IntelliPaat

Data Science

Statistics

Agenda

01 Introduction to Statistics

02 Categories of Statistics

03 Measures of Central Tendency & Spread

04 Probability

05 Covariance & Correlation

06 Hypothesis Testing

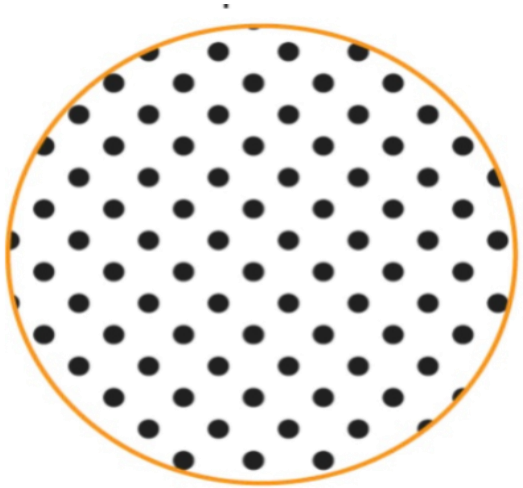
Introduction to Statistics

Statistics is a very broad subject, with applications in a vast number of different fields. Generally, one can say that statistics is the methodology for collecting, analyzing, interpreting and drawing conclusions from information.

Statistical Terminology

Statistical Terminology

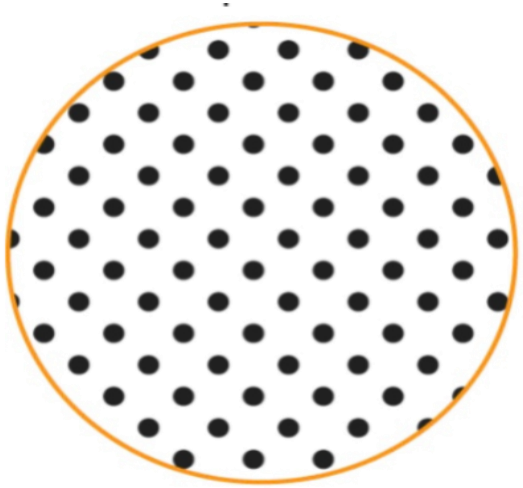
A **population** includes all of the elements from a set of data.



A **sample** consists one or more observations drawn from the population.

Statistical Terminology

Population

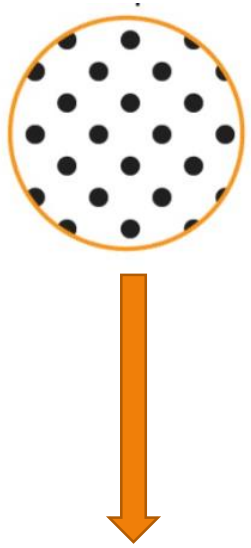


A collection of all items of interest to our study

N

Parameters

Sample



A subset of the population

n

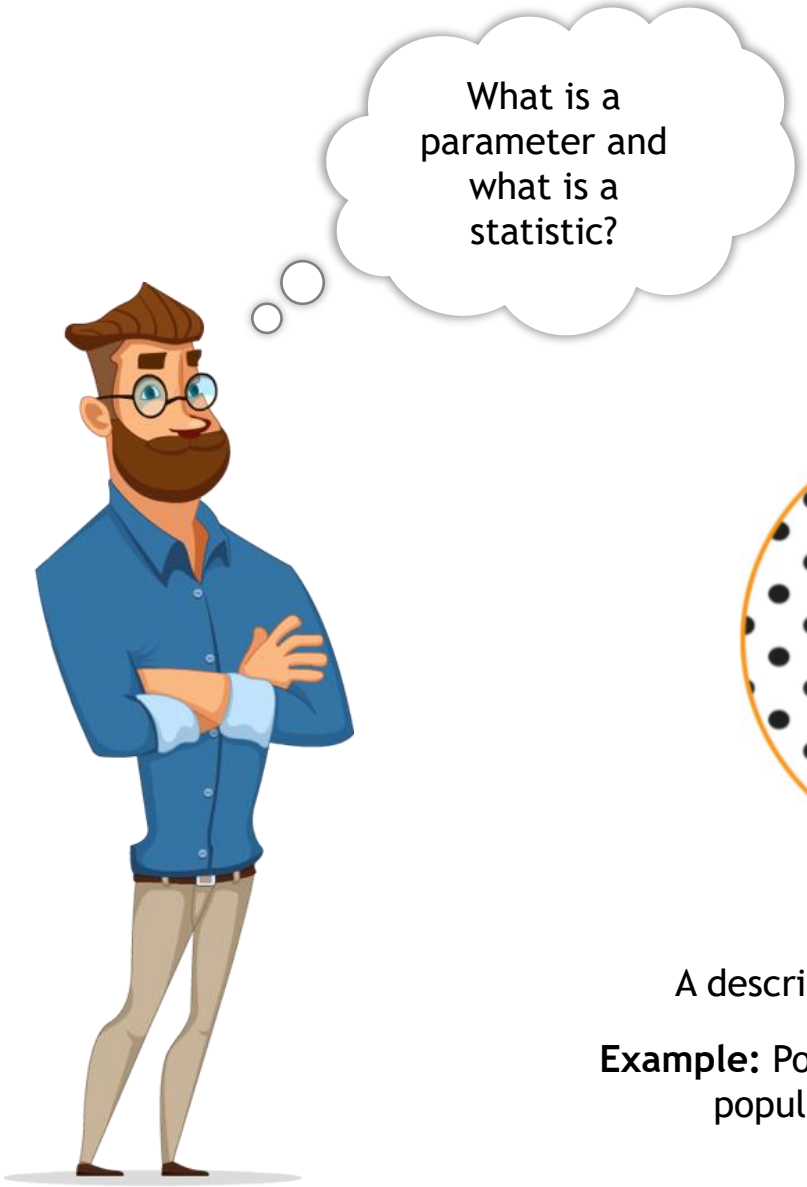
Statistics

Statistical Terminology

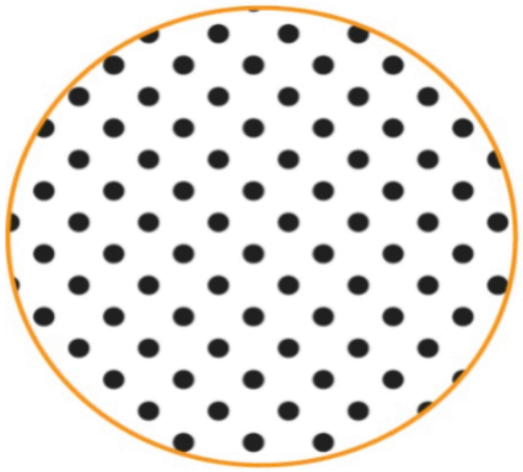
Census
Gathering data from the whole population of interest

Survey
Gathering data from a sample in order to make conclusions about the population

Statistical Terminology



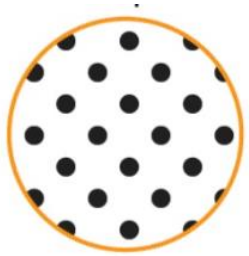
Population



Parameter
A descriptive measure of the population

Example: Population mean, population variance, population standard deviation, etc.

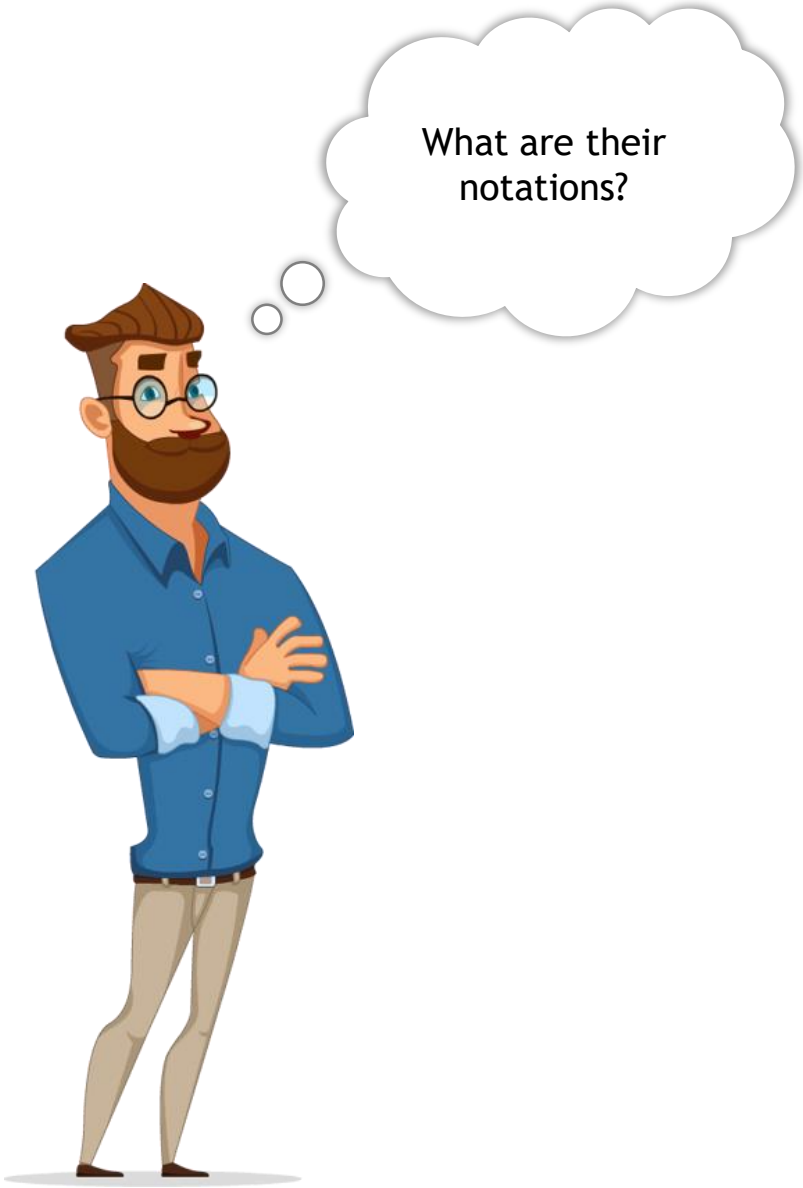
Sample



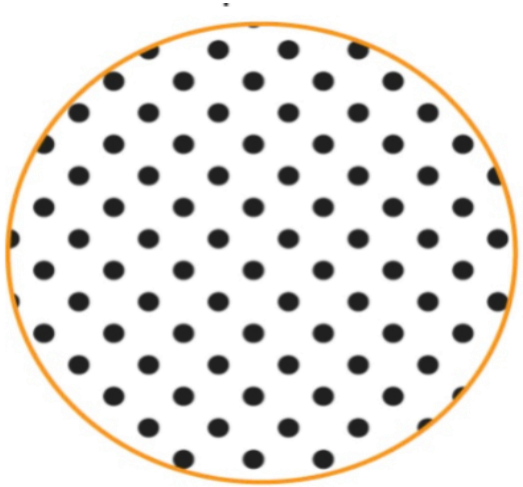
Statistic
A descriptive measure of the sample

Example: Sample mean, sample variance, sample standard deviation, etc.

Statistical Terminology



Population



Greek - Population Parameter

Mean - μ

Variance - σ^2

Standard Deviation - σ

Sample

Roman - Sample Statistic

Mean - $\bar{x}$

Variance - s^2

Standard Deviation - s

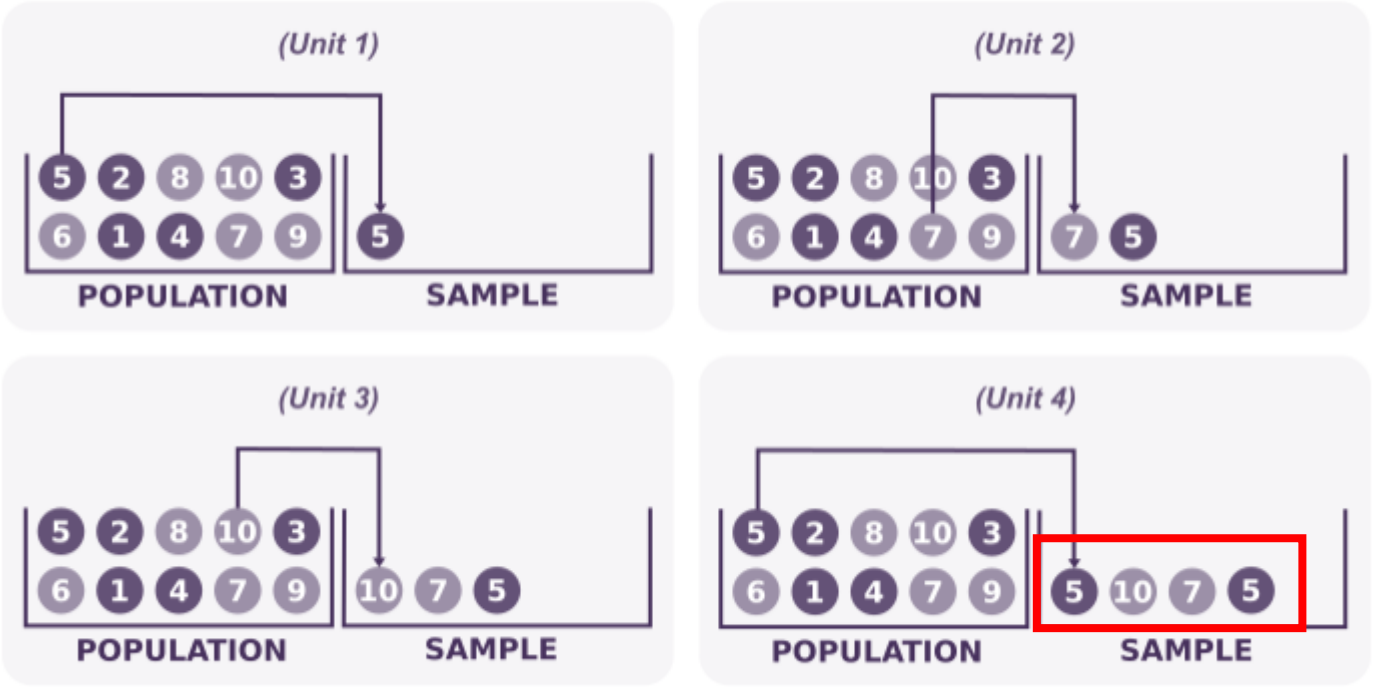
Sampling

Sampling

Sampling Techniques

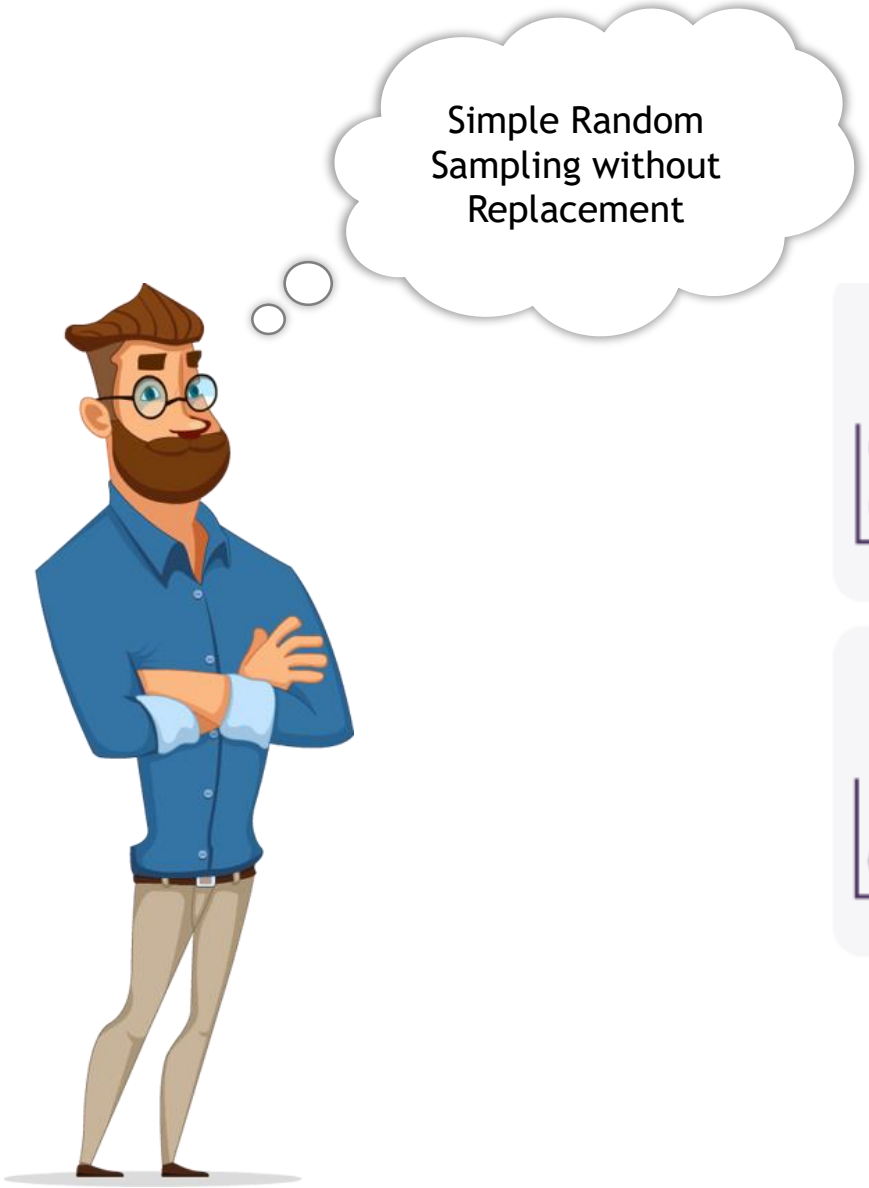
Simple Random Sampling

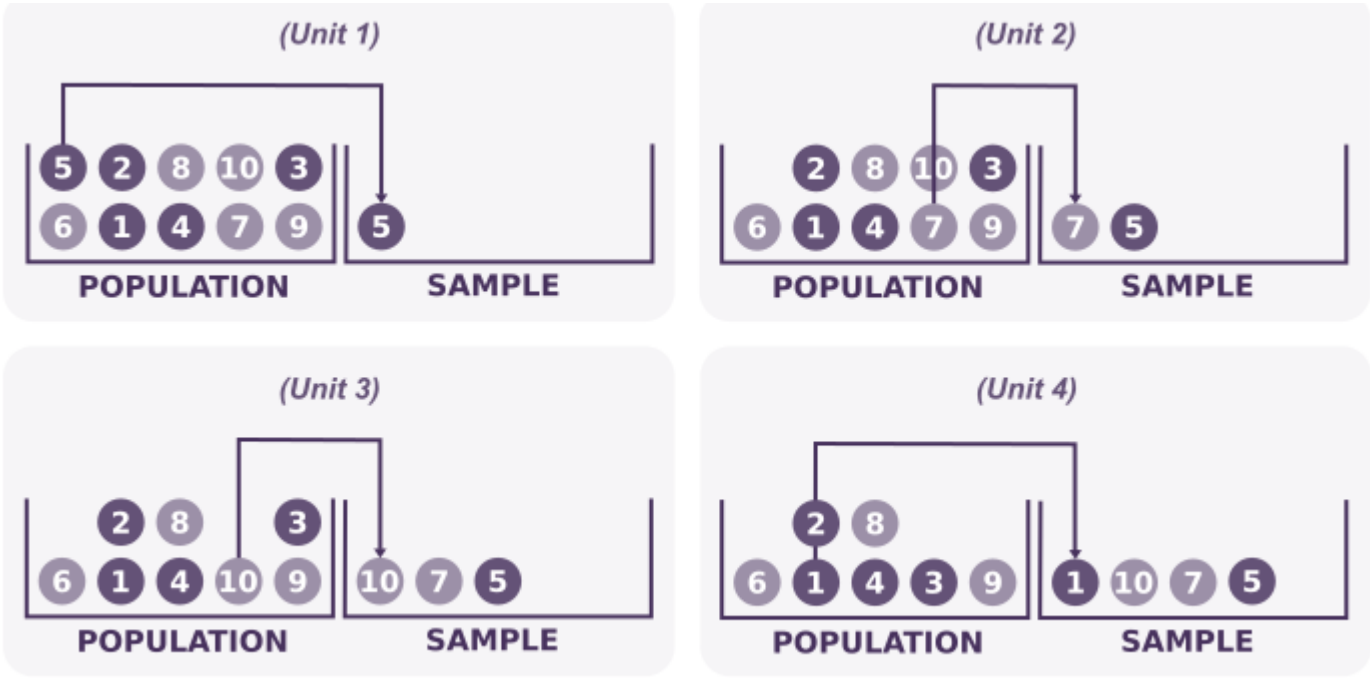
Every subject in the population has an equal chance of being selected.
Randomly picking subjects from the whole population



Simple Random Sampling with Replacement

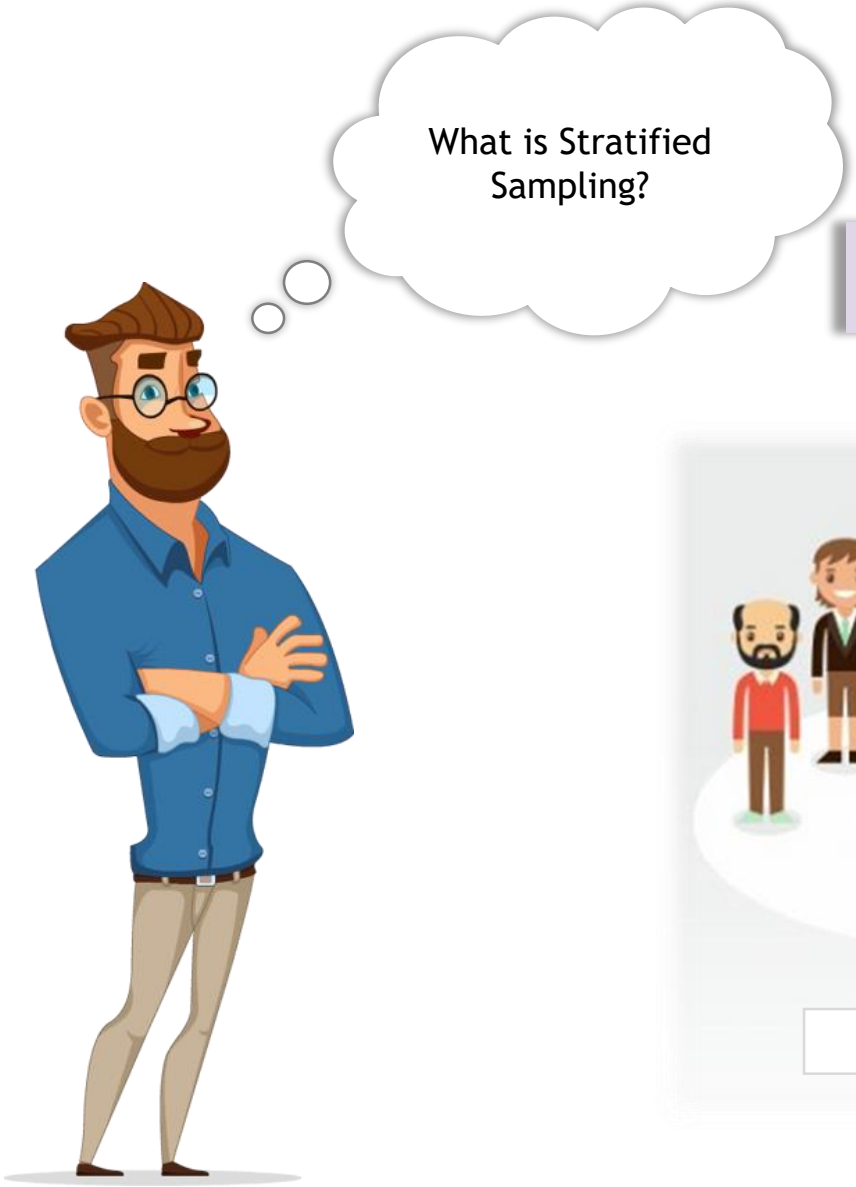
Simple Random Sampling



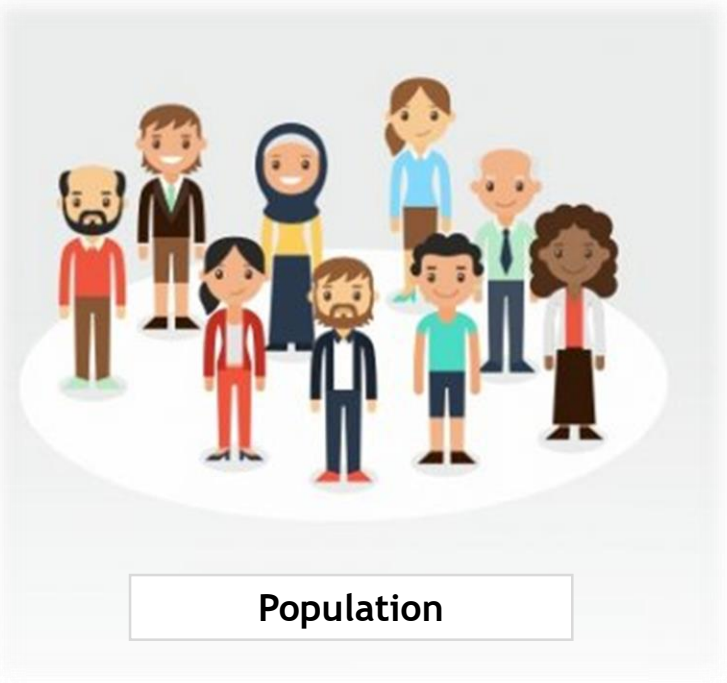


Simple Random Sampling without Replacement

Stratified Sampling



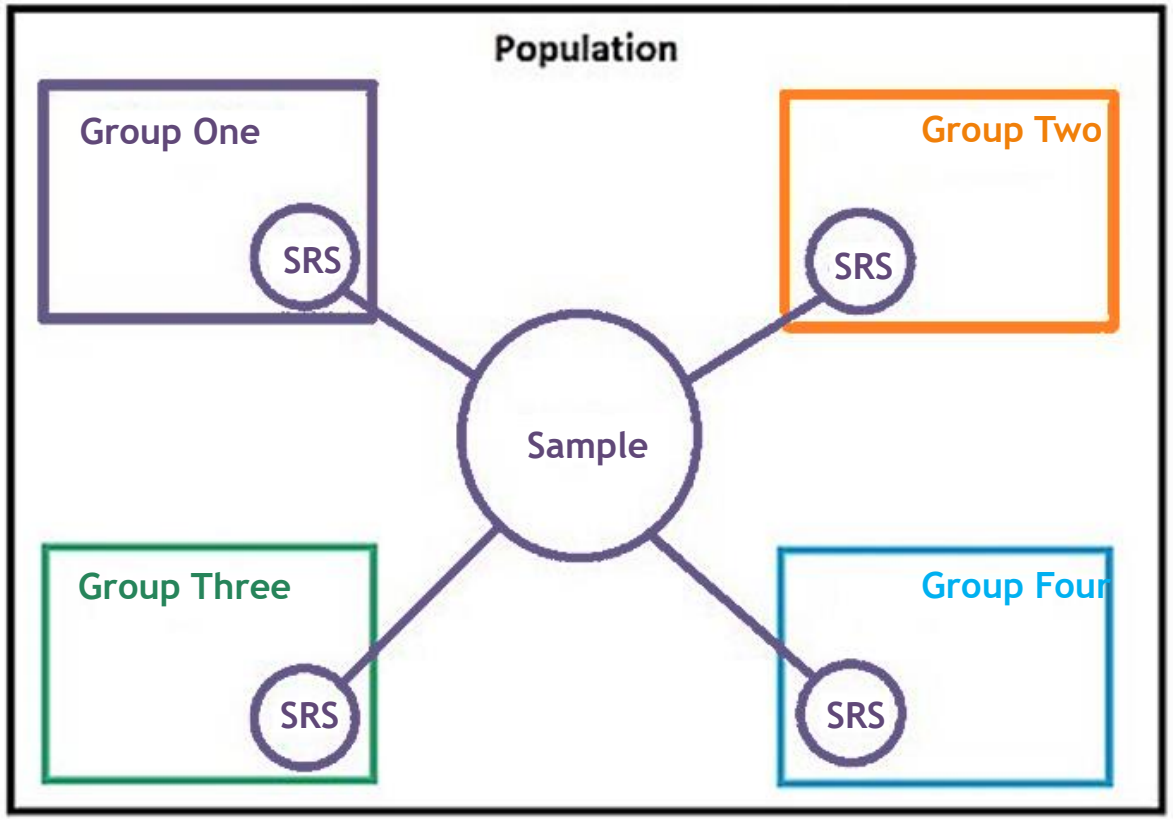
The population is partitioned into non-overlapping groups called strata, and a sample is selected by some design within each stratum.



Population

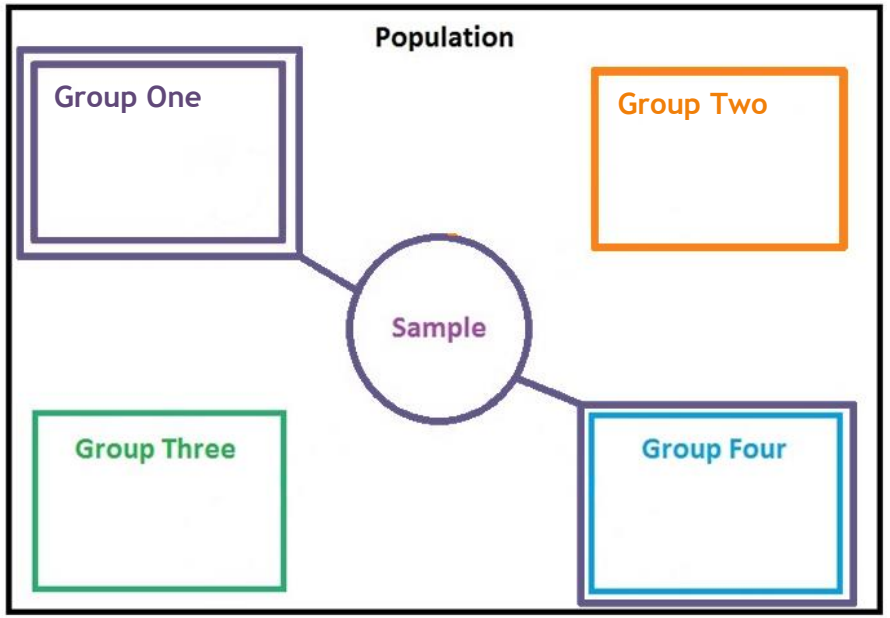
Strata

Stratified Sampling

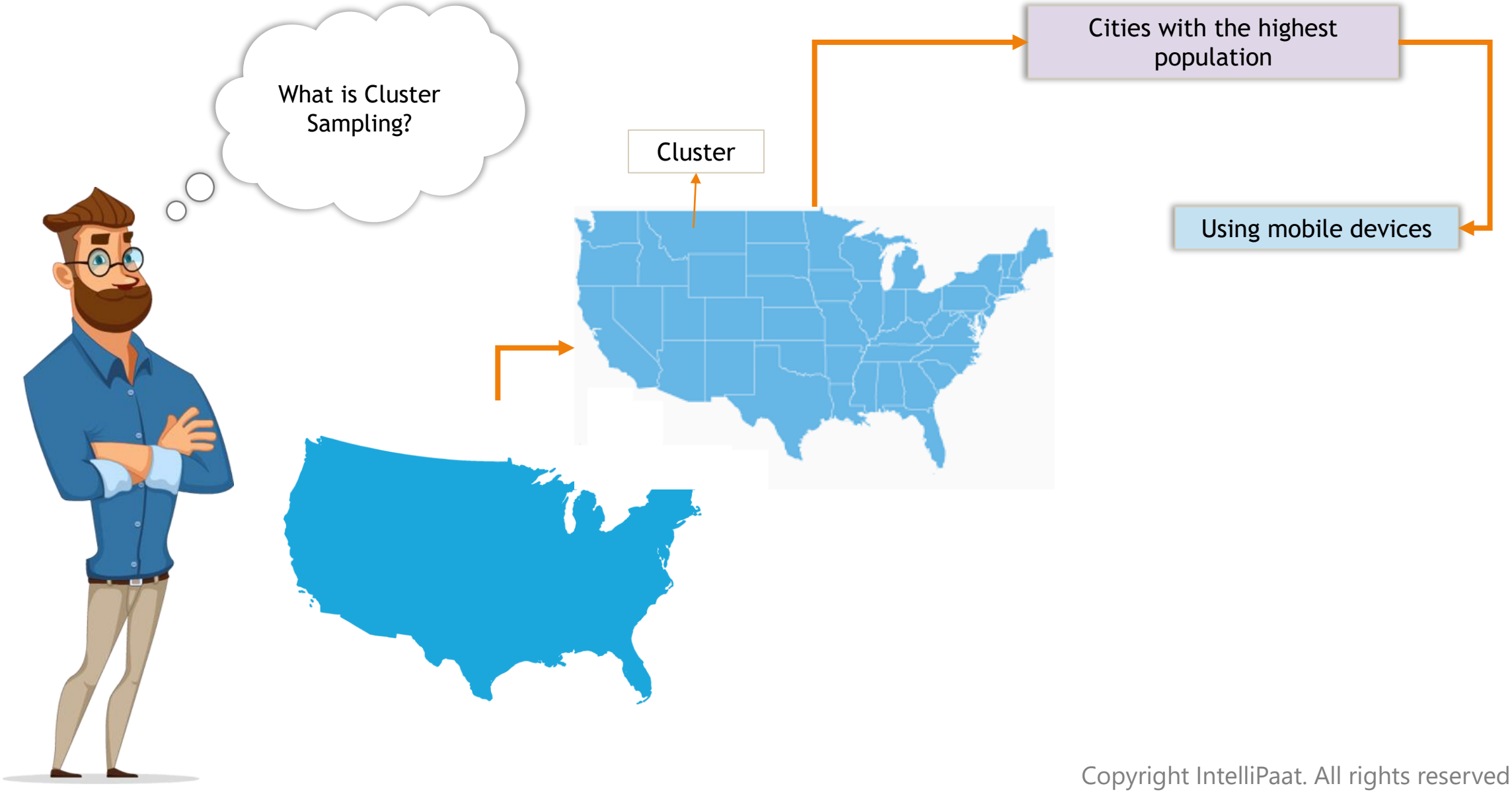


Cluster Sampling

- Divide the population into groups (clusters)
- Obtain a simple random sample of clusters from all possible clusters
- Obtain data on every sampling unit in each of the randomly selected clusters

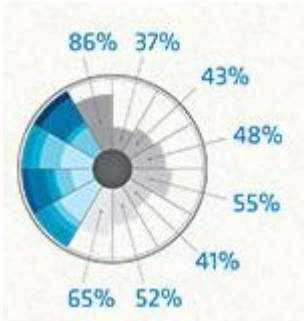


Cluster Sampling

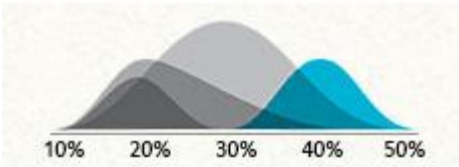


Categories of Statistics

Categories of Statistics

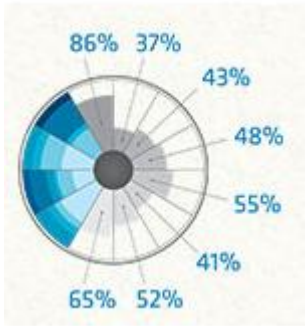


Descriptive Statistics



Inferential Statistics

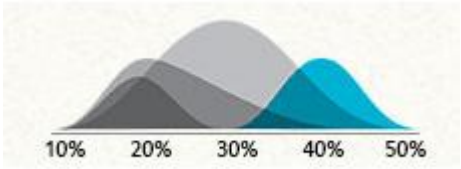
Categories of Statistics



The analysis of data that helps describe, show or summarize the data in a meaningful way such that, for example, patterns might emerge from the data.

Just describes and summarizes data

Categories of Statistics

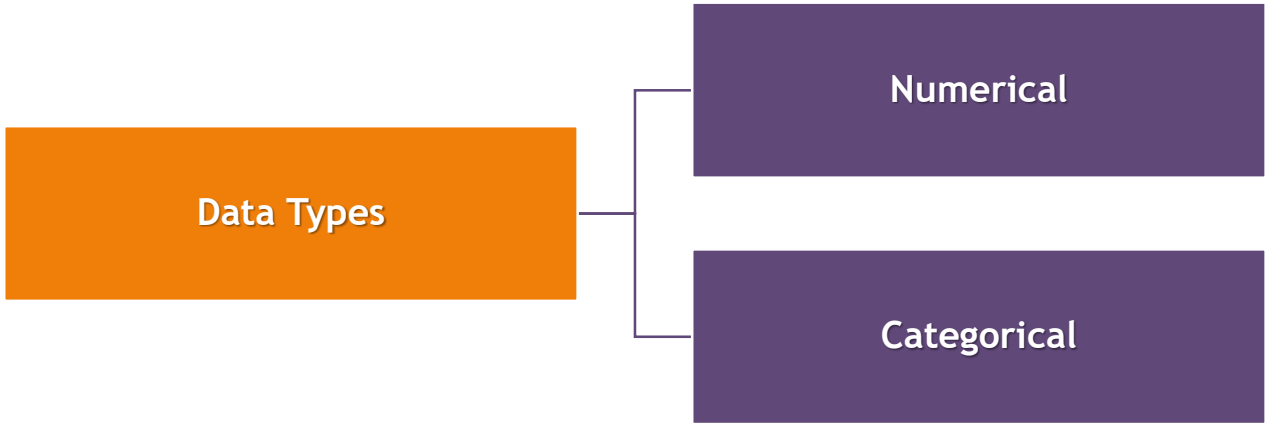


Inferential Statistics takes data from a sample and makes inferences about the larger population from which the sample was drawn.

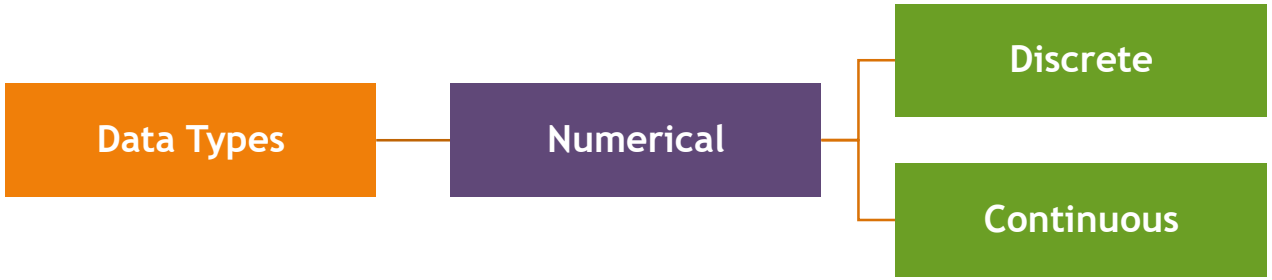
Studies a sample of the same data

Types of Data

Types of Data



Types of Data - Numerical Data



- Deals with numbers
- Data which can be measured
- Length, height, area, volume, weight, speed, time, temperature, humidity, sound, etc.

Types of Data - Numerical Data

Values or observations that is counted as distinct and separate and can only take particular values

Counted

Types of Data - Numerical Data

You can measure continuous data. Values or observations may take on any value within a finite or infinite interval.

Measured

Temperature?

- - 10
- -5
- 0
- + 5
- + 10
- + 15

Types of Data - Categorical Data

Types of Data - Categorical Data

Values or observations can be ranked (put in order) or have a rating scale attached. You can count and order but not measure ordinal data.

Logical Ordering

How do you feel today?

- 1 – Very Unhappy
- 2 – Unhappy
- 3 – OK
- 4 – Happy
- 5 – Very Happy

How satisfied are you with our service?

- 1 – Very Unsatisfied
- 2 – Somewhat Unsatisfied
- 3 – Neutral
- 4 – Somewhat Satisfied
- 5 – Very Satisfied

Types of Data - Categorical Data

Values or observations can be assigned a code in the form of a number where the numbers are simply labels. You can count but not order or measure nominal data.

Name or Label

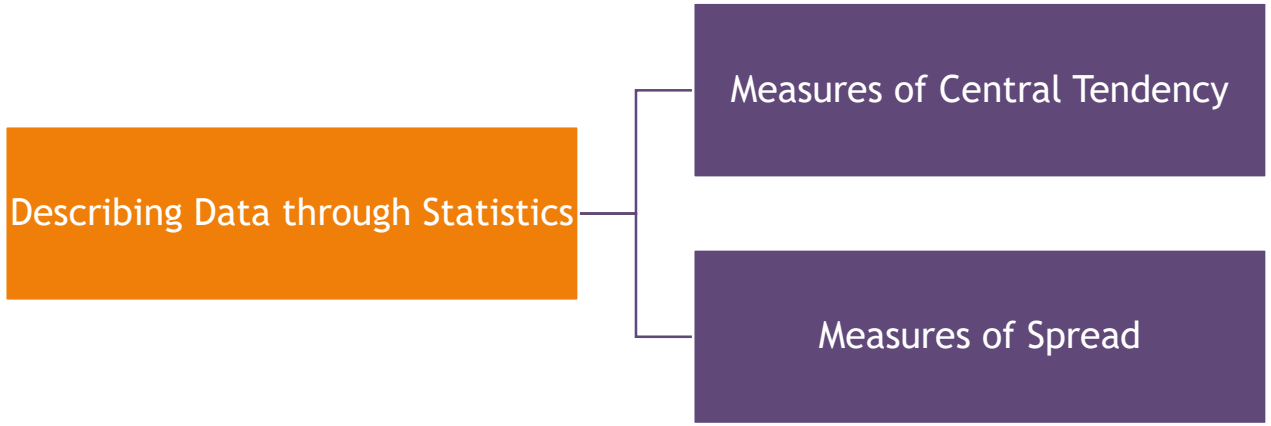
What is your gender?
- M – Male
- F – Female

What is your hair color?
- 1 – Brown
- 2 – Black
- 3 – Blonde
- 4 – Gray
- 5 – Other

Where do you live?
- A – North of the equator
- B – South of the equator
- C – Neither: In the international space station

Describing Data through Statistics

Describing Data through Statistics



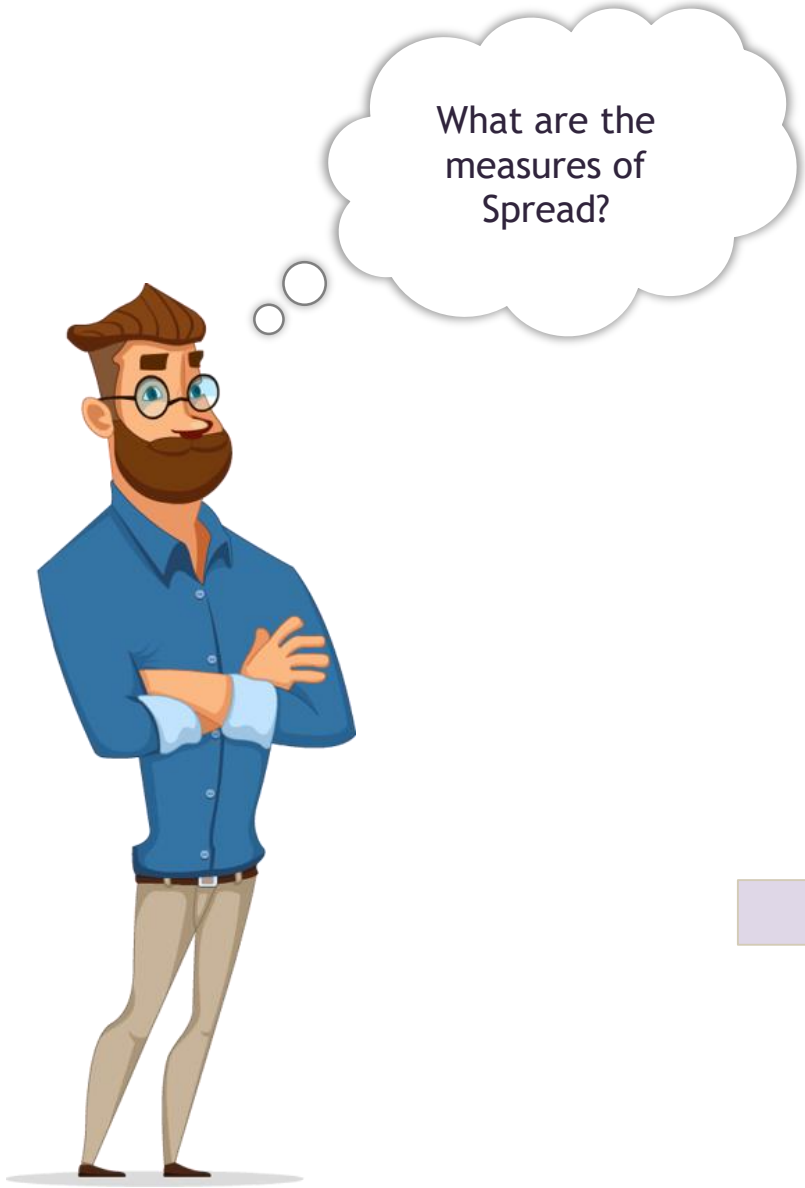
Describing Data through Statistics

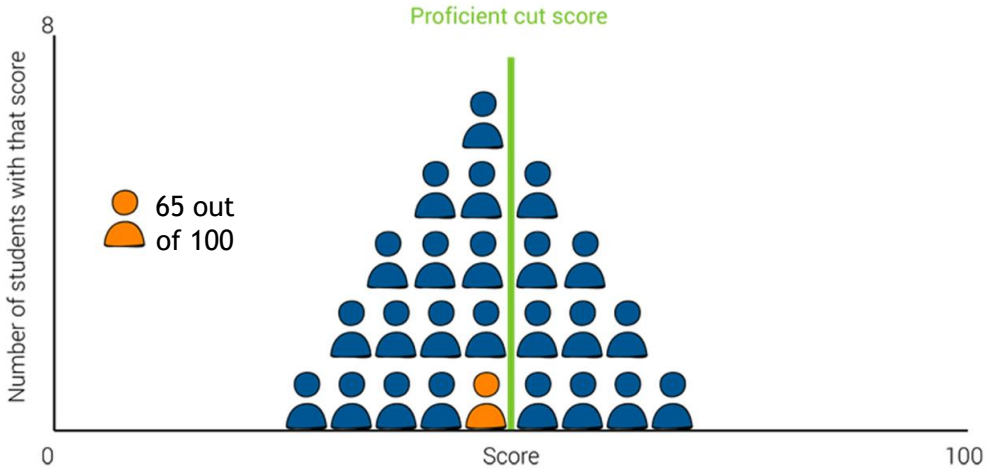
These are ways of describing the central position of a frequency distribution for a group of data.

Mean | Median | Mode

Summarize a bunch of scores with a single number

Describing Data through Statistics





These are ways of summarizing a group of data by describing how spread out the scores are.

Range | Quartiles | Variance | Standard Deviation

Know the spread of scores within a bunch of scores

The Central Tendencies

Mean

The mean is the most common measure of center. It is what most people think of when they hear the word "average". However, the mean is affected by extreme values so it may not be the best measure of center to use in a skewed distribution.

Used with both discrete and continuous data

$$Mean = \bar{x} = \frac{\sum_i^n x_i}{n} = \frac{x_1, x_2, x_3, \ldots xi}{i}$$

$$Mean = \frac{(1+2+3+4+5)}{5} \rightarrow \frac{15}{5} \rightarrow 3$$

Trimmed Mean

A variation of the mean, which you calculate by dropping a fixed number of sorted values at each end and then taking average of the remaining values.
Trimmed mean with *p* smallest and largest values omitted

Marks of 5 student = 67, 15, 75, 72, 85

$$\textit{Trimmed Mean} = \bar{x} = \frac{\sum_{i=p+1}^{n-p} x_i}{n-2p}$$

$$\textit{Trimmed Mean} = \frac{(67+75+72)}{3} \rightarrow \frac{214}{3} \rightarrow 71.3$$

Implementation in R

customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService
7590-VHVEG	Female	0	Yes	No	1	No
5575-GNVDE	Male	0	No	No	34	Yes
3668-QPYBK	Male	0	No	No	2	Yes
7795-CFOCW	Male	0	No	No	45	No
9237-HQITU	Female	0	No	No	2	Yes
9305-CDSKC	Female	0	No	No	8	Yes
1452-KIOVK	Male	0	No	Yes	22	Yes
6713-OKOMC	Female	0	No	No	10	No
7892-POOKP	Female	0	Yes	No	28	Yes
6388-TABGU	Male	0	No	Yes	62	Yes
9763-GRSKD	Male	0	Yes	Yes	13	Yes

```
mean(customer_churn$MonthlyCharges)
```

Median

The median is the middle number in a sorted list of the data.

$$\boldsymbol{Median} = \frac{n+1}{2}$$

If n =7, $\boldsymbol{Median} = \frac{7+1}{2}$ = 4th value

$$\boldsymbol{Median} = \frac{n}{2}, \left(\frac{n}{2}\right) + 1$$

If n =6, $\boldsymbol{Median} = \frac{6}{2}, \left(\frac{6}{2}\right) + 1$ = 3rd and 4th value

Median

If we have more outliers in our datasets, then it is best to use median than mean because mean will give poor central tendency.

An outlier is a rare chance of occurrence within a given dataset.

Implementation in R

customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService
7590-VHVEG	Female	0	Yes	No	1	No
5575-GNVDE	Male	0	No	No	34	Yes
3668-QPYBK	Male	0	No	No	2	Yes
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7892-POOKP	Female	0	Yes	No	28	Yes
6388-TABGU	Male	0	No	Yes	62	Yes
9763-GRSKD	Male	0	Yes	Yes	13	Yes

```
median(customer_churn$MonthlyCharges)
```

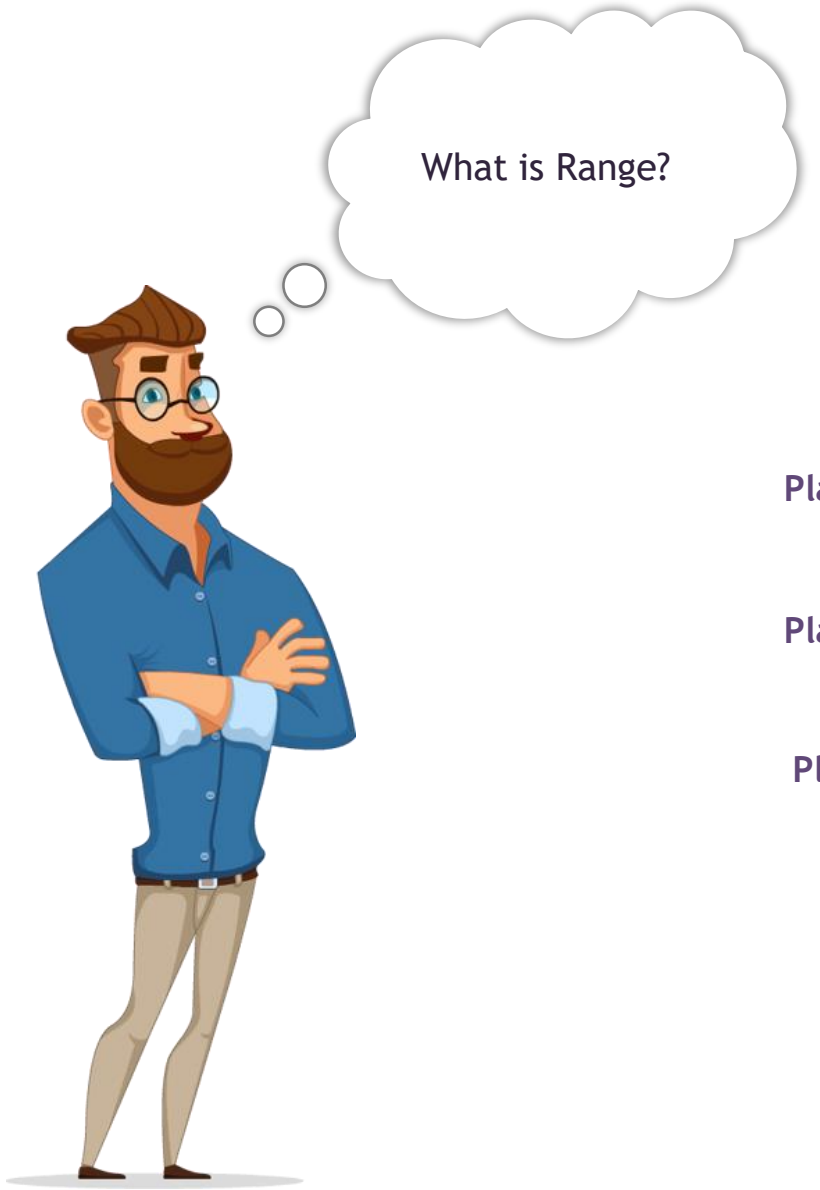
Mode

The most frequently occurring data point

Mean and median need not be in a dataset, but mode has to be in it.

Variability and Spread

Range



Range = Max − Min

Player 1 = 13 – 7

Points scored per game	7	8	9	10	11	12	13
Frequency, f	1	1	2	2	2	1	1

Player 2 = 13 – 7

Points scored per game	7	9	10	11	13
Frequency, f	1	2	4	2	1

Player 3 = 30 – 3

Points scored per game	3	6	7	10	11	13	30
Frequency, f	2	1	2	3	1	1	1

Implementation in R

customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService
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5575-GNVDE	Male	0	No	No	34	Yes
3668-QPYBK	Male	0	No	No	2	Yes
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6388-TABGU	Male	0	No	Yes	62	Yes
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```
range(customer_churn$MonthlyCharges)
```

Quartiles

Quartiles tell us about the spread of a dataset by breaking the dataset into quarters, just like the median breaks it in half.

Lower quartile (25th percentile, Q1) = $\frac{(n+1)}{4}$th

Middle quartile = Median = $\frac{2*(n+1)}{4}$th

Upper quartile (75th percentile, Q3) = $\frac{3*(n+1)}{4}$th

Interquartile range, IQR = Q3-Q1 (central 50% of data)

Implementation in R

customerID	gender	SeniorCitizen	Partner	Dependents	tenure	PhoneService
7590-VHVEG	Female	0	Yes	No	1	No
5575-GNVDE	Male	0	No	No	34	Yes
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6388-TABGU	Male	0	No	Yes	62	Yes
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```
IQR(customer_churn$MonthlyCharges)
```

Variance & Standard Deviation

The variance of the data is the average squared distance between the mean and each data value.

Variance = $(Unit)^2$

Variance of length = $(m)^2$

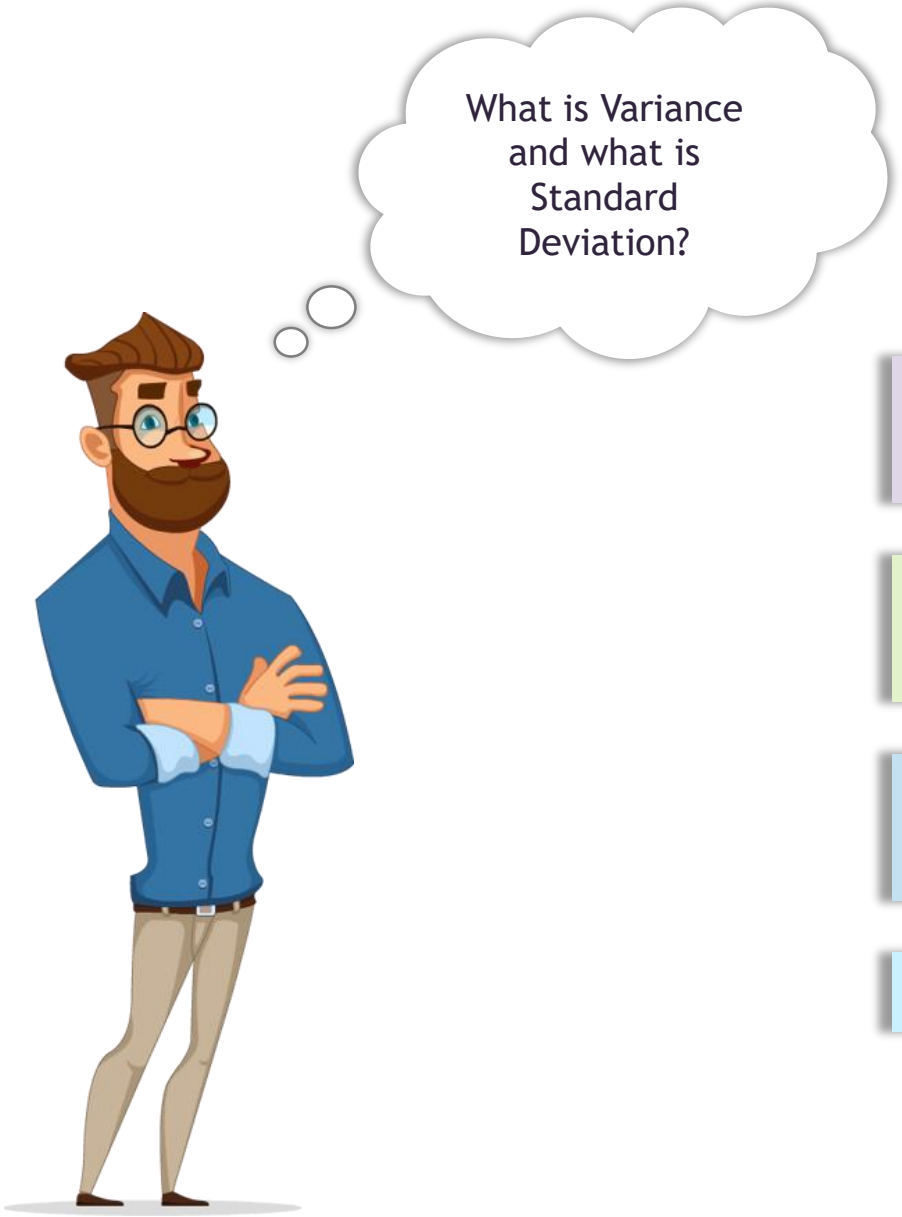
Standard deviation measures how spread out the values in a dataset are around the mean. Square root of the variance

Variance & Standard Deviation

$$\text{Variance} = S^2 = \frac{\sum (x - \bar{x})^2}{n - 1}$$

$$\text{Stantard Deviation} = S = \sqrt{\text{variance}}$$

Variance & Standard Deviation



Standard deviation is the measure of spread most commonly used in statistical practice when the mean is used to calculate central tendency.

Standard deviation is also influenced by outliers. One value could contribute largely to the results of the standard deviation.

Standard deviation is also useful when comparing the spread of two separate datasets that have approximately the same mean.

The more widely spread the values are the larger the standard deviation is.

Implementation in R

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6388-TABGU	Male	0	No	Yes	62	Yes
9763-GRSKD	Male	0	Yes	Yes	13	Yes

```
var(customer_churn$MonthlyCharges)

sd(customer_churn$MonthlyCharges)
```

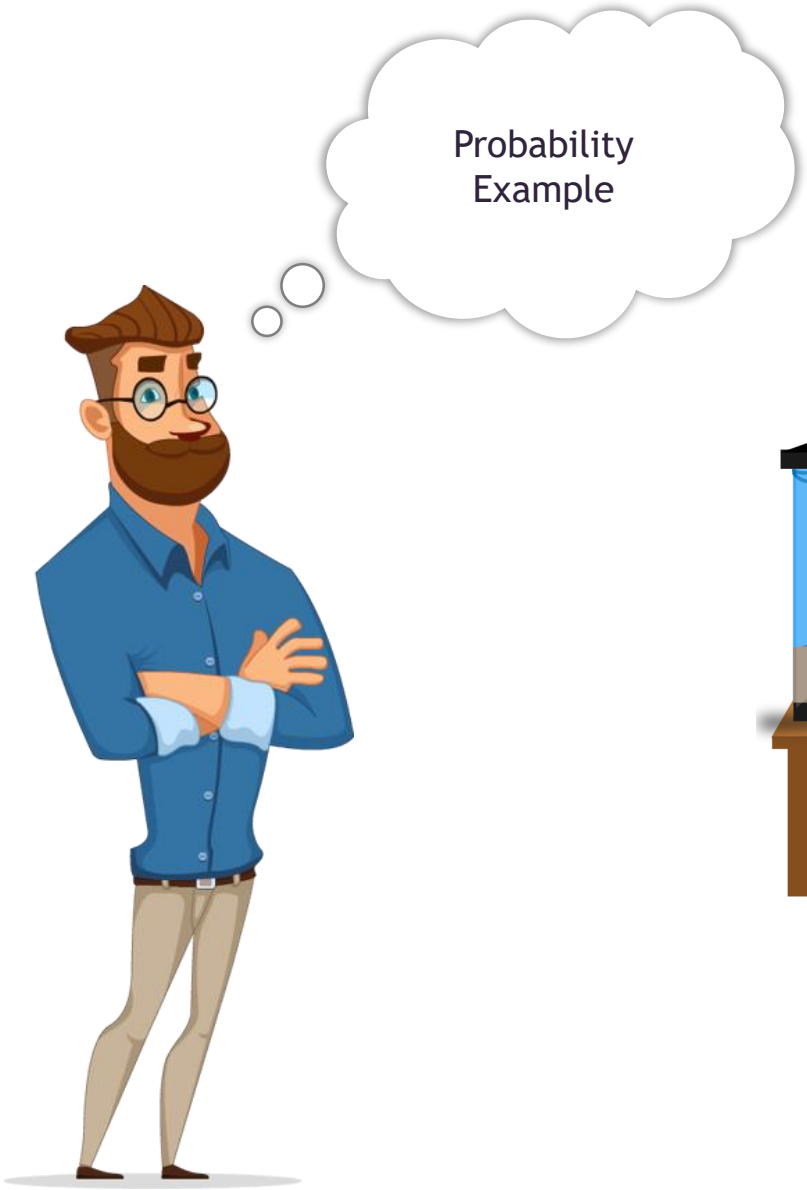
Probability

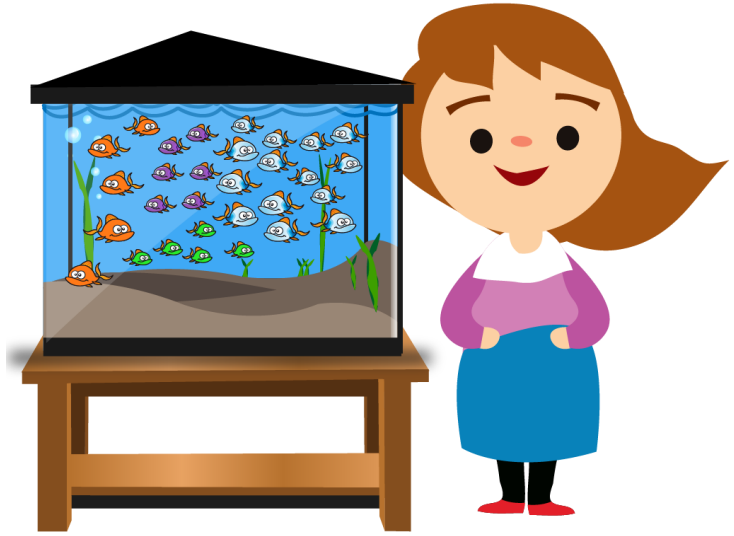
Probability

Probability can be determined post conducting a thought experiment.

$$P(E) = \frac{\#\ of\ times\ an\ event\ occured}{total\ \#\ of\ opportunities\ for\ the\ event\ to\ have\ occurred}$$

Probability



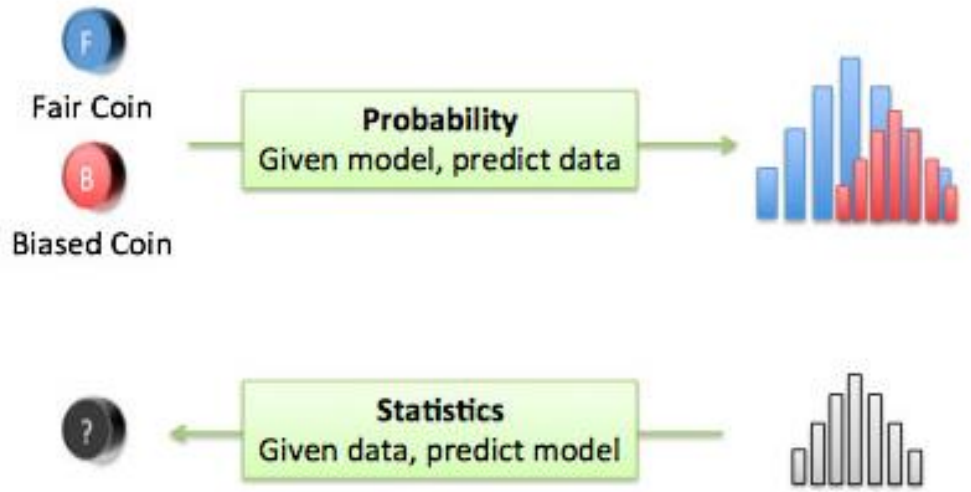


	=	14
	=	5
	=	5
	=	6
Total	=	30

Probability  = $\frac{6}{30}$ = $\frac{1}{5}$

Probability Vs. Statistics

Probability Vs. Statistics



Probability	• Predict the likelihood of a future event • What will happen in a given ideal world?
Statistics	• Analyze the past events • How ideal is the world?

Probability Terminology

Probability Terminology

Experiment

A test to see what will happen in case you do something.

Outcome

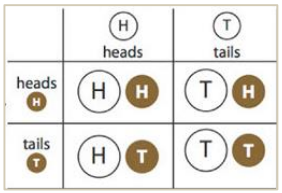
Refers to a single (one) result of an experiment.

Event

The set of a group of different outcomes of an experiment.

Sample Space

The total number of all different possible outcomes of a given experiment.

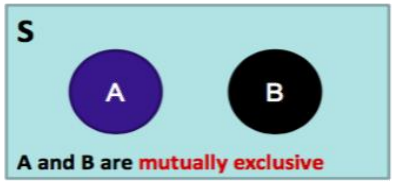


Probability Rules

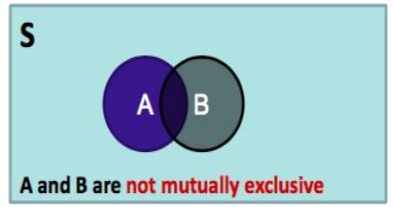
Probability Rules

$$P(S) = 1$$

$$0 \leq P(A) \leq 1$$

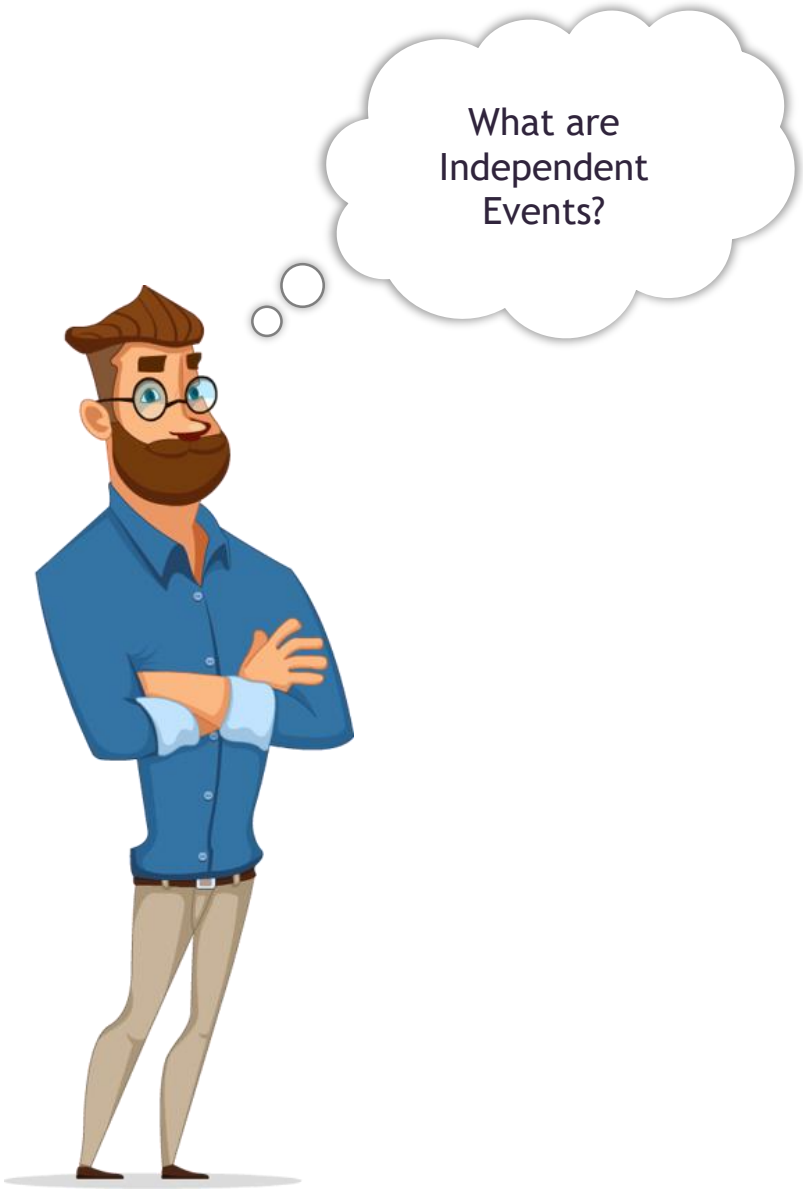


$$P(A \text{ or } B) = P(A) + P(B)$$



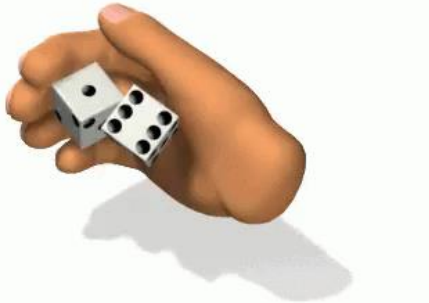
$$P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$$

Independent Events



The outcome of the event B is not dependent on the outcome of the event A

P(A and B) = P(A) * P(B)

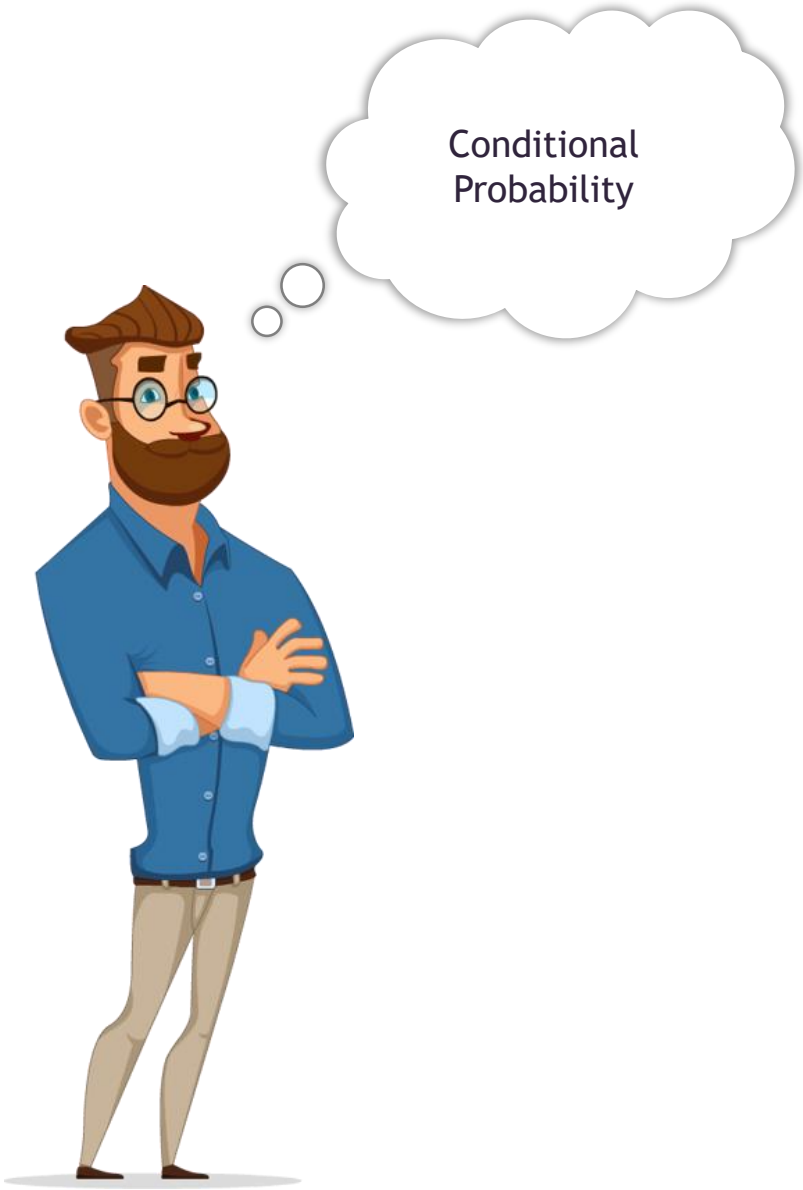


Probability Categories

Probability Categories

- Probability
  - Frequent
    - Finds the chance of a particular outcome
  - Conditional
    - Measures the probability of an event if another event has already occurred

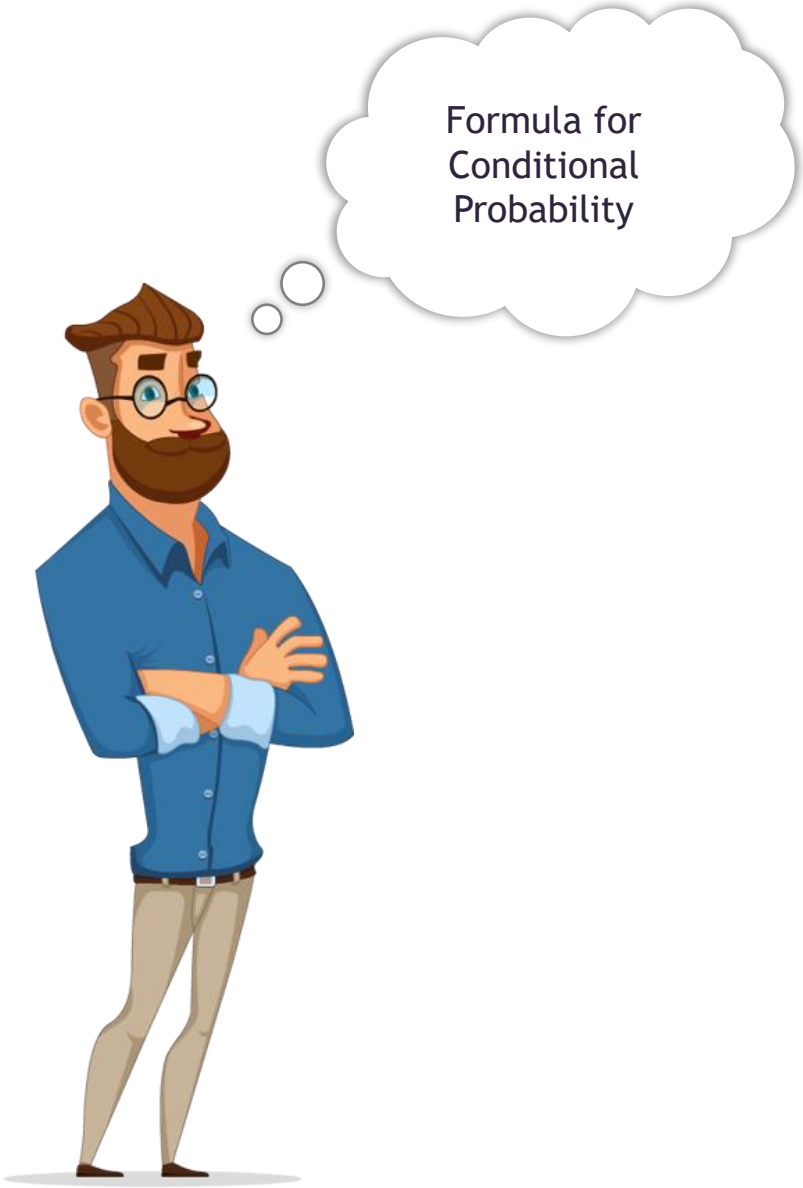
Conditional Probability



$$P(B|A) = \frac{P(A \cap B)}{P(A)}$$

$$\text{or } P(A \cap B) = P(A)P(B|A)$$

Conditional Probability



$$P(A|B) = \frac{P(A \text{ and } B)}{P(B)} \Rightarrow P(A \text{ and } B) = P(B) * P(A|B)$$

Similarly

$$P(B|A) = \frac{P(A \text{ and } B)}{P(A)} \Rightarrow P(A \text{ and } B) = P(A) * P(B|A)$$

Equating, we get

$$P(A|B) * P(B) = P(A) * P(B|A)$$

$$\therefore P(A|B) = \frac{P(A) * P(B|A)}{P(B)}$$

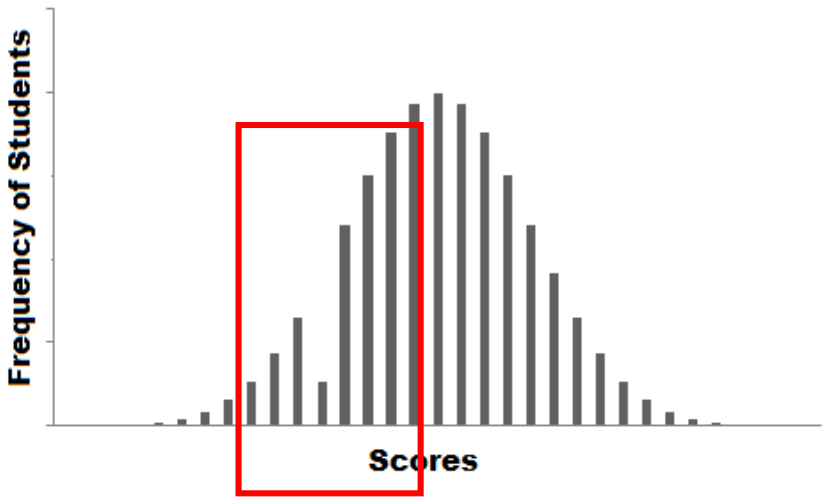
Probability Distribution

Probability Distribution

The probability function for a discrete random variable is the probability mass function.

It shows the exact probabilities for a particular value of the random variable.

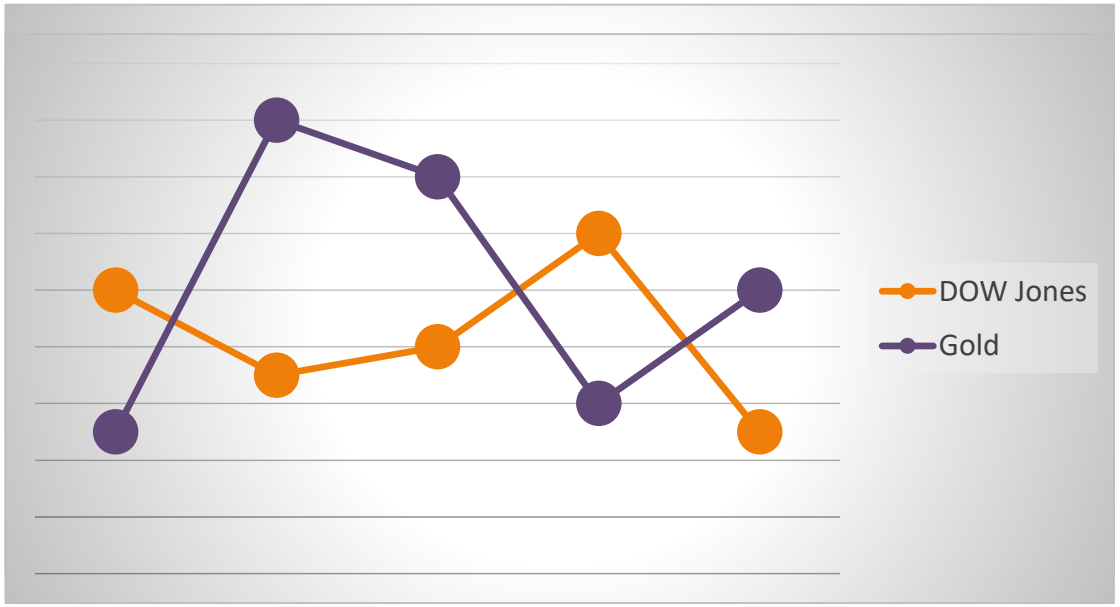
S. No.	Scores
1	25
2	27
3	38
4	42
5	
6	16
7	35
8	46
9	48
10	31



Covariance & Correlation

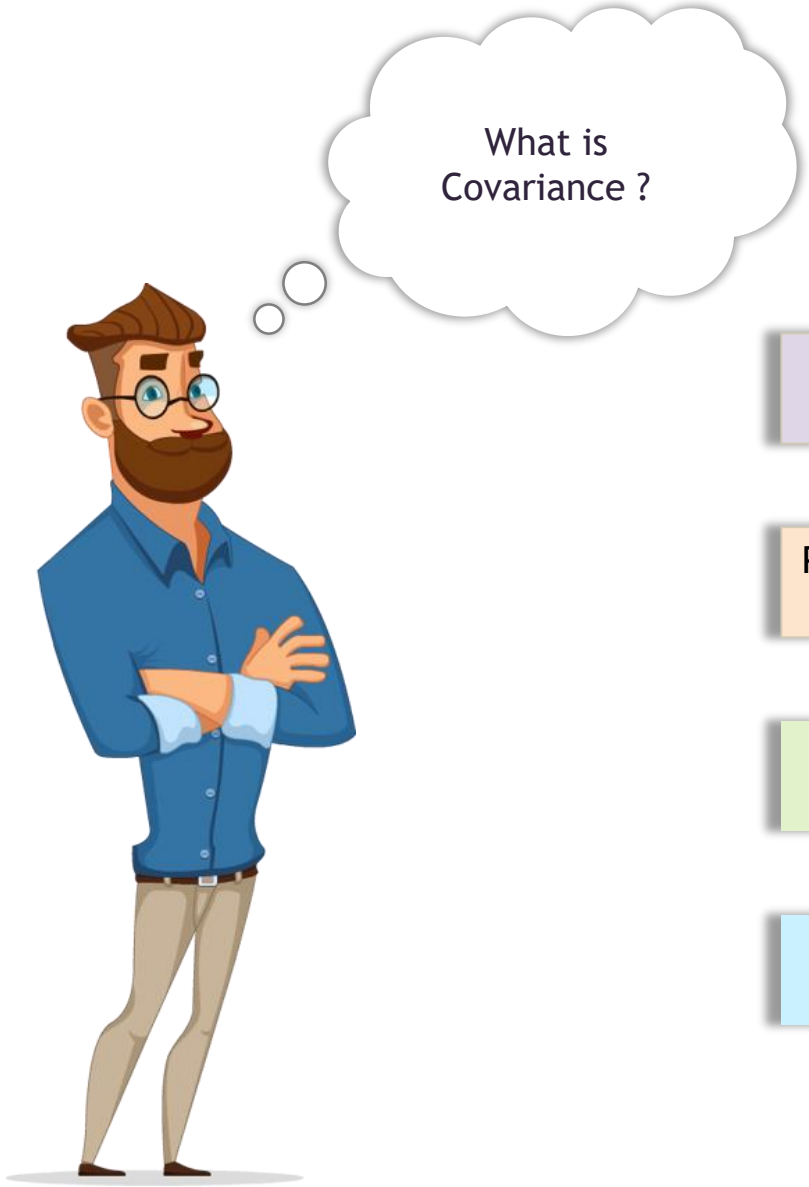
Correlation

When you say that two items correlate, you are saying that a change in one item effects a change in another item. You will always talk about correlation as a range between −1 and 1.



Correlation values are dependent on units of measure of “X” and “Y”.

Covariance



If you say that two items tend to vary together, then you are talking about the covariance between the two items which can be positive or negative covariance.

Positive covariance indicates that higher than average values of one variable tend to be paired with higher than average values of the other variable.

Negative covariance indicates that higher than average values of one variable tend to be paired with lower than average values of the other variable.

Covariance is not standardized, unlike the correlation coefficient. Therefore, covariance values can range from negative infinity to positive infinity.

Covariance & Correlation

- Covariance
  - Positive Covariance
  - Negative Covariance
- Correlation
  - Positive Correlation
  - Negative Correlation
  - Zero Correlation

Covariance & Correlation

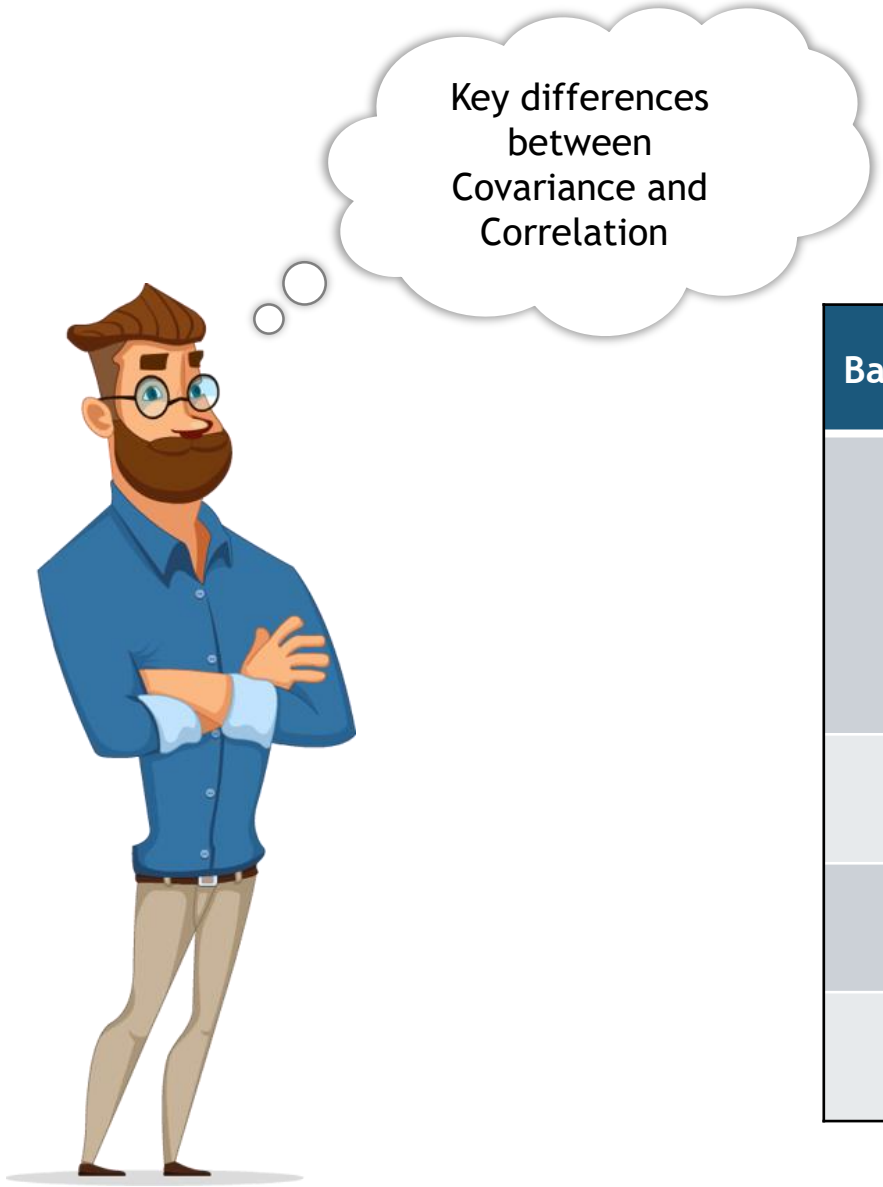
Correlation is dimensionless; i.e., it is a unit-free measure of the relationship between variables, unlike covariance where the value is obtained by the product of the units of the two variables.

Covariance & Correlation

$$COV(X,Y) = \frac{\sum_{i=1}^{n}\left(X_i - \bar{X}\right)\left(Y_i - \bar{Y}\right)}{n-1}$$

$$Correlation = \rho = \frac{\mathrm{cov}(X,Y)}{\sigma_X \sigma_Y}$$

Covariance & Correlation



Basis for comparison	Covariance	Correlation
Meaning	A measure indicating the extant to which two random variables change in tandem	A measure indicating that how strongly two random variables are related
What is it?	Measure of correlation	Scaled version of covariance
Values	Lies between $-\infty$ and $+\infty$	Lies between −1 and +1
Change in scale	Affects covariance	Does not affect correlation

Covariance & Correlation

Sunshine (hours)	1.9	2.5	3.2	3.8	4.7	5.5	5.9	7.2
Concert attendance (100s)	22	33	30	42	38	49	42	55

Covariance & Correlation

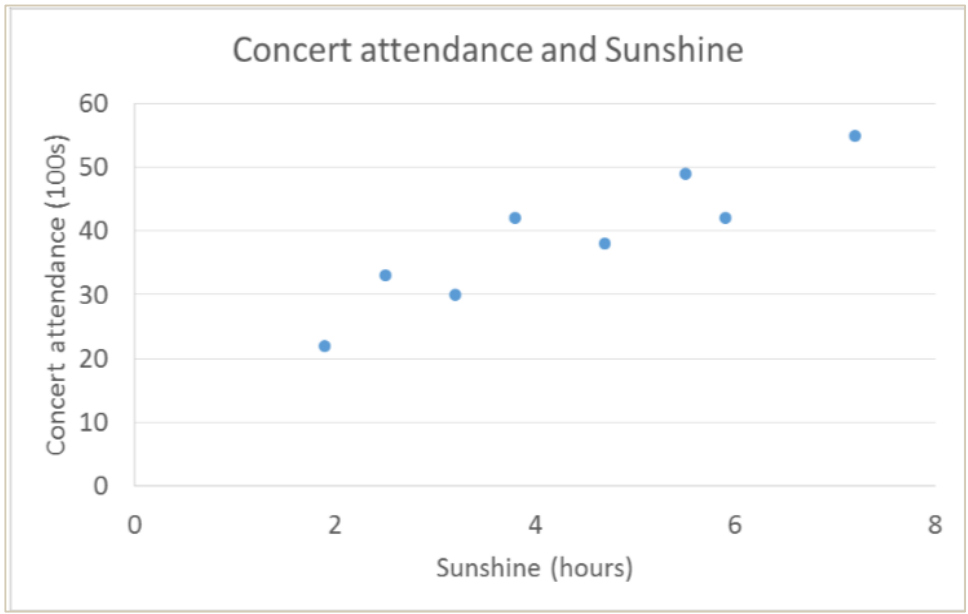
Independent variable (explanatory): Sunshine (Plotted on x-axis)

Dependent variable (response): Concert attendance (Plotted on y-axis)

Sunshine (hours)	1.9	2.5	3.2	3.8	4.7	5.5	5.9	7.2
Concert attendance (100s)	22	33	30	42	38	49	42	55

Covariance & Correlation

The number of attendees increase with increase in sunshine



Covariance & Correlation

Positive Linear Correlation

Negative Linear Correlation

No Correlation

Correlation Coefficient

Correlation Coefficient

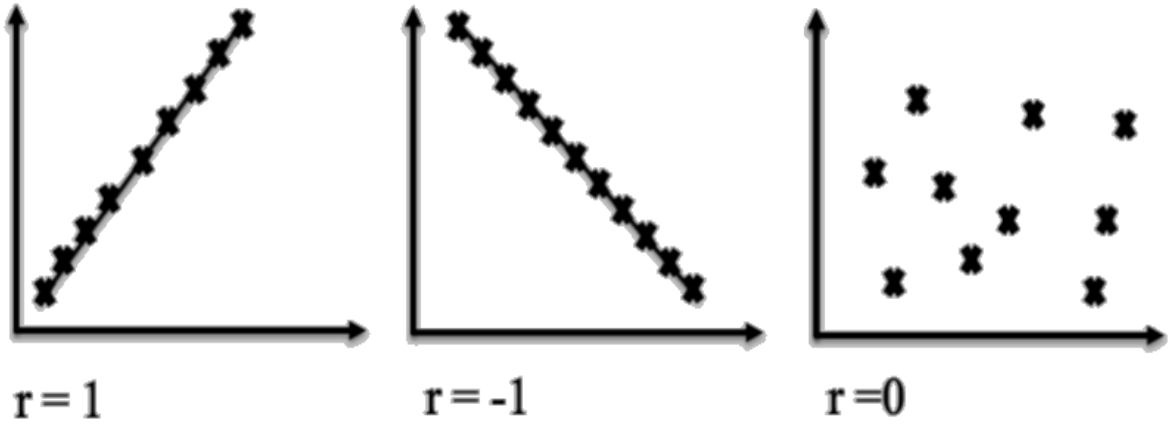
Correlation coefficient is used to find how strong a relationship is between data.

It returns a value between –1 and 1, where:

1	–1	0
indicates a strong positive relationship.	indicates a strong negative relationship.	indicates no relationship at all.

Correlation Coefficient

$$r = r_{xy} = \frac{\mathrm{Cov}(x, y)}{S_x \times S_y}$$



Correlation Is Not Causation!

Because two things correlating does not necessarily mean that one causes the other

Correlation Does Not Cause Causation

Correlation describes the size and direction of a relationship between two or more variables.

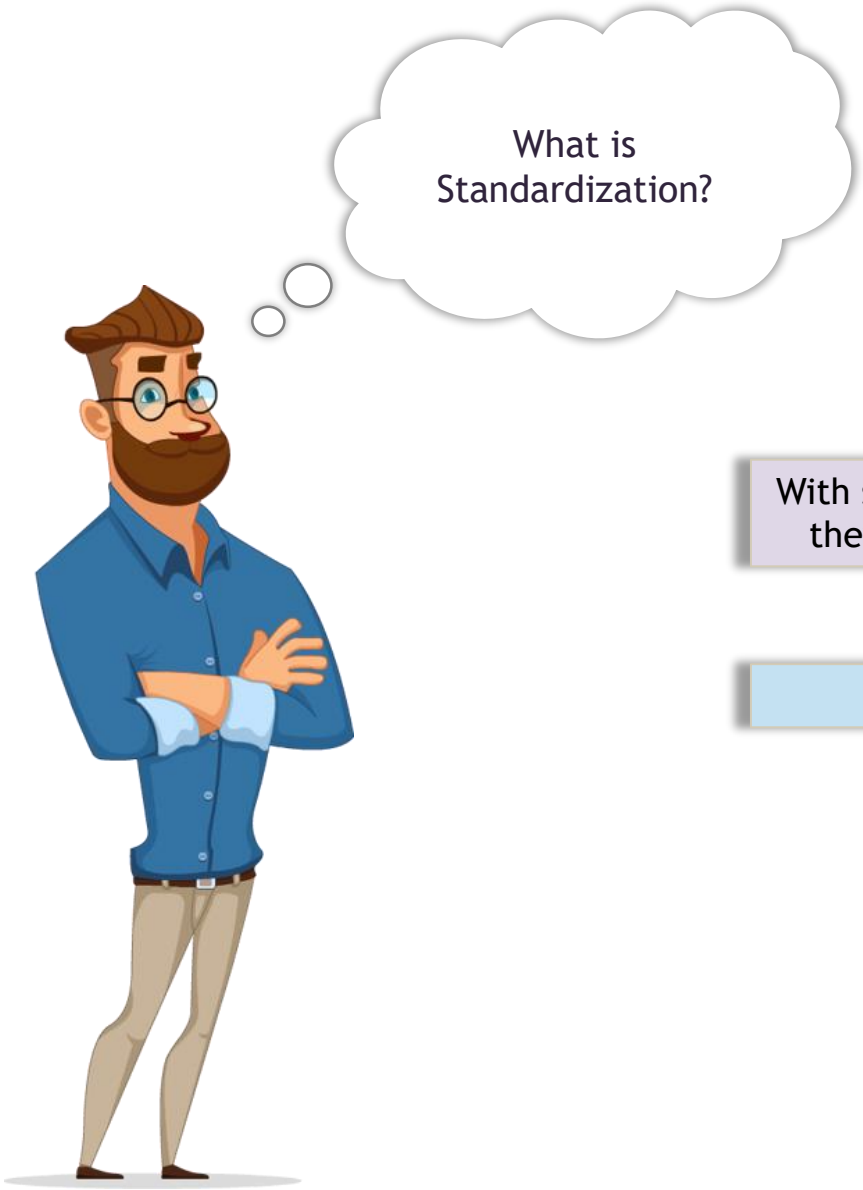
Causation indicates that one event is the result of the occurrence of the other event.

Smoking → Correlates → Alcoholism

Smoking → Causes → The risk of developing Lung Cancer

Standardization & Normalization

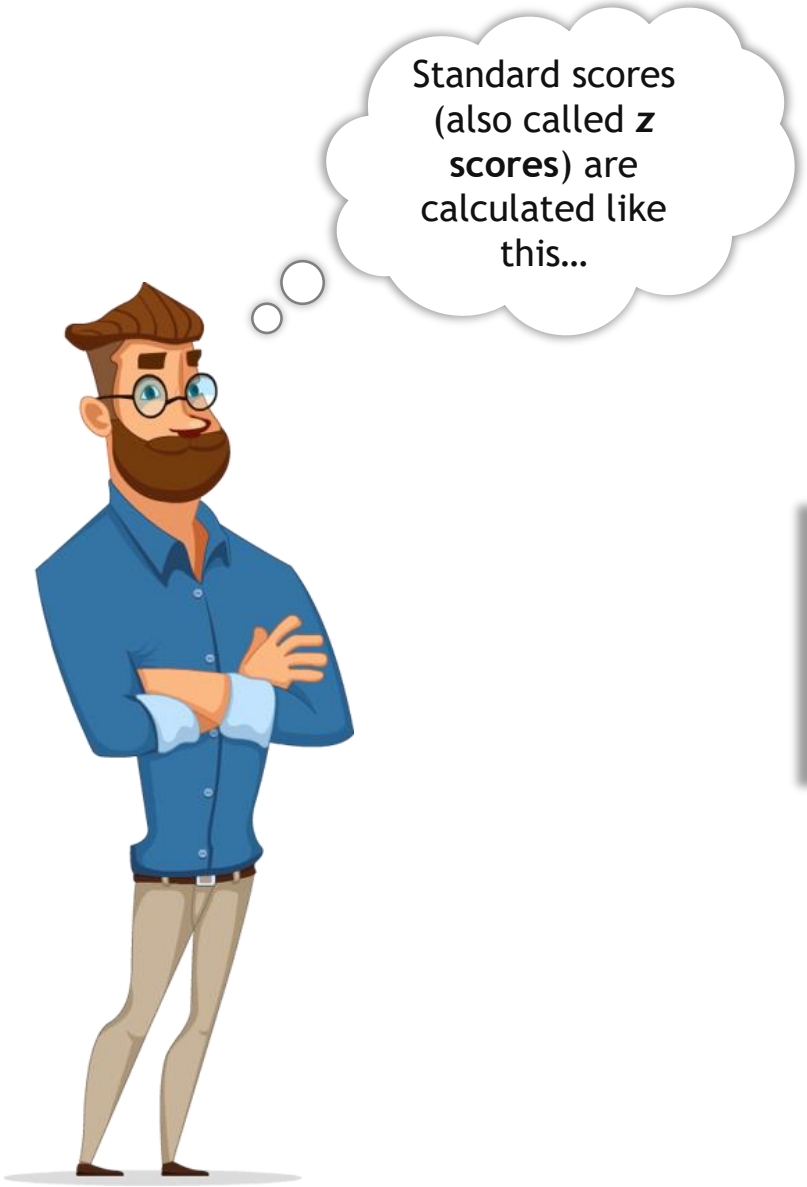
Standardization



With standardization (or Z-score normalization), the features can be rescaled so that they'll have the properties of a standard normal distribution with $\mu = 0$ and $\sigma = 1$

Where, μ is the mean and σ is the standard deviation from the mean

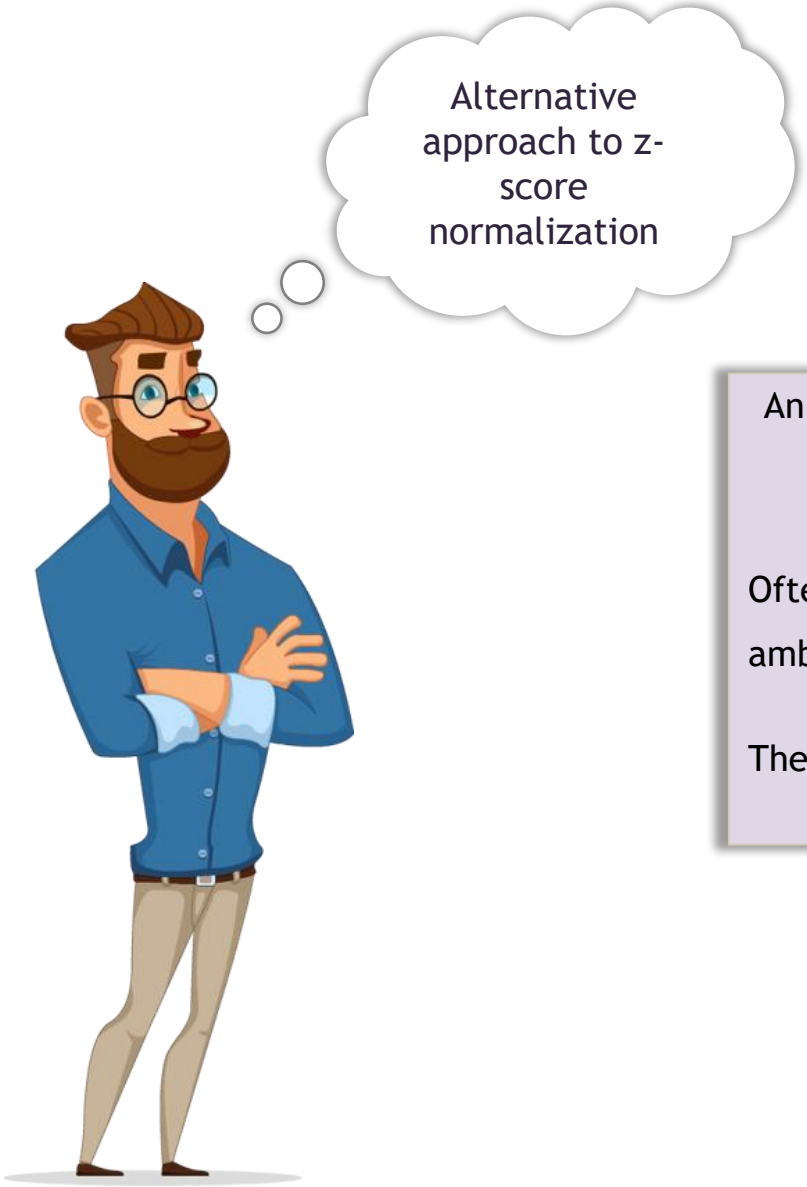
Standardization



$$z = x - \mu / \sigma$$

Standardizing the features so that they are centered around 0 with a standard deviation of 1 is not only important if we are comparing measurements that have different units, but it is also a general requirement for many machine learning algorithms

Normalization

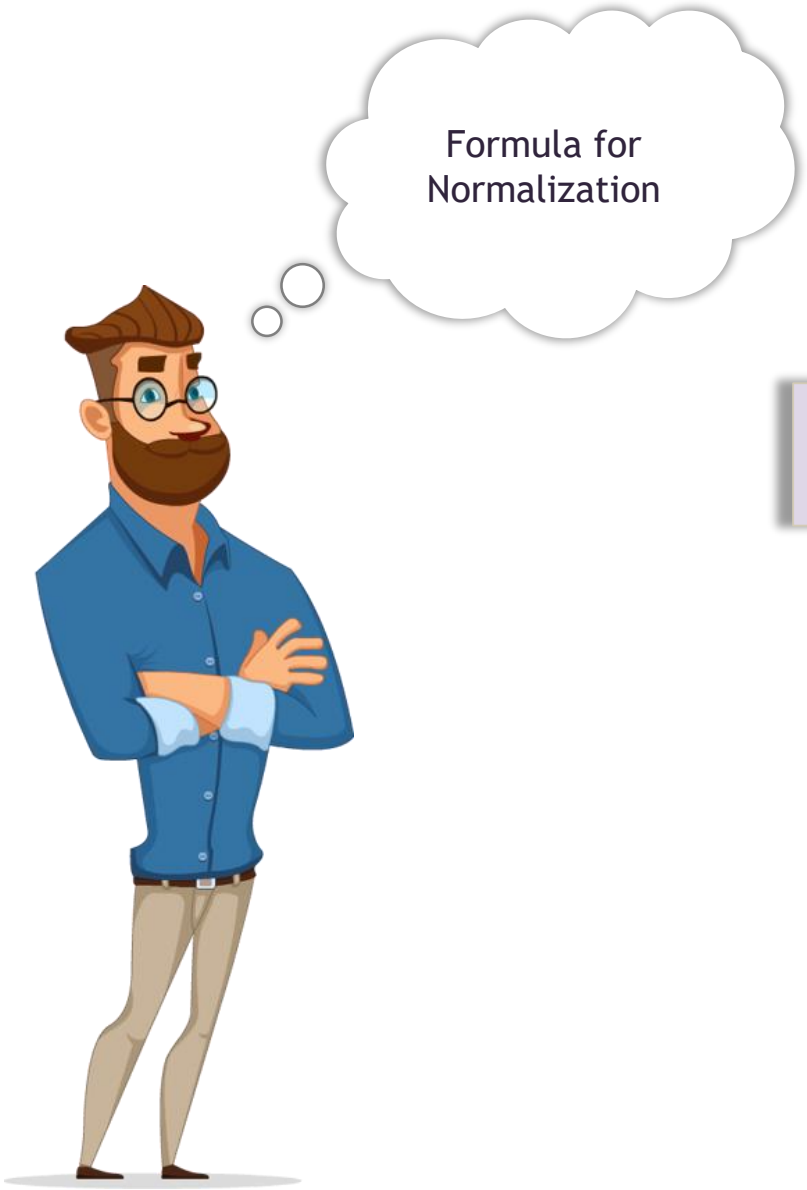


An alternative approach to Z-score normalization (or standardization) is the so-called **Min-Max scaling.**

Often, it is also simply called “Normalization”, a common cause for ambiguities.

The data is scaled to a fixed range: 0 to 1.

Normalization



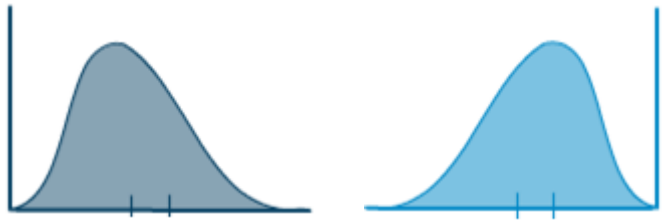
The cost of having this bounded range——in contrast to standardization——is that we will end up with smaller standard deviations, which can suppress the effect of outliers

$$x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}$$

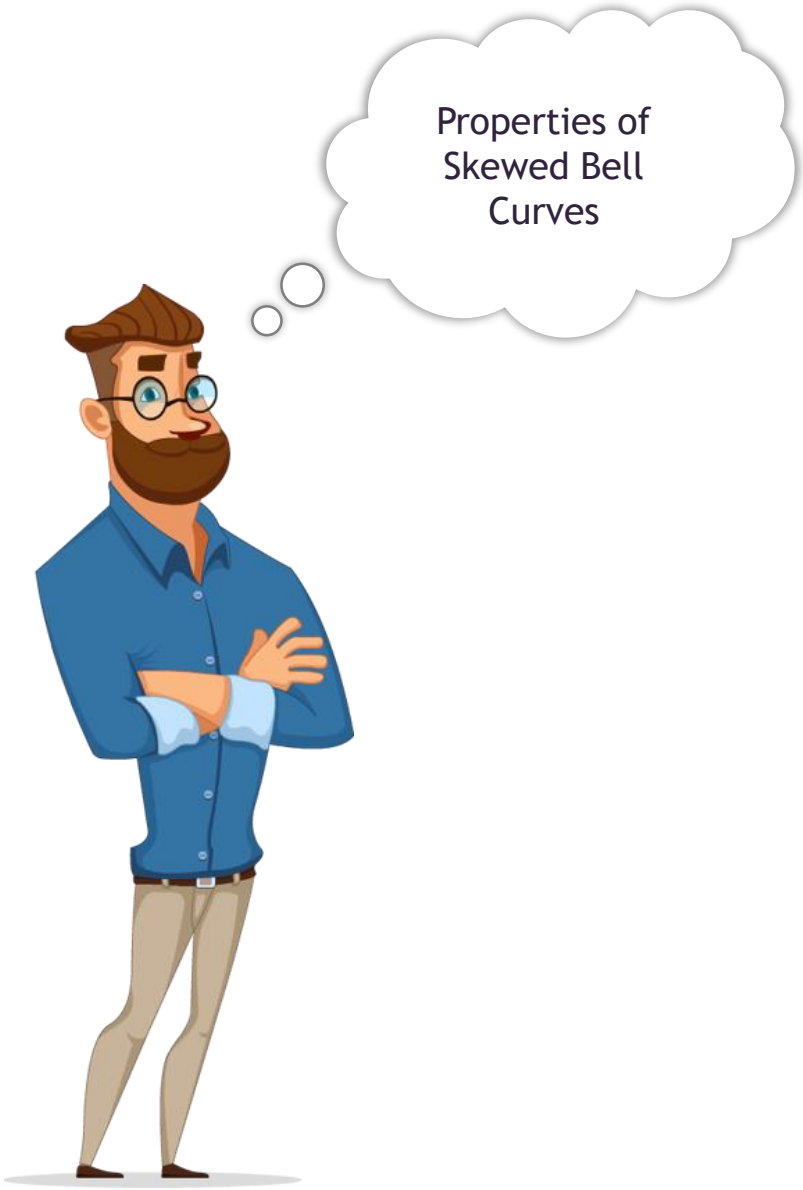
Skewness

Skewness

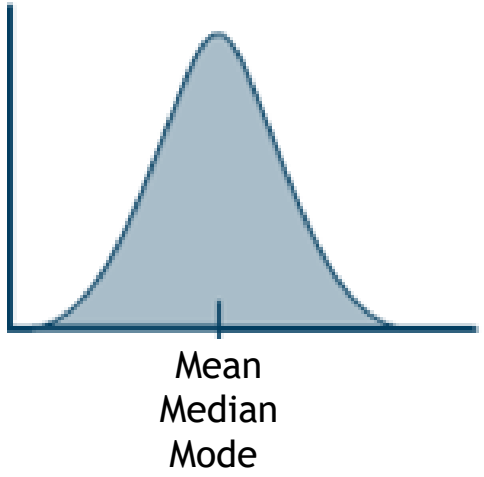
Skewness represents an imbalance and asymmetry from the mean of a data distribution



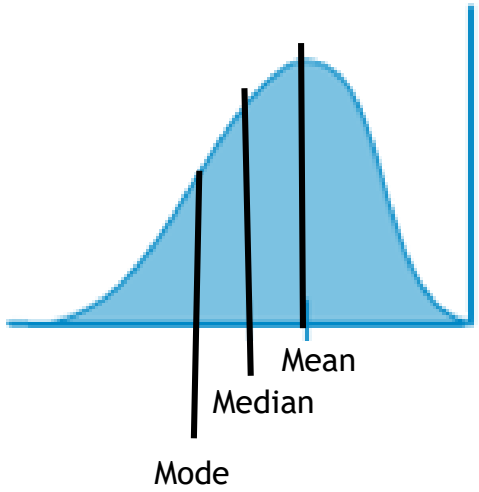
Skewness



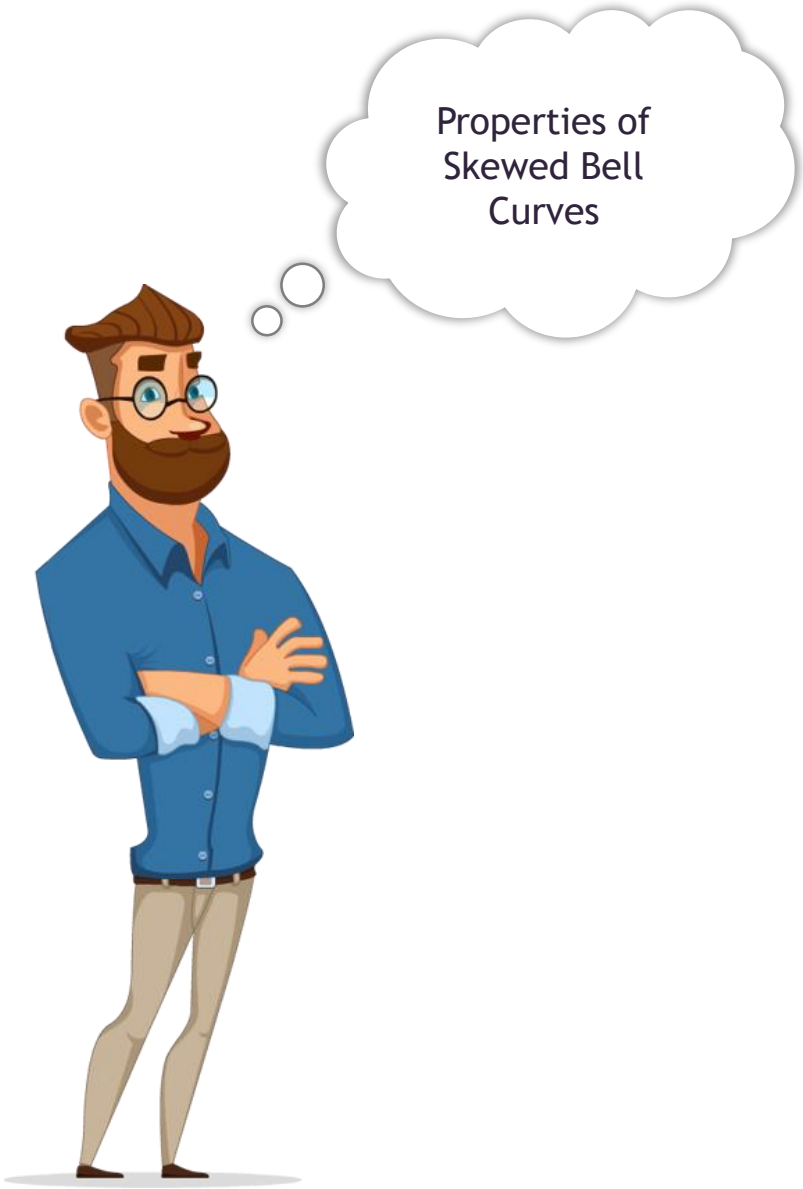
Symmetric Distribution

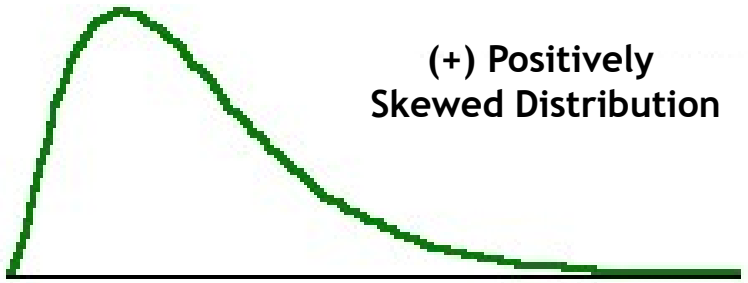


Skewed Distribution

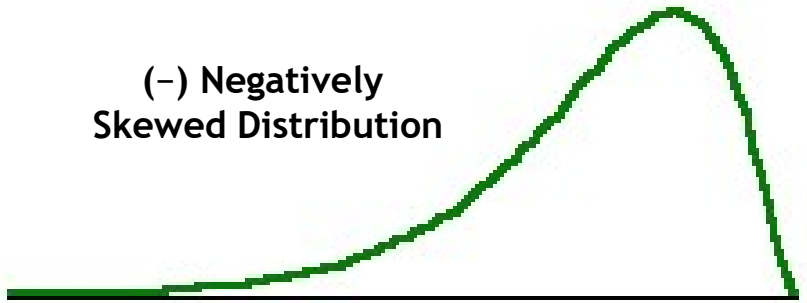


Skewness





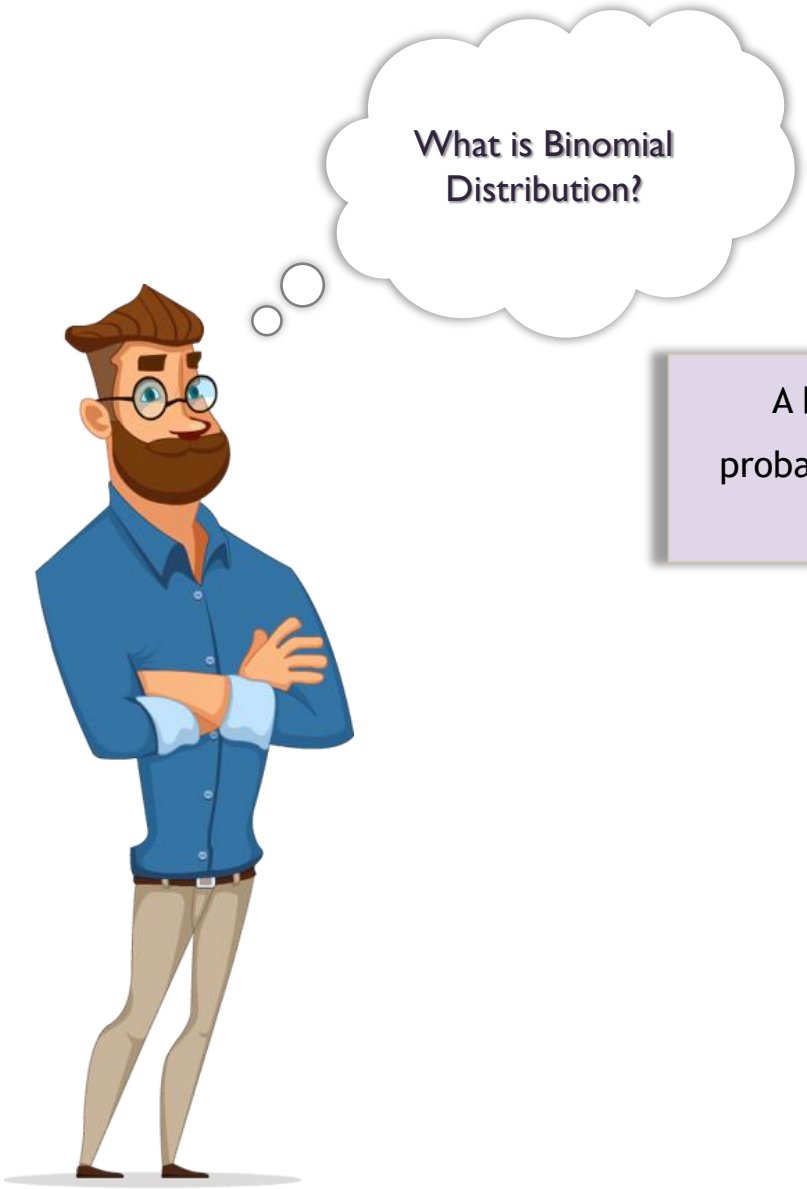
(+) Positively Skewed Distribution



(−) Negatively Skewed Distribution

Binomial Distribution

Binomial Distribution



A binomial distribution is a specific probability distribution. It is used to model the probability of obtaining one of two outcomes, a certain number of times (k), out of fixed number of trials (N) of a discrete random event.

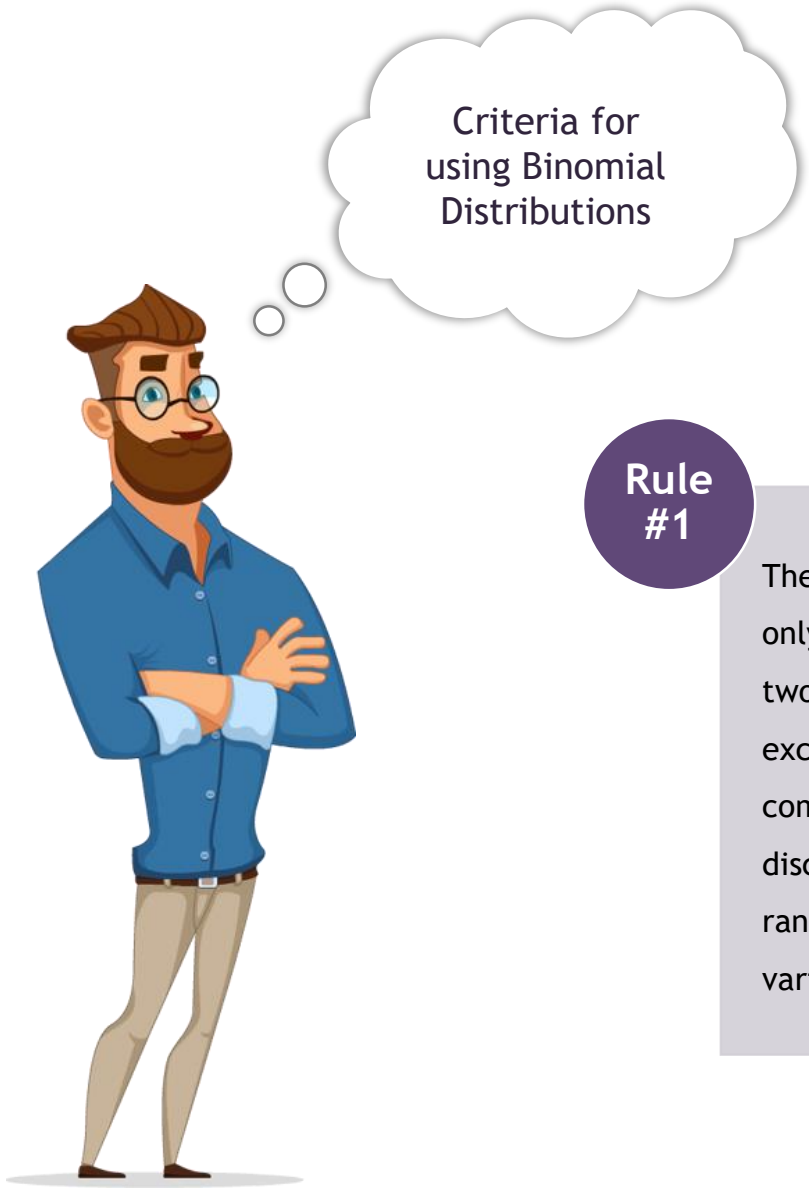
Expected Outcome
Successful Outcome

p

Other Outcome
Failure

$1 - p$

Binomial Distribution



Rule #1

There are only two mutually exclusive out comes for a discrete random variable.

Rule #2

There is a fixed number of repeated trials.

Rule #3

Each trial is an independe nt event.

Rule #4

The probability of success for each trial is fixed.

Binomial Distribution

The probability of getting *x* successes in *n* Bernoulli trials

This starts the count of number of ways an event can occur.

This is the probability of success for *x* trials.

$$P(x) = \frac{n!}{(n-x)!\,x!}\,p^x q^{n-x}$$

This is the probability of failure for *x* trials.

This ends the count of number of ways an event can occur.

This deletes duplications.

Geometric Distribution

Geometric Distribution

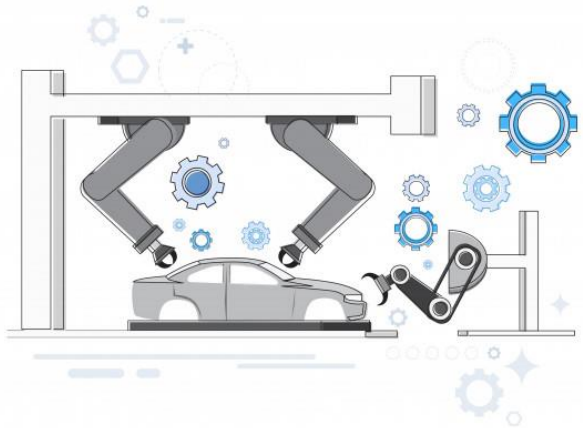
The geometric distribution represents the number of failures before you get a success in a series of Bernoulli trials.

$$f(x) = (1 - p)^{x-1}p$$

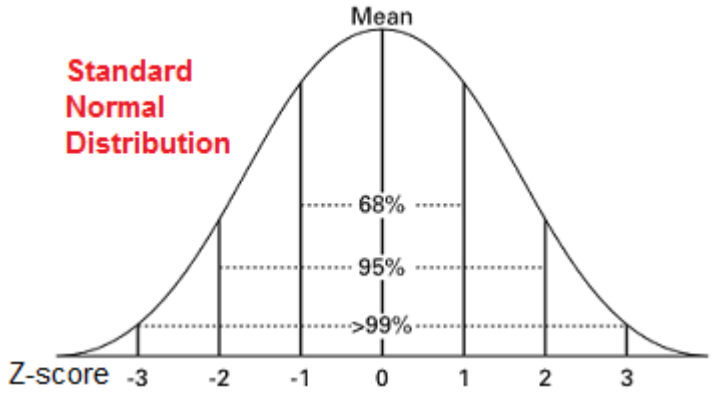
Normal Distribution

Normal Distribution

84th percentile or above

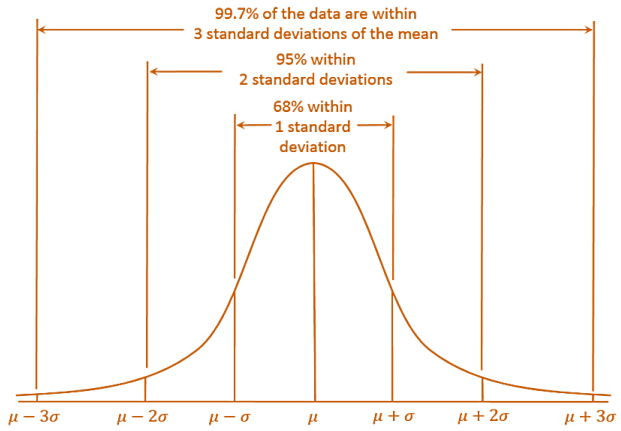


95% of the lithium ion batteries



Normal Distribution

- Symmetric bell shape
- Mean and median are equal
- The area under the normal curve is equal to 1.0
- Normal distributions are denser in the center and less dense in the tails
- 68% of the area of a normal distribution is within one standard deviation of the mean
- Approximately 95% of the area of a normal distribution is within two standard deviations of the mean



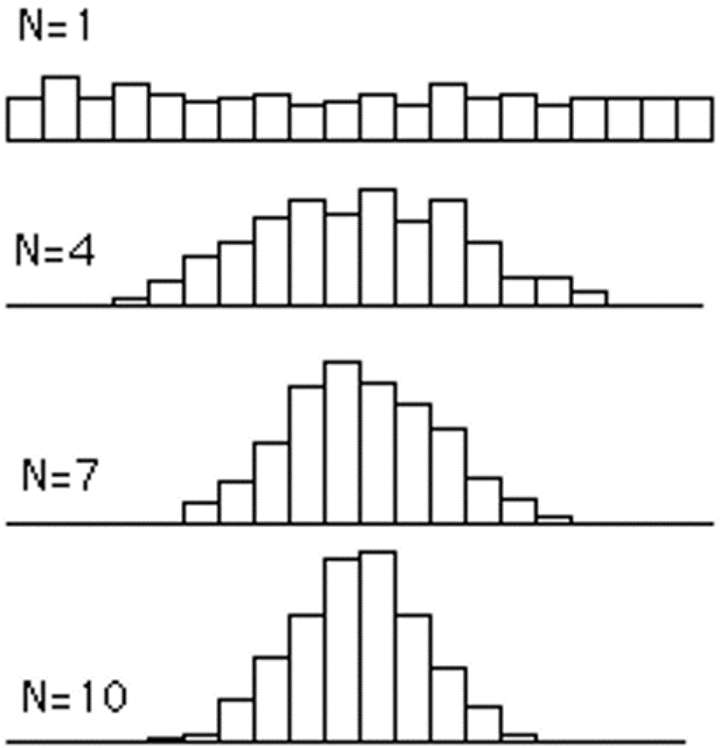
Central Limit Theorem

Central Limit Theorem

The Central Limit Theorem states that the sampling distribution of the sample means approaches a normal distribution as the sample size gets larger, no matter what the shape of the population distribution is.

This fact holds especially true for sample sizes over 30.

Central Limit Theorem

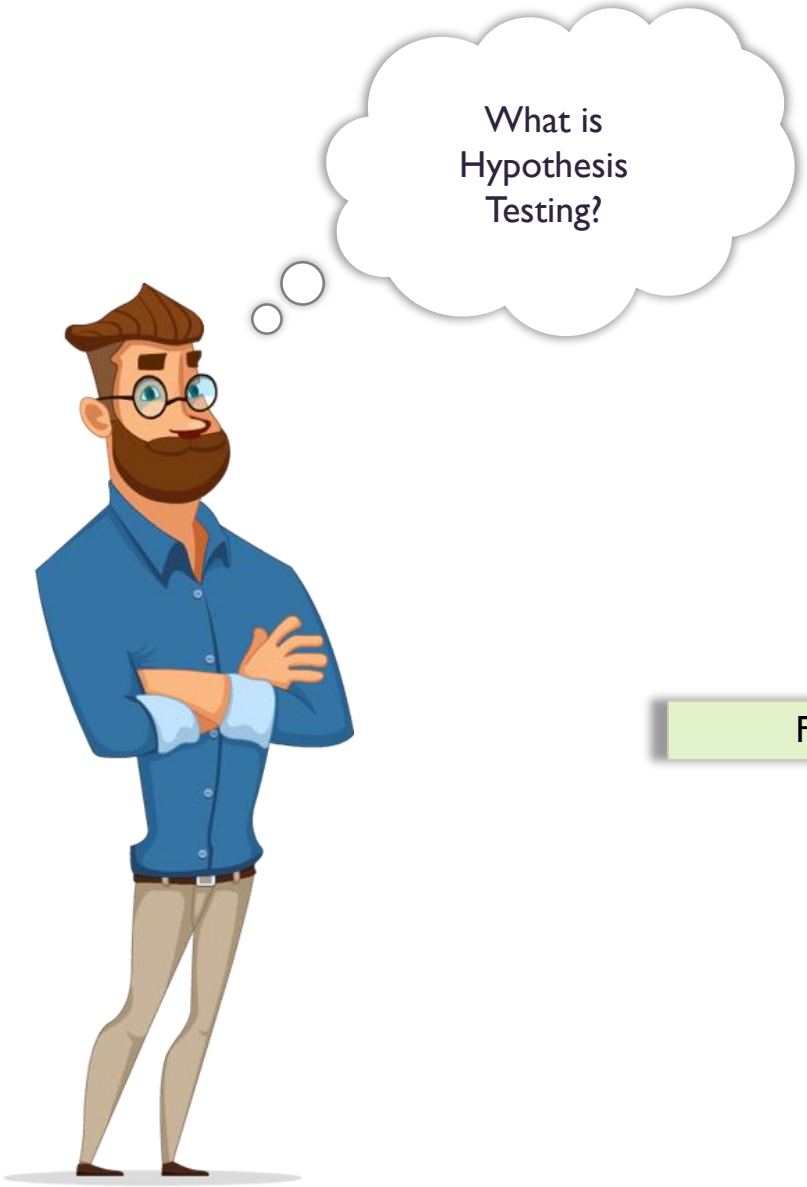


When *N* increases:

1. the distributions become more and more normal.
2. the spread of the distributions decreases.

Hypothesis Testing

Hypothesis Testing

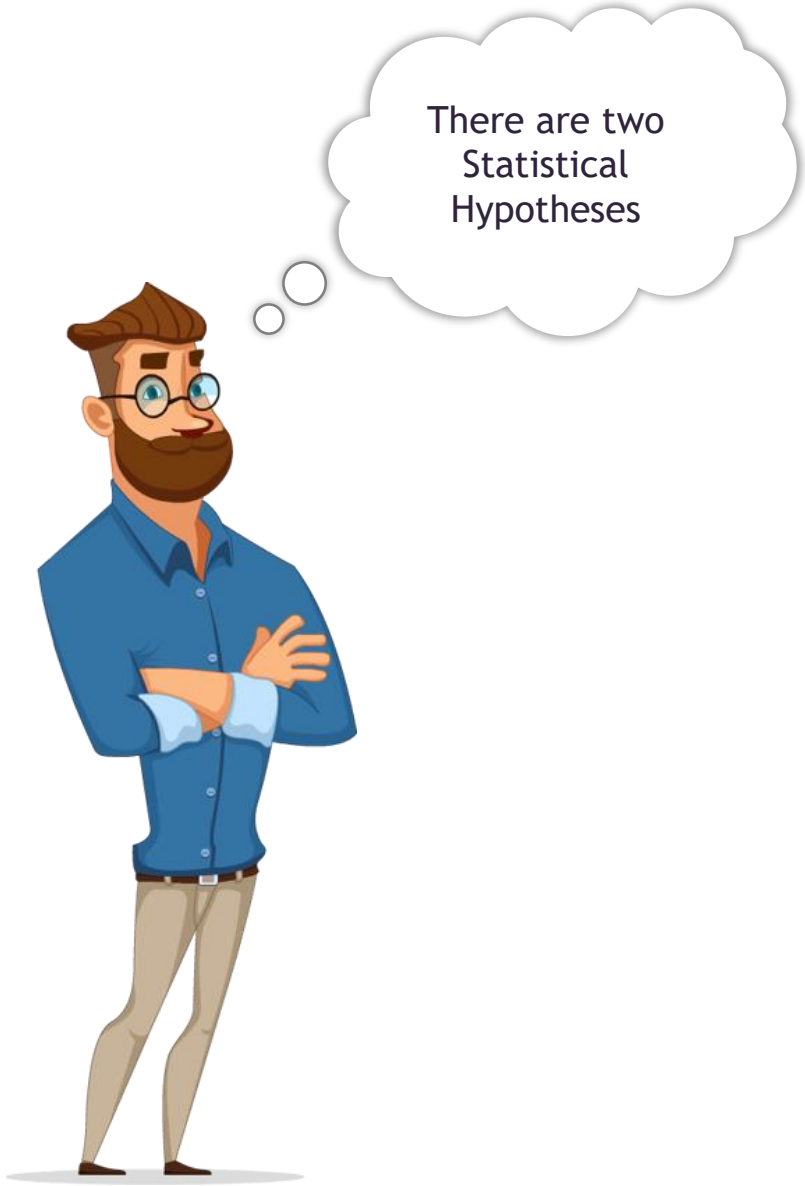


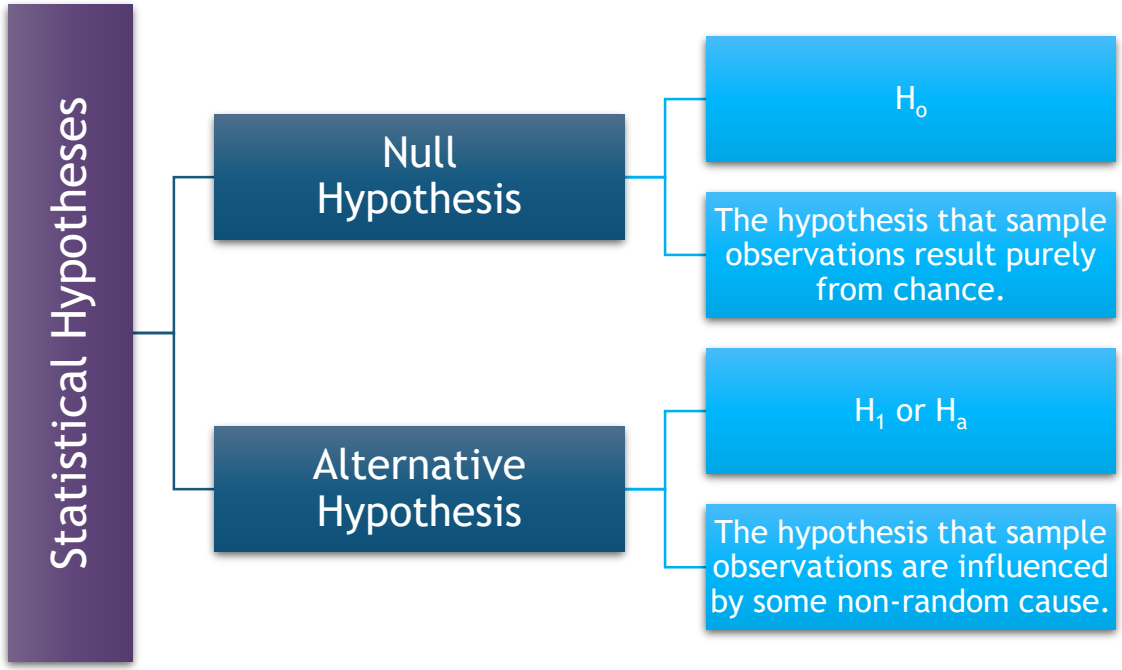
An assumption about a population parameter

This assumption may or may not be true.

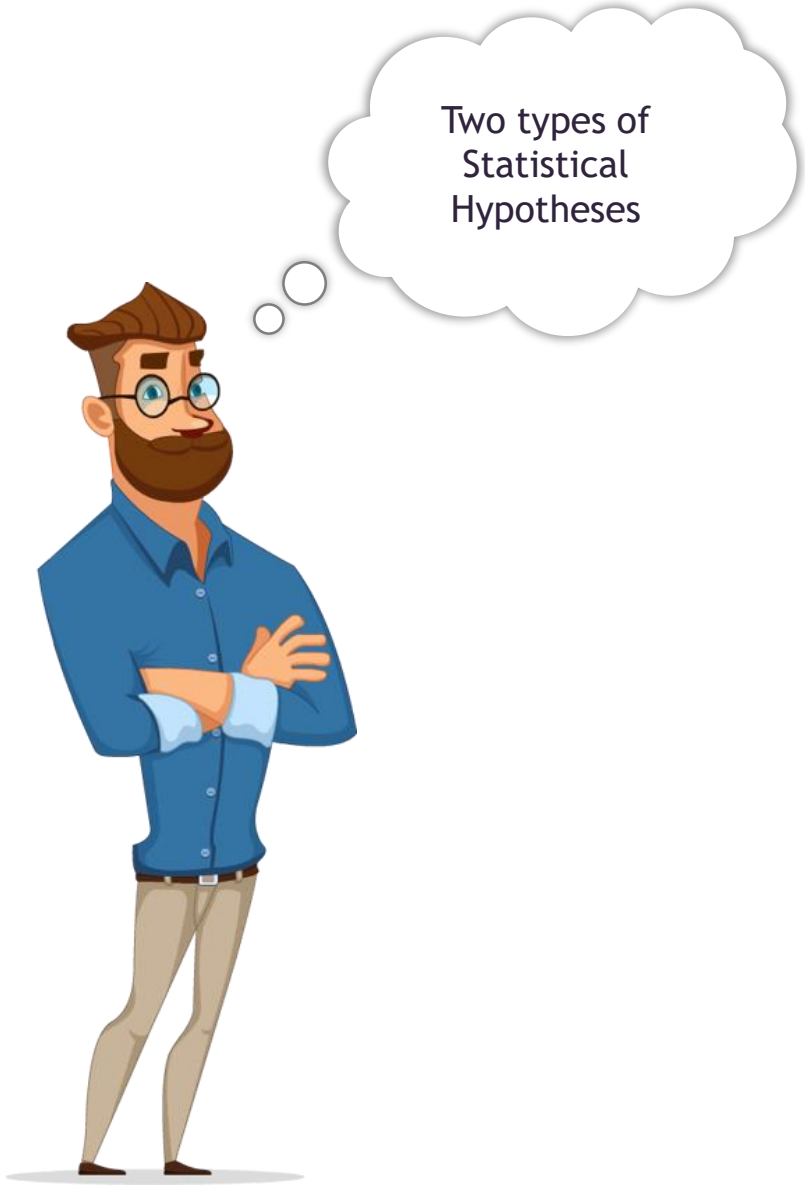
Formal procedures used by statisticians to accept or reject statistical hypotheses

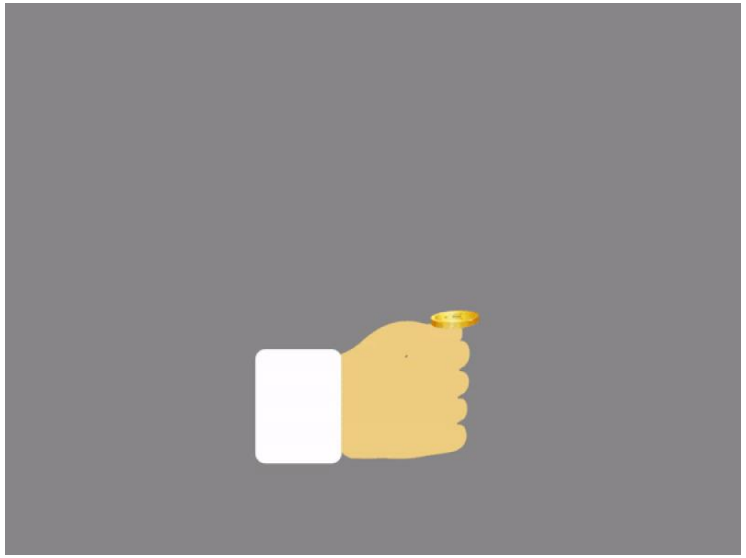
Hypothesis Testing





Hypothesis Testing



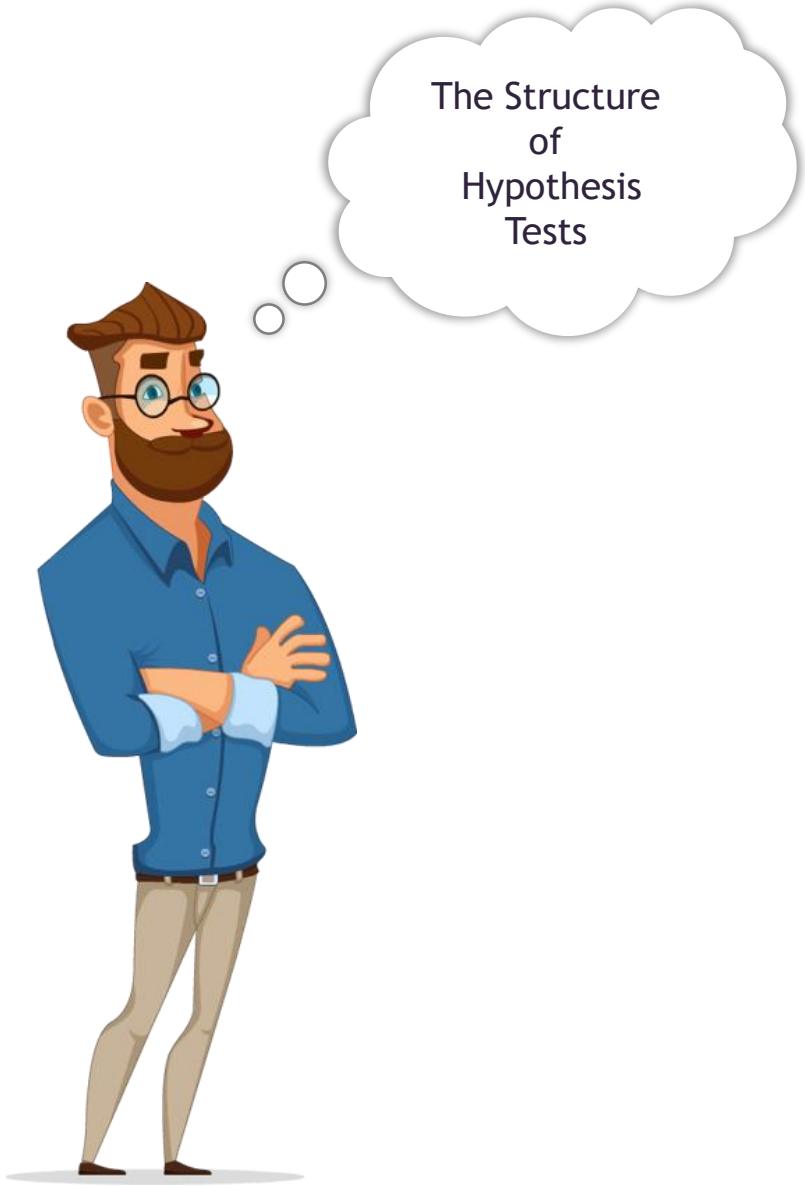


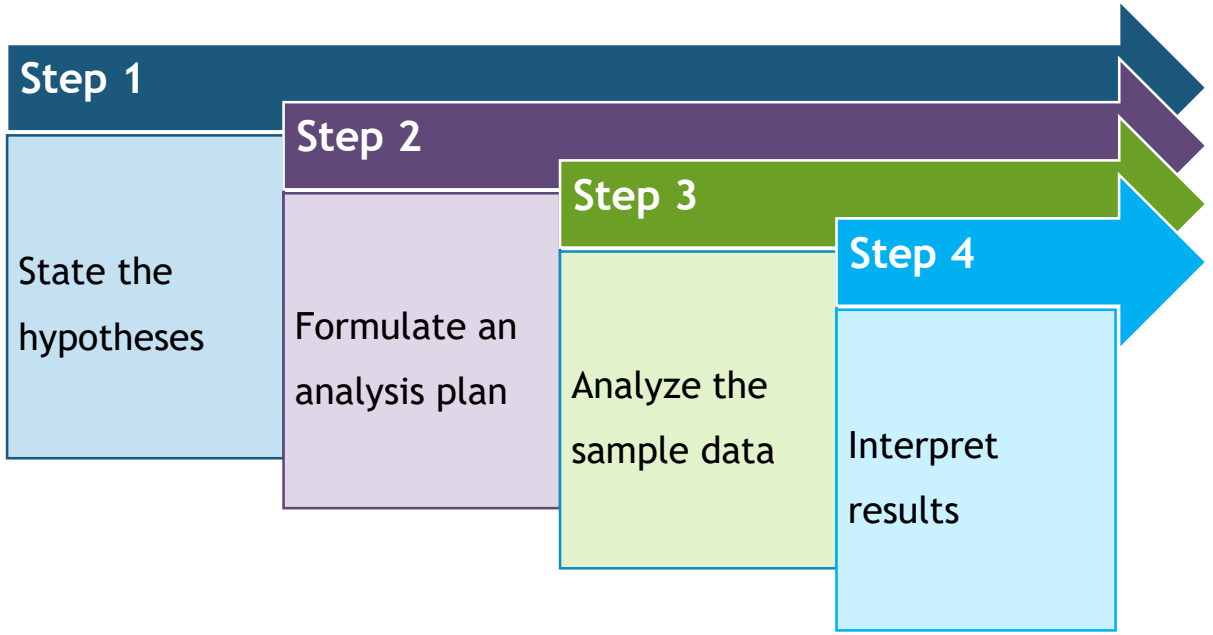
H_o: P = 0.5
H_1: P ≠ 0.5

Coin Flip = 50 times → 40 Heads and 10 Tails

Reject the Hypothesis

Hypothesis Testing



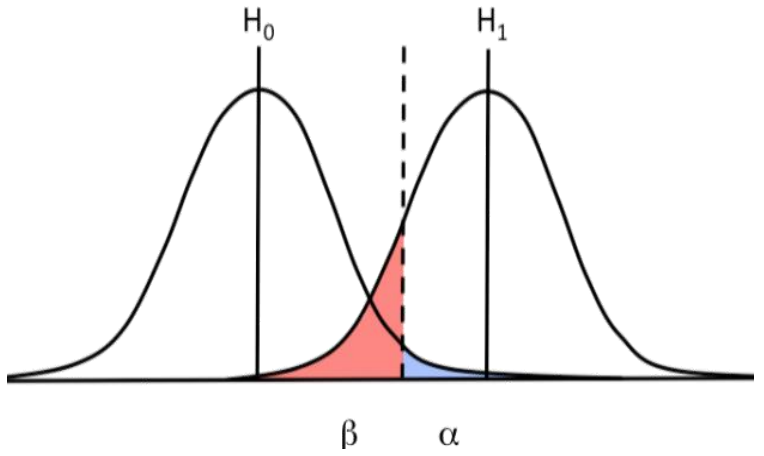


Decision Error

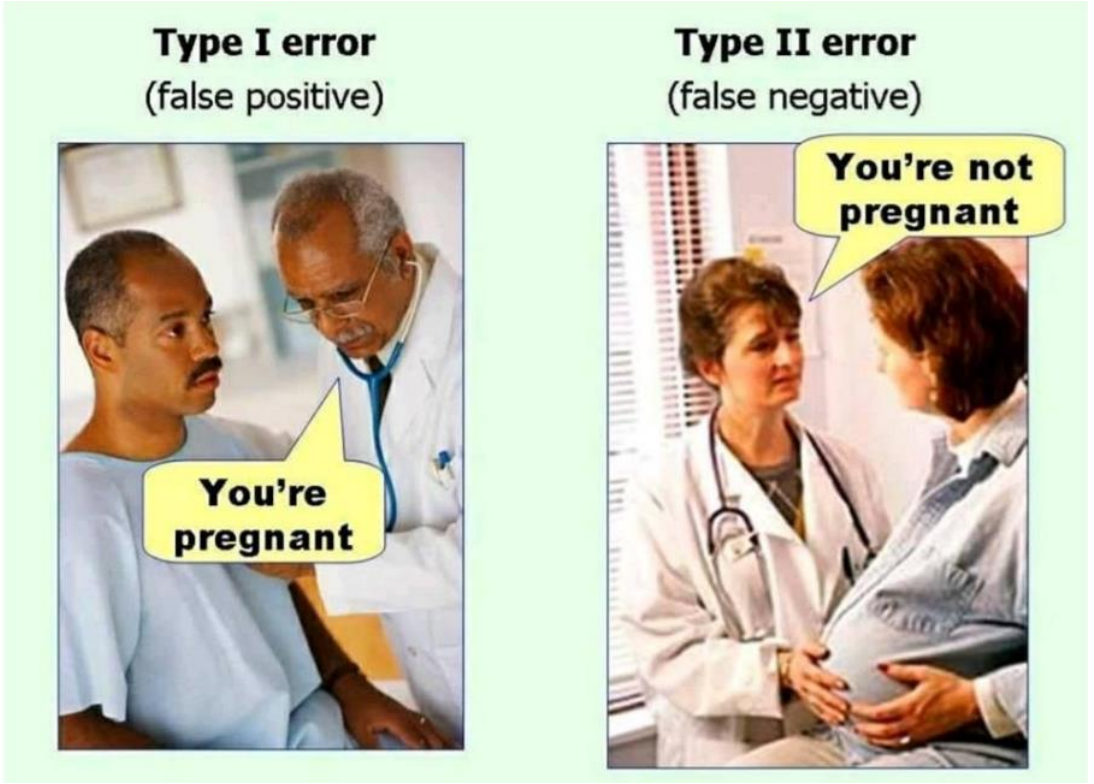
Decision Error

Type II Error

Type I Error

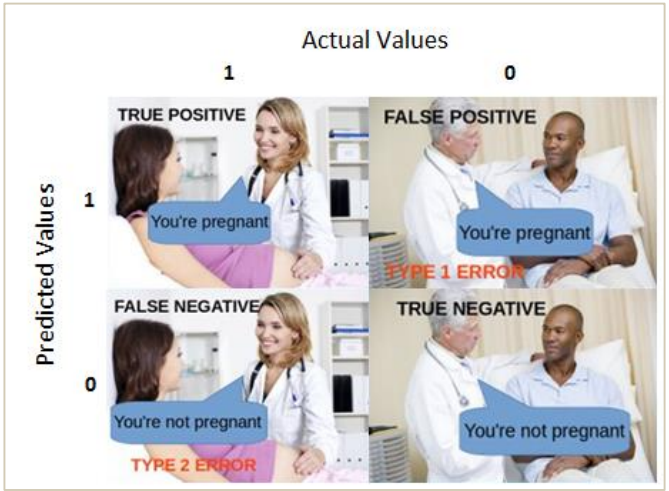


Decision Error



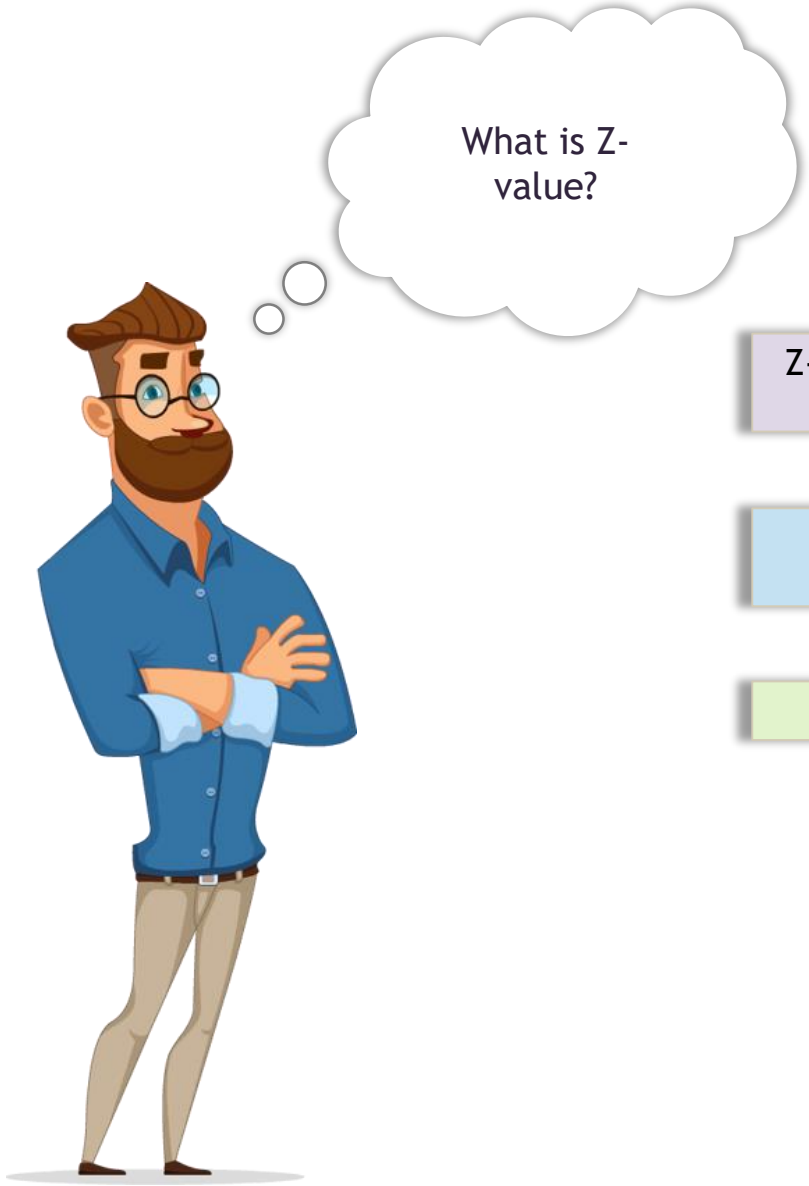
Decision Error

		Condition	
		Condition Positive	Condition Negative
Test Outcome	Test Outcome Positive	**True Positive**	**False Positive** (Type I error)
	Test Outcome Negative	**False Negative** (Type II error)	**True Negative**



Decision Rules

Decision Rules



Z-value is a measure of standard deviation, i.e., how many standard deviations away from the mean is the observed value.

For example, the value of z-value = +1.8 which can be interpreted as the observed value is +1.8 standard deviations away from the mean.

P-values are probabilities.

$$z = \frac{(X - \mu)}{\sigma}$$

$$z = \frac{(190 - 150)}{25} = 1.6$$

Decision Rules

Z-$score$ < 0, an element less than the mean.

Z-$score$ > 0, an element greater than the mean.

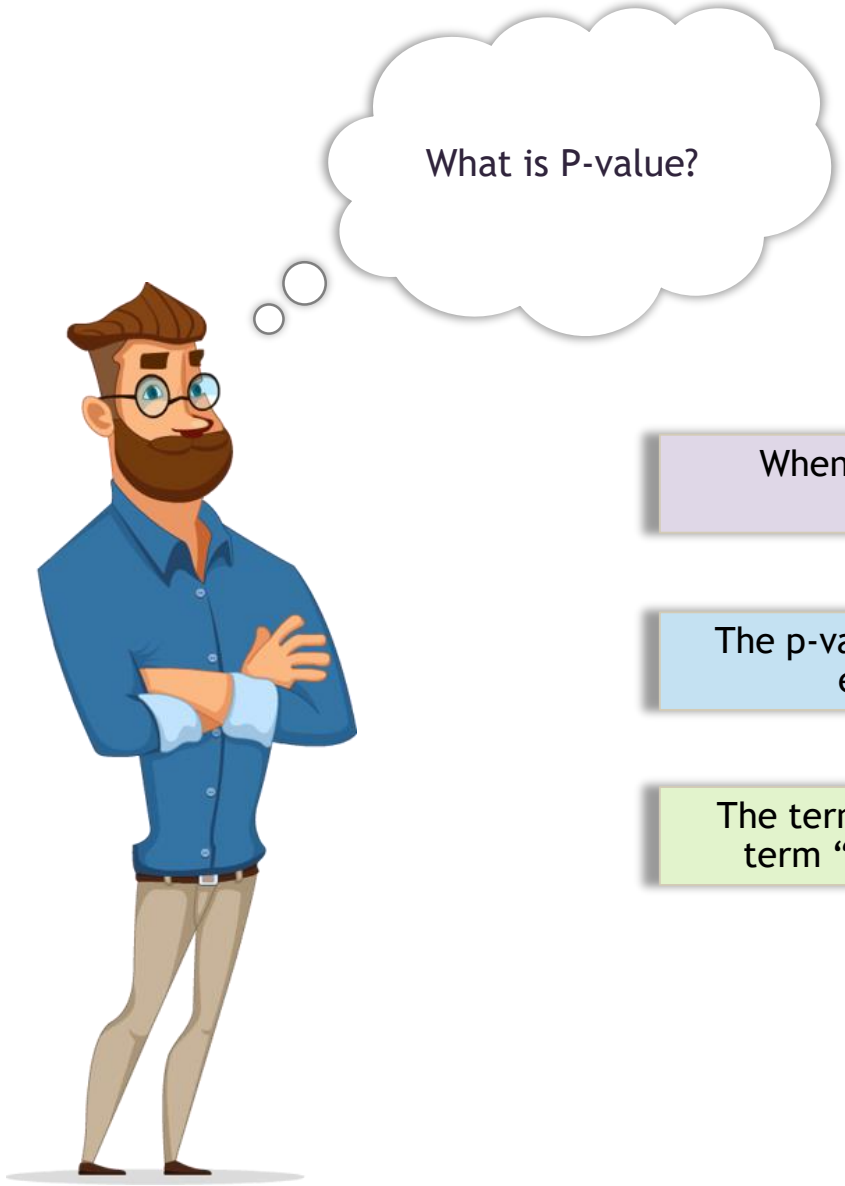
Z-$score$ = 0, an element equal to the mean.

Z-$score$ = 1, an element that is 1 standard deviation greater than the mean; z-$score$ = 2, an element 2 standard deviations greater than the mean; etc.

Z-$score$ = −1, an element that is 1 standard deviation less than the mean; z-$score$ = −2, an element 2 standard deviations less than the mean; etc.

If the number of elements in the set is large, about 68% of the elements have a z-score between −1 and 1; about 95% have a z-score between −2 and 2; and about 99% have a z-score between −3 and 3. Z-$score$ > 3, an element is an outlier.

Decision Rules

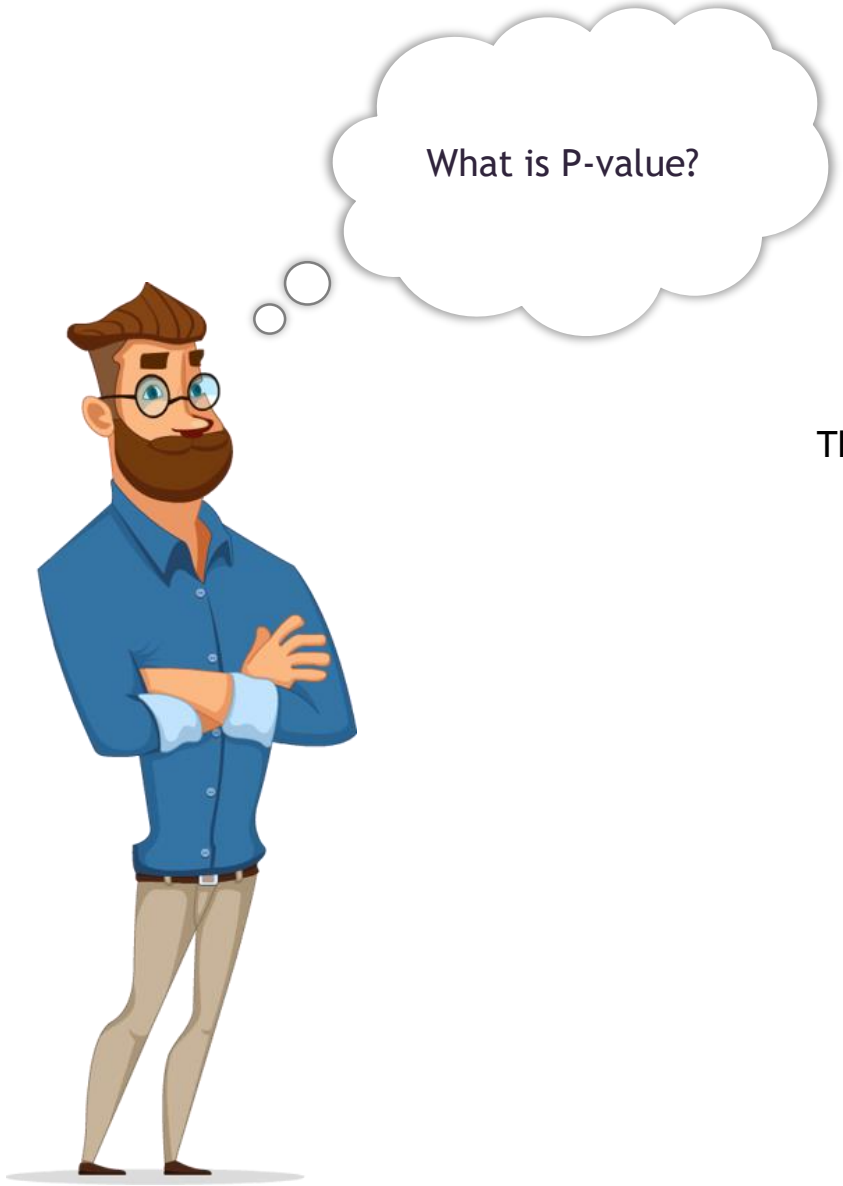


When you perform a hypothesis test in statistics, a p-value helps you determine the significance of your results.

The p-value, or calculated probability, is the probability of finding the observed, or more extreme, results when the null hypothesis (H_0) of a study question is true.

The term “significance level” (alpha) is used to refer to a pre-chosen probability and the term “p-value" is used to indicate a probability that you calculate after a given study.

Decision Rules



The p-value is a number between 0 and 1 and interpreted in the following way:

- A small p-value (typically ≤ 0.05) indicates strong evidence against the null hypothesis, so you reject the null hypothesis.
- A large p-value (> 0.05) indicates weak evidence against the null hypothesis, so you fail to reject the null hypothesis.
- p-values very close to the cutoff (0.05) are considered to be marginal (could go either way). Always report the p-value so that your readers can draw their own conclusions.

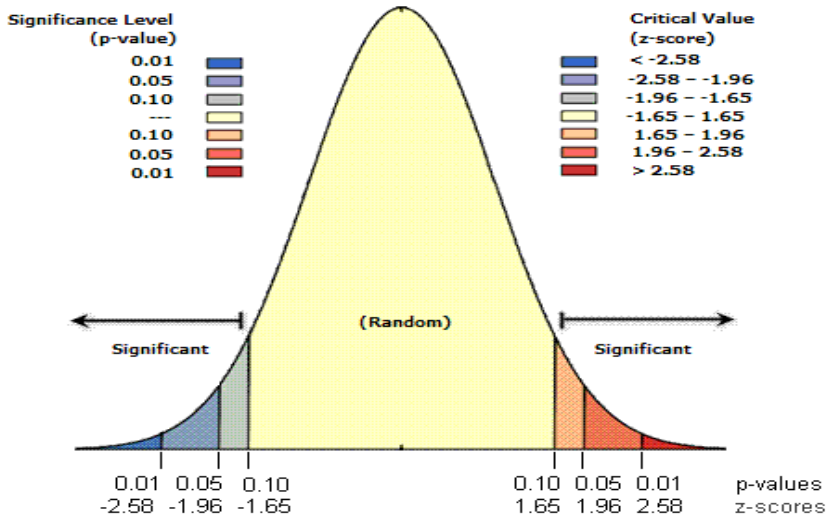
Decision Rules

30 MINUTES OR LESS ON AVERAGE

Mean Delivery Time is 30 minutes max, is incorrect

p-value turns out to be 0.001, which is much less than 0.05

Decision Rules



z-score (Standard Deviations)	p-value (Probability)	Confidence level
< -1.65 or > +1.65	< 0.10	90%
< -1.96 or > +1.96	< 0.05	95%
< -2.58 or > +2.58	< 0.01	99%

When the absolute value of the z-score is large and the probabilities are small

Quiz

Quiz

Which of the following statements describes descriptive statistics?

a. Descriptive statistics involves organizing, displaying and describing data

b. Descriptive statistics uses a random sample of data taken from a population to describe and make inferences about the population

c. All of the above

d. None of the above

Quiz

Which of the following statements describes discrete data?

a. Discrete data are continuous

b. Discrete data are whole numbers and are usually a count of objects

c. Discrete data have labels

d. All of the above

Quiz

Which of the following are four measurement scales?

a. arrange, mutate, summary and ordinal

b. mutate, nominal, interval and arrange

c. nominal, ordinal, interval and ratio

d. All of the above

Quiz

Which of the following are the properties of normal distribution?

a. Mean = median = mode

b. Symmetry about the center

c. The total area under the curve is 1

d. All of the above

Quiz

Which of the following is the formula for z-score?

a. $z = x - \mu / \sigma$

b. $z = x - \mu / s$

c. $z = x / \sigma$

d. None of the above

Thank You

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