Hertie School/SCRIPTS Data Science Workshop Series

Session 1: A gentle introduction to base R and RStudio

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Plan for this workshop series

This workshop series is geared toward learning basic data management in `R`. This includes tasks like manipulating variables, creating new variables, subsetting data, reshaping data, and merging. We will also cover some introductory regular expression applications. In this workshop series we will cover only basic visualization methods in `R`. Aspects like data analysis, web-scraping, or higher-level statistical programming are not covered.

Scheduled sessions:

1. **Introduction to R** (working directories, arithmetic, logical operators, basic indexing, data types, basic functions such as sum, mean, names, seq, rep, installing packages, reading and writing data, dealing with missing data, data frames, indexing on data frames, getting an overview of the data with numerical and graphical summaries).
2. **Modern data management in R using the tidyverse** (`dplyr`, `tidyr`, `readr`, and `lubridate` packages)

Getting started in `R`

`R` is a programming language for statistical computing and data visualization, that is a open source alternative to commercial statistical packages such as Stata or SPSS. `R` is maintained and developed by a vibrant community of programmers and statisticians and offers many user-written packages to extend basic functionality.

In this workshop, we will be using RStudio Cloud as an online environment to write `R` code.

Setting up RStudio Cloud

1. After clicking the link sent in the rstudio.cloud invite email, you will be prompted to create an account.
2. You will then be redirected to your workspace. In the sidebar, you will see a link for "SCRIPTS/Hertie Data Science Workshop Series" project.
3. Before you work on any project, you need to first save a permanent copy of a specific project or session to save your individual changes.

Getting Help

The key to learning `R` is: **Google**! This workshop will give you an overview over basic `R` functions, but to really learn `R` you will have to actively use it yourself, trouble shoot, ask questions, and google! The `R` mailing list and other help pages such as http://stackoverflow.com offer a rich archive of questions and answers by the `R` community. For example, if you google "recode data in r" you will find a variety of useful websites explaining how to do this on the first page of the search results. Also, don't be surprised if you find a variety of different ways to execute the same task.

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RStudio also has a useful help menu. In addition, you can get information on any function or integrated data set in `R` through the console, for example:

```
?plot
```

In addition, there are a lot of free `R` comprehensive guides, such as Quick-R at http://www.statmethods.net or the `R` cookbook at http://www.cookbook-r.com.

Executing a line of code

To execute a single line of code. In RStudio, with the curser in the line you want `R` to execute,

1. click the "Run" button at the top of the editor pane, OR
2. press `command + return` (on macOS) or `Crtl + Enter` (on Windows).

To execute multiple lines of code at once, highlight the respective portion of the code and then run it using one of the operations above.

Arithmetic in `R`

You can use `R` as a calculator!

	Operator	Example
Addition	`+`	`2+4`
Subtraction	`-`	`2-4`
Multiplication	`*`	`2*4`
Division	`/`	`4/2`
Exponentiation	`^`	`2^4`
Square Root	`sqrt()`	`sqrt(144)`
Absolute Value	`abs()`	`abs(-4)`

```
4*9
```

```
## [1] 36
```

```
sqrt(144)
```

```
## [1] 12
```

Just like any regular calculator, you have to pay attention to the order of operations! Example:

```
6 * 8 - sqrt(7) + abs(-10)
```

```
## [1] 55.35425
```

```
6 * (8 - sqrt(7)) + abs(-10)
```

```
## [1] 42.12549
```

Logical operators

	Operator
Less than	`<`
Less than or equal to	`<=`
Greater than	`>`
Greater than or equal to	`>=`

	Operator
Exactly equal to	`==`
Not equal to	`!=`
Not `x`	`!x`
`x` or `y`	`x	y`
`x` and `y`	`x & y`

Logical operators are incredibly helpful for any type of exploratory analysis, data cleaning and/or visualization task.

```
4 > 2
```

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

```
4 <= 2
```

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

Objects in R

Assigning values to objects

`R` stores information as an *object*. You can name objects whatever you like. Just remember to not use names that are reserved for build-in functions or functions in the packages you use, such as `sum`, `mean`, or `abs`. Most of the time, `R` will let you use these as names, but it leads to confusion in your code.

A few things to remember

- Do not use special characters such as `$` or `%`. Common symbols that are used in variable names include `.` or `_`.
- Remember that `R` is case sensitive.
- To assign values to objects, we use the assignment operator `<-`. Sometimes you will also see `=` as the assignment operator. This is a matter of preference and subject to debate among `R` programmers. Personally, I use `<-` to assign values to objects and `=` within functions.
- The `#` symbol is used for commenting and demarcation. Any code following `#` will not be executed.

Below, `R` stores the result of the calculation in an object named `result`. We can access the value by referring to the object name.

```
result <- 5/3
result
```

```
## [1] 1.666667
```

If we assign a different value to the object, the value of the object will be changed.

```
result <- 5-3
result
```

```
## [1] 2
```

Vectors

`R` can deal with a variety of data types, including vectors, scalars, matrices, data frames, and lists. First, we focus on vectors.

A **vector** is one of the simplest type of data you can work with in `R`. "A vector or a one-dimensional array simply represents a collection of information stored in a specific order" (Imai 2017: 14). It is essentially a list of data of a single type (either numerical, character, or logical).

To create a vector, we use the function `c()` (‘`concatenate'') to combine separate data points. The general format for creating a vector in R is as follows:`name_of_vector <- c(“what you want to put into the vector”)‘

Suppose, we have data on the population in millions for the five most populous countries in 2016. The data come from the World Bank.

```
pop1 <- c(1379, 1324, 323, 261, 208)
pop1
```

```
## [1] 1379 1324  323  261  208
```

We can use the function `c()` to combine two vectors. Suppose we had data on 5 additional countries.

```
pop2 <- c(194, 187, 161, 142, 127)
pop <- c(pop1, pop2)
pop
```

```
##  [1] 1379 1324  323  261  208  194  187  161  142  127
```

Variable types

There are four main variable types you should be familiar with:

- **Numerical**: Any number. **Integer** is a numerical variable without any decimals.
- **Character**: This is what Stata (and other programming languages such as Python) calls a string. We typically store any alphanumeric data that is not ordered as a character vector.
- **Logical**: A collection of `TRUE` and `FALSE` values.
- **Factor**: Think about it as an ordinal variable, i.e. an ordered categorical variable.

First, lets check which variable type our population data were stored in. The output below tells us that the object `pop` is of class *numeric*, and has the dimensions `[1:10]`, that is 10 elements in one dimension.

```
str(pop)
```

```
##  num [1:10] 1379 1324 323 261 208 ...
```

Suppose, we wanted to add information on the country names. We can enter these data in *character* format. To save time, we will only do this for the five most populous countries.

```
cname <- c("CHN", "IND", "USA", "IDN", "BRA")
str(cname)
```

```
##  chr [1:5] "CHN" "IND" "USA" "IDN" "BRA"
```

Now, lets code a *logical* variable that shows whether the country is in Asia or not. Note that `R` recognizes both `TRUE` and `T` (and `FALSE` and `F`) as logical values.

```
asia <- c(TRUE, TRUE, F, T, F)
str(asia)
```

```
##  logi [1:5] TRUE TRUE FALSE TRUE FALSE
```

Lastly, we define a factor variable for the regime type of a country in 2016. This variable can take on one of four values (based on data from the Economist Intelligence Unit): Full Democracy, Flawed Democracy, Hybrid Regimes, and Autocracy. Note that empirically, we don’t have a “hybrid category” here. We could define an empty factor level, but we will skip this step here.

```
regime <- c("Autocracy", "FlawedDem", "FullDem", "FlawedDem", "FlawedDem")
regime <- as.factor(regime)
str(regime)
```

```
##  Factor w/ 3 levels "Autocracy","FlawedDem",..: 1 2 3 2 2
```

Data types are important! `R` will not perform certain operations if you don't get the variable type right. The good news is that we can switch between data types. This can sometimes be tricky, especially when you are switching from a factor to a numerical type[1]. We won't go into this too much here; just remember: Google is your friend!

Let's convert the factor variable `regime` into a character. Also, for practice, lets convert the `asia` variable to character and back to logical.

```
regime <- as.character(regime)
str(regime)
```

```
##  chr [1:5] "Autocracy" "FlawedDem" "FullDem" "FlawedDem" "FlawedDem"
```

```
asia <- as.character(asia)
str(asia)
```

```
##  chr [1:5] "TRUE" "TRUE" "FALSE" "TRUE" "FALSE"
```

```
asia <- as.logical(asia)
str(asia)
```

```
##  logi [1:5] TRUE TRUE FALSE TRUE FALSE
```

Exercise 1: Why won't `R` let us do the following?

`no_good <- (a,b,c)`

`no_good_either <- c(one, two, three)`

Exercise 2: What's the difference? (Bonus: What do you think is the class of the output vector?)

```
diff <-c(TRUE,"TRUE")
```

Exercise 3: What is the class of the following vector?

```
vec <- c("1", "2", "3")
```

Vector operations

You can do a variety of things like have `R` print out particular values or ranges of values in a vector, replace values, add additional values, etc. We will not get into all of these operations today, but be aware that (for all practical purposes) if you can think of a vector manipulation operation, `R` can probably do it.

We can do arithmatic operations on vectors! Let's use the vector of population counts we created earlier and double it.

```
pop1
```

```
## [1] 1379 1324  323  261  208
```

```
pop1_double <- pop1 * 2
pop1_double
```

```
## [1] 2758 2648  646  522  416
```

Exercise 4: What do you think this will do?

```
pop1 + pop2
```

Exercise 5: And this?

[1] Sometimes you have to do a work around, like switching to a character first, and then converting the character to numeric. You can concatenate commands: `myvar <- as.numeric(as.character(myvar))`.

```r
pop_c <- c(pop1, pop2)
```

Functions

There are a number of special functions that operate on vectors and allow us to compute measures of location and dispersion of our data.

	Function
`min()`	Returns the minimum of the values or object.
`max()`	Returns the maximum of the values or object.
`sum()`	Returns the sum of the values or object.
`length()`	Returns the length of the values or object.
`mean()`	Returns the average of the values or object.
`median()`	Returns the median of the values or object.
`var()`	Returns the varianve of the values or object.
`sd()`	Returns the varianve of the values or object.

```r
min(pop)
```

```
## [1] 127
```

```r
max(pop)
```

```
## [1] 1379
```

```r
mean(pop)
```

```
## [1] 430.6
```

Exercise 6: Using functions in `R`, how else could we compute the mean population value?

```
## [1] 430.6
```

Accessing elements of vectors

There are many ways to access elements that are stored in an object. Here, we will focus on a method called *indexing*, using square brackets as an operator.

Below, we use square brackets and the index `1` to access the first element of the top 5 population vector and the corresponding country name vector.

```r
pop1[1]
```

```
## [1] 1379
```

```r
cname[1]
```

```
## [1] "CHN"
```

We can use indexing to access multiple elements of a vector. For example, below we use indexing to implicitly print the second and fifth elements of the population and the country name vectors, respectively.

```r
pop[c(2,5)]
```

```
## [1] 1324  208
```

```r
cname[c(2,5)]
```

```
## [1] "IND" "BRA"
```

We can assign the first element of the population vector to a new object called `first`.

```
first <- pop[1]
```

Below, we make a copy of the country name vector and delete the *last* element. Note, that we can use the `length()` function to achieve the highest level of *generalizability* in our code. Using `length()`, we do not need to know the index of the last element of out vector to drop the last element.

```
cname_copy <- cname
## Option 1: Dropping the 5th element
cname_copy[-5]
```

```
## [1] "CHN" "IND" "USA" "IDN"
```

```
## Option 2 (for generalizability): Getting the last element and dropping it.
length(cname_copy)
```

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

```
cname_copy[-length(cname_copy)]
```

```
## [1] "CHN" "IND" "USA" "IDN"
```

Indexing can be used to alter values in a vector. Suppose, we notice that we wrongly entered the second element of the regime type vector (or the regime type changed).

```
regime
```

```
## [1] "Autocracy" "FlawedDem" "FullDem"   "FlawedDem" "FlawedDem"
```

```
regime[2] <- "FullDem"
regime
```

```
## [1] "Autocracy" "FullDem"   "FullDem"   "FlawedDem" "FlawedDem"
```

Exercise 7: We made even more mistakes when entering the data! We want to subtract 10 from the third and fifth element of the top 5 population vector. *How would you do it*?

More functions

The myriad of functions that are either built-in to base `R` or parts of user-written packages are the greatest stength of `R`. For most applications we encounter in our daily programming practice, `R` already has a function, or someone smart wrote one. Below, we introduce a few additional helpful functions from base `R`.

	Function
`seq()`	Returns sequence from input1 to input2 by input3.
`rep()`	Repeats input1 input2 number of times.
`names()`	Returns the names (labels) of objects.
`which()`	Returns the index of objects.

Let's create a vector of indices for our top 5 population data.

```
cindex <- seq(from = 1, to = length(pop1), by = 1)
cindex
```

```
## [1] 1 2 3 4 5
```

Suppose we wanted to only print a sequence of even numbers between 2 and 10. We can do so by adjusting the `by` operator.

```r
seq(2, 10, 2)
```

```
## [1]  2  4  6  8 10
```

We can use the `rep()` function to repeat data.

```r
rep(30, 5)
```

```
## [1] 30 30 30 30 30
```

Suppose, we wanted to record whether we had completed the data collection process for the top 10 most populous countries. First, suppose we completed the process on every second country.

```r
completed <- rep(c("yes","no"), 5)
completed
```

```
##  [1] "yes" "no"  "yes" "no"  "yes" "no"  "yes" "no"  "yes" "no"
```

Now suppose that we have completed the data collection process for the first 5 countries, but not the latter 5 countries (we don't have their names, location, or regime type yet).

```r
completed2 <- rep(c("yes","no"), each = 5)
completed2
```

```
##  [1] "yes" "yes" "yes" "yes" "yes" "no"  "no"  "no"  "no"  "no"
```

We can give our data informative labels. Let's use the country names vector as labels for our top 5 population vector.

```r
names(pop1)
```

```
## NULL
```

```r
cname
```

```
## [1] "CHN" "IND" "USA" "IDN" "BRA"
```

```r
names(pop1) <- cname
names(pop1)
```

```
## [1] "CHN" "IND" "USA" "IDN" "BRA"
```

```r
pop1
```

```
##  CHN  IND  USA  IDN  BRA
## 1379 1324  323  261  208
```

We can use labels to access data using indexing and logical operators. Suppose, we wanted to access the population count for Brazil in our top 5 population data.

```r
pop1[names(pop1) == "BRA"]
```

```
## BRA
## 208
```

Exercise 9 Access all top 5 population ratings that are greater or equal than the mean value of population ratings.

```
## [1] 699
```

```
##  CHN  IND
## 1379 1324
```

Exercise 10 Access all top 5 population ratings that are less than the population of the most populous country, but not the US.

```
##  IND  IDN  BRA
## 1324  261  208
```

Operating on multiple vectors simultaneously

We did not work with data frames yet, but remember that our data input is ordered. The first element of the `pop1` vector corresponds with the first element of the `cname`, `regime`, and `asia` vectors. We can use this to run more sophisticated queries on our data.

Suppose, we wanted to know the regime type of Indonesia. Given that our vectors are ordered, we can use indexing to extract the data. First, lets see what happens if we run a simple logical query.

```
cname == "IDN"
```

```
## [1] FALSE FALSE FALSE  TRUE FALSE
```

```
regime[cname == "IDN"]
```

```
## [1] "FlawedDem"
```

We can also use the `which()` function that returns the index of the vector element.

```
which(cname == "IDN")
```

```
## [1] 4
```

```
regime[which(cname == "IDN")]
```

```
## [1] "FlawedDem"
```

Using logical statements, we can run more complex queries. Below, we print the population count for all Asian countries within the top 5 most populous countries that are not autocracies.

```
pop1[asia == T & regime != "Autocracy"]
```

```
##  IND  IDN
## 1324  261
```

Working with data frames in R

Using packages

So far, we have only used functions that are already built into R. One of the greatest strengths of R is its massive collection of user-written packages that contain task-specific functions. The official repository for R packages, CRAN, currently records 15365 packages,[2] with many more under development.

If a package is available on CRAN, you can install it in two ways.

1. In RStudio, click on the "Install" button under the "Packages" tab, enter the package name and desired location on your computer (in most cases, do not change the default), and click "Install". OR
2. Run `install.packages("packagename")`, where `packagename` should be replaced with the name of the desired package.

Below, we will use use the `foreign` package to import a .csv file. To make the `foreign` package available for use, install it and then use the `library()` command to load it. While packages need to be installed only once, the `library()` command needs to be run every time you want to use a particular package.[3]

```
#install.packages("foreign") #alternatively use "Install" button
library(foreign)
```

Importing data

Most data formats we commonly use are not native to R and need to be imported. Luckily, there is a variety of packages available to import just about any non-native format. One of the essential libraries is called `foreign` and includes functions to import .csv, .dta (Stata), .dat, ,.sav (SPSS), etc.

In this example, we will use a subset of data from the Armed Conflict Location & Event Data Project (ACLED), which offers real-time data and analysis on political violence and protests around the world. The `ACLED_countries.csv` dataset includes the count of riot and protest events from January 2000 to December 2019 for many countries.[4]

Below, we read the data using the `read.csv()` command.[5]

```
mydata <- read.csv("ACLED_countries.csv",
                   stringsAsFactors = F)
```

Dimensions of a data frame

Let's find out what these data look like. First, use the `str()` function to explore the variable names and which data class they are stored in. Note: `int` stands for `integer` and is a special case of the class `numeric`.

```
str(mydata)
```

```
## 'data.frame':    103 obs. of  5 variables:
##  $ country                : chr  "Afghanistan" "Albania" "Algeria" "Angola" ...
##  $ region                 : chr  "Southern Asia" "Europe" "Northern Africa" "Middle Africa" ...
##  $ nconflicts             : int  40765 582 7362 1108 3118 12627 1861 16802 293 215 ...
##  $ nconflict_no_fatalities: int  23946 581 5321 728 3110 12578 1846 13114 293 165 ...
##  $ fatalities             : int  119973 1 8451 13788 8 59 22 4640 0 114 ...
```

[2] https://cran.r-project.org/web/packages/.

[3] Full dislosure: On many machines, the `foreign` package is pre-installed. We install it above for practice purposes.

[4] ACLED uses the following definition: "A protest describes a non-violent, group public demonstration, often against a government institution. Rioting is a violent form of demonstration," see Raleigh, C. and C. Dowd (2015): Armed Conflict Location and Event Data Project (ACLED) Codebook.)

[5] When running this example on your own machine, not RStudio Cloud, you need to either specify the complete file name or change your working directory using `setwd()` to the folder in which you saved the data. See the bottom of this script for more info.

If we are only interested in what the variables are called, we can use the `names()` function.

```
names(mydata)
```

```
## [1] "country"                 "region"
## [3] "nconflicts"              "nconflict_no_fatalities"
## [5] "fatalities"
```

We can alter the names of vectors by using the `names()` function and indexing. Because data frames are essentially just combinations of vectors, we can do the same for variable names inside data frames. Suppose we want to change the variable `nconflicts`.

```
names(mydata)[3] <- "nconflict"
names(mydata)
```

```
## [1] "country"                 "region"
## [3] "nconflict"               "nconflict_no_fatalities"
## [5] "fatalities"
```

We can use the `summary()` function to get a first look at the data.

```
summary(mydata)
```

```
##    country             region            nconflict
##  Length:103         Length:103         Min.   :    1.0
##  Class :character   Class :character   1st Qu.:  315.5
##  Mode  :character   Mode  :character   Median : 1250.0
##                                        Mean   : 6216.3
##                                        3rd Qu.: 5993.5
##                                        Max.   :70734.0
##  nconflict_no_fatalities   fatalities
##  Min.   :    1          Min.   :     0.0
##  1st Qu.:  289          1st Qu.:    17.5
##  Median : 1037          Median :   236.0
##  Mean   : 4667          Mean   :  9543.3
##  3rd Qu.: 4536          3rd Qu.:  7020.0
##  Max.   :63665          Max.   :119973.0
```

A data frame has two dimensions: rows and columns.

```
nrow(mydata) # Number of rows
```

```
## [1] 103
```

```
ncol(mydata) # Number of columns
```

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

```
dim(mydata) # Rows first then columns.
```

```
## [1] 103   5
```

Accessing elements of a data frame

As a rule, whenever we use two-dimensional indexing in `R`, the order is: `[row, column]`. To access the first row of the data frame, we specify the row we want to see and leave the column slot following the comma empty.

```
mydata[1, ]
```

```
##       country        region nconflict nconflict_no_fatalities fatalities
```

```
## 1 Afghanistan Southern Asia     40765                   23946     119973
```

We can use the concatenate function `c()` to access multiple rows (or columns) at once. Below we print out the first and second row of the dataframe.

```r
mydata[c(1,2), ]
```

```
##       country        region nconflict nconflict_no_fatalities fatalities
## 1 Afghanistan Southern Asia     40765                   23946     119973
## 2     Albania        Europe       582                     581          1
```

We can also access a range of rows by separating the minimum and maximum value with a `:`. Below we print out the first five rows of the dataframe.

```r
mydata[1:5,]
```

```
##       country                    region nconflict nconflict_no_fatalities
## 1 Afghanistan             Southern Asia     40765                   23946
## 2     Albania                    Europe       582                     581
## 3     Algeria           Northern Africa      7362                    5321
## 4      Angola            Middle Africa      1108                     728
## 5     Armenia Caucasus and Central Asia      3118                    3110
##   fatalities
## 1     119973
## 2          1
## 3       8451
## 4      13788
## 5          8
```

If we try to access a data point that is out of bounds, `R` returns the value `NULL`.

```r
mydata[3,7]
```

```
## NULL
```

Exercise 1 Access the element of the dataframe `mydata` that is stored in row 1, column 1.

```
## [1] "Afghanistan"
```

Exercise 2 Access the element of the data frame `mydata` that is stored in column 3, row 100.

```
## [1] 503
```

The $ operator

The `$` operator in `R` is used to specify a variable within a data frame. This is an alternative to indexing.

```r
mydata$nconflict
```

```
##   [1] 40765   582  7362  1108  3118 12627  1861 16802   293   215   459
##  [12]    52   765  2105  7760  1919  2621  4625   912   411   312 14519
##  [23]   112 10260    50   191   190  5122   215   197  1446   858  1312
##  [34]  1121   151 67561  3371  5708 22354  1580  1838   491   374  6427
##  [45]   289    39   319    41  2956    83  1294  8857  1365   512   384
##  [56]  3193   598   444   213  2177  1250  9070   682  5143   971 15011
##  [67]   275     9 54496  6568  9690     5   243  1134  3734   370  6096
##  [78]   963  1275  1079 29667 11667  6227     2  3855 12528 70734    68
##  [89]   782  7420   321  5756     1 10334    21  4866 30131     4   102
## [100]   503 45298  1148  5891
```

table() function

The `table()` function can be used to tabularize one or more variables. For example, lets find out how many observations (i.e. individual countries) we have per region.

```
table(mydata$region)
```

```
## 
## Caucasus and Central Asia            Eastern Africa 
##                         8                        13 
##                    Europe             Middle Africa 
##                        15                         8 
##               Middle East           Northern Africa 
##                        15                         7 
##        South-Eastern Asia           Southern Africa 
##                         8                         8 
##            Southern Asia            Western Africa 
##                         6                        15
```

Using logical operations, we can create more complex tabularizations. For example, below, we show how many countries have above average number of conflict events per region.

```
summary(mydata$nconflict)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
##     1.0   315.5  1250.0  6216.3  5993.5 70734.0
```

```
table(mydata$region, mydata$nconflict > mean(mydata$nconflict))
```

```
##                            
##                             FALSE TRUE
##   Caucasus and Central Asia     7    1
##   Eastern Africa                9    4
##   Europe                       14    1
##   Middle Africa                 7    1
##   Middle East                  10    5
##   Northern Africa               3    4
##   South-Eastern Asia            5    3
##   Southern Africa               7    1
##   Southern Asia                 2    4
##   Western Africa               14    1
```

Exercise 3: How would you access all elements of the variable `country` using indexing rather than the `$` operator?

```
## [1] "Afghanistan" "Albania"     "Algeria"     "Angola"      "Armenia"    
## [6] "Azerbaijan"
```

```
## [1] "Afghanistan" "Albania"     "Algeria"     "Angola"      "Armenia"    
## [6] "Azerbaijan"
```

Exercise 4: How would you find the maximum value for number of events using the `$` operator?

```
## [1] 70734
```

Exercise 5: Print the country that corresponds to the maximum world population value using the `$` operator and indexing!

```
## [1] "Syria"
```

Exercise 6: Print out every second element from the variable `country` using indexing methods and the sequence function `seq()`.

```
## [1] "Afghanistan"            "Algeria"
## [3] "Armenia"                "Bahrain"
## [5] "Belarus"                "Bosnia and Herzegovina"
```

NAs in `R`

`NA` is how `R` denotes missing values. For certain functions, `NA`s cause problems.

```
vec <- c(4, 1, 2, NA, 3)
mean(vec) #Result is NA!
```

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

```
sum(vec) #Result is NA!
```

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

We can tell `R` to remove the NA and execute the function on the remainder of the data.

```
mean(vec, na.rm = T)
```

```
## [1] 2.5
```

```
sum(vec, na.rm = T)
```

```
## [1] 10
```

Adding observations

First, lets add another observation to the data. Suppose we wanted to add an observation for Germany, which will be a missing value. We can use the same operations we used for vectors to add data. Here, we will use the `rbind()` function to do so. `rbind()` stands for "row bind." Save the output in a new data frame!

```
obs <- c("Germany", "Europe", NA, NA, NA)
mydata_new <- rbind(mydata, obs)
dim(mydata_new)
```

```
## [1] 104   5
```

Adding variables

We can also create new variables that use information from the existing data. If we know the number of conflict events without fatalities by country, we can calculate the number of conflict events *with* fatalities to generate the variable `nconflict_fatalities`. By using the `$` operator, we can directly assign the new variable to the data frame `mydata_new`.

```
mydata$nconflict_fatalities <- mydata$nconflict - mydata$nconflict_no_fatalities
head(mydata, 3) #prints out the first 3 rows of the data frame
```

```
##       country          region nconflict nconflict_no_fatalities fatalities
## 1 Afghanistan   Southern Asia     40765                   23946     119973
## 2     Albania          Europe       582                     581          1
## 3     Algeria Northern Africa      7362                    5321       8451
##   nconflict_fatalities
## 1                16819
## 2                    1
## 3                 2041
```

Subsetting data

Suppose we want to figure out which country in Northern Africa has the highest number of riot and protest events. We can figure this out by first subsetting our dataset to only include countries in the region, then looking up the maximum value for `nconflict`. Below, we assign the output to a new object called `mydata_na`.

```
mydata_na <- mydata[mydata$region == "Northern Africa",]
max(mydata_na$nconflict)
```

```
## [1] 12528
```

```
mydata_na$country[mydata_na$nconflict == max(mydata_na$nconflict)]
```

```
## [1] "Sudan"
```

Saving data

Suppose we wanted to save this newly created data frame. We have multiple options to do so. If we wanted to save it as a native `.RData` format, we would run the following command.

```
# Make sure you specified the right working directory!
# save(mydata, file = "mydata_new.RData")
```

Most of the time, however, we would want to save our data in formats that can be read by other programs as well. `.csv` is an obvious choice.

```
# write.csv(mydata_new, file = "mydata_new.csv")
```

(Very basic) data visualization

Today, we will be covering some basics of data visualization in `R` using the native plotting functions. For more advanced data visualization functions, see the `ggplot2` package and the related material for a three-session workshop on advanced data visualization https://github.com/thereseanders/workshop-dataviz-fsu.

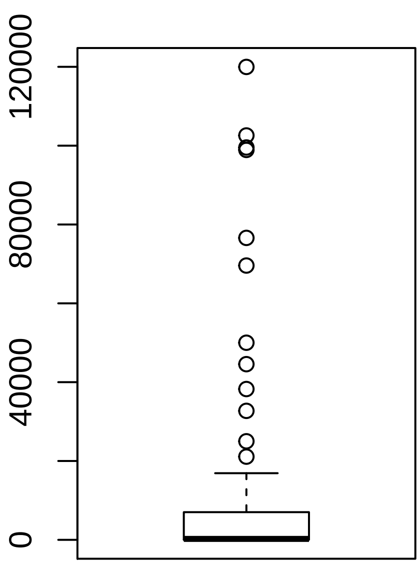
Basic graphical summaries of data

Type	Operator
Histogram	`hist()`
Boxplot	`boxplot()`
Kernel density plot	`plot(density())`
Basic scatterplot	`plot()`

Boxplot of population density

We can get an overview of the number of conflict events per country using the `boxplot()` function. The distribution appears to be highly skewed.

```
boxplot(mydata$fatalities)
```



Suppose we wanted to know whether there are more fatalities in countries with a higher overall number of conflicts. Let's first look at the distribution of number of conflicts.

```
summary(mydata$nconflict)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
##     1.0   315.5  1250.0  6216.3  5993.5 70734.0
```

Create a new dummy (binary) variable that codes whether a state has a relatively high number of conflicts (greater than the median) using the `ifelse()` function.

```
median(mydata$nconflict)
```

```
## [1] 1250
```

```
mydata$nconflict_high <- ifelse(mydata$nconflict > median(mydata$nconflict), 1, 0)
head(mydata$nconflict_high)
```

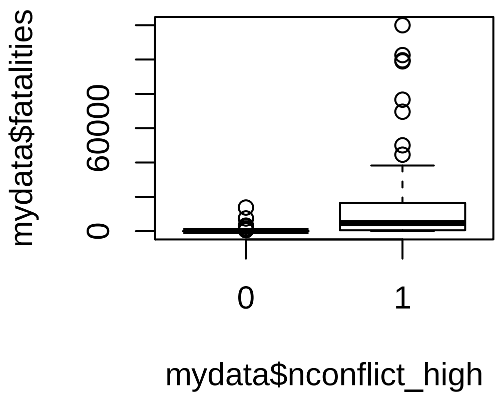
```
## [1] 1 0 1 0 1 1
```

```r
table(mydata$nconflict_high) # We split the observations (almost) sexactly in half.
```

```
##
##  0  1
## 52 51
```

We can display two indicators in the same boxplot. We can use this feature to answer the question whether states with more conflict events also see more overall fatalities (which is, as expected, the case).

```r
boxplot(mydata$fatalities ~ mydata$nconflict_high)
```

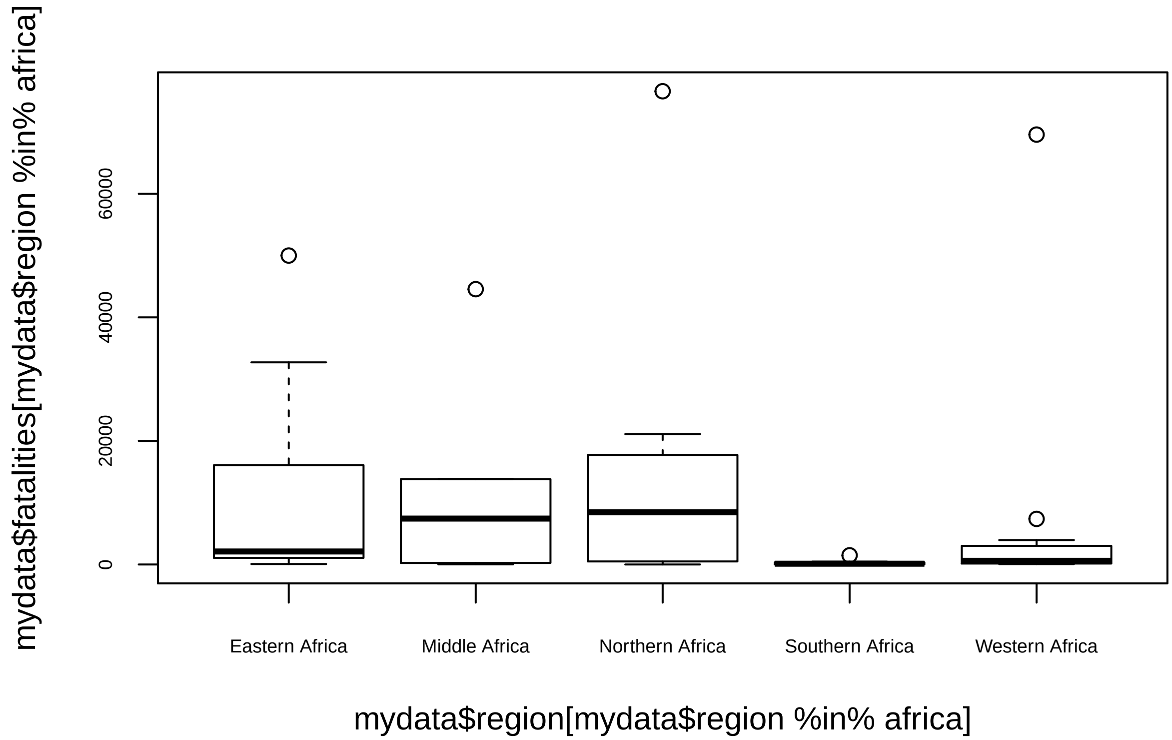


Suppose we wanted to know which region in Africa sees the most fatalities in riots or protests. Below we introduce the `%in%` operator to subset to a set of values.

```r
table(mydata$region)
```

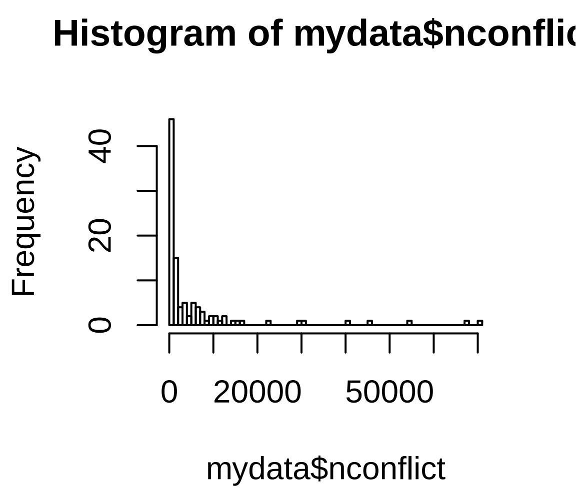
```
##
## Caucasus and Central Asia            Eastern Africa
##                         8                        13
##                    Europe            Middle Africa
##                        15                         8
##               Middle East           Northern Africa
##                        15                         7
##        South-Eastern Asia           Southern Africa
##                         8                         8
##            Southern Asia            Western Africa
##                         6                        15
```

```r
africa <- c("Eastern Africa",
            "Middle Africa",
            "Northern Africa",
            "Southern Africa",
            "Western Africa")
boxplot(mydata$fatalities[mydata$region %in% africa] ~ mydata$region[mydata$region %in% africa],
        cex.axis = 0.6)
```



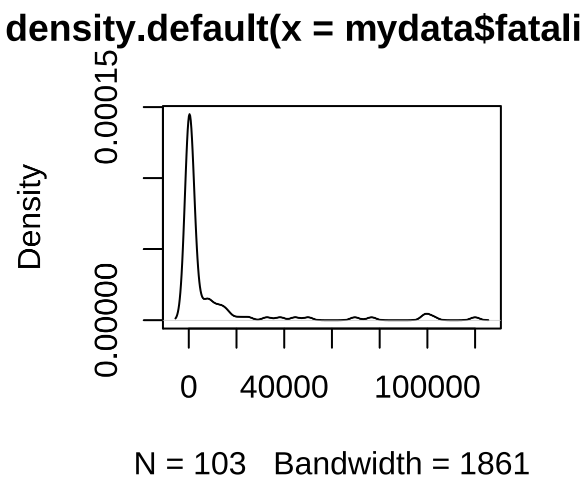
Histogram of number of conflict events

```
hist(mydata$nconflict, breaks = 100)
```



Density plot of fatalities

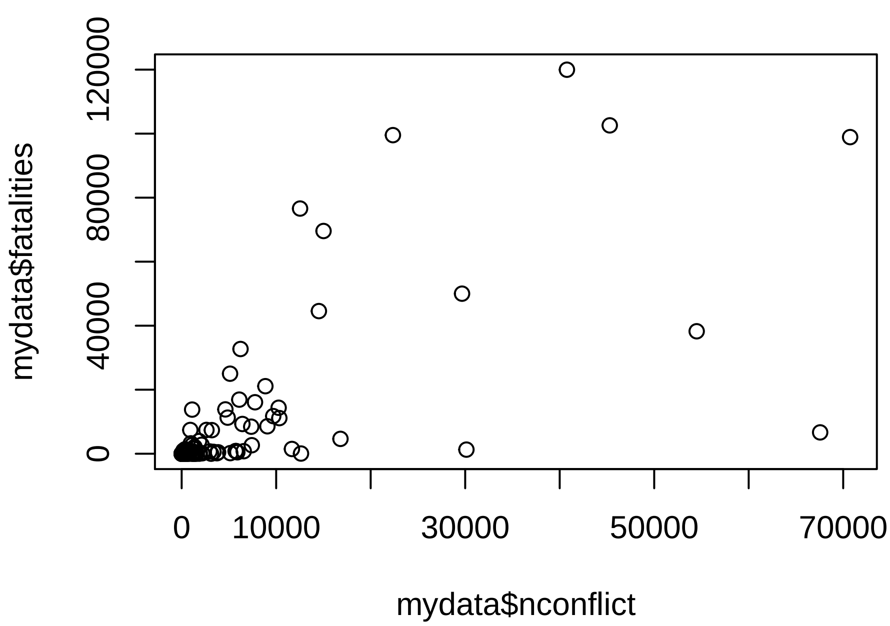
```
plot(density(mydata$fatalities))
```



Basic scatter plots

Does the number of fatalities vary with the number of overall conflict events?

```
plot(mydata$nconflict, mydata$fatalities)
```



This is really hard to see. We could log-transform both variables to make the relationship clearer. The distribution of the log-transformed variables are less skewed and closer to a normal distribution. Not that logging the variable will drop 8 observations in which the number of protests/riots without fatalities is zero.

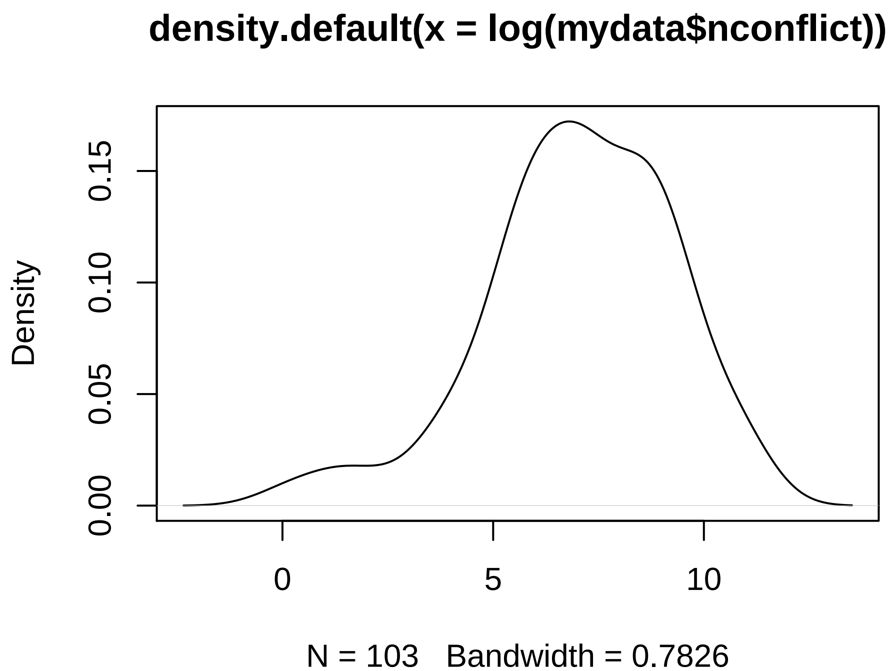
```
length(mydata$nconflict[mydata$nconflict == 0])
```

```
## [1] 0
```

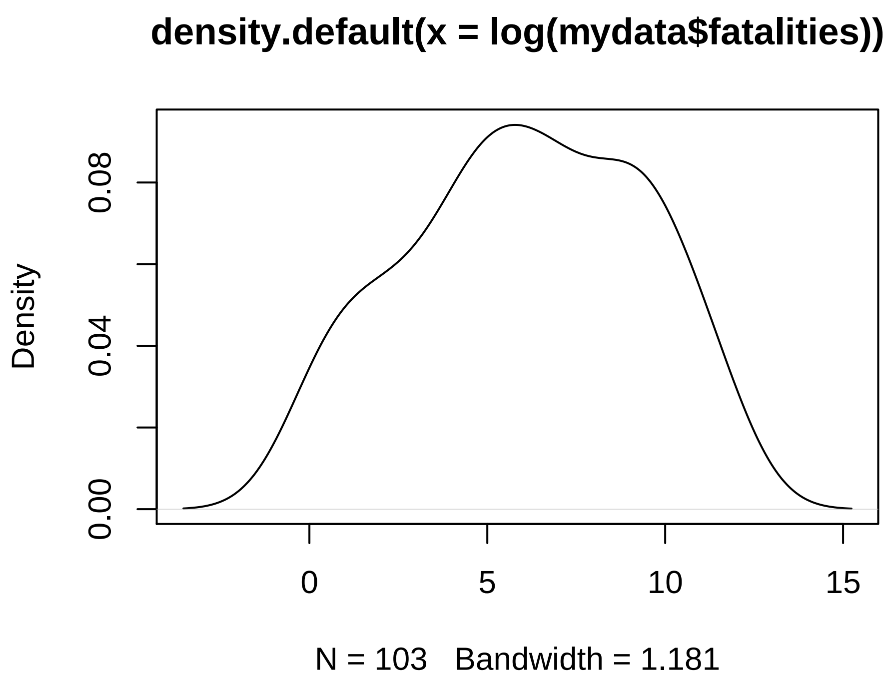
```
length(mydata$fatalities[mydata$fatalities == 0])
```

```
## [1] 8
```

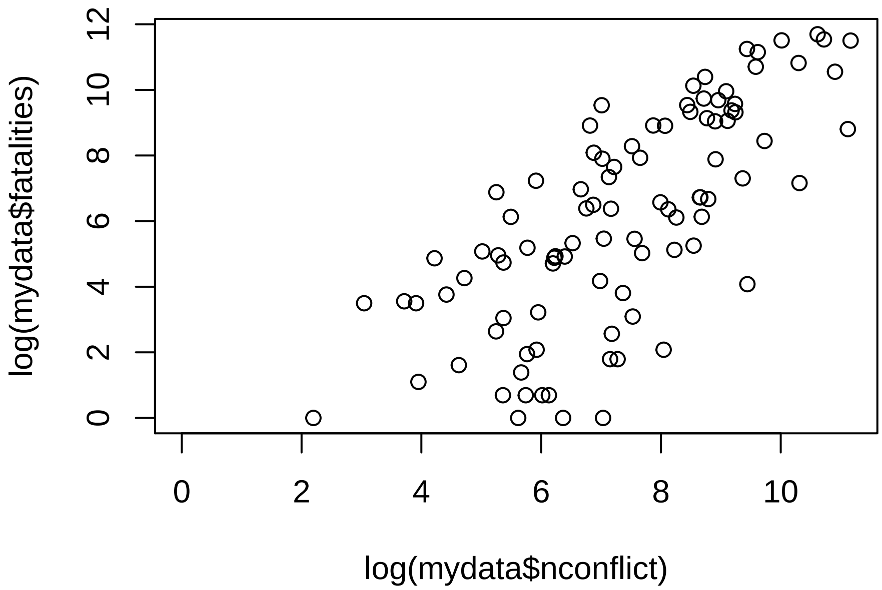
```
plot(density(log(mydata$nconflict)))
```




```
plot(density(log(mydata$fatalities)))
```



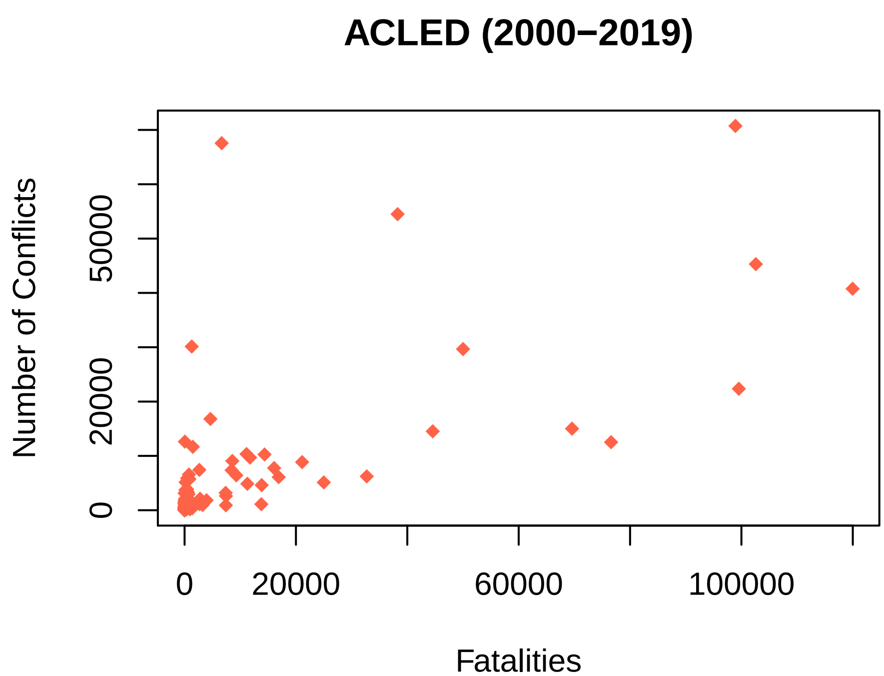

```
plot(log(mydata$nconflict), log(mydata$fatalities))
```



Basic graphic options

Aside from arguably not being very informative, the plot above is not very pretty. Lets give it titles, use color and shapes!

```
plot(mydata$fatalities,mydata$nconflict,
     main = "ACLED (2000-2019)", #Adding a main title.
     xlab = "Fatalities", #Adding a x-axis title.
     ylab = "Number of Conflicts", #Adding a y-axis title.
     col = "tomato", #Changing the color of the data points.
     pch = 18) #Changing the shape
```



Yeah, ok. Its not much prettier (especially the labeling on the axes), but you get the point…

A few additional notes on graphical options:

- R can display any color in the RBG or HEX system. However it also has a ton of colors that you can just refer to by name, see http://www.stat.columbia.edu/~tzheng/files/Rcolor.pdf.
- Same with the shapes and line types, see http://www.cookbook-r.com/Graphs/Shapes_and_line_types/.
- R colors in all their glory: http://www.stat.columbia.edu/~tzheng/files/Rcolor.pdf.

Working with R on your machine

In this workshop, we used RStudio Cloud. In future work on your own computer, you should use R together with the integrated development environment (IDE) **RStudio**. In addition to offering a 'cleaner' programming development than the basic R editor, RStudio offers a large number of added functionalities for integrating code into documents, built-in tools and web-development. To get started, please download the latest version of RStudio and R from this website:

https://www.rstudio.com/products/rstudio/download/

Working Directories

When working with R on your own machine, the program needs to know where to look for files if you want to read data and where to store files if you write data. The `getwd()` command returns the current working directory. We can change the working directory with `setwd()` (see below).

Think of your computer as a filing cabinet. R scripts are essentially text files with commands that you want R to execute. In order to execute these files, we need to tell R where to look for the list of commands we want to execute. Setting a working directory is analogous to telling R in which file in the filing cabinet we stored our document (code) and into which file in the filing cabinet to put new documents (such as graphs, new data frames, new code).

```
getwd() # Prints the current working directory
```

```
## [1] "/Users/thereseanders/Dropbox/Dissertation/TerritorialControl/Analysis/tc_hmm_decay_191011/ds-wo
```

```
#setwd("/Users/thereseanders/Projects")
```

Important for Windows users: In R, the backslash is an escape character. Therefore, entering file paths is a little different in Windows than on a Mac. On a windows machine you would enter:

`setwd("C:/Documents and Settings/Data")`

OR

`setwd("C:\\Users\\thereseanders\\Projects")`

Sources

Economist Intelligence Unit (2017): *Democracy Index*. https://infographics.economist.com/2017/DemocracyIndex/.

Imai, Kosuke (2017): *Quantitative Social Science. An Introduction.* Princeton and Oxford: Princeton University Press.

Raleigh, Clionadh, Andrew Linke, Håvard Hegre and Joakim Karlsen. 2010. Introducing ACLED – Armed Conflict Location and Event Data. *Journal of Peace Research* 47(5), 651-660.

World Bank (2017): *Population, total.* https://data.worldbank.org/indicator/sp.pop.totl?end=2016&start=2015.