Package 'effectsize'

July 27, 2020

Type Package

Title Indices of Effect Size and Standardized Parameters

Version 0.3.2

Maintainer Mattan S. Ben-Shachar <matanshm@post.bgu.ac.il>

URL https://easystats.github.io/effectsize

BugReports https://github.com/easystats/effectsize/issues

Description Provide utilities to work with indices of effect size and standardized parameters for a wide variety of models (see support list of insight; Lüdecke, Waggoner & Makowski (2019) <doi:10.21105/joss.01412>), allowing computation and conversion of indices such as Cohen's d, r, odds, etc.

License GPL-3

Encoding UTF-8

LazyData true

Depends R (>= 3.5)

Imports insight (>= 0.9.0), bayestestR (>= 0.7.2), parameters (>= 0.8.2), stats, utils

Suggests afex, brms, boot, car, correlation, covr, dplyr, emmeans, gamm4, ggplot2, knitr, lmerTest, lm.beta, lme4, MuMIn, modelbased, performance, rlang, rmarkdown, rstan, rstanarm, rstantools, see, testthat, tidyr

RoxygenNote 7.1.1

Language en-GB

VignetteBuilder knitr

NeedsCompilation no

Author Mattan S. Ben-Shachar [aut, cre] (<https://orcid.org/0000-0002-4287-4801>), Dominique Makowski [aut] (<https://orcid.org/0000-0001-5375-9967>), Daniel Lüdecke [aut] (<https://orcid.org/0000-0002-8895-3206>), Ken Kelley [ctb], David Stanley [ctb]

Repository CRAN

Date/Publication 2020-07-27 16:10:02 UTC

R topics documented:

adjust *Adjust data for the effect of other variable(s)*

Description

This function can be used to adjust the data for the effect of other variables present in the dataset. It is based on an underlying fitting of regressions models, allowing for quite some flexibility, such as including factors as random effects in mixed models (multilevel partialization), continuous variables as smooth terms in general additive models (non-linear partialization) and/or fitting these models under a Bayesian framework. The values returned by this function are the residuals of the regression models. Note that a regular correlation between two "adjusted" variables is equivalent to the partial correlation between them.

Usage

```
adjust(
  data,
  effect = NULL,
  select = NULL,
  exclude = NULL,
  multilevel = FALSE,
  additive = FALSE,
  bayesian = FALSE
)
```

Arguments

data	A dataframe.
effect	Character vector of column names to be adjusted for (regressed out). If NULL (the default), all variables will be selected.
select	Character vector of column names. If NULL (the default), all variables will be selected.
exclude	Character vector of column names to be excluded from selection.
multilevel	If TRUE, the factors are included as random factors. Else, if FALSE (default), they are included as fixed effects in the simple regression model.
additive	If TRUE, continuous variables as included as smooth terms in additive models. The goal is to regress-out potential non-linear effects.
bayesian	If TRUE, the models are fitted under the Bayesian framework using rstanarm.

Examples

```
adjust(iris, effect = "Species", select = "Sepal.Length")

adjust(iris, effect = "Species", select = "Sepal.Length", multilevel = TRUE)
adjust(iris, effect = "Species", select = "Sepal.Length", bayesian = TRUE)
adjust(iris, effect = "Petal.Width", select = "Sepal.Length", additive = TRUE)
```

```
adjust(iris, effect = "Petal.Width", select = "Sepal.Length",
       additive = TRUE, bayesian = TRUE)
adjust(iris, effect = c("Petal.Width", "Species"), select = "Sepal.Length",
       multilevel = TRUE, additive = TRUE)
adjust(iris)
```

`change_scale` *Rescale a numeric variable*

Description

Rescale a numeric variable to a new range.

Usage

```
change_scale(x, ...)

## S3 method for class 'numeric'
change_scale(x, to = c(0, 100), range = NULL, verbose = TRUE, ...)

## S3 method for class 'grouped_df'
change_scale(
  x,
  select = NULL,
  exclude = NULL,
  to = c(0, 100),
  range = NULL,
  ...
)

## S3 method for class 'data.frame'
change_scale(
  x,
  select = NULL,
  exclude = NULL,
  to = c(0, 100),
  range = NULL,
  ...
)
```

Arguments

`x`	Object.
`...`	Arguments passed to or from other methods.
`to`	New range of values of the data after rescaling.

range	Initial (old) range of values. If NULL, will take the range of data.
verbose	Toggle warnings on or off.
select	Character vector of column names. If NULL (the default), all variables will be selected.
exclude	Character vector of column names to be excluded from selection.

Value

A rescaled object.

See Also

normalize() standardize() ranktransform()

Examples

```
change_scale(c(0, 1, 5, -5, -2))
change_scale(c(0, 1, 5, -5, -2), to = c(-5, 5))

head(change_scale(iris))
```

---

chisq_to_phi *Conversion between Effect sizes for Contingency Tables (Chi2, Phi, Cramer's V...)*

Description

Convert between Chi square, (χ^2), phi (ϕ) and Cramer's V.

Usage

```
chisq_to_phi(chisq, n, nrow, ncol, ci = 0.95, adjust = FALSE, ...)

chisq_to_cramers_v(chisq, n, nrow, ncol, ci = 0.95, adjust = FALSE, ...)

phi_to_chisq(phi, n, ...)
```

Arguments

chisq	The Chi2 statistic.
n	Sample size.
nrow, ncol	The number of rows/columns in the contingency table (ignored for Phi when adjust=FALSE and CI=NULL).
ci	Confidence Interval (CI) level
adjust	Should the effect size be bias-corrected? Defaults to FALSE.
...	Arguments passed to or from other methods.
phi	The Phi statistic.

Details

These functions use the following formulae:

$$\phi = \sqrt{\chi^2/n}$$

$$Cramer's V = \phi/\sqrt{min(nrow, ncol) - 1}$$

For adjusted versions, see Bergsma, 2013.

Confidence Intervals:

Confidence intervals are estimated using the Noncentrality parameter method; These methods searches for a the best ncp (non-central parameters) for of the noncentral F distribution for the desired tail-probabilities, and then convert these ncps to the corresponding effect sizes.

Value

A data frame with the effect size(s) between 0-1, and confidence interval(s).

References

- Cumming, G., & Finch, S. (2001). A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. Educational and Psychological Measurement, 61(4), 532-574.
- Bergsma, W. (2013). A bias-correction for Cramer's V and Tschuprow's T. Journal of the Korean Statistical Society, 42(3), 323-328.

Examples

```
contingency_table <- as.table(rbind(c(762, 327, 468), c(484, 239, 477), c(484, 239, 477)))

chisq.test(contingency_table)
#
#         Pearson's Chi-squared test
#
# data:  ctab
# X-squared = 41.234, df = 4, p-value = 2.405e-08

chisq_to_phi(41.234,
  n = sum(contingency_table),
  nrow = nrow(contingency_table),
  ncol = ncol(contingency_table)
)
chisq_to_cramers_v(41.234,
  n = sum(contingency_table),
  nrow = nrow(contingency_table),
  ncol = ncol(contingency_table)
)
```

cohens_d *Effect size for differences*

Description

Compute different indices of effect size. For very small sample sizes (n < 20) Hedges' g is considered as less biased than Cohen's d. For sample sizes > 20, the results for both statistics are roughly equivalent.

The Glass's delta is appropriate if standard deviations are significantly different between groups, as it uses only the *second* group's standard deviation.

Usage

```
cohens_d(
  x,
  y = NULL,
  data = NULL,
  correction = FALSE,
  pooled_sd = TRUE,
  paired = FALSE,
  ci = 0.95
)

hedges_g(
  x,
  y = NULL,
  data = NULL,
  correction = FALSE,
  pooled_sd = TRUE,
  paired = FALSE,
  ci = 0.95
)

glass_delta(x, y = NULL, data = NULL, correction = FALSE, ci = 0.95)
```

Arguments

x	A formula, a numeric vector, or a character name of one in data.
y	A numeric vector, a grouping (character / factor) vector, a or a character name of one in data. Ignored if x is a formula.
data	An optional data frame containing the variables.
correction	If TRUE, applies a correction to make it less biased for small samples (McGrath & Meyer, 2006).
pooled_sd	If TRUE (default), a sd_pooled() is used (assuming equal variance). Else the mean SD from both groups is used instead.

paired	If TRUE, the values of x and y are considered as paired.
ci	Confidence Interval (CI) level

Value

A data frame with the effect size(s) and confidence interval(s).

Confidence Intervals:
Confidence intervals are estimated using the Noncentrality parameter method; These methods searches for a the best ncp (non-central parameters) for of the noncentral t distribution for the desired tail-probabilities, and then convert these ncps to the corresponding effect sizes.

References

- Cohen, J. (2013). Statistical power analysis for the behavioral sciences. Routledge.
- McGrath, R. E., & Meyer, G. J. (2006). When effect sizes disagree: the case of r and d. Psychological methods, 11(4), 386.
- Hedges, L. V. & Olkin, I. (1985). Statistical methods for meta-analysis. Orlando, FL: Academic Press.

Examples

```
cohens_d(iris$Sepal.Length, iris$Sepal.Width)
hedges_g("Sepal.Length", "Sepal.Width", data = iris)

cohens_d(mpg ~ am, data = mtcars)
cohens_d(mpg ~ am, data = mtcars, pooled_sd = FALSE)
hedges_g(mpg ~ am, data = mtcars)
glass_delta(mpg ~ am, data = mtcars)
```

---

convert_z_to_percentile

Z score to Percentile

Description

Convert between Z scores (values expressed in terms of standard deviation) to percentiles (the proportion of a normal distribution below).

Usage

```
convert_z_to_percentile(z)

convert_percentile_to_z(percentile)

z_to_percentile(z)

percentile_to_z(percentile)
```

Arguments

`z, percentile`	Z score or percentile.

Examples

```
z_to_percentile(1.96)
percentile_to_z(0.975)
```

`effectsize` *Effect Size*

Description

This function trys to return the best effect-size measure for the provided input model. See details below.

Usage

```
effectsize(model, ...)
```

Arguments

`model`	Statistical model or object of class `htest`.
`...`	Arguments passed to or from other methods.

Details

- For an object of class `htest`:
  - A **t-test** returns *Cohen's d* via `t_to_d()`.
  - A **correlation test** returns *r*. See `t_to_r()`.
  - A **Chi-squared test** returns *Cramer's V* via `cramers_v()`.
  - A **One-way ANOVA test** returns *Eta squared* via `F_to_eta2()`.
- An object of class anova is passed to `eta_squared()`.
- Other objects are passed to `standardize_parameters()`.

Examples

```
contingency_table <- as.table(rbind(c(762, 327, 468), c(484, 239, 477), c(484, 239, 477)))
Xsq <- chisq.test(contingency_table)
effectsize(Xsq)

Ts <- t.test(1:10, y = c(7:20))
effectsize(Ts)

Aov <- oneway.test(extra ~ group, data = sleep)
effectsize(Aov)
```

```
fit <- lm(mpg ~ factor(cyl) * wt + hp, data = mtcars)
effectsize(fit)

anova_table <- anova(fit)
effectsize(anova_table)
```

`equivalence_test.effectsize_table` *Test for Practical Equivalence*

Description

Perform a **Test for Practical Equivalence** for indices of effect size.

Usage

```
## S3 method for class 'effectsize_table'
equivalence_test(
  x,
  range = "default",
  rule = c("classic", "cet", "bayes"),
  ...
)
```

Arguments

`x`	An effect size table, such as returned by `cohens_d()`, `eta_squared()`, `F_to_r()`, etc.
`range`	The range of practical equivalence of an effect. If a single value is provided, the test is done against `c(-range,range)`. For effect sizes that cannot be negative, the lower bound is set to 0. If `"default"`, will be set to [-.1, .1].
`rule`	How should acceptance and rejection be decided? See details.
`...`	Arguments passed to or from other methods.

Details

The CIs used in the equivalence test are the ones in the provided effect size table. For results equivalent (ha!) to those that can be obtained using the TOST approach (e.g., Lakens, 2017), appropriate CIs should be extracted using the function used to make the effect size table (cohens_d, eta_squared, F_to_r, etc). See examples.

The Different Rules:

- `"classic"` - **the classic method**:
  - If the CI is completely within the ROPE - *Accept H0*
  - Else, if the CI does not contain 0 - *Reject H0*

  - Else - *Undecided*
- `"cet"` - **conditional equivalence testing**:
  - If the CI does not contain 0 - *Reject H0*
  - Else, If the CI is completely within the ROPE - *Accept H0*
  - Else - *Undecided*
- `"bayes"` - **The Bayesian approach**, as put forth by Kruschke:
  - If the CI does is completely outsie the ROPE - *Reject H0*
  - Else, If the CI is completely within the ROPE - *Accept H0*
  - Else - *Undecided*

Value

A data frame.

References

- Campbell, H., & Gustafson, P. (2018). Conditional equivalence testing: An alternative remedy for publication bias. PLOS ONE, 13(4), e0195145. https://doi.org/10.1371/journal.pone.0195145
- Kruschke, J. K. (2014). Doing Bayesian data analysis: A tutorial with R, JAGS, and Stan. Academic Press
- Kruschke, J. K. (2018). Rejecting or accepting parameter values in Bayesian estimation. Advances in Methods and Practices in Psychological Science, 1(2), 270-280. doi: 10.1177/2515245918771304
- Lakens, D. (2017). Equivalence Tests: A Practical Primer for t Tests, Correlations, and Meta-Analyses. Social Psychological and Personality Science, 8(4), 355–362. https://doi.org/10.1177/1948550617697177

See Also

For more details, see `bayestestR::equivalence_test()`.

Examples

```
model <- aov(mpg ~ factor(am) * factor(cyl), data = mtcars)
es <- eta_squared(model)
equivalence_test(es, range = 0.15)

ds <- t_to_d(t = c(0.45, -0.65, 7, -2.2, 2.25),
             df_error = c(675, 525, 2000, 900, 1875),
             ci = 0.9) # TOST approach
equivalence_test(ds, range = 0.2)

# Can also plot
if (require(see)) plot(equivalence_test(ds, range = 0.2))
if (require(see)) plot(equivalence_test(ds, range = 0.2, rule = "cet"))
if (require(see)) plot(equivalence_test(ds, range = 0.2, rule = "bayes"))
```

`eta_squared` *Effect size for ANOVA*

Description

Functions to compute effect size measures for ANOVAs, such as Eta, Omega and Epsilon squared, and Cohen's f (or their partialled versions) for `aov`, `aovlist` and `anova` models. These indices represent an estimate of how much variance in the response variables is accounted for by the explanatory variable(s).

Effect sizes are computed using the sums of squares obtained from `anova(model)` which might not always be appropriate (***Yeah... ANOVAs are hard...***). See details.

Usage

```
eta_squared(model, partial = TRUE, ci = 0.9, ...)

omega_squared(model, partial = TRUE, ci = 0.9, ...)

epsilon_squared(model, partial = TRUE, ci = 0.9, ...)

cohens_f(model, partial = TRUE, ci = 0.9, ...)
```

Arguments

`model`	A model, ANOVA object, or the result of `parameters::model_parameters`.
`partial`	If `TRUE`, return partial indices.
`ci`	Confidence Interval (CI) level
`...`	Arguments passed to or from other methods (ignored).

Details

For `aov` and `aovlist` models, the effect sizes are computed directly with Sums-of-Squares. For all other model, the model is passed to `anova()`, and effect sizes are approximated via test statistic conversion (see [F_to_eta2] for more details.)

Type of Sums of Squares:

The sums of squares (or F statistics) used for the computation of the effect sizes is based on those returned by `anova(model)` (whatever those may be - for `aov` and `aovlist` these are *type-1* sums of squares; for `merMod` these are *type-3* sums of squares). Make sure these are the sums of squares you are intrested in (you might want to pass the result of `car::Anova(mode,type = 3)`).

It is generally recommended to fit models with `contr.sum` *factor weights* and *centered covariates*, for sensible results. See examples.

Confidence Intervals:
Confidence intervals are estimated using the Noncentrality parameter method; These methods searches for a the best ncp (non-central parameters) for of the noncentral F distribution for the desired tail-probabilities, and then convert these ncps to the corresponding effect sizes.

Special care should be taken when interpreting CIs with a lower bound equal to (or small then) 0, and even more care should be taken when the *upper* bound is equal to (or small then) 0 (Steiger, 2004; Morey et al., 2016).

Omega Squared:
Omega squared is considered as a lesser biased alternative to eta-squared, especially when sample sizes are small (Albers \& Lakens, 2018). Field (2013) suggests the following interpretation heuristics:

- Omega Squared = 0 - 0.01: Very small
- Omega Squared = 0.01 - 0.06: Small
- Omega Squared = 0.06 - 0.14: Medium
- Omega Squared > 0.14: Large

Epsilon Squared:
It is one of the least common measures of effect sizes: omega squared and eta squared are used more frequently. Although having a different name and a formula in appearance different, this index is equivalent to the adjusted R2 (Allen, 2017, p. 382).

Cohen's f:
Cohen's f can take on values between zero, when the population means are all equal, and an indefinitely large number as standard deviation of means increases relative to the average standard deviation within each group. Cohen has suggested that the values of 0.10, 0.25, and 0.40 represent small, medium, and large effect sizes, respectively.

Value

A data frame with the effect size(s) and confidence interval(s).

A data frame containing the effect size values and their confidence intervals.

References

- Albers, C., \& Lakens, D. (2018). When power analyses based on pilot data are biased: Inaccurate effect size estimators and follow-up bias. Journal of experimental social psychology, 74, 187-195.
- Allen, R. (2017). Statistics and Experimental Design for Psychologists: A Model Comparison Approach. World Scientific Publishing Company.
- Kelley, T. (1935) An unbiased correlation ratio measure. Proceedings of the National Academy of Sciences. 21(9). 554-559.
- Morey, R. D., Hoekstra, R., Rouder, J. N., Lee, M. D., & Wagenmakers, E. J. (2016). The fallacy of placing confidence in confidence intervals. Psychonomic bulletin & review, 23(1), 103-123.
- Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. Psychological Methods, 9, 164-182.

See Also

F_to_eta2()

Examples

```
library(effectsize)
mtcars$am_f <- factor(mtcars$am)
mtcars$cyl_f <- factor(mtcars$cyl)

model <- aov(mpg ~ am_f * cyl_f, data = mtcars)

eta_squared(model)
omega_squared(model)
epsilon_squared(model)
cohens_f(model)
(etas <- eta_squared(model, partial = FALSE))

if(require(see)) plot(etas)


model <- aov(mpg ~ cyl_f * am_f + Error(vs / am_f), data = mtcars)
epsilon_squared(model)

# Recommended:
# Type-3 effect sizes + effects coding
if (require(car, quietly = TRUE)) {
  contrasts(mtcars$am_f) <- contr.sum
  contrasts(mtcars$cyl_f) <- contr.sum

  model <- aov(mpg ~ am_f * cyl_f, data = mtcars)
  model_anova <- car::Anova(model, type = 3)

  eta_squared(model_anova)
}

if (require("parameters")) {
  model <- lm(mpg ~ wt + cyl, data = mtcars)
  mp <- model_parameters(model)
  eta_squared(mp)
}

if (require(lmerTest, quietly = TRUE)) {
  model <- lmer(mpg ~ am_f * cyl_f + (1|vs), data = mtcars)
  omega_squared(model)
}
```

---

eta_squared_posterior *Simulate Eta Squared from Posterior Predictive Distribution*

Description

This function simulates data from the posterior predictive distribution (ppd) and for each simulation the Eta Squared is computed for the model's fixed effects.

Effect sizes are computed using the sums of squares obtained from `car::Anova(model,...)` which might not always be appropriate (***Yeah... ANOVAs are hard...***), e.g., when factors aren't 0-mean codded and covariates aren't centered; a warning will be given in such predictors are detected. See *details* section in `eta_squared()`.

Usage

```
eta_squared_posterior(
  model,
  partial = TRUE,
  type = 3,
  draws = 500,
  verbose = TRUE,
  ...
)
```

Arguments

`model`	A Bayesian linear model, fit with `brms` or `rstanarm`.
`partial`	Whether Partial Eta should be returned.
`type`	Type of sum-of-squares to use. See `car::Anova()`.
`draws`	An integer indicating the number of draws from the posterior predictive distribution to return. Larger numbers take longer to run, but provide estimates that are more stable.
`verbose`	Show messages.
`...`	Currently not used.

Value

A data frame containing the ppd of the Eta squared for each fixed effect, which can then be passed to `bayestestR::describe_posterior()` for summary stats.

Examples

```
if (require(rstanarm)) {
  fit_bayes <- stan_glm(mpg ~ factor(cyl) * wt + qsec,
                        data = mtcars,
                        family = gaussian(),
                        refresh = 0)

  es <- eta_squared_posterior(fit_bayes, partial = FALSE, type = 3)

  print(bayestestR::describe_posterior(es))
```

```
  # compare to:
  if (require(car)) {
    fit_freq <- lm(mpg ~ factor(cyl) * wt + qsec,
                   data = mtcars)
    aov_table <- car::Anova(fit_freq, type = 3)
    print(eta_squared(aov_table, partial = FALSE))
  }
}
```

`format_standardize` *Transform a standardized vector into character*

Description

Transform a standardized vector into character, e.g., `c("-1 SD","Mean","+1 SD")`.

Usage

```
format_standardize(x, reference = x, robust = FALSE, digits = NULL, ...)
```

Arguments

`x`	A standardized numeric vector.
`reference`	The reference vector from which to compute the mean and SD.
`robust`	Logical, if `TRUE`, centering is done by subtracting the median from the variables and dividing it by the median absolute deviation (MAD). If `FALSE`, variables are standardized by subtracting the mean and dividing it by the standard deviation (SD).
`digits`	Number of significant digits.
`...`	Arguments passed to or from other methods.

Examples

```
format_standardize(c(-1, 0, 1))
format_standardize(c(-1, 0, 1, 2), reference = rnorm(1000))
format_standardize(c(-1, 0, 1, 2), reference = rnorm(1000), robust = TRUE)
```

`F_to_eta2` *Convert test statistics (F, t) to indices of* **partial** *variance explained (***partial** *Eta / Omega / Epsilon squared and Cohen's f)*

Description

These functions are convenience functions to convert F and t test statistics to **partial** Eta squared, (η_p^2), Omega squared (ω_p^2), Epsilon squared (ϵ_p^2; an alias for the adjusted Eta squared) and Cohen's f. These are useful in cases where the various Sum of Squares and Mean Squares are not easily available or their computation is not straightforward (e.g., in liner mixed models, contrasts, etc.). For test statistics derived from `lm` and `aov` models, these functions give exact results. For all other cases, they return close approximations.
See Effect Size from Test Statistics vignette.

Usage

```
F_to_eta2(f, df, df_error, ci = 0.9, ...)

t_to_eta2(t, df_error, ci = 0.9, ...)

F_to_epsilon2(f, df, df_error, ci = 0.9, ...)

t_to_epsilon2(t, df_error, ci = 0.9, ...)

F_to_eta2_adj(f, df, df_error, ci = 0.9, ...)

t_to_eta2_adj(t, df_error, ci = 0.9, ...)

F_to_omega2(f, df, df_error, ci = 0.9, ...)

t_to_omega2(t, df_error, ci = 0.9, ...)

F_to_f(f, df, df_error, ci = 0.9, ...)

t_to_f(t, df_error, ci = 0.9, ...)
```

Arguments

`df, df_error`	Degrees of freedom of numerator or of the error estimate (i.e., the residuals).
`ci`	Confidence Interval (CI) level
`...`	Arguments passed to or from other methods.
`t, f`	The t or the F statistics.

Details

These functions use the following formulae:

$$\eta_p^2 = \frac{F \times df_{num}}{F \times df_{num} + df_{den}}$$

$$\epsilon_p^2 = \frac{(F-1) \times df_{num}}{F \times df_{num} + df_{den}}$$

$$\omega_p^2 = \frac{(F-1) \times df_{num}}{F \times df_{num} + df_{den} + 1}$$

$$f_p = \sqrt{\frac{\eta_p^2}{1-\eta_p^2}}$$

For t, the conversion is based on the equality of $t^2 = F$ when $df_{num} = 1$.

Confidence Intervals:

Confidence intervals are estimated using the Noncentrality parameter method; These methods searches for a the best ncp (non-central parameters) for of the noncentral F distribution for the desired tail-probabilities, and then convert these ncps to the corresponding effect sizes.

Special care should be taken when interpreting CIs with a lower bound equal to (or small then) 0, and even more care should be taken when the *upper* bound is equal to (or small then) 0 (Steiger, 2004; Morey et al., 2016).

Value

A data frame with the effect size(s) between 0-1, and confidence interval(s) (Note that for ω_p^2 and ϵ_p^2 it is possible to compute a negative number; even though this doesn't make any practical sense, it is recommended to report the negative number and not a 0).

Note

$Adj.\eta_p^2$ is an alias for ϵ_p^2.

References

- Albers, C., & Lakens, D. (2018). When power analyses based on pilot data are biased: Inaccurate effect size estimators and follow-up bias. Journal of experimental social psychology, 74, 187-195. doi: 10.31234/osf.io/b7z4q
- Cumming, G., & Finch, S. (2001). A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. Educational and Psychological Measurement, 61(4), 532-574.

- Friedman, H. (1982). Simplified determinations of statistical power, magnitude of effect and research sample sizes. Educational and Psychological Measurement, 42(2), 521-526. doi: 10.1177/001316448204200214
- Mordkoff, J. T. (2019). A Simple Method for Removing Bias From a Popular Measure of Standardized Effect Size: Adjusted Partial Eta Squared. Advances in Methods and Practices in Psychological Science, 2(3), 228-232. doi: 10.1177/2515245919855053
- Morey, R. D., Hoekstra, R., Rouder, J. N., Lee, M. D., & Wagenmakers, E. J. (2016). The fallacy of placing confidence in confidence intervals. Psychonomic bulletin & review, 23(1), 103-123.
- Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. Psychological Methods, 9, 164-182.

Examples

```
if (require("afex")) {
  data(md_12.1)
  aov_ez("id", "rt", md_12.1,
    within = c("angle", "noise"),
    anova_table = list(correction = "none", es = "pes")
  )
}
# compare to:
(etas <- F_to_eta2(
  f = c(40.72, 33.77, 45.31),
  df = c(2, 1, 2),
  df_error = c(18, 9, 18)
))

if(require(see)) plot(etas)


if (require("lmerTest")) { # for the df_error
  fit <- lmer(extra ~ group + (1 | ID), sleep)
  anova(fit)
  # Type III Analysis of Variance Table with Satterthwaite's method
  #       Sum Sq Mean Sq NumDF DenDF F value   Pr(>F)
  # group 12.482  12.482     1     9  16.501 0.002833 **
  # ---
  # Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
  F_to_eta2(16.501, 1, 9)
  F_to_omega2(16.501, 1, 9)
  F_to_epsilon2(16.501, 1, 9)
  F_to_f(16.501, 1, 9)
}

## Use with emmeans based contrasts
if (require(emmeans)) {
  warp.lm <- lm(breaks ~ wool * tension, data = warpbreaks)

  jt <- joint_tests(warp.lm, by = "wool")
```

```
  F_to_eta2(jt$F.ratio, jt$df1, jt$df2)
}
```

`interpret` *Generic function for interpretation*

Description

Interpret a value based on a set of rules. See `rules()`.

Usage

```
interpret(x, rules)
```

Arguments

`x`	Vector of value break points (edges defining categories).
`rules`	Set of `rules()`.

See Also

rules

Examples

```
rules_grid <- rules(c(0.01, 0.05), c("very significant", "significant", "not significant"))
interpret(0.001, rules_grid)
interpret(0.021, rules_grid)
interpret(0.08, rules_grid)
interpret(c(0.01, 0.005, 0.08), rules_grid)

interpret(c(0.35, 0.15), c("small" = 0.2, "large" = 0.4))
interpret(c(0.35, 0.15), rules(c(0.2, 0.4), c("small", "medium", "large")))
```

`interpret_bf` *Bayes Factor (BF) Interpretation*

Description

Bayes Factor (BF) Interpretation

Usage

```
interpret_bf(bf, rules = "jeffreys1961", include_value = FALSE)
```

Arguments

bf	Value or vector of Bayes factor (BF) values.
rules	Can be "jeffreys1961" (default), "raftery1995" or custom set of rules().
include_value	Include the value in the output.

References

- Jeffreys, H. (1961), Theory of Probability, 3rd ed., Oxford University Press, Oxford.
- Raftery, A. E. (1995). Bayesian model selection in social research. Sociological methodology, 25, 111-164.
- Jarosz, A. F., & Wiley, J. (2014). What are the odds? A practical guide to computing and reporting Bayes factors. The Journal of Problem Solving, 7(1), 2.

Examples

```
interpret_bf(1)
interpret_bf(c(5, 2))
```

---

interpret_d *Standardized difference interpretation*

Description

Interpretation of indices using different sets of rules of thumb. Click here for details.

Usage

```
interpret_d(d, rules = "funder2019")

interpret_g(g, rules = "funder2019")

interpret_delta(delta, rules = "funder2019")
```

Arguments

d, g, delta	Value or vector of effect size values.
rules	Can be "funder2019" (default), "gignac2016", "cohen1988", "sawilowsky2009" or custom set of rules().

References

- Funder, D. C., & Ozer, D. J. (2019). Evaluating effect size in psychological research: sense and nonsense. Advances in Methods and Practices in Psychological Science.
- Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. Personality and individual differences, 102, 74-78.
- Cohen, J. (1988). Statistical power analysis for the behavioural sciences.
- Sawilowsky, S. S. (2009). New effect size rules of thumb.

Examples

```
interpret_d(.02)
interpret_d(c(.5, .02))
```

`interpret_direction` *Direction interpretation*

Description

Direction interpretation

Usage

```
interpret_direction(x)
```

Arguments

x	Numeric value.

Examples

```
interpret_direction(.02)
interpret_direction(c(.5, -.02))
#
```

`interpret_ess` *Bayesian indices interpretation*

Description

Interpretation of Bayesian indices, such as Effective Sample Size (ESS), Rhat, or percentage in ROPE.

Usage

```
interpret_ess(ess, rules = "burkner2017")

interpret_rhat(rhat, rules = "vehtari2019")

interpret_rope(rope, ci = 0.9, rules = "default")
```

Arguments

ess	Value or vector of Effective Sample Size (ESS) values.
rules	A character string (see details) or a custom set of rules().
rhat	Value or vector of Rhat values.
rope	Value or vector of percentages in ROPE.
ci	The Credible Interval (CI) probability, corresponding to the proportion of HDI, that was used. Can be 1 in the case of "full ROPE".

Details

Rules sets:

- **ESS**: Can be "burkner2017" (default).
- **Rhat**: Can be "vehtari2019" (default) or "gelman1992".
- **ROPE**: Can be "default".

References

- Bürkner, P. C. (2017). brms: An R package for Bayesian multilevel models using Stan. Journal of Statistical Software, 80(1), 1-28.
- Gelman, A., & Rubin, D. B. (1992). Inference from iterative simulation using multiple sequences. Statistical science, 7(4), 457-472.
- Vehtari, A., Gelman, A., Simpson, D., Carpenter, B., & Bürkner, P. C. (2019). Rank-normalization, folding, and localization: An improved Rhat for assessing convergence of MCMC. arXiv preprint arXiv:1903.08008.
- BayestestR's reporting guidelines

Examples

```
interpret_ess(1001)
interpret_ess(c(852, 1200))

interpret_rhat(1.00)
interpret_rhat(c(1.5, 0.9))

interpret_rope(0, ci = 0.9)
interpret_rope(c(0.005, 0.99), ci = 1)
```

`interpret_gfi` *Interpretation of indices of fit*

Description

Interpretation of indices of fit found in confirmatory analysis or structural equation modelling, such as RMSEA, CFI, NFI, IFI, etc.

Usage

```
interpret_gfi(x, rules = "default")

interpret_agfi(x, rules = "default")

interpret_nfi(x, rules = "byrne1994")

interpret_nnfi(x, rules = "byrne1994")

interpret_cfi(x, rules = "default")

interpret_rmsea(x, rules = "default")

interpret_srmr(x, rules = "default")

interpret_rfi(x, rules = "default")

interpret_ifi(x, rules = "default")

interpret_pnfi(x, rules = "default")
```

Arguments

x	vector of values.
rules	Can be "default" or custom set of rules().

Details

Indices of fit:

- **Chisq**: The model Chi-squared assesses overall fit and the discrepancy between the sample and fitted covariance matrices. Its p-value should be > .05 (i.e., the hypothesis of a perfect fit cannot be rejected). However, it is quite sensitive to sample size.
- **GFI/AGFI**: The (Adjusted) Goodness of Fit is the proportion of variance accounted for by the estimated population covariance. Analogous to R2. The GFI and the AGFI should be > .95 and > .90, respectively.
- **NFI/NNFI/TLI**: The (Non) Normed Fit Index. An NFI of 0.95, indicates the model of interest improves the fit by 95\

- **CFI**: The Comparative Fit Index is a revised form of NFI. Not very sensitive to sample size (Fan, Thompson, & Wang, 1999). Compares the fit of a target model to the fit of an independent, or null, model. It should be > .90.
- **RMSEA**: The Root Mean Square Error of Approximation is a parsimony-adjusted index. Values closer to 0 represent a good fit. It should be < .08 or < .05. The p-value printed with it tests the hypothesis that RMSEA is less than or equal to .05 (a cutoff sometimes used for good fit), and thus should be not significant.
- **RMR/SRMR**: the (Standardized) Root Mean Square Residual represents the square-root of the difference between the residuals of the sample covariance matrix and the hypothesized model. As the RMR can be sometimes hard to interpret, better to use SRMR. Should be < .08.
- **RFI**: the Relative Fit Index, also known as RHO1, is not guaranteed to vary from 0 to 1. However, RFI close to 1 indicates a good fit.
- **IFI**: the Incremental Fit Index (IFI) adjusts the Normed Fit Index (NFI) for sample size and degrees of freedom (Bollen's, 1989). Over 0.90 is a good fit, but the index can exceed 1.
- **PNFI**: the Parsimony-Adjusted Measures Index. There is no commonly agreed-upon cutoff value for an acceptable model for this index. Should be > 0.50.

See the documentation for `lavaan::fitmeasures()`.

What to report:

For structural equation models (SEM), Kline (2015) suggests that at a minimum the following indices should be reported: The model **chi-square**, the **RMSEA**, the **CFI** and the **SRMR**.

References

- Awang, Z. (2012). A handbook on SEM. Structural equation modeling.
- Byrne, B. M. (1994). Structural equation modeling with EQS and EQS/Windows. Thousand Oaks, CA: Sage Publications.
- Tucker, L. R., \& Lewis, C. (1973). The reliability coefficient for maximum likelihood factor analysis. Psychometrika, 38, 1-10.
- Schumacker, R. E., \& Lomax, R. G. (2004). A beginner's guide to structural equation modeling, Second edition. Mahwah, NJ: Lawrence Erlbaum Associates.
- Fan, X., B. Thompson, \& L. Wang (1999). Effects of sample size, estimation method, and model specification on structural equation modeling fit indexes. Structural Equation Modeling, 6, 56-83.
- Kline, R. B. (2015). Principles and practice of structural equation modeling. Guilford publications.

Examples

```
interpret_gfi(c(.5, .99))
interpret_agfi(c(.5, .99))
interpret_nfi(c(.5, .99))
interpret_nnfi(c(.5, .99))
interpret_cfi(c(.5, .99))
interpret_rmsea(c(.5, .99))
interpret_srmr(c(.5, .99))
```

```
interpret_rfi(c(.5, .99))
interpret_ifi(c(.5, .99))
interpret_pnfi(c(.5, .99))
```

`interpret_odds` *(Log) Odds ratio interpretation*

Description

(Log) Odds ratio interpretation

Usage

```
interpret_odds(odds, rules = "chen2010", log = FALSE)
```

Arguments

`odds`	Value or vector of (log) odds ratio values.
`rules`	Can be "chen2010" (default), `"cohen1988"` (through transformation to standardized difference, see `odds_to_d()`) or custom set of `rules()`.
`log`	Are the provided values log odds ratio.

References

- Cohen, J. (1988). Statistical power analysis for the behavioural sciences.
- Chen, H., Cohen, P., & Chen, S. (2010). How big is a big odds ratio? Interpreting the magnitudes of odds ratios in epidemiological studies. Communications in Statistics—Simulation and Computation, 39(4), 860-864.
- Sánchez-Meca, J., Marín-Martínez, F., & Chacón-Moscoso, S. (2003). Effect-size indices for dichotomized outcomes in meta-analysis. Psychological methods, 8(4), 448.

Examples

```
interpret_odds(1)
interpret_odds(c(5, 2))
```

interpret_omega_squared *ANOVA effect size interpretation*

Description

ANOVA effect size interpretation

Usage

```
interpret_omega_squared(omega_squared, rules = "field2013")
```

Arguments

omega_squared	Value or vector of omega squared values.
rules	Can be "field2013" (default) or custom set of rules().

References

- Field, A (2013) Discovering statistics using IBM SPSS Statistics. Fourth Edition. Sage:London.

See Also

http://imaging.mrc-cbu.cam.ac.uk/statswiki/FAQ/effectSize

Examples

```
interpret_omega_squared(.02)
interpret_omega_squared(c(.5, .02))
```

interpret_p *p-values interpretation*

Description

p-values interpretation

Usage

```
interpret_p(p, rules = "default")
```

Arguments

p	Value or vector of p-values.
rules	Can be "default" or custom set of rules().

Examples

```
interpret_p(.02)
interpret_p(c(.5, .02))
```

`interpret_parameters` *Automated Interpretation of Effect Sizes*

Description

Automated interpretation of effect sizes.

Usage

```
interpret_parameters(model, ...)

## S3 method for class 'lm'
interpret_parameters(
  model,
  parameters = NULL,
  interpretation = "funder2019",
  standardize_method = "refit",
  standardize_robust = FALSE,
  ...
)
```

Arguments

`model`	A statistical model.
`...`	Arguments passed to or from other methods.
`parameters`	A custom parameters table. If `NULL`, will use `standardize_parameters()` to get it.
`interpretation`	Interpretation grid (i.e., the set of rules of thumb) used to interpret the effects.
`standardize_method`	See `standardize_parameters()`.
`standardize_robust`	See `standardize_parameters()`.

Examples

```
model <- lm(Sepal.Length ~ Species * Petal.Width, data = iris)
```

`interpret_r` *Correlation interpretation*

Description

Correlation interpretation

Usage

```
interpret_r(r, rules = "funder2019")
```

Arguments

`r`	Value or vector of correlation coefficient.
`rules`	Can be `"funder2019"` (default), `"gignac2016"`, `"cohen1988"`, `"evans1996"` or custom set of `rules()`.

References

- Funder, D. C., & Ozer, D. J. (2019). Evaluating effect size in psychological research: sense and nonsense. Advances in Methods and Practices in Psychological Science.
- Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. Personality and individual differences, 102, 74-78.
- Cohen, J. (1988). Statistical power analysis for the behavioural sciences.
- Evans, J. D. (1996). Straightforward statistics for the behavioral sciences. Thomson Brooks/Cole Publishing Co.

See Also

Page 88 of APA's 6th Edition.

Examples

```
interpret_r(r = .015)
interpret_r(r = c(.5, -.02))
```

interpret_r2 *Coefficient of determination (R2) interpretation*

Description

Coefficient of determination (R2) interpretation

Usage

```
interpret_r2(r2, rules = "cohen1988")
```

Arguments

r2	Value or vector of R2 values.
rules	Can be "cohen1988" (default), "falk1992", "chin1998", "hair2011" or custom set of rules()].

References

- Cohen, J. (1988). Statistical power analysis for the behavioural sciences.
- Falk, R. F., & Miller, N. B. (1992). A primer for soft modeling. University of Akron Press.
- Chin, W. W. (1998). The partial least squares approach to structural equation modeling. Modern methods for business research, 295(2), 295-336.
- Hair, J. F., Ringle, C. M., & Sarstedt, M. (2011). PLS-SEM: Indeed a silver bullet. Journal of Marketing theory and Practice, 19(2), 139-152.

Examples

```
interpret_r2(.02)
interpret_r2(c(.5, .02))
```

is_effectsize_name *Checks if character is of a supported effect size*

Description

For use by other functions and packages.

Usage

```
is_effectsize_name(x)
```

Arguments

x	A character, or a vactor / list of ones.

normalize *Normalization*

Description

Performs a normalization of data, i.e., it scales all numeric variables in the range 0 - 1. This is a special case of `change_scale()`.

Usage

```
normalize(x, ...)

## S3 method for class 'numeric'
normalize(x, include_bounds = TRUE, verbose = TRUE, ...)

## S3 method for class 'grouped_df'
normalize(x, select = NULL, exclude = NULL, include_bounds = TRUE, ...)

## S3 method for class 'data.frame'
normalize(x, select = NULL, exclude = NULL, include_bounds = TRUE, ...)
```

Arguments

`x`	Object.
`...`	Arguments passed to or from other methods.
`include_bounds`	Logical, if `TRUE`, return value may include 0 and 1. If `FALSE`, the return value is compressed, using the formula `(x * (n -1) + 0.5) / n` (*Smithson and Verkuilen 2006*), to avoid zeros and ones in the normalized variables. This can be useful in case of beta-regression, where the response variable is not allowed to include zeros and ones.
`verbose`	Toggle warnings on or off.
`select`	Character vector of column names. If `NULL` (the default), all variables will be selected.
`exclude`	Character vector of column names to be excluded from selection.

Value

A normalized object.

References

- Smithson M, Verkuilen J (2006). A Better Lemon Squeezer? Maximum-Likelihood Regression with Beta-Distributed Dependent Variables. Psychological Methods, 11(1), 54–71.

See Also

`ranktransform()` `standardize()` `change_scale()`

Examples

```
normalize(c(0, 1, 5, -5, -2))
normalize(c(0, 1, 5, -5, -2), include_bounds = FALSE)

head(normalize(iris))
```

---

percentage_to_d *General effect size conversion*

Description

Enables a conversion between different indices of effect size, such as standardized difference (Cohen's d), correlation r or (log) odds ratios.

Usage

```
percentage_to_d(percentage, ...)

d_to_percentage(d, ...)

convert_percentage_to_d(percentage, ...)

convert_d_to_percentage(d, ...)

d_to_r(d, ...)

r_to_d(r, ...)

convert_d_to_r(d, ...)

convert_r_to_d(r, ...)

odds_to_d(odds, log = FALSE, ...)

convert_odds_to_d(odds, log = FALSE, ...)

logodds_to_d(odds, log = TRUE, ...)

d_to_odds(d, log = FALSE, ...)

convert_d_to_odds(d, log = FALSE, ...)

odds_to_r(odds, log = FALSE, ...)

convert_odds_to_r(odds, log = FALSE, ...)
```

```
logodds_to_r(odds, log = TRUE, ...)

r_to_odds(r, log = FALSE, ...)

convert_r_to_odds(r, log = FALSE, ...)

odds_to_probs(odds, log = FALSE, ...)

## S3 method for class 'data.frame'
odds_to_probs(odds, log = FALSE, select = NULL, exclude = NULL, ...)

probs_to_odds(probs, log = FALSE, ...)

convert_odds_to_probs(odds, log = FALSE, ...)

convert_probs_to_odds(probs, log = FALSE, ...)
```

Arguments

`percentage`	Percentage value (e.g., `0.01` for one percent).
`...`	Arguments passed to or from other methods.
`d`	Standardized difference value (Cohen's d).
`r`	Correlation coefficient r.
`odds`	Odds values in vector or dataframe.
`log`	Take in or output log odds (such as in logistic models).
`select`	When a dataframe is passed, character or list of of column names to be transformed.
`exclude`	When a dataframe is passed, character or list of column names to be excluded from transformation.
`probs`	Probability values.

Details

- *d to r*: $d = \frac{2*r}{\sqrt{1-r^2}}$
- *r to d*: $r = \frac{d}{\sqrt{d^2+4}}$
- *odds to d*: $d = \frac{\log(odds) \times \sqrt{3}}{\pi}$
- *d to odds*: $log(odds) = d * \frac{\pi}{\sqrt{(3)}}$

Value

Converted index.

References

- Sánchez-Meca, J., Marín-Martínez, F., & Chacón-Moscoso, S. (2003). Effect-size indices for dichotomized outcomes in meta-analysis. Psychological methods, 8(4), 448.
- Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Converting among effect sizes. Introduction to meta-analysis, 45-49.

Examples

```
r_to_d(0.5)
d_to_odds(d = 1.154701)
odds_to_r(odds = 8.120534)

d_to_r(d = 1)
r_to_odds(0.4472136, log = TRUE)
odds_to_d(1.813799, log = TRUE)
```

---

phi *Effect size for contingency tables*

Description

Compute Cramer's V and phi (ϕ) from contingency tables.

Usage

```
phi(x, y = NULL, CI = 0.95, adjust = FALSE, ...)

cramers_v(x, y = NULL, CI = 0.95, adjust = FALSE, ...)
```

Arguments

x	a numeric vector or matrix. x and y can also both be factors.
y	a numeric vector; ignored if x is a matrix. If x is a factor, y should be a factor of the same length.
CI	Confidence Interval (CI) level
adjust	Should the effect size be bias-corrected? Defaults to FALSE.
...	Ignored.

Value

A data frame with the effect size(s) between 0-1, and confidence interval(s).

See Also

chisq_to_phi() for details regarding estimation and CIs.

Examples

```
contingency_table <- as.table(rbind(c(762, 327, 468), c(484, 239, 477), c(484, 239, 477)))

phi(contingency_table)

cramers_v(contingency_table)
```

`ranktransform` *(Signed) rank transformation*

Description

Transform numeric values with the integers of their rank (i.e., 1st smallest, 2nd smallest, 3rd smallest, etc.). Setting the `sign` argument to `TRUE` will give you signed ranks, where the ranking is done according to absolute size but where the sign is preserved (i.e., 2, 1, -3, 4).

Usage

```
ranktransform(x, ...)

## S3 method for class 'numeric'
ranktransform(x, sign = FALSE, method = "average", verbose = TRUE, ...)

## S3 method for class 'grouped_df'
ranktransform(
  x,
  select = NULL,
  exclude = NULL,
  sign = FALSE,
  method = "average",
  ...
)

## S3 method for class 'data.frame'
ranktransform(
  x,
  select = NULL,
  exclude = NULL,
  sign = FALSE,
  method = "average",
  ...
)
```

Arguments

x	Object.
...	Arguments passed to or from other methods.
sign	Logical, if TRUE, return signed ranks.
method	Treatment of ties. Can be one of "average" (default), "first", "last", "random", "max" or "min". See rank() for details.
verbose	Toggle warnings on or off.
select	Character vector of column names. If NULL (the default), all variables will be selected.
exclude	Character vector of column names to be excluded from selection.

Value

A rank-transformed object.

See Also

normalize() standardize() change_scale()

Examples

```
ranktransform(c(0, 1, 5, -5, -2))
ranktransform(c(0, 1, 5, -5, -2), sign = TRUE)

head(ranktransform(iris))
```

---

rules *Interpretation Grid*

Description

Create a container for interpretation rules of thumb. Usually used in conjunction with interpret.

Usage

```
rules(values, labels = NULL)

is.rules(x)
```

Arguments

values	Vector of reference values (edges defining categories or critical values).
labels	Labels associated with each category. If NULL, will try to infer it from values (if it is a named vector or a list), otherwise, will return the breakpoints.
x	An arbitrary R object.

See Also

interpret

Examples

```
rules(c(0.05), c("significant", "not significant"))
rules(c(0.2, 0.5, 0.8), c("small", "medium", "large"))
rules(c("small" = 0.2, "medium" = 0.5))
```

`sd_pooled` *Pooled Standard Deviation*

Description

The Pooled Standard Deviation is a weighted average of standard deviations for two or more groups, with more "weight" given to larger sample sizes.

Usage

```
sd_pooled(x, y = NULL, data = NULL)

mad_pooled(x, y = NULL, data = NULL)
```

Arguments

`x`	A formula, a numeric vector, or a character name of one in `data`.
`y`	A numeric vector, a grouping (character / factor) vector, a or a character name of one in `data`. Ignored if `x` is a formula.
`data`	An optional data frame containing the variables.

Value

Numeric, the pooled standard deviation.

See Also

`cohens_d()`

Examples

```
sd_pooled(mpg ~ am, data = mtcars)
```

`standardize` *Standardization (Z-scoring)*

Description

Performs a standardization of data (z-scoring), i.e., centering and scaling, so that the data is expressed in terms of standard deviation (i.e., mean = 0, SD = 1) or Median Absolute Deviance (median = 0, MAD = 1). When applied to a statistical model, this function extracts the dataset, standardizes it, and refits the model with this standardized version of the dataset. The `normalize()` function can also be used to scale all numeric variables within the 0 - 1 range.

Usage

```
standardize(x, ...)

## S3 method for class 'data.frame'
standardize(
  x,
  robust = FALSE,
  two_sd = FALSE,
  select = NULL,
  exclude = NULL,
  verbose = TRUE,
  force = FALSE,
  append = FALSE,
  suffix = "_z",
  ...
)

## Default S3 method:
standardize(
  x,
  robust = FALSE,
  two_sd = FALSE,
  include_response = TRUE,
  verbose = TRUE,
  ...
)
```

Arguments

`x`	A data frame, a vector or a statistical model.
`...`	Arguments passed to or from other methods.
`robust`	Logical, if `TRUE`, centering is done by subtracting the median from the variables and dividing it by the median absolute deviation (MAD). If `FALSE`, variables are standardized by subtracting the mean and dividing it by the standard deviation (SD).

two_sd — If TRUE, the variables are scaled by two times the deviation (SD or MAD depending on robust). This method can be useful to obtain model coefficients of continuous parameters comparable to coefficients related to binary predictors (Gelman, 2008).

select — Character vector of column names. If NULL (the default), all variables will be selected.

exclude — Character vector of column names to be excluded from selection.

verbose — Toggle warnings on or off.

force — Logical, if TRUE, forces standardization of factors as well. Factors are converted to numerical values, with the lowest level being the value 1 (unless the factor has numeric levels, which are converted to the corresponding numeric value).

append — Logical, if TRUE and x is a data frame, standardized variables will be added as additional columns; if FALSE, existing variables are overwritten.

suffix — Character value, will be appended to variable (column) names of x, if x is a data frame and append = TRUE.

include_response — For a model, if TRUE (default), the response value will also be standardized. If FALSE, only the predictors will be standardized. Note that for certain models (logistic regression, count models, ...), the response value will never be standardized, to make re-fitting the model work.

Details

If x is a model object, standardization is done by completely refitting the model on the standardized data. Hence, this approach is equal to standardizing the variables before fitting the model and will return a new model object. However, this method is particularly recommended for complex models that include interactions or transformations (e.g., polynomial or spline terms). The robust (default to FALSE) argument enables a robust standardization of data, i.e., based on the median and MAD instead of the mean and SD. See standardize_parameters() for other methods of standardizing model coefficients.

Value

The standardized object (either a standardize data frame or a statistical model fitted on standardized data).

Note

When x is a data frame or vector, missing values are preserved, so the return value has the same length / number of rows as the original input.

See Also

normalize() standardize_parameters()

Examples

```
# Data frames
summary(standardize(iris))

# Models
model <- lm(Sepal.Length ~ Species * Petal.Width, data = iris)
coef(standardize(model))
```

`standardize_info` *Get Standardization Information*

Description

This function extracts information, such as the deviations (SD or MAD) from parent variables, that are necessary for post-hoc standardization of parameters. This function gives a window on how standardized are obtained, i.e., by what they are devided. The "basic" method of standardization uses

Usage

```
standardize_info(model, robust = FALSE, ...)
```

Arguments

`model`	A statistical model.
`robust`	Logical, if `TRUE`, centering is done by subtracting the median from the variables and dividing it by the median absolute deviation (MAD). If `FALSE`, variables are standardized by subtracting the mean and dividing it by the standard deviation (SD).
`...`	Arguments passed to or from other methods.

Examples

```
model <- lm(Sepal.Width ~ Sepal.Length * Species, data = iris)
```

`standardize_parameters`
Parameters standardization

Description

Compute standardized model parameters (coefficients).

Usage

```
standardize_parameters(
  model,
  parameters = NULL,
  method = "refit",
  ci = 0.95,
  robust = FALSE,
  two_sd = FALSE,
  verbose = TRUE,
  centrality = "median",
  ...
)

standardize_posteriors(
  model,
  method = "refit",
  robust = FALSE,
  two_sd = FALSE,
  verbose = TRUE,
  ...
)
```

Arguments

model	A statistical model.
parameters	An optional table containing the parameters to standardize. If NULL, will automatically retrieve it from the model.
method	The method used for standardizing the parameters. Can be "refit" (default), "posthoc", "smart" or "basic". See 'Details'.
ci	Confidence Interval (CI) level
robust	Logical, if TRUE, centering is done by subtracting the median from the variables and dividing it by the median absolute deviation (MAD). If FALSE, variables are standardized by subtracting the mean and dividing it by the standard deviation (SD).
two_sd	If TRUE, the variables are scaled by two times the deviation (SD or MAD depending on robust). This method can be useful to obtain model coefficients of continuous parameters comparable to coefficients related to binary predictors (Gelman, 2008).
verbose	Toggle warnings on or off.
centrality	For Bayesian models, which point-estimates (centrality indices) to compute. Character (vector) or list with one or more of these options: "median", "mean", "MAP" or "all".
...	Arguments passed to or from other methods.

Details

Methods::

- **refit**: This method is based on a complete model re-fit with a standardized version of data. Hence, this method is equal to standardizing the variables before fitting the model. It is the "purest" and the most accurate (Neter et al., 1989), but it is also the most computationally costly and long (especially for heavy models such as, for instance, for Bayesian models). This method is particularly recommended for complex models that include interactions or transformations (e.g., polynomial or spline terms). The `robust` (default to `FALSE`) argument enables a robust standardization of data, i.e., based on the `median` and `MAD` instead of the `mean` and `SD`.
- **posthoc**: Post-hoc standardization of the parameters, aiming at emulating the results obtained by "refit" without refitting the model. The coefficients are divided by the standard deviation (or MAD if `robust`) of the outcome (which becomes their expression 'unit'). Then, the coefficients related to numeric variables are additionally multiplied by the standard deviation (or MAD if `robust`) of the related terms, so that they correspond to changes of 1 SD of the predictor (e.g., "A change in 1 SD of `x` is related to a change of 0.24 of the SD of `y`). This does not apply to binary variables or factors, so the coefficients are still related to changes in levels. This method is not accurate and tend to give aberrant results when interactions are specified.
- **smart** (Standardization of Model's parameters with Adjustment, Reconnaissance and Transformation): Similar to `method = "posthoc"` in that it does not involve model refitting. The difference is that the SD of the response is computed on the relevant section of the data. For instance, if a factor with 3 levels A (the intercept), B and C is entered as a predictor, the effect corresponding to B vs. A will be scaled by the variance of the response at the intercept only. As a results, the coefficients for effects of factors are similar to a Glass' delta.
- **basic**: This method is similar to `method = "posthoc"`, but treats all variables as continuous: it also scales the coefficient by the standard deviation of model's matrix' parameter of factors levels (transformed to integers) or binary predictors. Although being inappropriate for these cases, this method is the one implemented by default in other software packages, such as `lm.beta::lm.beta()`.

When `method = "smart"` or `method = "classic"`, `standardize_parameters()` also returns the standard errors for the standardized coefficients. Then, `ci()` can be used to calculate confidence intervals for the standardized coefficients. See 'Examples'.

Value

Standardized parameters table.

References

- Neter, J., Wasserman, W., & Kutner, M. H. (1989). Applied linear regression models.
- Gelman, A. (2008). Scaling regression inputs by dividing by two standard deviations. Statistics in medicine, 27(15), 2865-2873.

See Also

standardize_info

Examples

```
library(effectsize)
data(iris)

model <- lm(Sepal.Length ~ Species * Petal.Width, data = iris)
standardize_parameters(model, method = "refit")


standardize_parameters(model, method = "posthoc")
standardize_parameters(model, method = "smart")
standardize_parameters(model, method = "basic")

# Robust and 2 SD
standardize_parameters(model, robust = TRUE)
standardize_parameters(model, two_sd = TRUE)


iris$binary <- ifelse(iris$Sepal.Width > 3, 1, 0)
model <- glm(binary ~ Species * Sepal.Length, data = iris, family = "binomial")
standardize_parameters(model, method = "refit")
standardize_parameters(model, method = "posthoc")
standardize_parameters(model, method = "smart")
standardize_parameters(model, method = "basic")



if (require("rstanarm")) {
 model <- stan_glm(Sepal.Length ~ Species + Petal.Width, data = iris, iter = 500, refresh = 0)
  standardize_posteriors(model, method = "refit")
  standardize_posteriors(model, method = "posthoc")
  standardize_posteriors(model, method = "smart")
  standardize_posteriors(model, method = "basic")

  standardize_parameters(model, method = "refit")
  standardize_parameters(model, method = "posthoc")
  standardize_parameters(model, method = "smart")
  standardize_parameters(model, method = "basic")
}
```

---

t_to_d *Convert test statistics (t, z, F) to effect sizes of differences (Cohen's d) or association (**partial** r)*

Description

These functions are convenience functions to convert t, z and F test statistics to Cohen's d and **partial** r. These are useful in cases where the data required to compute these are not easily available or their computation is not straightforward (e.g., in liner mixed models, contrasts, etc.).
See Effect Size from Test Statistics vignette.

Usage

```
t_to_d(t, df_error, paired = FALSE, ci = 0.95, pooled, ...)

z_to_d(z, n, paired = FALSE, ci = 0.95, pooled, ...)

F_to_d(f, df, df_error, paired = FALSE, ci = 0.95, pooled, ...)

t_to_r(t, df_error, ci = 0.95, ...)

z_to_r(z, n, ci = 0.95, ...)

F_to_r(f, df, df_error, ci = 0.95, ...)
```

Arguments

`t`, `f`, `z`	The t, the F or the z statistics.
`paired`	Should the estimate accout for the t-value being testing the difference between dependant means?
`ci`	Confidence Interval (CI) level
`pooled`	Deprecated. Use `paired`.
`...`	Arguments passed to or from other methods.
`n`	The number of observations (the sample size).
`df`, `df_error`	Degrees of freedom of numerator or of the error estimate (i.e., the residuals).

Details

These functions use the following formulae:

$$r_{partial} = t/\sqrt{t^2 + df_{error}}$$

$$r_{partial} = z/\sqrt{z^2 + N}$$

$$Cohen'sd = 2 * t/\sqrt{df_{error}}$$

$$Cohen'sd_z = t/\sqrt{df_{error}}$$

$$Cohen'sd = 2 * z/\sqrt{N}$$

Confidence Intervals:

Confidence intervals are estimated using the Noncentrality parameter method; These methods searches for a the best ncp (non-central parameters) for of the noncentral F distribution for the desired tail-probabilities, and then convert these ncps to the corresponding effect sizes.

Value

A data frame with the effect size(s) between 0-1, and confidence interval(s)

References

- Friedman, H. (1982). Simplified determinations of statistical power, magnitude of effect and research sample sizes. Educational and Psychological Measurement, 42(2), 521-526. doi: 10.1177/001316448204200214
- Wolf, F. M. (1986). Meta-analysis: Quantitative methods for research synthesis (Vol. 59). Sage.
- Rosenthal, R. (1991). Meta-analytic procedures for social research. Newbury Park, CA: SAGE Publications, Incorporated.
- Steiger, J. H. (2004). Beyond the F test: Effect size confidence intervals and tests of close fit in the analysis of variance and contrast analysis. Psychological Methods, 9, 164-182.
- Cumming, G., & Finch, S. (2001). A primer on the understanding, use, and calculation of confidence intervals that are based on central and noncentral distributions. Educational and Psychological Measurement, 61(4), 532-574.

Examples

```
## t Tests
res <- t.test(1:10, y = c(7:20), var.equal = TRUE)
t_to_d(t = res$statistic, res$parameter)
t_to_r(t = res$statistic, res$parameter)

res <- with(sleep, t.test(extra[group == 1], extra[group == 2], paired = TRUE))
t_to_d(t = res$statistic, res$parameter, paired = TRUE)
t_to_r(t = res$statistic, res$parameter)


## Linear Regression
model <- lm(Sepal.Length ~ Sepal.Width + Petal.Length, data = iris)
library(parameters)
(param_tab <- parameters(model))

(rs <- t_to_r(param_tab$t[2:3], param_tab$df_error[2:3]))

if(require(see)) plot(rs)

# How does this compare to actual partial correlations?
if (require("correlation")) {
  correlation::correlation(iris[,1:3], partial = TRUE)[1:2, c(2,3,7,8)]
}
```

```
## Use with emmeans based contrasts (see also t_to_eta2)
if (require(emmeans)) {
  warp.lm <- lm(breaks ~ wool * tension, data = warpbreaks)

  conts <- summary(pairs(emmeans(warp.lm,  ~ tension | wool)))
  t_to_d(conts$t.ratio, conts$df)
}
```

Index