

THE FIRST STEP EXPLORATORY DATA ANALYSIS

Alejandro Ordonez

Assistant Professor - Department of Bioscience
Section for Ecoinformatics & Biodiversity
Center for Biodiversity Dynamics in a Changing World (BIOCHANGE)

EXPLORATORY DATA ANALYSIS

WHAT WE WILL TALK ABOUT TODAY

Exploratory Data Analysis - Why?

Summary statistics – Get an overview of your data

Visualisation – A figure is worth 1000 words

Transformations – Making data symmetrical and comparable

Modelling – Establish simple relations between variables

Statistical Test – What are they doing?

Any questions?

Ready to start?

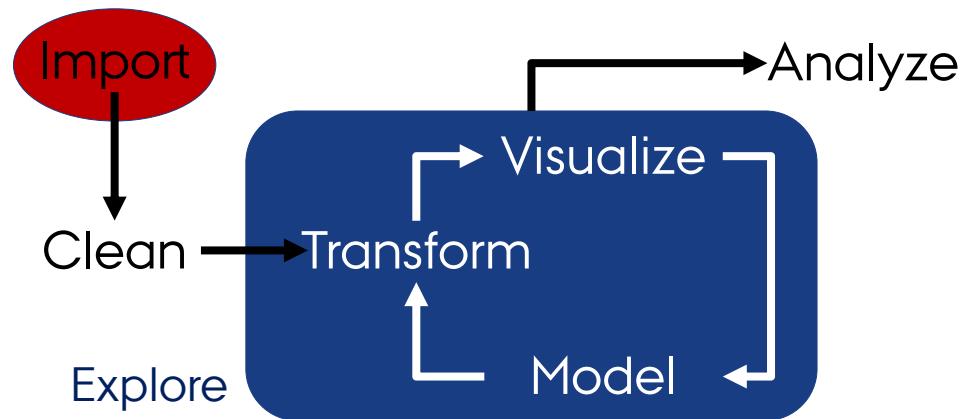
EXPLORATORY DATA ANALYSIS: WHY?

Exploratory Data Analysis (**EDA**) is *the art of looking at your data* to rapidly generate many promising leads that you can later explore in more depth.

EDA is the base for statistical analysis of multidimensional data as it:

- Provides an overview of the data → is it meaningful?
- Establishes if there are errors, outliers, or patterns.
- Help to determine the need to transform or recode some variables → are the analytical assumptions meet?
- Orient further analyses.

BEFORE EXPLORATORY DATA ANALYSIS: GET YOUR DATA IN.



Before doing anything in R you need to get your data in the program.

External data is usually a txt or csv file that needs to be “read” using one of two functions.

`read.table?`

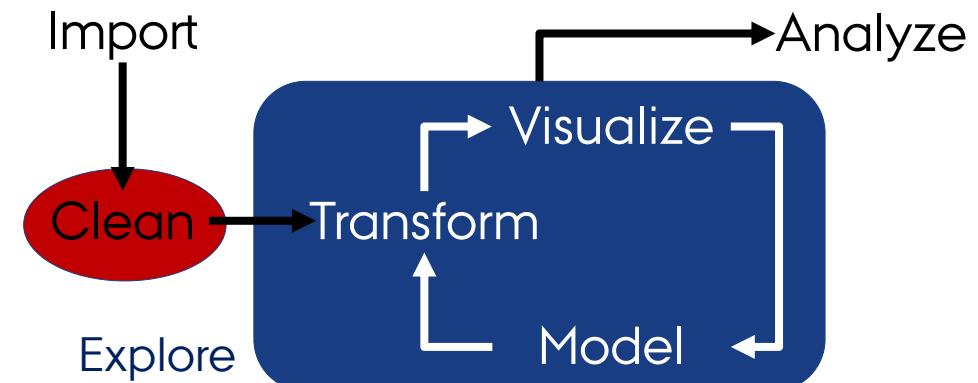
`read.csv?`

Reading is not enough, It needs to be stored it as an object!!

BEFORE EXPLORATORY DATA ANALYSIS: CLEAN YOUR DATA

There are three interrelated rules which make a dataset suited to be used in 

- Each variable must have its own column.
- Each observation must have its own row.
- Each value must have its own cell.



country	year	cases	population
Afghanistan	1999	745	1987071
Afghanistan	2000	2666	2059360
Brazil	1999	37737	172006362
Brazil	2000	80488	174504898
China	1999	212258	1272915272
China	2000	21666	128042583

variables

country	year	cases	population
Afghanistan	1999	745	1987071
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Brazil	1999	37737	172006362
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observations

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values



BEFORE EXPLORATORY DATA ANALYSIS: CLEAN YOUR DATA.

Step 1. Remove

- Leading/Trailing spaces.
- Comma, dots, hyphens and apostrophes.
- (Multiple) spaces for strings.

Step 2. Standardise

- To lowercase/UPPERCASE *Or* Capitalise.
- Put/remove a dots at the end and punctuation.
- Change “,” to “;” in the text.
- Date formats.
- Precision [Nº of decimals]

Step 3. Error checking

- Correcting or removing corrupt or inaccurate records.
- Eliminate duplicate entries.
- Data type consistency within a column.

EXPLORATORY DATA ANALYSIS

WHAT TO DO BEFORE YOU START?

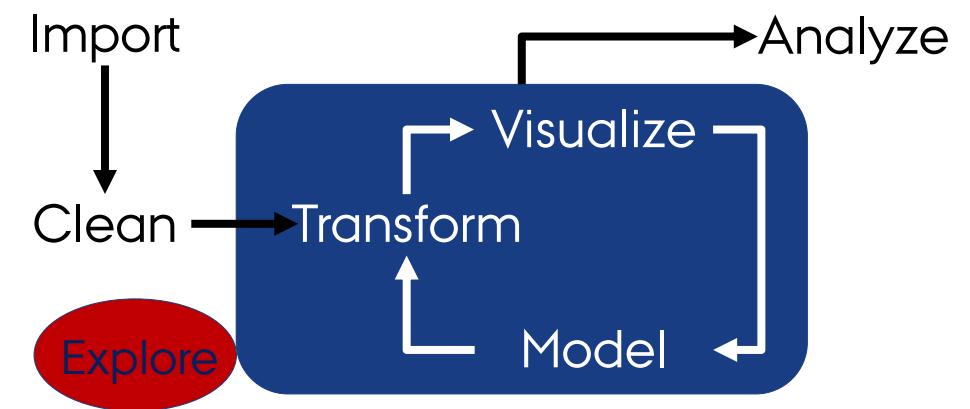
The two crucial questions you will **always** ask:

1. *What type of variation occurs within my variables?*

Variation is a description of how a random variable is dispersed, or spread out.

2. *What type of covariation occurs between my variables?*

Covariation is a description of the relationship between two random variables



EXPLORATORY DATA ANALYSIS: TOOLS

EDA uses **four** main tools to answer the two key questions:

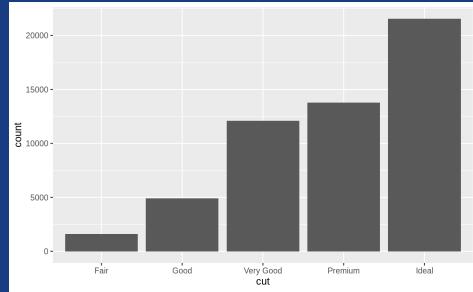
- **Descriptive statistics:** Quantitative descriptions or summaries of the features from a collection of information.
- **Visualisation:** The graphical representation of information and data to see and understand trends, outliers, and patterns.
- **Transformation:** process of changing the format, structure, or values of data.
- **Modelling:** simple low-dimensional summaries of a dataset, and trends assessments.

EXPLORATORY DATA ANALYSIS: TOOLS

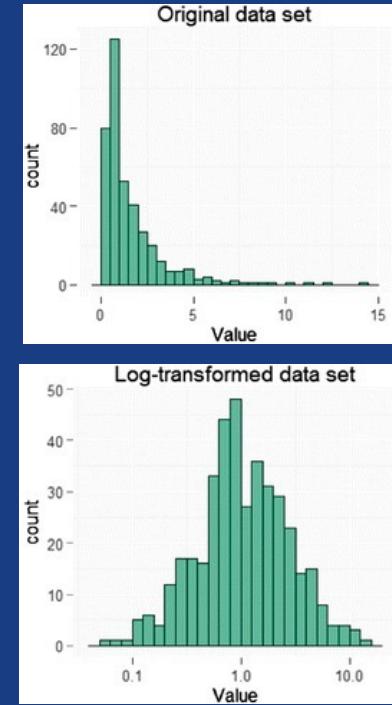
Descriptive statistics

Country	Gender	Height	Basketball players
United Kingdom	Male	$1.95 \pm 7\%$	50% (1/2)
United Kingdom	Female	$1.8 \pm 0\%$	100% (1/1)
Canada	Male	NA	NA
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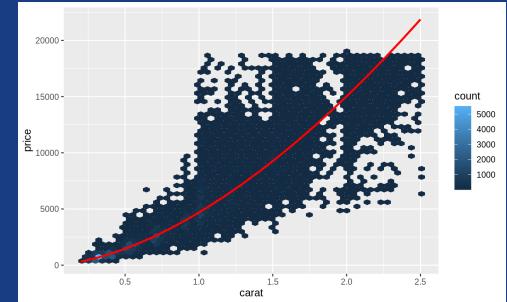
Visualisation



Transformation



Modelling

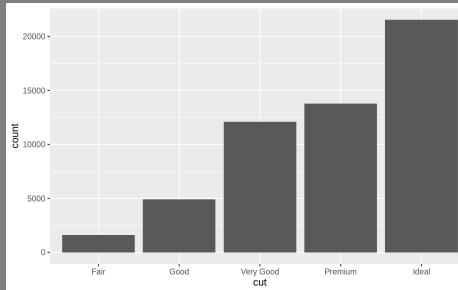


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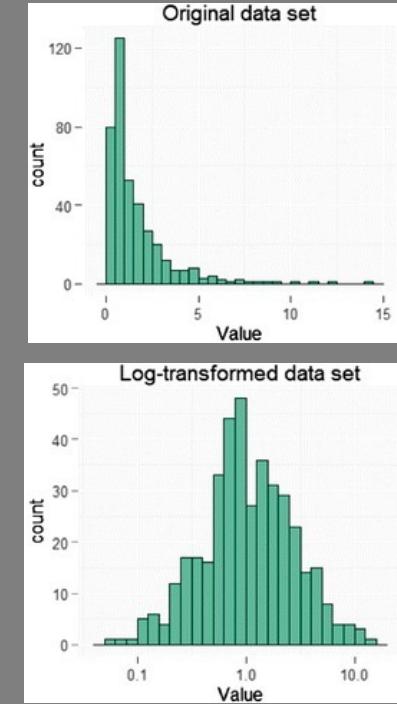
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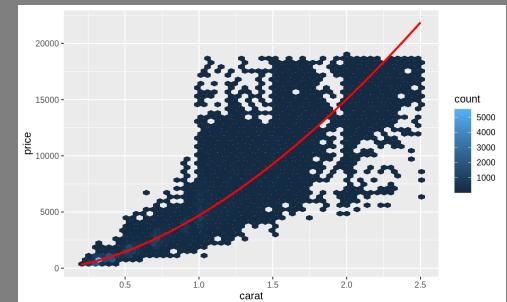
Visualisation



Transformation



Modelling



EDA - DESCRIPTIVE STATISTICS

Summaries provide a good way to:

- Look at patterns and the quality of your data.
- Communicate the largest amount of information as simply as possible.

All your observations regarding a single variable can be described in terms of:

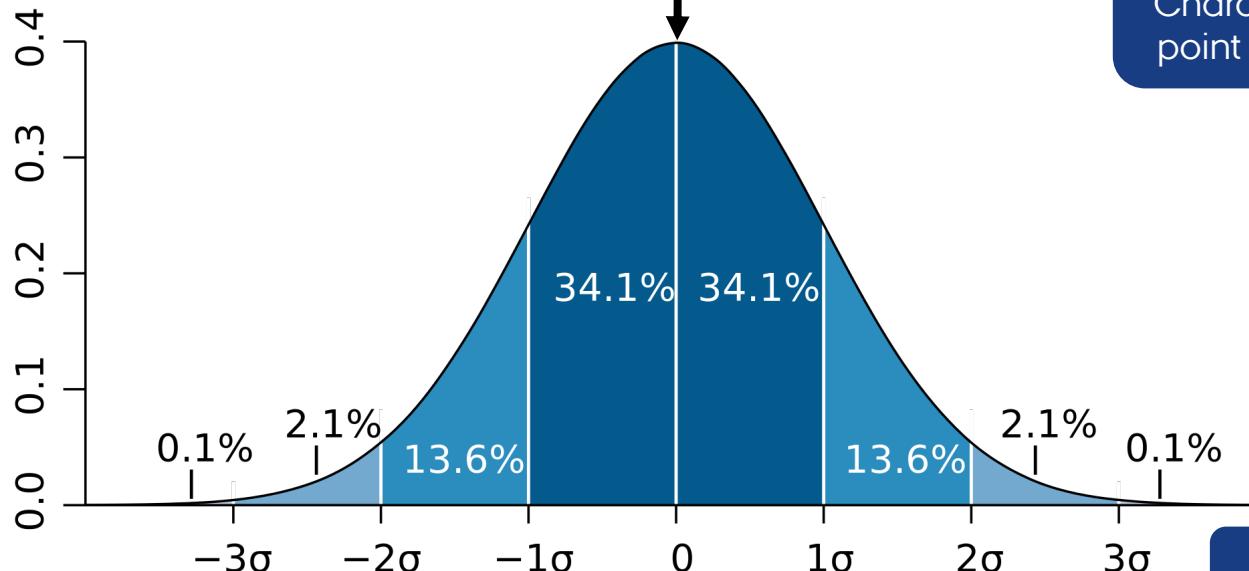
Central tendency (*mean, median, mode*).

Dispersion (*variance, standard deviation, coefficient of variation*).

Shape of the distribution (*skewness, kurtosis*).

Statistical dependence (correlation coefficients).

EDA - DESCRIPTIVE STATISTICS



Central tendency

Characterises the central point of the observations

Mean
Median
Mode



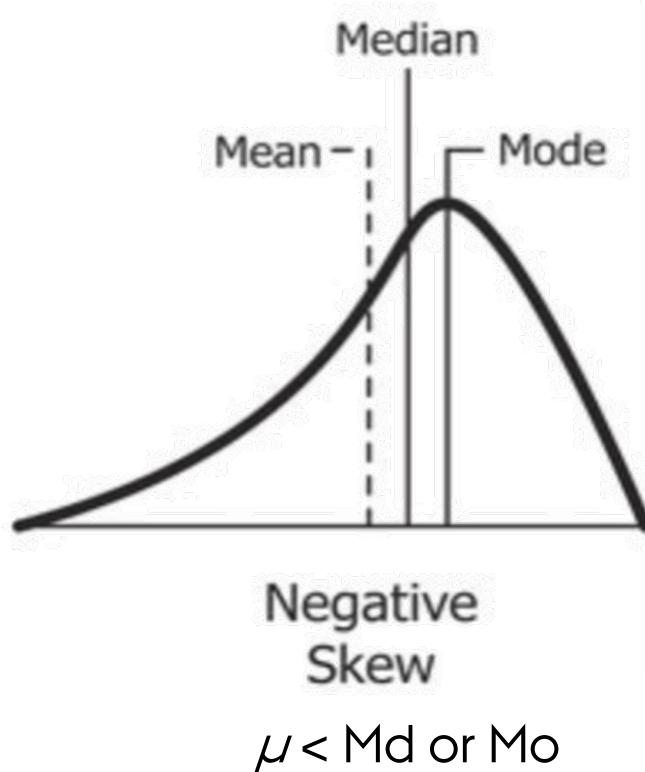
Dispersion

Characterises the variability of the observations

$$\begin{aligned}\sigma^2 &= \text{Variance} \\ \sigma &= \text{Standard Deviation} \\ \frac{\sigma}{\sqrt{n}} &= \text{Standard Error}\end{aligned}$$

$$\sigma^2 = \sqrt{\frac{\sum(x_i - \mu)^2}{N}}$$

EDA - DESCRIPTIVE STATISTICS



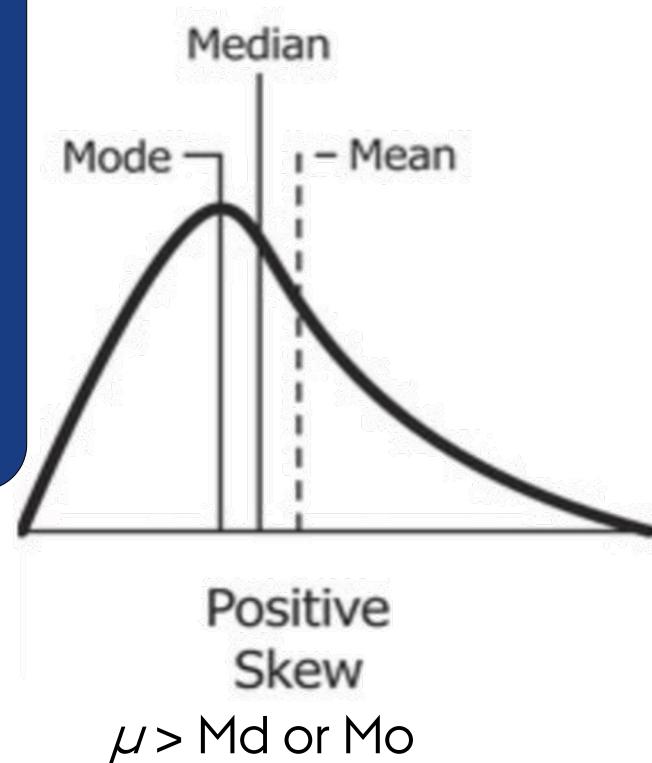
Shape
Characterize the deviation from a normal (symmetrical) distribution

↓

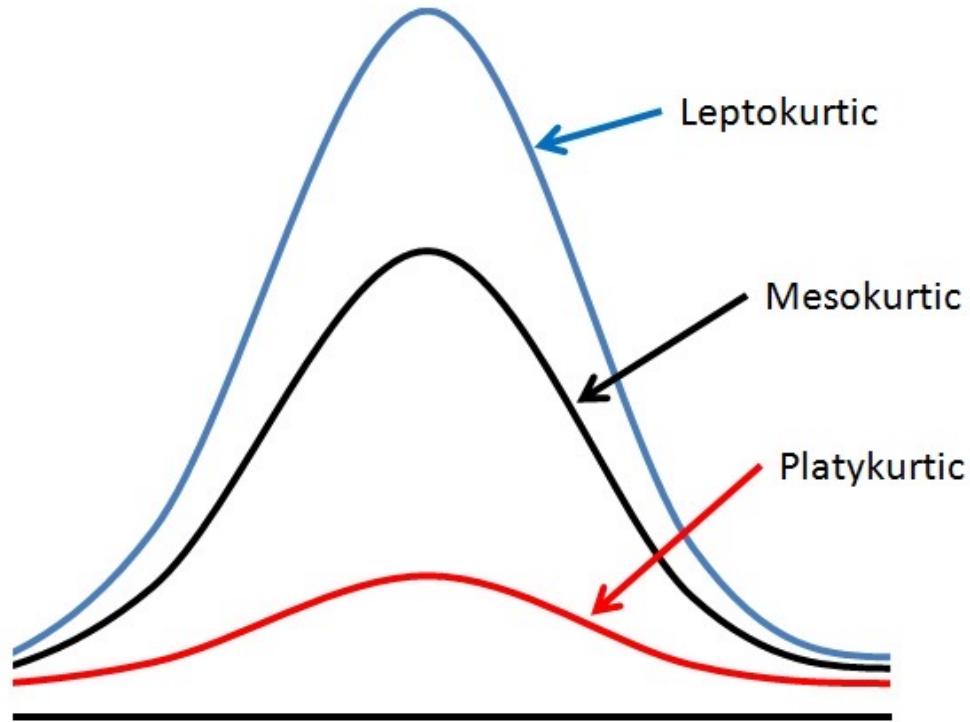
Skewness

$$Sk_1 = \frac{\mu - Mo}{\sigma^2}$$
$$Sk_2 = \frac{3(\mu - Md)}{\sigma^2}$$

Skewness direction
given by the sign



EDA - DESCRIPTIVE STATISTICS



$$g_2 = \frac{m_4}{m_2^2} - 3 = \frac{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^4}{\left[\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2 \right]^2} - 3$$

Shape

Help to identify outlier problems.

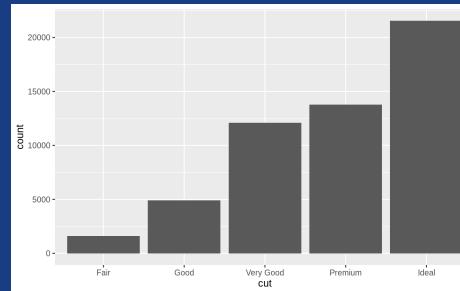
Kurtosis
Larger kurtosis = serious outlier problem

EXPLORATORY DATA ANALYSIS: TOOLS

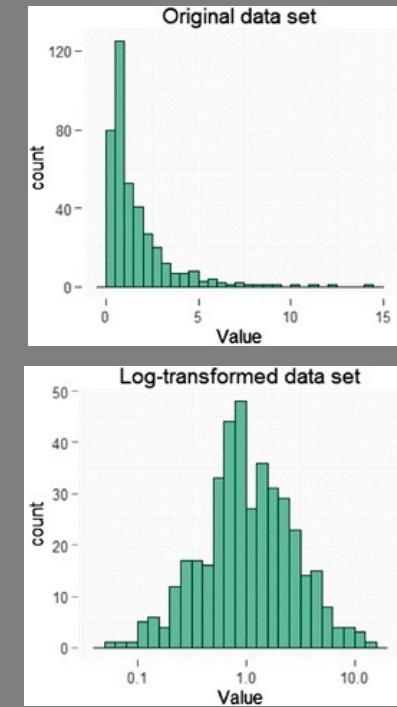
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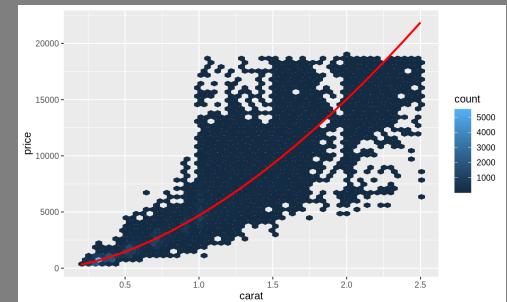
Visualisation



Transformation



Modelling

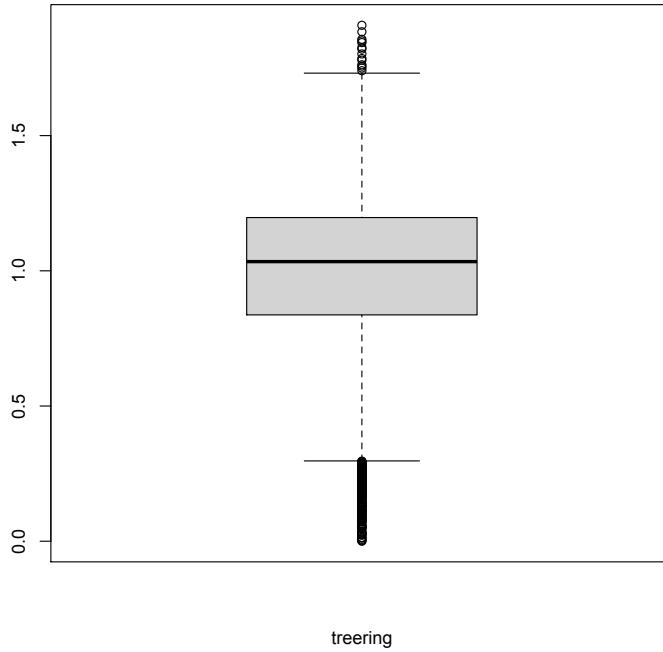


EDA - VISUALIZATION

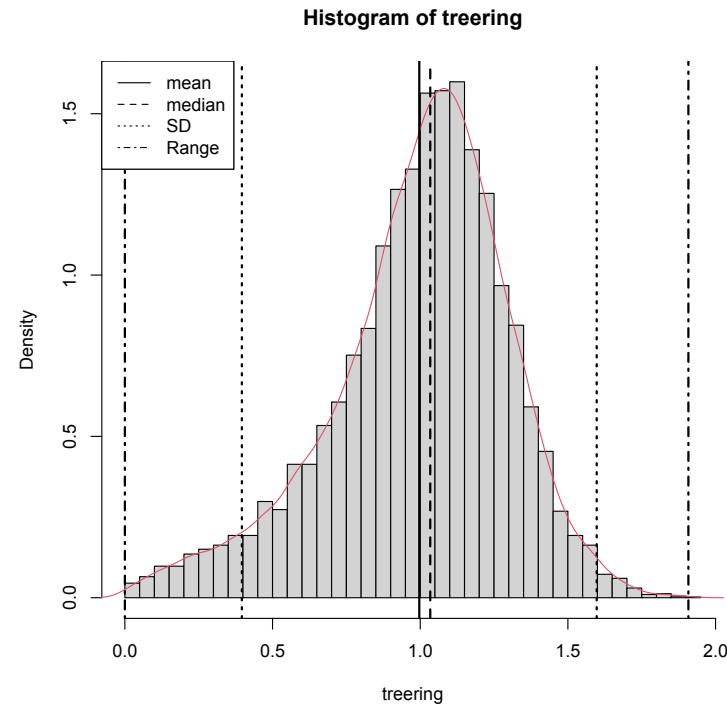
The Three main functions of graphical displays in data analysis:

- **Explore:** Checking data for unusual values, making sure the data meet the assumptions of the chosen analysis and occasionally deciding what analysis (or model) to use.
- **Analyse:** Checking assumptions and ensuring that the chosen model is a realistic fit to the data.
- **Present:** Summarizing numerical information and graphical displays for specific statistical purposes.

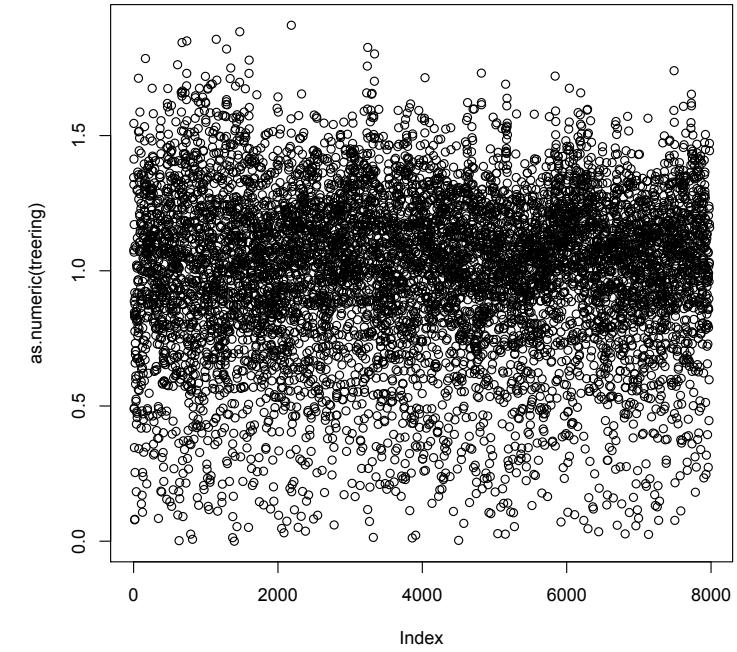
VISUALIZATION: BASIC TYPES



Box-plots
graphical representation of
different descriptive
statistics

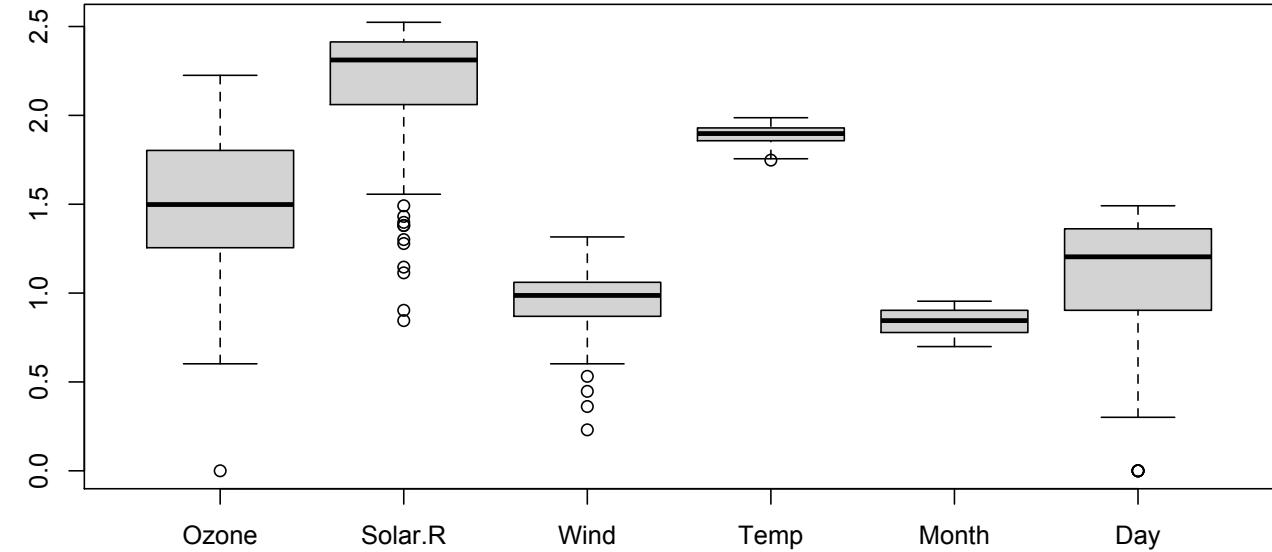
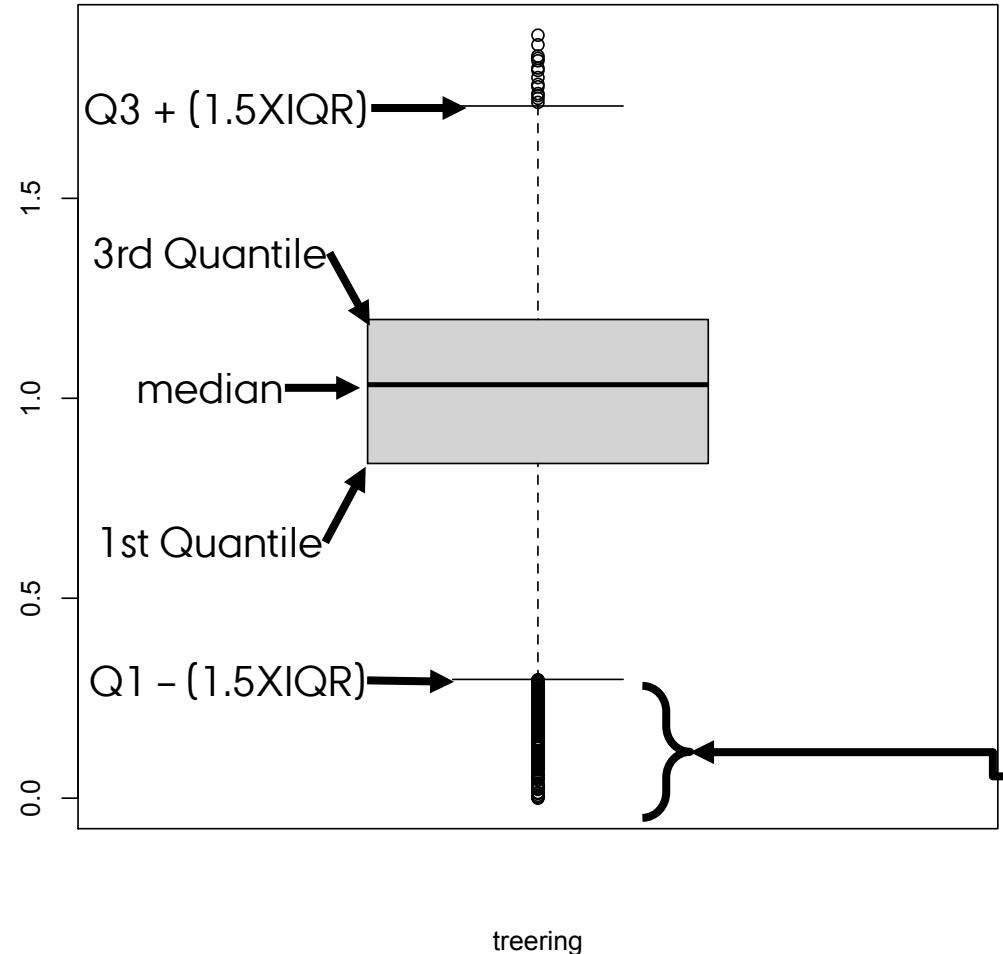


Histograms
graphical representation of
a frequency (or density) of
the observations.



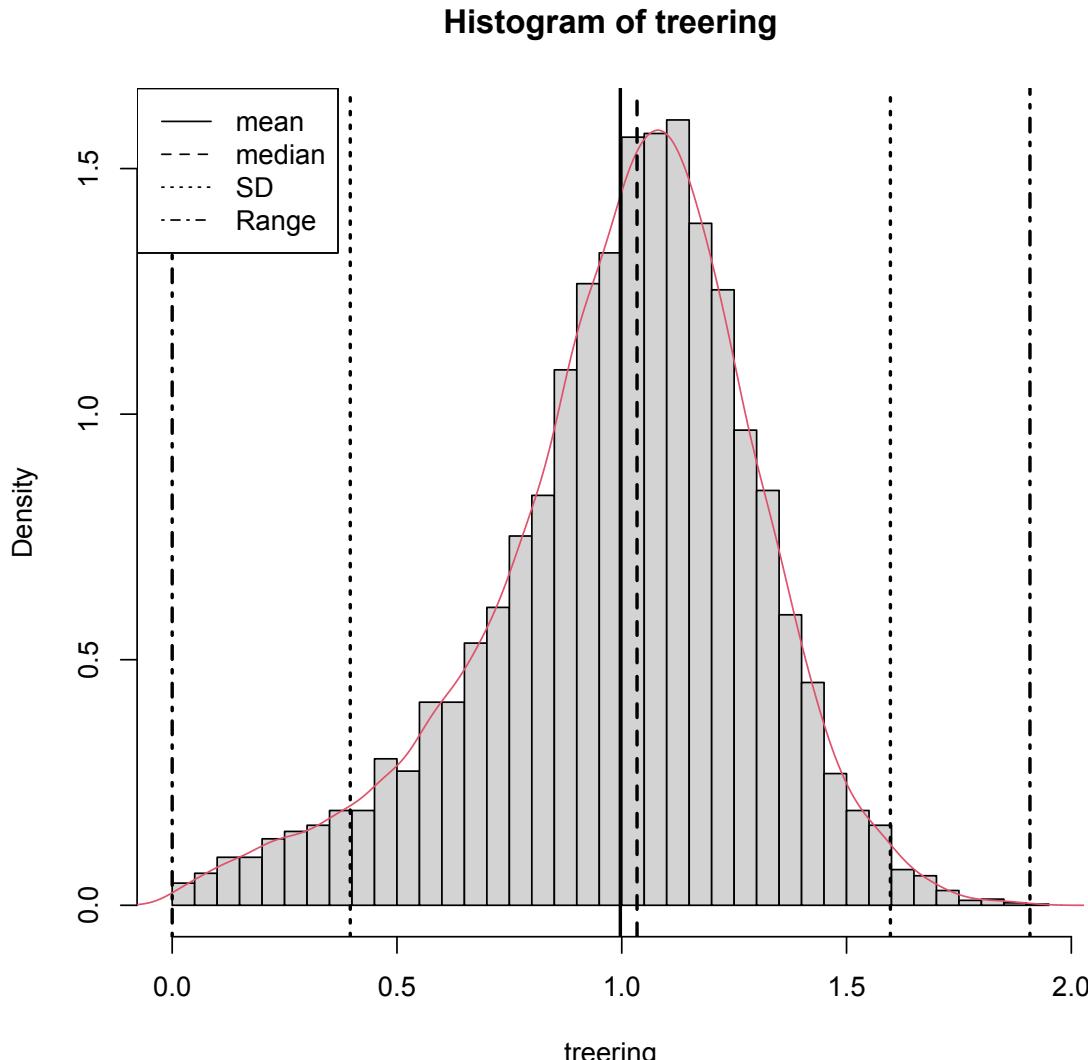
Dotplots
Each observation is
represented by a single dot
or symbol.

VISUALIZATION: BOX-PLOTS



How would identify and outlier using a Boxplot

VISUALIZATION: HISTOGRAM



Which is the shape of the distribution?

This is the most important point we want to know about our observations, and therefore about the population from which our data came

Why?: Most of “common” the statistical tests assume that the variables being analysed have normal distributions

R FUNDAMENTALS: NORMALITY TEST

Normality of a series of observations can be **tested** by using the Shapiro-Wilk test

`shapiro.test()`

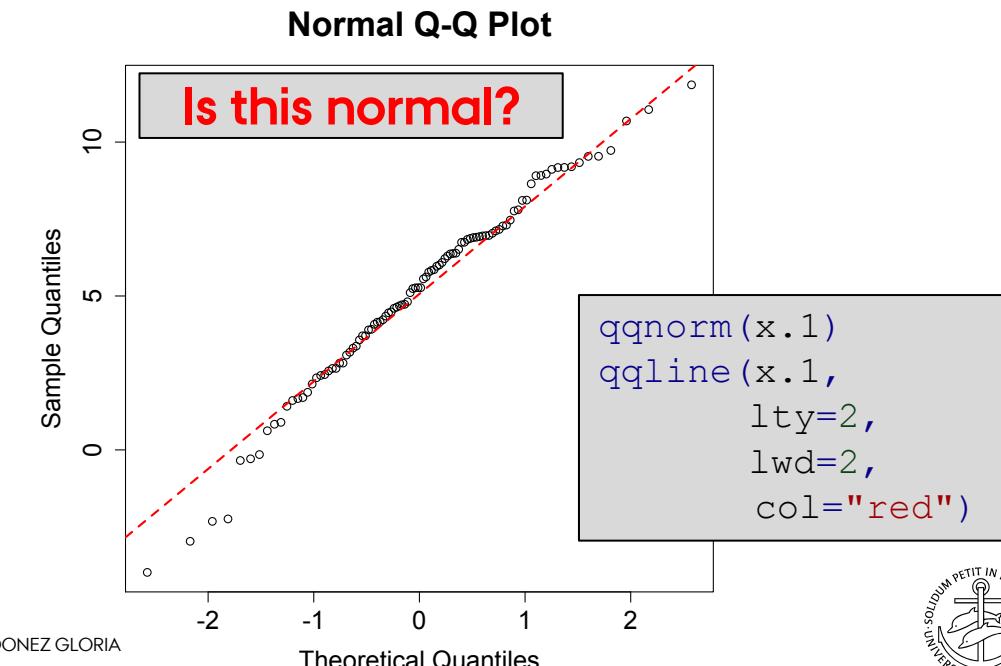
If the test is Non significant you have normality!

```
> # Normality Tests
> ### test using a Normal distribution
> shapiro.test(rnorm(100, mean = 5, sd = 3))
Shapiro-Wilk normality test
data: rnorm(100, mean = 5, sd = 3)
W = 0.98122, p-value = 0.1654
> ### test using a Poisson distribution
> shapiro.test(rpois(1000, lambda=5))
Shapiro-Wilk normality test
data: rpois(1000, lambda = 5)
W = 0.97227, p-value = 6.871e-13
```

Normality of a series of observations can be **evaluated** by using quantile-quantile plots

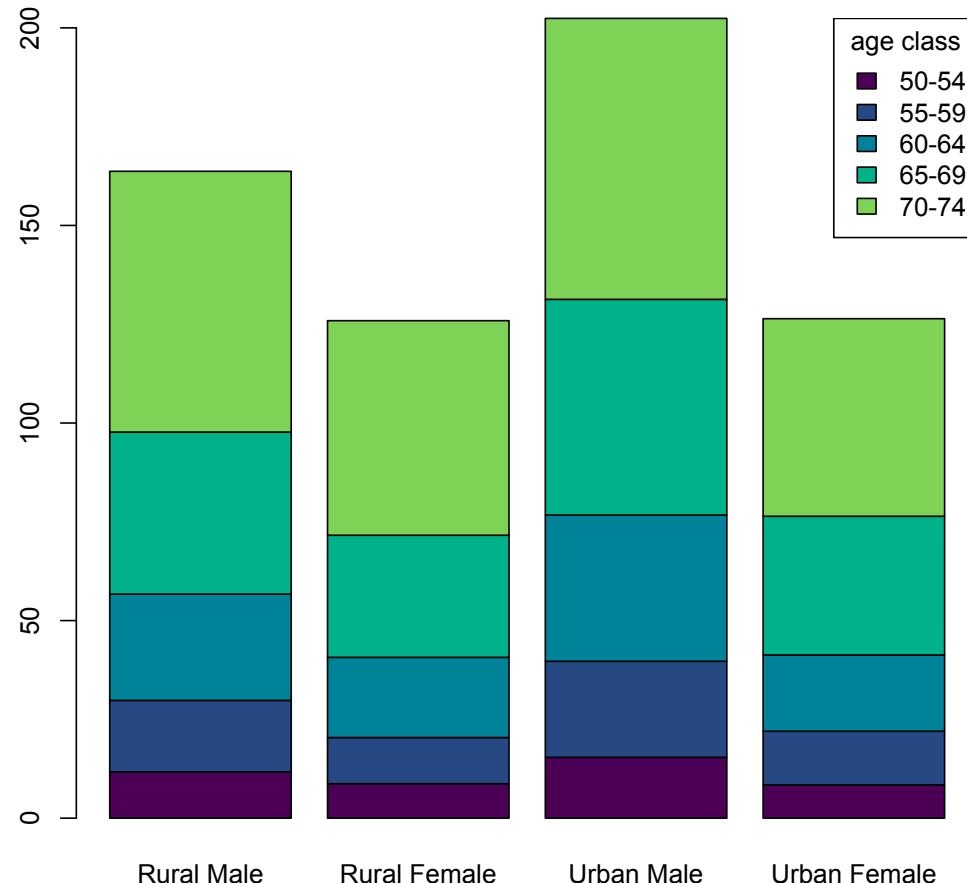
`qqnorm()` and `qqline()`

Departures from normality show up as S-shapes or banana shapes

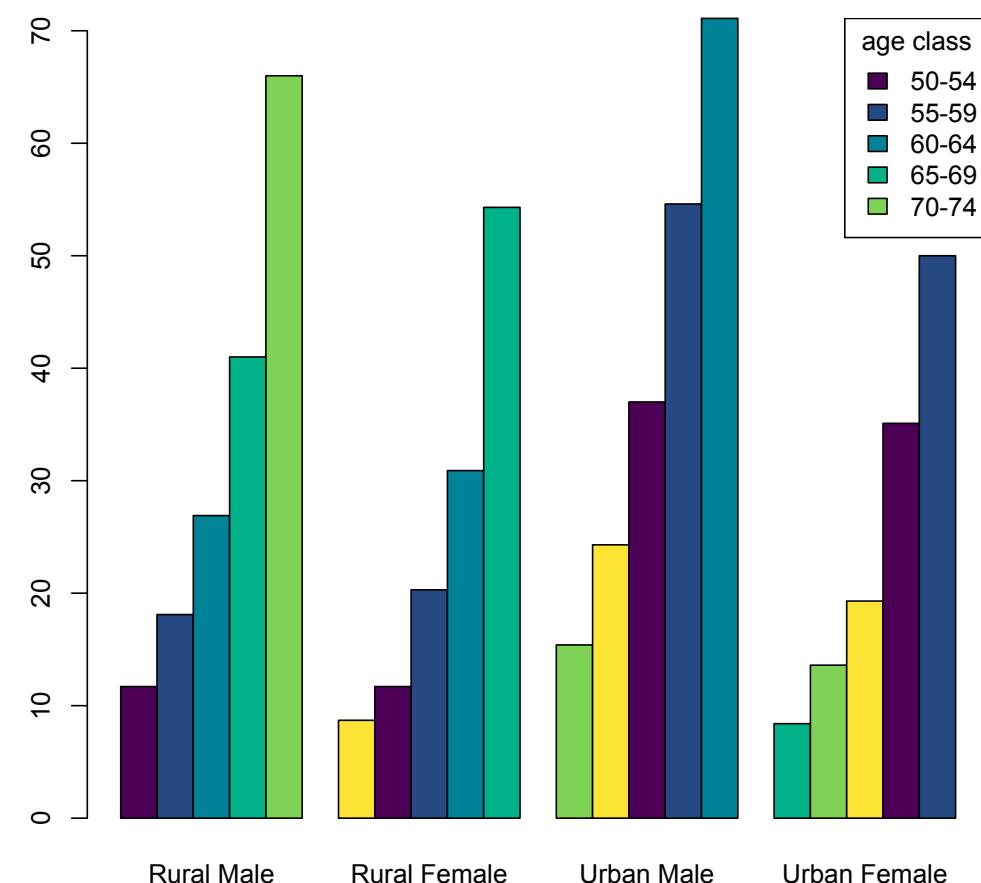


VISUALIZATION: BAR PLOTS

Death Rates in Virginia

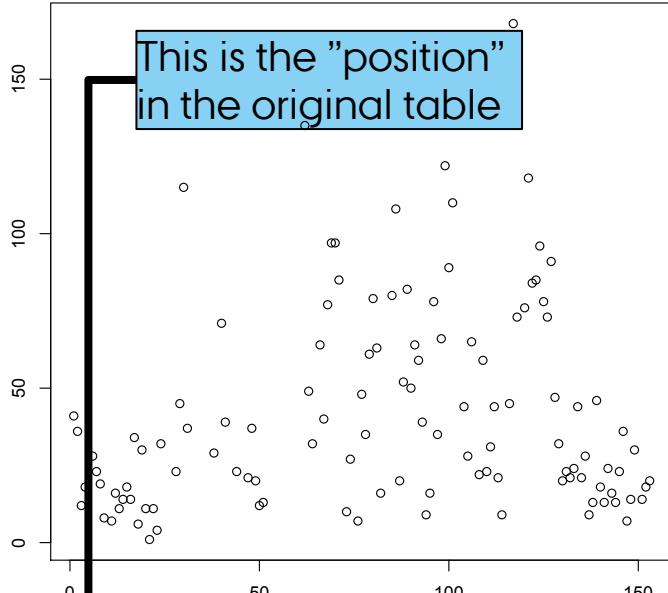


Death Rates in Virginia

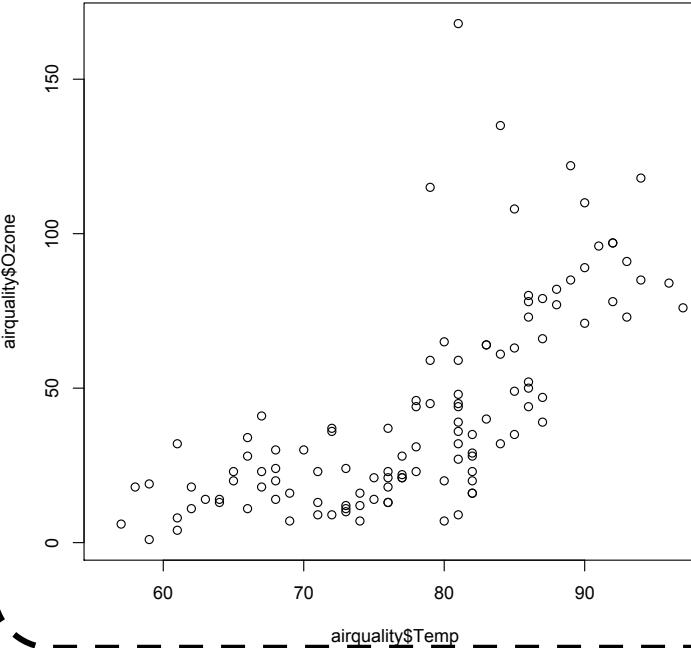


VISUALIZATION: DOTPLOT

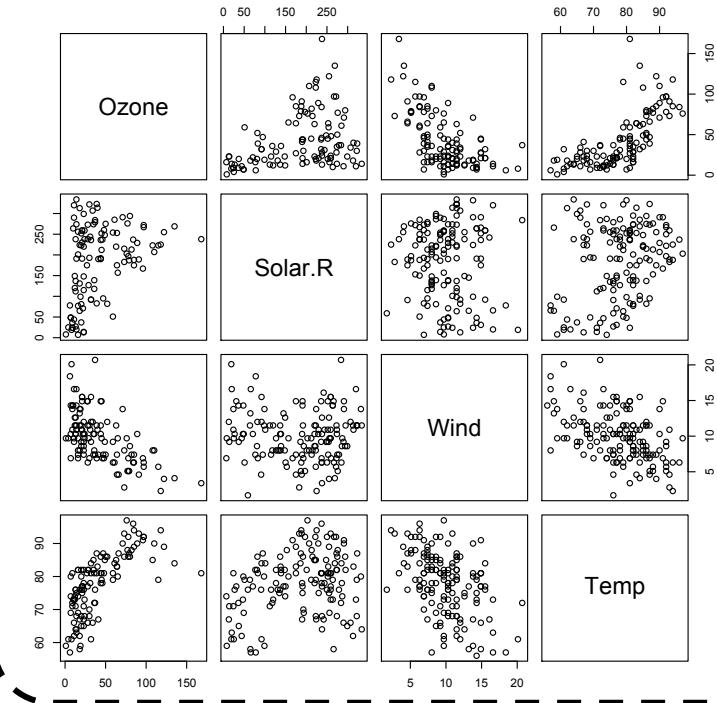
One variable Dotplot



Two variables Scatterplot



Multiple variables Scatterplot

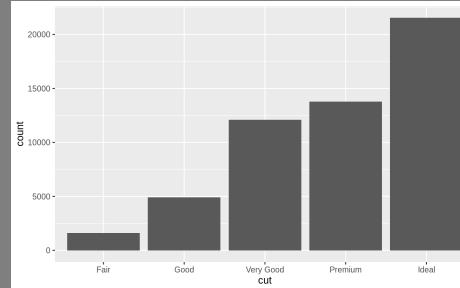


EXPLORATORY DATA ANALYSIS: TOOLS

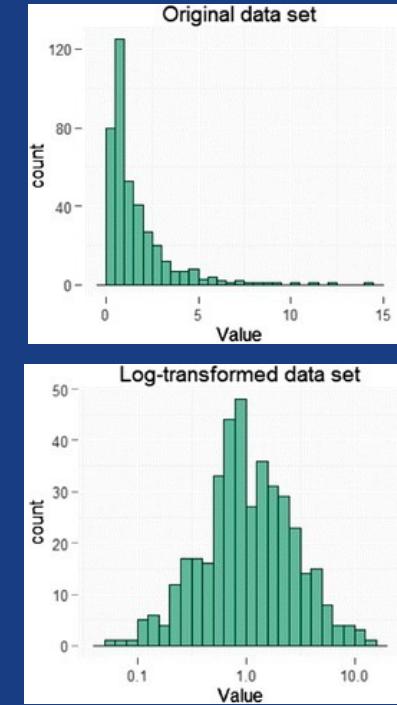
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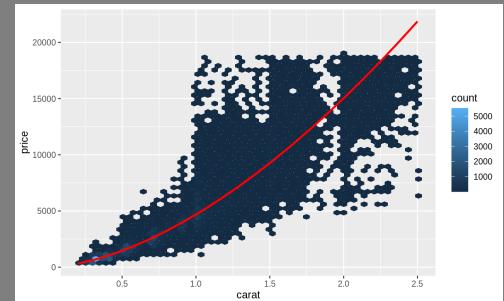
Visualisation



Transformation



Modelling



EDA - TRANSFORMATIONS

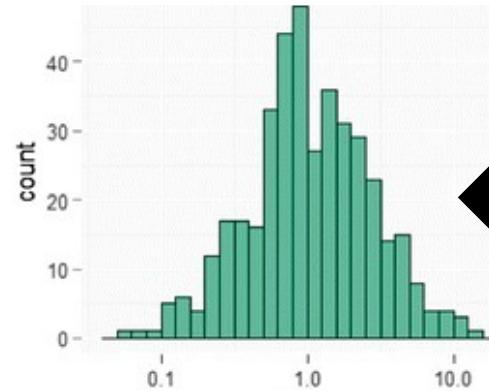
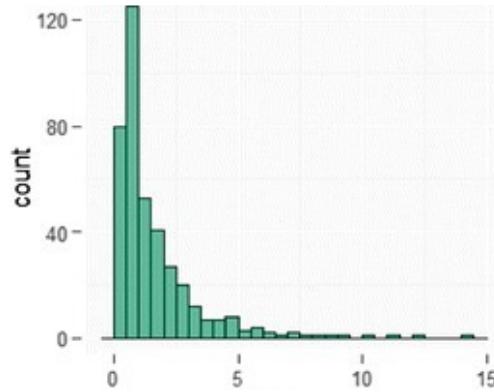
Data transformation: Converting data from one format or structure into another format or structure.

Aims of data transformations are:

1. Make the data and the model error terms closer to a normal distribution.
2. Reduce any relationship between the mean and the variance.
3. Reduce the influence of outliers, especially when they are at one end of a distribution.
4. Make effects that are multiplicative on the raw scale additive on a transformed scale.

EDA - TRANSFORMATIONS

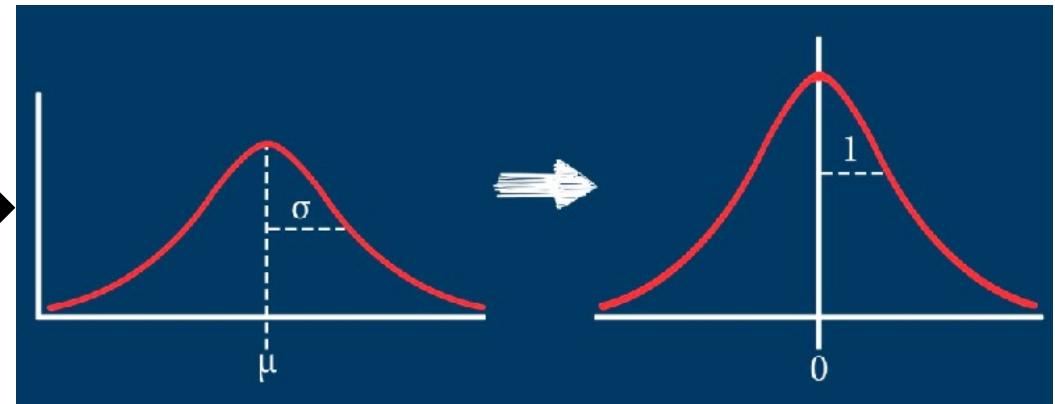
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Normalizing

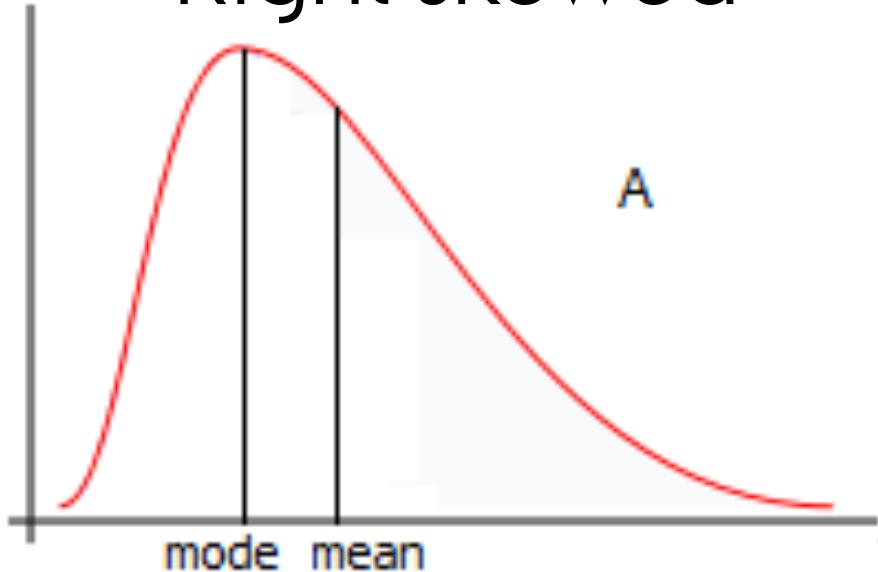
Make the distribution of the data symmetrical

Standardising
Put all variable in units of variation
[mean of 0 and a standard deviation of 1]

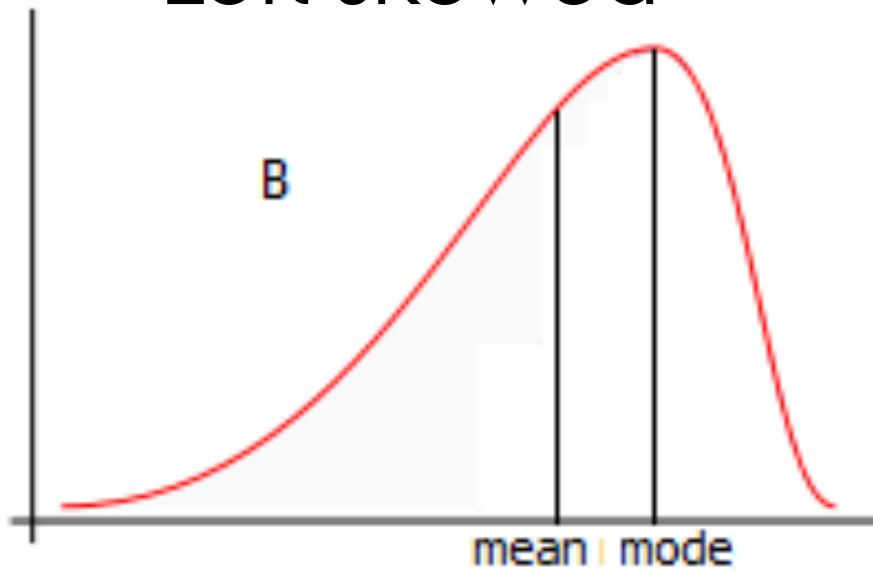


EDA - NORMALIZING

Right skewed



Left skewed



Normalizing these distributions is useful in statistical modelling because:

1. Makes data and errors **Normal**.
2. Reduces relations between Mean and variance.
3. Reduces the influence of outliers.
4. Makes multiplicative effects on a raw scale linear on the transformed scale.

EDA - NORMALIZING

Power [Y^p]: Useful for long tails data

- The Root transformation [$Y^{1/p}$]: Useful for counts data **Which is not normal!!**

Log [$\log(Y+c)$]: make positively skewed (hump on the left side) distributions more symmetrical

Logit [$\log\left(\frac{p}{1-p}\right)$]: Use to make linear portion or probability data **Which is not normal!!**

Arcsine [$\sin^{-1}(Y^{0.5})$]: Use to make linear portion or probability data **Which is not normal!!**

The Box-Cox family of transformations

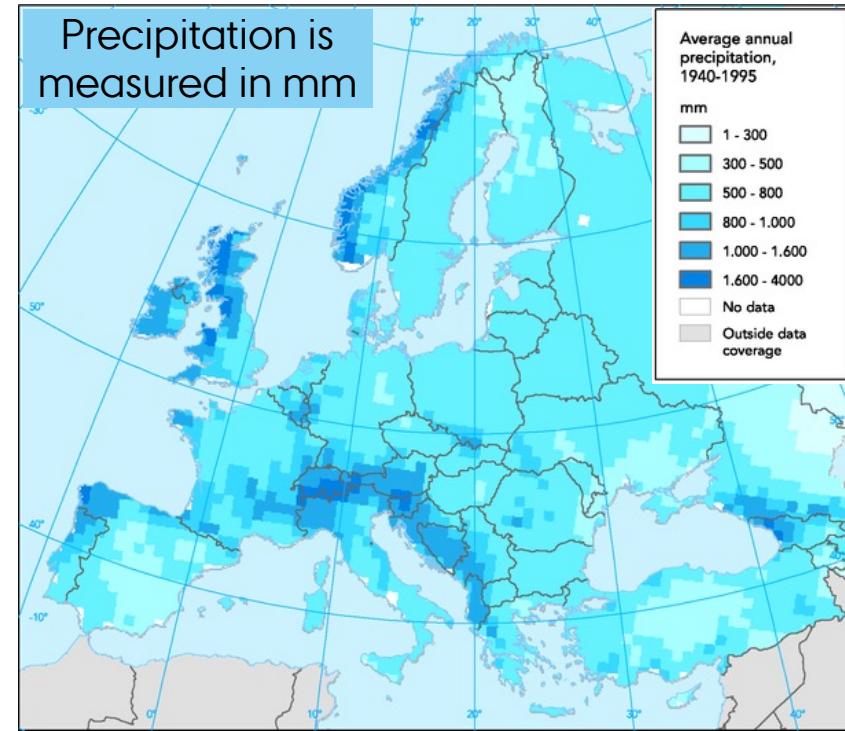
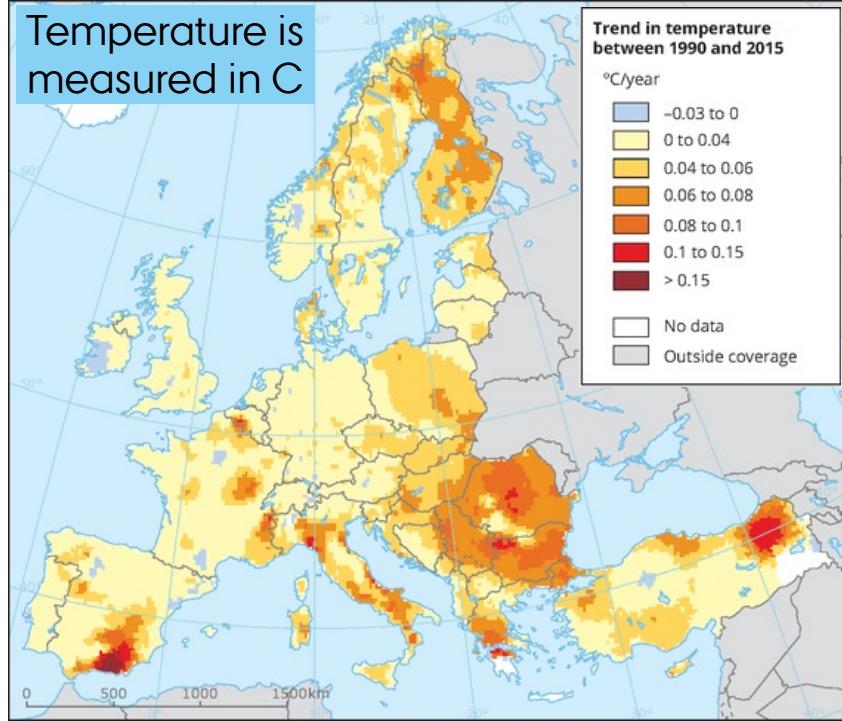
Can also be used to find the best transformation

$$\frac{Y^{\lambda}-1}{\lambda} \text{ when } \lambda \neq 0$$

$$\log(Y) \text{ when } \lambda = 0$$

The goal is achieving normality

EDA - STANDARDISATIONS



Stabilization allows contrasting the effects of variables measured in different units in modelling frameworks

EDA – STANDARDISATIONS

Different standardisations are possible:

Centring: Making the mean Zero

$$y_i = y_i - \bar{y}$$

Ranging: Marking the observations values to range between zero (minimum) to one (maximum)

$$y_i = \frac{y_i}{y_{max}} \text{ or } y_i = \frac{y_i - y_{min}}{y_{max} - y_{min}}$$

Centring and Ranging

useful as standardisations of abundance data before multivariate analyses

Scaling: Changing a variable so it has a mean of zero and a standard deviation (and variance) of one

$$y_i = \frac{y_i - \bar{y}}{s}$$

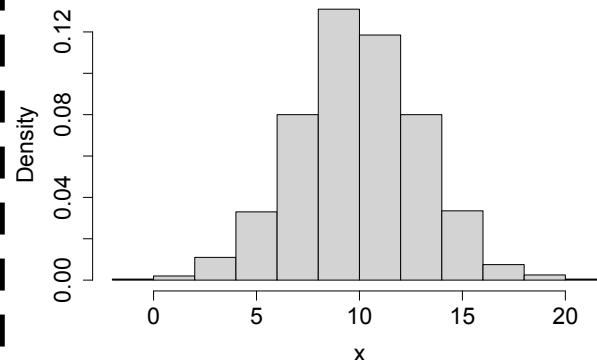
Scaling

useful to convert all the variables to a similar scale

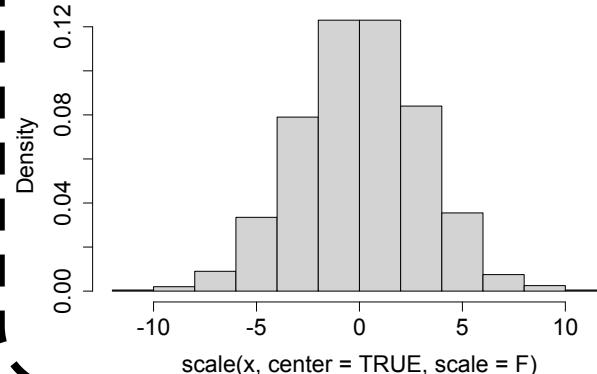
EDA - STANDARDISATIONS

Centring

Original



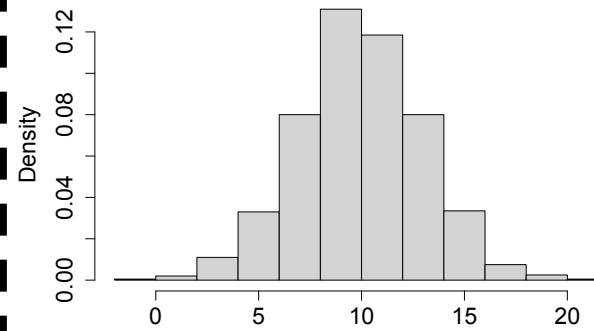
Centered



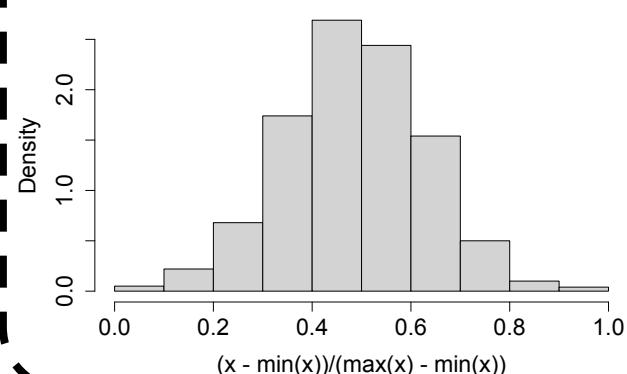
`scale(x, center = TRUE, scale = F)`

Ranging

Original

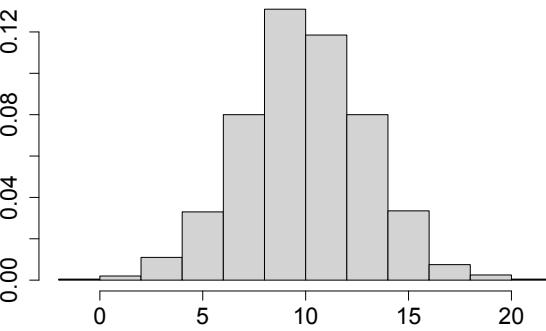


Ranging

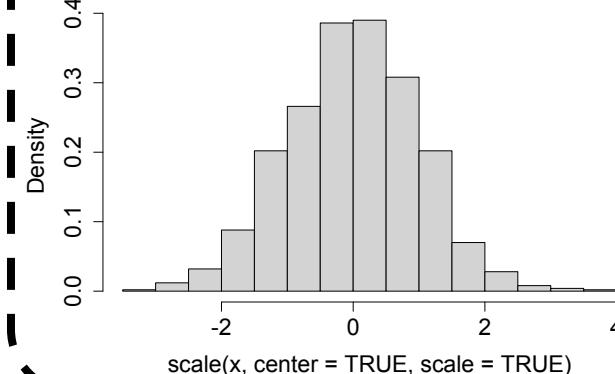


Scaling

Original



Scaled



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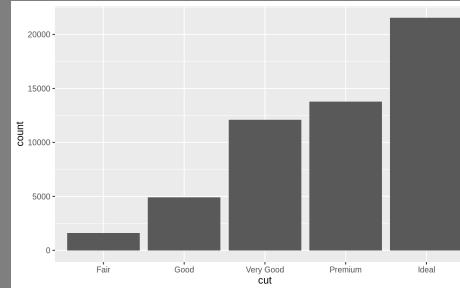


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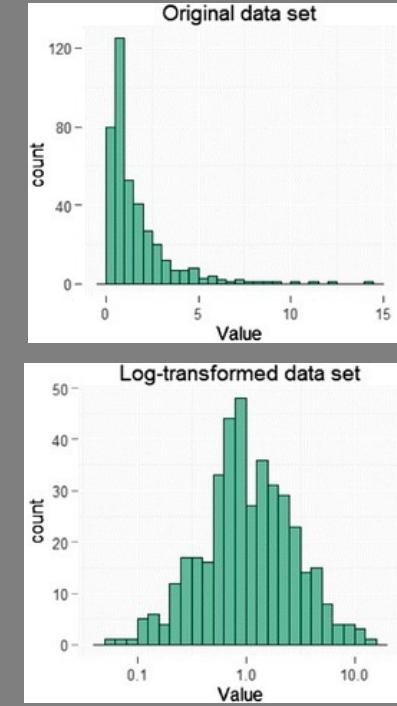
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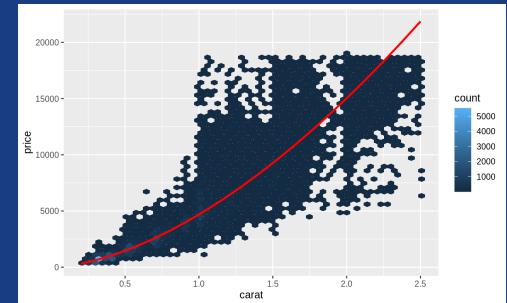
Visualisation



Transformation



Modelling



EDA - MODELLING

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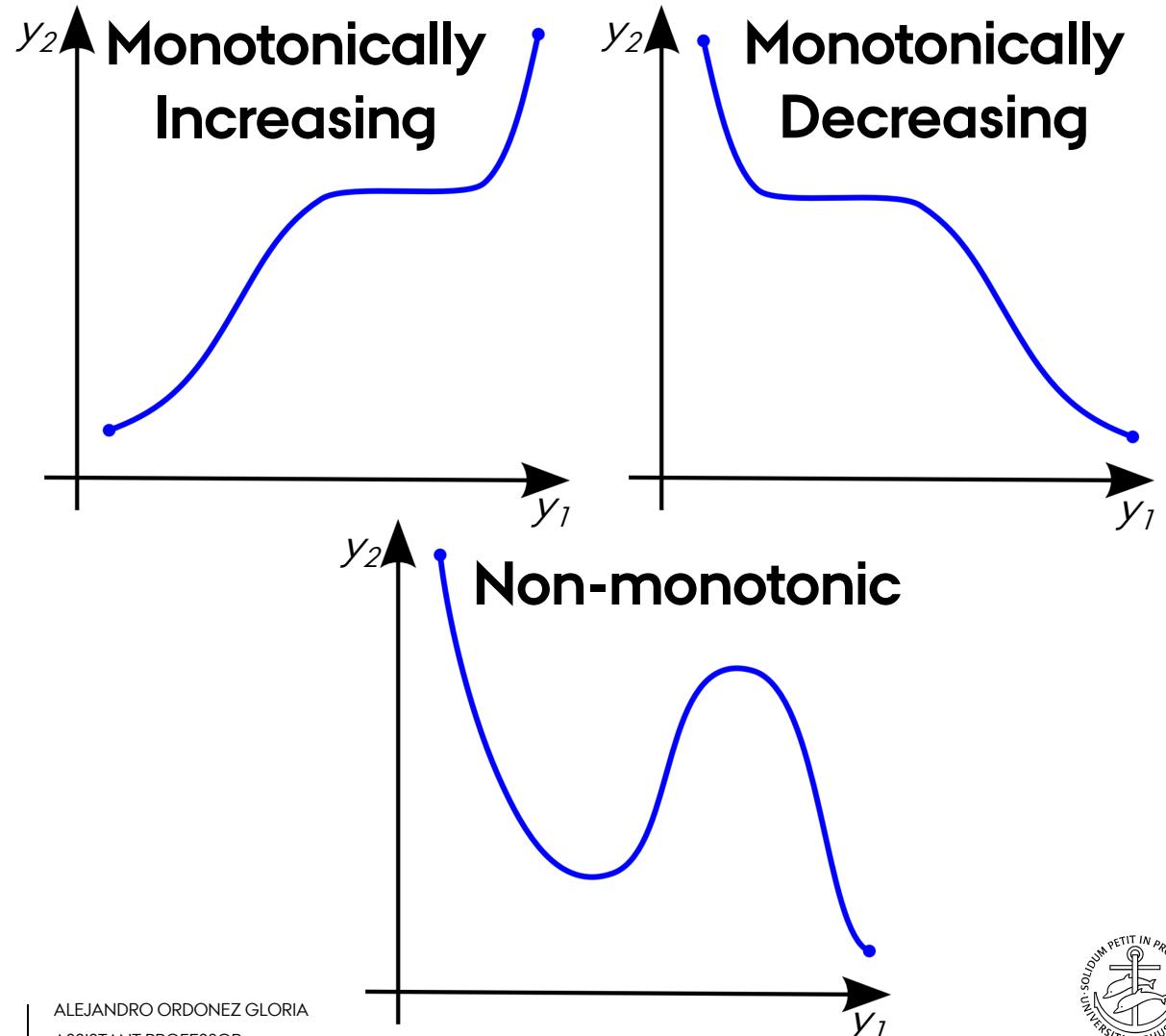
Aims of Modelling before doing any analyses are:

1. Assess regressions assumptions (**more on this next week**).
2. Determine (in)dependence between variables → correlations
3. Establish additive effects if variables are dependent → linearity

MODELLING – CORRELATIONS

Correlation coefficients is a statistical measure which determines the '**strength**' of the **covariance** or **association** of two continuous variables (y_1 and y_2).

- Correlation coefficients assume **monotonic** relations → always changes in the same direction
- Correlation coefficients bounded between -1 and 1



MODELLING - CORRELATION

Parametric indices

Pearson correlation (r)

$$r_{Y_1 Y_2} = \frac{\sum_{i=1}^n [(y_{i1} - \bar{y}_1)(y_{i2} - \bar{y}_2)]}{\sqrt{\sum_{i=1}^n (y_{i1} - \bar{y}_1)^2 \sum_{i=1}^n (y_{i2} - \bar{y}_2)^2}}$$

Other assumptions: normality of variables and linearity

Correlation **DOES NOT** mean directionality or causality.

Non-Parametric indices

Spearman's rank correlation (r_s)

$$r_s = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}.$$

n is the number of pairs d_i is the difference of
of measurements the i^{th} pair of rankings

Kendall's rank correlation (τ_A)

$$\tau_A = \frac{n_c - n_d}{n_0}$$

$$n_0 = n(n - 1)/2$$

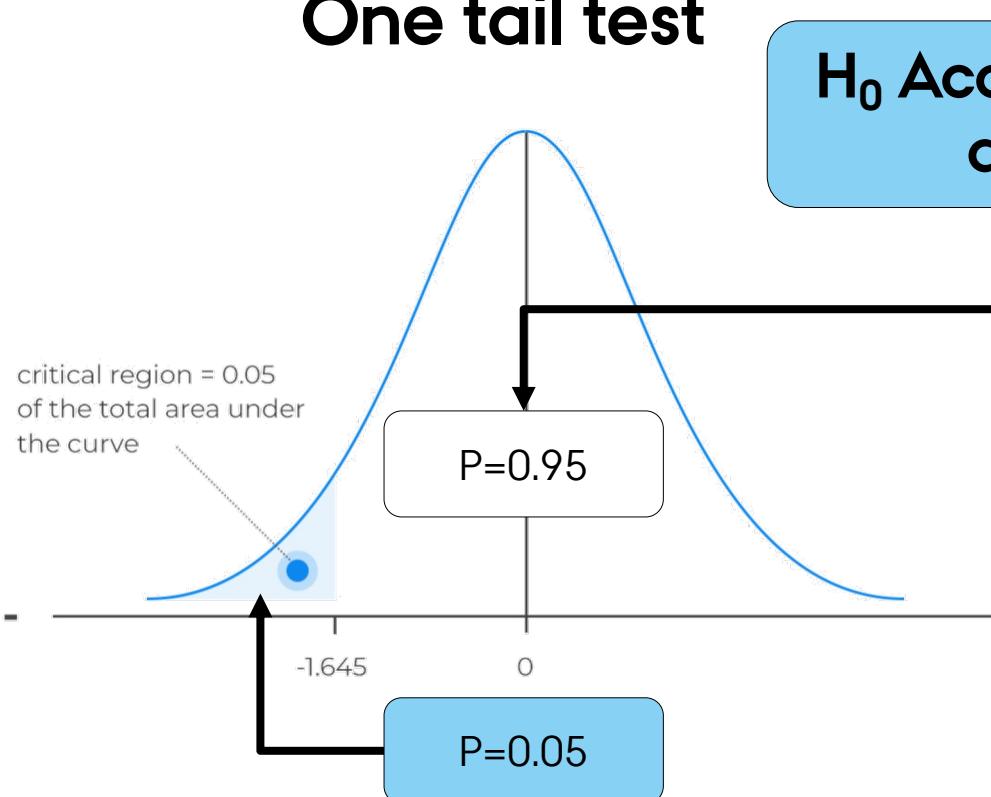
n_c = Number of concordant pairs

n_d = Number of discordant pairs

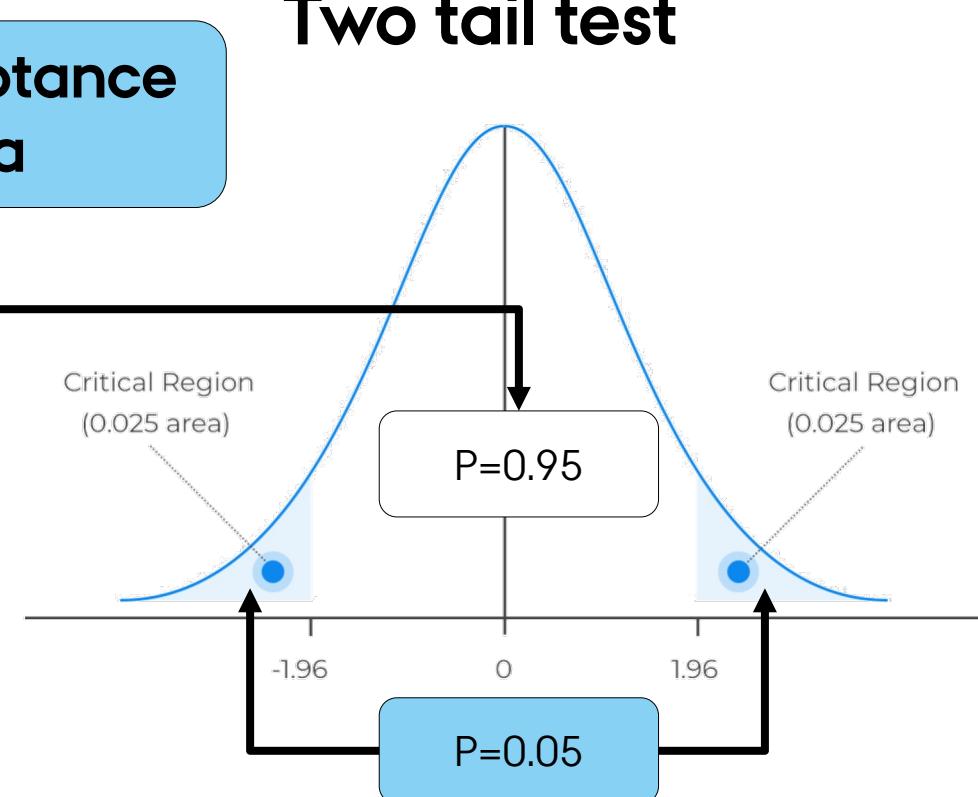
MODELLING – SIGNIFICANCE

Statistically significant means that if the **Null Hypothesis (H_0)** is false.

One tail test



Two tail test

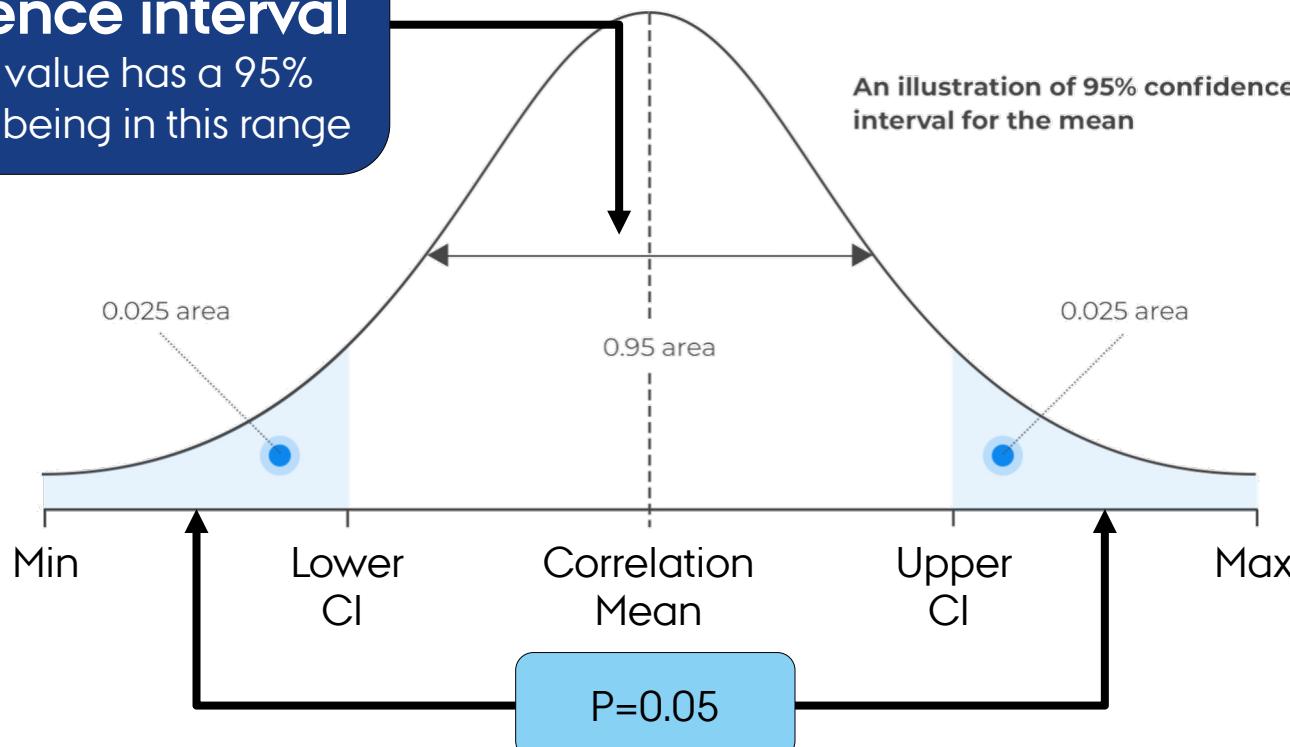


MODELLING - SIGNIFICANCE & CORRELATION

Estimate 95% confidence interval

The **true** value has a 95% chance of being in this range

Two tail test



H_0 = Correlation estimate 95% CI *includes 0*

Confidence Interval Formula

$$CI = \mu \pm t_{\alpha/2} \times \frac{s}{\sqrt{n}}$$

$\frac{s}{\sqrt{n}}$ = Standard deviation

$t_{\alpha/2}$ = T-score

μ = Mean or estimate

So far so good?

Any questions?

Ready to finish?

SUMMARY

Exploratory Data Analysis (**EDA**) is the art of looking at your data
EDA is also the base for statistical analysis of multidimensional
data

Before you stat you need to import and clean your data

The two crucial questions you will **always** ask:

What type of variation occurs within my variables?

What type of covariation occurs between my variables?

SUMMARY

EDA uses **four** main tools:

- **Descriptive statistics**: Quantitative descriptions or summaries of the features from a collection of information.
- **Visualisation**: The graphical representation of information and data to see and understand trends, outliers, and patterns.
- **Transformation**: process of changing the format, structure, or values of data
- **Modelling**: simple low-dimensional summaries of a dataset, and trends assessments.



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