Basic Concept of Statistics

Paolo Girardi and Livio Finos

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Contents

Ph.D. Course in Neuroscience – Academic Year 2020-2021

Basic Concept of Statistics

Lesson 1 - Optional and preliminary course on use of R

Basic use of R

Working-space and helps

R is an integrated software environment for data manipulation, computation and graphic representation. To start a session, it is necessary to perform a double mouse click on the icon of R or (RStudio). This will open the command window e the command prompt will be proposed:
>

The entities that R creates during a work session are called objects. These latter can be numbers, strings, vectors, matrices, functions, or more general structures. Such items are saved by name and stored in a dedicated area called workspace. At any time, it is possible check the objects available in the workspace using the command *ls()*

```
ls()
```

```
## character(0)
```

```
# empty workspace
```

I can remove an objects with the command *rm()*

```
rm(thing)
```

```
## Warning in rm(thing): oggetto "thing" non trovato
```

```
# attention... no thing in the working space
```

The working space can be saved and restored with the commands *save.image()* and *load()*

```
save.image("my_working_space.Rdata")
load("my_working_space.Rdata")
```

Files can be loaded and saved in a specific working directory in a local folder. We can use the functions *setwd()* and *getwd()* to set or to retrieve the folder location.

```
setwd("/Users/Paolo/Dropbox/Dottorato_Neurosciences/2020_2021")
getwd()
```

```
## [1] "/Users/Paolo/Dropbox/Dottorato_neurosciences/2020_2021"
```

For any request of help about R functions, a series of help function can be used

```
help(setwd)
?setwd
# and if I don't remember the function name help.search() or apropos()
apropos("setw")
```

```
## [1] "setwd"
```

Basic operation

R can be employed as a simple scientific calculator

```
1+1
```

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

```
3/2
```

```
## [1] 1.5
```

```
1>2
```

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

using a several local functions. Each function can be applied by means of round brackets with an argument inside

```
#squared root
sqrt(2)
```

```
## [1] 1.414214
```

```
#log - natural basis
log(10)
```

```
## [1] 2.302585
```

```
#exponential
exp(4)
```

```
## [1] 54.59815
```

```
#sin function
sin(pi)
```

```
## [1] 1.224647e-16
```

```
# the result is 0... pi is the greek pi constant
pi
```

```
## [1] 3.141593
```

```
#I can combine more functions
log(sqrt(2))*exp(4)
```

```
## [1] 18.92228
```

I can assign to an object values or results of operations as follows

```
x<-1
x
```

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

```
y<-3/2
y
```

```
## [1] 1.5
```

```
z<-1>2
z
```

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

Vectors and Matrix

To create a vector, a basic function is *c()*

```
x<-c(1,2,3,9,12)
x
```

```
## [1]  1  2  3  9 12
```

or a sequence can be created in these two ways

```
x1<-1:20
x1
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

```
x2<-seq(from=1,to=20,by=1)
x2
```

```
##  [1]  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20
```

```
# the result is the same
```

Other useful functions are

```
#replicate
x<-rep(2,5)
x
```

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

```
#multiplicate for scalar *
x<-1:5
x<-x*3
# x has been overwritten... pay attention!
x
```

```
## [1]  3  6  9 12 15
```

```
# other functions
sum(x)
```

```
## [1] 45
```

```
prod(x)
```

```
## [1] 29160
```

```
min(x)
```

```
## [1] 3
```

```
max(x)
```

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

```
length(x)
```

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

A matrix can be define with command *matrix()*

```
mat<-matrix(data=1:9,nrow=3,ncol=3)
mat
```

```
##      [,1] [,2] [,3]
## [1,]    1    4    7
## [2,]    2    5    8
## [3,]    3    6    9
```

```
# by default elements are placed by col
```

and square brackets are used to select elements in a vector or matrix (or even a vector) as follows

```
# in a vector
x[3]
```

```
## [1] 9
```

```
x[1:2]
```

```
## [1] 3 6
```

```
# in a matrix
mat[1,2]
```

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

```
mat[1:2,3]
```

```
## [1] 7 8
```

```
# creating subselection
x[-1] #dropping the first element
```

```
## [1]  6  9 12 15
```

```
mat[-1,] #for the first row
```

```
##      [,1] [,2] [,3]
## [1,]    2    5    8
## [2,]    3    6    9
```

Type of ojects in R

In R we can define many type of data. R can automatically define an object on the basis of the object characteristics.
A numeric vector

```
x<-1:3
is(x)
```

```
## [1] "integer"              "double"               "numeric"
## [4] "vector"               "data.frameRowLabels"
```

```
is.numeric(x)
```

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

A matrix

```
mat<-matrix(data=1:9,nrow=3,ncol=3)
is(mat)
```

```
## [1] "matrix"    "array"     "structure" "vector"
```

A char vector (a vector of letters or even not numbers)

```
label<-c("white","red","black")
is(label)
```

```
## [1] "character"            "vector"               "data.frameRowLabels"
## [4] "SuperClassMethod"
```

I can combine numbers and characters in a list

```
list<-list(x,label)
list
```

```
## [[1]]
## [1] 1 2 3
##
## [[2]]
## [1] "white" "red"   "black"
```

```
list[[1]] # first element of a list with double square brackets
```

```
## [1] 1 2 3
```

and rename each single element

```
names(list)<-c("numbers","colours")
```

We can combine number and characters in a data.frame, that is the default object when I manage different type of variables (numeric, factor, char, boolean).

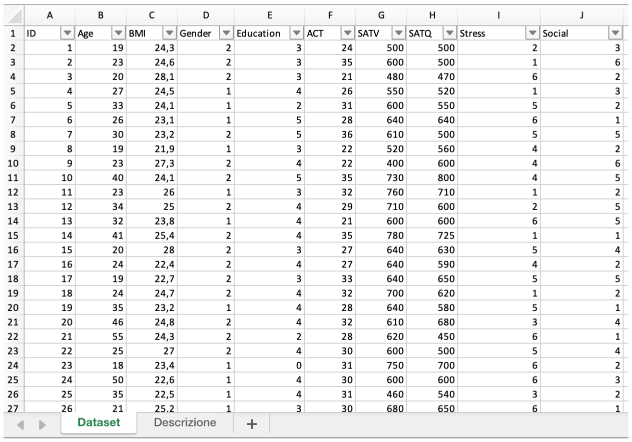
```
data<-data.frame(numbers=x,colours=label)
data # the result is a typical dataset format
```

```
##   numbers colours
## 1       1   white
## 2       2     red
## 3       3   black
```

Import a dataset

R permits to import data in several formats and from other statistical softwares (STATA, SPSS, SAS, EXCEL, etc..). When R import a file it creates a *data.frame* object. For each format there are specific functions. We are going to explore the most used functions.
However, a beginner user can follow a guided importation process from
File > Import Dataset > and then to select the importing format.

A classical format for dataset is the text (extension csv, txt, dat).
Text can be imported in R with the function *read.csv()* or *read.table()*.
This dataset called "test" collected the results on proficieny test (SAT and ACT score) in a sample of 150 respondents. Subject are by row, while characteristics by column. In Excel we have this output:



	A	B	C	D	E	F	G	H	I	J
1	ID	Age	BMI	Gender	Education	ACT	SATV	SATQ	Stress	Social
2	1	19	24,3	2	3	24	500	500	2	3
3	2	23	24,6	2	3	35	600	500	1	6
4	3	20	28,1	2	3	21	480	470	6	2
5	4	27	24,5	1	4	26	550	520	1	3
6	5	33	24,1	1	2	31	600	550	5	2
7	6	26	23,1	1	5	28	640	640	6	1
8	7	30	23,2	2	5	36	610	500	5	5
9	8	19	21,9	1	3	22	520	560	4	2
10	9	23	27,3	2	4	22	400	600	4	6
11	10	40	24,1	2	5	35	730	800	4	5
12	11	23	26	1	3	32	760	710	1	2
13	12	34	25	2	4	29	710	600	2	5
14	13	32	23,8	1	4	21	600	600	6	5
15	14	41	25,4	2	4	35	780	725	1	1
16	15	20	28	2	3	27	640	630	5	4
17	16	24	22,4	2	4	27	640	590	4	2
18	17	19	22,7	2	3	33	640	650	5	5
19	18	24	24,7	2	4	32	700	620	1	2
20	19	35	23,2	1	4	28	640	580	5	1
21	20	46	24,8	2	4	32	610	680	3	4
22	21	55	24,3	2	2	28	620	450	6	1
23	22	25	27	2	4	30	600	500	5	4
24	23	18	23,4	1	0	31	750	700	6	2
25	24	50	22,6	1	4	30	600	600	6	3
26	25	35	22,5	1	4	31	460	540	3	2
27	26	21	25,2	1	3	30	680	650	6	1

Figure 1: The dataset in Excel

We save them in a CSV format and import with the function *read.csv()* in R.

```
test<-read.csv("test.csv",sep=";",header=T,dec=",")
head(test) #the first 6 rows
```

```
##   ID Age  BMI Gender    Education ACT SATV SATQ Stress Social
## 1  1  19 24.3      F    secondary  24  500  500      2      3
## 2  2  23 24.6      F    secondary  35  600  500      1      6
## 3  3  20 28.1      F    secondary  21  480  470      6      2
## 4   4   27 24.5       M         degree  26  550  520       1       3
## 5   5   33 24.1       M upper primary  31  600  550       5       2
## 6   6   26 23.1       M   post-degree  28  640  640       6       1
```

```
names(test)
```

```
##   [1] "ID"         "Age"        "BMI"        "Gender"     "Education" "ACT"
##   [7] "SATV"       "SATQ"       "Stress"     "Social"
```

Reproducible Statistical Analysis with R-Markdown

Why use R-Markdown

The use of RStudio with R-Markdown provides the basis to edit text and executable R code in the same text file.
R-Markdown permits to
- create HTML, PDF, or MS Word output;
- use beamer, ioslides, and slidy presentations; - manage tables, figures and bibliographies; - create a customizable environment.

There are a lot of sites with guides and vignette. More about R Markdown:

- rmarkdown.rstudio.com

- online reference guide

Create a R-markdown file

Create an Rmd report

From RStudio, create a new R Markdown file

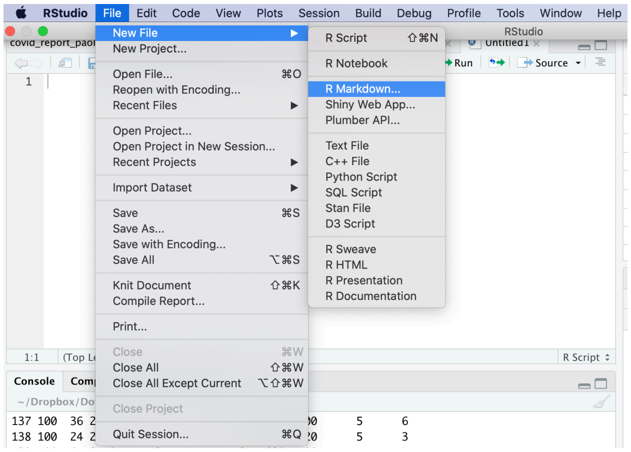


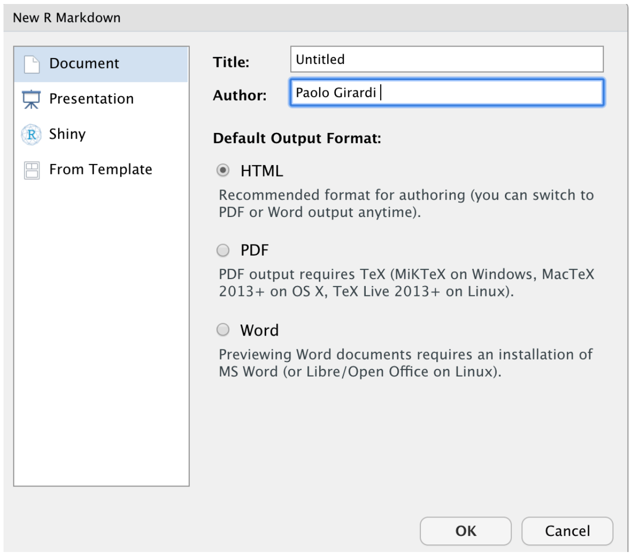
Figure 2: rmarkdown.rstudio.com

Select HTML output (for now). We can change it later.

An untitled R Markdown file is created with some default text and R code.

File -> Save As to the project directory with an Rmd suffix, for example, `test-report.Rmd`.

Click `Knit HTML` to render the document in HTML.



Title: Untitled

Author: Paolo Girardi

Default Output Format:

● HTML

Recommended format for authoring (you can switch to PDF or Word output anytime).

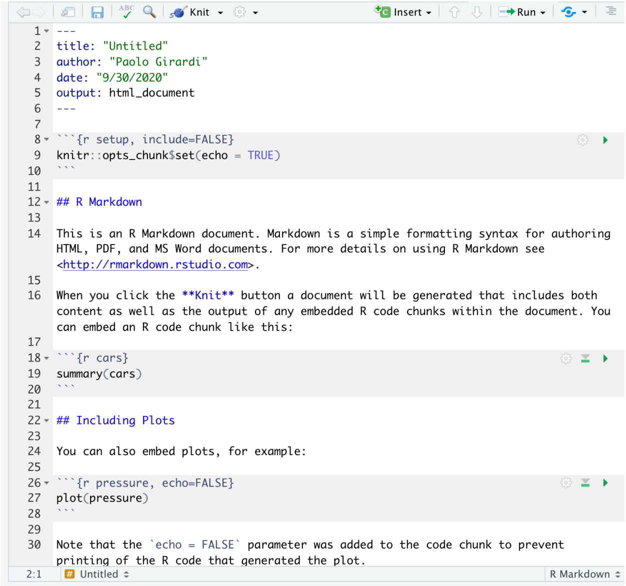
○ PDF

PDF output requires TeX (MiKTeX on Windows, MacTeX 2013+ on OS X, TeX Live 2013+ on Linux).

○ Word

Previewing Word documents requires an installation of MS Word (or Libre/Open Office on Linux).

Figure 3: rmarkdown.rstudio.com



~~~
---
title: "Untitled"
author: "Paolo Girardi"
date: "9/30/2020"
output: html_document
---

```{r setup, include=FALSE}
knitr::opts_chunk$set(echo = TRUE)
```

## R Markdown

This is an R Markdown document. Markdown is a simple formatting syntax for authoring
HTML, PDF, and MS Word documents. For more details on using R Markdown see
<http://rmarkdown.rstudio.com>.

When you click the **Knit** button a document will be generated that includes both
content as well as the output of any embedded R code chunks within the document. You
can embed an R code chunk like this:

```{r cars}
summary(cars)
```

## Including Plots

You can also embed plots, for example:

```{r pressure, echo=FALSE}
plot(pressure)
```

Note that the `echo = FALSE` parameter was added to the code chunk to prevent
printing of the R code that generated the plot.
~~~

Figure 4: rmarkdown.rstudio.com

The report appears in your RStudio viewer (or can be opened in other HTML viewer).

Compareing the markup to the output

To compare the Rmd markup to the HTML output. For example,

- markup `<http://rmarkdown.rstudio.com>` creates a link, http://rmarkdown.rstudio.com

- markup `**Knit**` produces a bold typeface, **Knit**

- single backtick markup ‘ produces highlighted inline code `Knit`.
- markup `*Knit*` produces an italic typeface, *Knit*

The code-chunk markup

echoes the R code in the HTML document, executes the *summary()* function, and writes the results to the output.

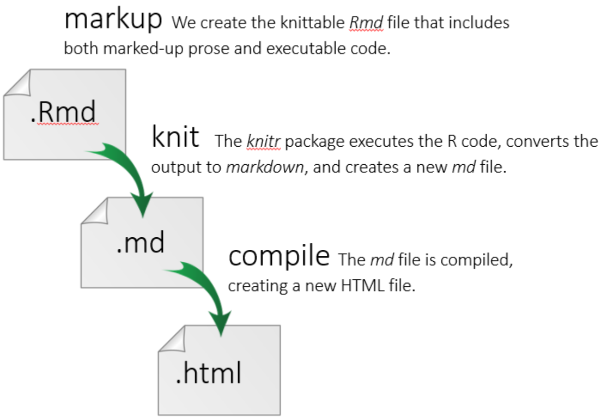
```
summary(cars)
```

```
##      speed           dist       
##  Min.   : 4.0   Min.   :  2.00  
##  1st Qu.:12.0   1st Qu.: 26.00  
##  Median :15.0   Median : 36.00  
##  Mean   :15.4   Mean   : 42.98  
##  3rd Qu.:19.0   3rd Qu.: 56.00  
##  Max.   :25.0   Max.   :120.00
```

The next code chunk includes an `echo=FALSE` argument that prevents printing the R code chunk to the output.

However, the code is executed and the graph is printed to the output document.

What the software is doing



markup We create the knittable *Rmd* file that includes both marked-up prose and executable code.

knit The *knitr* package executes the R code, converts the output to *markdown*, and creates a new *md* file.

compile The *md* file is compiled, creating a new HTML file.

Figure 5: rmarkdown.rstudio.com

The resulting output file is placed in the same directory as your Rmd file.

Changing the output format

The YAML header or front-matter in the Rmd file controls how the file is rendered. (YAML: YAML Ain't Markup Language)

Let's change the title to *Test Report*.

The `output:` option recognizes three document types:

- html_document

- pdf_document

- word_document

You can type these directly in the Rmd YAML header or you can use the RStudio `Knit` pulldown menu

---

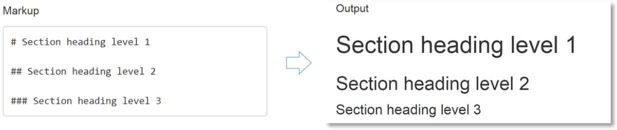
Formatting the output

Articles on the RStudio website for formatting output.

- Formatting an HTML document
- Formatting a PDF document
- Formatting a Word document

Markdown basics

Section headings



```
# Section heading level 1

## Section heading level 2

### Section heading level 3
```

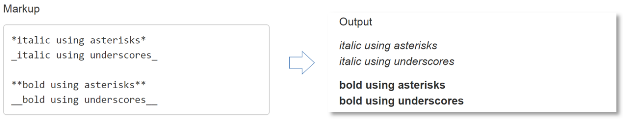
Section heading level 1

Section heading level 2

Section heading level 3

Figure 6: rmarkdown.rstudio.com

Emphasis



```
*italic using asterisks*
_italic using underscores_

**bold using asterisks**
__bold using underscores__
```

italic using asterisks
italic using underscores

bold using asterisks
bold using underscores

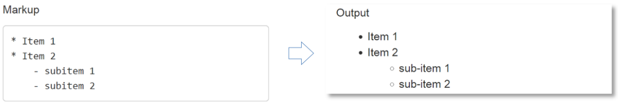
Figure 7: rmarkdown.rstudio.com

Itemize

Sub-items begin with 4 spaces.
Every line ends with two spaces.

Enumerate

Sub-items begin with 4 spaces.
Every line ends with two spaces.



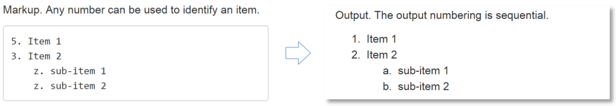
Markup

```
* Item 1
* Item 2
    - subitem 1
    - subitem 2
```

Output

- Item 1
- Item 2
    - sub-item 1
    - sub-item 2

Figure 8: rmarkdown.rstudio.com



Markup. Any number can be used to identify an item.

```
5. Item 1
3. Item 2
    z. sub-item 1
    z. sub-item 2
```

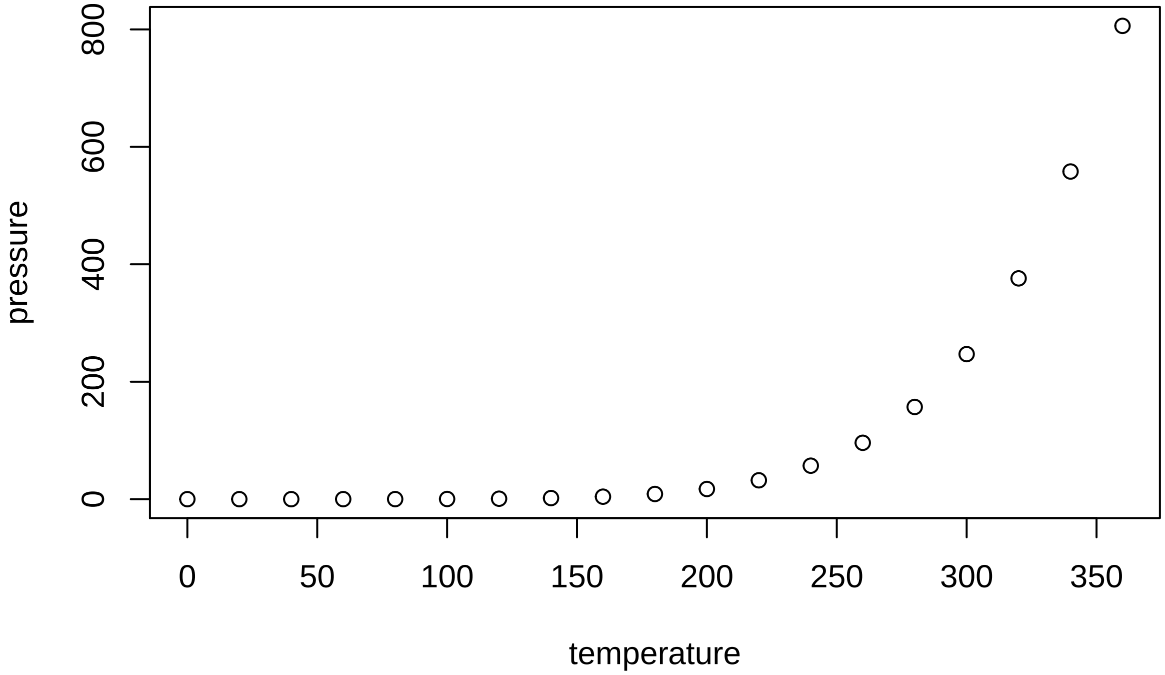
Output. The output numbering is sequential.

1. Item 1
2. Item 2
    a. sub-item 1
    b. sub-item 2

Figure 9: rmarkdown.rstudio.com

Including Plots

You can also embed plots, for example:



Note that the `echo = FALSE` parameter was added to the code chunk to prevent printing of the R code that generated the plot.

Data visualization and base statistics with R

The normal distribution

R has some basic functions for calculating density, cumulative distribution function and quantiles for many distributions of interest. It is also possible to generate achievements' pseudo-random from the distribution. For example, considering the distribution normal standard, there are 4 main functions:

- dnorm (x) calculates the density value in x;

- pnorm (x) calculates the value cumulative distribution function into x;

- qnorm (p) computes the quantile of level p;

- rnorm (n) generates a sample from a normal standard of size n (N(0,1)).

The prefix (d, p, q and r) descriminates the type of function associated to the random variable. R contains some functions related to several random variables by default. In particular

```
## Warning in rbind(c("norm", "normal", "mean, sd", "0, 1"), c("lnorm", "log-
## normal", : number of columns of result is not a multiple of vector length (arg
## 4)
```

norm	normal	mean, sd	0, 1
lnorm	log-normal	meanlog, sdlog	0, 1
t	t di Student	df	-
chisq	chi-quadrato df	-	chisq
f	F	df1, df2	-, -
unif	uniform	min, max	0, 1
exp	exponential	rate	1
gamma	gamma	shape, scale	-, 1
binom	binomial	size, prob	-,-
pois	Poisson	lambda	-

Other random variables can be added with “external R-Packages” or built by yourself. Some example of the functions related to the normal

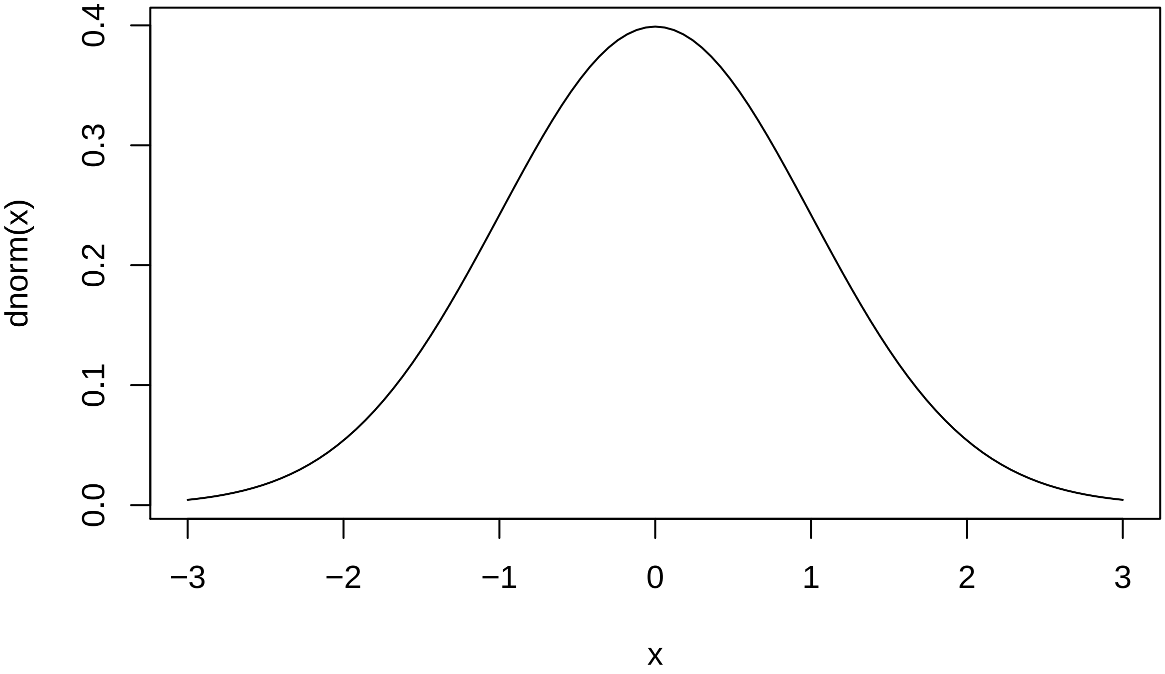
```
## [1] 0.3989423
```

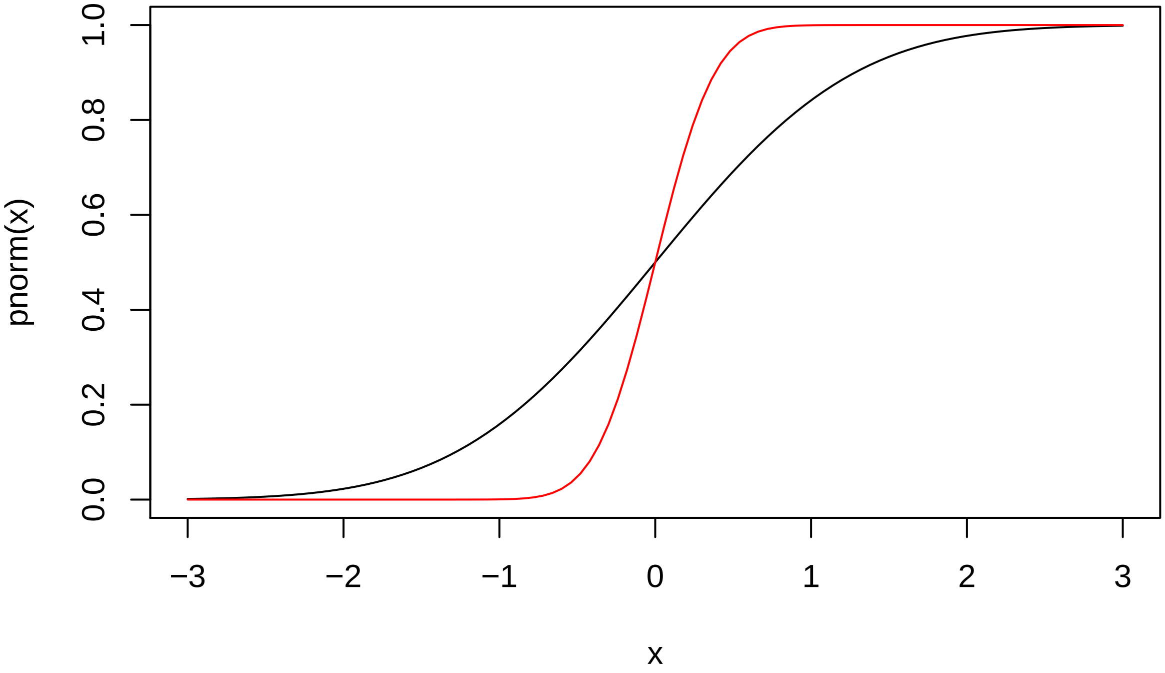
```
## [1] 0.5
```

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

```
## [1]  0.04646966 -0.42713869 -0.99031453
```

```
## [1] -0.6264538  0.1836433 -0.8356286
```





To build a function in R

R permits to build personal functions.
The structure is similar to other programming codes. The function *function()* permits to define a new function. Here an example that returns the area of a rectangle given the basis and the height

```
## [1] 40
```

We can expand this function calculating the perimeter and the area, and then returning this two results in a list

```
## $area
## [1] 40
##
## $perimeter
## [1] 28
```

Basic statistics function with R

From the last imported dataset test

```
test<-read.csv("test.csv",sep=";",header=T,dec=",")
head(test) #the first 6 rows
```

```
##   ID Age  BMI Gender     Education ACT SATV SATQ Stress Social
## 1  1  19 24.3      F     secondary  24  500  500      2      3
## 2  2  23 24.6      F     secondary  35  600  500      1      6
## 3  3  20 28.1      F     secondary  21  480  470      6      2
## 4  4  27 24.5      M        degree  26  550  520      1      3
## 5  5  33 24.1      M upper primary  31  600  550      5      2
## 6  6  26 23.1      M   post-degree  28  640  640      6      1
```

Useful functions to visualize a dataset are:

- *View()*: to visualize a dataset like in rows and columns

- *str()*: to analyse the structure of a dataset

- *names()*: to obtain the name of each variabile in a vector

```
#View(test)
str(test)
```

```
## 'data.frame':    150 obs. of  10 variables:
##  $ ID       : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ Age      : int  19 23 20 27 33 26 30 19 23 40 ...
##  $ BMI      : num  24.3 24.6 28.1 24.5 24.1 23.1 23.2 21.9 27.3 24.1 ...
##  $ Gender   : Factor w/ 2 levels "F","M": 1 1 1 2 2 2 1 2 1 1 ...
##  $ Education: Factor w/ 6 levels "degree","lower primary",..: 5 5 5 1 6 3 3 5 1 3 ...
##  $ ACT      : int  24 35 21 26 31 28 36 22 22 35 ...
##  $ SATV     : int  500 600 480 550 600 640 610 520 400 730 ...
##  $ SATQ     : int  500 500 470 520 550 640 500 560 600 800 ...
##  $ Stress   : int  2 1 6 1 5 6 5 4 4 4 ...
##  $ Social   : int  3 6 2 3 2 1 5 2 6 5 ...
```

```
names(test)
```

```
##  [1] "ID"        "Age"       "BMI"       "Gender"    "Education" "ACT"
##  [7] "SATV"      "SATQ"      "Stress"    "Social"
```

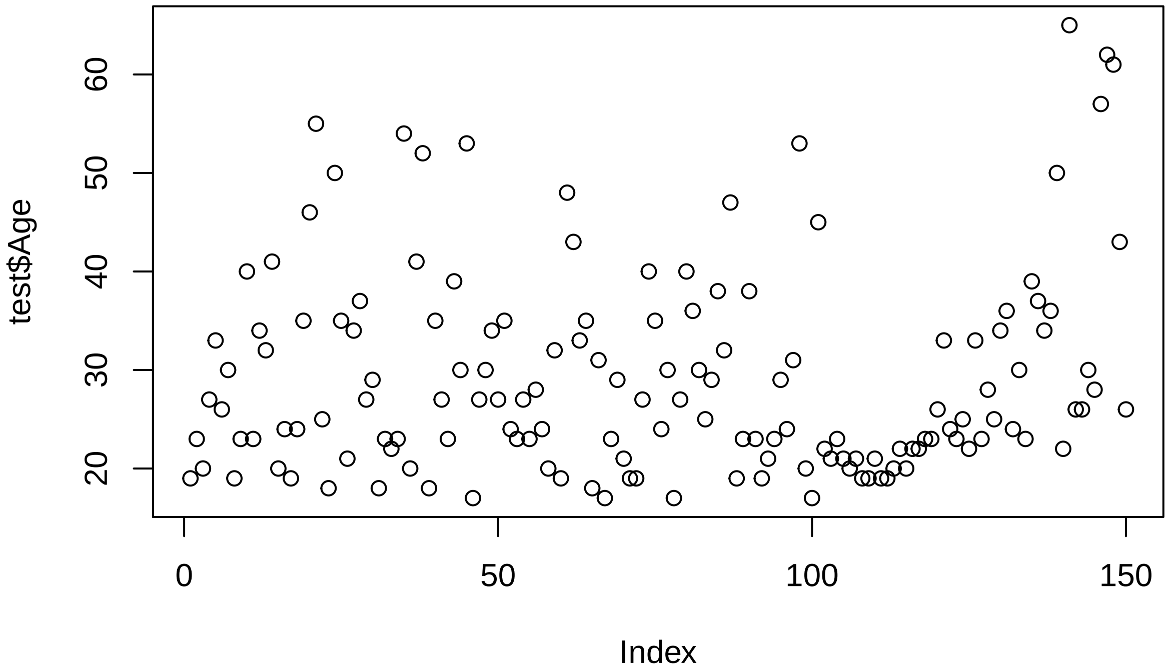
Some useful functions for basic statistics:

- *summary()*: compute a 5 number of Tukey + mean for numeric variables or frequency for categorical variables
- *plot()*: an object sensitive function, perform a barplot for categorical or dispersion diagram for numeric variables
- others: *sd()* compute standard deviation, *length()* the number of element in a vector, *dim()* the dimensions of a dataset or array, *median()* compute the median, *quantile()* calculates the quantile of a vector, *scale()* standardize a numeric vector, *IQR()* interquantile range

```
summary(test$Age)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   17.00   22.00   26.00   29.22   34.00   65.00
```

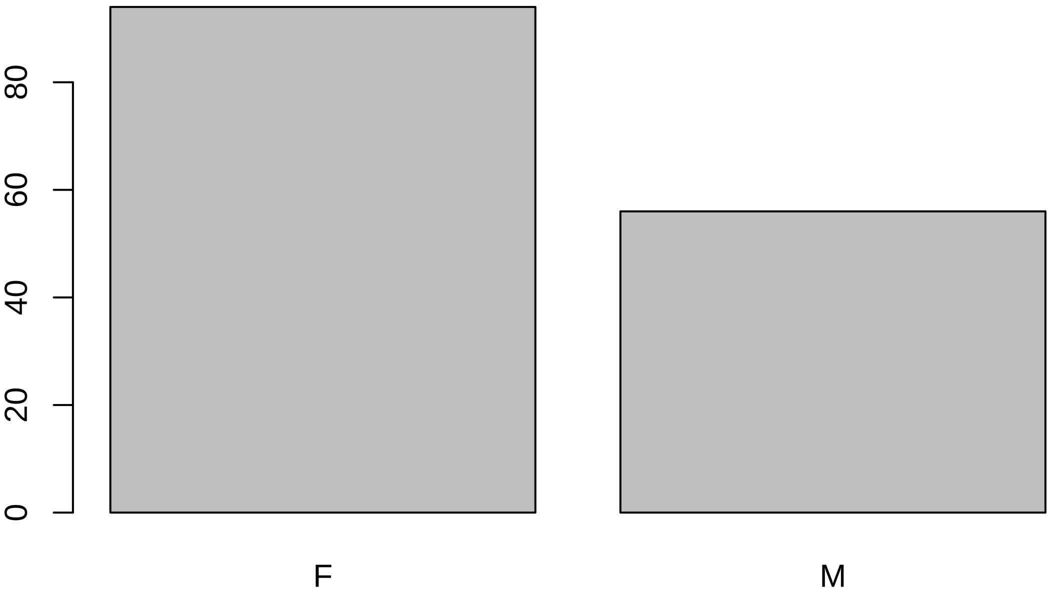
```
plot(test$Age)
```



```
summary(test$Gender)
```

```
##  F  M
## 94 56
```

```
plot(test$Gender)
```



Now we try to build a function that extracts from a numeric vector the followings indices: mean, sd, median, IQR an the length.

```
fun_sum<-function(x){
c(M=mean(x),SD=sd(x),Me=median(x),IQR=IQR(x),n=length(x))
}
fun_sum(test$Age)
```

```
##         M        SD        Me       IQR         n
##  29.22000  10.39416  26.00000  12.00000 150.00000
```