# Continuous x Continous data (1 of 2)

*Aug 7, 2023*

## Exploring bivariate Continuous x Continuous data

THIS CHAPTER explores how to summarize and visualize the interaction between *bivariate continuous data* using correlation analysis, scatter plots, scatter plot matrices and other such techniques.

**Data**: Suppose we run the following code to prepare the `mtcars` data for subsequent analysis and save it in a tibble called `tb`.

```
# Load the required libraries, suppressing annoying startup messages
library(tibble)
suppressPackageStartupMessages(library(dplyr))
# Read the mtcars dataset into a tibble called tb
data(mtcars)
tb <- as_tibble(mtcars)
# Convert relevant columns into factor variables
tb$cyl <- as.factor(tb$cyl) # cyl = {4,6,8}, number of cylinders
tb$am <- as.factor(tb$am) # am = {0,1}, 0:automatic, 1: manual transmission
tb$vs <- as.factor(tb$vs) # vs = {0,1}, v-shaped engine, 0:no, 1:yes
tb$gear <- as.factor(tb$gear) # gear = {3,4,5}, number of gears
# Directly access the data columns of tb, without tb$mpg
attach(tb)
```

## Scatterplots

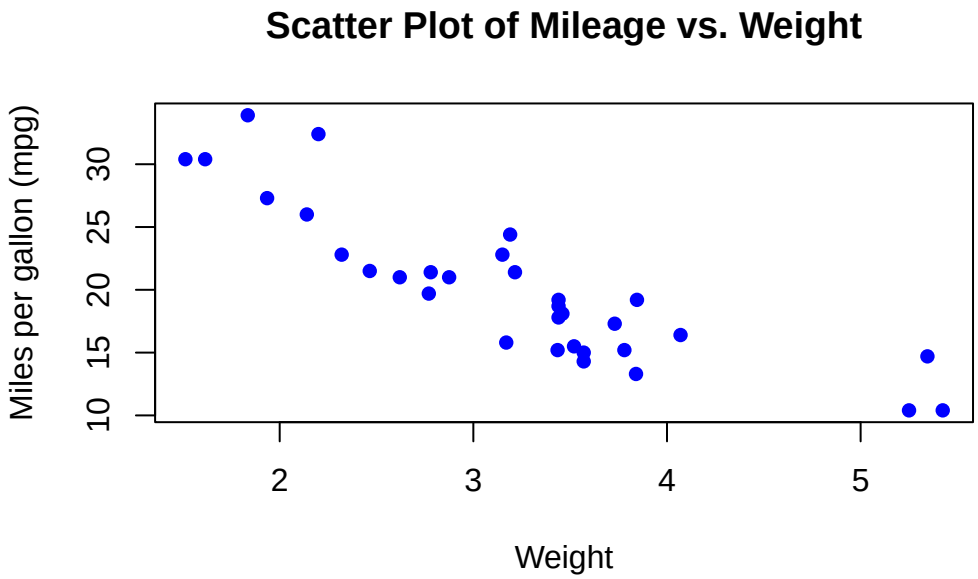
1. A scatter plot is used to display the relationship between two continuous variables. It is a graphical representation of a bivariate distribution, where the values of two variables are plotted as points on a two-dimensional coordinate system.

2. A scatter plot can be used to identify trends, clusters, outliers, and other patterns in the data. It is also useful for detecting the presence of any outliers or influential observations that may affect the analysis. [1]

3. To create a scatter plot of `mpg` (miles per gallon) against `wt` (weight) in the `mtcars` data set, we can use the following code:

### Scatterplot using `plot()`

```
plot(tb$wt,
     tb$mpg,
     main = "Scatter Plot of Mileage vs. Weight",
     xlab = "Weight", ylab = "Miles per gallon (mpg)",
     pch = 16,
     col="blue")
```




4. **Discussion**:

- This code will first load the mtcars data set, then create a scatter plot of `mpg` against `wt` using the `plot()` function.
- The `main` argument adds a title to the plot, the `xlab` and `ylab` arguments add axis labels
- The `pch` argument sets the shape of the points to a solid circle. pch = 15 gives a filled square. Recall other popular values: pch = 16 gives a filled circle, pch = 17 gives a

filled triangle (pointing upwards), pch = 18 gives a filled diamond, pch = 19 gives a solid circle, pch = 20 gives a filled bullet (smaller than pch = 19)

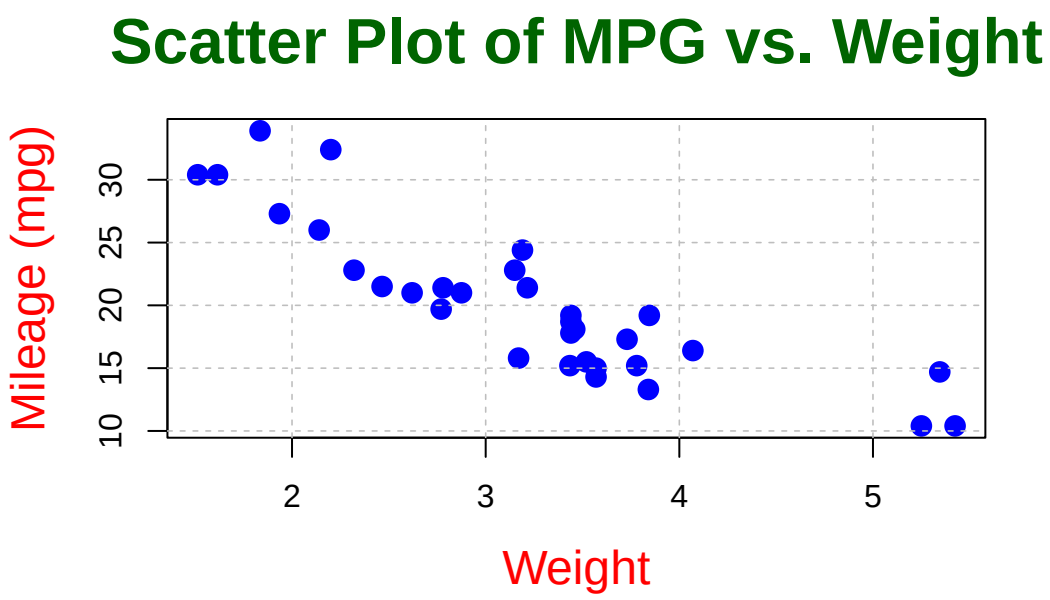
- the `col` argument specifies the color of the data points. Recall we can use any named color in R, or we can use hexadecimal color codes. For instance, `col = "#FF0000"` would give us red points. [2]

5. **Personalizing Scatter Plots**

- We can personalize the appearance of the scatterplot in a variety of additional ways.

```
# Create the scatterplot
plot(tb$wt,
     tb$mpg,
     main = "Scatter Plot of MPG vs. Weight",
     xlab = "Weight", ylab = "Mileage (mpg)",
     pch = 16, cex = 1.5, col="blue",
     col.lab="red", cex.lab=1.5,
     col.main="darkgreen", cex.main=2,
     bg = "gray")

# Add a grid
grid(col = "gray", lty = "dashed", lwd = 0.8)
```




6. **Discussion**

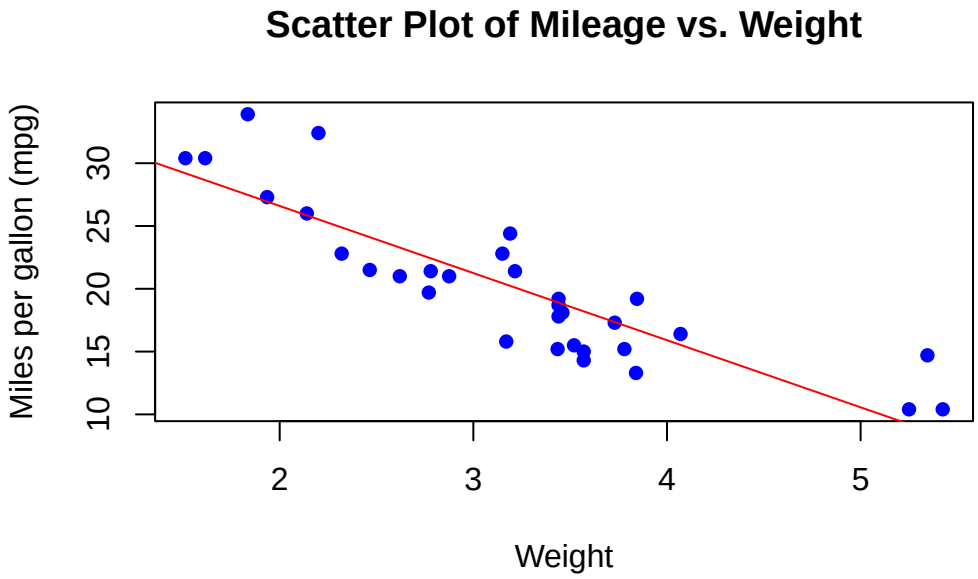
- Point Size: In the second plot, the size of the points is 1.5 times the default size (`cex = 1.5`), while in the first plot, the size of the points is the default size as `cex` is not specified.
- Axis Labels' Color and Size: The second plot has red-colored, larger size axis labels (`col.lab="red", cex.lab=1.5`), while the first plot uses the default color and size as these parameters are not specified.
- Title's Color and Size: The second plot has a dark green title that is twice the default size (`col.main="darkgreen", cex.main=2`), while the first plot uses the default color and size for the title as these parameters are not specified.
- Background Color: The second plot has a light gray background (`bg = "lightgray"`), while the first plot uses the default background color as the bg parameter is not specified.
- Grid: The second plot includes a grid with gray dotted lines (`grid(col = "gray", lty = "dotted", lwd = 0.5)`), while the first plot does not have a grid as the grid() function is not called. [2]

7. **Scatterplot with best fit line**

- We can add a line of best fit (a regression line) to your scatterplot using the `abline()` and `lm()` functions. `lm()` is used to fit linear models, and `abline()` adds a straight line to the plot.

```r
# Create the scatterplot
plot(tb$wt,
     tb$mpg,
     main = "Scatter Plot of Mileage vs. Weight",
     xlab = "Weight", ylab = "Miles per gallon (mpg)",
     pch = 16,
     col="blue")

# Fit a linear model
fit <- lm(tb$mpg ~ tb$wt)
# Add a regression line
abline(fit, col = "red")
```



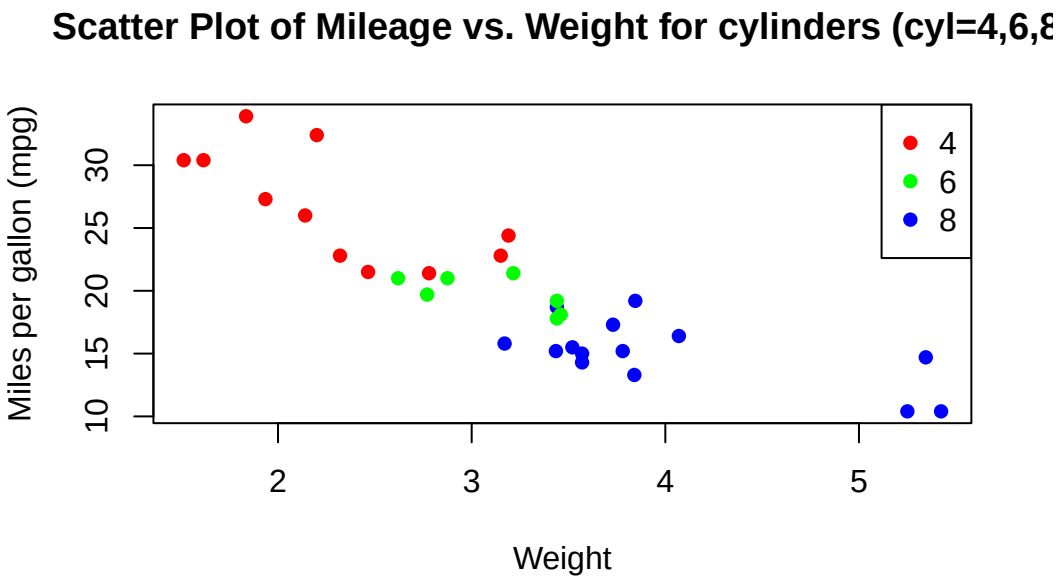

8. **Discussion**:

- `lm(tb$mpg ~ tb$wt)` fits a linear model predicting `mpg` from `wt`. The `~` operator is a formula operator in R that separates the response variable (on the left of `~`) from the predictor variables (on the right of `~`). `abline(fit, col = "red")` subsequently adds the regression line to the plot, drawn in red color. [3]

9. **Visualizing Continuous x Continuous x Categorical data**

- Consider the issue of visualizing two continuous variables `wt` (Weight and `mpg` (Miles per gallon) for different levels of a categorical variable `cyl` (Cylinders).

```
# Create the scatterplot with points colored by cyl
plot(tb$wt,
     tb$mpg,
     main = "Scatter Plot of Mileage vs. Weight for cylinders (cyl=4,6,8)",
     xlab = "Weight", ylab = "Miles per gallon (mpg)",
     pch = 16,
     col=c("red","green","blue")[tb$cyl]
     )
# Add a legend
legend("topright",
       legend = levels(tb$cyl),
       col = c("red", "green", "blue"),
       pch = 16)
```




10. Discussion

- In the snippet `col=c("red","green","blue")[tb$cyl]`, we assign the color of the data points according to the `cyl` variable. It translates to distinct colors for different `cyl` values in the plot.
- Moreover, when we incorporate the `legend()` function with parameters such as `"topright"`, we place a legend at the top-right corner of the plot. The identifiers and color scheme in the legend correspond to the unique values of the `cyl` variable. [2]

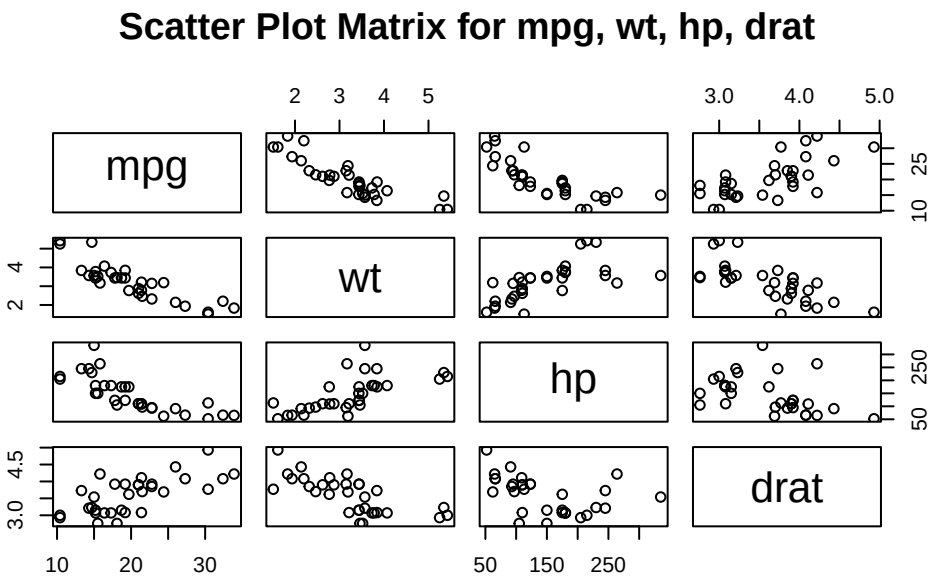
## Scatterplot Matrix

1. A scatter plot matrix, also known as a pairs plot or SPLOM, is a powerful visual tool that helps us in depicting the pair-wise relationships among a group of variables. In this matrix, every distinct variable from the dataset is charted against each other in a grid-like structure. This enables us to delve into the associations between variable pairs and identify possible trends or patterns in the dataset.
2. When dealing with multivariate datasets, scatter plot matrices can be remarkably handy. They equip us with a rapid way to discern potential correlations among variable pairs – whether they are strong, weak, or non-existent. It's also a convenient method to spot non-linear relationships between variables. In addition, it's a beneficial tool to recognize outliers or peculiar data points and to observe clusters or collections of observations. [4]

### Scatterplot Matrix using `pairs()`

1. The following R code creates a scatter plot matrix, also known as a pairs plot, for four variables: `mpg` (miles per gallon), `wt` (weight), `hp` (horsepower), and `drat` (rear axle ratio). This is performed on the data stored in the `tb` data frame.

```
# scatter plot matrix for mpg, wt, hp, drat
columns = c("mpg","wt","hp","drat")
pairs(tb[ ,columns],
      main = "Scatter Plot Matrix for mpg, wt, hp, drat"
      )
```



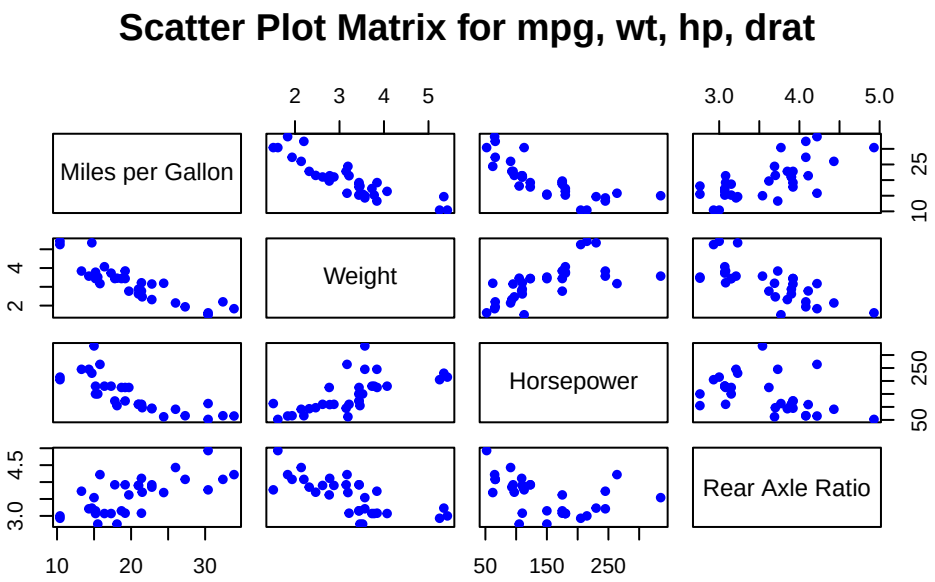

2. **Discussion**:

- The `pairs()` function in R is designed to take a subset of the tb data frame consisting of the columns specified in the columns vector and construct a matrix of scatter plots.
- The plots are arranged in a grid format, where the variable for each row is plotted against the variable for each column. [5]

3. **Personalizing Scatterplot Matrix using `pairs()`**

```
# scatter plot matrix for mpg, wt, hp, drat
pairs(tb[,c("mpg","wt","hp","drat")],
      main = "Scatter Plot Matrix for mpg, wt, hp, drat",
      pch = 19,
```

```
labels = c("Miles per Gallon", "Weight", "Horsepower", "Rear Axle Ratio"),
col = c("blue"),
cex = 0.8
)
```




4. **Discussion**:

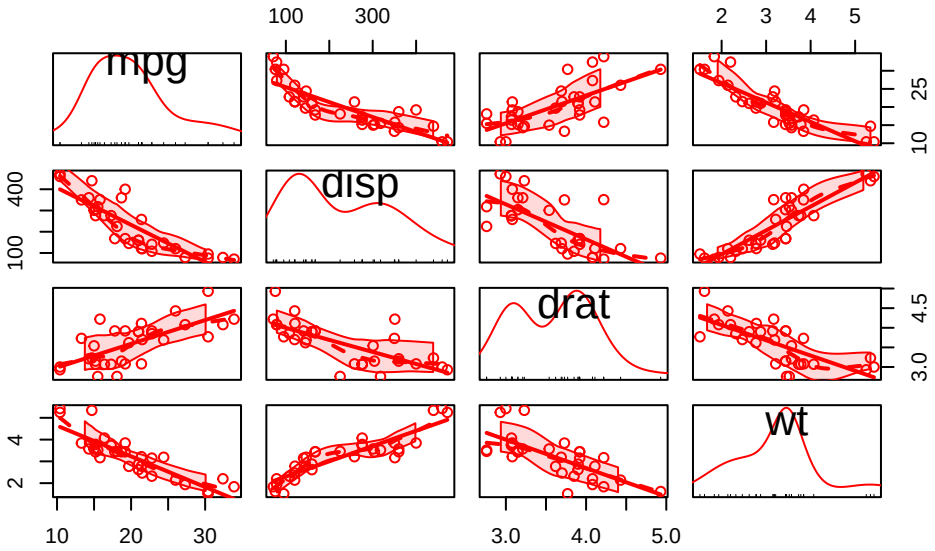
- Symbol: The `pch` parameter is used to specify the symbol that represents data points in a plot.
- Labels: The `labels` parameter lets us customize the variable labels that appear on the diagonal:
- Color: We can specify different colors for the points in each scatter plot with the `col` parameter.
- Point Size: The `cex` parameter controls the size of the points in the scatter plot.

### Scatter Plot Matrix using `scatterplotMatrix()` from package `car`

1. The following code creates an alternate scatterplot matrix for each pair of the variables `mpg`, `disp`, `drat`, and `wt`, allowing us to explore the relationships among these four variables.

```
# Load the car package
library(car)
```

```r
# Create a scatterplot matrix using scatterplotMatrix()
scatterplotMatrix(data = tb,
                  ~ mpg + disp +drat +wt,
                  col = c("red"))
```



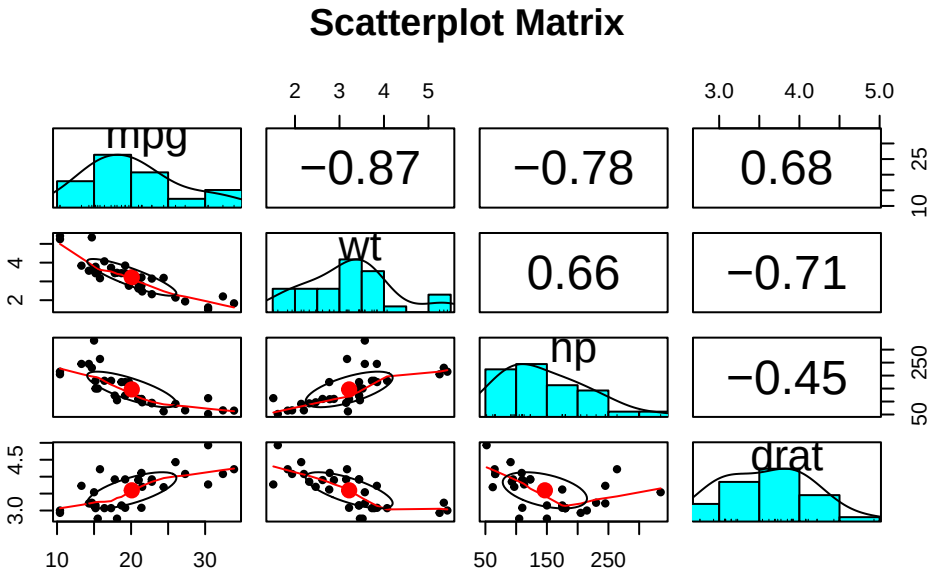

2. **Discussion**:

- The `car` package, short for Companion to Applied Regression, contains numerous functions and datasets that are helpful for regression analysis.
- The next step is creating a scatterplot matrix. For this, we use the `scatterplotMatrix()` function from the `car` package. This function creates a scatter plot matrix, which is a grid of scatter plots that shows pairwise relationships between several variables.
- Here, the `data` argument specifies the data frame we are working with, `tb`.
- The formula `~ mpg + disp + drat + wt` indicates the variables to be included in the scatter plot matrix. Recall `mpg`, `disp`, `drat`, and `wt` represent miles per gallon, displacement, rear axle ratio, and weight, respectively.
- The `col` argument is used to set the color of the points in the scatter plots. Here, all points are colored red. [6]

### Scatter Plot Matrix using `pairs.panels()` in package `psych`

```
# Load the psych package
library(psych)

# Create a scatterplot matrix using pairs.panels()
pairs.panels(tb[,c("mpg","wt","hp","drat")],
             main = "Scatterplot Matrix")
```




**Discussion**:

- The `psych` package contains a variety of functions useful for psychological, psychometric, and personality research.
- We utilize the `pairs.panels()` function from the `psych` package to create a scatterplot matrix. This function is very helpful as it produces a matrix of bivariate scatter plots on the lower panels, histograms or kernel density plots on the diagonals, and correlations on the upper panels.
- The `tb[,c("mpg","wt","hp","drat")]` in the code specifies the subset of the `tb` data frame that we want to include in the scatterplot matrix. In this case, it refers to the columns `mpg` (miles per gallon), `wt` (weight), `hp` (horsepower), and `drat` (rear axle ratio).
- The `main` parameter sets the main title for the plot, which in this instance is "Scatterplot Matrix". [7]

## Summary of Chapter

## References

[1]

Everitt, B. S., & Hothorn, T. (2014). A Handbook of Statistical Analyses Using R. Chapman and Hall/CRC. (

[2]

R Core Team. (2023). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/

[3]

Fox, J., & Weisberg, S. (2019). An R Companion to Applied Regression (3rd ed.). Sage.

[4]

Everitt, B., & Hothorn, T. (2011). An introduction to applied multivariate analysis with R. Springer.

[5] Chick, J. (2020). Data visualisation with R: 100 Examples. CRC Press.

[6] Fox, J., & Weisberg, S. (2019). An R Companion to Applied Regression (3rd ed.). SAGE Publications.

Revelle, W. (2020). Procedures for Psychological, Psychometric, and Personality Research. Northwestern University.

[7] Revelle, W. (2020). Procedures for personality and psychological research. Northwestern University, Evanston. Retrieved from https://CRAN.R-project.org/package=psych.