

# Quantitative Methods - Computer Lab 0

Ralf Becker

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## Learning Outcomes

This initial Computer Lab is for you to experience some very basic functionality in R/RStudio.

In particular this is for you

- to explore the RStudio interface
- to learn how to search for help
- to not be scared by error messages
- to know how to load libraries
- to upload a datafile
- to explore the contents of this datafile
- to learn what functions
- to learn about data types
- to undertake some basic data manipulation

This Computer Lab assumes that you have R and RStudio installed on your computer. If not, you will have to do that first. See, for instance, the advice on [http://eclr.humanities.manchester.ac.uk/index.php/R#Installing\\_the\\_Software](http://eclr.humanities.manchester.ac.uk/index.php/R#Installing_the_Software).

## Prepare your Workspace

Before you start you should create a space (i.e. a folder) on your computer from where you are planning to do all your R work. Make sure you understand where that folder is and that you know the path to that folder (Apple users, if you do not know how to find the path to a particular folder, then look at this <https://piazza.com/class/kkdsg2fz8vf3y1?cid=6>). If you are using a computer lab computer you should create a folder for your R work on the P drive. This will be accessible to you whenever you log on to a University computer, or from anywhere via <https://pdrives.manchester.ac.uk/horde/login.php>.

Let's say you named your folder `Rwork` directly on the P drive and in that folder created a subfolder for this unit `QM`, then the path to your folder will be `P:\Rwork\QM`.

For this computer lab we are using exactly the same data as for the first lecture. So please make sure that you have the datafile `CK_public.xlsx` in the folder you just created and want to work from. It will also be useful to have `CK_codebook.txt` readily available (also from BB, Lecture 1).

## Exploring RStudio and searching

RStudio is a software which makes working with the actual statistical software R easier. In fact, once you followed the installation advice and have R and RStudio installed, you will never really have to worry about R anymore. Just start RStudio.

When you load RStudio for the first time you should see something like this.

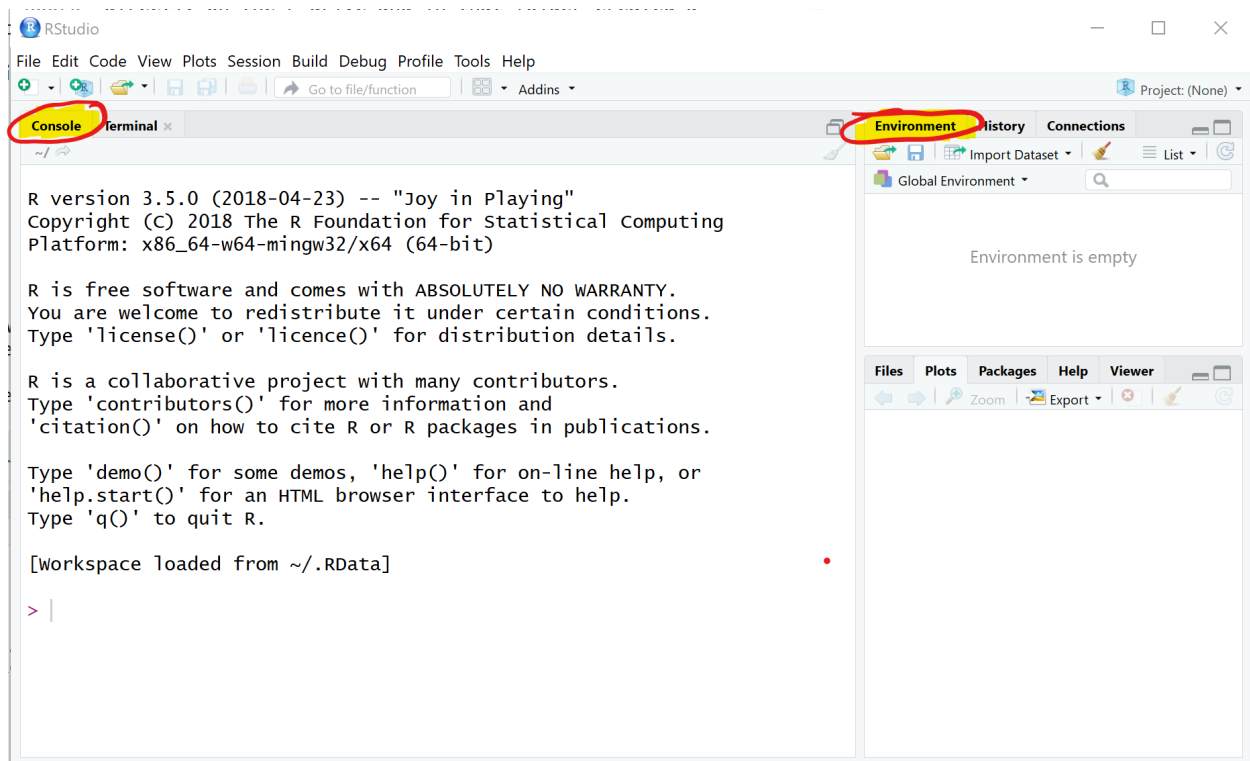


Figure 1: RStudio when loading for the first time

There are two important areas on that screen, the Console and the Environment. The Console is something like your main computational area. In there you can see some information but at the end an “>”. This indicates that RStudio is standing ready to do whatever you want it to do.

Say you want to calculate  $3+4$  ... yes, trivial but let's start small. Type  $3+4$  into the console (behind the “>” sign and press enter). Yes you should see the correct result.

```
3+4
```

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

That was easy, let's see whether you can get R to calculate  $13^2$ ,  $\sqrt{7569}$ ,  $e^5$  and  $\ln(5)$ . The first you achieve as follows:

```
13^2
```

```
## [1] 169
```

What about the others. Well, at this stage we will introduce you to the most important programming technique there is, searching on the Web (say in Google, Bing, Baidu or DuckDuckGo)! For instance if you want to know how to calculate a square root in R you may want to search for “how to calculate a square root in R” and you should find the appropriate advice. Practice your search technique to calculate the above solutions. Check against your calculator.

## Functions

Functions are important building blocks of any programming language. You just used your first function. Hopefully you found out that the way to calculate  $\sqrt{7569}$  was to type

```
sqrt(7569)
```

```
## [1] 87
```

Giving you the result 87. What you used here is a function, namely the `sqrt` function which some clever programmer wrote in order to calculate a square root. The anatomy of a function is `function_name(input)`. Think of a function as a drink machine.



Figure 2: RStudio when loading for the first time

Most functions require some input. Our function, the `sqrt` function needs a number of which to take the square root. The output in our example, 87, is then returned. In our case it is returned to be printed in the

Console window.

Extension: If you feel that so far there was nothing new, you can try and find out how to write your own functions in R. (If any of the above was new to you then ignore this extension!!!)

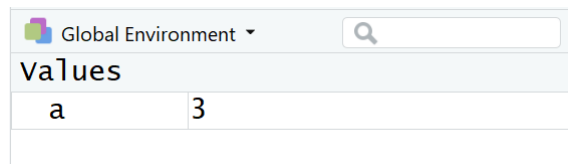
## Creating variables

So far you have learned that R can be used as a glorified calculator. Let's start to explore why R is way more powerful than that. You can save the results of as many calculations as you want and you can easily reuse the results of some calculations in later calculations.

Type "a<-12/3" into the console (without the quotation marks) and press enter

```
a <- 12/4
```

You will see that in the console the correct result does not show, but in the Environment pane of your RStudio window you should now see an entry



The screenshot shows the RStudio Environment pane. At the top, it says "Global Environment" with a search icon. Below that, the word "values" is written in a bold font. Underneath, there is a table with two columns: the variable name and its value. The first row shows the variable "a" with the value "3".

values	
a	3

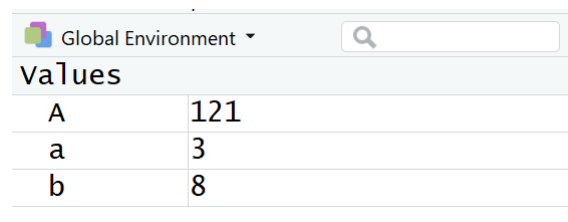
Figure 3: RStudio Environment saves variables

What did the command "a<-12/4" actually do? In words: "Calculate 12/4 and assign (<-) the result to a variable called a."

With that in mind implement the following: "Calculate 11\*11 and assign (<-) the result to a variable called A."

You should now see two variables in your Environment pane. Let's add another: "Calculate the square root of 64 and assign (<-) the result to a variable called b."

Note that we used the `sqrt` function again, but this time the output was not sent to be printed in the Console, but instead it was sent to the new variable `b`. If you have done everything right your Environment panel should now look as follows



The screenshot shows the RStudio Environment pane. At the top, it says "Global Environment" with a search icon. Below that, the word "values" is written in a bold font. Underneath, there is a table with two columns: the variable name and its value. The first row shows the variable "A" with the value "121". The second row shows the variable "a" with the value "3". The third row shows the variable "b" with the value "8".

values	
A	121
a	3
b	8

Figure 4: RStudio Environment saves variables

Note that `a` and `A` are different variables, so R is case-sensitive! All the variables listed in the Environment can be re-used for further calculations. For example:

```
d <- A - a + 2*b
```

Let's perform another calculation in which we use the result of the last calculation:

```
e <- D - 3*a
```

```
## Error in D - 3 * a: non-numeric argument to binary operator
```

You will see R throwing an error message at you: “Error in D - 3 \* a : non-numeric argument to binary operator”. Ehmmm ... what does this mean? Actually not a lot. In the first instance this tells you that something went wrong in that command. Can you see what the problem is? Remember R is trying to perform the calculation to the right of <- and then assign this to a new variable **e**. Does it have all the info on the right hand side? Check your list of variables in the Environment panel. Recall that R is case sensitive.

An important lesson with respect to error messages

- You will see them ALL THE TIME, and that is fine
- You cannot break the computer with any errors in R, so don't worry, just try.
- Re-read what you typed, is it actually what you wanted to do.
- Read the error message. Sometimes it will give you a clue as to what the problem is ... unfortunately not here!

So, we have done a bit of work so far. Let's take a short break. Please close RStudio and click “Don't Save” when you get the following message

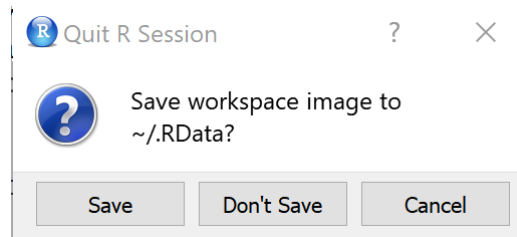


Figure 5: RStudio Environment saves variables

Get up, stretch your legs and get yourself a glass to drink. Then come back and open RStudio again so that we can continue our work.

As you open you should get exactly the same initial layout as before ... What value did **e** have again???? (125 if you managed to correct the above error) Where are our calculations???

## Preparing your script file and libraries

For all significant work you want to make sure that you save the work you have done, such that you do not have to re-type things which you did yesterday ... or just before I asked you to get a glass of water. The way to ensure that is to save all your work in a script file. A script file is basically a text file which saves all your commands (and comments - see below) and from where RStudio can easily execute these commands.

Let's create a script file. Via the RStudio menu (FILE - NEW FILE - R SCRIPT) open a new script file and save it in the folder from which you want to work (see above).

Start by creating a comment line at the top of that file which may say something like

```
# File for first QM Computer Lab  
# February 2021
```

Note: Adding comments to your code is absolutely vital if you want to understand tomorrow what you did today. I am not joking, adding comments to explain to your future self what you are doing is absolutely critical. Everything which follows the # sign is a comment and is effectively ignored by R. It is written not for R but for your future self!

If not mentioned otherwise all the following code should be added to that script file and executed from there. Save that file and make sure you know where you save it as, next week, you should be continuing to work on this.

Next you should ensure that you set the working directory to the directory where your scriptfile and datafile is in. If your folder was P:\Rwork\QM then the command below should read `setwd("P:/Rwork/QM")`. Note that all backward slashes (\) have to be replaced by forward slashes (/). Don't ask why, just accept ;-).

```
setwd("XXXX/XXXX") # replace the XXXX with your drive and path
```

Load the libraries which we want to use.

```
library(tidyverse) # for almost all data handling tasks
```

```
## -- Attaching packages -----
```

```
## v ggplot2 3.2.1    v purrr  0.3.3
## v tibble  2.1.3    v dplyr  0.8.4
## v tidyr   1.0.2    v stringr 1.4.0
## v readr   1.3.1    v forcats 0.4.0
```

```
## -- Conflicts -----
```

```
## x dplyr::filter() masks stats::filter()
## x dplyr::lag()     masks stats::lag()
```

```
library(readxl) # to import Excel data
library(ggplot2) # to produce nice graphics
library(stargazer) # to produce nice results tables
```

```
##
```

```
## Please cite as:
```

```
## Hlavac, Marek (2018). stargazer: Well-Formatted Regression and Summary Statistics Tables.
```

```
## R package version 5.2.2. https://CRAN.R-project.org/package=stargazer
```

Note: Libraries are collections of functions which add great functionality. They are not included in the base R installation and hence need to be added to your computer (see installation advice for packages below - this only has to be done once on each computer). However, even once they are installed on you need to make this new functionality available to your code. This is what the `library` functions do. This has to be done at the beginning of every script file in which you want to use the respective functionality.

By just typing these commands into the script file nothing is actually happening. If you want R to execute any of the commands in your script file you have to do one of the following:

1. Press the "Source" button, in which case R will execute all commands in the script file
2. Press the "Run" button, in which case R will run the command in which the cursor currently is
3. Press the "CTRL"+"ENTER" on the keyboard, in which case R will run the command in which the cursor currently is
4. Highlight several lines and press "CTRL"+"ENTER" on the keyboard, in which case R will run the commands in the highlighted lines

If RStudio tells you that one or more of these libraries are not installed then install these (not any others) on the machine you are working from. For instance, if `stargazer` was not installed you would receive an error message like "Error in library(stargazer) : there is no package called 'stargazer'", and in that case you should run:

```
install.packages("stargazer")
```

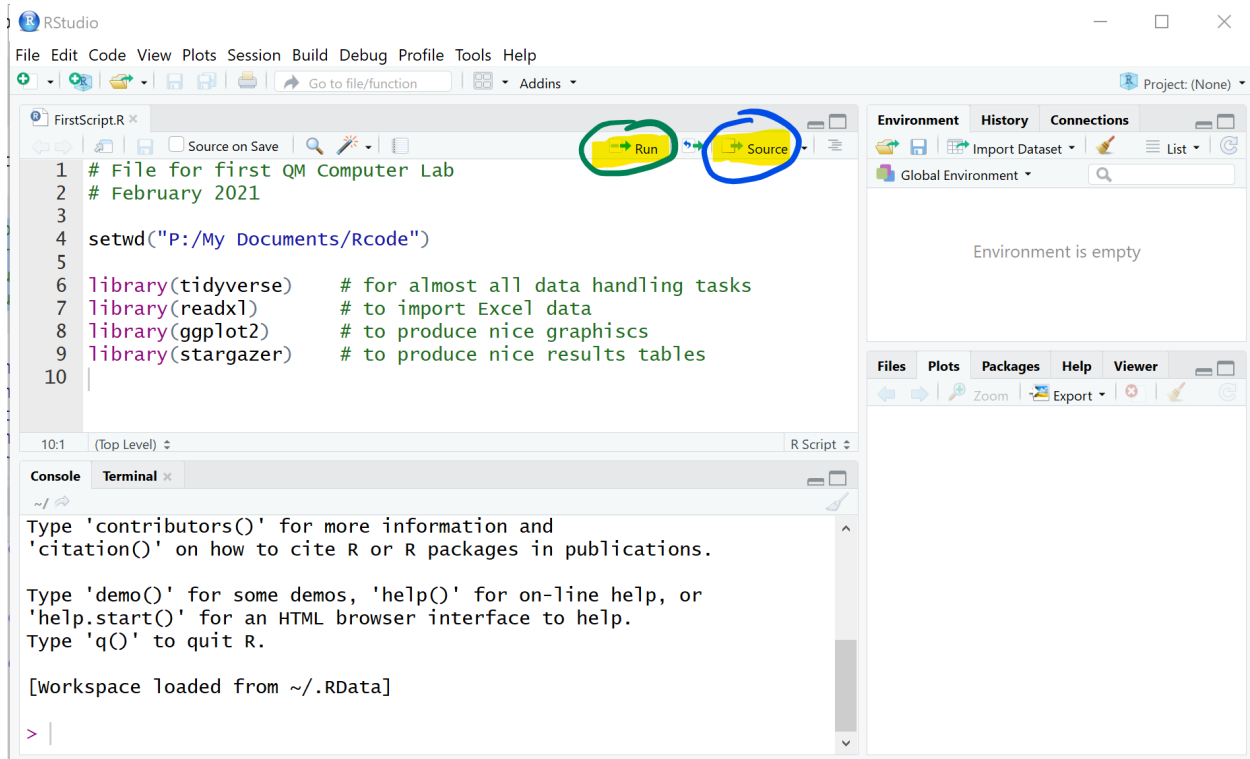


Figure 6: RStudio Environment saves variables

You can run this straight from the command/console or you could instead install the package via the packages tab on the right hand side. **Do not do this on computer lab computers as these packages should be pre-installed.**

You will need to do this only once on your computer and once you have done that you can call `library(stargazer)` again without running into problems.

## Data Upload

Make sure you have set the working directory to the directory in which you saved your script file (see above). As we are dealing with data in an excel file we will use the `read_excel` function to load the data. Before you run this command open the actual spreadsheet and try to see how missing data are coded. In this case they are coded as dots (“.”). But in other datafiles you may find “NA”, “n.a.”, “-9999” or other ways to code missing data. It is best to let R know how missing data look. This will simplify your life tremendously.

```
CKdata <- read_excel("CK_public.xlsx", na = ".")
```

It is well possible that you receive the following error message as you execute this command “Error: path does not exist: ‘CK\_public.xlsx’”. The most likely reason for this is that the “CK\_public.xlsx” is not saved in your working directory. Make sure you download that file from Blackboard and save it in the working directory you created earlier and you used in the `setwd()` command.

Make sure that your data upload is successful. If you did you should see an object `CKdata` in your environment. You can also run the `str` (structure) function.

```
str(CKdata) # prints some basic info on variables
```

```

## Classes 'tbl_df', 'tbl' and 'data.frame':   410 obs. of  46 variables:
## $ SHEET : num  46 49 506 56 61 62 445 451 455 458 ...
## $ CHAIN : num  1 2 2 4 4 4 1 1 2 2 ...
## $ CO_OWNED: num  0 0 1 1 1 1 0 0 1 1 ...
## $ STATE : num  0 0 0 0 0 0 0 0 0 0 ...
## $ SOUTHJ : num  0 0 0 0 0 0 0 0 0 0 ...
## $ CENTRALJ: num  0 0 0 0 0 0 0 0 0 0 ...
## $ NORTHJ : num  0 0 0 0 0 0 0 0 0 0 ...
## $ PA1 : num  1 1 1 1 1 1 0 0 0 1 ...
## $ PA2 : num  0 0 0 0 0 0 1 1 1 0 ...
## $ SHORE : num  0 0 0 0 0 0 0 0 0 0 ...
## $ NCALLS : num  0 0 0 0 0 2 0 0 0 2 ...
## $ EMPFT : num  30 6.5 3 20 6 0 50 10 2 2 ...
## $ EMPPT : num  15 6.5 7 20 26 31 35 17 8 10 ...
## $ NMGRS : num  3 4 2 4 5 5 3 5 5 2 ...
## $ WAGE_ST : num  NA NA NA 5 5.5 5 5 5 5.25 5 ...
## $ INCTIME : num  19 26 13 26 52 26 26 52 13 19 ...
## $ FIRSTINC: num  NA NA 0.37 0.1 0.15 0.07 0.1 0.25 0.25 0.15 ...
## $ BONUS : num  1 0 0 1 1 0 0 0 0 0 ...
## $ PCTAFF : num  NA NA 30 0 0 45 0 0 0 0 ...
## $ MEALS : num  2 2 2 2 3 2 2 2 1 1 ...
## $ OPEN : num  6.5 10 11 10 10 10 6 0 11 11 ...
## $ HRSOPEN : num  16.5 13 10 12 12 12 18 24 10 10 ...
## $ PSODA : num  1.03 1.01 0.95 0.87 0.87 0.87 1.04 1.05 0.73 0.94 ...
## $ PFRY : num  1.03 0.9 0.74 0.82 0.77 0.77 0.88 0.84 0.73 0.73 ...
## $ PENTREE : num  0.52 2.35 2.33 1.79 1.65 0.95 0.94 0.96 2.32 2.32 ...
## $ NREGS : num  3 4 3 2 2 2 3 6 2 4 ...
## $ NREGS11 : num  3 3 3 2 2 2 3 4 2 4 ...
## $ TYPE2 : num  1 1 1 1 1 1 1 1 1 1 ...
## $ STATUS2 : num  1 1 1 1 1 1 1 1 1 1 ...
## $ DATE2 : num  111792 111292 111292 111492 111492 ...
## $ NCALLS2 : num  1 NA NA NA NA NA NA 2 NA 1 ...
## $ EMPFT2 : num  3.5 0 3 0 28 NA 15 26 3 2 ...
## $ EMPPT2 : num  35 15 7 36 3 NA 18 9 12 9 ...
## $ NMGRS2 : num  3 4 4 2 6 NA 5 6 2 2 ...
## $ WAGE_ST2: num  4.3 4.45 5 5.25 4.75 NA 4.75 5 5 5 ...
## $ INCTIME2: num  26 13 19 26 13 26 26 26 13 13 ...
## $ FIRSTIN2: num  0.08 0.05 0.25 0.15 0.15 NA 0.15 0.2 0.25 0.25 ...
## $ SPECIAL2: num  1 0 NA 0 0 0 0 0 0 0 ...
## $ MEALS2 : num  2 2 1 2 2 2 2 2 2 1 ...
## $ OPEN2R : num  6.5 10 11 10 10 10 6 0 11 11 ...
## $ HRSOPEN2: num  16.5 13 11 12 12 12 18 24 11 10.5 ...
## $ PSODA2 : num  1.03 1.01 0.95 0.92 1.01 NA 1.04 1.11 0.94 0.9 ...
## $ PFRY2 : num  NA 0.89 0.74 0.79 0.84 0.84 0.86 0.84 0.84 0.73 ...
## $ PENTREE2: num  0.94 2.35 2.33 0.87 0.95 1.79 0.94 0.94 2.32 2.32 ...
## $ NREGS2 : num  4 4 4 2 2 3 3 6 4 4 ...
## $ NREGS112: num  4 4 3 2 2 3 3 3 3 3 ...

```

You should now see the `CKdata` object in your Environment (right hand pane).

There are 410 observations, each representing one fast-food restaurant. Each restaurant has some variables which characterise the store and then two sets of variables which are observed before the new minimum wage was introduced to New Jersey (Wave 1: Feb 15 to Mar 14, 1992) and after the policy change (Wave 2: Nov 5 to Dec 31, 1992). Variables which relate to the second wave will have a 2 at the end of the variable name.



The following variables will be important for the analysis here:

- SHEET, this is a unique identifier for each restaurant
- STATE, 1 if New Jersey (NJ); 0 if Pennsylvania (Pa)
- WAGE\_ST, starting wage (\$/hr), Wave 1
- WAGE\_ST2, starting wage (\$/hr), after policy, Wave 2
- STATUS2, the status of the Wave 2 interview, 0 = refused, 1 = completed, 3, permanently closed, 2, 4 and 5 = temporarily closed
- CHAIN, 1 = Burger King; 2 = KFC; 3 = Roy Rogers; 4 = Wendy's
- EMPFT, # full-time employees before policy implementation
- EMPFT2, # full-time employees after policy implementation
- EMPPT, # part-time employees before policy implementation
- EMPPT2, # part-time employees after policy implementation
- NMGRS, # managers/ass't managers before policy implementation
- NMGRS2, # managers/ass't managers before policy implementation

You wrote your first script. It is time to have another break. Make sure you save your script and the close RStudio (you don't need to do that in general, but please do it at this point to help me demonstrate the value of scripts). After relaxing for a few minutes and telling your flatmate that you are on your way to become an expert programmer, come back and re-open RStudio. Load the script file (if it wasn't loaded automatically). The environment should, at this stage be empty, but if you click on the "Source" button then R will automatically execute all the commands you had in your script and `CKdata` should be available in the Environment panel.

So that is the value of scripts! You can easily pick up where you left your work, no need to redo anything.

## Accessing data

The `CKdata` item in your environment basically contains the entire spreadsheet of data. You can look at the entire spreadsheet by clicking on the tiny spreadsheet in the `CKdata` line. This will open a new tab with the spreadsheet. Have a look and then close the tab again.

It is important to know how you can access subsets of data. Run through the following commands to see what happens. Perhaps also experiment a bit by changing the commands and predicting what the outcome should be.

```
CKdata[1,]
CKdata[,2]
CKdata[3,4]
CKdata[,4:6]
CKdata[4:6]
CKdata[2:4,5:10]
CKdata$SOUTHJ
CKdata$SOUTHJ[1:5]
CKdata[c("CHAIN", "STATE")]
```

These are all different ways to select particular observations (rows in a spreadsheet) and variables (columns in a spreadsheet). There were two particular techniques which are important

- `CKdata$CHAIN` did address the `CHAIN` variable in the `CKdata` dataset (`DATASET$VARIABLE`).
- `c("CHAIN", "STATE")` allowed us to access two very particular variables, ignoring all other 44 variables. It is useful to know what `c("CHAIN", "STATE")` actually does.

```
c("CHAIN", "STATE")
```

```
## [1] "CHAIN" "STATE"
```

It creates a list with two elements, here two text strings. But you can also create lists with numbers.

```
c(3.5,2/3)
```

```
## [1] 3.5000000 0.6666667
```

In fact you could even create lists which mixed datatypes.

```
c("Countries in the EU", 28-1, ":-(")
```

```
## [1] "Countries in the EU" "27" ":-("
```

Lists are quite fundamental to the way how R stores data. If you assigned any of the above to a variable, for instance

```
silly_list <- c("Countries in the EU", 28-1, ":-(")
```

you would have saved it in the Environment and could re-use it.

All the commands in this section were really only to explore the functionality of R. There is no need to save these in your script file. But no harm either as none of these actually changed the values of the data in CKdata.

## Data Formats

We can see (from the output to `str(CKdata)`) that all variables are numeric (`num`) variables, i.e. the software will treat them as numbers. If you check the `CK_codebook.txt` on BB you will find what all the numbers mean. For instance an entry of 2 in the `CHAIN` variable means that this is a “KFC” restaurant.

For later it will be convenient to have `STATE` and `CHAIN` variables which aren’t numeric, but categorical variables. In R these are called `factor` variables. Hence we will create two new variables, `STATEf` and `CHAINf` which contain the same info, but just in a way easier to understand.

```
CKdata$STATEf <- as.factor(CKdata$STATE) # translates a variable into a factor variable
levels(CKdata$STATEf) <- c("Pennsylvania", "New Jersey") # changes the names of the categories
```

There are a number of important elements in these two lines

- `CKdata$STATEf <-` creates a new variable in the `CKdata` object, called `STATEf`. `<-` is called the assignment operator and it assigns some value to that new variable. It will assign whatever comes to the right hand side of `<-`
- `as.factor()` is a function called `as.factor`. If you want to find out what a function does you can call the help function `?as.factor`. This one ensures that creates a variable as a factor (categorical) variable. But it requires an input (Whatever comes inside the parenthesis). Here we ask R to change the `num` variable `CKdata$STATE` into a factor variable.
- `levels(CKdata$STATEf) <- c("Pennsylvania", "New Jersey")` then changes the names of the levels (categories) into sensible names. Here we use again the assignment operator `<-`. The order matters, but we learn from the codebook that: “1 if NJ; 0 if Pa”. As `STATE` is a numerical variable it will order the categories in numerical order, 0 (PA) first and 1 (NJ) next. In doubt you will have to check that you have used the right ordering by comparing the `STATE` and `STATEf` variable.

Now create a new variable `CHAINf` which achieves the same for the `CHAIN` variable. Replace the `XXXX` to make this code work. You will have to check the codebook for the right ordering.

```
CKdata$XXXX <- as.factor(XXXX$XXXX)
XXXX(CKdata$CHAINf) XXXX c("XXXX", "KFC", "XXXX", "Wendy's")
```

Confirm that you have added the new variables and that they are indeed of the factor type.

Or to avoid such a long output

Make sure you save your script file and for next week's exercise you will pick up from this point.

Just as reminder, you learned quite a lot today. You can do some basic navigation in RStudio and some very basic data manipulation. We will continue doing some more and important investigation next week.