Enhancing Research Reproducibility and Collaboration with RStudio, Git, and GitHub

JP Courneya

May, 2023

Table of contents

Preface

Welcome to the Malaria Research Program at The University of Maryland Baltimore - Center for Vaccine Development and Global Health https://www.medschool.umaryland.edu/malaria/.

These training materials are developed and made publicly available for increasing awareness of reproducible science and enhancing data and programming skills.

Acknowledgements

Git and Github lessons adapt material from:

- Happy Git with R

This is a Quarto book. To learn more about Quarto books visit https://quarto.org/docs/books.

1 Introduction to R and RStudio

The following chapter will provide you with a hands on opportunity to familiarize yourself with RStudio. Learning RStudio is a big topic and we will not be able to cover everything, by the end of this session we hope that you will feel comfortable starting to use R on your own for working with Git and GitHub.

1.1 Learning Objectives

- Navigate RStudio
- Use Posit Cloud (formerly RStudio Cloud)

1.2 Why learn R?

- **R is free, open-source, and cross-platform.** Anyone can inspect the source code to see how R works. Because of this transparency, there is less chance for mistakes, and if you (or someone else) find some, you can report and fix bugs. Because R is open source and is supported by a large community of developers and users, there is a very large selection of third-party add-on packages which are freely available to extend R's native capabilities.
- **R code is great for reproducibility**. Reproducibility is when someone else (including your future self) can obtain the same results from the same dataset when using the same analysis. R integrates with other tools to generate manuscripts from your code. If you collect more data, or fix a mistake in your dataset, the figures and the statistical tests in your manuscript are updated automatically.
- **R relies on a series of written commands, not on remembering a succession of pointing and clicking.** If you want to redo your analysis because you collected more data, you don't have to remember which button you clicked in which order to obtain your results; you just have to run your script again.
- **R is interdisciplinary and extensible** With 10,000+ packages that can be installed to extend its capabilities, R provides a framework that allows you to combine statistical approaches from many scientific disciplines to best suit the analytical framework you

need to analyze your data. For instance, R has packages for image analysis, GIS, time series, population genetics, and a lot more.

- **R works on data of all shapes and sizes.** The skills you learn with R scale easily with the size of your dataset. Whether your dataset has hundreds or millions of lines, it won't make much difference to you. R is designed for data analysis. It comes with special data structures and data types that make handling of missing data and statistical factors convenient. R can connect to spreadsheets, databases, and many other data formats, on your computer or on the web.
- **R produces high-quality graphics.** The plotting functionalities in R are endless, and allow you to adjust any aspect of your graph to convey most effectively the message from your data.
- **R has a large and welcoming community.** Thousands of people use R daily. Many of them are willing to help you through mailing lists and websites such as Stack Overflow, or on the RStudio community. Questions which are backed up with short, reproducible code snippets are more likely to attract knowledgeable responses.

1.3 Starting out in R

R is both a programming language and an interactive environment for data exploration and statistics.

Working with R is primarily text-based. The basic mode of use for R is that the user provides commands in the R language and then R computes and displays the result.

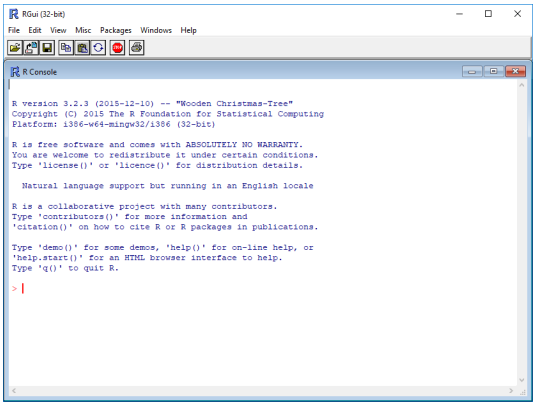
1.3.1 Downloading, Installing and Running R

Download
R can be downloaded from CRAN (The Comprehensive R Archive Network) for Windows, Linux, or Mac.

Install
Installation of R is like most software packages and you will be guided. Should you have any issues or need help you can refer to R Installation and Administration

Running
R can be launched from your software or applications launcher or When working at a command line on UNIX or Windows, the command `R` can be used for starting the main R program in the form `R`

You will see a console similar to this appear:



While it is possible to work solely through the console or using a command line interface, the ideal environment to work in R is RStudio.

1.3.2 RStudio

RStudio is a user interface for working with R. It is called an Integrated Development Environment (IDE): a piece of software that provides tools to make programming easier. RStudio acts as a sort of wrapper around the R language. You can use R without RStudio, but it's much more limiting. RStudio makes it easier to import datasets, create and write scripts, and makes using R much more effective. RStudio is also free and open source. To function correctly, RStudio needs R and therefore both need to be installed on your computer. For this training we'll be using a browser based version called Posit Cloud (see directions in the Posit Cloud section below.

RStudio interface is conveniently organized into four divisions called "panes".

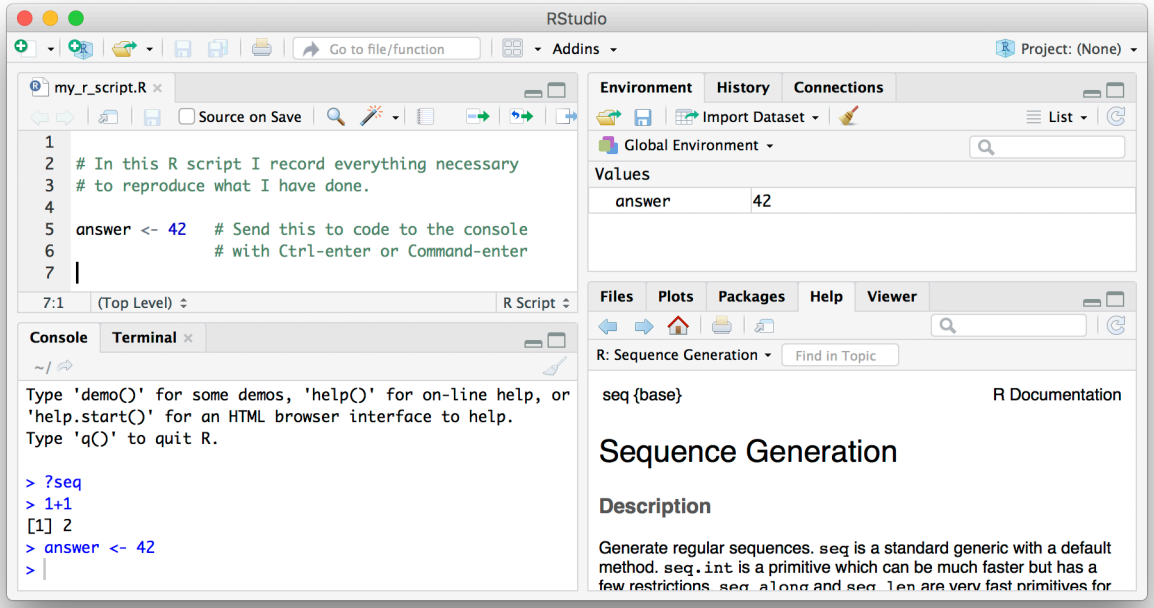
The Default Layout is:

- Top Left - **Source**: your scripts and documents
- Bottom Left - **Console**: what R would look and be like without RStudio
- Top Right - **Environment/History**: look here to see what you have done
- Bottom Right - **Files** and more: see the contents of the project/working directory here, like your Script.R file

The placement of these panes and their content can be customized (see menu, Tools -> Global Options -> Pane Layout)

1.3.3 Posit Cloud (formerly RStudio Cloud)

Posit Cloud is a web browser-based version of RStudio. It will allow you to use RStudio without needing to download anything to your computer. You can also easily share your R



projects with others. To use Posit Cloud a user account is required. While we recommend downloading RStudio for routine R programming use, we will be using Posit Cloud for this training.

To access Posit Cloud

1. In a new browser window or tab create your account at https://posit.cloud/plans/free.
2. Log in with Goolge or GitHub or however you choose!
3. Create a new project.
4. Write amazing code!

1.4 Using this book

For these instructions code will appear in the gray box as follows:

```
fake code
```

To run the code you can copy and paste the code and run it in your RStudio session console at the prompt > which looks like a greater than symbol.

```
> fake code
```

The code can also be added to an R Script to be run.

When the code is run in RStudio the console prints out results like so:

```
[1] Result
```

In this tutorial results from code will appear like so:

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

1.5 Working in the Console

The console is an interactive environment for RStudio, click on the "Console" pane, type `3 + 3` and press enter. R displays the result of the calculation.

```
3 + 3
```

```
[1] 6
```

`+` is called an operator. R has the operators you would expect for for basic mathematics:

Arithmetic operators

operator	meaning
+	plus
-	minus
*	times
/	divided by
^	exponent

Logical Operators

operator	meaning
==	exactly equal
!=	not equal to
<	less than
<=	less than or equal to

operator	meaning
>	greater than
>=	greater than or equal to
x|y	x or y
x&y	x and y
!x	not x

Spaces can be used to make code easier to read.

```
2 * 2 == 4
```

```
[1] TRUE
```

You can also run commands in the consile for working with your computers filesystem.

```
getwd() # similar to UNIX PWD
```

1.6 Working in the Terminal

The embedded Terminal in RStudio is a command-line interface within the IDE, allowing users to execute system commands and interact with the operating system directly.

- It shares the same working directory as the RStudio session and supports various commands for file management, package installation, and more.
- Integration into the IDE streamlines workflows by eliminating the need to switch between applications, enhancing productivity and enabling seamless interaction between R programming and system administration tasks.


Console
Terminal
Background Jobs
Terminal 1
~/Library/CloudStorage/OneDrive-UniversityofMarylandSchoolofMedicine/Projects/BC01_Bioinformat
(base) MEDM-58458:MRP_git_training jean-paul.courneya$

2 Reproducible Project Management

R and RStudio allow you to tackle a wide variety of analytic and programmatic tasks not all corresponding to the same project. Knowing what really needs to be saved and establishing a procedure to keep all of the stuff together for any given project will help in preventing a data loss or information loss.

2.1 RStudio Projects

R experts keep all the files associated with a project together. This is such a wise and common practice that RStudio has built-in support for this via Rprojects.

What are they?

- RStudio feature enabling users to create self-contained environments for their data analysis and coding projects.
- Provide a dedicated workspace where researchers and developers can organize their R scripts, data files, and related resources, simplifying project management, version control, and collaboration among team members.
- Encapsulate everything within a project, including configurations and dependencies
- Because of this they promote reproducibility and streamline the development process.

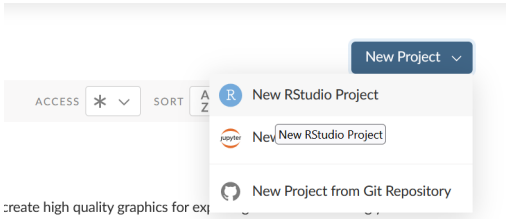
2.2 Creating an RStudio Cloud project

RStudio Cloud organizes everything into projects automatically.

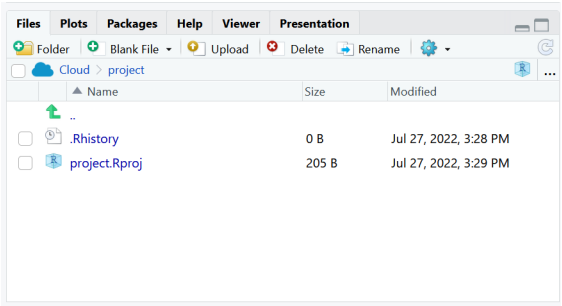
Let's create a new project in RStudio Cloud now.

First make sure you are logged in to your RStudio Cloud account (or create a free account if you haven't yet.)

Then from `Your Workspace`, select `New Project > New RStudio Project`.



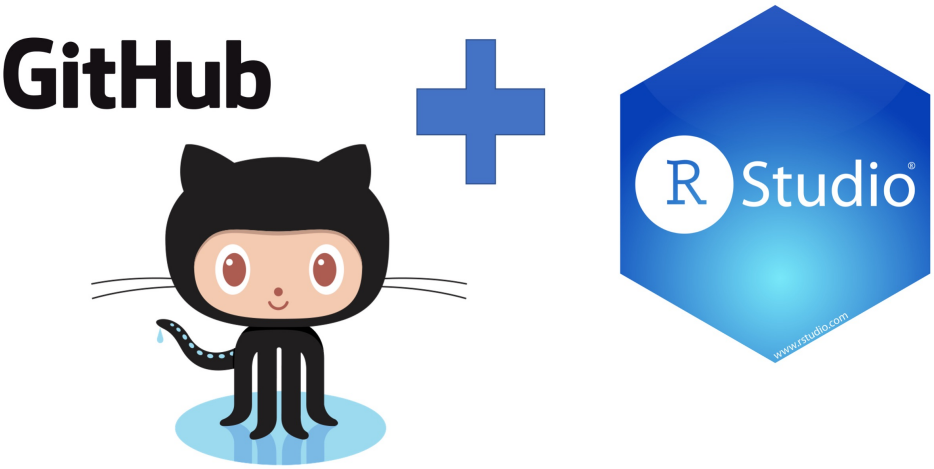
It will take a moment for your project to launch. Then you can give it a name. Let's call this `Reproducible Project Example`. Note that you have a `.Rproj` in your file pane.



Whenever you are in a project, the project is your working directory.

Now that you have mastered this skill we will switch gears and talk about version control with git and GitHub and how to intergrate them with RStudio projects!

3 Version Control and RStudio



3.1 Why Git?

Git is a version control system. Its original purpose was to help groups of developers work collaboratively on big software projects. Git manages the evolution of a set of files – called a repository – in a sane, highly structured way. If you have no idea what I'm talking about, think of it as the "Track Changes" features from Microsoft Word on a raw vegan diet taking wheat grass and pomegranate shots 3 times a day.

Git has been re-purposed by the data science community. In addition to using it for source code, we use it to manage the motley collection of files that make up typical data analytical projects, which often consist of data, figures, reports, and, yes, source code.

3.2 What's GitHub?

GitHub, Bitbucket, and GitLab are online services that provide a home for your Git-based projects on the internet. If you have no idea what I'm talking about, think of them as DropBox but much, much better. The remote host acts as a distribution channel or clearinghouse for your Git-managed project. It allows other people to see your stuff, sync up with you, and perhaps even make changes. These hosting providers improve upon traditional Unix Git servers with well-designed web-based interfaces.

Even for private solo projects, it's a good idea to push your work to a remote location for peace of mind. Why? Because it's fairly easy to screw up your local Git repository, especially when you're new at this. The good news is that often only the Git infrastructure is borked up. Your files are just fine! Which makes your Git pickle all the more frustrating. There are official Git solutions to these problems, but they might require expertise and patience you can't access at 3a.m. If you've recently pushed your work to GitHub, it's easy to grab a fresh copy, patch things up with the changes that only exist locally, and get on with your life. Don't get too caught up on public versus private at this point. There are many ways to get private repositories from the major providers for low or no cost. Just get started and figure out if and how Git/GitHub is going to work for you!

We will not be covering all the in's and outs of version control with Git, Github and all the resources to be found there since our time is limited. Instead you will learn how to:

- Set up a remote repository on Github
- Checking out a project from a version control remote repository
- Connecting RStudio to Github
- Set up a personal access token on Github
- Making some changes, using the Rstudio Git controls and pushing those changes to Github

3.3 Setting up a remote repository on Github

First thing we do is navigate to Github and make sure youre logged in.

Click green "New repository" button. Or, if you are on your own profile page, click on "Repositories", then click the green "New" button.

How to fill this in:

- Repository name: myrepo (or whatever you wish, we'll delete this soon anyway).
- Description: "testing my setup" (or whatever, but some text is good for the README).

- Public.
- YES Initialize this repository with a README.
- For everything else, just accept the default.

Click big green button "Create repository."

Copy the HTTPS clone URL to your clipboard via the green "Clone or Download" button.

3.4 Connecting Rstudio Cloud to Github

Here we verify that RStudio can issue Git commands on your behalf. This means you'll be able to pull from and push to GitHub from RStudio.

3.5 Checking out a project from a version control remote repository

Hopefully it has been a joy configuring your Git setup on your computer. Now we will put all of that machinery to work and test it out. Picking up were we left off when Setting up a remote repository copy the HTTPS clone URL to your clipboard via the green "Clone or Download" button.

References