

Introduction to R

Research Methods and Skills

12/10/2022

Who are we?

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Replicability and reproducibility

Scientists Replicated 100 Psychology Studies, and Fewer Than Half Got the Same Results

The massive project shows that reproducibility problems are widespread across top scientific journals

A question of trust: fixing the replication crisis

The crisis of non-replications in experimental social psychology is a crisis of trust. What's the solution?

RESEARCH ARTICLE

Estimating the reproducibility of psychological science

Open Science Collaboration^{*,†}

* See all authors and affiliations

Science 28 Aug 2015:

Vol. 349, Issue 6251, aac4716

DOI: 10.1126/science.aac4716

Power failure: why small sample size undermines the reliability of neuroscience

Katherine S. Button, John P. A. Ioannidis, Claire Mokrysz, Brian A. Nosek, Jonathan Flint, Emma S. J. Robinson & Marcus R. Munafò ✉

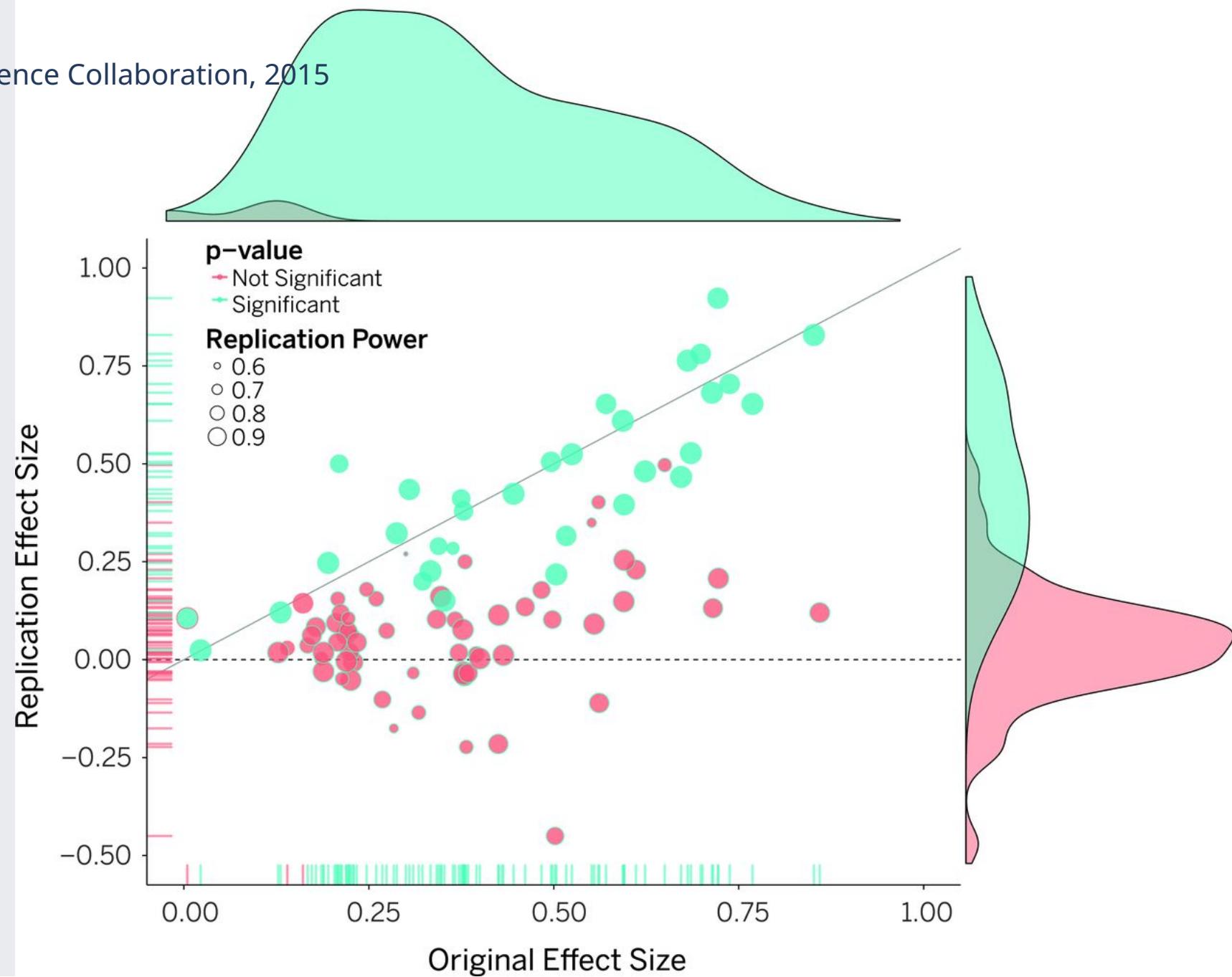
Nature Reviews Neuroscience 14, 365–376 (2013) | Download Citation ↓



Why Most Published Research Findings Are False

John P. A. Ioannidis

Published: August 30, 2005 • <https://doi.org/10.1371/journal.pmed.0020124>



Scenario A

You've just started work in a psychology lab. You're asked to help analyse some old data. There is reaction time data from 50 participants. Each participant's data is stored in a separate text file.

- How do you combine the data from each participant together to be able to analyse the data?
- It turns out some of the participants only completed part of the experiment - which ones, and what should you do with their data?
- What steps should you take to select and perform appropriate statistical analysis?

Scenario B

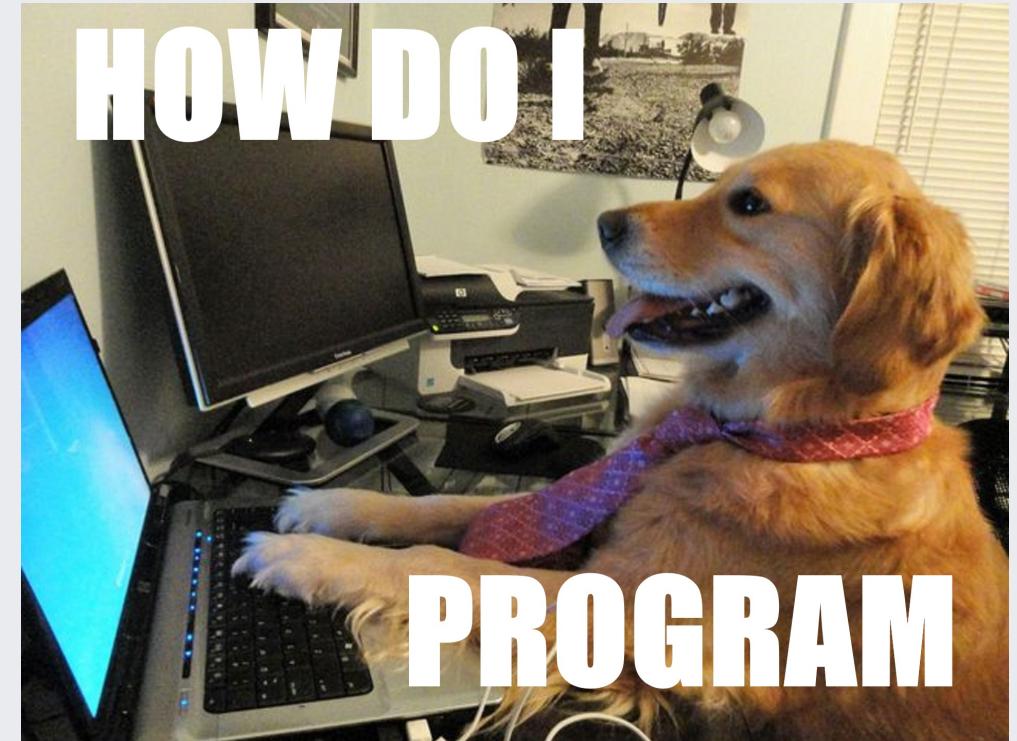
You've been asked to design, implement, and evaluate a new treatment regime across several psychiatric institutes. Several colleagues are skeptical that it can deliver the kind of improvements in outcomes indicated in a publication describing the method.

- How do you interpret the strength of the previously published evidence?
- How do you design a rigorous test of the treatment efficacy?
- How do you evaluate and report on the outcomes of your trial?

Research Methods and Skills



HOW DO I STATISTICS?



HOW DO I
PROGRAM

Course outline

Weeks 1-5

- Introduction to R
- Basic R programming
- Plotting with ggplot2
- Data import, selection and manipulation
- Describing and summarising your data

Weeks 6-10

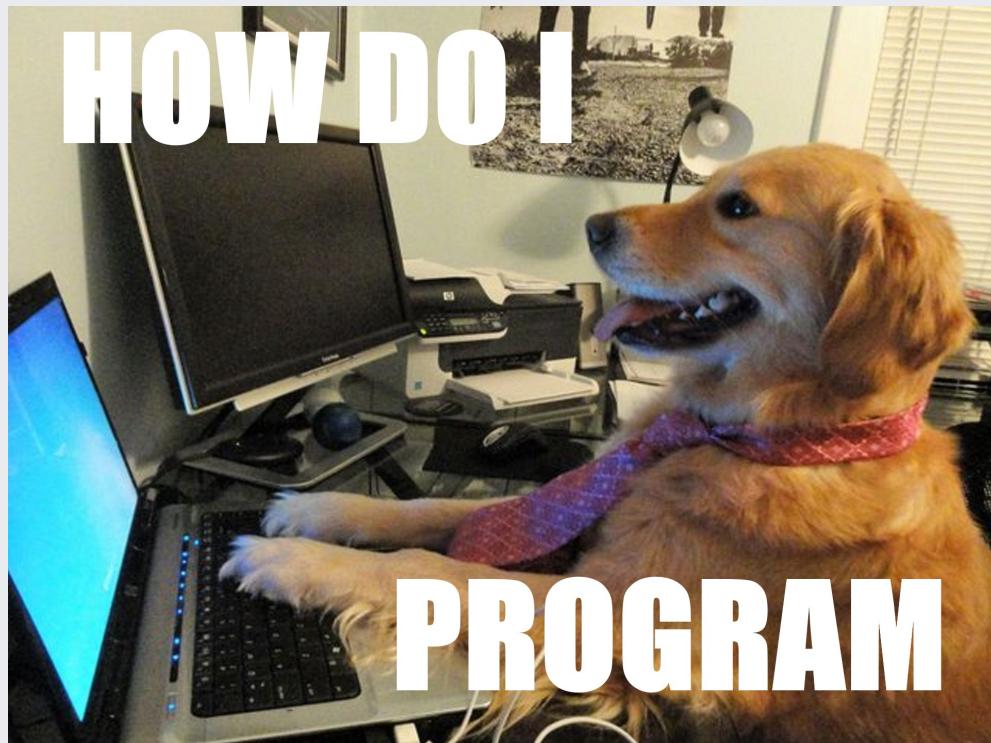
- Hypothesis testing and estimation
- *t*-tests and comparing two groups
- Correlation and linear regression
- One-way ANOVA
- Factorial ANOVA

Weeks 11-13

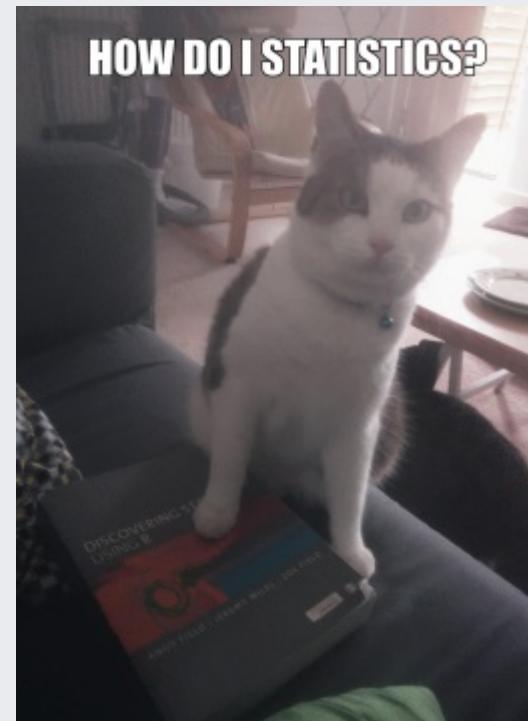
- Qualitative methods

Course outline

Weeks 1-5

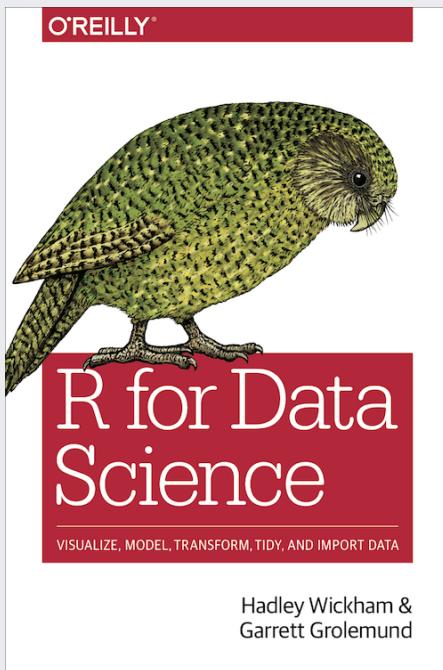


Weeks 5, 7-10

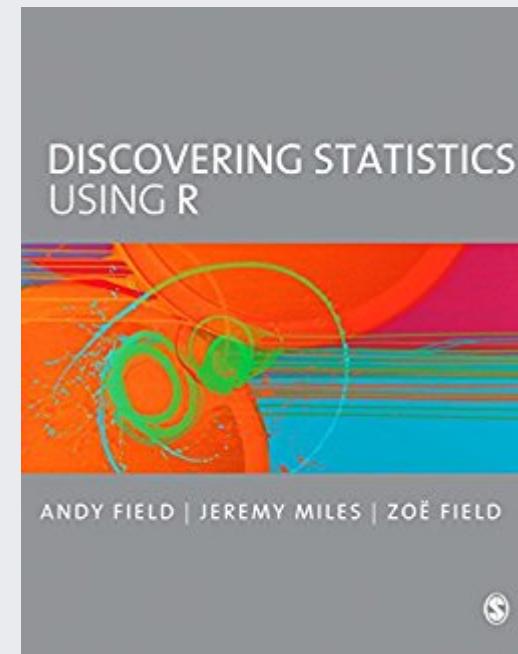


Course outline

Weeks 1-5



Weeks 5-10



How it's going to work

Where possible you'll be provided with a set of pre-recorded videos each week introducing the core topics for that week.

Most weeks you will be provided with some exercises to work on and complete formative assignment. The aim of the formative stage of the assignment is to enable you to produce an outline of your proposed summative for feedback from the module team.

In the timetabled (lecture) sessions we will spend the first hour going over the topic for that week. In the second hour (workshop), you can spend the time working together on the exercises, and we'll be available to help out. You will finish up with a formative assignment for that week and receive a formative feedback.

If you get stuck **ask us!**

Introduction to R and RStudio

What is R?

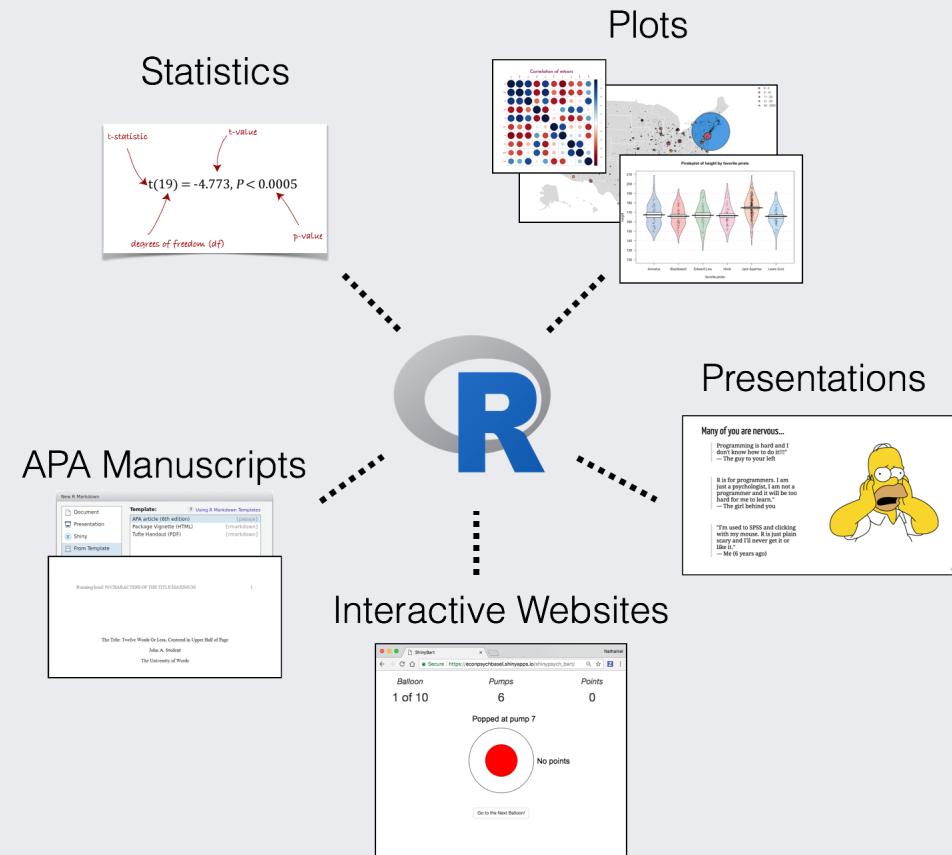


R is a statistical, mathematical programming language

- Created in 1993
- Designed from the ground up to support many statistical tasks
- Covers all aspects of data analysis from import through to production of reports
- Free, open source
 - Can be downloaded from the R-project website
- Continually evolving
 - R has over 12,000 *packages* that add additional functions

But WHY?

What can you do with R?



Source: N. D. Phillips

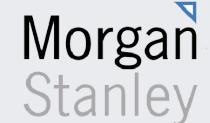
Companies that use R for Analytics



Gartner



Welcome to possible



TATA CONSULTANCY SERVICES

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Deloitte.

accenture
High performance. Delivered.



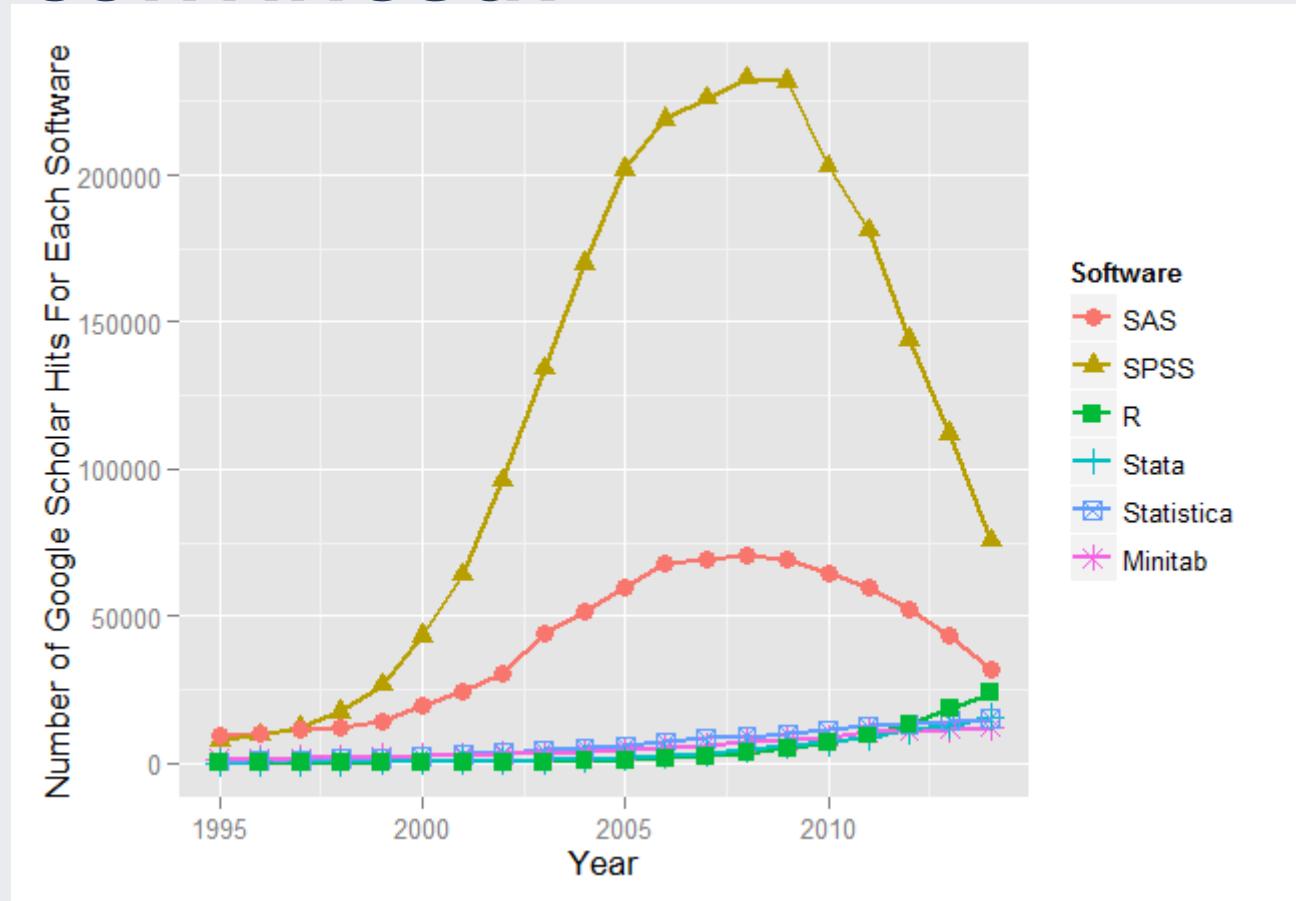
Booz | Allen | Hamilton

strategy and technology consultants

Cognizant



Still not convinced?

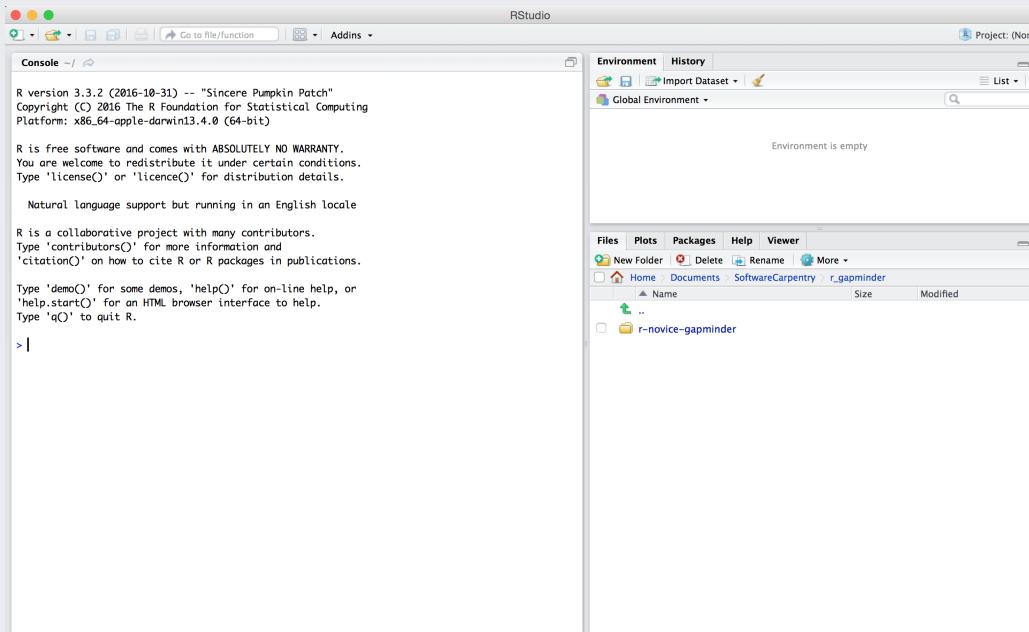


Getting started

What is RStudio?

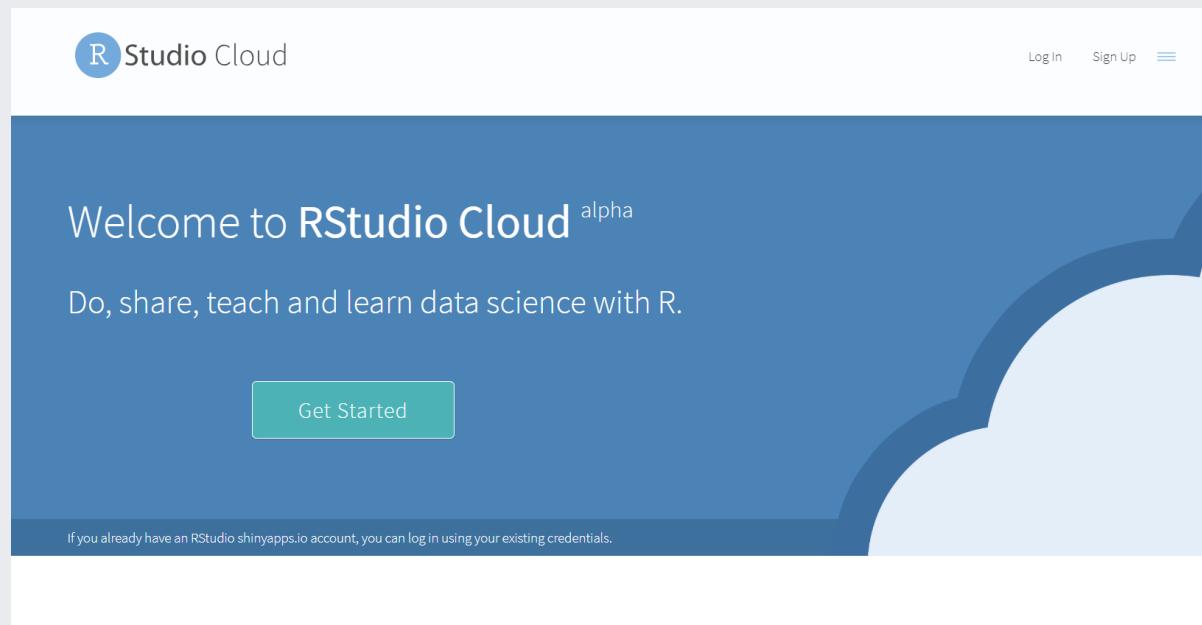


- An **Integrated Development Environment (IDE)**
- An interface for R that makes your life much, much easier
- Makes many things explicit that you would otherwise have to guess



Getting started TODAY

1. Open up a web browser
2. Go to <https://rstudio.cloud>
3. Sign up! Use your REAL NAME, and your University of Lincoln email address.





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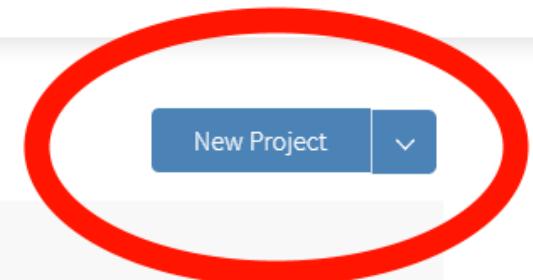
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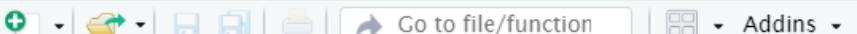
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R 3.5.0

Console Terminal x Jobs x

/cloud/project/ ↵

```
R version 3.5.0 (2018-04-23) -- "Joy in Playing"  
Copyright (C) 2018 The R Foundation for Statistical Computing  
Platform: x86_64-pc-linux-gnu (64-bit)
```

```
R is free software and comes with ABSOLUTELY NO WARRANTY.  
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```

```
R is a collaborative project with many contributors.  
Type 'contributors()' for more information and  
'citation()' on how to cite R or R packages in publications.
```

```
Type 'demo()' for some demos, 'help()' for on-line help, or  
'help.start()' for an HTML browser interface to help.  
Type 'q()' to quit R.
```

>

Environment History Connections



Global Environment

Environment is empty

Files Plots Packages Help Viewer

	Name	Size	Modified
	..		
	.Rhistory	0 B	Sep 18, 2018
	project.Rproj	205 B	Sep 18, 2018

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```
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Type 'q()' to quit R.
```

> |

Tools Help

Install Packages...

Check for Package Updates...

Version Control

Shell...

Terminal

Addins

Keyboard Shortcuts Help Shift+Alt+K

Modify Keyboard Shortcuts...

Project Options...

Global Options...

R 3.5.0

Dataset Connections

List

Environment is empty

Pages Help Viewer

Cloud > project			
	Name	Size	Modified
<input type="checkbox"/>	.Rhistory	0 B	Sep 24, 2018, 11:53 AM
<input type="checkbox"/>	project.Rproj	205 B	Sep 24, 2018, 12:29 PM

RStudio Cloud

https://rstudio.cloud/project/84901

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```
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Platform: x86_64-pc-linux-gnu (64-bit)
```

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'citation()' on how to cite R or

Type 'demo()' for some demos, 'help.start()' for an HTML browser
Type 'q()' to quit R.

> |

Options

RStudio theme: Modern

Editor Font size: 10

Editor theme: Ambiance

General Appearance Pane Layout Packages R Markdown Sweave Spelling Git/SVN Publishing Terminal

```
# plotting of R objects  
plot <- function (x, y, ...)  
{  
  if (is.function(x) &&  
      is.null(attr(x, "class")))  
  {  
    if (missing(y))  
      y <- NULL  
  
    # check for ylab argument  
    hasylab <- function(...)  
    !all(is.na(  
      pmatch(names(list(...)),  
             "ylab")))  
  
    if (hasylab(...))  
      plot.function(x, y, ...)  
  
    else  
      plot.function(  
        x, y,  
        ylab = paste(  
          deparse(substitute(x)),  
          "(x)"),  
        ...)  
  }  
  else  
    UseMethod("plot")  
}
```

OK Cancel Apply

R 3.5.0

List

Search

Empty

Renamer More

Size	Modified
0 B	Sep 24, 2018, 11:53 AM
205 B	Sep 24, 2018, 12:29 PM

How it works!



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```
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'help.start()' for an HTML browser interface to help.  
Type 'q()' to quit R.
```

>

Environment History Connections

Import Dataset ↵

Global Environment ↵

Environment is empty

Files Plots Packages Help Viewer

	Name	Size	Modified
<input type="checkbox"/>	..		
<input type="checkbox"/>	.Rhistory	0 B	Sep 18, 2018
<input type="checkbox"/>	project.Rproj	205 B	Sep 18, 2018



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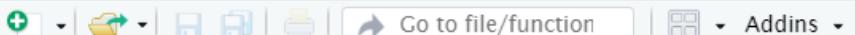
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Go to file/function

Addins

R 3.5.0

Console Terminal x Jobs x

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```

>

Environment History Connections



Global Environment



Environment is empty

Files Plots Packages Help Viewer



Cloud > project

Name	Size	Modified
..		Sep 18, 2018
.Rhistory	0 B	Sep 18, 2018
project.Rproj	205 B	Sep 18, 2018

REPL

How to use R

- The R Console
 - REPL: Read/Evaluate/Print/Loop
 - Type stuff in, it tries to do it

When you see the > symbol -

```
>
```

... R is waiting for your input.

```
> 5  
[1] 5
```

Warming up

Try using R like a calculator!

Basic arithmetic operators

Symbol	Operation
+	addition
-	subtraction
*	multiplication
/	division
^	exponentiation
%%	modulo

Warming up

You can break up long maths expressions over multiple lines:

```
2 + 4 + 5 +  
5 + 6 + 7 + 8 +  
10
```

```
## [1] 47
```

Note that when you do that, the ">" symbol changes to a "+"

```
> 5 +  
+ 5  
[1] 10
```

Remember!

> means R is waiting for input.

```
>
```

+ means R is waiting for you to finish your command.

```
+
```

Either finish your command, or press the **Esc** key to cancel it.

Text input

R can also accept text strings as input.

```
"hello world!"  
[1] "hello world!"
```

You need to use quotation marks ("") to tell R that this is text:

```
hello world!
```

```
## Error: <text>:1:7: unexpected symbol  
## 1: hello world  
##           ^
```

Otherwise, you'll receive an error like the one above.

Why is there an error?

In R, you can assign values to an **object** for subsequent use. **Objects** have names that are written as text.

The assignment operator is the two-character symbol:

```
<-
```

You assign values to objects by putting the <- sign between the name of the object and the value you want to give it:

```
example <- 5  
example
```

```
## [1] 5
```

Note that R does not immediately provide output when you assign the output to an object.

The assignment operator

Think of `<-` as meaning "is now". i.e.

```
example <- 5
```

can be read as

```
The object "example" is now 5
```

Working with objects

Once an object is assigned, the name that you gave it *stands in* for the *value* that you assigned to it, and can be used as if it were that value:

example

```
## [1] 5
```

example + 10

```
## [1] 15
```

example + 13 - 1 * 2 %% 4

```
## [1] 16
```

RStudio Cloud

https://rstudio.cloud/project/84901

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'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
> example <- 10
> hi_there <- "hi there!"
> hi_there
[1] "hi there!"
> example
[1] 10
> |
```

Environment History Connections

Import Dataset

Global Environment

Values	
example	10
hi_there	"hi there!"

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New Folder Upload Delete Rename More

Cloud > project

Name	Size	Modified
..		
.Rhistory	0 B	Sep 24, 2018, 11:53 AM
project.Rproj	205 B	Sep 24, 2018, 1:06 PM

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```
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Type 'q()' to quit R.

>
> example <- 10
> hi_there <- "hi there!"
> hi_there
[1] "hi there!"
> example
[1] 10
> |
```

Environment History Connections

Import Dataset

Global Environment

Values

example	10
hi_there	"hi there!"

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Cloud > project

Name	Size	Modified
..		
.Rhistory	0 B	Sep 24, 2018, 11:53 AM
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R 3.5.0

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```
>
> example <- 10
> hi_there <- "hi there!"
> hi_there
[1] "hi there!"
> example
[1] 10
>
```

Environment History Connections

To Console To Source

```
example <- 10
hi_there <- "hi there!"
hi_there
example
```

Files Plots Packages Help Viewer

.Rhistory 0 B Sep 24, 2018

project.Rproj 205 B Sep 24, 2018

History

Try it out!

Try a few things out!

1. Assign some values to objects using the assignment operator (<-)
2. Try using arithmetic operations (e.g. *, /, %%) on those objects
3. Try using arithmetic operations to combine multiple numerical objects
4. Try using arithmetic operations on text

Combining multiple things

Sometimes you want to allocate more than one value to an object. You can use the **c()** function to do this.

```
c(8, 5, 10)
```

```
## [1] 8 5 10
```

```
example <- c(8, 5, 10)  
example
```

```
## [1] 8 5 10
```

```
c("hello", "how", "are", "you")
```

```
## [1] "hello" "how"   "are"    "you"
```

IMPORTANT: BRACKETS () AFTER A WORD MEAN THAT THIS IS A FUNCTION

Vectors

The function **c()** is creating **vectors**.

Vectors are simply a one-dimensional collection of things that all have the same *type* (we will cover data types next week!).

Note that mixing, for example, text and numbers, will yield a *character* vector.

```
c(5, "five", 2)
```

```
## [1] "5"     "five"   "2"
```

Functions

Functions are commands that operate on **objects**.

For example, to calculate the *mean* of several numbers, you can use the function **mean()**. The output of functions can also be assigned to **objects** using **<-**.

```
mean(c(8, 5, 10))
```

```
## [1] 7.666667
```

```
example <- c(8, 5, 10)
mean(example)
```

```
## [1] 7.666667
```

```
example_mean <- mean(example)
example_mean
```

```
## [1] 7.666667
```

Try it out!

1. Use **c()** to create a vector of numbers.
2. Use **c()** to create a vector of strings.
3. Calculate the **mean()** of a vector of numbers.
4. Try guessing some other simple statistics (e.g. other types of *average*) that you can use.

Getting help

If you don't know how to use a function, R has built-in help!

There are several ways you can access it:

```
help("mean")
?mean
??mean
```

The screenshot shows the RStudio interface with three main panes. The left pane displays the R console history with the command `?mean` and its output. The middle pane shows the R environment with global variables `example`, `hi_there`, and `example`. The right pane is the Help Viewer, which is highlighted with a red box. It shows the documentation for the `mean` function, including the title "Arithmetic Mean", a brief description, the usage (`mean(x, ...)`), the default S3 method (`mean(x, trim = 0, na.rm = FALSE, ...)`), and the arguments (`x`).

```
/cloud/project/ >
R version 3.5.0 (2018-04-23) -- "Joy in Playing"
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Type 'q()' to quit R.

> example <- 10
> hi_there <- "hi there!"
> hi_there
[1] "hi there!"
> example
[1] 10
> ?mean
>
```

```
example <- 10
hi_there <- "hi there!"
hi_there
example
?mean
```

```
Files Plots Packages Help Viewer
R: Arithmetic Mean - Find in Topic
mean (base) R Documentation

Arithmetic Mean
Description
Generic function for the (trimmed) arithmetic mean.

Usage
mean(x, ...)

## Default S3 method:
mean(x, trim = 0, na.rm = FALSE, ...)

Arguments
x An R object. Currently there are methods for numeric/logical vectors
and date, date-time and time interval objects. Complex vectors are
```

Packages

Packages are the key to R's versatility. Over 12000 are currently available from the **Comprehensive R Archive Network** - CRAN. The `install.packages()` function can be used to install packages.

Let's install the "cowsay" package. **cowsay** is an extraordinarily useful package, as you'll see.

One way to install the package is using the console:

```
install.packages("cowsay")
```

Once it's installed, use the `library()` function to load the package!

```
library(cowsay)
```

But **another** way to install is using the GUI!

RStudio Cloud

https://rstudio.cloud/project/84901

Your Workspace / Untitled Project *Click to name your project*

Matt Craddock

File Edit Code View Plots Session Build Debug Profile Tools Help

Console Terminal x Jobs x

/cloud/project/ ↵

```
R version 3.5.0 (2018-04-23) -- "Joy in Playing"
Copyright (C) 2018 The R Foundation for Statistical Computing
Platform: x86_64-pc-linux-gnu (64-bit)

R is free software and comes with ABSOLUTELY NO WARRANTY.
You are welcome to redistribute it under certain conditions.
Type 'license()' or 'licence()' for distribution details.

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'citation()' on how to cite R or R packages in publications.

Type 'demo()' for some demos, 'help()' for on-line help, or
'help.start()' for an HTML browser interface to help.
Type 'q()' to quit R.

>
> example <- 10
> hi_there <- "hi there!"
> hi_there
[1] "hi there!"
> example
[1] 10
> ?mean
> |
```

Environment History Connections

To Console To Source

```
example <- 10
hi_there <- "hi there!"
hi_there
example
?mean
```

Files Plots Packages Help Viewer

Install Update Packrat

Name	Description	Version
boot	Bootstrap Functions (Originally by Angelo Canty for S)	1.3-20
class	Functions for Classification	7.3-14
cluster	"Finding Groups in Data": Cluster Analysis Extended Rousseeuw et al.	2.0.7-1
codetools	Code Analysis Tools for R	0.2-15
compiler	The R Compiler Package	3.5.0
datasets	The R Datasets Package	3.5.0
foreign	Read Data Stored by 'Minitab', 'S', 'SAS', 'SPSS', 'Stata', 'Systat', 'Weka', 'dBase', ...	0.8-70
graphics	The R Graphics Package	3.5.0
grDevices	The R Graphics Devices and Support for Colours and Fonts	3.5.0
grid	The Grid Graphics Package	3.5.0
KernSmooth	Functions for Kernel Smoothing Supporting Wand & Jones (1995)	2.23-15
lattice	Trellis Graphics for R	0.20-35
MASS	Support Functions and Datasets for Venables and Ripley's MASS	7.3-49

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```
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> hi_there
[1] "hi there!"
> example
[1] 10
> ?mean
>
```

Environment History Connections

example <- 10
hi_there <- "hi there!"
hi_there
example
?mean

Install Packages

Install from: Repository (CRAN, RSPM) Configuring Repositories

Packages (separate multiple with space or comma): cowsay

cowsay Library: /home/rstudio-user/R/x86_64-pc-linux-gnu-library/3.5 [Default]

Install dependencies

Install Cancel

Packrat

Description	Version
Bootstrap Functions (Originally by Angelo Canty for S)	1.3-20
Functions for Classification	7.3-14
"Finding Groups in Data": Cluster Analysis Extended Rousseeuw et al.	2.0.7-1
Code Analysis Tools for R	0.2-15
The R Compiler Package	3.5.0
The R Datasets Package	3.5.0
Read Data Stored by 'Minitab', 'S', 'SAS', 'SPSS', 'Stata', 'Systat', 'Weka', 'dBase', ...	0.8-70
The R Graphics Package	3.5.0
The R Graphics Devices and Support for Colours and Fonts	3.5.0
The Grid Graphics Package	3.5.0
Functions for Kernel Smoothing Supporting Wand & Jones (1995)	2.23-15
Trellis Graphics for R	0.20-35
Support Functions and Datasets for Venables and Ripley's MASS	7.3-49

Try out the cowsay package

cowsay adds a function called **say()**. Load the function in as follows, and look at the help for **say()**.

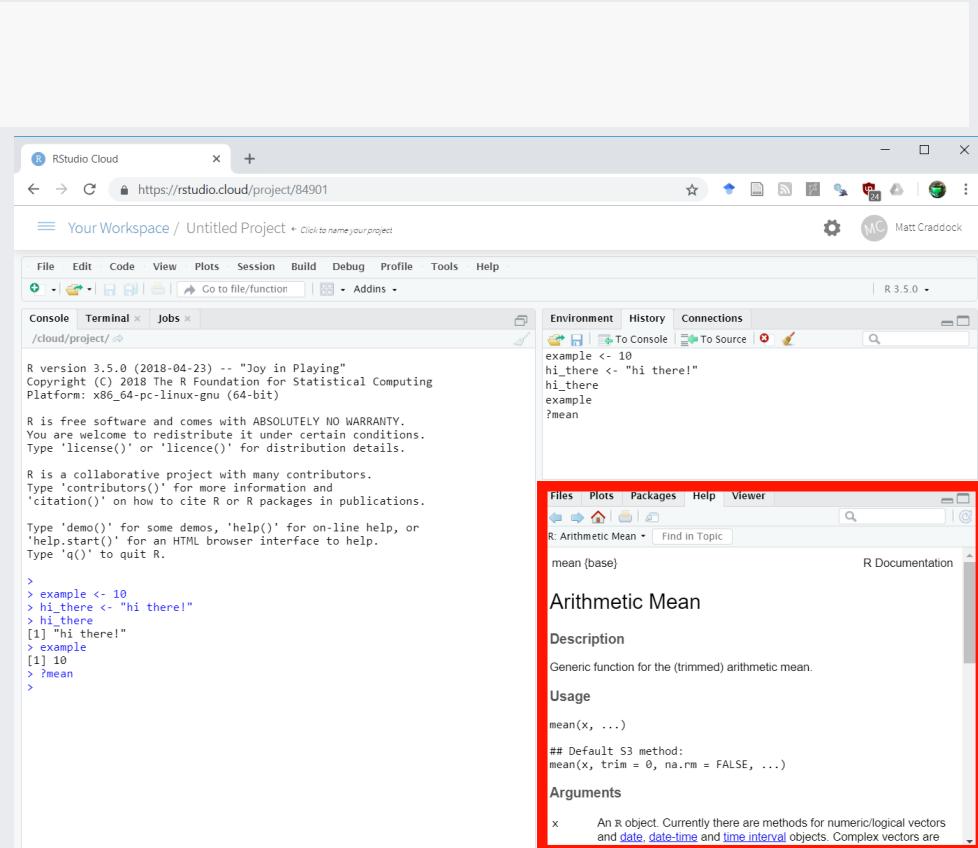
```
library(cowsay)  
?say()
```

Remember that help appears in the bottom right window!

Look at **Usage** and **Arguments**

Usage is how to use the function.

Arguments are what the functions expect and understand.



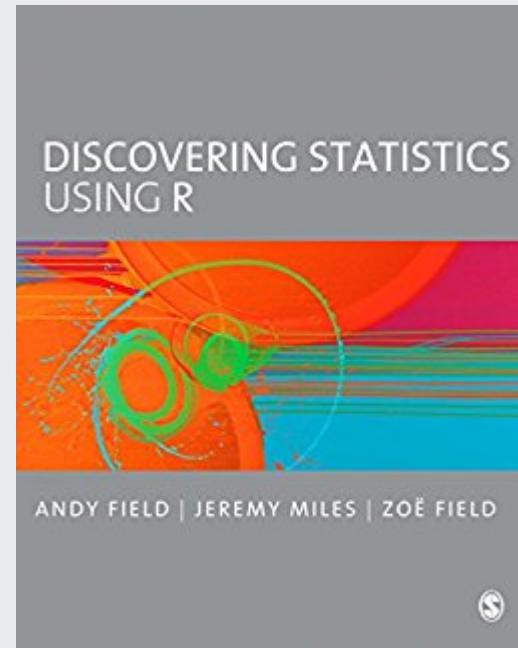
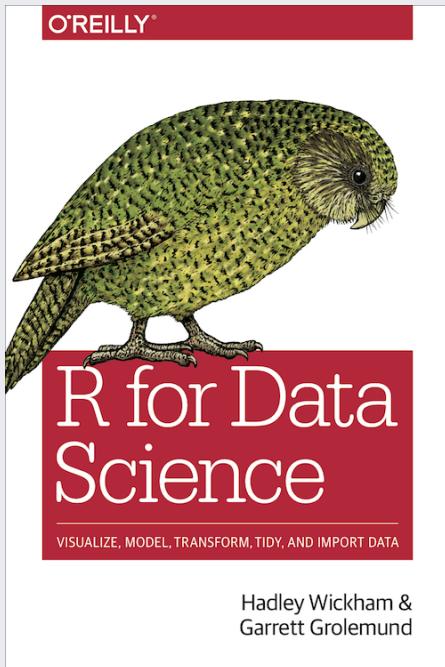
```
say(what = "Feed me, human.", by = "cat")
```

```
##  
## -----  
## Feed me, human.  
## -----  
##      \  
##      \|/  
##      \  /  
##      ==) \_ / | ==  
##          \   ^  /  
##          )=★=(  
##          /     \  
##          |     |  
##          /     |     | \\  
##          \    |     | - | /  
##          jgs  // _/_ \_ /  
##                      \_)  
##
```

Try out the say() function

1. Try a few different animals by changing the **by** argument
2. Change what the animals say by changing the **what** argument.

Additional resources



There are copies of both these books in the library.

R for Data Science is available freely online at <http://r4ds.had.co.nz/>

An additional recommendation...

Hands-on Programming with R

Basic R programming book, also available for free online

<https://rstudio-education.github.io/hopr/index.html>



This week's goals

1. Download R and RStudio! You'll find links and instructions on Blackboard.
2. Read through Chapter 1 of R for Data Science
3. Try out some of the introductory things mentioned in the slides, just to get a feel for using RStudio!