and what are the important quantities?

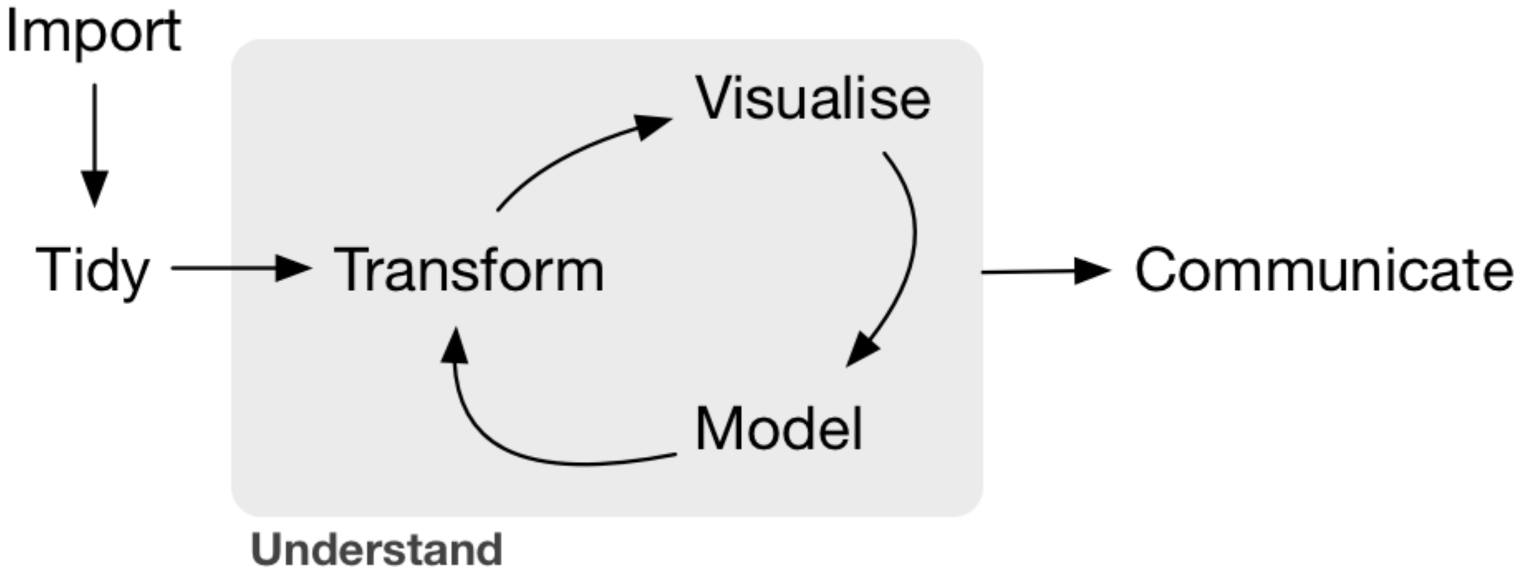
Discussion

- What do your results say about the question you hoped to answer?
- What were the limitations of your data or your analysis?
- What open questions remain? Are any of these solvable with the current data?
- What are your next steps?

Some true stuff about writing

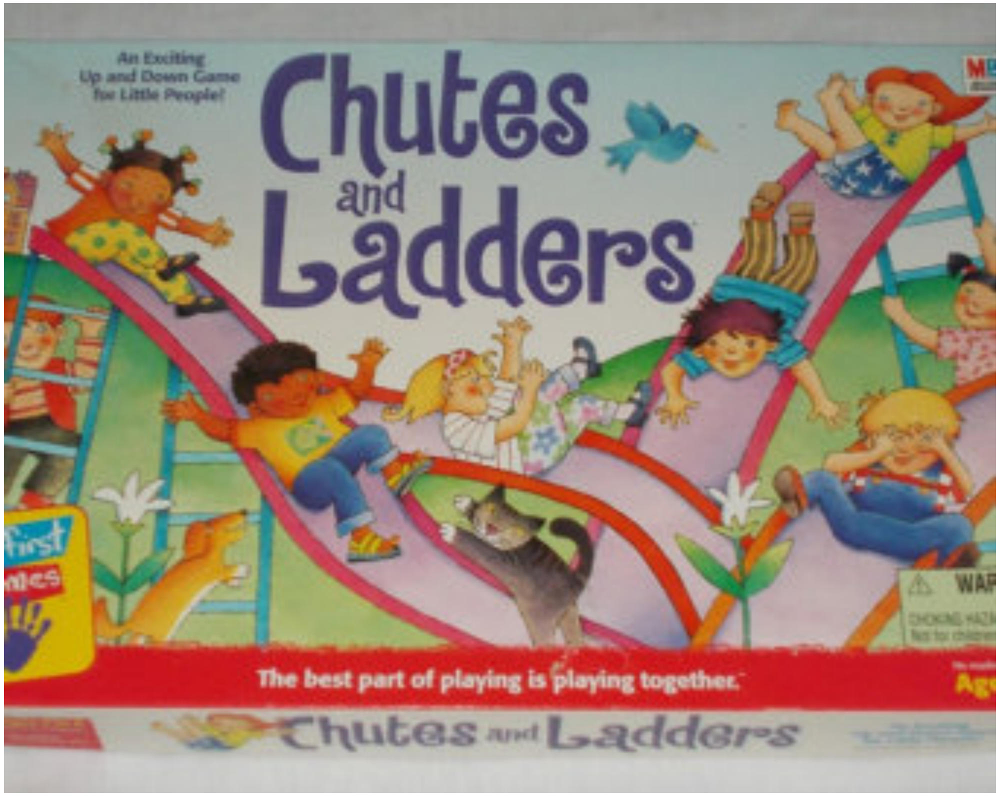
- It is not easy
- It takes practice
- It is critical to do well

Recall …

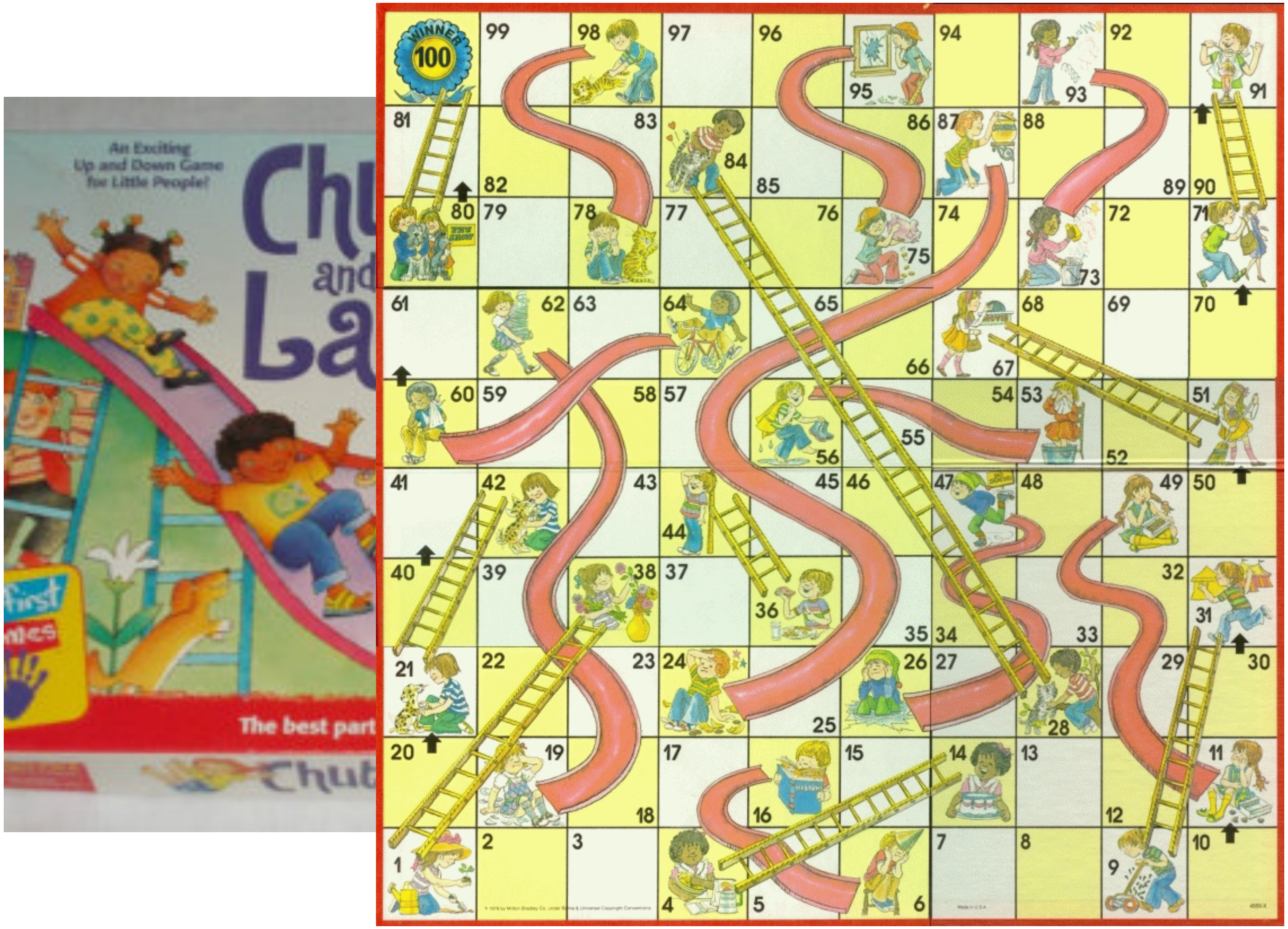


R for Data Science

How analyses are in reality


An Exciting Up and Down Game for Little People!
Chutes and Ladders
The best part of playing is playing together.
Chutes and Ladders

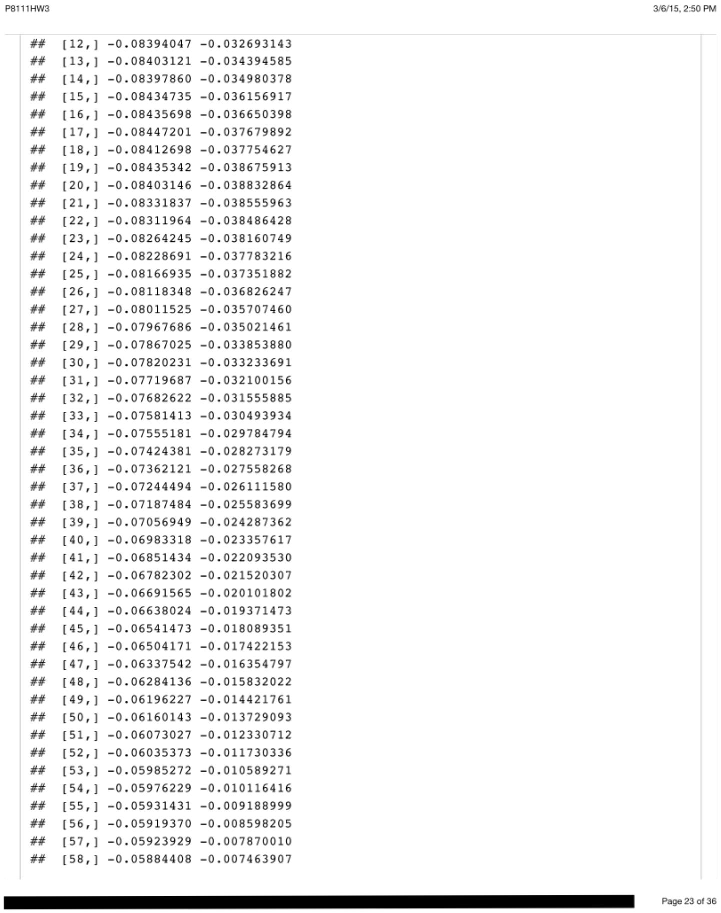
How analyses are in reality



How analyses are presented

Be complete …

… but not too complete.



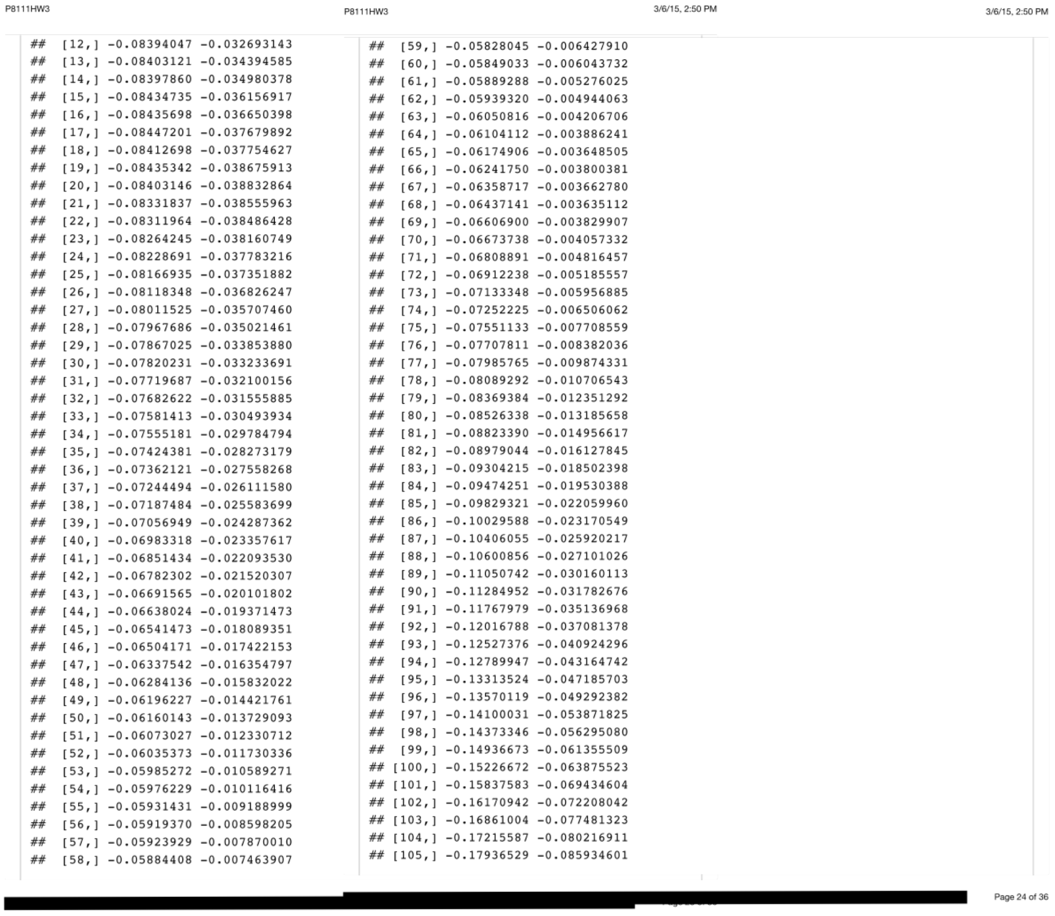
P8111HW3 3/6/15, 2:50 PM

```
## [12,] -0.08394047 -0.032693143
## [13,] -0.08403121 -0.034394585
## [14,] -0.08397860 -0.034980378
## [15,] -0.08434735 -0.036156917
## [16,] -0.08435698 -0.036650398
## [17,] -0.08447201 -0.037679892
## [18,] -0.08412698 -0.037754627
## [19,] -0.08435342 -0.038675913
## [20,] -0.08403146 -0.038832864
## [21,] -0.08331837 -0.038555963
## [22,] -0.08311964 -0.038486428
## [23,] -0.08264245 -0.038160749
## [24,] -0.08228691 -0.037783216
## [25,] -0.08166935 -0.037351882
## [26,] -0.08118348 -0.036826247
## [27,] -0.08011525 -0.035707460
## [28,] -0.07967686 -0.035021461
## [29,] -0.07867025 -0.033853880
## [30,] -0.07820231 -0.033233691
## [31,] -0.07719687 -0.032100156
## [32,] -0.07682622 -0.031555885
## [33,] -0.07581413 -0.030493934
## [34,] -0.07555181 -0.029784794
## [35,] -0.07424381 -0.028273179
## [36,] -0.07362121 -0.027558268
## [37,] -0.07244494 -0.026111580
## [38,] -0.07187484 -0.025583699
## [39,] -0.07056949 -0.024287362
## [40,] -0.06983318 -0.023357617
## [41,] -0.06851434 -0.022093530
## [42,] -0.06782302 -0.021520307
## [43,] -0.06691565 -0.020101802
## [44,] -0.06638024 -0.019371473
## [45,] -0.06541473 -0.018089351
## [46,] -0.06504171 -0.017422153
## [47,] -0.06337542 -0.016354797
## [48,] -0.06284136 -0.015832022
## [49,] -0.06196227 -0.014421761
## [50,] -0.06160143 -0.013729093
## [51,] -0.06073027 -0.012330712
## [52,] -0.06035373 -0.011730336
## [53,] -0.05985272 -0.010589271
## [54,] -0.05976229 -0.010116416
## [55,] -0.05931431 -0.009188999
## [56,] -0.05919370 -0.008598205
## [57,] -0.05923929 -0.007870010
## [58,] -0.05884408 -0.007463907
```

[redacted] Page 23 of 36

Be complete …

… but not too complete.



P8111HW3 3/6/15, 2:50 PM

```
##  [12,] -0.08394047 -0.032693143
##  [13,] -0.08403121 -0.034394585
##  [14,] -0.08397860 -0.034980378
##  [15,] -0.08434735 -0.036156917
##  [16,] -0.08435698 -0.036650398
##  [17,] -0.08447201 -0.037679892
##  [18,] -0.08412698 -0.037754627
##  [19,] -0.08435342 -0.038675913
##  [20,] -0.08403146 -0.038832864
##  [21,] -0.08331837 -0.038555963
##  [22,] -0.08311964 -0.038486428
##  [23,] -0.08264245 -0.038160749
##  [24,] -0.08228691 -0.037783216
##  [25,] -0.08166935 -0.037351882
##  [26,] -0.08118348 -0.036826247
##  [27,] -0.08011525 -0.035707460
##  [28,] -0.07967686 -0.035021461
##  [29,] -0.07867025 -0.033853880
##  [30,] -0.07820231 -0.033233691
##  [31,] -0.07719687 -0.032100156
##  [32,] -0.07682622 -0.031555885
##  [33,] -0.07581413 -0.030493934
##  [34,] -0.07555181 -0.029784794
##  [35,] -0.07424381 -0.028273179
##  [36,] -0.07362121 -0.027558268
##  [37,] -0.07244494 -0.026111580
##  [38,] -0.07187484 -0.025583699
##  [39,] -0.07056949 -0.024287362
##  [40,] -0.06983318 -0.023357617
##  [41,] -0.06851434 -0.022093530
##  [42,] -0.06782302 -0.021520307
##  [43,] -0.06691565 -0.020101802
##  [44,] -0.06638024 -0.019371473
##  [45,] -0.06541473 -0.018089351
##  [46,] -0.06504171 -0.017422153
##  [47,] -0.06337542 -0.016354797
##  [48,] -0.06284136 -0.015832022
##  [49,] -0.06196227 -0.014421761
##  [50,] -0.06160143 -0.013729093
##  [51,] -0.06073027 -0.012330712
##  [52,] -0.06035373 -0.011730336
##  [53,] -0.05985272 -0.010589271
##  [54,] -0.05976229 -0.010116416
##  [55,] -0.05931431 -0.009188999
##  [56,] -0.05919370 -0.008598205
##  [57,] -0.05923929 -0.007870010
##  [58,] -0.05884408 -0.007463907
```

[redacted]

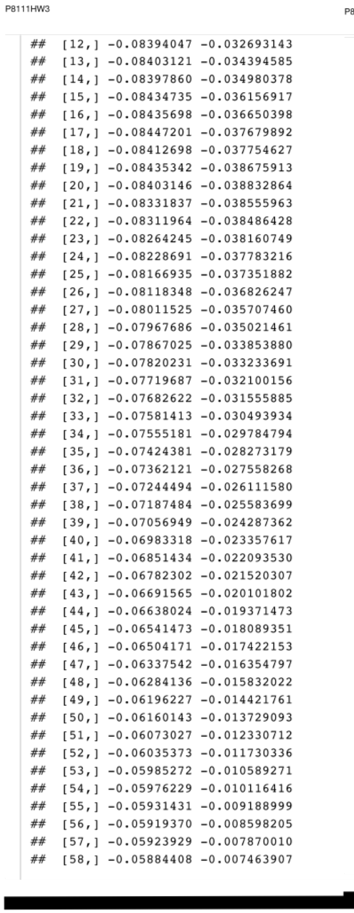
P8111HW3 3/6/15, 2:50 PM

```
##  [59,] -0.05828045 -0.006427910
##  [60,] -0.05849033 -0.006043732
##  [61,] -0.05889288 -0.005276025
##  [62,] -0.05939320 -0.004944063
##  [63,] -0.06050816 -0.004206706
##  [64,] -0.06104112 -0.003886241
##  [65,] -0.06174906 -0.003648505
##  [66,] -0.06241750 -0.003800381
##  [67,] -0.06358717 -0.003662780
##  [68,] -0.06437141 -0.003635112
##  [69,] -0.06606900 -0.003829907
##  [70,] -0.06673738 -0.004057332
##  [71,] -0.06808891 -0.004816457
##  [72,] -0.06912238 -0.005185557
##  [73,] -0.07133348 -0.005956885
##  [74,] -0.07252225 -0.006506062
##  [75,] -0.07551133 -0.007708559
##  [76,] -0.07707811 -0.008382036
##  [77,] -0.07985765 -0.009874331
##  [78,] -0.08089292 -0.010706543
##  [79,] -0.08369384 -0.012351292
##  [80,] -0.08526338 -0.013185658
##  [81,] -0.08823390 -0.014956617
##  [82,] -0.08979044 -0.016127845
##  [83,] -0.09304215 -0.018502398
##  [84,] -0.09474251 -0.019530388
##  [85,] -0.09829321 -0.022059960
##  [86,] -0.10029588 -0.023170549
##  [87,] -0.10406055 -0.025920217
##  [88,] -0.10600856 -0.027101026
##  [89,] -0.11050742 -0.030160113
##  [90,] -0.11284952 -0.031782676
##  [91,] -0.11767979 -0.035136968
##  [92,] -0.12016788 -0.037081378
##  [93,] -0.12527376 -0.040924296
##  [94,] -0.12789947 -0.043164742
##  [95,] -0.13313524 -0.047185703
##  [96,] -0.13570119 -0.049292382
##  [97,] -0.14100031 -0.053871825
##  [98,] -0.14373346 -0.056295080
##  [99,] -0.14936673 -0.061355509
## [100,] -0.15226672 -0.063875523
## [101,] -0.15837583 -0.069434604
## [102,] -0.16170942 -0.072208042
## [103,] -0.16861004 -0.077481323
## [104,] -0.17215587 -0.080216911
## [105,] -0.17936529 -0.085934601
```

[redacted] Page 24 of 36

Be complete …

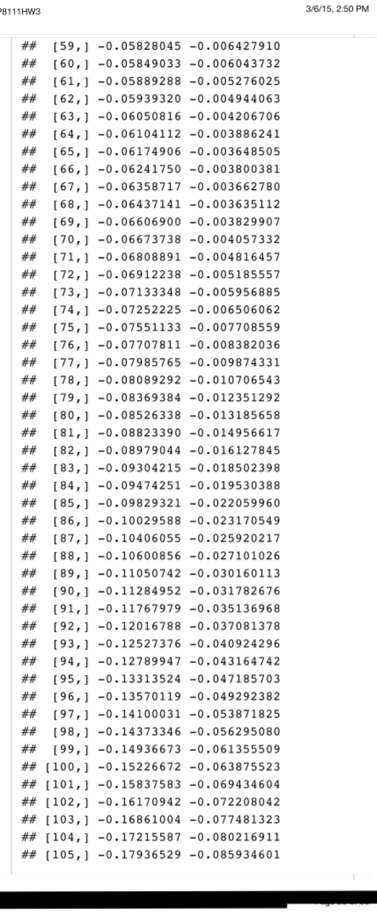
… but not too complete.



P8111HW3

```
##  [12,] -0.08394047 -0.032693143
##  [13,] -0.08403121 -0.034394585
##  [14,] -0.08397860 -0.034980378
##  [15,] -0.08434735 -0.036156917
##  [16,] -0.08435698 -0.036650398
##  [17,] -0.08447201 -0.037679892
##  [18,] -0.08412698 -0.037754627
##  [19,] -0.08435342 -0.038675913
##  [20,] -0.08403146 -0.038832864
##  [21,] -0.08331837 -0.038555963
##  [22,] -0.08311964 -0.038486428
##  [23,] -0.08264245 -0.038160749
##  [24,] -0.08228691 -0.037783216
##  [25,] -0.08166935 -0.037351882
##  [26,] -0.08118348 -0.036826247
##  [27,] -0.08011525 -0.035707460
##  [28,] -0.07967686 -0.035021461
##  [29,] -0.07867025 -0.033853880
##  [30,] -0.07820231 -0.033233691
##  [31,] -0.07719687 -0.032100156
##  [32,] -0.07682622 -0.031555885
##  [33,] -0.07581413 -0.030493934
##  [34,] -0.07555181 -0.029784794
##  [35,] -0.07424381 -0.028273179
##  [36,] -0.07362121 -0.027558268
##  [37,] -0.07244494 -0.026111580
##  [38,] -0.07187484 -0.025583699
##  [39,] -0.07056949 -0.024287362
##  [40,] -0.06983318 -0.023357617
##  [41,] -0.06851434 -0.022093530
##  [42,] -0.06782302 -0.021520307
##  [43,] -0.06691565 -0.020101802
##  [44,] -0.06638024 -0.019371473
##  [45,] -0.06541473 -0.018089351
##  [46,] -0.06504171 -0.017422153
##  [47,] -0.06337542 -0.016354797
##  [48,] -0.06284136 -0.015832022
##  [49,] -0.06196227 -0.014421761
##  [50,] -0.06160143 -0.013729093
##  [51,] -0.06073027 -0.012330712
##  [52,] -0.06035373 -0.011730336
##  [53,] -0.05985272 -0.010589271
##  [54,] -0.05976229 -0.010116416
##  [55,] -0.05931431 -0.009188999
##  [56,] -0.05919370 -0.008598205
##  [57,] -0.05923929 -0.007870010
##  [58,] -0.05884408 -0.007463907
```

[redacted]

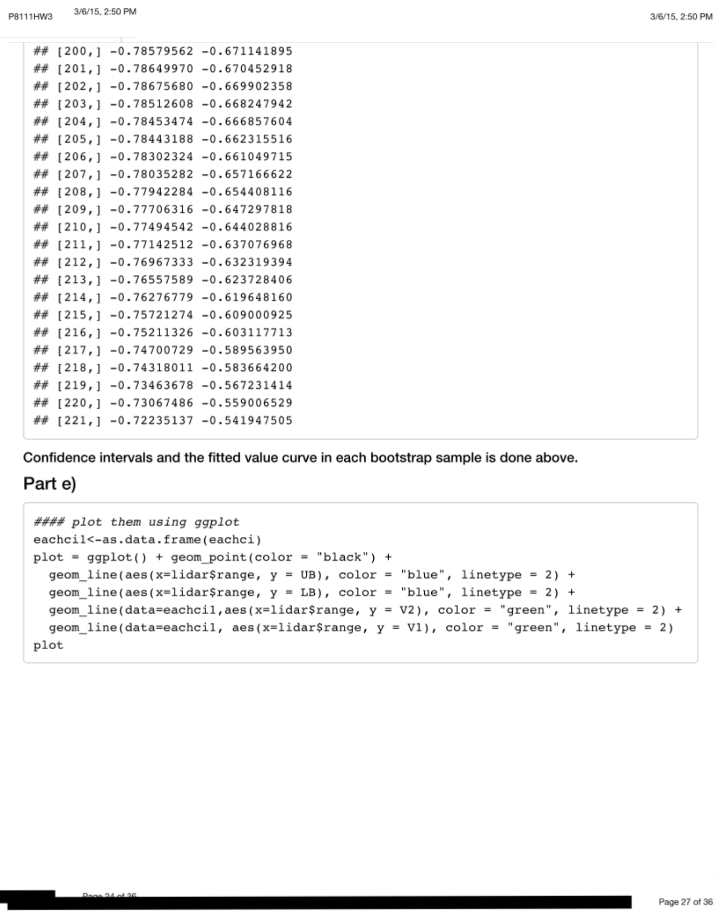


P8111HW3 3/6/15, 2:50 PM

```
##  [59,] -0.05828045 -0.006427910
##  [60,] -0.05849033 -0.006043732
##  [61,] -0.05889288 -0.005276025
##  [62,] -0.05939320 -0.004944063
##  [63,] -0.06050816 -0.004206706
##  [64,] -0.06104112 -0.003886241
##  [65,] -0.06174906 -0.003648505
##  [66,] -0.06241750 -0.003800381
##  [67,] -0.06358717 -0.003662780
##  [68,] -0.06437141 -0.003635112
##  [69,] -0.06606900 -0.003829907
##  [70,] -0.06673738 -0.004057332
##  [71,] -0.06808891 -0.004816457
##  [72,] -0.06912238 -0.005185557
##  [73,] -0.07133348 -0.005956885
##  [74,] -0.07252225 -0.006506062
##  [75,] -0.07551133 -0.007708559
##  [76,] -0.07707811 -0.008382036
##  [77,] -0.07985765 -0.009874331
##  [78,] -0.08089292 -0.010706543
##  [79,] -0.08369384 -0.012351292
##  [80,] -0.08526338 -0.013185658
##  [81,] -0.08823390 -0.014956617
##  [82,] -0.08979044 -0.016127845
##  [83,] -0.09304215 -0.018502398
##  [84,] -0.09474251 -0.019530388
##  [85,] -0.09829321 -0.022059960
##  [86,] -0.10029588 -0.023170549
##  [87,] -0.10406055 -0.025920217
##  [88,] -0.10600856 -0.027101026
##  [89,] -0.11050742 -0.030160113
##  [90,] -0.11284952 -0.031782676
##  [91,] -0.11767979 -0.035136968
##  [92,] -0.12016788 -0.037081378
##  [93,] -0.12527376 -0.040924296
##  [94,] -0.12789947 -0.043164742
##  [95,] -0.13313524 -0.047185703
##  [96,] -0.13570119 -0.049292382
##  [97,] -0.14100031 -0.053871825
##  [98,] -0.14373346 -0.056295080
##  [99,] -0.14936673 -0.061355509
## [100,] -0.15226672 -0.063875523
## [101,] -0.15837583 -0.069434604
## [102,] -0.16170942 -0.072208042
## [103,] -0.16861004 -0.077481323
## [104,] -0.17215587 -0.080216911
## [105,] -0.17936529 -0.085934601
```

[redacted]

● ● ●



P8111HW3 3/6/15, 2:50 PM 3/6/15, 2:50 PM

```
## [200,] -0.78579562 -0.671141895
## [201,] -0.78649970 -0.670452918
## [202,] -0.78675680 -0.669902358
## [203,] -0.78512608 -0.668247942
## [204,] -0.78453474 -0.666857604
## [205,] -0.78443188 -0.662315516
## [206,] -0.78302324 -0.661049715
## [207,] -0.78035282 -0.657166622
## [208,] -0.77942284 -0.654408116
## [209,] -0.77706316 -0.647297818
## [210,] -0.77494542 -0.644028816
## [211,] -0.77142512 -0.637076968
## [212,] -0.76967333 -0.632319394
## [213,] -0.76557589 -0.623728406
## [214,] -0.76276779 -0.619648160
## [215,] -0.75721274 -0.609000925
## [216,] -0.75211326 -0.603117713
## [217,] -0.74700729 -0.589563950
## [218,] -0.74318011 -0.583664200
## [219,] -0.73463678 -0.567231414
## [220,] -0.73067486 -0.559006529
## [221,] -0.72235137 -0.541947505
```

Confidence intervals and the fitted value curve in each bootstrap sample is done above.

Part e)

```
#### plot them using ggplot
eachci1<-as.data.frame(eachci)
plot = ggplot() + geom_point(color = "black") +
  geom_line(aes(x=lidar$range, y = UB), color = "blue", linetype = 2) +
  geom_line(aes(x=lidar$range, y = LB), color = "blue", linetype = 2) +
  geom_line(data=eachci1,aes(x=lidar$range, y = V2), color = "green", linetype = 2) +
  geom_line(data=eachci1, aes(x=lidar$range, y = V1), color = "green", linetype = 2)
plot
```

[redacted]

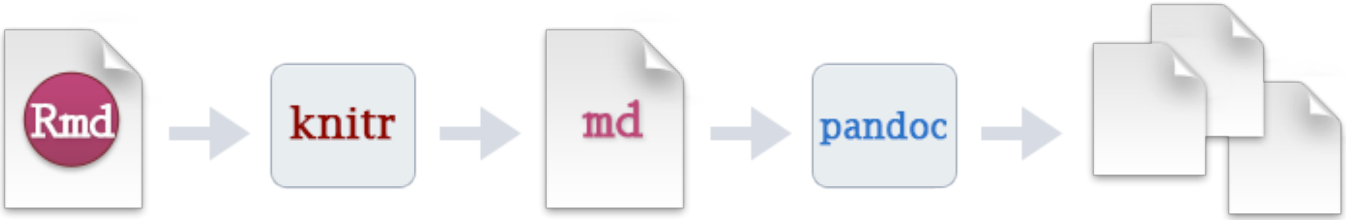
Page 27 of 36

Striking a balance

- This is where practice comes in

R Markdown?

- A “Markdown” language is a lightweight syntax that can be easily converted to HTML or another format (PDF, Word)
- R Markdown lets you combine formatted text with code chunks and the results of those chunks



R for Data Science

- Having text and code in the same place, and having the combined output be user-friendly, is huge for your workflow