Package 'TOSTER'

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Title Two One-Sided Tests (TOST) Equivalence Testing

Description Two one-sided tests (TOST) procedure to test equivalence for t-tests, correlations, differences between proportions, and meta-analyses, including power analysis for t-tests and correlations. Allows you to specify equivalence bounds in raw scale units or in terms of effect sizes. See: Lakens (2017) <doi:10.1177/1948550617697177>.

Author Daniel Lakens <D.Lakens@tue.nl>

Maintainer Daniel Lakens <D.Lakens@tue.nl>

License GPL-3

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R topics documented:

`dataTOSTone` *TOST One Sample T-Test*

Description

TOST One Sample T-Test

Usage

```
dataTOSTone(data, vars, mu = 0, low_eqbound = -0.5,
  high_eqbound = 0.5, eqbound_type = "d", alpha = 0.05,
  desc = FALSE, plots = FALSE, low_eqbound_d = -999999999,
  high_eqbound_d = -999999999)
```

Arguments

`data`	the data as a data frame
`vars`	a vector of strings naming variables of interest in `data`
`mu`	a number (default: 0) to compare against
`low_eqbound`	a number (default: -0.5) the lower equivalence bounds
`high_eqbound`	a number (default: 0.5) the upper equivalence bounds
`eqbound_type`	`'d'` (default) or `'raw'`; whether the bounds are specified in Cohen's d or raw units respectively
`alpha`	alpha level (default = 0.05)
`desc`	`TRUE` or `FALSE` (default), provide descriptive statistics
`plots`	`TRUE` or `FALSE` (default), provide plots
`low_eqbound_d`	deprecated
`high_eqbound_d`	deprecated

Value

A results object containing:

results$tost	a table
results$eqb	a table
results$desc	a table
results$plots	an array of images

Tables can be converted to data frames with asDF or as.data.frame. For example:

```
results$tost$asDF
as.data.frame(results$tost)
```

Examples

```
library("TOSTER")

dataTOSTone(data=iris, vars="Sepal.Width", mu=3, low_eqbound=-0.3, high_eqbound=0.3,
            alpha=0.05, desc=TRUE, plots=TRUE)

TOSTone(m=3.05733, mu=3, sd=0.4358663, n=150, low_eqbound_d=-0.3, high_eqbound_d=0.3, alpha=0.05)
```

---

dataTOSTpaired *TOST Paired Samples T-Test*

Description

TOST Paired Samples T-Test

Usage

```
dataTOSTpaired(data, pairs, low_eqbound = -0.5, high_eqbound = 0.5,
  eqbound_type = "d", alpha = 0.05, desc = FALSE, plots = FALSE,
  low_eqbound_dz = -999999999, high_eqbound_dz = -999999999)
```

Arguments

data	the data as a data frame
pairs	a list of vectors of strings naming variables to pair from data
low_eqbound	a number (default: 0.5) the lower equivalence bounds
high_eqbound	a number (default: 0.5) the upper equivalence bounds
eqbound_type	'd' (default) or 'raw'; whether the bounds are specified in standardized mean difference (Cohen's dz) or raw units respectively
alpha	alpha level (default = 0.05)
desc	TRUE or FALSE (default), provide descriptive statistics
plots	TRUE or FALSE (default), provide plots
low_eqbound_dz	deprecated
high_eqbound_dz	deprecated

Value

A results object containing:

`results$tost`	a table
`results$eqb`	a table
`results$desc`	a table
`results$plots`	an array of images

Tables can be converted to data frames with `asDF` or `as.data.frame`. For example:

```
results$tost$asDF
as.data.frame(results$tost)
```

References

Mara, C. A., & Cribbie, R. A. (2012). Paired-Samples Tests of Equivalence. Communications in Statistics - Simulation and Computation, 41(10), 1928-1943. https://doi.org/10.1080/03610918.2011.626545, formula page 1932. Note there is a typo in the formula: n-1 should be n (personal communication, 31-08-2016)

Examples

```
library("TOSTER")

dataTOSTpaired(data = randu, pairs = list(c(i1="x",i2="y")), low_eqbound = -0.3,
               high_eqbound = 0.3, alpha = 0.05, desc = TRUE, plots = TRUE)
```

`dataTOSTr` *TOST Correlation*

Description

TOST Correlation

Usage

```
dataTOSTr(data, pairs, low_eqbound_r = -0.3, high_eqbound_r = 0.3,
  alpha = 0.05, desc = FALSE, plots = FALSE)
```

Arguments

`data`	the data as a data frame
`pairs`	a list of vectors of strings naming variables to correlate from `data`
`low_eqbound_r`	lower equivalence bounds (e.g., -0.3) expressed in a correlation effect size
`high_eqbound_r`	upper equivalence bounds (e.g., 0.3) expressed in a correlation effect size

alpha	alpha level (default = 0.05)
desc	TRUE or FALSE (default), provide descriptive statistics
plots	TRUE or FALSE (default), provide plots

Value

A results object containing:

results$tost	a table
results$eqb	a table
results$desc	a table
results$plots	an array of images

Tables can be converted to data frames with asDF or as.data.frame. For example:

```
results$tost$asDF
```

```
as.data.frame(results$tost)
```

---

dataTOSTtwo *TOST Independent Samples T-Test*

Description

TOST Independent Samples T-Test

Usage

```
dataTOSTtwo(data, deps, group, var_equal = FALSE, low_eqbound = -0.5,
  high_eqbound = 0.5, eqbound_type = "d", alpha = 0.05,
  desc = FALSE, plots = FALSE, low_eqbound_d = -999999999,
  high_eqbound_d = -999999999)
```

Arguments

data	the data as a data frame
deps	a vector of strings naming dependent variables in data
group	a string naming the grouping variable in data; must have two levels
var_equal	TRUE or FALSE (default), assume equal variances
low_eqbound	a number (default: -0.5) the lower equivalence bounds
high_eqbound	a number (default: 0.5) the upper equivalence bounds
eqbound_type	'd' (default) or 'raw'; whether the bounds are specified in Cohen's d or raw units respectively
alpha	alpha level (default = 0.05)

desc	TRUE or FALSE (default), provide descriptive statistics
plots	TRUE or FALSE (default), provide plots
low_eqbound_d	deprecated
high_eqbound_d	deprecated

Value

A results object containing:

results$tost	a table
results$eqb	a table
results$desc	a table
results$plots	an array of images

Tables can be converted to data frames with asDF or as.data.frame. For example:

```
results$tost$asDF
```

```
as.data.frame(results$tost)
```

References

Berger, R. L., & Hsu, J. C. (1996). Bioequivalence Trials, Intersection-Union Tests and Equivalence Confidence Sets. Statistical Science, 11(4), 283-302.

Gruman, J. A., Cribbie, R. A., & Arpin-Cribbie, C. A. (2007). The effects of heteroscedasticity on tests of equivalence. Journal of Modern Applied Statistical Methods, 6(1), 133-140, formula for Welch's t-test on page 135

Examples

```
library(TOSTER)

## Load iris dataset, remove one of the three groups so two are left

data<-iris[which(iris$Species!="versicolor"),]

## TOST procedure on the raw data

dataTOSTtwo(data, deps="Sepal.Width", group="Species", var_equal = TRUE, low_eqbound = -0.5,
            high_eqbound = 0.5, alpha = 0.05, desc = TRUE, plots = TRUE)
```

---

datatosttwoprop *TOST Two Proportions*

Description

TOST Two Proportions

Usage

```
datatosttwoprop(data, var, level, group, low_eqbound = -0.1,
  high_eqbound = 0.1, alpha = 0.05, desc = FALSE, plot = FALSE)
```

Arguments

data	.
var	.
level	.
group	.
low_eqbound	a number (default: -0.1) the lower equivalence bounds
high_eqbound	a number (default: 0.1) the upper equivalence bounds
alpha	alpha level (default = 0.05)
desc	TRUE or FALSE (default), provide descriptive statistics
plot	TRUE or FALSE (default), provide plot

Value

A results object containing:

results$tost	a table
results$eqb	a table
results$desc	a table
results$plot	an image

Tables can be converted to data frames with asDF or as.data.frame. For example:

```
results$tost$asDF
```

```
as.data.frame(results$tost)
```

---

powerTOSTone *Power analysis for TOST for one-sample t-test (Cohen's d).*

Description

Power analysis for TOST for one-sample t-test (Cohen's d).

Usage

```
powerTOSTone(alpha, statistical_power, N, low_eqbound_d, high_eqbound_d)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	sample size (e.g., 108)
low_eqbound_d	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's d)
high_eqbound_d	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's d)

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.1.9

Examples

```
## Sample size for alpha = 0.05, 90% power, equivalence bounds of
## Cohen's d = -0.3 and Cohen's d = 0.3, and assuming true effect = 0
powerTOSTone(alpha=0.05, statistical_power=0.9, low_eqbound_d=-0.3, high_eqbound_d=0.3)

## Power for sample size of 121, alpha = 0.05, equivalence bounds of
## Cohen's d = -0.3 and Cohen's d = 0.3, and assuming true effect = 0

powerTOSTone(alpha=0.05, N=121, low_eqbound_d=-0.3, high_eqbound_d=0.3)

## Equivalence bounds for sample size of 121, alpha = 0.05, statistical power of
## 0.9, and assuming true effect = 0

powerTOSTone(alpha=0.05, N=121, statistical_power=.9)
```

---

powerTOSTone.raw *Power analysis for TOST for one-sample t-test (raw scores).*

Description

Power analysis for TOST for one-sample t-test (raw scores).

Usage

```
powerTOSTone.raw(alpha, statistical_power, N, sd, low_eqbound,
  high_eqbound)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	sample size (e.g., 108)
sd	population standard deviation
low_eqbound	lower equivalence bounds (e.g., -0.5) expressed in raw scores
high_eqbound	upper equivalence bounds (e.g., 0.5) expressed in raw scores

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.1.9

Examples

```
## Sample size for alpha = 0.05, 90% power, equivalence bounds of -0.3 and 0.3 in
## raw units, assuming pooled standard deviation of 1, and assuming true effect = 0
powerTOSTone.raw(alpha=0.05, statistical_power=0.9, sd = 1, low_eqbound=-0.3, high_eqbound=0.3)

## Power for sample size of 121, alpha = 0.05, equivalence bounds of
## -0.3 and 0.3 in raw units, assuming pooled standard deviation of 1, and assuming true effect = 0

powerTOSTone.raw(alpha=0.05, N=121, sd = 1, low_eqbound=-0.3, high_eqbound=0.3)

## Power for sample size of 121, alpha = 0.05, statistical power of
## 0.9, and assuming true effect = 0

powerTOSTone.raw(alpha=0.05, N=121, statistical_power=.9, sd=1)
```

---

powerTOSTpaired *Power analysis for TOST for dependent t-test (Cohen's dz).*

Description

Power analysis for TOST for dependent t-test (Cohen's dz).

Usage

```
powerTOSTpaired(alpha, statistical_power, N, low_eqbound_dz,
  high_eqbound_dz)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	number of pairs (e.g., 96)
low_eqbound_dz	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's dz)
high_eqbound_dz	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's dz)

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.1.9

Examples

```
## Sample size for alpha = 0.05, 80% power, equivalence bounds of
## Cohen's dz = -0.3 and Cohen's d = 0.3, and assuming true effect = 0
powerTOSTpaired(alpha=0.05,statistical_power=0.8,low_eqbound_dz=-0.3,high_eqbound_dz=0.3)

## Sample size for alpha = 0.05, N = 96 pairs, equivalence bounds of
## Cohen's dz = -0.3 and Cohen's d = 0.3, and assuming true effect = 0
powerTOSTpaired(alpha=0.05,N=96,low_eqbound_dz=-0.3,high_eqbound_dz=0.3)

## Equivalence bounds for alpha = 0.05, N = 96 pairs, statistical power of
## 0.8, and assuming true effect = 0
powerTOSTpaired(alpha=0.05,N=96,statistical_power=0.8)
```

---

powerTOSTpaired.raw *Power analysis for TOST for dependent t-test (raw scores).*

Description

Power analysis for TOST for dependent t-test (raw scores).

Usage

```
powerTOSTpaired.raw(alpha, statistical_power, N, sdif, low_eqbound,
  high_eqbound)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	number of pairs (e.g., 96)
sdif	standard deviation of the difference scores
low_eqbound	lower equivalence bounds (e.g., -0.5) expressed in raw mean difference
high_eqbound	upper equivalence bounds (e.g., 0.5) expressed in raw mean difference

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.1.9

Examples

```
## Sample size for alpha = 0.05, 80% power, equivalence bounds of -3 and 3 in raw units
## and assuming a standard deviation of the difference scores of 10, and assuming a true effect = 0
powerTOSTpaired.raw(alpha=0.05,statistical_power=0.8,low_eqbound=-3, high_eqbound=3, sdif=10)

## Sample size for alpha = 0.05, N = 96 pairs, equivalence bounds of -3 and 3 in raw units
## and assuming a standard deviation of the difference scores of 10, and assuming a true effect = 0
powerTOSTpaired.raw(alpha=0.05,N=96,low_eqbound=-3, high_eqbound=3, sdif=10)

## Equivalence bounds for alpha = 0.05, N = 96 pairs, statistical power of 0.8
## and assuming a standard deviation of the difference scores of 10, and assuming a true effect = 0
powerTOSTpaired.raw(alpha=0.05,N=96, statistical_power=0.8, sdif=10)
```

---

powerTOSTr *Power analysis for TOST for correlations.*

Description

Power analysis for TOST for correlations.

Usage

```
powerTOSTr(alpha, statistical_power, N, low_eqbound_r, high_eqbound_r)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	number of pairs (e.g., 96)
low_eqbound_r	lower equivalence bounds (e.g., -0.3) expressed in a correlation effect size
high_eqbound_r	upper equivalence bounds (e.g., 0.3) expressed in a correlation effect size

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

Examples

```
## Sample size for alpha = 0.05, 90% power, equivalence bounds of
## r = -0.1 and r = 0.1, assuming true effect = 0
powerTOSTr(alpha=0.05, statistical_power=0.9, low_eqbound_r=-0.1, high_eqbound_r=0.1)

## Sample size for alpha = 0.05, N=536, equivalence bounds of
## r = -0.1 and r = 0.1, assuming true effect = 0
powerTOSTr(alpha=0.05, N=536, low_eqbound_r=-0.1, high_eqbound_r=0.1)

## Equivalence bounds for alpha = 0.05, N=536, statistical power of
## 0.9, assuming true effect = 0
powerTOSTr(alpha=0.05, N=536, statistical_power=0.9)
```

---

powerTOSTtwo *Power analysis for TOST for independent t-test (Cohen's d).*

Description

Power analysis for TOST for independent t-test (Cohen's d).

Usage

```
powerTOSTtwo(alpha, statistical_power, N, low_eqbound_d, high_eqbound_d)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
N	sample size per group (e.g., 108)

low_eqbound_d lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's d)

high_eqbound_d upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's d)

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.2.4 with k = 1

Examples

```
## Sample size for alpha = 0.05, 80% power, equivalence bounds of
## Cohen's d = -0.4 and Cohen's d = 0.4, assuming true effect = 0
powerTOSTtwo(alpha=0.05, statistical_power=0.8, low_eqbound_d=-0.4, high_eqbound_d=0.4)

## Statistical power for alpha = 0.05, N = 108 per group, equivalence bounds of
## Cohen's d = -0.4 and Cohen's d = 0.4, assuming true effect = 0
powerTOSTtwo(alpha=0.05, N=108, low_eqbound_d=-0.4, high_eqbound_d=0.4)

## Equivalence bounds for alpha = 0.05, N = 108 per group, statistical power of
## 0.8, assuming true effect = 0
powerTOSTtwo(alpha=0.05, N=108, statistical_power=0.8)
```

---

powerTOSTtwo.prop *Power analysis for TOST for difference between two proportions using Z-test (pooled)*

Description

Power analysis for TOST for difference between two proportions using Z-test (pooled)

Usage

```
powerTOSTtwo.prop(alpha, statistical_power, prop1, prop2, N,
  low_eqbound_prop, high_eqbound_prop)
```

Arguments

alpha	alpha used for the test (e.g., 0.05)
statistical_power	desired power (e.g., 0.8)
prop1	expected proportion in control condition
prop2	expected proportion in the experimental condition
N	sample size (e.g., 108)
low_eqbound_prop	lower equivalence bounds (e.g., -0.05) expressed in proportion
high_eqbound_prop	upper equivalence bounds (e.g., 0.05) expressed in proportion

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Silva, G. T. da, Logan, B. R., & Klein, J. P. (2008). Methods for Equivalence and Noninferiority Testing. Biology of Blood and Marrow Transplantation: Journal of the American Society for Blood and Marrow Transplantation, 15(1 Suppl), 120-127. https://doi.org/10.1016/j.bbmt.2008.10.004 Julious, S. A. & Campell, M. J. (2012). Tutorial in biostatistics: sample sizes for parallel group clinical trials with binary data. Statistics in Medicine, 31:2904-2936. Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition (2 edition). Boca Raton: Chapman and Hall/CRC.

Examples

```
## Sample size for alpha = 0.05, 90% power, assuming true effect prop1 = prop 2 = 0.5,
## equivalence bounds of 0.4 and 0.6 (so low_eqbound_prop = -0.1 and high_eqbound_prop = 0.1)

powerTOSTtwo.prop(alpha = 0.05, statistical_power = 0.9, prop1 = 0.5, prop2 = 0.5,
   low_eqbound_prop = -0.1, high_eqbound_prop = 0.1)

## Power for alpha = 0.05, N 542 , assuming true effect prop1 = prop 2 = 0.5,
## equivalence bounds of 0.4 and 0.6 (so low_eqbound_prop = -0.1 and high_eqbound_prop = 0.1)

powerTOSTtwo.prop(alpha = 0.05, N = 542, prop1 = 0.5, prop2 = 0.5,
   low_eqbound_prop = -0.1, high_eqbound_prop = 0.1)

## Equivalence bounds for alpha = 0.05, N 542 , assuming true effect prop1 = prop 2 = 0.5,
## and 90% power

powerTOSTtwo.prop(alpha=0.05, statistical_power=0.9, N=542, prop1 = 0.5, prop2 = 0.5)

#Example 4.2.4 from Chow, Wang, & Shao (2007, p. 93)
powerTOSTtwo.prop(alpha=0.05, statistical_power=0.8, prop1 = 0.75, prop2 = 0.8,
```

```
   low_eqbound_prop = -0.2, high_eqbound_prop = 0.2)

# Example 5 from Julious & Campbell (2012, p. 2932)
powerTOSTtwo.prop(alpha=0.025, statistical_power=0.9, prop1 = 0.8, prop2 = 0.8,
   low_eqbound_prop=-0.1, high_eqbound_prop=0.1)
# From Machin, D. (Ed.). (2008). Sample size tables for clinical studies (3rd ed).

# Example 9.4b equivalence of two proportions (p. 113) #
powerTOSTtwo.prop(alpha=0.010, statistical_power=0.8, prop1 = 0.5, prop2 = 0.5,
   low_eqbound_prop = -0.2, high_eqbound_prop = 0.2)/2
```

`powerTOSTtwo.raw` *Power analysis for TOST for independent t-test (raw scores).*

Description

Power analysis for TOST for independent t-test (raw scores).

Usage

```
powerTOSTtwo.raw(alpha, statistical_power, N, sdpooled, low_eqbound,
  high_eqbound)
```

Arguments

`alpha`	alpha used for the test (e.g., 0.05)
`statistical_power`	desired power (e.g., 0.8)
`N`	sample size per group (e.g., 108)
`sdpooled`	specify the pooled standard deviation
`low_eqbound`	lower equivalence bounds (e.g., -0.5) expressed in raw scale units (e.g., scale-points)
`high_eqbound`	upper equivalence bounds (e.g., 0.5) expressed in raw scale units (e.g., scale-points)

Value

Calculate either achieved power, equivalence bounds, or required N, assuming a true effect size of 0. Returns a string summarizing the power analysis, and a numeric variable for number of observations, equivalence bounds, or power.

References

Chow, S.-C., Wang, H., & Shao, J. (2007). Sample Size Calculations in Clinical Research, Second Edition - CRC Press Book. Formula 3.2.4 with k = 1

Examples

```
## Sample size for alpha = 0.05, 80% power, equivalence bounds of -200 and 200 in raw
## units, assuming pooled standard deviation of 350, and assuming true effect = 0
powerTOSTtwo.raw(alpha=0.05,statistical_power=0.8,low_eqbound=-200,high_eqbound=200,sdpooled=350)

## Power for alpha = 0.05, N = 53 per group, equivalence bounds of
## -200 and 200 in raw units, assuming sdpooled = 350 and true effect = 0
powerTOSTtwo.raw(alpha=0.05, N=53, low_eqbound=-200, high_eqbound=200, sdpooled=350)

## Equivalence bounds for alpha = 0.05, N = 108 per group, statistical power of
## 0.8, assuming true effect = 0
powerTOSTtwo.raw(alpha=0.05, N=53, statistical_power=0.8, sdpooled=350)
```

TOSTmeta *TOST function for meta-analysis*

Description

TOST function for meta-analysis

Usage

```
TOSTmeta(ES, var, se, low_eqbound_d, high_eqbound_d, alpha, plot = TRUE,
  verbose = TRUE)
```

Arguments

ES	meta-analytic effect size
var	meta-analytic variance
se	standard error
low_eqbound_d	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's d)
high_eqbound_d	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's d)
alpha	alpha level (default = 0.05)
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST Z-value 1, TOST p-value 1, TOST Z-value 2, TOST p-value 2, alpha, low equivalence bound d, high equivalence bound d, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Rogers, J. L., Howard, K. I., & Vessey, J. T. (1993). Using significance tests to evaluate equivalence between two experimental groups. Psychological Bulletin, 113(3), 553, formula page 557.

Examples

```
## Run TOSTmeta by specifying the standard error
TOSTmeta(ES=0.12, se=0.09, low_eqbound_d=-0.2, high_eqbound_d=0.2, alpha=0.05)
## Run TOSTmeta by specifying the variance
TOSTmeta(ES=0.12, var=0.0081, low_eqbound_d=-0.2, high_eqbound_d=0.2, alpha=0.05)
## If both variance and se are specified, TOSTmeta will use standard error and ignore variance
TOSTmeta(ES=0.12, var=9999, se = 0.09, low_eqbound_d=-0.2, high_eqbound_d=0.2, alpha=0.05)
```

TOSTone *TOST function for a one-sample t-test (Cohen's d)*

Description

TOST function for a one-sample t-test (Cohen's d)

Usage

```
TOSTone(m, mu, sd, n, low_eqbound_d, high_eqbound_d, alpha, plot = TRUE,
  verbose = TRUE)
```

Arguments

m	mean
mu	value to compare against
sd	standard deviation
n	sample size
low_eqbound_d	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's d)
high_eqbound_d	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's d)
alpha	alpha level (default = 0.05)
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, Lower limit confidence interval TOST, Upper limit confidence interval TOST

Examples

```
## Test observed mean of 0.54 and standard deviation of 1.2 in sample of 100 participants
## against 0.5 given equivalence bounds of Cohen's d = -0.3 and 0.3, with an alpha = 0.05.
TOSTone(m=0.54,mu=0.5,sd=1.2,n=100,low_eqbound_d=-0.3, high_eqbound_d=0.3, alpha=0.05)
```

`TOSTone.raw` *TOST function for a one-sample t-test (raw scores)*

Description

TOST function for a one-sample t-test (raw scores)

Usage

```
TOSTone.raw(m, mu, sd, n, low_eqbound, high_eqbound, alpha, plot = TRUE,
  verbose = TRUE)
```

Arguments

`m`	mean
`mu`	value to compare against
`sd`	standard deviation
`n`	sample size
`low_eqbound`	lower equivalence bounds (e.g., -0.5) expressed in raw units
`high_eqbound`	upper equivalence bounds (e.g., 0.5) expressed in raw units
`alpha`	alpha level (default = 0.05)
`plot`	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
`verbose`	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, Lower limit confidence interval TOST, Upper limit confidence interval TOST

Examples

```
## Test observed mean of 0.52 and standard deviation of 0.52 in sample of 300 participants
## against 0.5 given equivalence bounds in raw units of -0.1 and 0.1, with an alpha = 0.05.
TOSTone.raw(m=0.52,mu=0.5,sd=0.5,n=300,low_eqbound=-0.1, high_eqbound=0.1, alpha=0.05)
```

TOSTpaired *TOST function for a dependent t-test (Cohen's dz)*

Description

TOST function for a dependent t-test (Cohen's dz)

Usage

```
TOSTpaired(n, m1, m2, sd1, sd2, r12, low_eqbound_dz, high_eqbound_dz,
  alpha, plot = TRUE, verbose = TRUE)
```

Arguments

n	sample size (pairs)
m1	mean of group 1
m2	mean of group 2
sd1	standard deviation of group 1
sd2	standard deviation of group 2
r12	correlation of dependent variable between group 1 and group 2
low_eqbound_dz	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's dz)
high_eqbound_dz	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's dz)
alpha	alpha level (default = 0.05)
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, low equivalence bound in dz, high equivalence bound in dz, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Mara, C. A., & Cribbie, R. A. (2012). Paired-Samples Tests of Equivalence. Communications in Statistics - Simulation and Computation, 41(10), 1928-1943. https://doi.org/10.1080/03610918.2011.626545, formula page 1932. Note there is a typo in the formula: n-1 should be n (personal communication, 31-8-2016)

Examples

```
## Test means of 5.83 and 5.75, standard deviations of 1.17 and 1.29 in sample of 65 pairs
## with correlation between observations of 0.75 using equivalence bounds in Cohen's dz of
## -0.4 and 0.4 (with default alpha setting of = 0.05).
TOSTpaired(n=65,m1=5.83,m2=5.75,sd1=1.17,sd2=1.29,r12=0.75,low_eqbound_dz=-0.4,high_eqbound_dz=0.4)
```

TOSTpaired.raw *TOST function for a dependent t-test (raw scores)*

Description

TOST function for a dependent t-test (raw scores)

Usage

```
TOSTpaired.raw(n, m1, m2, sd1, sd2, r12, low_eqbound, high_eqbound, alpha,
  plot = TRUE, verbose = TRUE)
```

Arguments

n	sample size (pairs)
m1	mean of group 1
m2	mean of group 2
sd1	standard deviation of group 1
sd2	standard deviation of group 2
r12	correlation of dependent variable between group 1 and group 2
low_eqbound	lower equivalence bounds (e.g., -0.5) expressed in raw scores
high_eqbound	upper equivalence bounds (e.g., 0.5) expressed in raw scores
alpha	alpha level (default = 0.05)
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Mara, C. A., & Cribbie, R. A. (2012). Paired-Samples Tests of Equivalence. Communications in Statistics - Simulation and Computation, 41(10), 1928-1943. https://doi.org/10.1080/03610918.2011.626545, formula page 1932. Note there is a typo in the formula: n-1 should be n (personal communication, 31-8-2016)

Examples

```
## Test means of 5.83 and 5.75, standard deviations of 1.17 and 1.30 in sample of 65 pairs
## with correlation between observations of 0.745 using equivalence bounds in raw units of
## -0.34 and 0.34, (with default alpha setting of = 0.05).
TOSTpaired.raw(n=65,m1=5.83,m2=5.75,sd1=1.17,sd2=1.30,r12=0.745,low_eqbound=-0.34,high_eqbound=0.34)
```

TOSTr *TOST function for a correlations*

Description

TOST function for a correlations

Usage

```
TOSTr(n, r, low_eqbound_r, high_eqbound_r, alpha, plot = TRUE,
  verbose = TRUE)
```

Arguments

n	number of pairs of observations
r	observed correlation
low_eqbound_r	lower equivalence bounds (e.g., -0.3) expressed in a correlation effect size
high_eqbound_r	upper equivalence bounds (e.g., 0.3) expressed in a correlation effect size
alpha	alpha level (default = 0.05)
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST p-value 1, TOST p-value 2, alpha, low equivalence bound r, high equivalence bound r, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Goertzen, J. R., & Cribbie, R. A. (2010). Detecting a lack of association: An equivalence testing approach. British Journal of Mathematical and Statistical Psychology, 63(3), 527-537. https://doi.org/10.1348/000711009X475
formula page 531.

Examples

```
TOSTr(n=100, r = 0.02, low_eqbound_r=-0.3, high_eqbound_r=0.3, alpha=0.05)
```

TOSTtwo *TOST function for an independent t-test (Cohen's d)*

Description

TOST function for an independent t-test (Cohen's d)

Usage

```
TOSTtwo(m1, m2, sd1, sd2, n1, n2, low_eqbound_d, high_eqbound_d, alpha,
  var.equal, plot = TRUE, verbose = TRUE)
```

Arguments

m1	mean of group 1
m2	mean of group 2
sd1	standard deviation of group 1
sd2	standard deviation of group 2
n1	sample size in group 1
n2	sample size in group 2
low_eqbound_d	lower equivalence bounds (e.g., -0.5) expressed in standardized mean difference (Cohen's d)
high_eqbound_d	upper equivalence bounds (e.g., 0.5) expressed in standardized mean difference (Cohen's d)
alpha	alpha level (default = 0.05)
var.equal	logical variable indicating whether equal variances assumption is assumed to be TRUE or FALSE. Defaults to FALSE.
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, low equivalence bound in Cohen's d, high equivalence bound in Cohen's d, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Berger, R. L., & Hsu, J. C. (1996). Bioequivalence Trials, Intersection-Union Tests and Equivalence Confidence Sets. Statistical Science, 11(4), 283-302.

Gruman, J. A., Cribbie, R. A., & Arpin-Cribbie, C. A. (2007). The effects of heteroscedasticity on tests of equivalence. Journal of Modern Applied Statistical Methods, 6(1), 133-140, formula for Welch's t-test on page 135

Examples

```
## Eskine (2013) showed that participants who had been exposed to organic
## food were substantially harsher in their moral judgments relative to
## those exposed to control (d = 0.81, 95% CI: [0.19, 1.45]). A
## replication by Moery & Calin-Jageman (2016, Study 2) did not observe
## a significant effect (Control: n = 95, M = 5.25, SD = 0.95, Organic
## Food: n = 89, M = 5.22, SD = 0.83). Following Simonsohn's (2015)
## recommendation the equivalence bound was set to the effect size the
## original study had 33% power to detect (with n = 21 in each condition,
## this means the equivalence bound is d = 0.48, which equals a
## difference of 0.384 on a 7-point scale given the sample sizes and a
## pooled standard deviation of 0.894). Using a TOST equivalence test
## with default alpha = 0.05, not assuming equal variances, and equivalence
## bounds of d = -0.43 and d = 0.43 is significant, t(182) = -2.69,
## p = 0.004. We can reject effects larger than d = 0.43.

TOSTtwo(m1=5.25,m2=5.22,sd1=0.95,sd2=0.83,n1=95,n2=89,low_eqbound_d=-0.43,high_eqbound_d=0.43)
```

`TOSTtwo.prop` *TOST function for two proportions (raw scores)*

Description

TOST function for two proportions (raw scores)

Usage

```
TOSTtwo.prop(prop1, prop2, n1, n2, low_eqbound, high_eqbound, alpha,
  plot = TRUE, verbose = TRUE)
```

Arguments

`prop1`	proportion of group 1
`prop2`	proportion of group 2
`n1`	sample size in group 1
`n2`	sample size in group 2
`low_eqbound`	lower equivalence bounds (e.g., -0.1) expressed in proportions
`high_eqbound`	upper equivalence bounds (e.g., 0.1) expressed in proportions
`alpha`	alpha level (default = 0.05)
`plot`	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
`verbose`	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST z-value 1, TOST p-value 1, TOST z-value 2, TOST p-value 2, low equivalence bound, high equivalence bound, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Tunes da Silva, G., Logan, B. R., & Klein, J. P. (2008). Methods for Equivalence and Noninferiority Testing. Biology of Blood Marrow Transplant, 15(1 Suppl), 120-127. Yin, G. (2012). Clinical Trial Design: Bayesian and Frequentist Adaptive Methods. Hoboken, New Jersey: John Wiley & Sons, Inc.

Examples

```
## Equivalence test for two independent proportions equal to .65 and .70, with 100 samples
## per group, lower equivalence bound of -0.1, higher equivalence bound of 0.1, and alpha of 0.05.

TOSTtwo.prop(prop1 = .65, prop2 = .70, n1 = 100, n2 = 100,
   low_eqbound = -0.1, high_eqbound = 0.1, alpha = .05)
```

TOSTtwo.raw *TOST function for an independent t-test (raw scores)*

Description

TOST function for an independent t-test (raw scores)

Usage

```
TOSTtwo.raw(m1, m2, sd1, sd2, n1, n2, low_eqbound, high_eqbound, alpha,
  var.equal, plot = TRUE, verbose = TRUE)
```

Arguments

m1	mean of group 1
m2	mean of group 2
sd1	standard deviation of group 1
sd2	standard deviation of group 2
n1	sample size in group 1
n2	sample size in group 2
low_eqbound	lower equivalence bounds (e.g., -0.5) expressed in raw scale units (e.g., scale-points)
high_eqbound	upper equivalence bounds (e.g., 0.5) expressed in raw scale units (e.g., scale-points)

alpha	alpha level (default = 0.05)
var.equal	logical variable indicating whether equal variances assumption is assumed to be TRUE or FALSE. Defaults to FALSE.
plot	set whether results should be plotted (plot = TRUE) or not (plot = FALSE) - defaults to TRUE
verbose	logical variable indicating whether text output should be generated (verbose = TRUE) or not (verbose = FALSE) - default to TRUE

Value

Returns TOST t-value 1, TOST p-value 1, TOST t-value 2, TOST p-value 2, degrees of freedom, low equivalence bound, high equivalence bound, Lower limit confidence interval TOST, Upper limit confidence interval TOST

References

Berger, R. L., & Hsu, J. C. (1996). Bioequivalence Trials, Intersection-Union Tests and Equivalence Confidence Sets. Statistical Science, 11(4), 283-302.

Gruman, J. A., Cribbie, R. A., & Arpin-Cribbie, C. A. (2007). The effects of heteroscedasticity on tests of equivalence. Journal of Modern Applied Statistical Methods, 6(1), 133-140, formula for Welch's t-test on page 135

Examples

```
## Eskine (2013) showed that participants who had been exposed to organic
## food were substantially harsher in their moral judgments relative to
## those exposed to control (d = 0.81, 95% CI: [0.19, 1.45]). A
## replication by Moery & Calin-Jageman (2016, Study 2) did not observe
## a significant effect (Control: n = 95, M = 5.25, SD = 0.95, Organic
## Food: n = 89, M = 5.22, SD = 0.83). Following Simonsohn's (2015)
## recommendation the equivalence bound was set to the effect size the
## original study had 33% power to detect (with n = 21 in each condition,
## this means the equivalence bound is d = 0.48, which equals a
## difference of 0.384 on a 7-point scale given the sample sizes and a
## pooled standard deviation of 0.894). Using a TOST equivalence test
## with alpha = 0.05, assuming equal variances, and equivalence
## bounds of d = -0.43 and d = 0.43 is significant, t(182) = -2.69,
## p = 0.004. We can reject effects larger than d = 0.43.

TOSTtwo.raw(m1=5.25,m2=5.22,sd1=0.95,sd2=0.83,n1=95,n2=89,low_eqbound=-0.384,high_eqbound=0.384)
```

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