THE UNIVERSITY of EDINBURGH

Week 1: Introductions to R and Statistics

Univariate Statistics and Methodology using R

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Part 1

Why R?

What is R?

- R is a 'statistical programming language'
- created mid-90s as a free version of S
- widespread adoption since v2 (2004)

- RStudio is an 'integrated development environment' (IDE)
- created 2011 'to improve R experience'
- widespread adoption since 2012

R vs RStudio

This is R

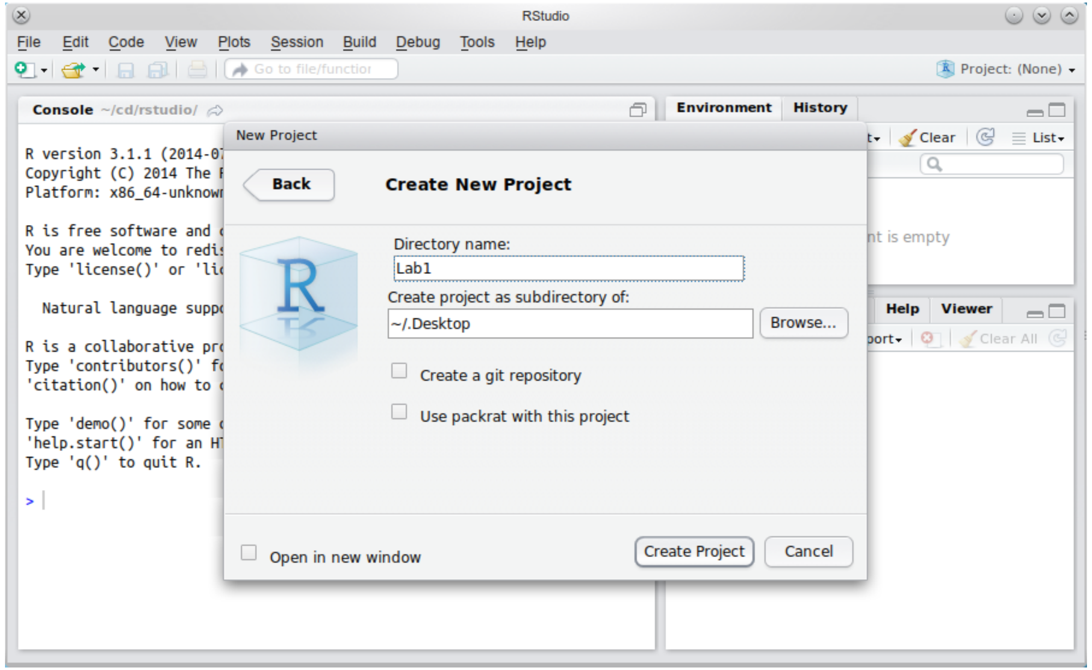
```
model <- lm(RT ~ (age+freq+handedness)^2, data=words)
summary(model)
```

R vs RStudio

This is R

```r
model <- lm(RT ~ (age+freq+handedness)^2, data=words)
summary(model)
```

This is RStudio



RMarkdown

- RMarkdown is a 'text markup language'
- created 2012 as a markup language for R
- widespread adoption since 2015

RMarkdown

```
### About RMarkdown
_This_ is some **RMarkdown**, which uses 'simple' codes to mark up text.

- it can include R code like `r sqrt(2)`
- it's simple to format things like bulleted lists
  + or even sublists
```

About RMarkdown

This is some **RMarkdown**, which uses 'simple' codes to mark up text.

- it can include R code like 1.4142
- it's simple to format things like bulleted lists
  - or even sublists

What is R Good For?

Managing Datasets

analysis.R × | data ×

4680 observations of 32 variables

	subject_nr	count_sequence	cr	frame	freq	freq_group	response_time_word1space	respo
1	1011	0	U	CP	7.11	g7	681	312
2	1011	1	G	T	6.83	g4	264	351
3	1011	2	U	T	0.00	fill	343	352
4	1011	3	U	I	0.00	fill	288	390
5	1011	4	U	I	7.88	g9	311	392
6	1011	5	G	CP	0.00	fill	368	767
7	1011	6	G	T	8.37	g2	277	310
8	1011	7	G	CP	0.00	fill	272	526
9	1011	8	U	I	6.30	g3	281	351
10	1011	9	G	I	5.57	g3	271	336
11	1011	10	U	T	6.31	g3	360	343
12	1011	11	U	T	7.48	g6	292	385
13	1011	12	U	CP	7.83	g2	309	344
14	1011	13	U	I	0.00	fill	264	327
15	1011	14	G	T	7.93	g9	289	286
16	1011	15	U	CP	7.18	g6	423	495
17	1011	16	G	I	7.24	g9	351	2904
18	1011	17	G	CP	6.69	g4	319	414
19	1011	18	G	T	8.80	g2	344	334

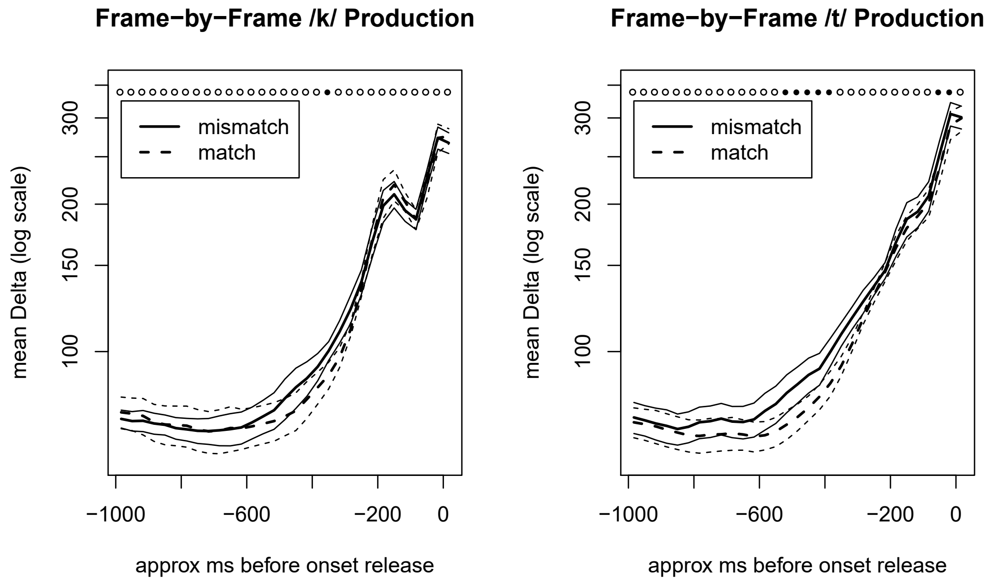
Displayed 1000 rows of 4680 (3680 omitted)

Doing Statistics

```
Generalized linear mixed model fit by maximum likelihood (Laplace
  Approximation) [glmerMod]
 Family: binomial  ( logit )
Formula: DV ~ sc(FvO) * sc(EvC) + (1 | Code) + (0 + (sc(FvO) * sc(EvC)) |
    Code) + (1 | Item)
   Data: feminine
Control: glmerControl(optimizer = "bobyqa")

     AIC      BIC   logLik deviance df.resid
   879.3    943.6   -427.7    855.3     1558
...
Fixed effects:
                Estimate Std. Error z value Pr(>|z|)
(Intercept)      -1.0566     1.1485   -0.92  0.35758
sc(FvO)           1.2453     0.3505    3.55  0.00038 ***
sc(EvC)          -0.0915     0.3080   -0.30  0.76638
sc(FvO):sc(EvC)   0.0221     0.6321    0.04  0.97207
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
...
```

Publication-Quality Graphics

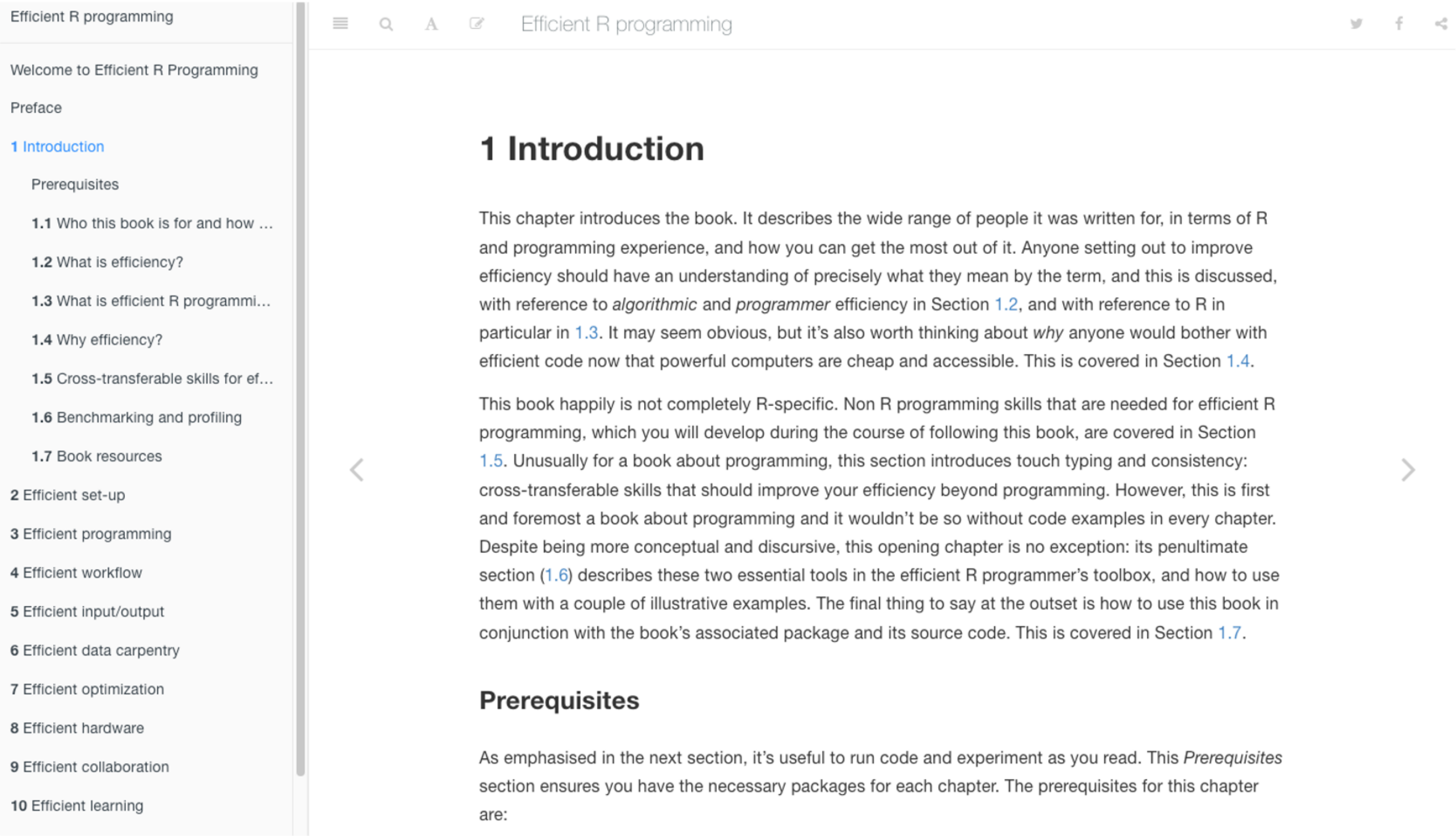


Data Visualisation

https://www.facebook.com/notes/facebook-engineering/visualizing-friendships/469716398919/

RMarkdown: Books

For example: https://bookdown.org/csgillespie/efficientR/



Efficient R programming

Welcome to Efficient R Programming

Preface

1 Introduction

Prerequisites

1.1 Who this book is for and how …

1.2 What is efficiency?

1.3 What is efficient R programmi…

1.4 Why efficiency?

1.5 Cross-transferable skills for ef…

1.6 Benchmarking and profiling

1.7 Book resources

2 Efficient set-up

3 Efficient programming

4 Efficient workflow

5 Efficient input/output

6 Efficient data carpentry

7 Efficient optimization

8 Efficient hardware

9 Efficient collaboration

10 Efficient learning

Efficient R programming

1 Introduction

This chapter introduces the book. It describes the wide range of people it was written for, in terms of R and programming experience, and how you can get the most out of it. Anyone setting out to improve efficiency should have an understanding of precisely what they mean by the term, and this is discussed, with reference to *algorithmic* and *programmer* efficiency in Section 1.2, and with reference to R in particular in 1.3. It may seem obvious, but it's also worth thinking about *why* anyone would bother with efficient code now that powerful computers are cheap and accessible. This is covered in Section 1.4.

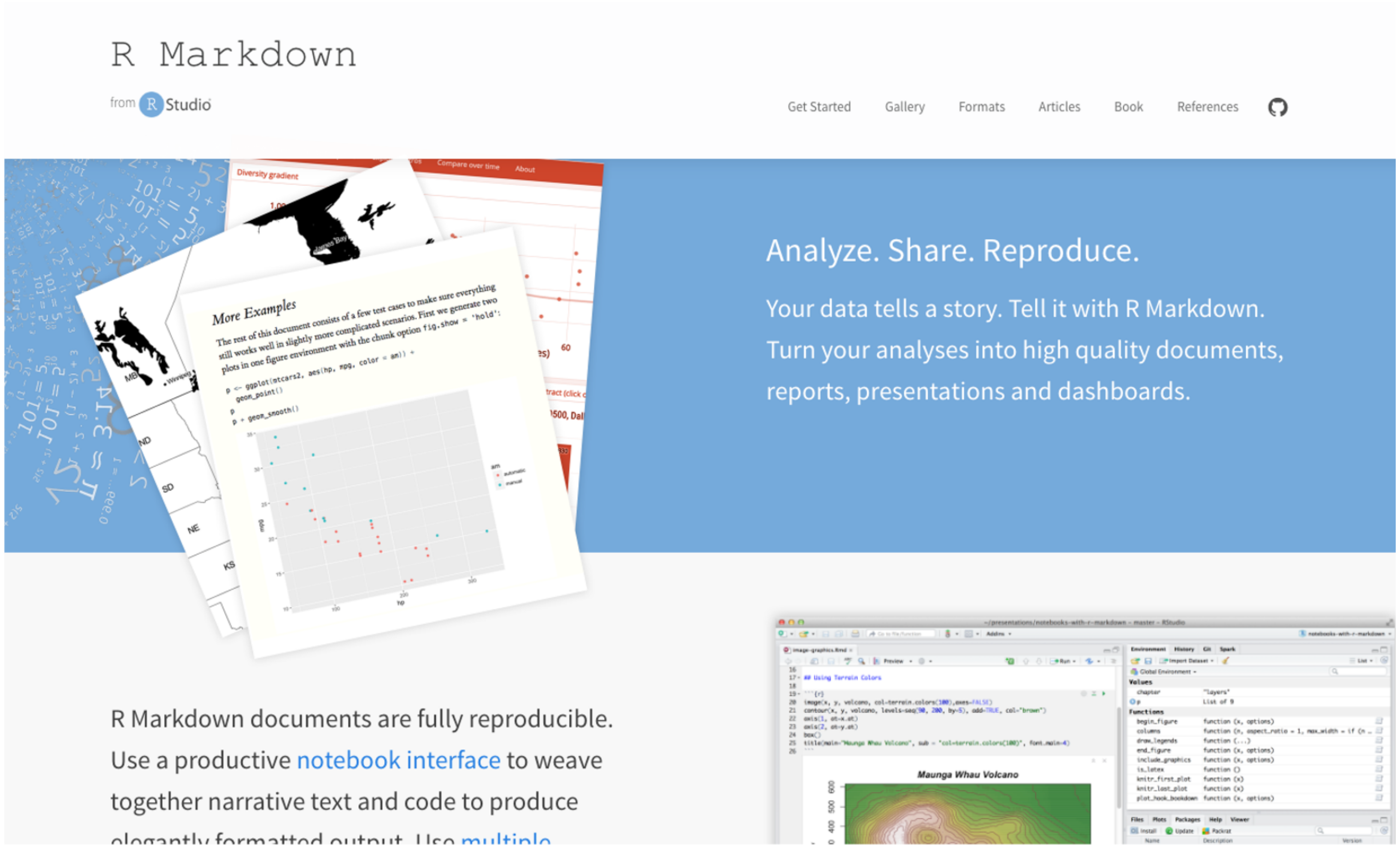
This book happily is not completely R-specific. Non R programming skills that are needed for efficient R programming, which you will develop during the course of following this book, are covered in Section 1.5. Unusually for a book about programming, this section introduces touch typing and consistency: cross-transferable skills that should improve your efficiency beyond programming. However, this is first and foremost a book about programming and it wouldn't be so without code examples in every chapter. Despite being more conceptual and discursive, this opening chapter is no exception: its penultimate section (1.6) describes these two essential tools in the efficient R programmer's toolbox, and how to use them with a couple of illustrative examples. The final thing to say at the outset is how to use this book in conjunction with the book's associated package and its source code. This is covered in Section 1.7.

Prerequisites

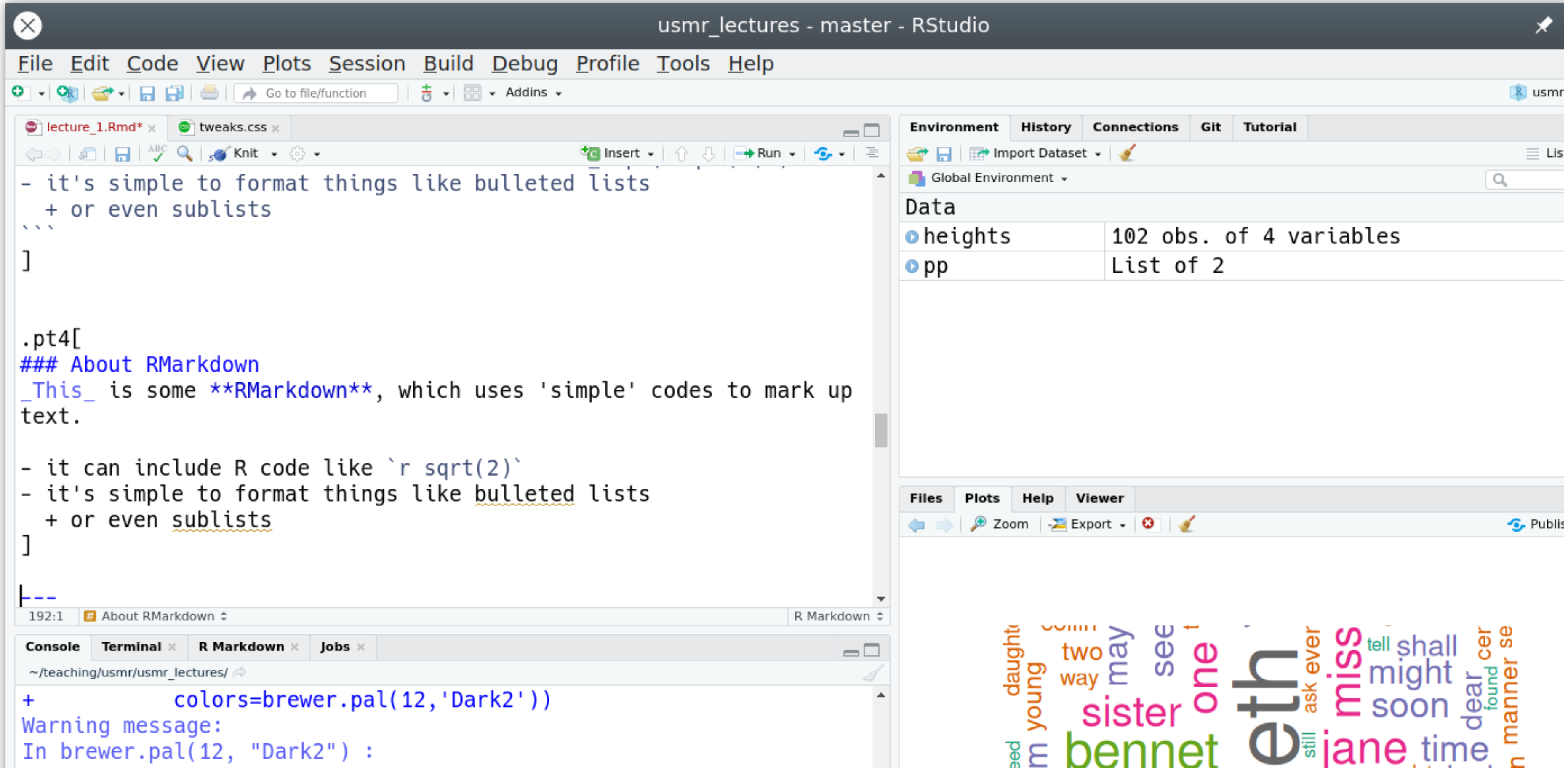
As emphasised in the next section, it's useful to run code and experiment as you read. This *Prerequisites* section ensures you have the necessary packages for each chapter. The prerequisites for this chapter are:

RMarkdown: Websites

For example: https://rmarkdown.rstudio.com/

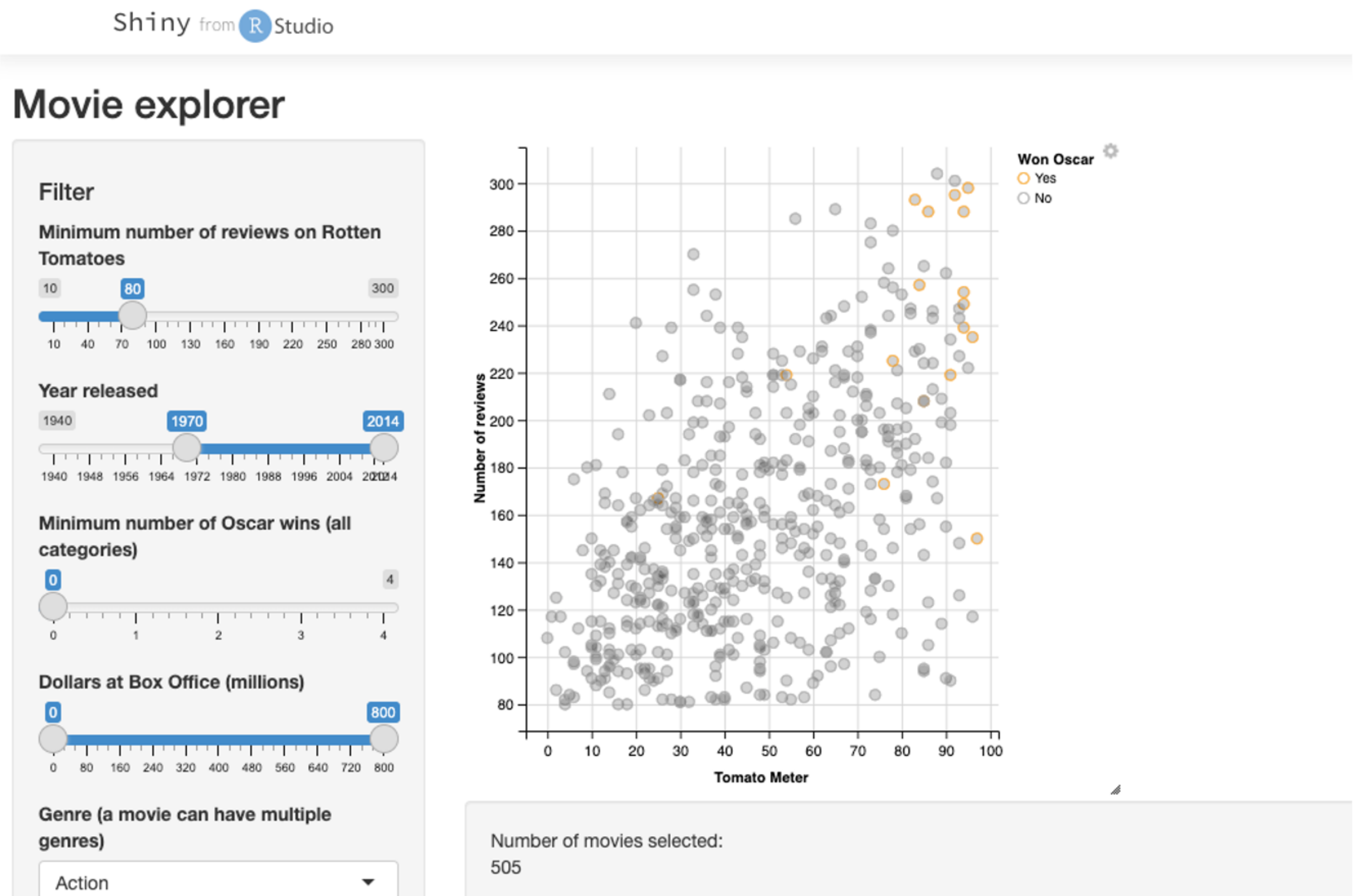


- USMR course materials (the readings, these lecture slides, etc) are all created in RStudio, using RMarkdown and R



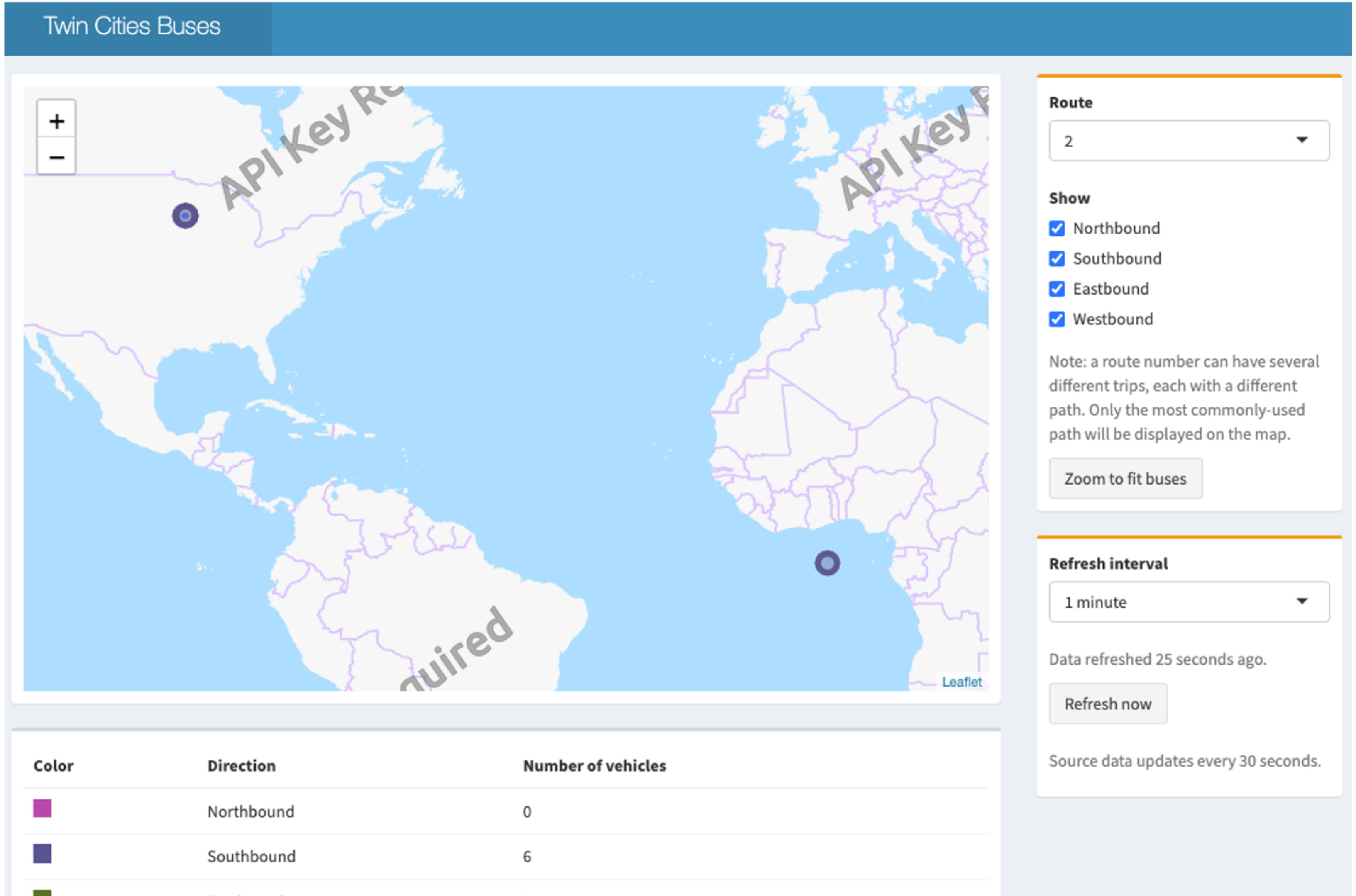
Online Interactive Visualisation

For example: https://shiny.rstudio.com/gallery/movie-explorer.html



Online Interactive Visualisation

For example: https://gallery.shinyapps.io/086-bus-dashboard/



R for Anything to do with Data

Pride and Prejudice

```r
require(tm)
require(wordcloud)
# load "Pride and Prejudice"
pp <- Corpus(DirSource('R/PP/'))
pp <- tm_map(pp,stripWhitespace)
pp <- tm_map(pp,tolower)
pp <- tm_map(pp,removeWords,
             stopwords('english'))
pp <- tm_map(pp,stemDocument)
pp <- tm_map(pp,removePunctuation)
pp <- tm_map(pp, PlainTextDocument)
wordcloud(pp, scale=c(5,0.5), max.words=150,
          random.order=FALSE, rot.per=0.35,
          colors=brewer.pal(12,'Dark2'))
```

The R Community

- *someone else* has done all the hard work to create wordclouds
- released as libraries or **packages** (like `lme4` and `tidyverse`)
- all I supplied was a text version of *Pride and Prejudice*

- **R** allows you to do *anything* with data
- if it's useful, chances are someone has already done it
- useful things include statistics!

The R Community

- if it serves no purpose, chances are that someone's already done it too

```
library(cowsay)
say("hello USMR")
```

```
## 
##  -------------- 
## hello USMR 
##  --------------
##     \
##       \
##         \
##             |\___/|
##           ==) ^Y^ (==
##             \  ^  /
##              )=*=(
##             /     \
##             |     |
##            /| | | |\
##            \| | |_|/\
##       jgs  //_// ___/
##                \_)
## 
```

Why Use R?

- because it's a *language*, I can easily show you what I did and you can copy it
- because it's a *language*, statisticians can use it to implement leading-edge stats
- because it's *free*, anyone can use it---and anyone can access your research
- because it's *open source*, anyone can fix or improve R

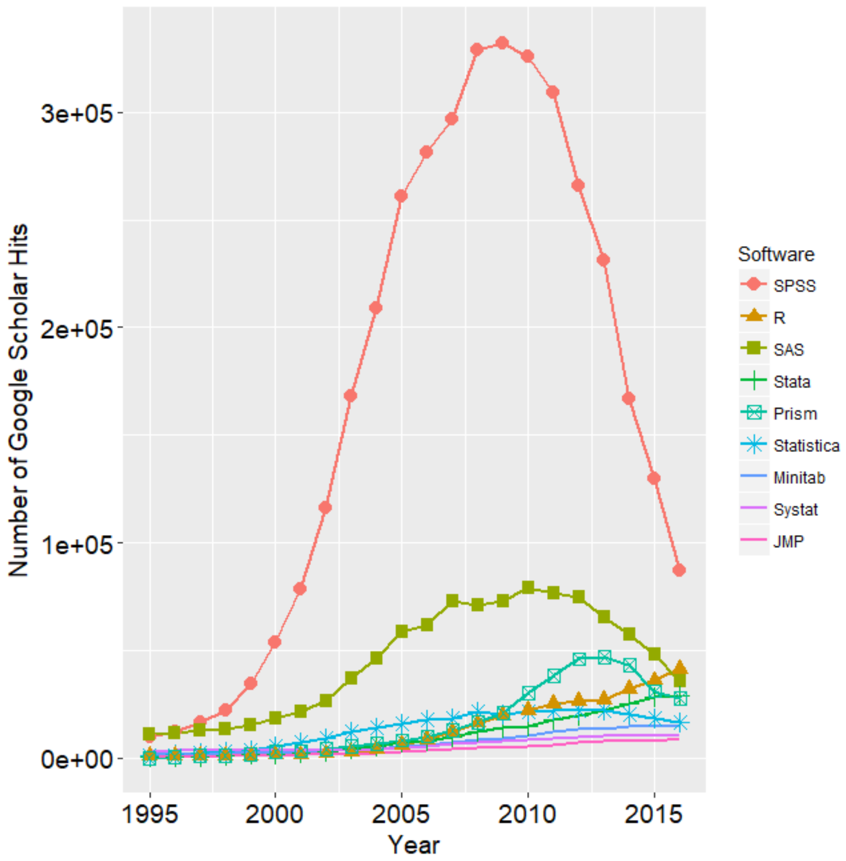
Devilish stuff

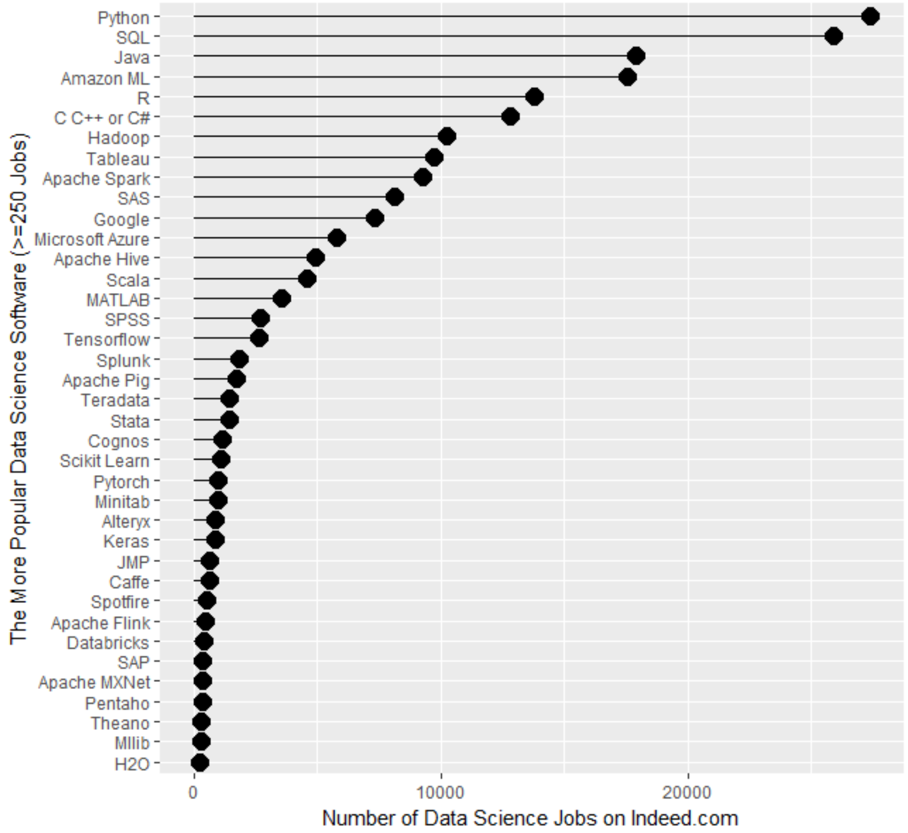
doing stats

coding

NB all indices in R start at 1

Why use R??





https://r4stats.com/articles/popularity

End of Part 1

Part 2

Getting to Grips with R

Data in R

- you can type **data** directly in to R

```
# a number
1.2
```

```
## [1] 1.2
```

```
# characters (a string)
"fáilte"
```

```
## [1] "fáilte"
```

- and you can do **operations** on data

```
1.2 + 7 * 2
```

```
## [1] 15.2
```

Variables

- you can assign data to variables

```
bodyTemp <- 37.8
```

- and use those variables

```
bodyTemp * (9/5) + 32 # to Fahrenheit
```

```
## [1] 100
```

- NB spelling/capitalization matter

```
BodyTemp - 37
```

```
## Error in eval(expr, envir, enclos): object 'BodyTemp' not found
```

Statistics is about groups of things

```r
allTemps <- c(37.8, 0, 37.4)

# vector maths
allTemps * (9/5) + 32
```

```
## [1] 100.04  32.00  99.32
```

- note the vectorization of the calculation
- R is designed from the bottom up to deal with groups

Not everything is a number

```
allHair <- c("brown","white","black")
allHair
```

```
## [1] "brown" "white" "black"
```

- these are called character strings
  - can be anything
- categories (nominal data) are from a limited set
  - called factors in R

```
as.factor(allHair)
```

```
## [1] brown white black
## Levels: black brown white
```

Basic types of data (stats)

- **Nominal**

  ('names of things': e.g., hair colour)
- **Ordinal**

  (order, no number: e.g., small-medium-large)
- **Interval**

  (number without a true zero: e.g., body temp in ℃)
- **Ratio**

  (number with a true zero: e.g., height)

NOIR in R

Type	R Variable Type
Nominal	character/factor
Ordinal	number
Interval	number
Ratio	number

- nominal

```
allHair <- as.factor(c("brown", "white", "black"))
allHair
```

```
## [1] brown white black
## Levels: black brown white
```

- interval

```
allTemps <- c(37.8, 0, 37.4)
allTemps
```

```
## [1] 37.8  0.0 37.4
```

NOIR in R

Type	R Variable Type
Nominal	character/factor
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- nominal

```
allHair <- as.factor(c("brown", "white", "black"))
allHair
```

```
## [1] brown white black
## Levels: black brown white
```

- interval

```
allTemps <- c(37.8, 0, 37.4)
allTemps
```

```
## [1] 37.8  0.0 37.4
```

- ordinal data can also be represented as **ordered factors** (`as.ordered()`)

Break it down

```
allHair <- c("brown","white","black")
```

`allHair`	• **variable** (can be anything that isn't *reserved*)
`<-`	• **assignment** ("goes in to")
`c()`	• **function** (`c()` *combines* its **arguments**)
`"brown"`	• **character** (arbitrary sequence of symbols)

Dataframes

- data can be grouped into a dataframe
- each *line* represents one set of observations
- each *column* represents one type of information
    - (a bit like a spreadsheet)

```
people <- data.frame(name=c('Johanna','Casper','Steve'),
                     temp=allTemps,
                     hair=as.factor(allHair),
                     height=c(132,205,181))
people
```

```
##       name temp  hair height
## 1 Johanna 37.8 brown    132
## 2  Casper  0.0 white    205
## 3   Steve 37.4 black    181
```

Can you run an function on a dataframe?

- youbetcha!

```
summary(people)
```

```
##      name                temp          hair        height   
##  Length:3           Min.   : 0.0   black:1   Min.   :132  
##  Class :character   1st Qu.:18.7   brown:1   1st Qu.:156  
##  Mode  :character   Median :37.4   white:1   Median :181  
##                     Mean   :25.1             Mean   :173  
##                     3rd Qu.:37.6             3rd Qu.:193  
##                     Max.   :37.8             Max.   :205  
```

- or on a vector

```
mean(people$temp) # just the temp column from people
```

```
## [1] 25.07
```

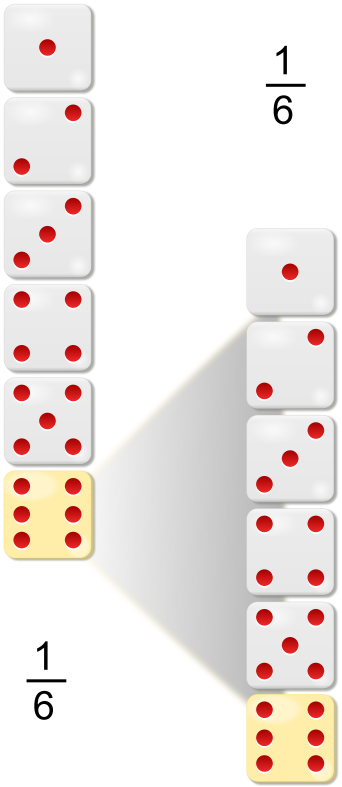
We know a little about R

- we've seen some R code
- we know about basic data types
- we know what variables are
- we've seen vectors, and dataframes
- we've seen a couple of examples of functions

End of Part 2

Part 3

How likely are you to throw 12 with two dice?



- pretty easy to work out
- one-in-six chance of throwing a six
- one-in-six chance of throwing a second six
  - NB., these observations are *independent*
  - (wouldn't matter if you threw one dice twice or two dice together)
- $\frac{1}{36}$ chance of throwing two sixes

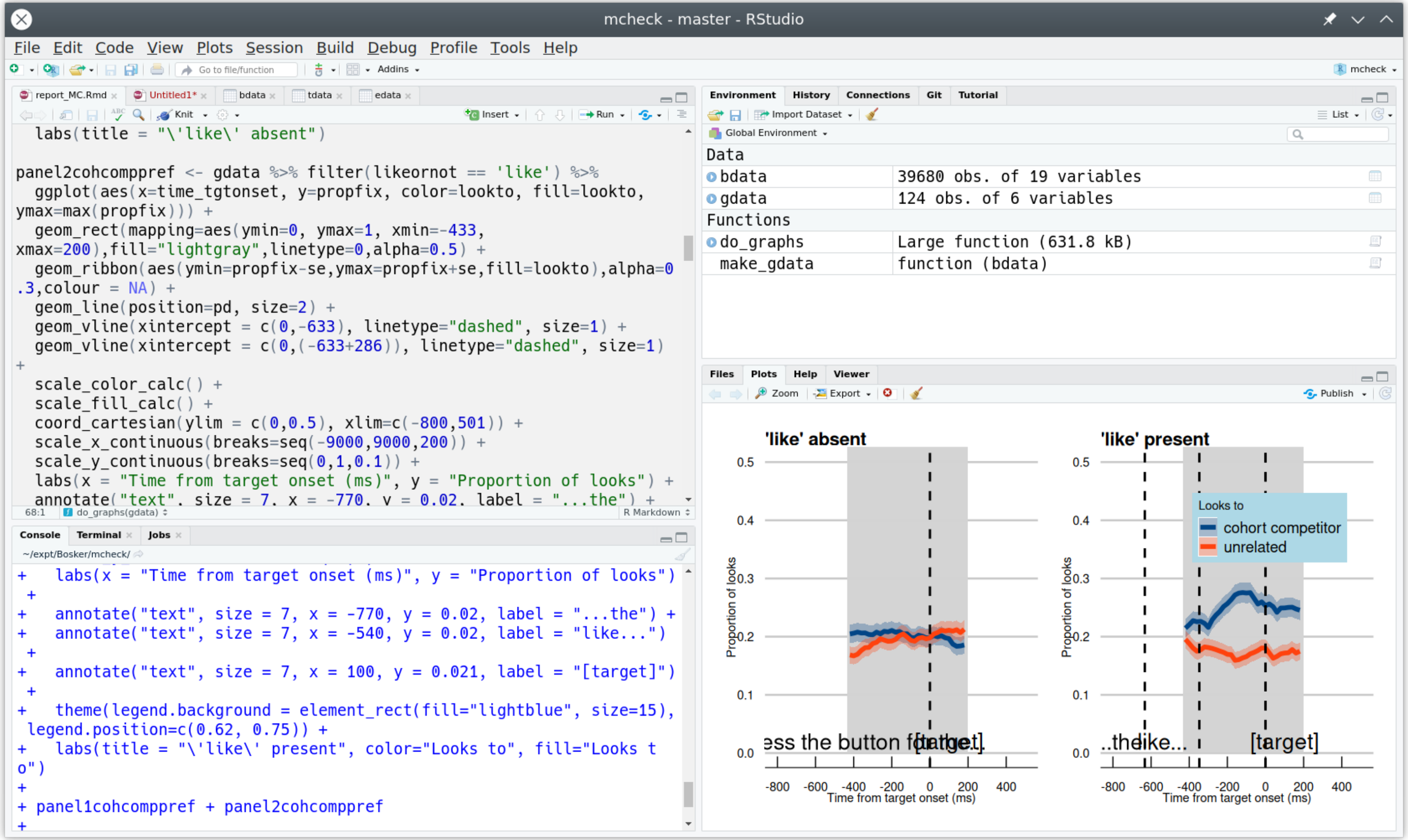
Are my dice fair?

- one way to find out: throw two dice many times and count the outcomes

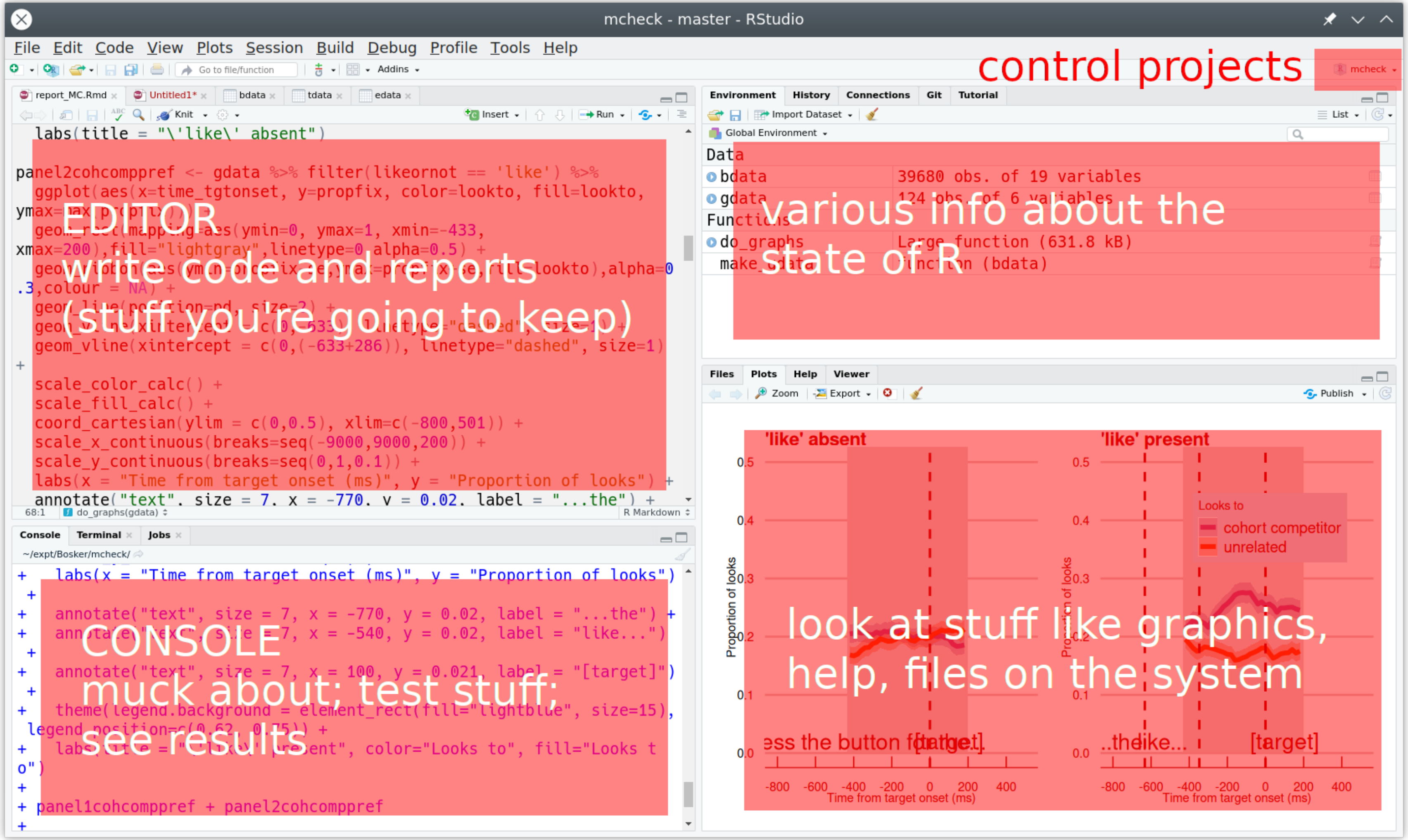
What would fair dice look like?

- we need a lot of throws
- first rule of coding: be lazy
- let the computer do the work

Using RStudio



Using RStudio



create some dice

Now we can throw dice a *lot* of times

```
dice <- function(num=1) {
  sum(sample(1:6, num, replace=TRUE))
}

dice()
```

```
## [1] 1
```

Now we can throw dice a *lot* of times

```
dice <- function(num=1) {
  sum(sample(1:6, num, replace=TRUE))
}

dice()
```

```
## [1] 1
```

```
dice(2)
```

```
## [1] 7
```

Throw two dice many times

```
replicate(250,dice(2))
```

```
##   [1] 11  7  7  4 10  9  7  6 12  3  4  9  6 11 10  6  7  8  9  9  7 10  8  6 12
##  [26] 10  7  6  7  7  8 11  3  5  6 11  3  4  7  9  7 11  3  6  8  8 10  8  8  6
##  [51]  3  4  7  7 10  9  9  7  5 11  7  8  5  3  9  5  4  3  8  4 11 10  5 10  6
##  [76]  7  6 11  5  7  7 10  5  5  2  6  7  5  4  7  5  9  8  6  6  9  7  9  8  6
## [101]  6  8  6  4  5  5  6  4 10  9  3  4  9  5  6  5  9  3  8  5  4  7  6  5  7
## [126]  8 11  9 10  7  8  6  6 12  8  3  7  7  9  6  4  4  6  5  7  7  2  5  9 12
## [151]  6 11  6  7  4  5  5  8  6  8 11  7  5  7  6  4  7 11  3  5  2  7  8  8  7
## [176] 10  6  7  7  3  3  5  4  3  4 11  3  9  7  8  7 10  9  9  6 10  7  7  6 10
## [201]  9  5  9  9  7  5  7  9  3  7  5  5  3  6  7  5  4  3  8  6 11 11  6  9  7
## [226] 10  9  6  4  8 10  7  8  4  5  8  8  7  9  9 11 11  6  5  9 10 11  9  7  9
```

Throw two dice many times

```
replicate(250,dice(2))
```

```
##   [1] 11  7  7  4 10  9  7  6 12  3  4  9  6 11 10  6  7  8  9  9  7 10  8  6 12
##  [26] 10  7  6  7  7  8 11  3  5  6 11  3  4  7  9  7 11  3  6  8  8 10  8  8  6
##  [51]  3  4  7  7 10  9  9  7  5 11  7  8  5  3  9  5  4  3  8  4 11 10  5 10  6
##  [76]  7  6 11  5  7  7 10  5  5  2  6  7  5  4  7  5  9  8  6  6  9  7  9  8  6
## [101]  6  8  6  4  5  5  6  4 10  9  3  4  9  5  6  5  9  3  8  5  4  7  6  5  7
## [126]  8 11  9 10  7  8  6  6 12  8  3  7  7  9  6  4  4  6  5  7  7  2  5  9 12
## [151]  6 11  6  7  4  5  5  8  6  8 11  7  5  7  6  4  7 11  3  5  2  7  8  8  7
## [176] 10  6  7  7  3  3  5  4  3  4 11  3  9  7  8  7 10  9  9  6 10  7  7  6 10
## [201]  9  5  9  9  7  5  7  9  3  7  5  5  3  6  7  5  4  3  8  6 11 11  6  9  7
## [226] 10  9  6  4  8 10  7  8  4  5  8  8  7  9  9 11 11  6  5  9 10 11  9  7  9
```

- ...and record the result

```
d <- replicate(250,dice(2))
```

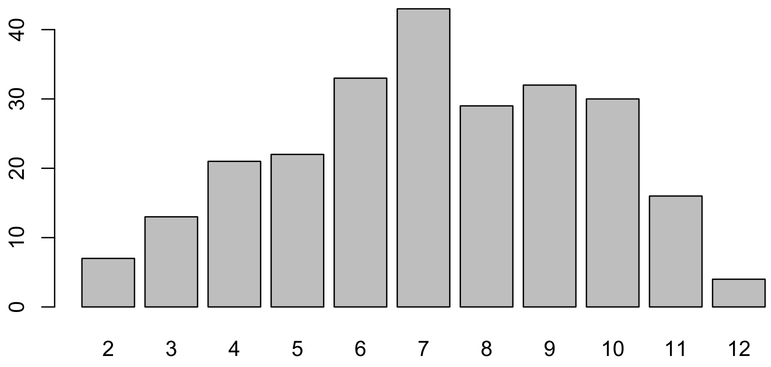
Make a graph

```
table(d)
```

```
## d
##  2  3  4  5  6  7  8  9 10 11 12
##  7 13 21 22 33 43 29 32 30 16  4
```

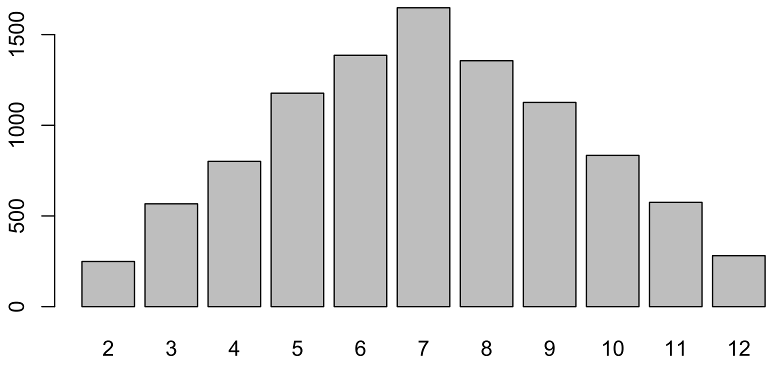
Make a graph

```
barplot(table(d))
```

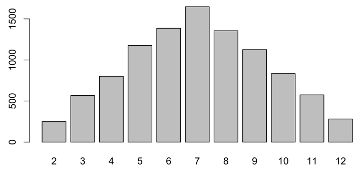


Many more throws

```
d <- replicate(10000,dice(2))
barplot(table(d))
```



10,000 dice throws



- we can work out the proportion of throws that summed to 12

```
sum(d == 12) / 10000
```

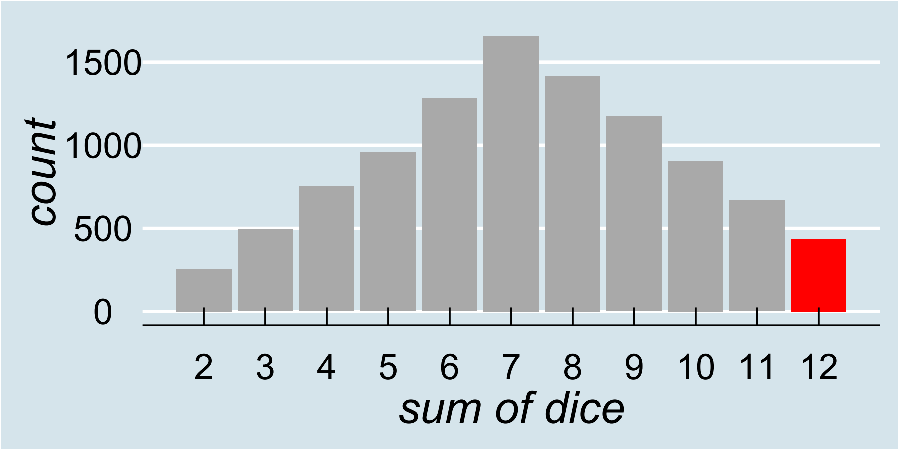
```
## [1] 0.0281
```

- and we know what that proportion should be if the dice are fair

```
1/36
```

```
## [1] 0.02778
```

Some more (fake) dice throws



are the patterns from the dice *different enough* from what we would expect from fair dice for us to conclude that they're unfair?

Statistical questions

- so the million-dollar question is a *negative* question

are we dissatisfied with the suggestion that the pattern of results we have observed should be attributed to chance?

- if we are, then maybe we can persuade you of a different explanation
- but note that the different explanation is not *proven*, it's *suggested*

End

Acknowledgements

- icons by Diego Lavecchia from the Noun Project