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>.

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URL https://aaroncaldwell.us/TOSTERpkg/

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R topics documented:

boot_t_TOST 2
dataTOSTone 5
dataTOSTpaired 6
dataTOSTr 8

dataTOSTtwo . . . 9
datatosttwoprop . . . 11
equ_anova . . . 12
equ_ftest . . . 13
hawthorne . . . 14
plot_cor . . . 14
plot_pes . . . 15
plot_smd . . . 16
powerTOSTone . . . 17
powerTOSTone.raw . . . 18
powerTOSTpaired . . . 19
powerTOSTpaired.raw . . . 20
powerTOSTr . . . 21
powerTOSTtwo . . . 22
powerTOSTtwo.prop . . . 23
powerTOSTtwo.raw . . . 24
power_eq_f . . . 26
power_t_TOST . . . 27
rbs . . . 28
TOSTmeta . . . 29
TOSTnp-methods . . . 30
TOSTone . . . 31
TOSTone.raw . . . 32
TOSTpaired . . . 33
TOSTpaired.raw . . . 34
TOSTr . . . 35
TOSTt-methods . . . 36
TOSTtwo . . . 37
TOSTtwo.prop . . . 39
TOSTtwo.raw . . . 40
tsum_TOST . . . 42
t_TOST . . . 43
wilcox_TOST . . . 46

Index **48**

`boot_t_TOST` *Bootstrapped TOST with t-tests*

Description

A function for a bootstrap method for TOST with all types of t-tests.

Usage

```
boot_t_TOST(x, ...)

## Default S3 method:
boot_t_TOST(
  x,
  y = NULL,
  hypothesis = "EQU",
  paired = FALSE,
  var.equal = FALSE,
  low_eqbound,
  high_eqbound,
  eqbound_type = "raw",
  alpha = 0.05,
  bias_correction = TRUE,
  mu = 0,
  R = 1999,
  ...
)

## S3 method for class 'formula'
boot_t_TOST(formula, data, subset, na.action, ...)
```

Arguments

`x`	a (non-empty) numeric vector of data values.
`...`	further arguments to be passed to or from methods.
`y`	an optional (non-empty) numeric vector of data values.
`hypothesis`	'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.
`paired`	a logical indicating whether you want a paired t-test.
`var.equal`	a logical variable indicating whether to treat the two variances as being equal. If TRUE then the pooled variance is used to estimate the variance otherwise the Welch (or Satterthwaite) approximation to the degrees of freedom is used.
`low_eqbound`	lower equivalence bounds
`high_eqbound`	upper equivalence bounds
`eqbound_type`	Type of equivalence bound. Can be set to "SMD" for standardized mean difference (i.e., Cohen's d) or "raw" for the mean difference. Default is "raw". Raw is strongly recommended as SMD bounds will produce biased results.
`alpha`	alpha level (default = 0.05)
`bias_correction`	Apply Hedges' correction for bias (default is TRUE).
`mu`	a number indicating the true value of the mean for the two tailed test (or difference in means if you are performing a two sample test).
`R`	number of bootstrap replicates

`formula`	a formula of the form lhs ~ rhs where lhs is a numeric variable giving the data values and rhs either 1 for a one-sample or paired test or a factor with two levels giving the corresponding groups. If lhs is of class "Pair" and rhs is 1, a paired test is done.
`data`	an optional matrix or data frame (or similar: see model.frame) containing the variables in the formula formula. By default the variables are taken from environment(formula).
`subset`	an optional vector specifying a subset of observations to be used.
`na.action`	a function which indicates what should happen when the data contain NAs. Defaults to getOption("na.action").

Details

The implemented test(s) corresponds to the proposal of Chapter 16 of Efron and Tibshirani (1993). Returns TOSTt class object with boostrapped based results. Please note that the repeated measures "corrected" effect size is not available at this time.

Value

An S3 object of class `"TOSTt"` is returned containing the following slots:

`"TOST"` A table of class `"data.frame"` containing two-tailed t-test and both one-tailed results.

`"eqb"` A table of class `"data.frame"` containing equivalence bound settings.

`"effsize"` table of class `"data.frame"` containing effect size estimates

`"hypothesis"` String stating the hypothesis being tested

`"smd"` List containing the results of the standardized mean difference calculations (e.g., Cohen's d).Items include: d (estimate), dlow (lower CI bound), dhigh (upper CI bound), d_df (degrees of freedom for SMD), d_sigma (SE), d_lambda (non-centrality), J (bias correction), smd_label (type of SMD), d_denom (denominator calculation)

`"alpha"` Alpha level set for the analysis.

`"method"` Type of t-test.

`"decision"` List included text regarding the decisions for statistical inference.

`"boot"` List containing the bootstrap samples.

References

Efron, B., & Tibshirani, R. J. (1994). An introduction to the bootstrap. CRC press.

`dataTOSTone` *TOST One Sample T-Test*

Description

TOST One Sample T-Test

Usage

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

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
`hypothesis`	`'EQU'` for equivalence (default), or `'MET'` for minimal effects test, the alternative hypothesis;
`low_eqbound`	a number (default: -0.5) the lower equivalence bounds
`high_eqbound`	a number (default: 0.5) the upper equivalence bounds
`eqbound_type`	`'SMD'` (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
`smd_type`	`'d'` (default) or `'g'`; whether the calculated effect size is biased (d) or bias-corrected (g).

Value

A results object containing:

`results$text`	a preformatted
`results$tost`	a table
`results$eqb`	a table
`results$effsize`	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,
  pair1,
  pair2,
  hypothesis = "EQU",
  low_eqbound = -0.5,
  high_eqbound = 0.5,
  eqbound_type = "raw",
  alpha = 0.05,
  desc = FALSE,
  plots = FALSE,
  low_eqbound_dz = -999999999,
```

```
  high_eqbound_dz = -999999999,
  indplot = FALSE,
  diffplot = FALSE,
  smd_type = "g"
)
```

Arguments

data	the data as a data frame
pair1	A string naming the first part of the pair
pair2	A string naming the second part of the pair
hypothesis	'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.
low_eqbound	a number (default: 0.5) the lower equivalence bounds
high_eqbound	a number (default: 0.5) the upper equivalence bounds
eqbound_type	'SMD' (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
indplot	TRUE or FALSE (default), provide plot of paired data.
diffplot	TRUE or FALSE (default), provide plot of difference scores.
smd_type	'd' (default) or 'g'; whether the calculated effect size is biased (d) or bias-corrected (g).

Value

A results object containing:

results$text	a preformatted
results$tost	a table
results$eqb	a table
results$effsize	a table
results$desc	a table
results$plots	an image
results$indplot	an image
results$diffplot	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)
```

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

```
## Not run:
library("TOSTER")

dataTOSTpaired(data = randu, pair1 = "x", pair2="y", low_eqbound = -0.3,
               high_eqbound = 0.3, alpha = 0.05, desc = TRUE, plots = TRUE)

## End(Not run)
```

---

dataTOSTr *TOST Correlation*

Description

TOST Correlation

Usage

```
dataTOSTr(
  data,
  pairs,
  cor_type = "pearson",
  hypothesis = "EQU",
  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`
`cor_type`	a character string indicating which correlation coefficient is to be used for the test. One of "pearson", "kendall", or "spearman", can be abbreviated.
`hypothesis`	`'EQU'` for equivalence (default), or `'MET'` for minimal effects test, the alternative hypothesis.

`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$text`	a preformatted
`results$tost`	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,
  hypothesis = "EQU",
  low_eqbound = -0.5,
  high_eqbound = 0.5,
  eqbound_type = "raw",
  alpha = 0.05,
  desc = FALSE,
  plots = FALSE,
  descplots = FALSE,
  low_eqbound_d = -999999999,
  high_eqbound_d = -999999999,
  smd_type = "g"
)
```

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
`hypothesis`	`'EQU'` for equivalence (default), or `'MET'` for minimal effects test, the alternative hypothesis.
`low_eqbound`	a number (default: -0.5) the lower equivalence/MET bounds
`high_eqbound`	a number (default: 0.5) the upper equivalence/MET bounds
`eqbound_type`	`'SMD'` (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 effect size plots
`descplots`	`TRUE` or `FALSE` (default), provide plots
`low_eqbound_d`	deprecated
`high_eqbound_d`	deprecated
`smd_type`	`'d'` (default) or `'g'`; whether the calculated effect size is biased (d) or bias-corrected (g).

Value

A results object containing:

`results$text`	a preformatted
`results$tost`	a table
`results$eqb`	a table
`results$effsize`	a table
`results$desc`	a table
`results$plots`	an array of images
`results$descplots`	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,
  hypothesis = "EQU",
  low_eqbound = -0.1,
  high_eqbound = 0.1,
  alpha = 0.05,
  desc = FALSE,
  plot = FALSE
)
```

Arguments

`data`	.
`var`	.
`level`	.
`group`	.
`hypothesis`	'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.
`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)`

`equ_anova` *Equivalence Test for ANOVA Results*

Description

Performs equivalence test on the partial eta-squared (pes) value from ANOVA results.

Usage

```
equ_anova(object, eqbound, MET = FALSE, alpha = 0.05)
```

Arguments

`object`	an object of returned by either `Anova`, `aov`, or `afex_aov`
`eqbound`	Equivalence bound for the partial eta-squared.
`MET`	logical indicator to perform a minimal effect test rather than equivalence test (default is FALSE).
`alpha`	alpha used for the test (e.g., 0.05).

Value

Returns a data frame containing the ANOVA results with equivalence tests added.

The following abbreviations are used in the table:

- effect name of the effect.

- df1 Degrees of Freedom in the numerator (i.e. DF effect).
- df2 Degrees of Freedom in the denominator (i.e., DF error).
- F F-value.
- p.null p-value (probability of the data given the null hypothesis).
- pes partial Eta-Squared measure of effect size.
- eqbound equivalence bound.
- p.equ p-value (probability of the data given the equivalence hypothesis)

References

Campbell, H., & Lakens, D. (2021). Can we disregard the whole model? Omnibus non-inferiority testing for R2 in multi-variable linear regression and in ANOVA. British Journal of Mathematical and Statistical Psychology, 74(1), 64-89. doi: 10.1111/bmsp.12201

`equ_ftest` *Equivalence Test using an F-test*

Description

Performs equivalence test on the partial eta-squared (pes) value for using an F-test.

Usage

```
equ_ftest(Fstat, df1, df2, eqbound, MET = FALSE, alpha = 0.05)
```

Arguments

`Fstat`	The F-statistic from the F-test.
`df1`	Degrees of freedom for the numerator.
`df2`	Degrees of freedom for the denominator.
`eqbound`	Equivalence bound for the partial eta-squared.
`MET`	logical indicator to perform a minimal effect test rather than equivalence test (default is FALSE).
`alpha`	alpha used for the test (e.g., 0.05).

Value

Object of class '"htest"

`"statistic"` The value of the F-statistic.

`"parameter"` The degrees of freedom for the F-statistic.

`"p.value"` The he p-value for the test.

`"conf.int"` A confidence interval for the partial eta-squared statistic.

`"estimate"` Estimate of partial eta-squared.

`"null.value"` The specified for the equivalence test.

`"method"` A string indicating the type of F-test.

`"data.name"` A required string indicating that this was calculated from summary statistics.

References

Campbell, H., & Lakens, D. (2021). Can we disregard the whole model? Omnibus non-inferiority testing for R2 in multi-variable linear regression and in ANOVA. British Journal of Mathematical and Statistical Psychology, 74(1), 64-89. doi: 10.1111/bmsp.12201

`hawthorne` *Data*

Description

A dataset from a study on the Hawthrone effect published by McCambridge et al. The dataset has 5 variables (participant_ID, totaldrinking.x, group, totaldrinking.y, totaldrinking.diff)

Usage

```
hawthorne
```

Format

An object of class `data.frame` with 5474 rows and 5 columns.

Source

McCambridge, J., Wilson, A., Attia, J., Weaver, N., & Kypri, K. (2019). Randomized trial seeking to induce the Hawthorne effect found no evidence for any effect on self-reported alcohol consumption online. Journal of Clinical Epidemiology, 108, 102–109.

`plot_cor` *Function to produce plots of the distribution of standard correlation coefficients*

Description

Function to produce plots of the distribution of standard correlation coefficients

Usage

```
plot_cor(
  r,
  n,
  method = "pearson",
  type = c("c", "cd"),
  levels = c(0.68, 0.9, 0.95, 0.999)
)
```

Arguments

r	The observed correlation coefficient.
n	Total number of observations (sample size).
method	The method by which the coefficient was calculated: pearson, spearman, or kendall (default is "pearson")
type	Choose whether to plot a "consonance" function ("c"), consonance density ("cd"), or both (c("c","cd"); defualt option).
levels	Numeric vector of confidence levels to display

Details

This function was created so that users could create consonance plots of Pearson's correlation coefficient. These types of plots are discussed by Schweder T, Hjort NL. (2016, ISBN:9781316445051) and Rafi Z, Greenland S. (2020) <doi:10.1186/s12874-020-01105-9>.

Value

Returns plot of the distribution of the correlation coefficient.

---

plot_pes — *Function to produce plots of the distribution of the standardized mean difference*

Description

Function to produce plots of the distribution of the standardized mean difference

Usage

```
plot_pes(
  Fstat,
  df1,
  df2,
  type = c("c", "cd"),
  levels = c(0.68, 0.9, 0.95, 0.999)
)
```

Arguments

Fstat	The F-statistic from the F-test.
df1	Degrees of freedom for the numerator.
df2	Degrees of freedom for the denominator.
type	Choose whether to plot a "consonance" function ("c"), consonance density ("cd"), or both (c("c","cd"); defualt option).
levels	Numeric vector of confidence levels to display

Details

This function was created so that users could create consonance plots of partial eta-squared from ANOVA-level effects. These types of plots are discussed by Schweder T, Hjort NL. (2016, ISBN:9781316445051) and Rafi Z, Greenland S. (2020) <doi:10.1186/s12874-020-01105-9>.

Value

Returns plot of the distribution of partial eta-squared

`plot_smd` *plot_smd*

Description

Function to produce plots of the distribution of the standardized mean difference

Usage

```
plot_smd(
  d,
  df,
  lambda,
  smd_label = "SMD",
  type = c("c", "cd"),
  levels = c(0.5, 0.9, 0.95, 0.999)
)
```

Arguments

`d`	Estimate of the standardized mean difference
`df`	degrees of freedom for the standardized mean difference
`lambda`	The non-centrality parameter for the standardized mean difference
`smd_label`	Label for the x-axis indicating the SMD measure
`type`	Choose whether to plot a "consonance" function ("c"), consonance density ("cd"), or both (c("c","cd"); defualt option).
`levels`	Numeric vector of confidence levels to display

Details

This function was created so that users could create plots from their own SMD calculations and were inspired by the concurve R package. The difficulty is that specific information must be past onto this function. The calculations for the standardized mean difference can be found in the vignettes of this package. These types of plots are discussed by Schweder T, Hjort NL. (2016, ISBN:9781316445051) and Rafi Z, Greenland S. (2020) <doi:10.1186/s12874-020-01105-9>.

Value

Returns plot of the distribution of the standardized mean difference.

`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,
  delta = 0
)
```

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)
`delta`	hypothesized true value for the difference between the 2 means. Default is zero.

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)
```

`power_eq_f` *Power analysis for TOST for an F-test*

Description

Power analysis for TOST for an F-test

Usage

```
power_eq_f(alpha = 0.05, df1, df2, eqbound)
```

Arguments

`alpha`	alpha used for the test (e.g., 0.05)
`df1`	Degrees of freedom for the numerator
`df2`	Degrees of freedom for the denominator
`eqbound`	Equivalence bound for the partial eta-squared

Value

Object of class '"power.htest"

References

Campbell, H., & Lakens, D. (2021). Can we disregard the whole model? Omnibus non-inferiority testing for R2 in multi-variable linear regression and in ANOVA. British Journal of Mathematical and Statistical Psychology, 74(1), 64-89. doi: 10.1111/bmsp.12201

Examples

```
## Statistical power for alpha = 0.05, 3 groups, n = 80 per group, equivalence bound of
## partial eta squared = 0.01, assuming true effect = 0.
## df1 = number of groups - 1 = 3 - 1 = 2.
## df2 = Total N - number of groups = 240 - 3 = 237.
# powerTOST_f(alpha=0.05, df1=3, df2 = 237, eqbound = 0.01)
```

`power_t_TOST` *Power calculations for TOST for t-tests*

Description

Calculates the exact power of two one sided t-tests (TOST) for one, two, and paired samples.

Usage

```
power_t_TOST(
  n = NULL,
  delta = 0,
  sd = 1,
  low_eqbound = NULL,
  high_eqbound = NULL,
  alpha = NULL,
  power = NULL,
  type = "two.sample"
)
```

Arguments

`n`	number of observations per group. 2 sample sizes, in a vector, can be provided for the two sample case.
`delta`	true difference in means (default is 0)
`sd`	population standard deviation. Standard deviation of the differences for paired samples
`low_eqbound`	The lower equivalence bound (raw units)
`high_eqbound`	The upper equivalence bound (raw units)
`alpha`	a priori alpha-level (i.e., significance level)
`power`	power of the TOST procedure (1-beta)
`type`	string specifying the type of t-test.

Details

The exact calculations of power are based on Owen's Q-function or by direct integration of the bivariate non-central t-distribution (inspired by the PowerTOST package). Approximate power is implemented via the non-central t-distribution or the 'shifted' central t-distribution.

Note

The power function in this package is limited. Please see the PowerTOST R package for more options.

References

Phillips KF. Power of the Two One-Sided Tests Procedure in Bioequivalence. J Pharmacokin Biopharm. 1990;18(2):137–44. doi: 10.1007/BF01063556

Diletti D, Hauschke D, Steinijans VW. Sample Size Determination for Bioequivalence Assessment by Means of Confidence Intervals. Int J Clin Pharmacol Ther Toxicol. 1991;29(1):1–8.

`rbs` *Rank-Biserial Correlation*

Description

Rank-Biserial Correlation

Usage

```
rbs(x, y = NULL, mu = 0, conf.level = 0.95, paired = FALSE)
```

Arguments

`x`	a (non-empty) numeric vector of data values.
`y`	an optional (non-empty) numeric vector of data values.
`mu`	a number indicating the value around which (a-)symmetry (for one-sample or paired samples) or shift (for independent samples) is to be estimated. See [stats::wilcox.test].
`conf.level`	confidence level of the interval.
`paired`	a logical indicating whether you want to calculate a paired test.

Details

This method was adapted from the effectsize R package. The rank-biserial correlation is appropriate for non-parametric tests of differences - both for the one sample or paired samples case, that would normally be tested with Wilcoxon's Signed Rank Test (giving the **matched-pairs** rank-biserial correlation) and for two independent samples case, that would normally be tested with Mann-Whitney's *U* Test (giving **Glass'** rank-biserial correlation). See [stats::wilcox.test]. In both cases, the correlation represents the difference between the proportion of favorable and unfavorable pairs / signed ranks (Kerby, 2014). Values range from '-1' indicating that all values of the second sample are smaller than the first sample, to '+1' indicating that all values of the second sample are larger than the first sample.

Ties When tied values occur, they are each given the average of the ranks that would have been given had no ties occurred. No other corrections have been implemented yet.

Confidence Intervals Confidence intervals for the rank-biserial correlation are estimated using the normal approximation (via Fisher's transformation).

Value

Returns a list of results including the rank biserial correlation, logical indicator if it was a paired method, setting for mu, and confidence interval.

References

- Cureton, E. E. (1956). Rank-biserial correlation. Psychometrika, 21(3), 287-290.

- Glass, G. V. (1965). A ranking variable analogue of biserial correlation: Implications for short-cut item analysis. Journal of Educational Measurement, 2(1), 91-95.

- Kendall, M.G. (1948) Rank correlation methods. London: Griffin.

- Kerby, D. S. (2014). The simple difference formula: An approach to teaching nonparametric correlation. Comprehensive Psychology, 3, 11-IT.

- King, B. M., & Minium, E. W. (2008). Statistical reasoning in the behavioral sciences. John Wiley & Sons Inc.

- Cliff, N. (1993). Dominance statistics: Ordinal analyses to answer ordinal questions. Psychological bulletin, 114(3), 494.

- Tomczak, M., & Tomczak, E. (2014). The need to report effect size estimates revisited. An overview of some recommended measures of effect size.

`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)
```

`TOSTnp-methods` *Methods for TOSTnp objects*

Description

Methods defined for objects returned from the agree functions.

Usage

```
## S3 method for class 'TOSTnp'
print(x, digits = getOption("digits"), ...)
```

Arguments

`x`	object of class `TOSTnp` as returned from the reli_stats function
`digits`	Number of digits to print for p-values
`...`	further arguments passed through, see description of return value for details. `TOSTnp-methods`.

Value

`print` Prints short summary of the Limits of Agreement

`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)
```

`TOSTt-methods` *Methods for TOSTt objects*

Description

Methods defined for objects returned from the t_TOST and boot_t_TOST functions.

Usage

```
## S3 method for class 'TOSTt'
print(x, digits = getOption("digits"), ...)

## S3 method for class 'TOSTt'
plot(x, type = "cd", estimates = c("raw", "SMD"), ci_lines, ci_shades, ...)
```

Arguments

`x`	object of class `TOSTt`
`digits`	Number of digits to print for p-values
`...`	further arguments passed through, see description of return value for details. `TOSTt-methods`.
`type`	Type of plot to produce. Default is a consonance density plot "cd". Consonance plots (type = "cd") and null distribution plots (type = "tnull") can also be produced. Note: null distribution plots only available for estimates = "raw".
`estimates`	indicator of what estimates to plot; options include "raw" or "SMD". Default is is both: c("raw","SMD").
`ci_lines`	Confidence interval lines for plots. Default is 1-alpha*2 (e.g., alpha = 0.05 is 90%)
`ci_shades`	Confidence interval shades when plot type is "cd".

Value

`print` Prints short summary of the Limits of Agreement

`plot` Returns a plot of the data points used in the reliability analysis

---

`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,
  ci_type = "normal",
  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)
`ci_type`	confidence interval type (default = "normal"). "wilson" produces Wilson score intervals with a Yates continuity correction while "normal" calculates the simple asymptotic method with no continuity correction.
`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)
```

tsum_TOST *TOSTt with Summary Statistics*

Description

A function for TOST with all types of t-tests from summary statistics.

Usage

```
tsum_TOST(
  m1,
  sd1,
  n1,
  m2 = NULL,
  sd2 = NULL,
  n2 = NULL,
  r12 = NULL,
  hypothesis = "EQU",
  paired = FALSE,
  var.equal = FALSE,
  low_eqbound,
  high_eqbound,
  mu = 0,
  eqbound_type = "raw",
  alpha = 0.05,
  bias_correction = TRUE,
  rm_correction = FALSE
)
```

Arguments

m1	mean of group 1
sd1	standard deviation of group 1
n1	sample size in group 1
m2	mean of group 2
sd2	standard deviation of group 2
n2	sample size in group 2
r12	correlation of dependent variable between group 1 and group 2
hypothesis	'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.

paired	a logical indicating whether you want a paired t-test.
var.equal	a logical variable indicating whether to treat the two variances as being equal. If TRUE then the pooled variance is used to estimate the variance otherwise the Welch (or Satterthwaite) approximation to the degrees of freedom is used.
low_eqbound	lower equivalence bounds
high_eqbound	upper equivalence bounds
mu	a number indicating the true value of the mean for the two tailed test (or difference in means if you are performing a two sample test).
eqbound_type	Type of equivalence bound. Can be set to "SMD" for standardized mean difference (i.e., Cohen's d) or "raw" for the mean difference. Default is "raw".
alpha	alpha level (default = 0.05)
bias_correction	Apply Hedges' correction for bias (default is TRUE).
rm_correction	Repeated measures correction to make standardized mean difference Cohen's d(rm). This only applies to repeated/paired samples. Default is FALSE.

Value

An S3 object of class "TOSTt" is returned containing the following slots:

"TOST" A table of class "data.frame" containing two-tailed t-test and both one-tailed results.

"eqb" A table of class "data.frame" containing equivalence bound settings.

"effsize" table of class "data.frame" containing effect size estimates

"hypothesis" String stating the hypothesis being tested

"smd" List containing the results of the standardized mean difference calculations (e.g., Cohen's d).Items include: d (estimate), dlow (lower CI bound), dhigh (upper CI bound), d_df (degrees of freedom for SMD), d_sigma (SE), d_lambda (non-centrality), J (bias correction), smd_label (type of SMD), d_denom (denominator calculation)

"alpha" Alpha level set for the analysis.

"method" Type of t-test.

"decision" List included text regarding the decisions for statistical inference.

---

t_TOST *TOST with t-tests*

Description

A function for TOST with all types of t-tests.

Usage

```
t_TOST(
  x,
  ...,
  hypothesis = "EQU",
  paired = FALSE,
  var.equal = FALSE,
  low_eqbound,
  high_eqbound,
  eqbound_type = "raw",
  alpha = 0.05,
  bias_correction = TRUE,
  rm_correction = FALSE
)

## Default S3 method:
t_TOST(
  x,
  y = NULL,
  hypothesis = "EQU",
  paired = FALSE,
  var.equal = FALSE,
  low_eqbound,
  high_eqbound,
  eqbound_type = "raw",
  alpha = 0.05,
  mu = 0,
  bias_correction = TRUE,
  rm_correction = FALSE,
  ...
)

## S3 method for class 'formula'
t_TOST(formula, data, subset, na.action, ...)
```

Arguments

`x`	a (non-empty) numeric vector of data values.
`...`	further arguments to be passed to or from methods.
`hypothesis`	'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.
`paired`	a logical indicating whether you want a paired t-test.
`var.equal`	a logical variable indicating whether to treat the two variances as being equal. If TRUE then the pooled variance is used to estimate the variance otherwise the Welch (or Satterthwaite) approximation to the degrees of freedom is used.
`low_eqbound`	lower equivalence bounds
`high_eqbound`	upper equivalence bounds

`eqbound_type` Type of equivalence bound. Can be set to "SMD" for standardized mean difference (i.e., Cohen's d) or "raw" for the mean difference. Default is "raw". Raw is strongly recommended as SMD bounds will produce biased results.

`alpha` alpha level (default = 0.05)

`bias_correction` Apply Hedges' correction for bias (default is TRUE).

`rm_correction` Repeated measures correction to make standardized mean difference Cohen's d(rm). This only applies to repeated/paired samples. Default is FALSE.

`y` an optional (non-empty) numeric vector of data values.

`mu` a number indicating the true value of the mean for the two tailed test (or difference in means if you are performing a two sample test).

`formula` a formula of the form lhs ~ rhs where lhs is a numeric variable giving the data values and rhs either 1 for a one-sample or paired test or a factor with two levels giving the corresponding groups. If lhs is of class "Pair" and rhs is 1, a paired test is done.

`data` an optional matrix or data frame (or similar: see model.frame) containing the variables in the formula formula. By default the variables are taken from environment(formula).

`subset` an optional vector specifying a subset of observations to be used.

`na.action` a function which indicates what should happen when the data contain NAs. Defaults to getOption("na.action").

Value

An S3 object of class `"TOSTt"` is returned containing the following slots:

`"TOST"` A table of class `"data.frame"` containing two-tailed t-test and both one-tailed results.

`"eqb"` A table of class `"data.frame"` containing equivalence bound settings.

`"effsize"` table of class `"data.frame"` containing effect size estimates

`"hypothesis"` String stating the hypothesis being tested

`"smd"` List containing the results of the standardized mean difference calculations (e.g., Cohen's d).Items include: d (estimate), dlow (lower CI bound), dhigh (upper CI bound), d_df (degrees of freedom for SMD), d_sigma (SE), d_lambda (non-centrality), J (bias correction), smd_label (type of SMD), d_denom (denominator calculation)

`"alpha"` Alpha level set for the analysis.

`"method"` Type of t-test.

`"decision"` List included text regarding the decisions for statistical inference.

wilcox_TOST *TOST with Wilcoxon Signed Rank test*

Description

A function for TOST using the non-parametric methods of the Wilcoxon signed rank test. This function uses the normal approximation and applies continuity correction automatically.

Usage

```
wilcox_TOST(
  x,
  ...,
  hypothesis = "EQU",
  paired = FALSE,
  low_eqbound,
  high_eqbound,
  alpha = 0.05
)

## Default S3 method:
wilcox_TOST(
  x,
  y = NULL,
  hypothesis = "EQU",
  paired = FALSE,
  low_eqbound,
  high_eqbound,
  alpha = 0.05,
  mu = 0,
  ...
)

## S3 method for class 'formula'
wilcox_TOST(formula, data, subset, na.action, ...)
```

Arguments

- `x` a (non-empty) numeric vector of data values.
- `...` further arguments to be passed to or from methods.
- `hypothesis` 'EQU' for equivalence (default), or 'MET' for minimal effects test, the alternative hypothesis.
- `paired` a logical indicating whether you want to calculate a paired test.
- `low_eqbound` lower equivalence bounds.
- `high_eqbound` upper equivalence bounds.

`alpha`	alpha level (default = 0.05)
`y`	an optional (non-empty) numeric vector of data values.
`mu`	number indicating the value around which (a-)symmetry (for one-sample or paired samples) or shift (for independent samples) is to be estimated. See [stats::wilcox.test].
`formula`	a formula of the form lhs ~ rhs where lhs is a numeric variable giving the data values and rhs either 1 for a one-sample or paired test or a factor with two levels giving the corresponding groups. If lhs is of class "Pair" and rhs is 1, a paired test is done.
`data`	an optional matrix or data frame (or similar: see model.frame) containing the variables in the formula formula. By default the variables are taken from environment(formula).
`subset`	an optional vector specifying a subset of observations to be used.
`na.action`	a function which indicates what should happen when the data contain NAs. Defaults to getOption("na.action").

Value

An S3 object of class `"TOSTnp"` is returned containing the following slots:

`"TOST"` A table of class `"data.frame"` containing two-tailed wilcoxon signed rank test and both one-tailed results.

`"eqb"` A table of class `"data.frame"` containing equivalence bound settings.

`"effsize"` table of class `"data.frame"` containing effect size estimates.

`"hypothesis"` String stating the hypothesis being tested.

`"smd"` List containing information on standardized effect size.

`"alpha"` Alpha level set for the analysis.

`"method"` Type of non-parametric test.

`"decision"` List included text regarding the decisions for statistical inference.

References

David F. Bauer (1972). Constructing confidence sets using rank statistics. Journal of the American Statistical Association 67, 687–690. doi: 10.1080/01621459.1972.10481279.

Myles Hollander and Douglas A. Wolfe (1973). Nonparametric Statistical Methods. New York: John Wiley & Sons. Pages 27–33 (one-sample), 68–75 (two-sample). Or second edition (1999).

Index

∗ **datasets**
  hawthorne, 14

as.data.frame, *6, 7*, *9, 10*, *12*

boot_t_TOST, 2

dataTOSTone, 5
dataTOSTpaired, 6
dataTOSTr, 8
dataTOSTtwo, 9
datatosttwoprop, 11

equ_anova, 12
equ_ftest, 13

hawthorne, 14

plot.TOSTt *(*TOSTt-methods*)*, 36
plot_cor, 14
plot_pes, 15
plot_smd, 16
power_eq_f, 26
power_t_TOST, 27
powerTOSTone, 17
powerTOSTone.raw, 18
powerTOSTpaired, 19
powerTOSTpaired.raw, 20
powerTOSTr, 21
powerTOSTtwo, 22
powerTOSTtwo.prop, 23
powerTOSTtwo.raw, 24
print.TOSTnp *(*TOSTnp-methods*)*, 30
print.TOSTt *(*TOSTt-methods*)*, 36

rbs, 28

t_TOST, 43
TOSTmeta, 29
TOSTnp-methods, 30
TOSTone, 31
TOSTone.raw, 32
TOSTpaired, 33
TOSTpaired.raw, 34
TOSTr, 35
TOSTt-methods, 36
TOSTtwo, 37
TOSTtwo.prop, 39
TOSTtwo.raw, 40
tsum_TOST, 42

wilcox_TOST, 46