UNIVERSITAT POLITÈCNICA DE CATALUNYA
BARCELONATECH
Departament d'Estadística
i Investigació Operativa

ACADEMIC YEAR 2021-22

STATISTICAL INFERENCE AND MODELLING – MASTER OF DATA SCIENCE

# Introduction to R: EDA

## Introduction to R software

Lecturer: Lídia Montero

September 2021 – Version 1.1

MASTER OF DATA SCIENCE

# 1. LAB SESSIONS

- 2 hours every 1 week, in a PC's classroom.
- Practical assignments posted through ATENEA - TASKS. Formative assessment will be given by the lecturer before the next laboratory session when deliverable is indicated.
- Guidelines for laboratory session posted in ATENEA Course webpage
- Datasets posted on ATENEA Course webpage.

**FIRST SESSION**: Introduction to *R and R Studio statistical software*

**R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.**

# 2. UNITS 1-2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

⇒Davis data: davis.RData (data.frame) - Use comands in davis.R for basics

```
> library(car)
Loading required package: MASS
Loading required package: nnet

> data(Davis)
> ls()
[1] "Davis"

> attributes(Davis)
$names
[1] "sex"    "weight" "height" "repwt"  "repht"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"
 …
[193] "193" "194" "195" "196" "197" "198" "199" "200"

>
```

# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

## 2.1 Univariate descriptive analysis – Numeric data

- ***Missing and Outliers might occur***
- **Numerical values**
  - Measures of Central Tendency: *Mean, Median, Mode*
  - Measures of Dispersion: *Variance, Standard Deviation, Quartiles, IQR, Maximum, Minimum.*
- **Graphical Representations**
  - Histogram, Cumulative Histogram. Absolute or relative.
  - *BoxPlot.*
  - *Dotplot*

# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

### *2.1.1 Continuous Univariate Descriptive Analysis: Numeric statistics*

```
> summary(dataframe)  # R command
```

- Mean $\bar{\boldsymbol{x}} = \frac{1}{n}\sum_{i=1}^{n} x_i$
- Median: Value of the *variable* such that

  *50% Observations are < Median (Q2) & 50% Observations are > Median (Q2)*
- Quartile Q1 of the 25% and quartile Q3 of the 75%: Values of the variable that

  *25% Observations are < Q1 & 75% Observations are > Q1*

  *75% Observations are < Q3 & 25% Observations are > Q3*
- Variance $\boldsymbol{s_x}^2 = \frac{1}{n-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2$
- Standard Deviation $\boldsymbol{s_x}$ (square root of variance)

# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

⇒Davis data: davis.RData (data.frame) - Use comands in davis.R for basics

```
> summary(Davis)
 sex        weight            height            repwt             repht      
 F:112   Min.   : 39.0   Min.   : 57.0   Min.   : 41.00   Min.   :148.0  
 M: 88   1st Qu.: 55.0   1st Qu.:164.0   1st Qu.: 55.00   1st Qu.:160.5  
         Median : 63.0   Median :169.5   Median : 63.00   Median :168.0  
         Mean   : 65.8   Mean   :170.0   Mean   : 65.62   Mean   :168.5  
         3rd Qu.: 74.0   3rd Qu.:177.2   3rd Qu.: 73.50   3rd Qu.:175.0  
         Max.   :166.0   Max.   :197.0   Max.   :124.00   Max.   :200.0  
                                         NA's   :17       NA's   :17     
> var(Davis[,3:4])
           weight    height
weight 227.85930  34.37588
height  34.37588 144.19055
```

- **Missing data: Do not miss them! Track them.**

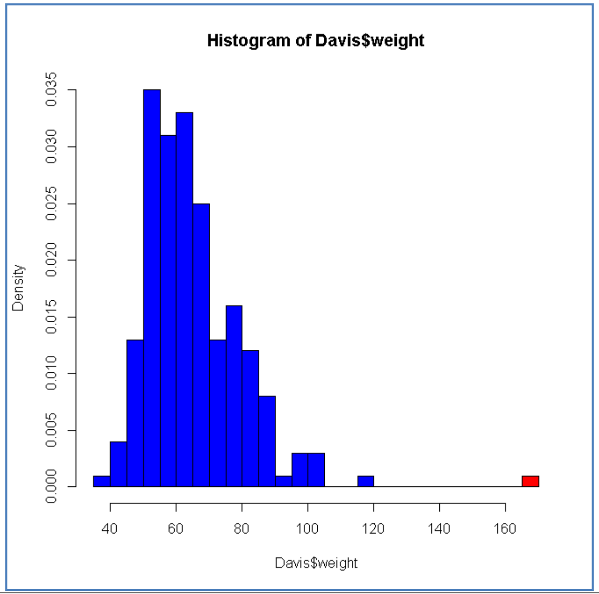
```
NA: Not available – Missing data
NaN: Not available for numerical reasons (divided by 0)
```

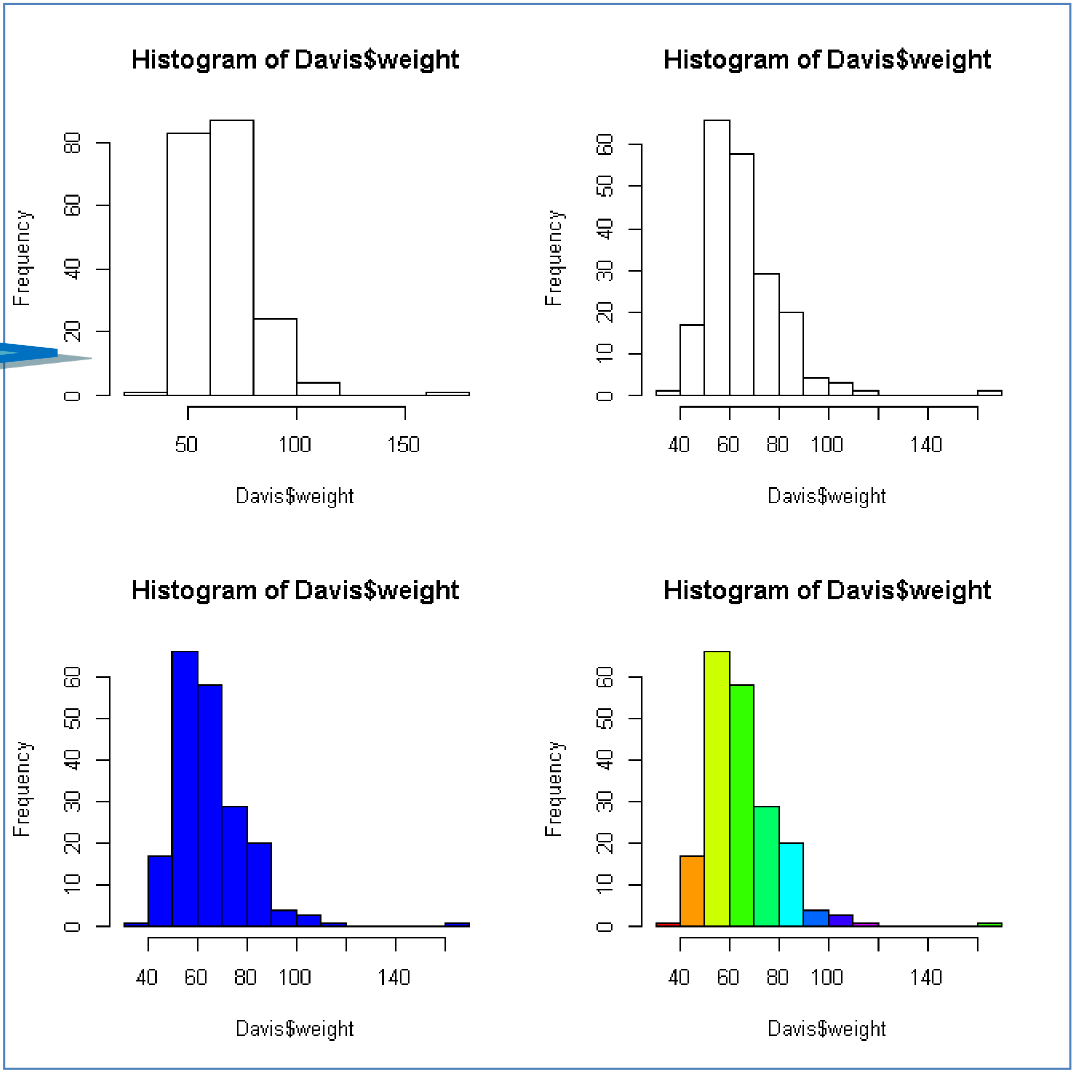
# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

## 2.1.2 Continuous Univariate Analysis Description: Histogram

Histogram (non-acumulative):

```
par(mfrow=c(2,2))
hist(Davis$weight)
hist(Davis$weight,10)
hist(Davis$weight,10,col="blue")
hist(Davis$weight,10,col=rainbow(10))

hist(Davis$weight,freq=F)   # Proportions
hist(Davis$weight,freq=F,
         col=…,breaks=seq(35,170,5))
```



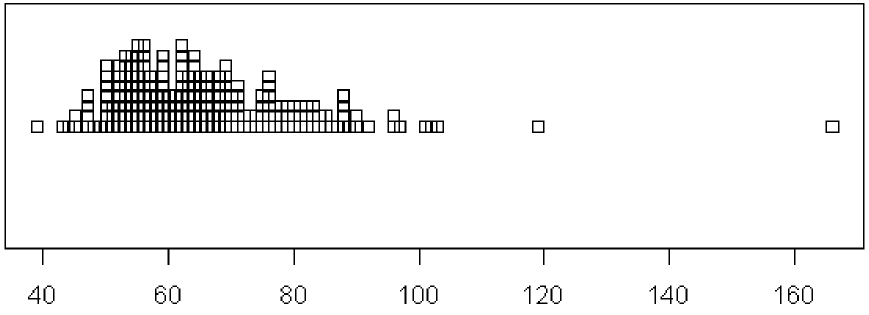


# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

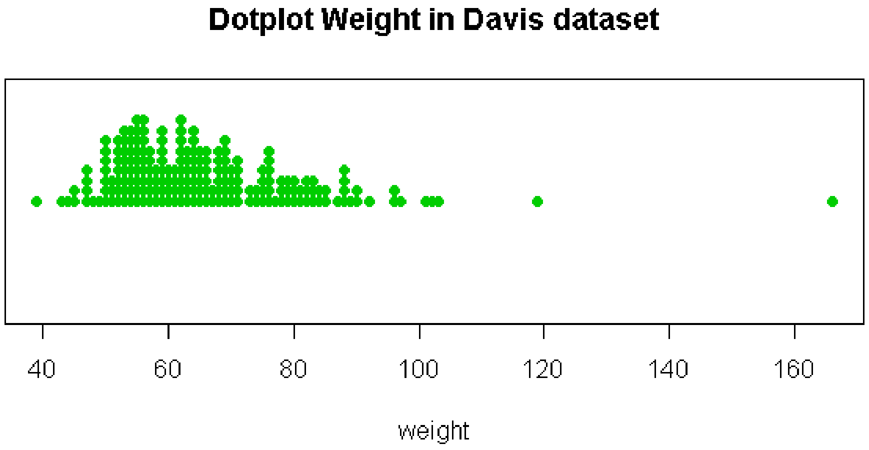
## *2.1.3 Continuous Univariate Analysis Description: Dotplot*

Dotplot:

```
# Dotplot
par(mfrow=c(2,1))
stripchart(Davis$weight,method="stack")
```



```
stripchart(Davis$weight,method="stack"
     ,xlab="weight",pch=19,
     col=3,
     main="Dotplot Weight in Davis dataset")
```

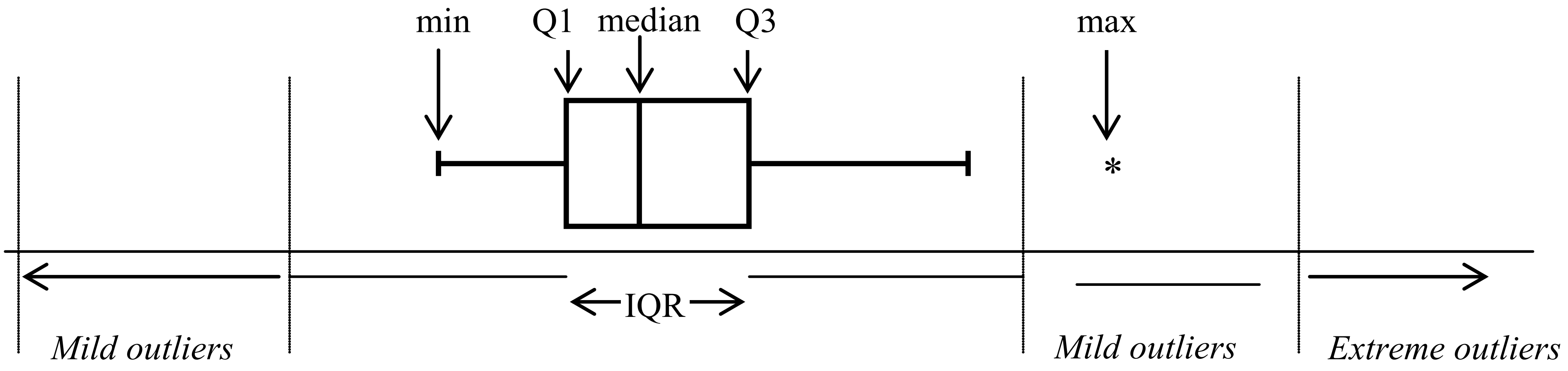


# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

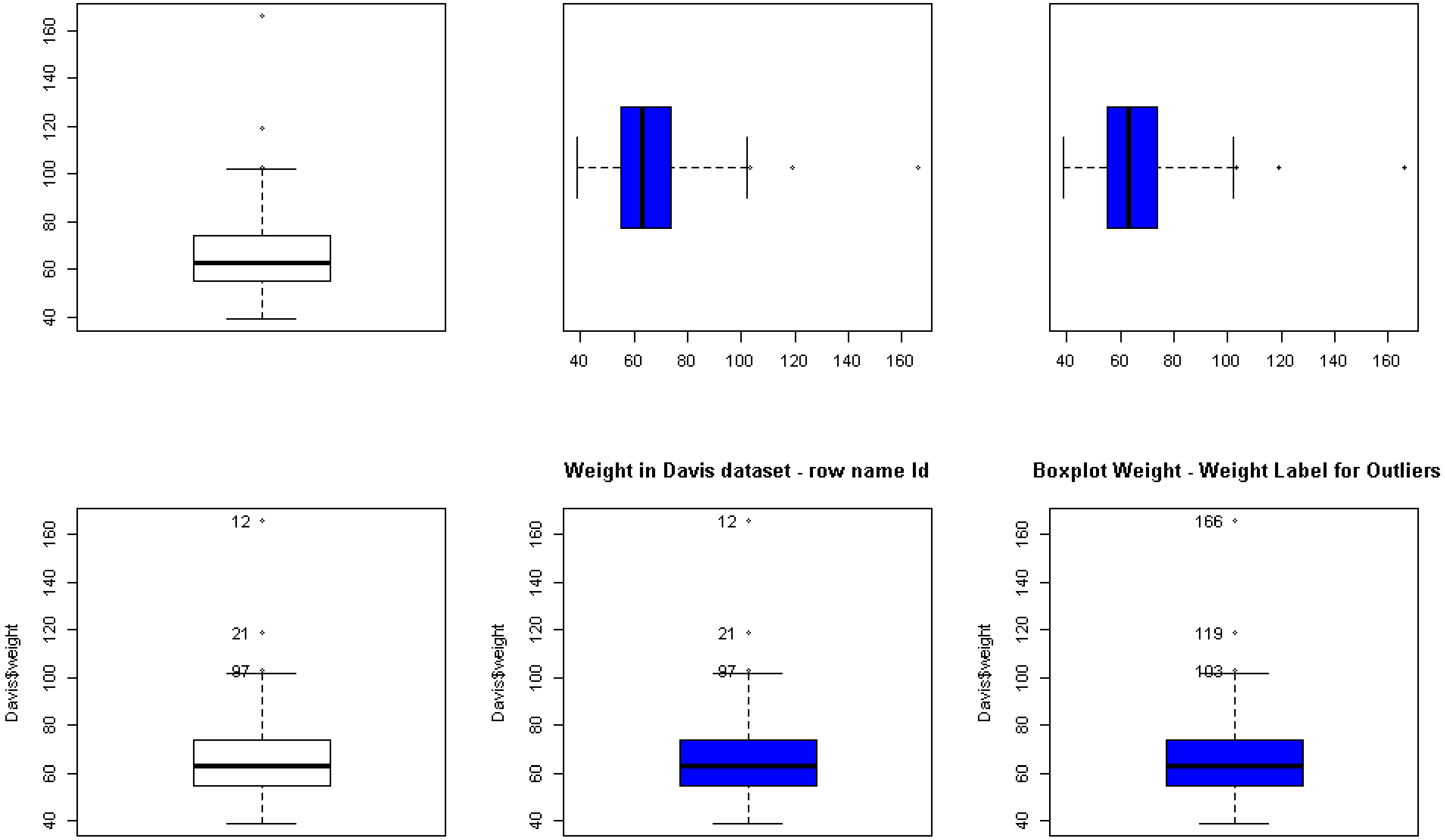
## *2.1.4 Continuous Univariate Analysis Description: Boxplot*

Boxplot: Basic implementation in boxplot() method, recommended Boxplot() method in car library

"Five issues Summary" (Min, Q1, Me, Q3, Max) for Univariate EDA, useful to detect the presence of outliers.



```
# Boxplot
par(mfrow=c(2,3))
boxplot(Davis$weight)
boxplot(Davis$weight,col="blue",horizontal = TRUE)
boxplot(Davis$weight,col="blue",horizontal = TRUE, pch=19,labels=Davis$weight)
Boxplot(Davis$weight)
Boxplot(Davis$weight,col="blue",main= "Weight in Davis dataset - row name Id")
Boxplot(Davis$weight,col="blue",main=" Boxplot Weight - Weight Label for
Outliers",labels=Davis$weight)
```


Weight in Davis dataset - row name Id
Boxplot Weight - Weight Label for Outliers
40
60
80
100
120
140
160
Davis$weight
12
21
97
166
119
103

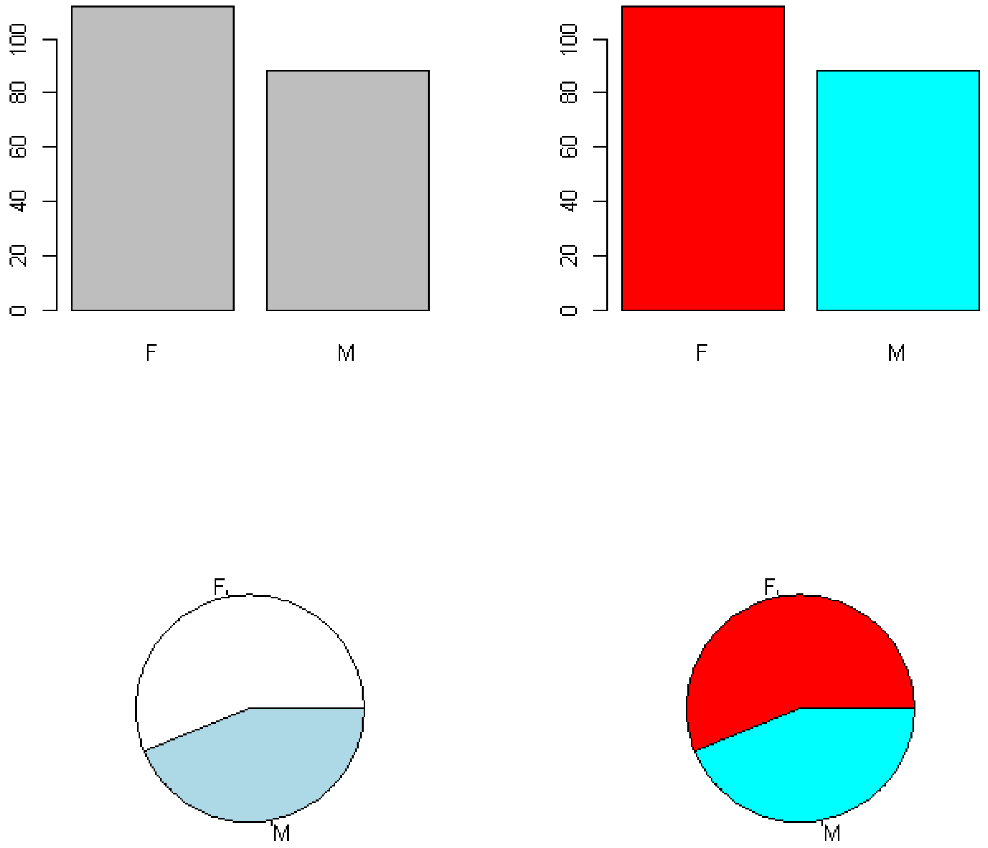
# UNITS 1 AND 2: EXPLORATORY DATA ANALYSIS (EDA)-UNIVARIATE

## 2.2 Univariate descriptive analysis – Categorical data

**Description of categorical variables: only 'missings' might occur. Graphical representations:**

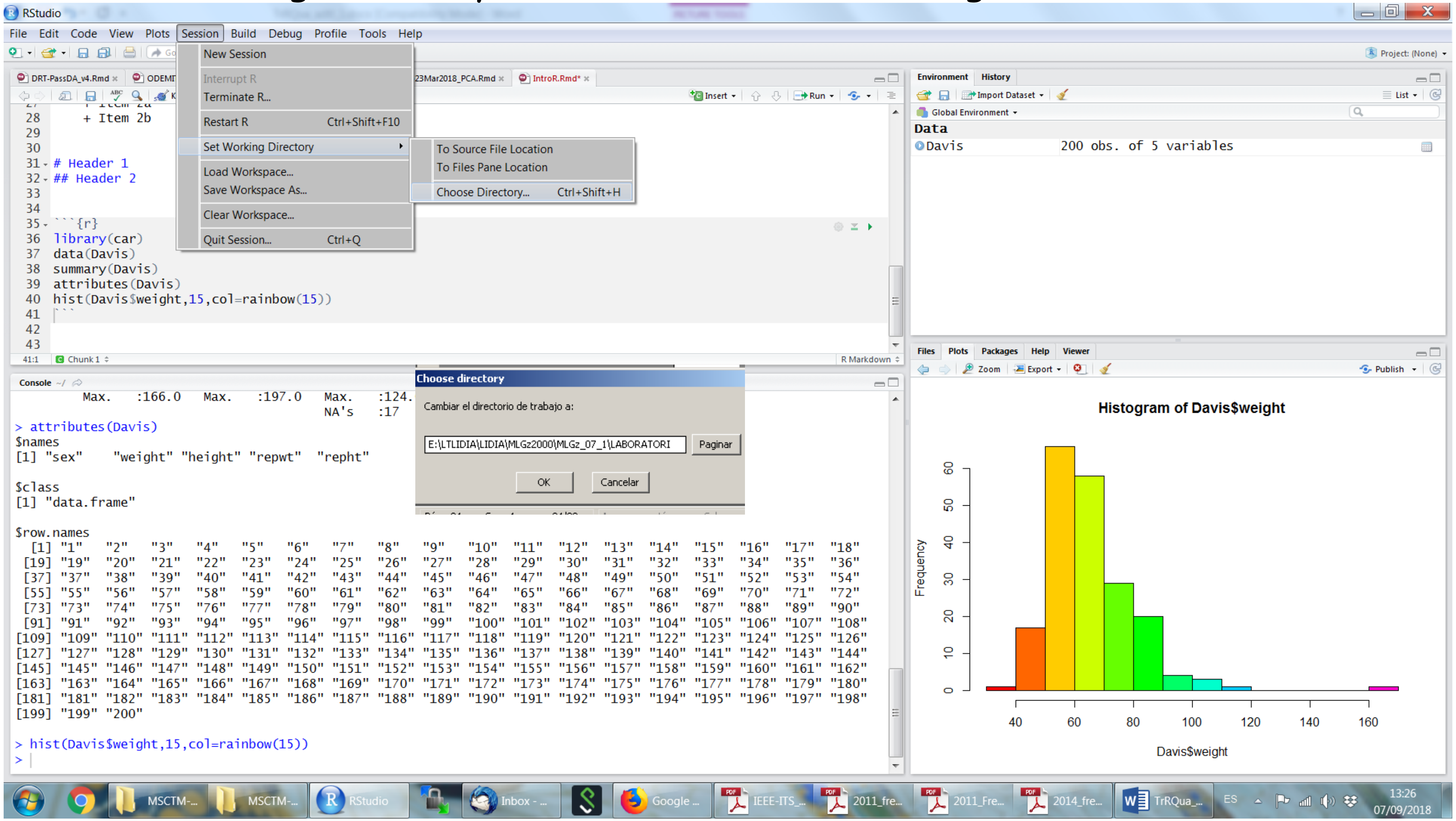
- barplot (a) absolute or relative (proportions) b) density or accumulated.
  - Suitable for graphical description of discrete-qualitative data (factor) with a few levels or categories.
- *Pie Chart.*

```
table(Davis$sex)
margin.table(table(Davis$sex))
prop.table(table(Davis$sex))

par(mfrow=c(2,2))
barplot(table(Davis$sex))
barplot(table(Davis$sex),col=rainbow(2))
pie(table(Davis$sex))
pie(table(Davis$sex),col=rainbow(2))
```



# 3. INTRODUCTION TO R

- *RStudio* for Windows: Basic Input/Output (R is *case sensitive*)
- Select working directory in R console window (Change dir / Cambiar dir …)



~~~
    + Item 2b


# Header 1
## Header 2


```{r}
library(car)
data(Davis)
summary(Davis)
attributes(Davis)
hist(Davis$weight,15,col=rainbow(15))
```
~~~

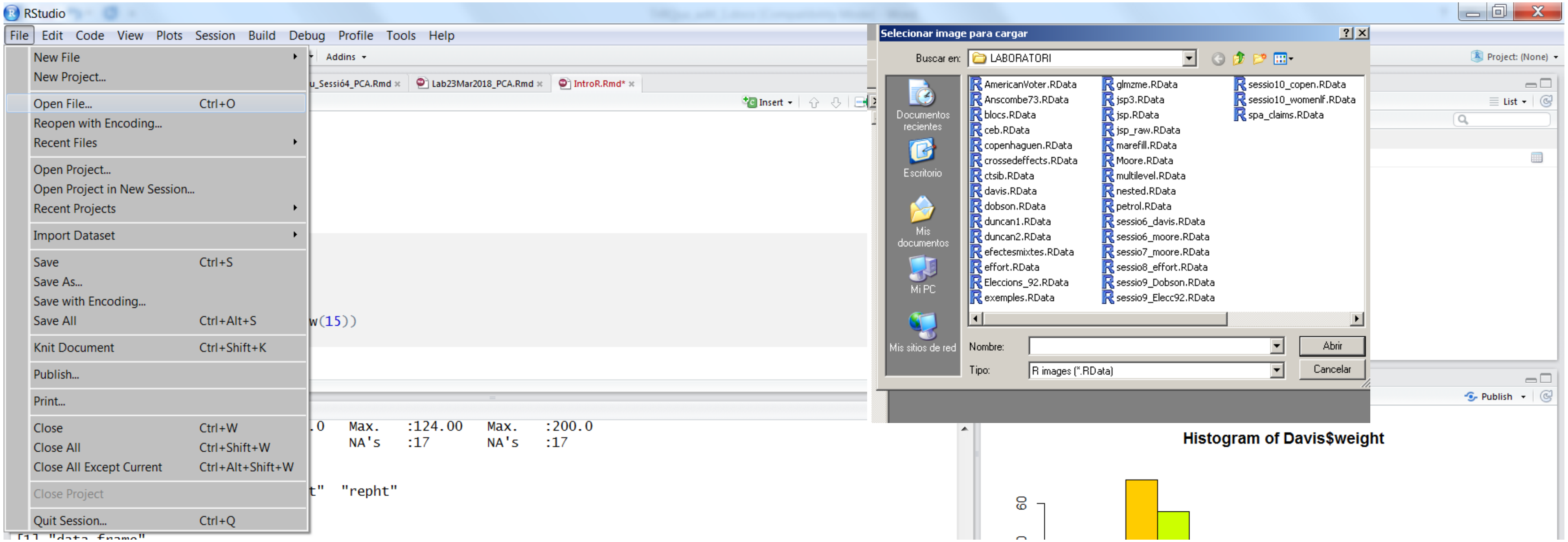
```
Data
Davis               200 obs. of 5 variables
```

Cambiar el directorio de trabajo a:

E:\LTLIDIA\LIDIA\MLGz2000\MLGz_07_1\LABORATORI

```
        Max.   :166.0   Max.   :197.0   Max.   :124.
                                        NA's   :17
> attributes(Davis)
$names
[1] "sex"    "weight" "height" "repwt"  "repht" 

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "13"  "14"  "15"  "16"  "17"  "18" 
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36" 
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54" 
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72" 
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90" 
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

> hist(Davis$weight,15,col=rainbow(15))
> 
```

# INTRODUCTION TO R: LOAD WORKSPACE (RETRIEVE PREVIOUS USED DATA)



```
w(15))
.0   Max.   :124.00   Max.   :200.0
     NA's   :17       NA's   :17
t"  "repht"
[1] "data.frame"
```

- Open (load) and Save Workspace – File Menu (*Archivo*)

  *File/Archivo* → Cargar área de trabajo (*load workspace*)

  *File/Archivo* → Guardar área de trabajo (*save workspace*)

  Example: Open/Load Davis.RData from a Workspace.

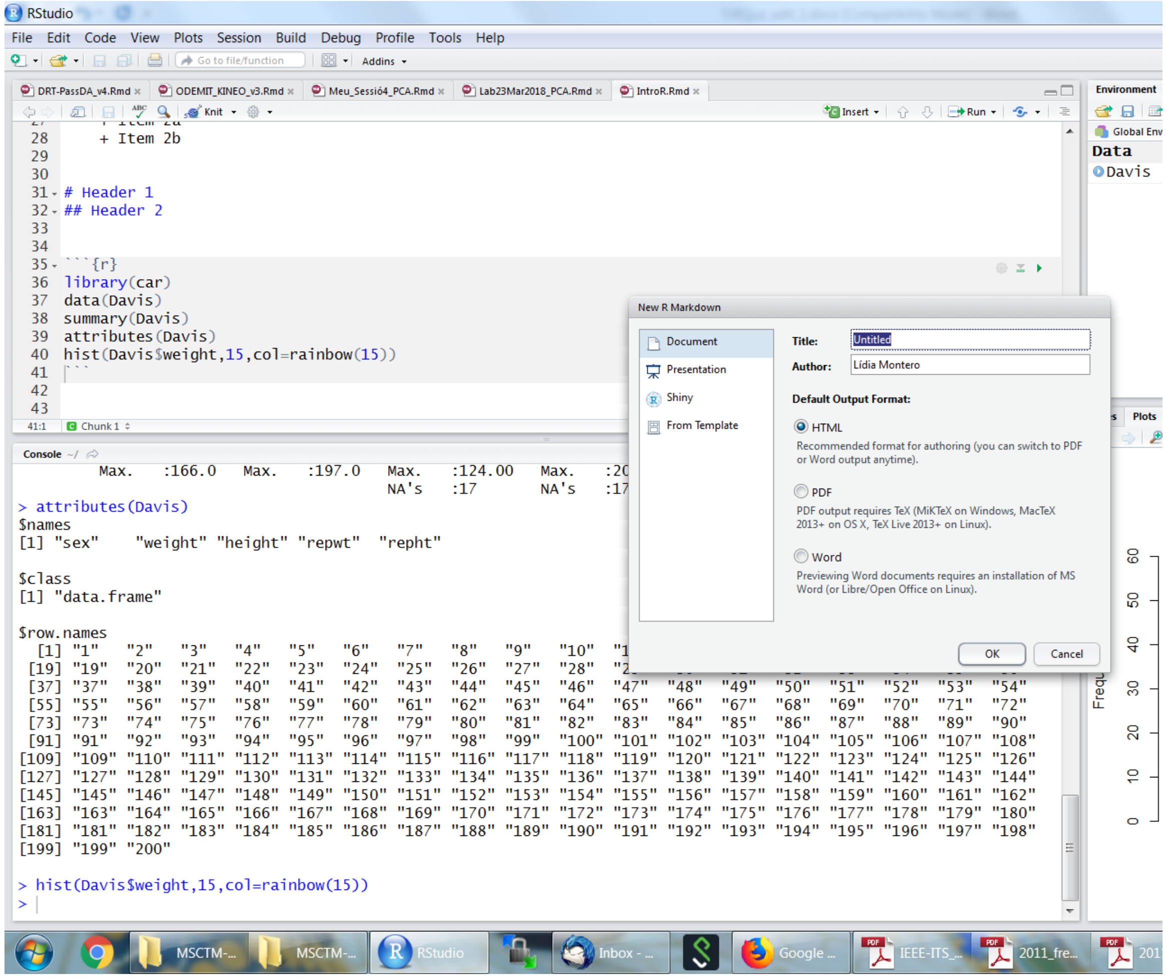
- To exit: *File/Archivo* → Salir or quit() command in R Console

# INTRODUCTION TO R: SCRIPTS

From Archivo (File) menu: you can **open, close, save, create a new, save as** scripts.

Scripts are text files containing R command. Always use them to track lab session commands

Markdown documents are dynamic documents combining ordinary text and R commands. They can be interpreted to produce an output: html, pdf or word.



~~~
    + Item 2b


# Header 1
## Header 2


```{r}
library(car)
data(Davis)
summary(Davis)
attributes(Davis)
hist(Davis$weight,15,col=rainbow(15))
```
~~~

```
      Max.   :166.0   Max.   :197.0   Max.   :124.00   Max.   :20
                                      NA's   :17       NA's   :17
> attributes(Davis)
$names
[1] "sex"    "weight" "height" "repwt"  "repht"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "1
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "2
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

> hist(Davis$weight,15,col=rainbow(15))
> 
```

New R Markdown

Title: Untitled
Author: Lídia Montero

Default Output Format:

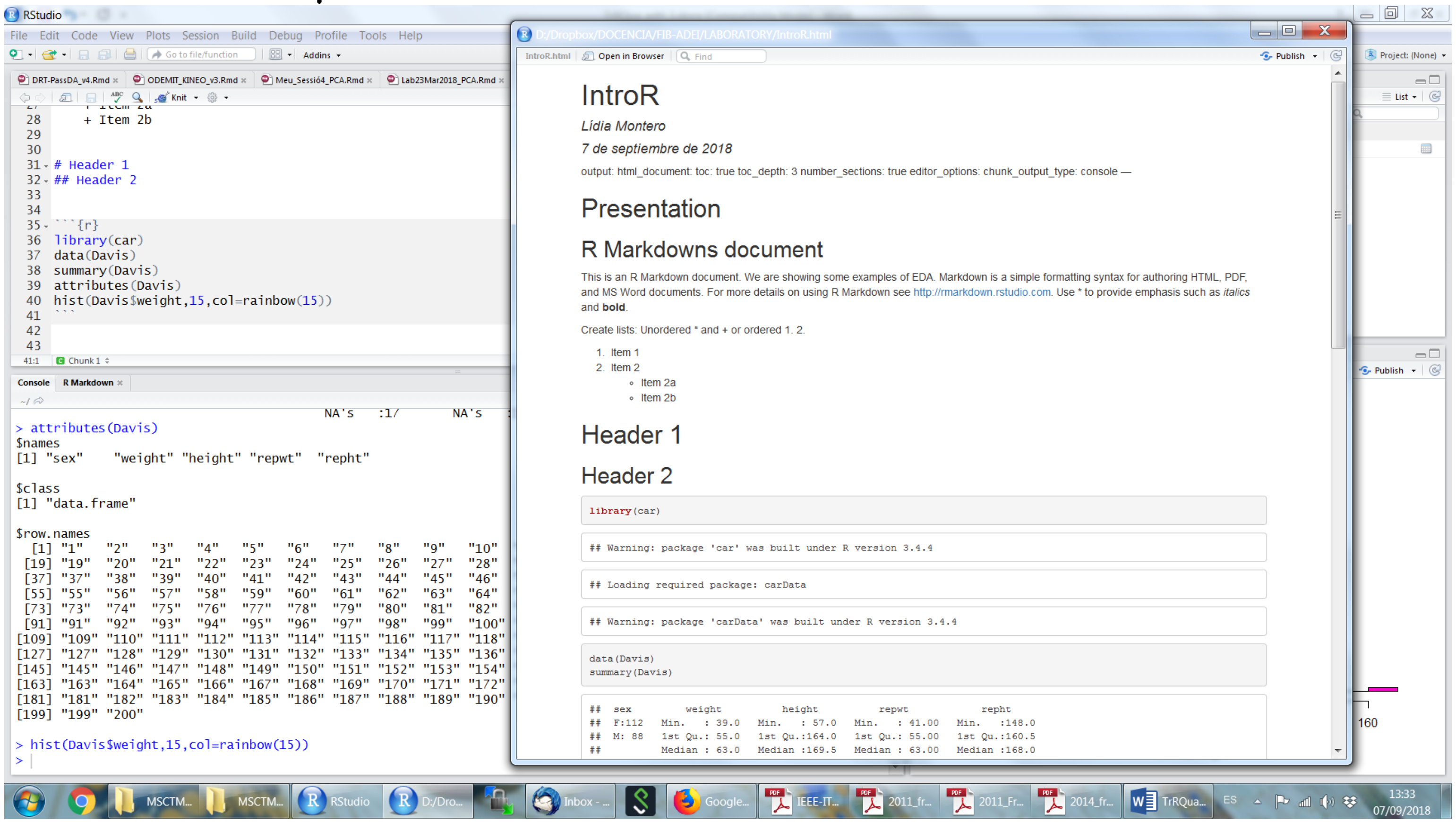
● HTML
Recommended format for authoring (you can switch to PDF or Word output anytime).

○ 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).

# INTRODUCTION TO R: FILE MENU

Knit to produce R Markdown output:



~~~
    + Item 2b


# Header 1
## Header 2


```{r}
library(car)
data(Davis)
summary(Davis)
attributes(Davis)
hist(Davis$weight,15,col=rainbow(15))
```
~~~

```
                                      NA's    :17        NA's    :
> attributes(Davis)
$names
[1] "sex"    "weight" "height" "repwt"  "repht"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190"
[199] "199" "200"

> hist(Davis$weight,15,col=rainbow(15))
>
```

IntroR

*Lídia Montero*

*7 de septiembre de 2018*

output: html_document: toc: true toc_depth: 3 number_sections: true editor_options: chunk_output_type: console —

Presentation

R Markdowns document

This is an R Markdown document. We are showing some examples of EDA. 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. Use * to provide emphasis such as *italics* and **bold**.

Create lists: Unordered * and + or ordered 1. 2.

1. Item 1
2. Item 2
    - Item 2a
    - Item 2b

Header 1

Header 2

```
library(car)
```

```
## Warning: package 'car' was built under R version 3.4.4
```

```
## Loading required package: carData
```

```
## Warning: package 'carData' was built under R version 3.4.4
```

```
data(Davis)
summary(Davis)
```

```
##  sex        weight          height          repwt            repht
##  F:112   Min.   : 39.0   Min.   : 57.0   Min.   : 41.00   Min.   :148.0
##  M: 88   1st Qu.: 55.0   1st Qu.:164.0   1st Qu.: 55.00   1st Qu.:160.5
##          Median : 63.0   Median :169.5   Median : 63.00   Median :168.0
```

## Critical Elements in R:

- Expressions and Objects (escalars, vectors, matrices, lists, etc)
- The basic object is a list: list().
- Data matrix – rows are individuals and columns are variables: *data.frame*.

# INTRODUCTION TO R: CONSOLE, DEVICES AND SCRIPTS

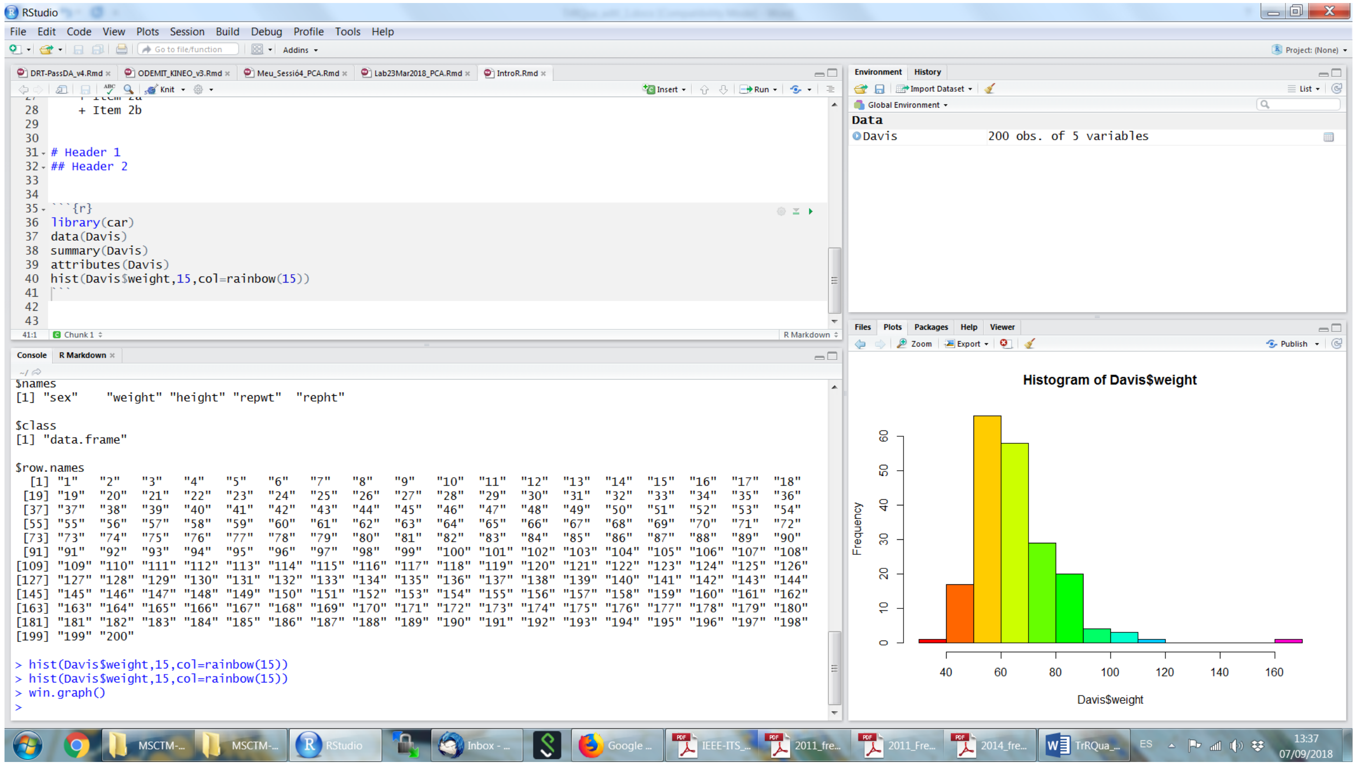
Available ones:

*R Console* (to write command and obtain results)

As many script windows as you want.

Data

Command `win.graph()` to create a new graphic device.



~~~
    + Item 2b


# Header 1
## Header 2


```{r}
library(car)
data(Davis)
summary(Davis)
attributes(Davis)
hist(Davis$weight,15,col=rainbow(15))
```
~~~

Data
Davis 200 obs. of 5 variables

```
$names
[1] "sex"    "weight" "height" "repwt"  "repht"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "13"  "14"  "15"  "16"  "17"  "18"
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36"
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

> hist(Davis$weight,15,col=rainbow(15))
> hist(Davis$weight,15,col=rainbow(15))
> win.graph()
>
```

Graphic Devices: *R graphics* has a matrix structure that allows to obtain several figures: for ex. 2 rows and 2 columns

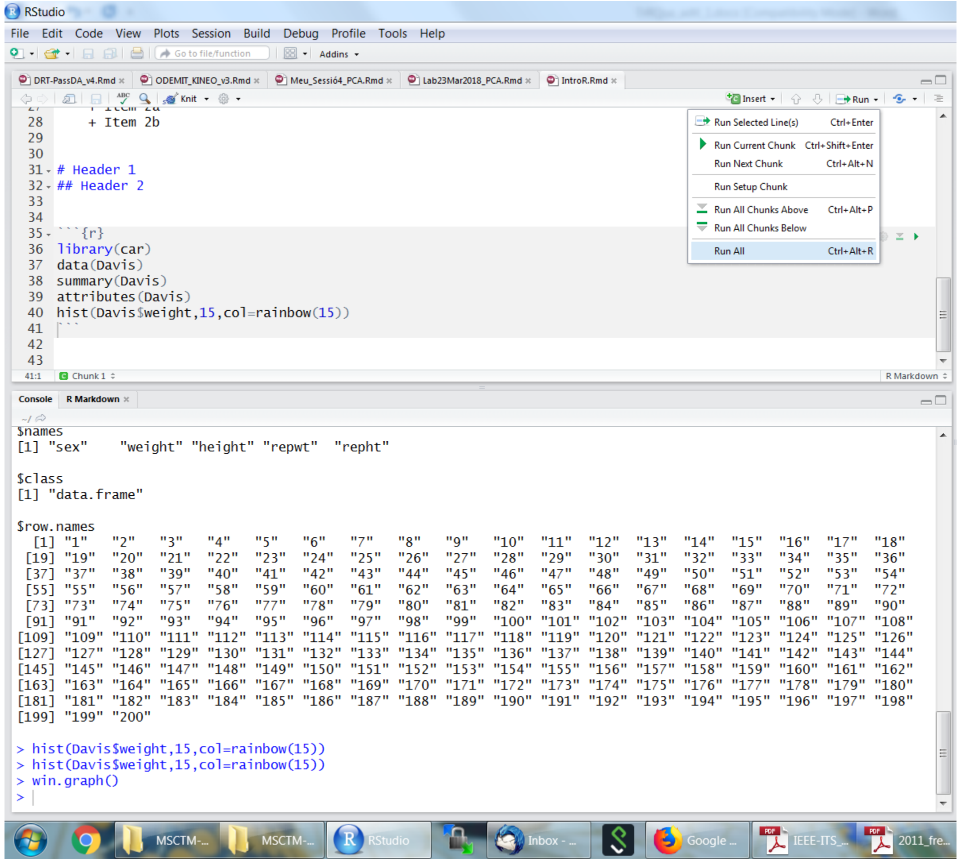
```
par(mfrow=c(2,2))
```

# INTRODUCTION TO R: COMMAND STRUCTURE

R Command structure:

> *Command* parameters <CR>

> *Command* parameters ; *Command* parameters <CR>



~~~
    + Item 2a
    + Item 2b


# Header 1
## Header 2


```{r}
library(car)
data(Davis)
summary(Davis)
attributes(Davis)
hist(Davis$weight,15,col=rainbow(15))
```
~~~

```
$names
[1] "sex"    "weight" "height" "repwt"  "repht"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "13"  "14"  "15"  "16"  "17"  "18"
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36"
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

> hist(Davis$weight,15,col=rainbow(15))
> hist(Davis$weight,15,col=rainbow(15))
> win.graph()
> 
```

To be written in *R console* or any *script* or *inside a chunk in R Markdown.*

To execute a command line included in a script: press `<ctrl- Enter>`.

To execute several command lines: select and `<ctrl- Enter>`.

To execute one or several chunks use R Studio menu.

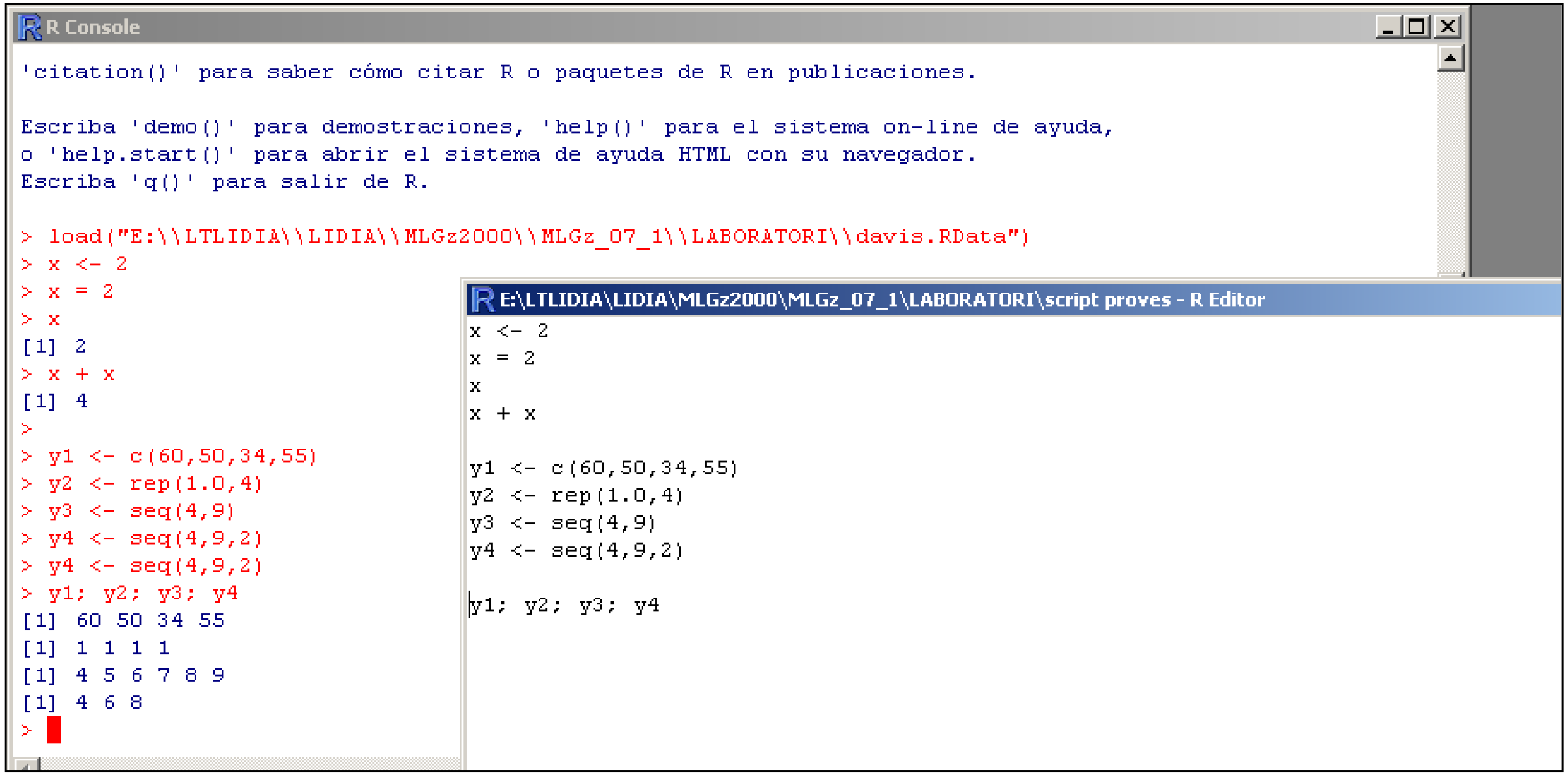
# INTRODUCTION TO R: SEQUENCES …

Example: create a vector with 4 integer elements

Concatenation: `c(.)`

Sequence: `seq(.)`

Replication: `rep(.)`

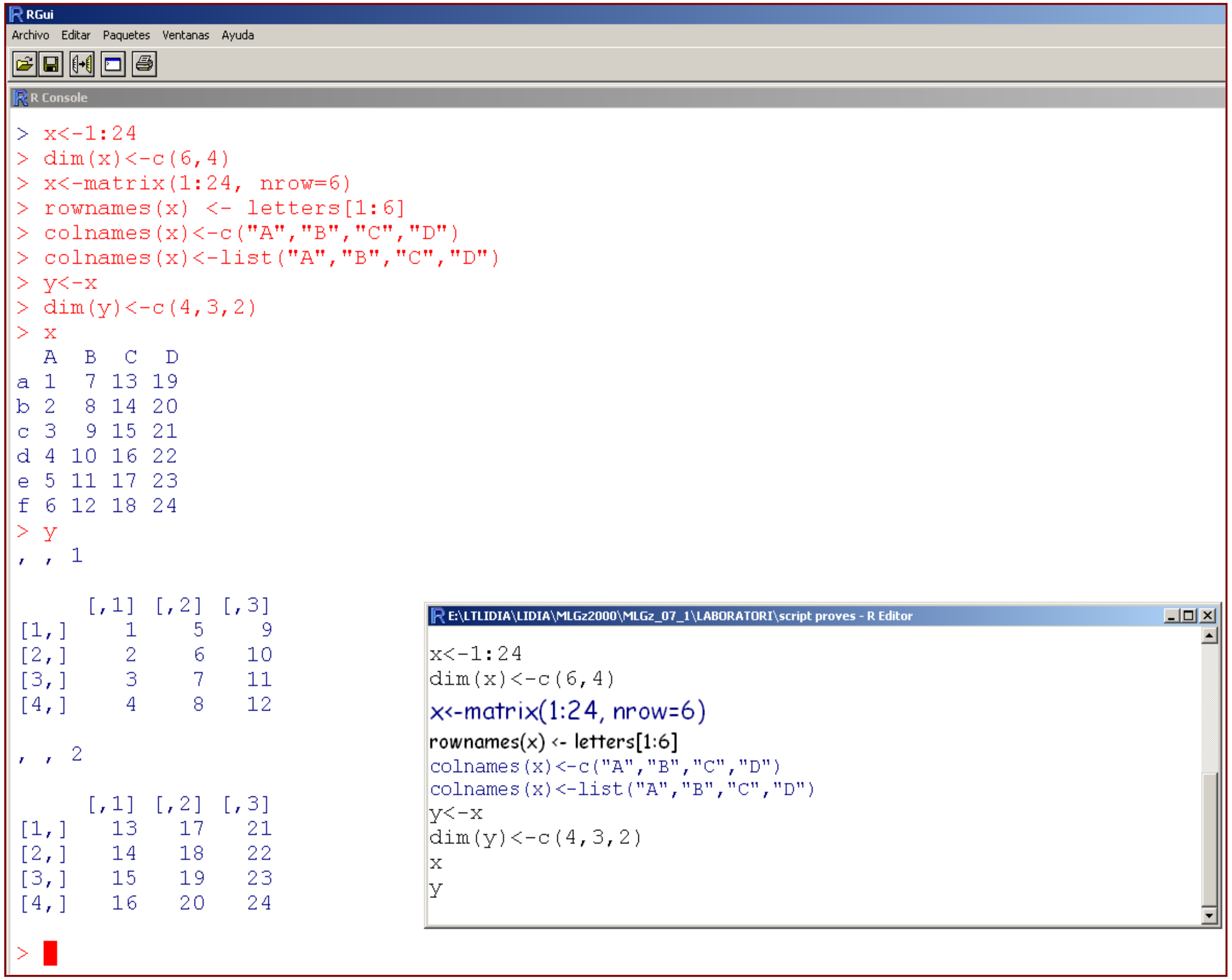

R Console
E:\LTLIDIA\LIDIA\MLGz2000\MLGz_07_1\LABORATORI\script proves - R Editor

```
'citation()' para saber cómo citar R o paquetes de R en publicaciones.

Escriba 'demo()' para demostraciones, 'help()' para el sistema on-line de ayuda,
o 'help.start()' para abrir el sistema de ayuda HTML con su navegador.
Escriba 'q()' para salir de R.

> load("E:\\LTLIDIA\\LIDIA\\MLGz2000\\MLGz_07_1\\LABORATORI\\davis.RData")
> x <- 2
> x = 2
> x
[1] 2
> x + x
[1] 4
>
> y1 <- c(60,50,34,55)
> y2 <- rep(1.0,4)
> y3 <- seq(4,9)
> y4 <- seq(4,9,2)
> y4 <- seq(4,9,2)
> y1; y2; y3; y4
[1] 60 50 34 55
[1] 1 1 1 1
[1] 4 5 6 7 8 9
[1] 4 6 8
>
```

```
x <- 2
x = 2
x
x + x

y1 <- c(60,50,34,55)
y2 <- rep(1.0,4)
y3 <- seq(4,9)
y4 <- seq(4,9,2)

y1; y2; y3; y4
```

# INTRODUCTION TO R – BASIC OBJECTS:

## Important Objects: lists, vectors, matrices and arrays


RGui
Archivo Editar Paquetes Ventanas Ayuda
R Console
E:\LTLIDIA\LIDIA\MLGz2000\MLGz_07_1\LABORATORI\script proves - R Editor

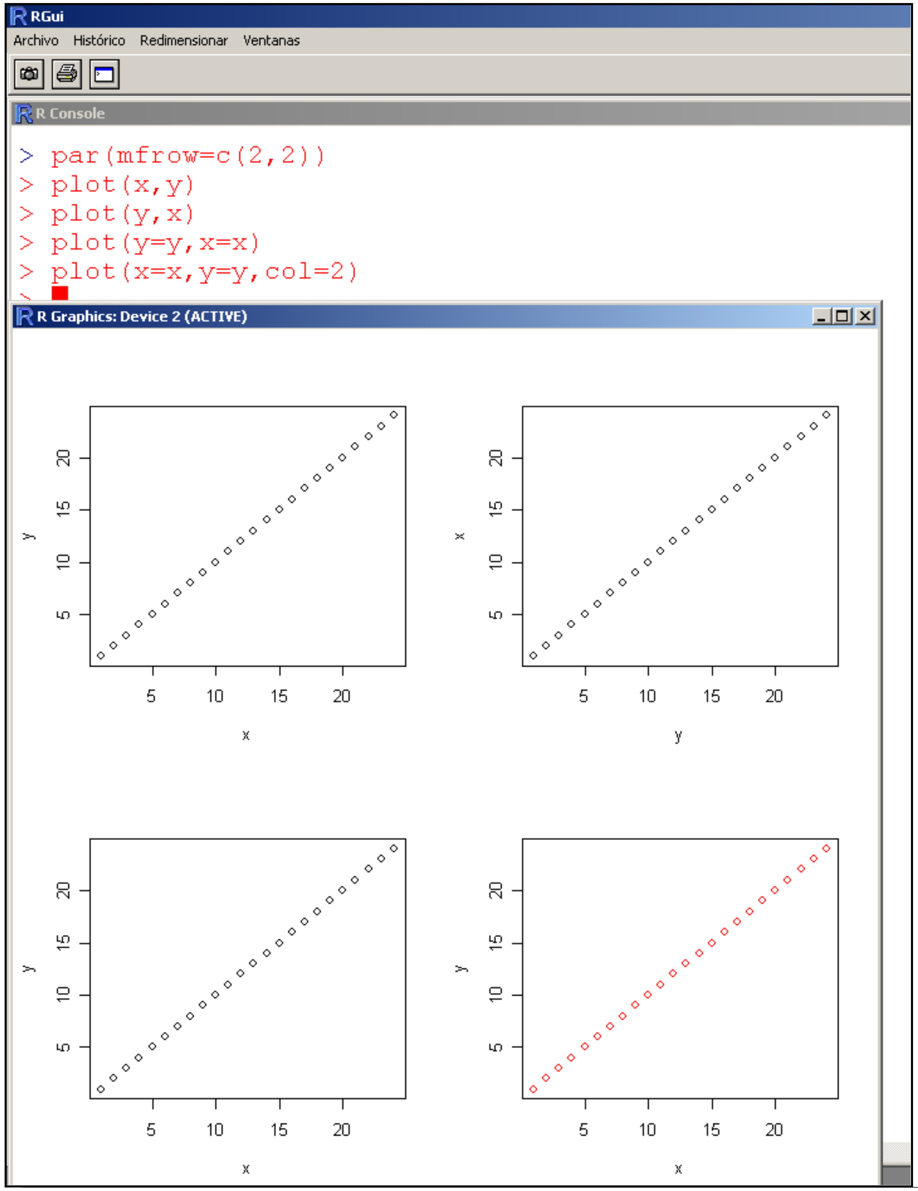
```
> x<-1:24
> dim(x)<-c(6,4)
> x<-matrix(1:24, nrow=6)
> rownames(x) <- letters[1:6]
> colnames(x)<-c("A","B","C","D")
> colnames(x)<-list("A","B","C","D")
> y<-x
> dim(y)<-c(4,3,2)
> x
  A  B  C  D
a 1  7 13 19
b 2  8 14 20
c 3  9 15 21
d 4 10 16 22
e 5 11 17 23
f 6 12 18 24
> y
, , 1

     [,1] [,2] [,3]
[1,]    1    5    9
[2,]    2    6   10
[3,]    3    7   11
[4,]    4    8   12

, , 2

     [,1] [,2] [,3]
[1,]   13   17   21
[2,]   14   18   22
[3,]   15   19   23
[4,]   16   20   24

>
```

```
x<-1:24
dim(x)<-c(6,4)
x<-matrix(1:24, nrow=6)
rownames(x) <- letters[1:6]
colnames(x)<-c("A","B","C","D")
colnames(x)<-list("A","B","C","D")
y<-x
dim(y)<-c(4,3,2)
x
y
```

- Matrices are arrays of 2 dimensions.
- Matrices and arrays of dimension greater than a 2 are allowed.
- Related commands: rownames(), colnames(), dim() to check dimensions.
- To create matrices:

```
> x<-matrix(1:24, nrow=6)
> rownames(x) <- letters
[1:6]
> colnames(x)<-
c("A","B","C","D")
> colnames(x)<-
list("A","B","C","D")
```

# INTRODUCTION TO R – FUNCTIONS AND ARGUMENTS

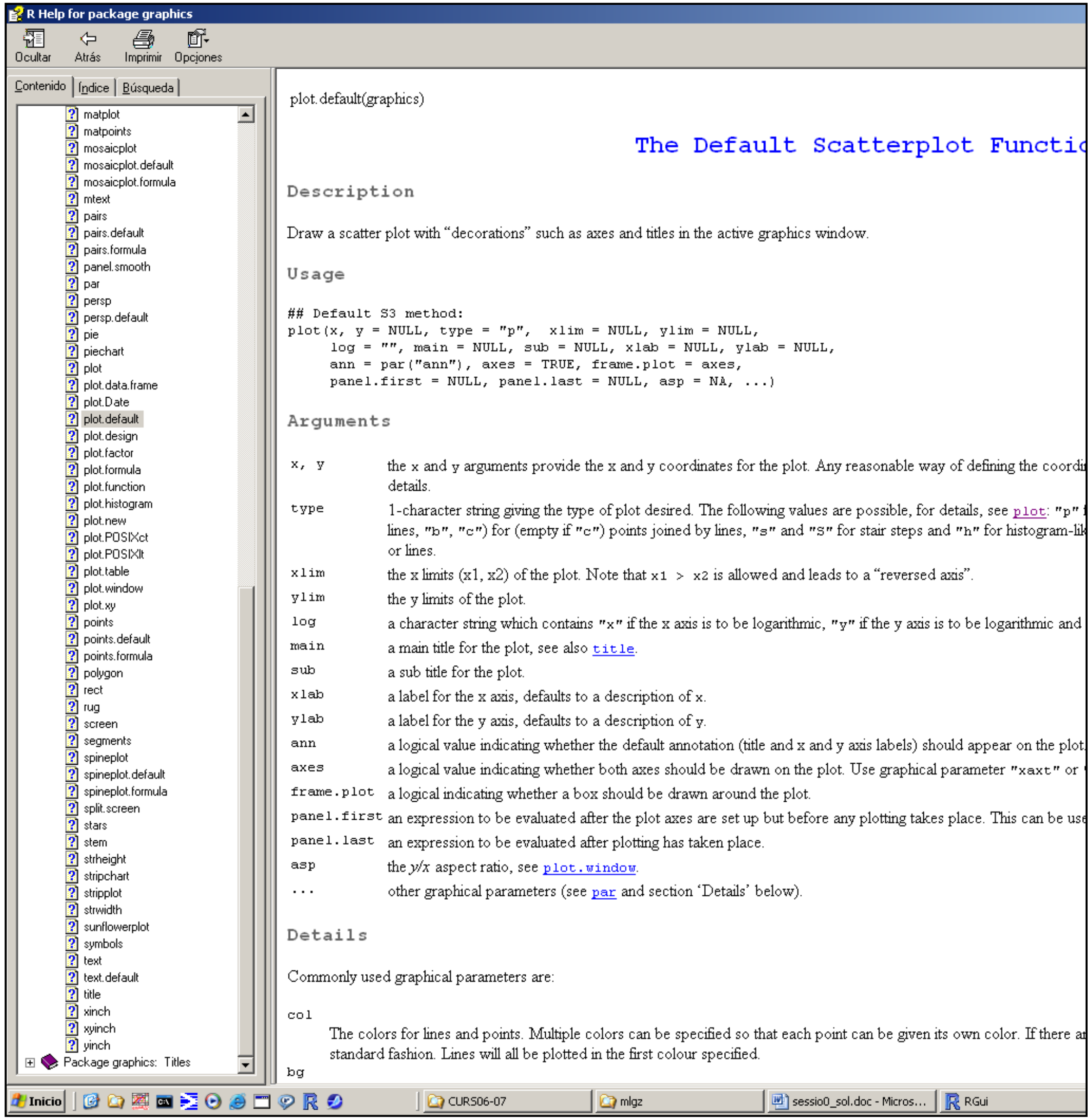


```
> par(mfrow=c(2,2))
> plot(x,y)
> plot(y,x)
> plot(y=y,x=x)
> plot(x=x,y=y,col=2)
>
```

## ***Functions*** and ***arguments***:

- An R function might be a mathematic or statistical function, as `log(x)`, but there are additional functions as `plot( height, weight )`.
- Functions have actual parameters (**actual arguments**) and formal parameters (*formal arguments*).
- Most arguments have default values and can be omitted.
- R functions *arguments* can be positionally *matched* (*positional matching*) or by name (*keyword matching*). You can mix *positional matching* with *matching* by name.

# INTRODUCTION TO R – FUNCTIONS AND ARGUMENTS



plot.default(graphics)

The Default Scatterplot Functic

Description

Draw a scatter plot with "decorations" such as axes and titles in the active graphics window.

Usage

```
## Default S3 method:
plot(x, y = NULL, type = "p",  xlim = NULL, ylim = NULL,
     log = "", main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
     ann = par("ann"), axes = TRUE, frame.plot = axes,
     panel.first = NULL, panel.last = NULL, asp = NA, ...)
```

Arguments

`x, y` the x and y arguments provide the x and y coordinates for the plot. Any reasonable way of defining the coordi details.

`type` 1-character string giving the type of plot desired. The following values are possible, for details, see plot: "p" f lines, "b", "c") for (empty if "c") points joined by lines, "s" and "S" for stair steps and "h" for histogram-lik or lines.

`xlim` the x limits (x1, x2) of the plot. Note that x1 > x2 is allowed and leads to a "reversed axis".

`ylim` the y limits of the plot.

`log` a character string which contains "x" if the x axis is to be logarithmic, "y" if the y axis is to be logarithmic and

`main` a main title for the plot, see also title.

`sub` a sub title for the plot.

`xlab` a label for the x axis, defaults to a description of x.

`ylab` a label for the y axis, defaults to a description of y.

`ann` a logical value indicating whether the default annotation (title and x and y axis labels) should appear on the plot.

`axes` a logical value indicating whether both axes should be drawn on the plot. Use graphical parameter "xaxt" or '

`frame.plot` a logical indicating whether a box should be drawn around the plot.

`panel.first` an expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be use

`panel.last` an expression to be evaluated after plotting has taken place.

`asp` the *y/x* aspect ratio, see plot.window.

`...` other graphical parameters (see par and section 'Details' below).

Details

Commonly used graphical parameters are:

`col`
The colors for lines and points. Multiple colors can be specified so that each point can be given its own color. If there ar standard fashion. Lines will all be plotted in the first colour specified.

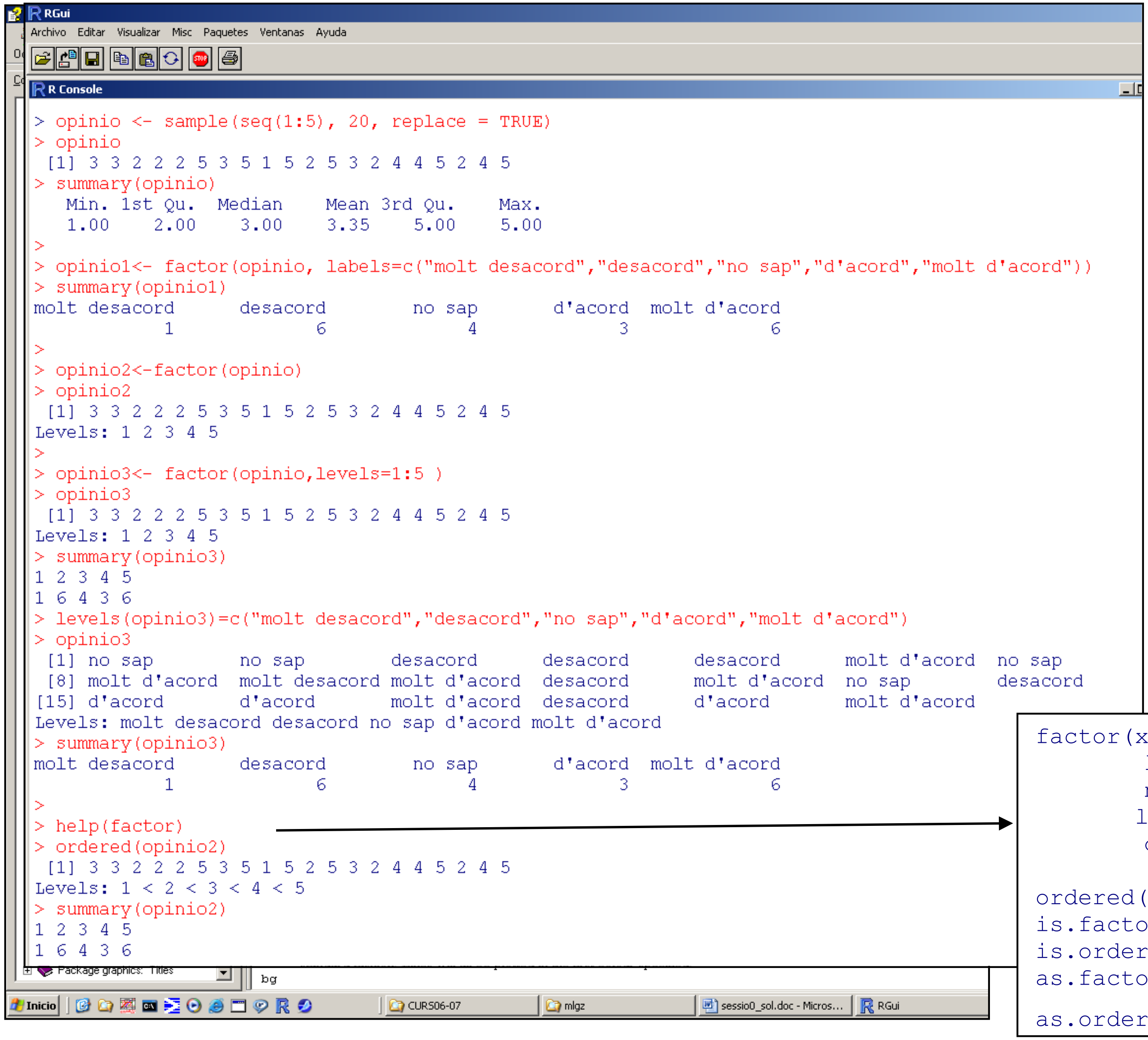
`bg`

For example:

- plot(height, weight) is a *positional matching call.*
- plot(height,weight, col=2) adds a *keyword matching* argument.
- plot(y=weight, x=height, col=2) allows arguments in any order (all arguments by *keyword matching*).

- Check parameters in:
  help(plot)
  args(plot.default)

# INTRODUCTION TO R – FACTORS


RGui
Archivo Editar Visualizar Misc Paquetes Ventanas Ayuda
R Console
Inicio
CURS06-07
mlgz
sessio0_sol.doc - Micros...
RGui

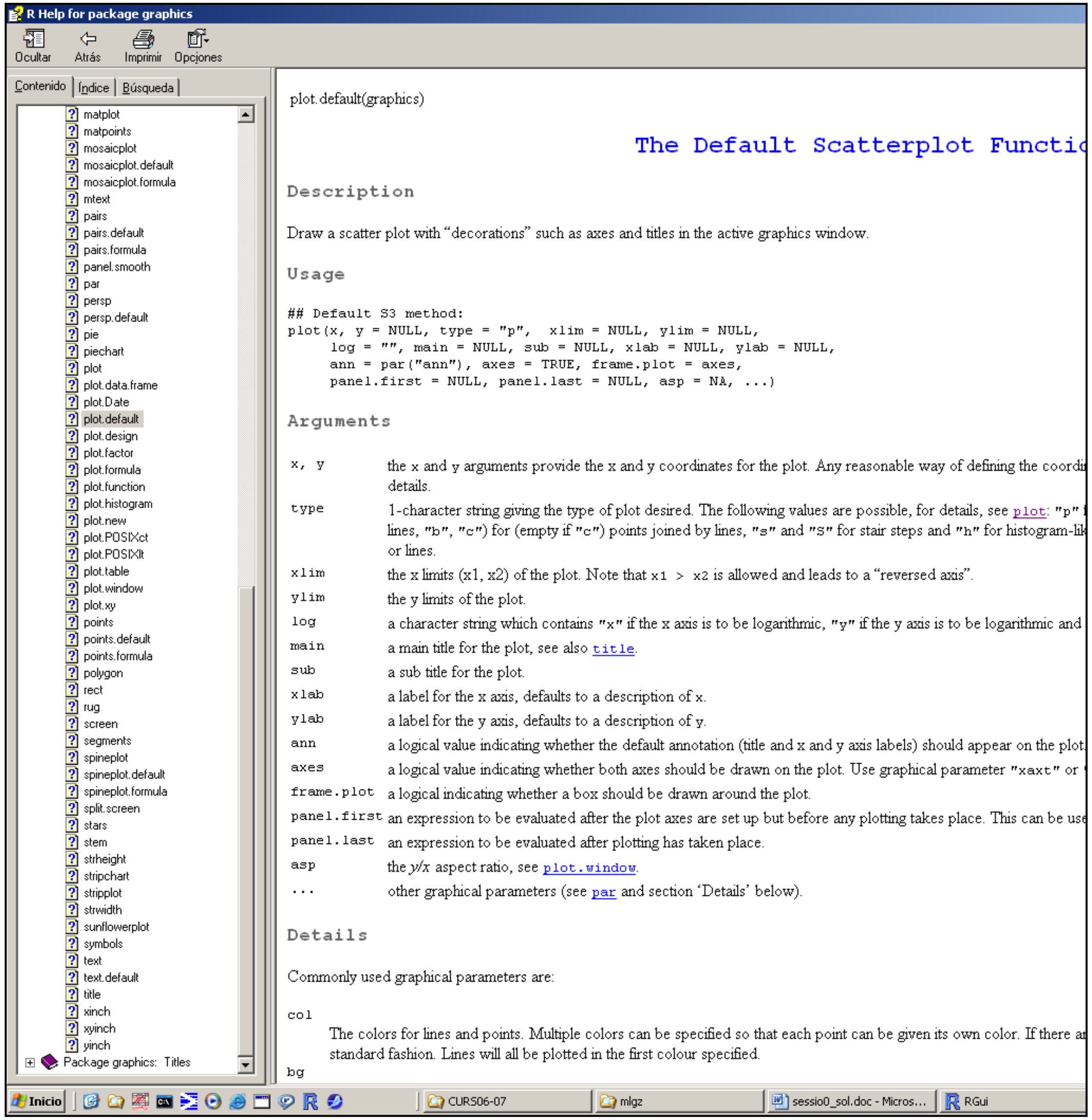
```
> opinio <- sample(seq(1:5), 20, replace = TRUE)
> opinio
 [1] 3 3 2 2 2 5 3 5 1 5 2 5 3 2 4 4 5 2 4 5
> summary(opinio)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   1.00    2.00    3.00    3.35    5.00    5.00
>
> opinio1<- factor(opinio, labels=c("molt desacord","desacord","no sap","d'acord","molt d'acord"))
> summary(opinio1)
molt desacord      desacord        no sap       d'acord  molt d'acord
            1             6             4             3             6
>
> opinio2<-factor(opinio)
> opinio2
 [1] 3 3 2 2 2 5 3 5 1 5 2 5 3 2 4 4 5 2 4 5
Levels: 1 2 3 4 5
>
> opinio3<- factor(opinio,levels=1:5 )
> opinio3
 [1] 3 3 2 2 2 5 3 5 1 5 2 5 3 2 4 4 5 2 4 5
Levels: 1 2 3 4 5
> summary(opinio3)
1 2 3 4 5
1 6 4 3 6
> levels(opinio3)=c("molt desacord","desacord","no sap","d'acord","molt d'acord")
> opinio3
 [1] no sap        no sap        desacord      desacord      desacord      molt d'acord  no sap
 [8] molt d'acord  molt desacord molt d'acord  desacord      molt d'acord  no sap        desacord
[15] d'acord       d'acord       molt d'acord  desacord      d'acord       molt d'acord
Levels: molt desacord desacord no sap d'acord molt d'acord
> summary(opinio3)
molt desacord      desacord        no sap       d'acord  molt d'acord
            1             6             4             3             6
>
> help(factor)
> ordered(opinio2)
 [1] 3 3 2 2 2 5 3 5 1 5 2 5 3 2 4 4 5 2 4 5
Levels: 1 < 2 < 3 < 4 < 5
> summary(opinio2)
1 2 3 4 5
1 6 4 3 6
```

***Factors*:**

- Vectors to represent qualitative variables.
- Ordered or not.
- Consider values as *levels* o *labels*.
- To convert labels into numeric values: as.numeric(*factor*)

```
factor(x = character(),
       levels = sort(unique.default(x),
       na.last = TRUE),
      labels = levels, exclude = NA,
       ordered = is.ordered(x))

ordered(x, ...)
is.factor(x)
is.ordered(x)
as.factor(x)

as.ordered(x)
```

# INTRODUCTION TO R – NEW VARIABLES



plot.default(graphics)

The Default Scatterplot Functic

Description

Draw a scatter plot with "decorations" such as axes and titles in the active graphics window.

Usage

```
## Default S3 method:
plot(x, y = NULL, type = "p",  xlim = NULL, ylim = NULL,
     log = "", main = NULL, sub = NULL, xlab = NULL, ylab = NULL,
     ann = par("ann"), axes = TRUE, frame.plot = axes,
     panel.first = NULL, panel.last = NULL, asp = NA, ...)
```

Arguments

x, y    the x and y arguments provide the x and y coordinates for the plot. Any reasonable way of defining the coordi details.

type    1-character string giving the type of plot desired. The following values are possible, for details, see plot: "p" lines, "b", "c") for (empty if "c") points joined by lines, "s" and "S" for stair steps and "h" for histogram-lik or lines.

xlim    the x limits (x1, x2) of the plot. Note that x1 > x2 is allowed and leads to a "reversed axis".

ylim    the y limits of the plot.

log    a character string which contains "x" if the x axis is to be logarithmic, "y" if the y axis is to be logarithmic and

main    a main title for the plot, see also title.

sub    a sub title for the plot.

xlab    a label for the x axis, defaults to a description of x.

ylab    a label for the y axis, defaults to a description of y.

ann    a logical value indicating whether the default annotation (title and x and y axis labels) should appear on the plot.

axes    a logical value indicating whether both axes should be drawn on the plot. Use graphical parameter "xaxt" or

frame.plot    a logical indicating whether a box should be drawn around the plot.

panel.first    an expression to be evaluated after the plot axes are set up but before any plotting takes place. This can be use

panel.last    an expression to be evaluated after plotting has taken place.

asp    the *y/x* aspect ratio, see plot.window.

...    other graphical parameters (see par and section 'Details' below).

Details

Commonly used graphical parameters are:

col

The colors for lines and points. Multiple colors can be specified so that each point can be given its own color. If there ar standard fashion. Lines will all be plotted in the first colour specified.

bg

## Manipulation of data matrices (data.frame) :

- Create a new variable from existent variables in the current workspace using mathematic functions:

○ For example, y<- log(x)+z+4.5 (x and z existent vectors.

○ In a *data.frame*: attach(Davis)

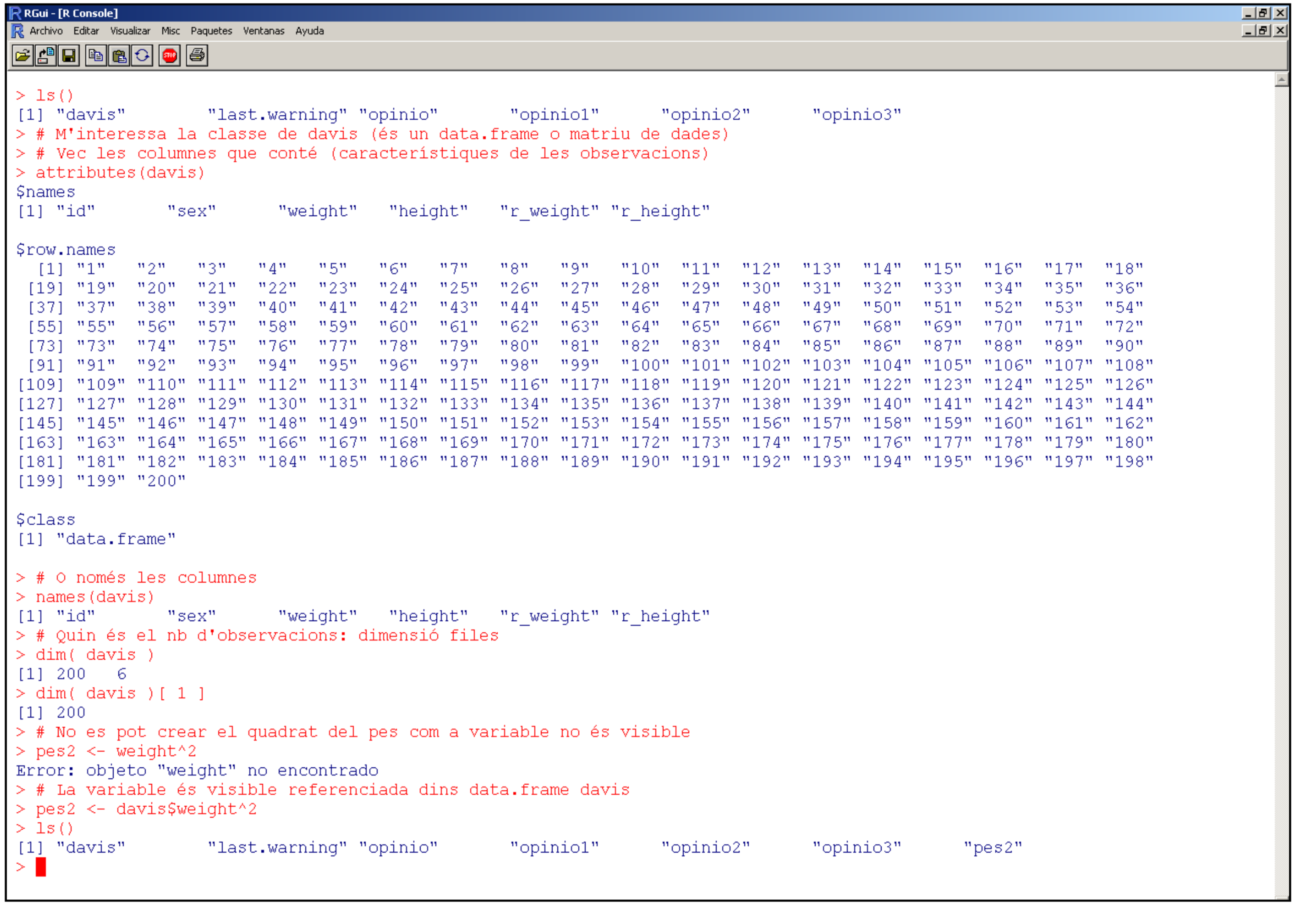
○ weight2 <- weight^2 new variable not included in Davis *data.frame*.

○ Davis$weight2 <- weight^2 new variable included in Davis *data.frame*, but a detach(Davis) and new attach( Davis ).

- Remove an object: rm(object-name).

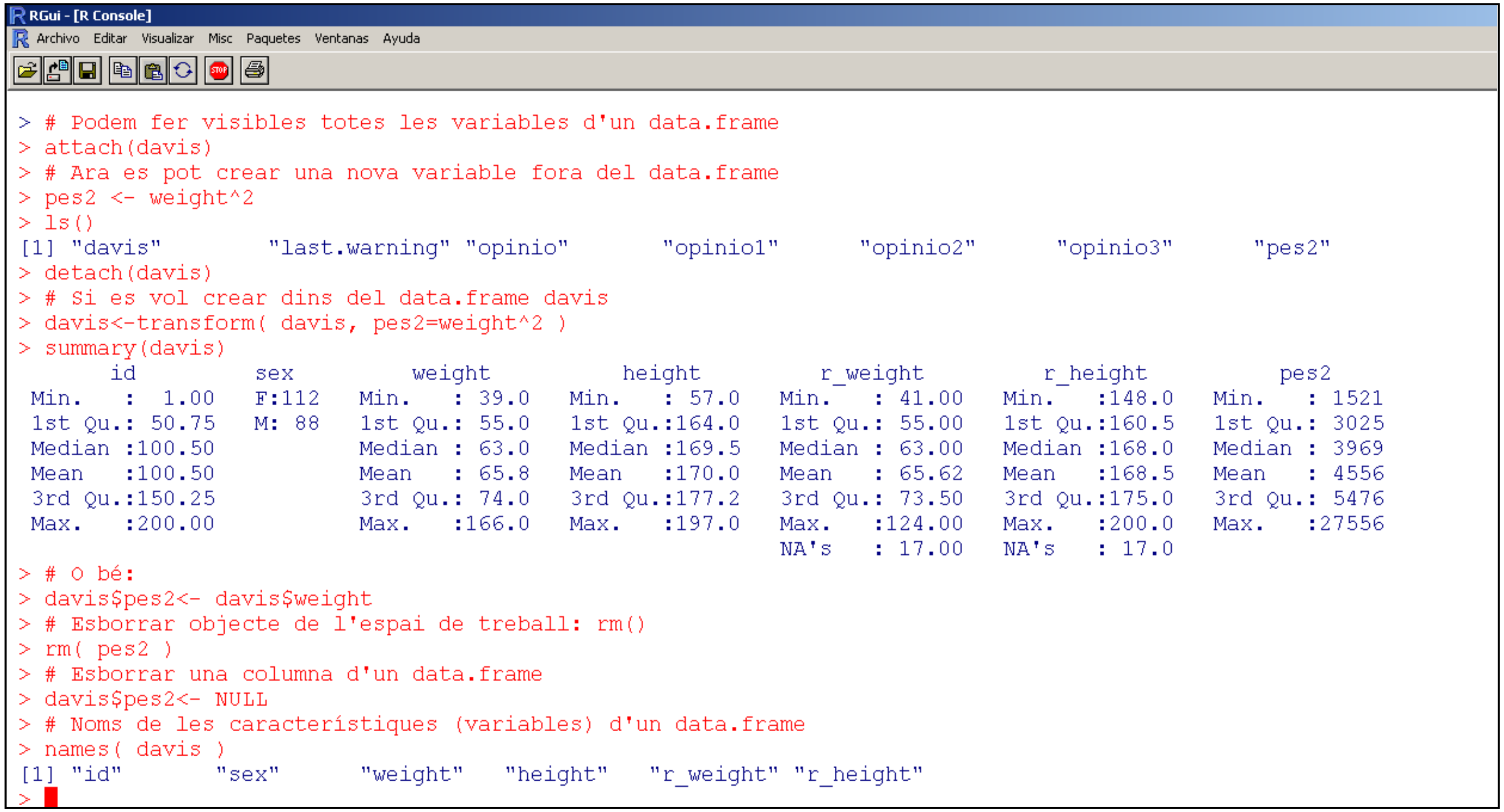
# INTRODUCTION TO R – NEW VARIABLES

- To remove a variable included in a data.frame: Davis$weight2<-NULL.
- Remove all objects in the current workspace: rm(list=ls()).
- Remove all objects in the current workspace beginning with 'la': rm(list=ls(pattern="la")).
- R can deal with multiple datasets at the same time.
  - ○ You just need to specify the name of the dataset and a "$" symbol before each variable name.
  - ○ If you don't want to write again and again the name of the dataset as a prefix for each variable, you can use attach()



```
> ls()
[1] "davis"        "last.warning" "opinio"       "opinio1"      "opinio2"      "opinio3"
> # M'interessa la classe de davis (és un data.frame o matriu de dades)
> # Vec les columnes que conté (característiques de les observacions)
> attributes(davis)
$names
[1] "id"       "sex"      "weight"   "height"   "r_weight" "r_height"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "13"  "14"  "15"  "16"  "17"  "18"
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36"
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

$class
[1] "data.frame"

> # O només les columnes
> names(davis)
[1] "id"       "sex"      "weight"   "height"   "r_weight" "r_height"
> # Quin és el nb d'observacions: dimensió files
> dim( davis )
[1] 200   6
> dim( davis )[ 1 ]
[1] 200
> # No es pot crear el quadrat del pes com a variable no és visible
> pes2 <- weight^2
Error: objeto "weight" no encontrado
> # La variable és visible referenciada dins data.frame davis
> pes2 <- davis$weight^2
> ls()
[1] "davis"        "last.warning" "opinio"       "opinio1"      "opinio2"      "opinio3"      "pes2"
> 
```

# INTRODUCTION TO R – SCOPE OF VISIBILITY: ATTACH COMMAND

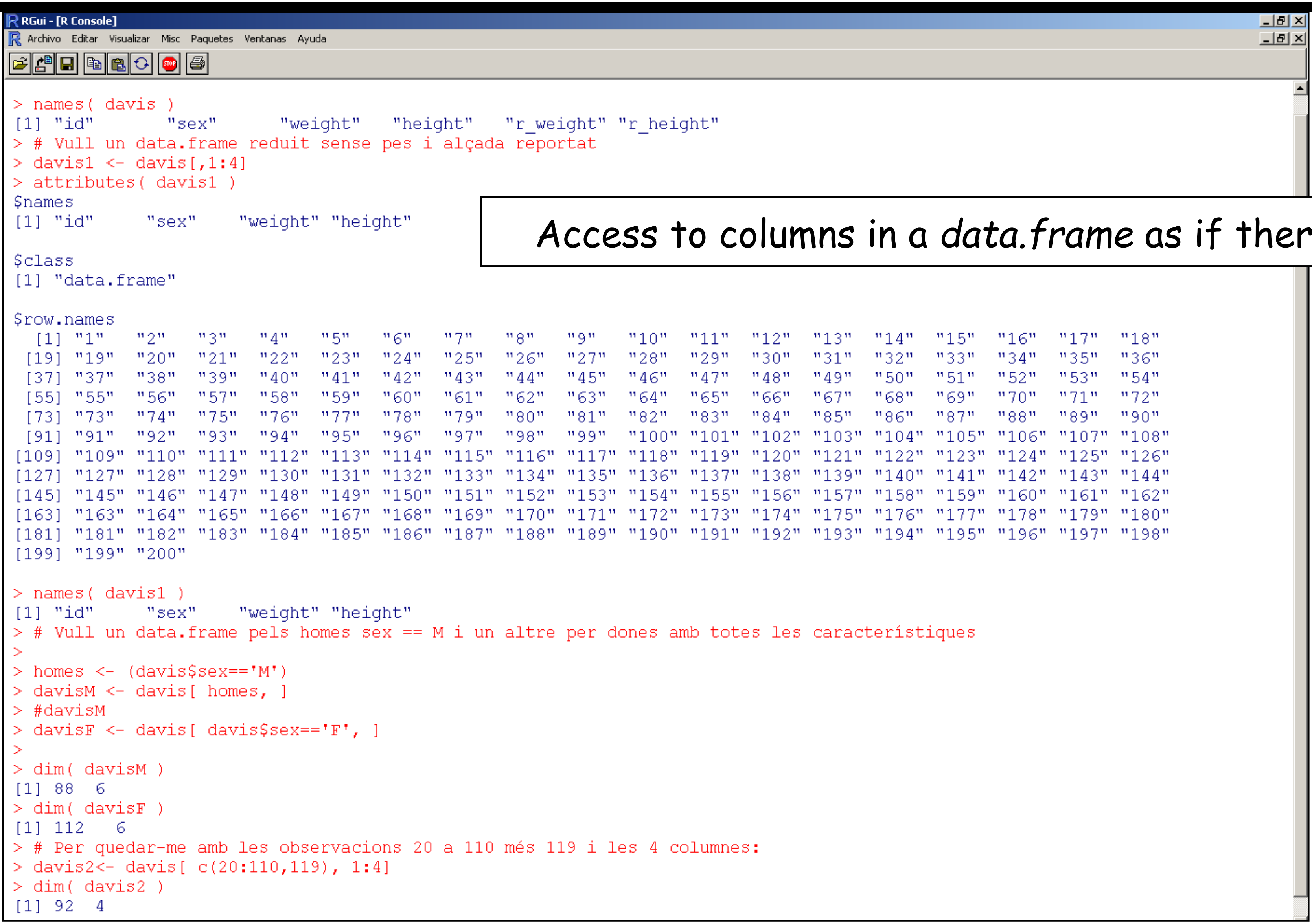


```
> # Podem fer visibles totes les variables d'un data.frame
> attach(davis)
> # Ara es pot crear una nova variable fora del data.frame
> pes2 <- weight^2
> ls()
[1] "davis"        "last.warning" "opinio"       "opinio1"      "opinio2"      "opinio3"      "pes2"
> detach(davis)
> # Si es vol crear dins del data.frame davis
> davis<-transform( davis, pes2=weight^2 )
> summary(davis)
       id         sex         weight          height         r_weight         r_height          pes2
 Min.   :  1.00   F:112   Min.   : 39.0   Min.   : 57.0   Min.   : 41.00   Min.   :148.0   Min.   : 1521
 1st Qu.: 50.75   M: 88   1st Qu.: 55.0   1st Qu.:164.0   1st Qu.: 55.00   1st Qu.:160.5   1st Qu.: 3025
 Median :100.50           Median : 63.0   Median :169.5   Median : 63.00   Median :168.0   Median : 3969
 Mean   :100.50           Mean   : 65.8   Mean   :170.0   Mean   : 65.62   Mean   :168.5   Mean   : 4556
 3rd Qu.:150.25           3rd Qu.: 74.0   3rd Qu.:177.2   3rd Qu.: 73.50   3rd Qu.:175.0   3rd Qu.: 5476
 Max.   :200.00           Max.   :166.0   Max.   :197.0   Max.   :124.00   Max.   :200.0   Max.   :27556
                                                          NA's   : 17.00   NA's   : 17.0
> # O bé:
> davis$pes2<- davis$weight
> # Esborrar objecte de l'espai de treball: rm()
> rm( pes2 )
> # Esborrar una columna d'un data.frame
> davis$pes2<- NULL
> # Noms de les característiques (variables) d'un data.frame
> names( davis )
[1] "id"       "sex"      "weight"   "height"   "r_weight" "r_height"
> 
```

- attach() command can be dangerous. Use detach() as soon as possible.
- Suggested command: Evaluate an R expression in an environment constructed from data, possibly modifying the original data:

```
with(Davis,{boxplot(height);summary(height)})
```

# INTRODUCTION TO R – NEW VARIABLES



```
> names( davis )
[1] "id"       "sex"      "weight"   "height"   "r_weight" "r_height"
> # Vull un data.frame reduit sense pes i alçada reportat
> davis1 <- davis[,1:4]
> attributes( davis1 )
$names
[1] "id"     "sex"    "weight" "height"

$class
[1] "data.frame"

$row.names
  [1] "1"   "2"   "3"   "4"   "5"   "6"   "7"   "8"   "9"   "10"  "11"  "12"  "13"  "14"  "15"  "16"  "17"  "18"
 [19] "19"  "20"  "21"  "22"  "23"  "24"  "25"  "26"  "27"  "28"  "29"  "30"  "31"  "32"  "33"  "34"  "35"  "36"
 [37] "37"  "38"  "39"  "40"  "41"  "42"  "43"  "44"  "45"  "46"  "47"  "48"  "49"  "50"  "51"  "52"  "53"  "54"
 [55] "55"  "56"  "57"  "58"  "59"  "60"  "61"  "62"  "63"  "64"  "65"  "66"  "67"  "68"  "69"  "70"  "71"  "72"
 [73] "73"  "74"  "75"  "76"  "77"  "78"  "79"  "80"  "81"  "82"  "83"  "84"  "85"  "86"  "87"  "88"  "89"  "90"
 [91] "91"  "92"  "93"  "94"  "95"  "96"  "97"  "98"  "99"  "100" "101" "102" "103" "104" "105" "106" "107" "108"
[109] "109" "110" "111" "112" "113" "114" "115" "116" "117" "118" "119" "120" "121" "122" "123" "124" "125" "126"
[127] "127" "128" "129" "130" "131" "132" "133" "134" "135" "136" "137" "138" "139" "140" "141" "142" "143" "144"
[145] "145" "146" "147" "148" "149" "150" "151" "152" "153" "154" "155" "156" "157" "158" "159" "160" "161" "162"
[163] "163" "164" "165" "166" "167" "168" "169" "170" "171" "172" "173" "174" "175" "176" "177" "178" "179" "180"
[181] "181" "182" "183" "184" "185" "186" "187" "188" "189" "190" "191" "192" "193" "194" "195" "196" "197" "198"
[199] "199" "200"

> names( davis1 )
[1] "id"     "sex"    "weight" "height"
> # Vull un data.frame pels homes sex == M i un altre per dones amb totes les característiques
>
> homes <- (davis$sex=='M')
> davisM <- davis[ homes, ]
> #davisM
> davisF <- davis[ davis$sex=='F', ]
>
> dim( davisM )
[1] 88  6
> dim( davisF )
[1] 112   6
> # Per quedar-me amb les observacions 20 a 110 més 119 i les 4 columnes:
> davis2<- davis[ c(20:110,119), 1:4]
> dim( davis2 )
[1] 92  4
```

Access to columns in a *data.frame* as if there were matric

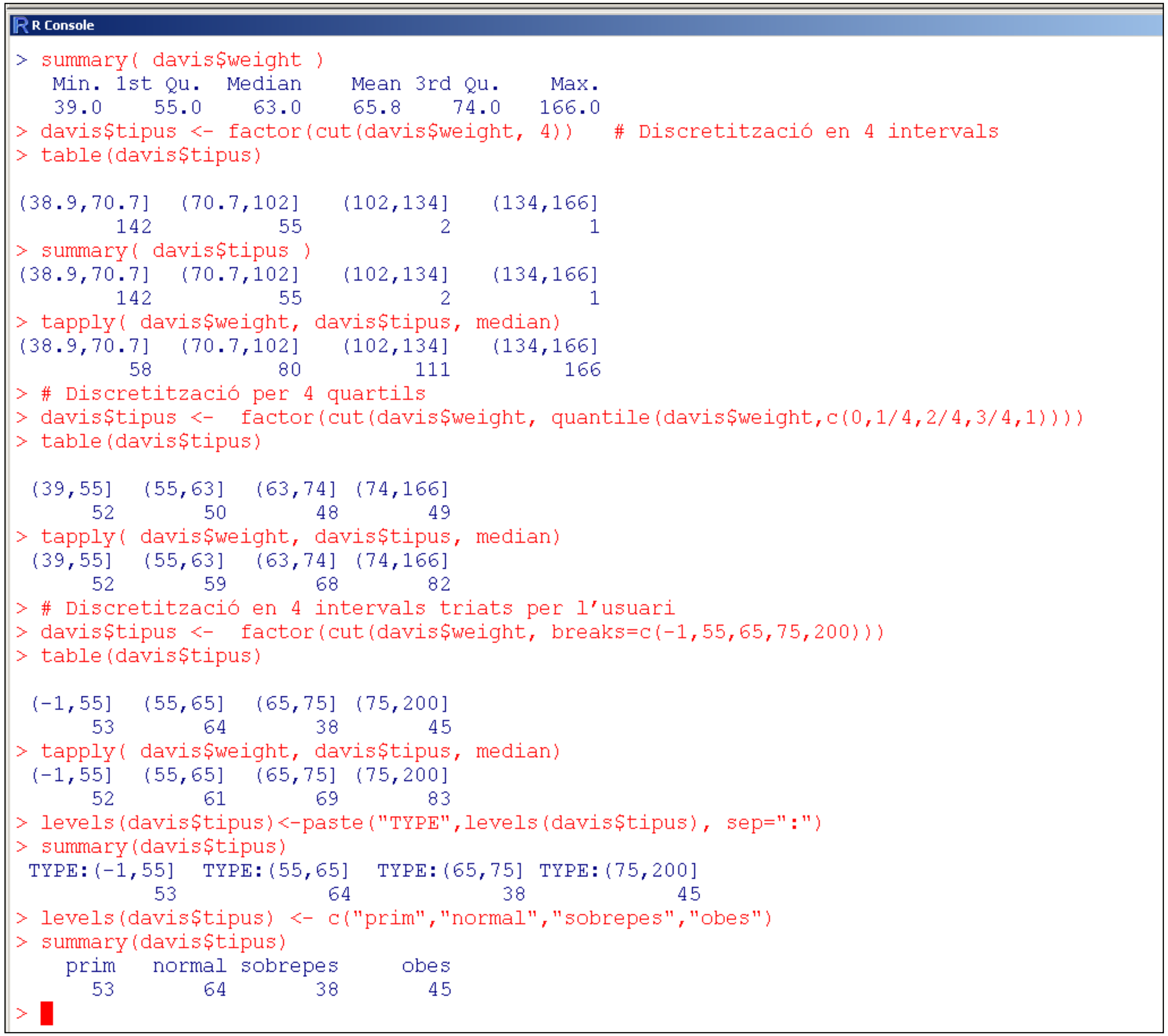
# INTRODUCTION TO R – INDEXING VARIABLES

- Indexing vectors?: weight2[ 29] position 29 in weight2 vector.
- Indexing matrices?: Davis[2,4] observation 2 and variable in 4th column.
- Row number 2 in a data.frame: Davis[ 2, ].
- Column number 4 in a *data.frame* : Davis[ , 4] (*height* is a vector with 200 observations).
- A set of columns: Davis[ , c(1,3:4) ].
- A set of rows (observations):
  - ○ Davis[ 1:100,] observations 1, 2, 3 … 100
  - ○ Davis[ seq(1,100,2), ] … observations 1, 3, 5, 7 …
  - ○ Davis[ sample(100:200,50,rep=T), ] 50 random rows contained in row numbers 1 tp 100.
  - ○ Davis[ rep(c(1,2),10) ,] observations (repeated)

1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2 1 2

```
> davis3<- Davis[ sample(100:200,10,rep=T), ]
> table(Davis3$id)
104 105 141 173 174 175 177 180 194
  1   1   1   1   1   1   2   1   1
```

# INTRODUCTION TO R – RECODIFICATION OF VARIABLES



```
> summary( davis$weight )
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max. 
   39.0    55.0    63.0    65.8    74.0   166.0 
> davis$tipus <- factor(cut(davis$weight, 4))   # Discretització en 4 intervals
> table(davis$tipus)

(38.9,70.7]  (70.7,102]   (102,134]   (134,166] 
        142          55           2           1 
> summary( davis$tipus )
(38.9,70.7]  (70.7,102]   (102,134]   (134,166] 
        142          55           2           1 
> tapply( davis$weight, davis$tipus, median)
(38.9,70.7]  (70.7,102]   (102,134]   (134,166] 
         58          80         111         166 
> # Discretització per 4 quartils
> davis$tipus <-  factor(cut(davis$weight, quantile(davis$weight,c(0,1/4,2/4,3/4,1))))
> table(davis$tipus)

 (39,55]  (55,63]  (63,74] (74,166] 
      52       50       48       49 
> tapply( davis$weight, davis$tipus, median)
 (39,55]  (55,63]  (63,74] (74,166] 
      52       59       68       82 
> # Discretització en 4 intervals triats per l'usuari
> davis$tipus <-  factor(cut(davis$weight, breaks=c(-1,55,65,75,200)))
> table(davis$tipus)

 (-1,55]  (55,65]  (65,75] (75,200] 
      53       64       38       45 
> tapply( davis$weight, davis$tipus, median)
 (-1,55]  (55,65]  (65,75] (75,200] 
      52       61       69       83 
> levels(davis$tipus)<-paste("TYPE",levels(davis$tipus), sep=":")
> summary(davis$tipus)
 TYPE:(-1,55]  TYPE:(55,65]  TYPE:(65,75] TYPE:(75,200] 
           53            64            38            45 
> levels(davis$tipus) <- c("prim","normal","sobrepes","obes")
> summary(davis$tipus)
    prim   normal sobrepes     obes 
      53       64       38       45 
> 
```

**Recodification: Create a new variable from an existent numerical one.**

- Discretization of a numeric variable:
  - Equal length intervals.
  - Intervals selected by the users.
  - Intervals defined by quantiles.

# INTRODUCTION TO R – DEFINING FACTORS

## Recoding: Creating a new variable by working with ranges.

- Grouping categories: create a new variable using ifelse() sentence.

```
> as.numeric( davis$tipus )
  [1] 4 2 1 3 2 4 4 3 3 2 3 4 1 2 1 2 4 2 4 2 4 2 2 3 1 1 2 2 1 4 3 3 4 1 3 2 2 3 4 2 1 4 2 4 4 1 3 1 1
 [50] 3 4 2 3 4 2 2 3 3 3 2 3 3 3 4 4 2 2 2 1 4 2 3 1 2 1 1 1 2 3 3 2 1 1 2 2 2 2 1 2 2 3 2 4 3 4 2 4 1
 [99] 1 1 1 2 1 1 2 1 1 2 2 2 4 4 1 3 4 2 4 4 3 2 4 3 3 1 3 1 1 1 3 1 2 4 2 1 4 1 2 2 4 4 3 1 1 1 2 1 1
[148] 2 3 4 2 1 1 1 1 1 3 2 2 2 1 1 1 2 2 2 2 3 4 1 4 1 2 4 2 3 2 3 4 3 4 1 4 2 3 2 2 2 4 1 4 4 2 1 2 3
[197] 4 4 4 4
> grup <- rep( 0, dim( davis )[1] )
> grup <- factor(ifelse( as.numeric(davis$tipus)>2,1,0))
> levels(grup) <- c("correcte","controlar")
> summary(grup)
 correcte controlar
      117        83
>
```

# INTRODUCTION TO R – EDA – BIVARIATE: NUMERIC VS FACTOR

TWO VARIABLES ARE INVOLVED:

RESPONSE VARIABLE IS NUMERIC, as Davis$height
EXPLANATORY VARIABLE IS A FACTOR, as Davis$sex (max 5-6 levels)

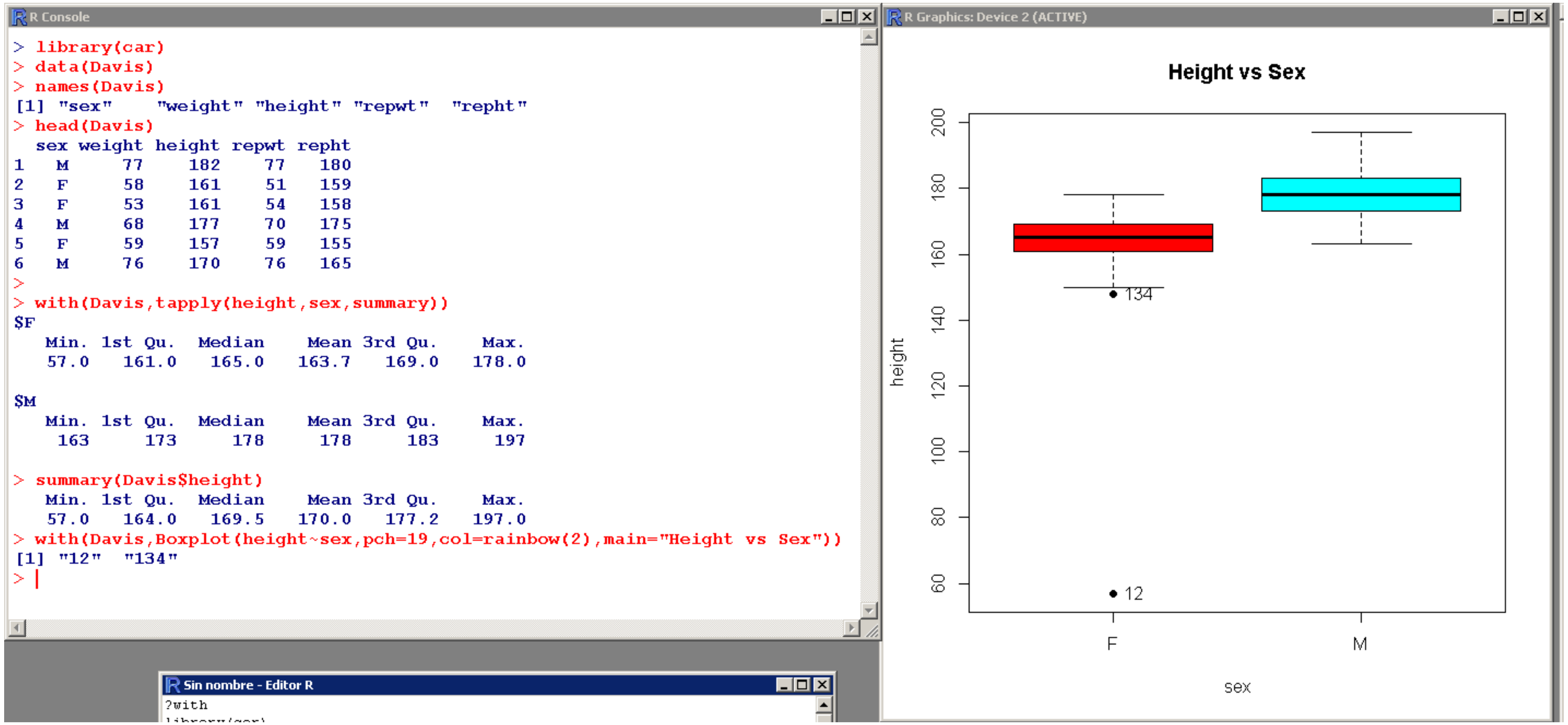
Goal: Do groups defined by levels of the factor determine a difference profile in the numeric response.

- Do height and sex show an independent behavior/profile? Statistical question: Is the profile of height the same for both levels of factor sex?
- If height and sex don't show any relationship- Statistical statement: The profile of height is the same for both levels in sex factor ?

EDA for a numeric variable according to groups defined by factor. Particular analysis: ANOVA – Analysis of Variance

# INTRODUCTION TO R – EDA – BIVARIATE: NUMERIC VS FACTOR

For example: Height (Y) vs Sex (A) – Formula expression in R: Y ~ A

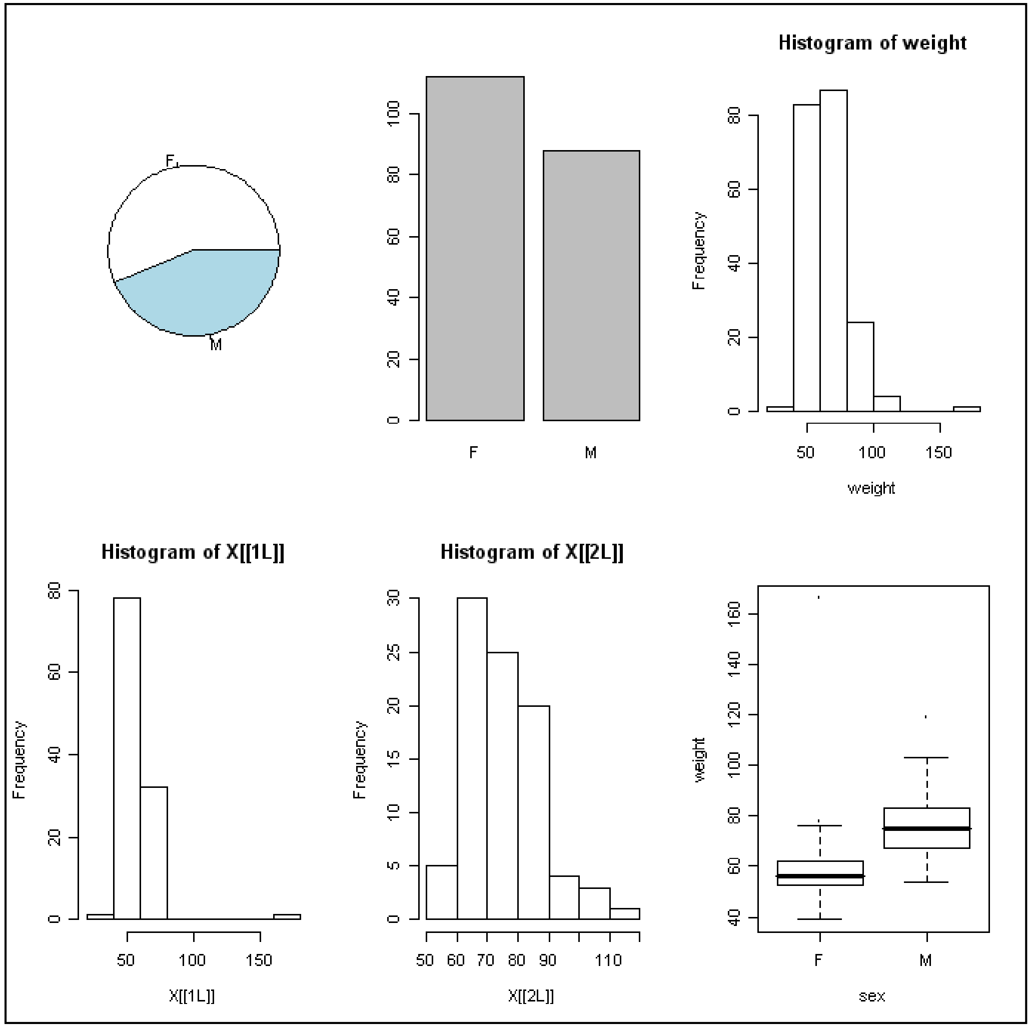


```
> library(car)
> data(Davis)
> names(Davis)
[1] "sex"     "weight" "height" "repwt"   "repht"
> head(Davis)
  sex weight height repwt repht
1   M     77    182    77   180
2   F     58    161    51   159
3   F     53    161    54   158
4   M     68    177    70   175
5   F     59    157    59   155
6   M     76    170    76   165
>
> with(Davis,tapply(height,sex,summary))
$F
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   57.0   161.0   165.0   163.7   169.0   178.0

$M
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
    163     173     178     178     183     197

> summary(Davis$height)
   Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
   57.0   164.0   169.5   170.0   177.2   197.0
> with(Davis,Boxplot(height~sex,pch=19,col=rainbow(2),main="Height vs Sex"))
[1] "12"  "134"
> |
```

```
library(car)
data(Davis)
names(Davis)
head(Davis)
with(Davis,tapply(height,sex,summary))
```

```
summary(Davis$height)
with(Davis,Boxplot(height~sex,pch=19,
     col=rainbow(2),main="Height vs Sex"))
```

# 4. INTRODUCTION TO R – EDA – BIVARIATE: NUMERIC VS FACTOR



```
par(mfrow=c(2,3))
attach(Davis)
pie( table( sex ))
barplot( table(sex) )
hist( weight )
```

```
tapply( weight, sex, hist )# Not nice
plot( weight ~ sex ) # Boxplot is
default plot
```

# 5. EDA – BIVARIATE: 2 NUMERICS Y VS X

## 5.1 Numeric statistics to assess linear relationship between Y and X

**Covariance,** COV(y,x)=COV(x,y), defined as E(YX) – E(X)E(Y)

- Disadvantage: Depends on units, so not direct interpretation

**Pearson's coefficient of correlation**, suitable for assessment in normal data

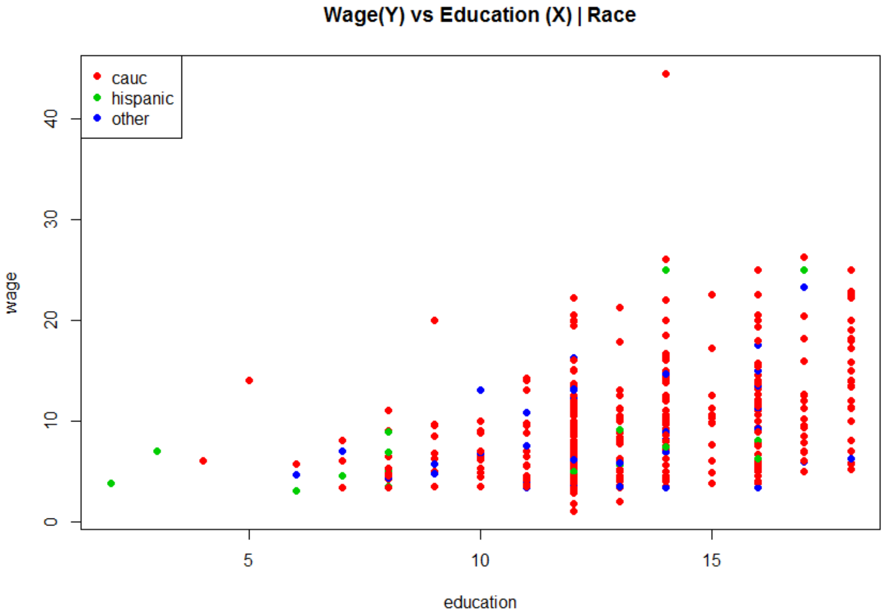
$$\rho(X,Y) = \frac{Cov(X,Y)}{\sigma_X \sigma_Y} \quad and \quad \sigma_X = \sqrt{Var(X)} \; \sigma_Y = \sqrt{Var(Y)}$$

- Advantage: Adimensional, no affected by units
  - $\rho(X,Y)$ **range is** $[-1,1]$ .
    - $\rho(X,Y)$ > 0 means positive relationship X and Y.
    - $\rho(X,Y)$ < 0 means negative relationship X and Y,.
    - $\rho(X,Y)$ = 0 indicates uncorrelated variables, not equivalent to independence.
  - If Y = aX + b then $\left|\rho(X,Y)\right| = 1$.
- **Spearman's coefficient of correlation,** is a nonparametric measure of statistical dependence.

# EDA - BIVARIATE: 2 NUMERICS Y VS X

In R, use var(Davis[,2:3]) or try with Census Data data("CPS1985") in library AER.

```
> library(AER)
> data("CPS1985")
> df<-CPS1985
> ls()
[1] "CPS1985" "df"
> dim( df )  # dimensions: rows and columns
[1] 534  11
> summary( df )
      wage          education       experience         age           ethnicity      region       gender        occupation
 Min.   : 1.000   Min.   : 2.00   Min.   : 0.00   Min.   :18.00   cauc    :440   south:156   male  :289   worker    :156
 1st Qu.: 5.250   1st Qu.:12.00   1st Qu.: 8.00   1st Qu.:28.00   hispanic: 27   other:378   female:245   technical :105
 Median : 7.780   Median :12.00   Median :15.00   Median :35.00   other   : 67                            services  : 83
 Mean   : 9.024   Mean   :13.02   Mean   :17.82   Mean   :36.83                                           office    : 97
 3rd Qu.:11.250   3rd Qu.:15.00   3rd Qu.:26.00   3rd Qu.:44.00                                           sales     : 38
Max.    :44.500  Max.    :18.00  Max.    :55.00  Max.    :64.00
           sector      union       married
 manufacturing: 99   no :438   no :184
 construction : 24   yes: 96   yes:350
 other        :411


> attach( df )
> # Bivariate analysis: 2 numeric variables
> plot(education,wage,col=as.numeric(ethnicity)+1,
       main="Wage(Y) vs Education (X) | Race",pch=19)

> legend("topleft",legend=levels(ethnicity),col=2:4,
       pch=19)
> cor(wage,education,method="spearman")
[1] 0.3813425
> cor(wage,education,method="pearson")  # The one defined
[1] 0.3819221
```



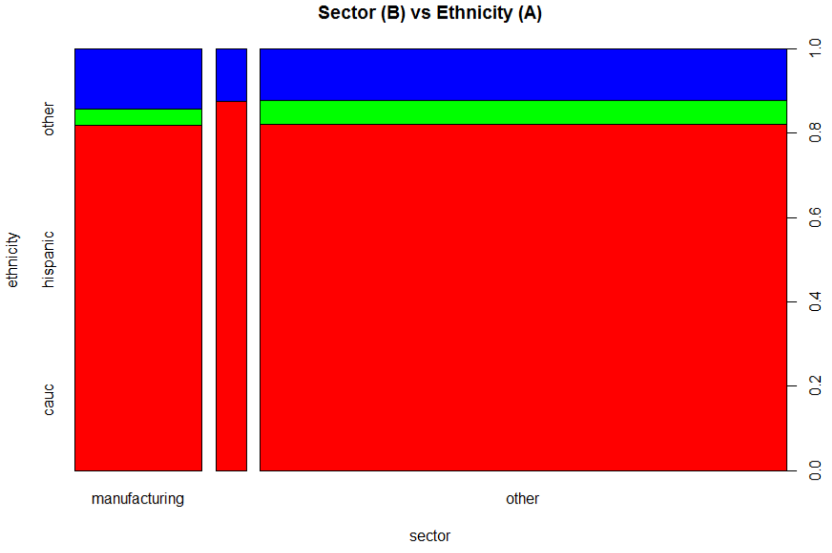
```
Nicer option: scatterplot, try in lab session

> library(car)
> scatterplot(wage~education|ethnicity,main="Wage(Y) vs Education (X) | Race",smooth=FALSE)
```

# 6. EDA - BIVARIATE: 2 FACTORS, A AND B

## 6.1 Numeric statistics to assess linear relationship A and B

Non-existent. Analysis of Contingency Tables and classical inference test to assess Independence of both factors using Chi-Squared Test: chisq.test() in R, arguments a contingency table.

```
> ta<-table(ethnicity,sector)
> ta
          sector
ethnicity  manufacturing construction other
  cauc                81           21   338
  hispanic             4            0    23
  other               14            3    50
> round(prop.table(ta,2),2)
          sector
ethnicity  manufacturing construction other
  cauc              0.82         0.88  0.82
  hispanic          0.04         0.00  0.06
  other             0.14         0.12  0.12

> plot(ethnicity~sector,main="Sector (B) vs Ethni
city (A)",col=rainbow(3))
> chisq.test(ta)

       Pearson's Chi-squared test data:  ta
X-squared = 1.9819, df = 4, p-value = 0.7391
Warning message:In chisq.test(ta) : Chi-squared approximation may be incorrect
```



# EDA – BIVARIATE: 2 FACTORS, A AND B

Graphic display (default in R): mosaic plot

More than 2 dimensions: use xtabs() command in R

```
> xtabs(~gender+ethnicity+sector)
, , sector = manufacturing

        ethnicity
gender   cauc hispanic other
  male     48        2    10
  female   33        2     4

, , sector = construction

        ethnicity
gender   cauc hispanic other
  male     19        0     3
  female    2        0     0

, , sector = other

        ethnicity
gender   cauc hispanic other
  male    169       12    26
  female  169       11    24

> ta<-xtabs(~gender+ethnicity+sector)
> chisq.test(ta)

        Chi-squared test for given probabilities

data:   ta
X-squared = 1573.753, df = 17, p-value < 2.2e-16
```