```
#sample average
def Meu(num_of_1,num_of_0):
  meu=num_of_1/(num_of_1+num_of_0)
  return meu
```

```
#standard deviation1
def SD1(num_of_1,num_of_0):
  sum1=num_of_1*((1-Meu(num_of_1,num_of_0))**2)
  sum0=num_of_0*((0-Meu(num_of_1,num_of_0))**2)
  sum_of_all=sum1+sum0
  sd=sum_of_all/(num_of_1+num_of_0)
  return sd
```

standard deviation1

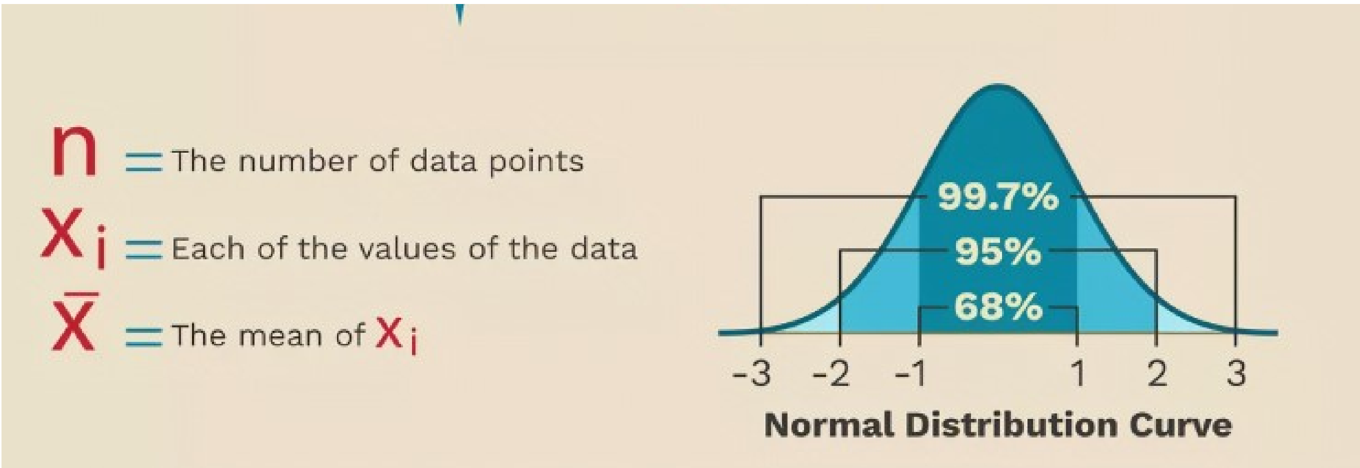
$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}.$$

```
#standard deviation2
def SD2(num_of_1,num_of_0):
  sum1=num_of_1*((1-Meu(num_of_1,num_of_0))**2)
  sum0=num_of_0*((0-Meu(num_of_1,num_of_0))**2)
  sum_of_all=sum1+sum0
  sd=sum_of_all/(num_of_1+num_of_0-1)
  return sd
```

standard deviation2

Calculating Standard Deviation

$$S_x = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}}$$




```
#==========Example 1==========
#total sms=40
#group A=20 :
print("mean of group A:",Meu(10,10))
print("standard deviation of group A:",SD1(10,10))
#group B=20 :
print("mean of group B:",Meu(18,2))
print("standard deviation of group B:",SD1(18,2))
```

```
mean of group A: 0.5
standard deviation of group A: 0.25
mean of group B: 0.9
standard deviation of group B: 0.09
```

Statistics Kingdom

Home > Mean > Two-Sample T (Welch's)

Two Sample T-Test Calculator (Welch's T-test)

Unknown unequal standard deviation

Expected difference between two populations' mean

Video Information T-Equal standard deviation Paired-T One sample T

Tails:	Two (H_1: μ1 ≠ μ2+d)	Significance level (α):	0.05
Effect:	Medium	Effect type:	Standardized effect size

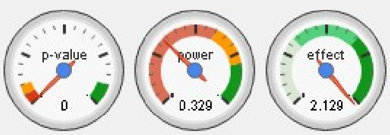
Effect Size:	0.5	Outliers:	Included
Difference (d):	0		

Enter raw data or Paste excel data or enter summarized data ($\bar{x}$, n, σ, S) below

Group name:	**Group-1**	**Group-2**
Sample average ($\bar{x}$):	0.5	0.9
Sample size (n):	20	20
Sample SD (S):	0.25	0.09

When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run



Two sample t-test (Welch), using T distribution (df=23.8434) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.
The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.
In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **5.994e-7**, (p(x≤T) = 2.997e-7). It means that the chance of type I error (rejecting a correct H_0) is small: 5.994e-7 (0.00006%).
The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **-6.7324**, which is not in the 95% region of acceptance: [-2.0646 : 2.0646].
$\bar{x}_1$-$\bar{x}_2$=-0.4, is not in the 95% region of acceptance: [-0.1227 : 0.1227].
The standard deviation of the difference, S' equals 0.0594, is used to calculate the statistic.

4. Effect size

The observed effect size d is **large**, **2.13**. This indicates that the magnitude of the difference between the average and average is large.

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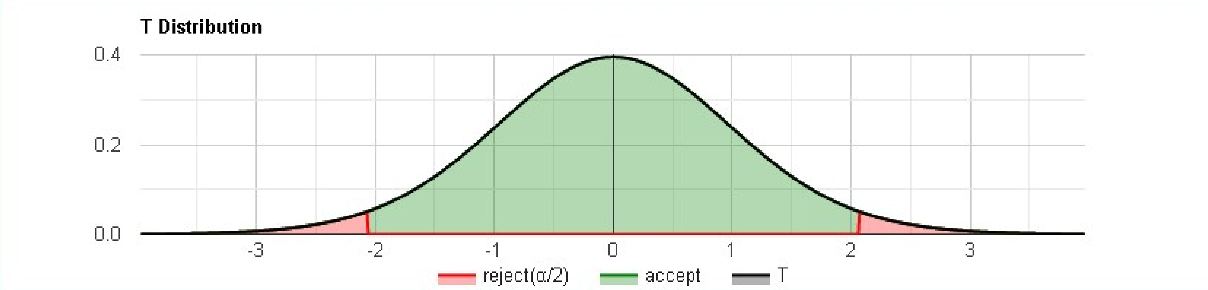
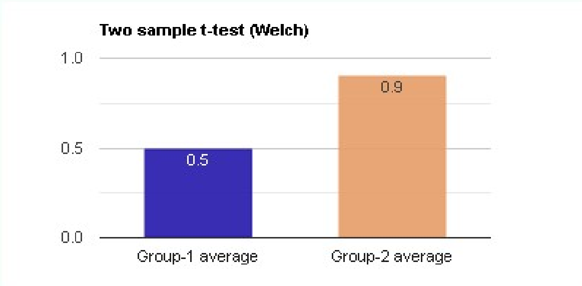




Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

  Although the priori power is low (0.3294), the H_0 is rejected.

- **Equality of variances assumption**

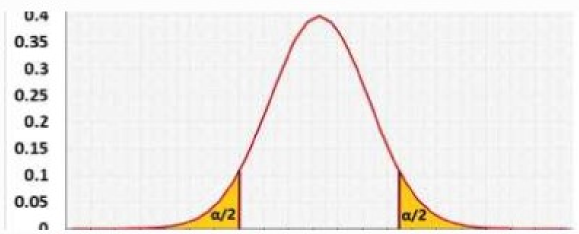
  Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is 0.0000437)
  F test assumes **equal** standard deviations, which is **not** your test assumption.

Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data
Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)
Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses	Test statistic
H_0: $\mu_1 = \mu_2+d$ H_1: $\mu_1 \neq \mu_2+d$	$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$ $$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

6 The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $\sigma_1\neq\sigma_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

$\bar{x}$ $\bar{x}_1$, $\bar{x}_2$ - Sample average of group1 and group2

n n_1,n_2 - Sample size of group1 and group2

S S_1,S_2 - Sample standard deviation of group1 and group2

<u>**Examples**</u>

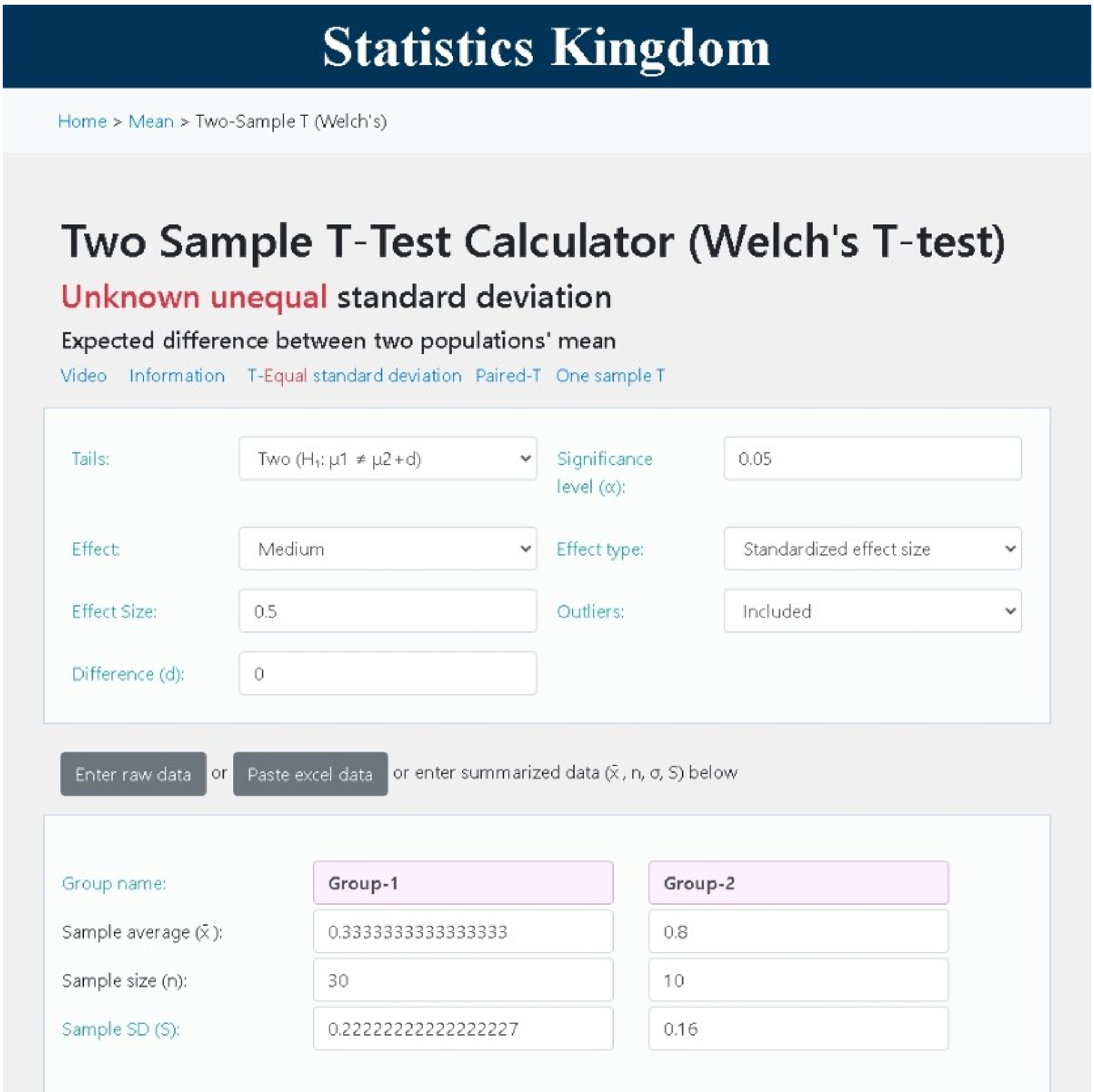
1. Two tailed test example:
A factory uses two identical machines to produce plastic plates. You would expect both machines to produce the same number of plates per minute.
Let μ1 = average number of plates produced by machine1 per minute.
Let μ2 = average number of plates produced by machine2 per minute.
We would expect μ1 to be equal to μ2. If one of the machines is slower than the other one, it should be serviced. In this case, we would like to know both if μ1 < μ2 or μ1 > μ2, since either machine could be slower.

2. Left tail example.
A farmer uses fertilizer-1 with good results.
A friend told him fertilizer-2 is better than fertilizer #1.
Let μ1 = average number of potatoes per square meter in gardens using fertilizer-1.
Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 2==========
#total sms=40
```

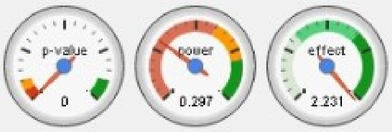
```
#group A=30 :
print("mean of group A:",Meu(10,20))
print("standard deviation of group A:",SD1(10,20))
#group B=10 :
print("mean of group B:",Meu(8,2))
print("standard deviation of group B:",SD1(8,2))
```

```
mean of group A: 0.3333333333333333
standard deviation of group A: 0.22222222222222227
mean of group B: 0.8
standard deviation of group B: 0.16
```



When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run



Two sample t-test (Welch), using T distribution (df=21.5323) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.
The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.
In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **3.717e-7**, (p(x≤T) = 1.858e-7). It means that the chance of type I error (rejecting a correct H_0) is small: 3.717e-7 (0.000037%).
The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **-7.1956**, which is not in the 95% region of acceptance: [-2.0765 : 2.0765].
$\bar{x}_1-\bar{x}_2$=-0.47, is not in the 95% region of acceptance: [-0.1347 : 0.1347].
The standard deviation of the difference, S' equals 0.0649, is used to calculate the statistic.

4. Effect size

The observed effect size d is **large**, **2.23**. This indicates that the magnitude of the difference between the average and average is large.

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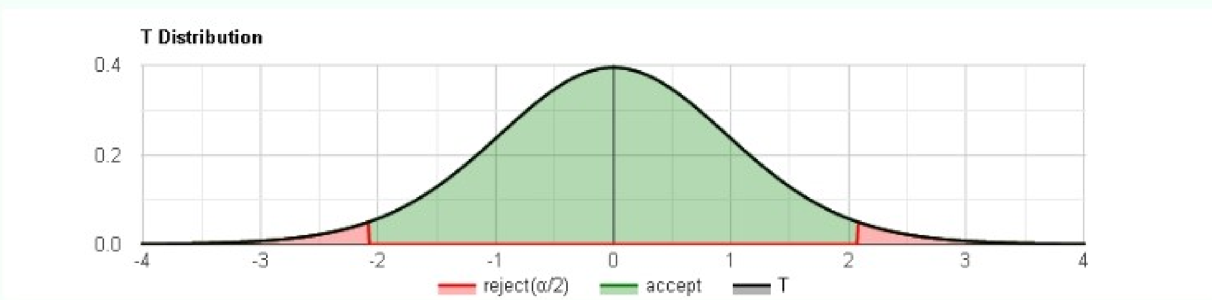
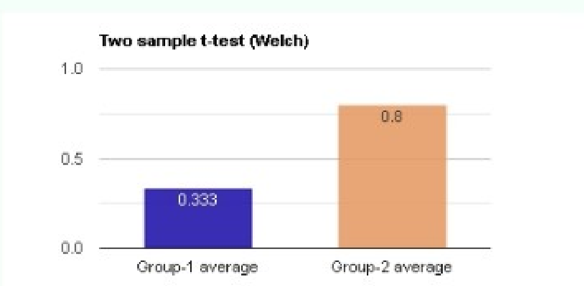




Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

  Although the priori power is low (0.2972), the H_0 is rejected.

- **Equality of variances assumption**

  Based on a two-tailed F test, σ_1 is considered as **equal** to σ_2 (p-value is 0.302)
  F test assumes **equal** standard deviations, which is **not** your test assumption.

Recommendations
The F-test can't reject the **unequal** variance assumption, since it is based on the **equal** variance assumption, which is not your preliminary assumption. You should continue with the Welch's t-test, which is also robust to variances equality.

Calculate T equal σ

Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data
Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)
Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses

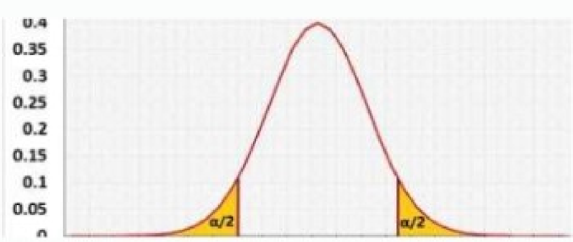
H_0: $\mu_1 = \mu_2 + d$
H_1: $\mu_1 \neq \mu_2 + d$

Test statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

6 The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $\sigma_1\neq\sigma_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

x̄ $\bar{x}_1, \bar{x}_2$ - Sample average of group1 and group2

n n_1, n_2 - Sample size of group1 and group2

S S_1, S_2 - Sample standard deviation of group1 and group2

Examples

1. Two tailed test example:
A factory uses two identical machines to produce plastic plates. You would expect both machines to produce the same number of plates per minute.
Let μ1 = average number of plates produced by machine1 per minute.
Let μ2 = average number of plates produced by machine2 per minute.
We would expect μ1 to be equal to μ2. If one of the machines is slower than the other one, it should be serviced. In this case, we would like to know both if μ1 < μ2 or μ1 > μ2, since either machine could be slower.

2. Left tail example.
A farmer uses fertilizer-1 with good results.
A friend told him fertilizer-2 is better than fertilizer #1.
Let μ1 = average number of potatoes per square meter in gardens using fertilizer-1.
Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 3==========
#total sms=1000
#group A=750 :
print("mean of group A:",Meu(98,617))
print("standard deviation of group A:",SD1(98,617))
#group B=250 :
print("mean of group B:",Meu(47,203))
print("standard deviation of group B:",SD1(47,203))
```

```
mean of group A: 0.13706293706293707
standard deviation of group A: 0.11827668834661842
mean of group B: 0.188
```

```
standard deviation of group B: 0.15265600000000001
```

Statistics Kingdom

Home > Mean > Two-Sample T (Welch's)

Two Sample T-Test Calculator (Welch's T-test)

Unknown unequal standard deviation

Expected difference between two populations' mean

Video Information T-Equal standard deviation Paired-T One sample T

Tails:	Two (H_1: $\mu1 \neq \mu2+d$)	Significance level (α):	0.05
Effect:	Medium	Effect type:	Standardized effect size
Effect Size:	0.5	Outliers:	Included
Difference (d):	0		

Enter raw data or Paste excel data or enter summarized data ($\bar{x}$, n, σ, S) below

Group name:	Group-1	Group-2
Sample average ($\bar{x}$):	0.13706293706293707	0.188
Sample size (n):	750	250
Sample SD (S):	0.11827668834661842	0.15265600000000001

When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run

Two sample t-test (Welch), using T distribution (df=353.9094) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.

The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.

In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **0.000002176**, ($p(x \le T) = 0.000001088$). It means that the chance of type I error (rejecting a correct H_0) is small: 0.000002176 (0.00022%).

The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **-4.8159**, which is not in the 95% region of acceptance: [-1.9667 : 1.9667].

$\bar{x}_1 - \bar{x}_2 = -0.051$, is not in the 95% region of acceptance: [-0.0208 : 0.0208].

The standard deviation of the difference, S' equals 0.0106, is used to calculate the statistic.

4. Effect size

The observed effect size d is **medium**, **0.4**. This indicates that the magnitude of the difference between the average and average is medium.

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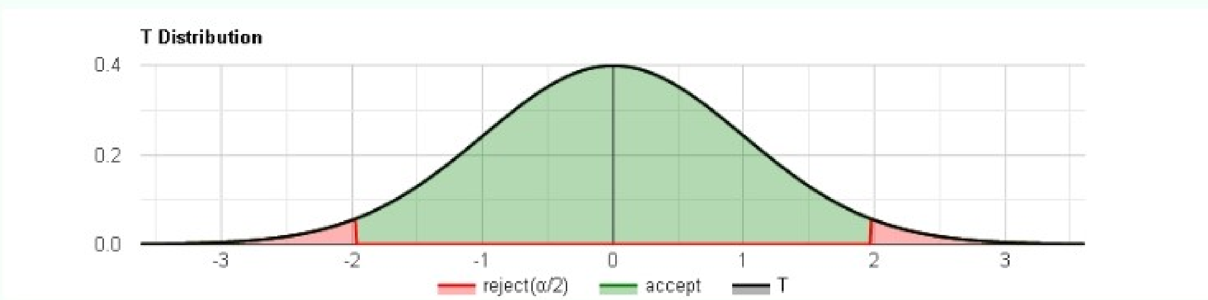
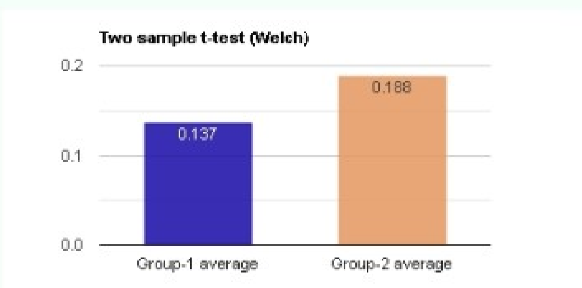




Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

  The test priori power is strong: 1

- **Equality of variances assumption**

  Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is 2.7e-7).

Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is 2.7e-7)
F test assumes **equal** standard deviations, which is **not** your test assumption.

Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data
Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)
Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses

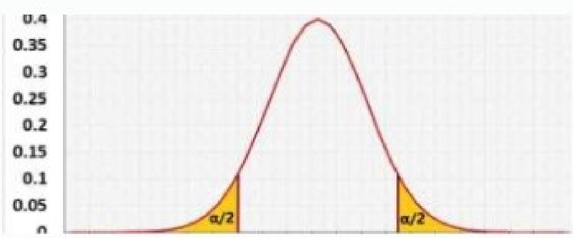
H_0: $\mu_1 = \mu_2 + d$
H_1: $\mu_1 \neq \mu_2 + d$

Test statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

6 The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $6_1 \neq 6_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

x̄ $\bar{x}_1, \bar{x}_2$ - Sample average of group1 and group2

n n_1, n_2 - Sample size of group1 and group2

S S_1, S_2 - Sample standard deviation of group1 and group2

Examples
1. Two tailed test example:
A factory uses two identical machines to produce plastic plates. You would expect both machines to produce the same

number of plates per minute.
Let μ1 = average number of plates produced by machine1 per minute.
Let μ2 = average number of plates produced by machine2 per minute.
We would expect μ1 to be equal to μ2. If one of the machines is slower than the other one, it should be serviced. In this case, we would like to know both if μ1 < μ2 or μ1 > μ2, since either machine could be slower.

2. Left tail example.
A farmer uses fertilizer-1 with good results.
A friend told him fertilizer-2 is better than fertilizer #1.
Let μ1 = average number of potatoes per square meter in gardens using fertilizer-1.
Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 4==========
#total sms=1000
#group A=750 :
print("mean of group A:",Meu(39,711))
print("standard deviation of group A:",SD1(39,711))
#group B=250 :
print("mean of group B:",Meu(9,241))
print("standard deviation of group B:",SD1(9,241))
```

```
mean of group A: 0.052
standard deviation of group A: 0.049296
mean of group B: 0.036
standard deviation of group B: 0.034704
```

Statistics Kingdom

Home > Mean > Two-Sample T (Welch's)

Two Sample T-Test Calculator (Welch's T-test)

Unknown unequal standard deviation

Expected difference between two populations' mean

Video Information T-Equal standard deviation Paired-T One sample T

Tails: Two (H_1: μ1 ≠ μ2+d) Significance 0.05

level (α):

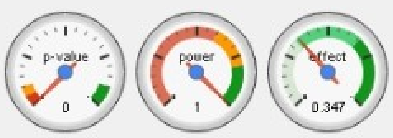
Effect:	Medium	Effect type:	Standardized effect size
Effect Size:	0.5	Outliers:	Included
Difference (d):	0		

Enter raw data or Paste excel data or enter summarized data ($\bar{x}$, n, σ, S) below

Group name:	Group-1	Group-2
Sample average ($\bar{x}$):	0.052	0.036
Sample size (n):	750	250
Sample SD (S):	0.049296	0.034704

When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run



Two sample t-test (Welch), using T distribution (df=605.5212) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.

The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.

In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **2.661e-8**, ($p(x \le T) = 1$). It means that the chance of type I error (rejecting a correct H_0) is small: 2.661e-8 (0.0000027%).

The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **5.6366**, which is not in the 95% region of acceptance: [-1.9639 : 1.9639].

$\bar{x}_1 - \bar{x}_2 = 0.016$, is not in the 95% region of acceptance: [-0.005575 : 0.005575].

The standard deviation of the difference, S' equals 0.00284, is used to calculate the statistic.

4. Effect size

The observed effect size d is **small**, **0.35**. This indicates that the magnitude of the difference between the average and average is small.

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(statskingdom@gmail.com)

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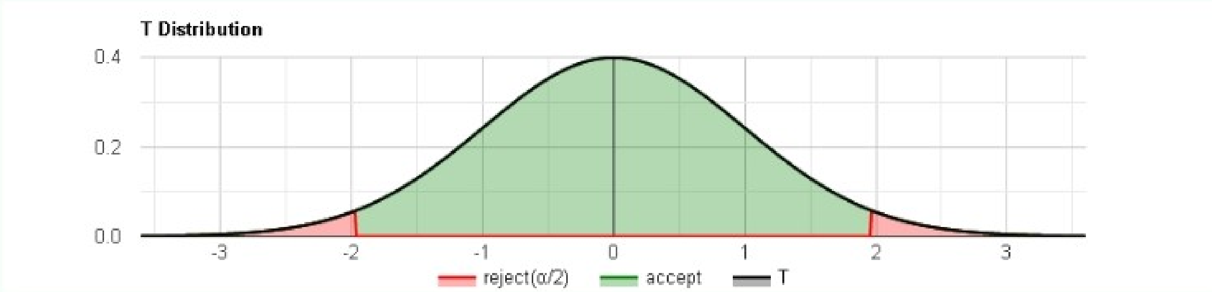
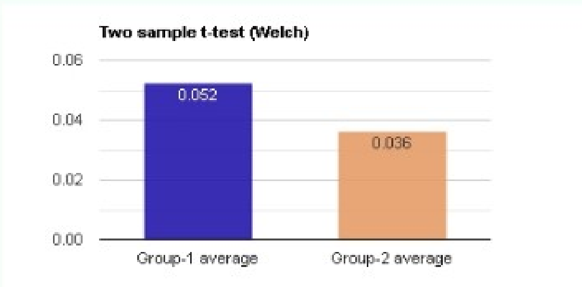




Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

The test priori power is strong: 1

- **Equality of variances assumption**

Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is 2.18e-10)
F test assumes **equal** standard deviations, which is **not** your test assumption.

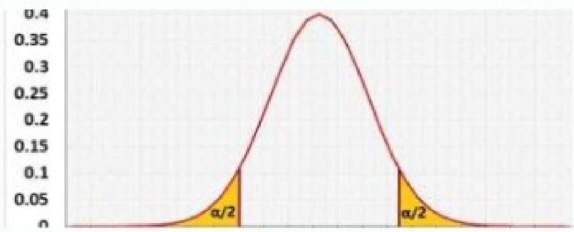
Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data
Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)
Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses	Test statistic
H_0: $\mu_1 = \mu_2 + d$ H_1: $\mu_1 \neq \mu_2 + d$	$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

6 The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $6_1 \neq 6_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

x̄ $\bar{x}_1, \bar{x}_2$ - Sample average of group1 and group2

n n_1,n_2 - Sample size of group1 and group2

S S_1,S_2 - Sample standard deviation of group1 and group2

Examples

1. Two tailed test example:
A factory uses two identical machines to produce plastic plates. You would expect both machines to produce the same number of plates per minute.
Let μ1 = average number of plates produced by machine1 per minute.
Let μ2 = average number of plates produced by machine2 per minute.
We would expect μ1 to be equal to μ2. If one of the machines is slower than the other one, it should be serviced. In this case, we would like to know both if μ1 < μ2 or μ1 > μ2, since either machine could be slower.

2. Left tail example.
A farmer uses fertilizer-1 with good results.
A friend told him fertilizer-2 is better than fertilizer #1.
Let μ1 = average number of potatoes per square meter in gardens using fertilizer-1.
Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 5==========
#total sms=10000
#group A=9000 :
print("mean of group A:",Meu(2927,6073))
print("standard deviation of group A:",SD1(2927,6073))
#group B=1000 :
print("mean of group B:",Meu(742,258))
print("standard deviation of group B:",SD1(742,258))
```

```
mean of group A: 0.32522222222222225
standard deviation of group A: 0.21945272839506172
mean of group B: 0.742
standard deviation of group B: 0.19143599999999997
```

Statistics Kingdom

Home > Mean > Two-Sample T (Welch's)

Two Sample T-Test Calculator (Welch's T-test)

Unknown unequal standard deviation

Expected difference between two populations' mean

Video Information T-Equal standard deviation Paired-T One sample T

Tails:	Two (H_1: $\mu 1 \neq \mu 2+d$)	Significance level (α):	0.05
Effect:	Medium	Effect type:	Standardized effect size
Effect Size:	0.5	Outliers:	Included
Difference (d):	0		

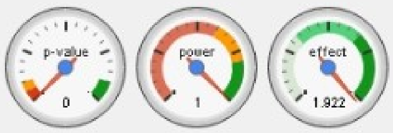
Enter raw data or Paste excel data or enter summarized data ($\bar{x}$, n, σ, S) below

Group name:	Group-1	Group-2
Sample average ($\bar{x}$):	0.32522222222222225	0.742
Sample size (n):	9000	1000

Sample SD (S):	0.21945272839506172	0.19143599999999997

When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run



Two sample t-test (Welch), using T distribution (df=1308.9351) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.

The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.

In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **0**, ($p(x \le T) = 0$). It means that the chance of type I error (rejecting a correct H_0) is small: 0 (0%).

The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **-64.3111**, which is not in the 95% region of acceptance: [-1.9618 : 1.9618].

$\bar{x}_1 - \bar{x}_2 = -0.42$, is not in the 95% region of acceptance: [-0.01271 : 0.01271].

The standard deviation of the difference, S' equals 0.00648, is used to calculate the statistic.

4. Effect size

The observed effect size d is **large**, **1.92**. This indicates that the magnitude of the difference between the average and average is large.

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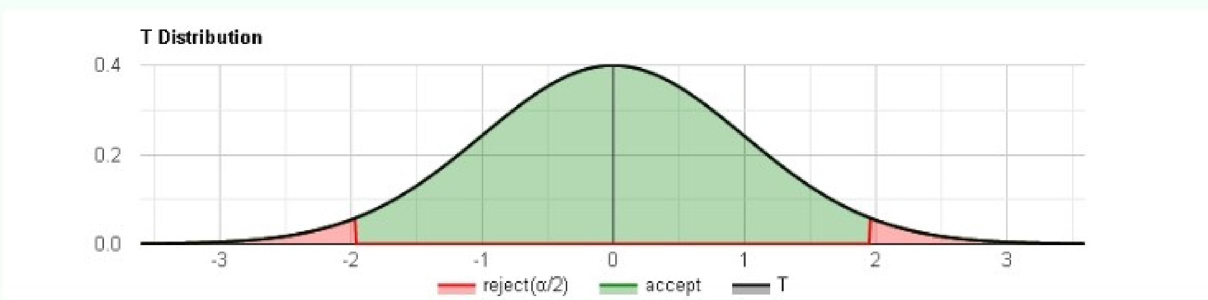


Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

  The test priori power is strong: 1

- **Equality of variances assumption**

  Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is NaN)
  F test assumes **equal** standard deviations, which is **not** your test assumption.

Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data
Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)
Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses

$H_0: \mu_1 = \mu_2 + d$

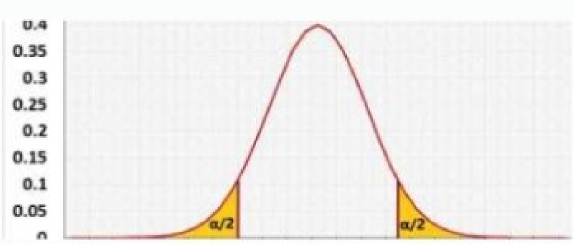
$H_1: \mu_1 \neq \mu_2 + d$

Test statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

σ The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $\sigma_1 \neq \sigma_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

x̄ $\bar{x}_1$, $\bar{x}_2$ - Sample average of group1 and group2

n n_1,n_2 - Sample size of group1 and group2

S S_1,S_2 - Sample standard deviation of group1 and group2

__Examples__

1. Two tailed test example:

A factory uses two identical machines to produce plastic plates. You would expect both machines to produce the same number of plates per minute.
Let μ1 = average number of plates produced by machine1 per minute.
Let μ2 = average number of plates produced by machine2 per minute.
We would expect μ1 to be equal to μ2. If one of the machines is slower than the other one, it should be serviced. In this case, we would like to know both if μ1 < μ2 or μ1 > μ2, since either machine could be slower.

2. Left tail example.

A farmer uses fertilizer-1 with good results.
A friend told him fertilizer-2 is better than fertilizer #1.
Let μ1 = average number of potatoes per square meter in gardens using fertilizer-1.
Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 6==========
#total sms=10000
#group A=9000 :
print("mean of group A:",Meu(7967,1033))
print("standard deviation of group A:",SD1(7967,1033))
#group B=1000 :
print("mean of group B:",Meu(617,383))
print("standard deviation of group B:",SD1(617,383))
```

```
mean of group A: 0.8852222222222222
standard deviation of group A: 0.10160383950617284
mean of group B: 0.617
standard deviation of group B: 0.236311
```

Statistics Kingdom

Home > Mean > Two-Sample T (Welch's)

Two Sample T-Test Calculator (Welch's T-test)

Unknown unequal standard deviation

Expected difference between two populations' mean

Video Information T-Equal standard deviation Paired-T One sample T

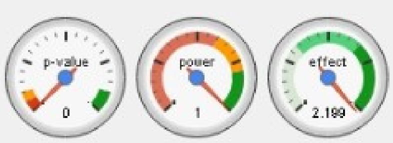
Tails:	Two (H_1: μ1 ≠ μ2+d)	Significance level (α):	0.05
Effect:	Medium	Effect type:	Standardized effect size
Effect Size:	0.5	Outliers:	Included
Difference (d):	0		

Enter raw data or Paste excel data or enter summarized data (x̄, n, σ, S) below

Group name:	Group-1	Group-2
Sample average (x̄):	0.8852222222222222	0.617
Sample size (n):	9000	1000
Sample SD (S):	0.10160383950617284	0.236311

When entering raw data, the t test calculator will run the Shapiro-Wilk normality test and calculate outliers, as part of the test calculation, and will generate the R code for your data.

Calculate test Clear Load last run



Two sample t-test (Welch), using T distribution (df=1040.4126) (two-tailed) (validation)

1. H_0 hypothesis

Since p-value < α, H_0 is rejected.

The average of **Group-1's** population is considered to be **not equal to** the average of **Group-2's** population.

In other words, the difference between the sample average of **Group-1** and **Group-2** is big enough to be statistically significant.

2. P-value

The p-value equals **0**, ($p(x \le T) = 1$). It means that the chance of type I error (rejecting a correct H_0) is small: 0 (0%).
The smaller the p-value the more it supports H_1.

3. The statistics

The test statistic T equals **35.53**, which is not in the 95% region of acceptance: [-1.9622 : 1.9622].
$\bar{x}_1 - \bar{x}_2 = 0.27$, is not in the 95% region of acceptance: [-0.01481 : 0.01481].
The standard deviation of the difference, S' equals 0.00755, is used to calculate the statistic.

4. Effect size

The observed effect size d is **large**, **2.2**. This indicates that the magnitude of the difference between the average and average is large.

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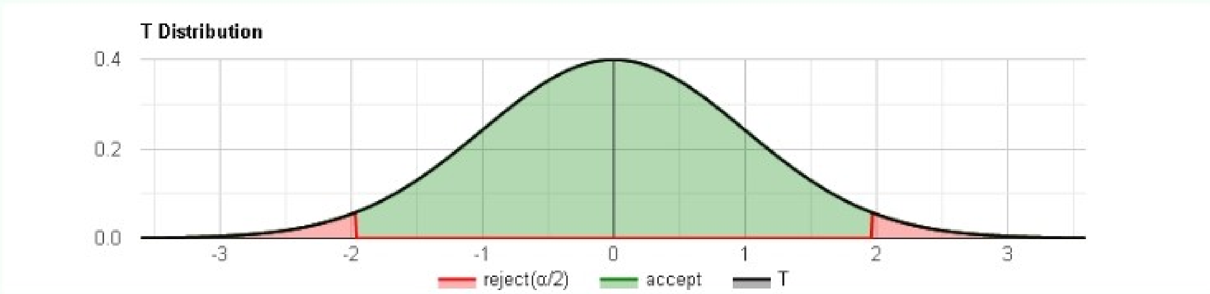
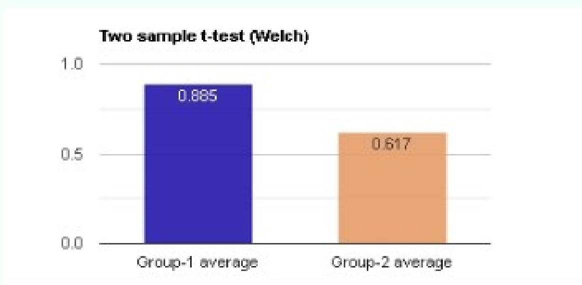




Test validation

The requested test was calculated, assumes **unequal** standard deviation (σ). it is likely you chose the right test.

- **Test power**

  The test priori power is strong: 1

- **Equality of variances assumption**

  Based on a two-tailed F test, σ_1 is considered as **unequal** to σ_2 (p-value is 2.67e-13)
  F test assumes **equal** standard deviations, which is **not** your test assumption.

Information

Target: To check if the difference between the average (mean) of two groups (populations) is significant, using sample data

Example1: A man of average is expected to be 10cm taller than a woman of average (d=10)

Example2: The average weight of an apple grown in field 1 is expected to be equal in weight to the average apple grown in field 2 (d=0)

Hypotheses

H_0: $\mu_1 = \mu_2 + d$

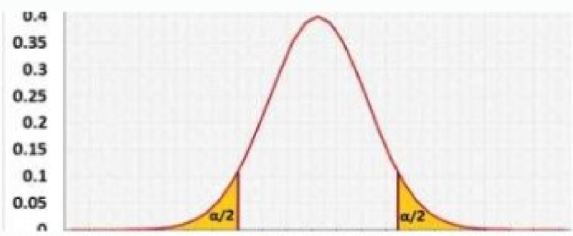
H_1: $\mu_1 \neq \mu_2 + d$

Test statistic

$$t = \frac{\bar{x}_1 - \bar{x}_2 - d}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

$$df = \frac{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)^2}{\frac{S_1^4}{n_1^2(n_1-1)} + \frac{S_2^4}{n_2^2(n_2-1)}}$$

Normal distribution



Assumptions

Normal distribution

6 The standard deviations of both populations not necessarily equal, so either $\sigma_1=\sigma_2$ or $\sigma_1 \neq \sigma_2$)

d Expected difference **d** between the populations's average is known

Required Sample Data

x̄ $\bar{x}_1$, $\bar{x}_2$ - Sample average of group1 and group2

n n_1,n_2 - Sample size of group1 and group2

S S_1,S_2 - Sample standard deviation of group1 and group2

Examples

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2. Left tail example.
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A friend told him fertilizer-2 is better than fertilizer #1.
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Let μ2 = average number of potatoes per square meter in gardens using fertilizer-2.
The farmer assumes that the fertilizer currently in use (fertilizer-1) is better than the suggested one.(or equal)
He is willing to change fertilizer only if the new one is better.
A one-tailed test is controversial. It increase the type I error. In this example, it may be important to know if fertilizer-2 is less effectinve than fertilizer-1, and use the two-tailes test.

```
#==========Example 1==========
#total sms=40
#group A=20 :
print("mean of group A:",Meu(10,10))
print("standard deviation of group A:",SD1(10,10))
#group B=20 :
print("mean of group B:",Meu(18,2))
print("standard deviation of group B:",SD1(18,2))
```

```
mean of group A: 0.5
standard deviation of group A: 0.25
mean of group B: 0.9
standard deviation of group B: 0.09
```

```
#==========Example 2==========
#total sms=40
#group A=30 :
print("mean of group A:",Meu(10,20))
print("standard deviation of group A:",SD1(10,20))
#group B=10 :
print("mean of group B:",Meu(8,2))
print("standard deviation of group B:",SD1(8,2))
```

```
mean of group A: 0.3333333333333333
standard deviation of group A: 0.2222222222222227
mean of group B: 0.8
standard deviation of group B: 0.16
```

```
#==========Example 3==========
```

```
#total sms=1000
#group A=750 :
print("mean of group A:",Meu(98,617))
print("standard deviation of group A:",SD1(98,617))
#group B=250 :
print("mean of group B:",Meu(47,203))
print("standard deviation of group B:",SD1(47,203))
```

```
mean of group A: 0.13706293706293707
standard deviation of group A: 0.11827668834661842
mean of group B: 0.188
standard deviation of group B: 0.15265600000000001
```

```
#==========Example 4==========
#total sms=1000
#group A=750 :
print("mean of group A:",Meu(39,711))
print("standard deviation of group A:",SD1(39,711))
#group B=250 :
print("mean of group B:",Meu(9,241))
print("standard deviation of group B:",SD1(9,241))
```

```
mean of group A: 0.052
standard deviation of group A: 0.049296
mean of group B: 0.036
standard deviation of group B: 0.034704
```

```
#==========Example 5==========
#total sms=10000
#group A=9000 :
print("mean of group A:",Meu(2927,6073))
print("standard deviation of group A:",SD1(2927,6073))
#group B=1000 :
print("mean of group B:",Meu(742,258))
print("standard deviation of group B:",SD1(742,258))
```

```
mean of group A: 0.32522222222222225
standard deviation of group A: 0.21945272839506172
mean of group B: 0.742
standard deviation of group B: 0.19143599999999997
```

```
#==========Example 6==========
#total sms=10000
```

```
#group A=9000 :
print("mean of group A:",Meu(7967,1033))
print("standard deviation of group A:",SD1(7967,1033))
#group B=1000 :
print("mean of group B:",Meu(617,383))
print("standard deviation of group B:",SD1(617,383))
```

```
mean of group A: 0.8852222222222222
standard deviation of group A: 0.10160383950617284
mean of group B: 0.617
standard deviation of group B: 0.236311
```