

Package ‘pimeta’

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Type Package

Title Prediction Intervals for Random-Effects Meta-Analysis

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Higgins et al. (2009) <doi:10.1111/j.1467-985X.2008.00552.x>, Partlett and Riley (2017) <doi:10.1002/sim.7140>, and Nagashima et al. (2019) <doi:10.1177/0962280218773520>, <arXiv:1804.01054>.

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pimeta-package	<i>Prediction Intervals for Random-Effects Meta-Analysis</i>
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Description

Prediction Intervals for Random-Effects Meta-Analysis

Author(s)

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cima	<i>Calculating Confidence Intervals</i>
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Description

This function calculates confidence intervals.

Usage

```
cima(y, se, v = NULL, alpha = 0.05, method = c("boot", "DL", "HK",
"sj", "KR", "APX", "PL", "BC"), B = 25000, parallel = FALSE,
seed = NULL, maxit1 = 1e+05, eps = 10^(-10), lower = 0,
upper = 1000, maxit2 = 1000, tol = .Machine$double.eps^0.25,
rnd = NULL, maxiter = 100)
```

Arguments

y	the effect size estimates vector
se	the within studies standard errors vector
v	the within studies variance estimates vector
alpha	the alpha level of the prediction interval
method	the calculation method for the prediction interval (default = "boot"). <ul style="list-style-type: none"> • boot: A parametric bootstrap confidence interval (Nagashima et al., 2018). • DL: A Wald-type t-distribution confidence interval (the DerSimonian & Laird estimator for τ^2 with an approximate variance estimator for the average effect, $(1/\sum \hat{w}_i)^{-1}$, $df = K - 1$). • HK: A Wald-type t-distribution confidence interval (the REML estimator for τ^2 with the Hartung (1999)'s variance estimator [the Hartung and Knapp (2001)'s estimator] for the average effect, $df = K - 1$). • SJ: A Wald-type t-distribution confidence interval (the REML estimator for τ^2 with the Sidik and Jonkman (2006)'s bias corrected SE estimator for the average effect, $df = K - 1$). • KR: Partlett–Riley (2017) confidence interval / (the REML estimator for τ^2 with the Kenward and Roger (1997)'s approach for the average effect, $df = \nu$). • APX: A Wald-type t-distribution confidence interval / (the REML estimator for τ^2 with an approximate variance estimator for the average effect, $df = K - 1$). • PL: Profile likelihood confidence interval (Hardy & Thompson, 1996). • BC: Profile likelihood confidence interval with Bartlett-type correction (Noma, 2011).
B	the number of bootstrap samples
parallel	the number of threads used in parallel computing, or FALSE that means single threading
seed	set the value of random seed
maxit1	the maximum number of iteration for the exact distribution function of Q
eps	the desired level of accuracy for the exact distribution function of Q
lower	the lower limit of random numbers of τ^2
upper	the lower upper of random numbers of τ^2
maxit2	the maximum number of iteration for numerical inversions
tol	the desired level of accuracy for numerical inversions
rnd	a vector of random numbers from the exact distribution of τ^2
maxiter	the maximum number of iteration for REML estimation

Details

Excellent reviews of heterogeneity variance estimation have been published (e.g., Veroniki, et al., 2018).

Value

- K: the number of studies.
- muhat: the average treatment effect estimate $\hat{\mu}$.
- lci, uci: the lower and upper confidence limits $\hat{\mu}_l$ and $\hat{\mu}_u$.
- tau2h: the estimate for τ^2 .
- i2h: the estimate for I^2 .
- nuc: degrees of freedom for the confidence interval.
- vmuhat: the variance estimate for $\hat{\mu}$.

References

- Veroniki, A. A., Jackson, D., Bender, R., Kuss, O., Langan, D., Higgins, J. P. T., Knapp, G., and Salanti, J. (2016). Methods to calculate uncertainty in the estimated overall effect size from a random-effects meta-analysis *Res Syn Meth. In press*. <https://doi.org/10.1002/jrsm.1319>.
- Nagashima, K., Noma, H., and Furukawa, T. A. (2018). Prediction intervals for random-effects meta-analysis: a confidence distribution approach. *Stat Methods Med Res. In press*. <https://doi.org/10.1177/0962280218773520>.
- Higgins, J. P. T., Thompson, S. G., Spiegelhalter, D. J. (2009). A re-evaluation of random-effects meta-analysis. *J R Stat Soc Ser A Stat Soc.* **172**(1): 137-159. <https://doi.org/10.1111/j.1467-985X.2008.00552.x>
- Partlett, C., and Riley, R. D. (2017). Random effects meta-analysis: Coverage performance of 95 confidence and prediction intervals following REML estimation. *Stat Med.* **36**(2): 301-317. <https://doi.org/10.1002/sim.7140>
- Hartung, J., and Knapp, G. (2001). On tests of the overall treatment effect in meta-analysis with normally distributed responses. *Stat Med.* **20**(12): 1771-1782. <https://doi.org/10.1002/sim.791>
- Sidik, K., and Jonkman, J. N. (2006). Robust variance estimation for random effects meta-analysis. *Comput Stat Data Anal.* **50**(12): 3681-3701. <https://doi.org/10.1016/j.csda.2005.07.019>
- Noma H. (2011) Confidence intervals for a random-effects meta-analysis based on Bartlett-type corrections. *Stat Med.* **30**(28): 3304-3312. <https://doi.org/10.1002/sim.4350>

See Also

[pima](#)

Examples

```
data(sbp, package = "pimeta")
set.seed(20161102)

# Nagashima-Noma-Furukawa confidence interval
pimeta::cima(sbp$y, sbp$sigma_k, seed = 3141592)

# A Wald-type t-distribution confidence interval
# An approximate variance estimator & DerSimonian-Laird estimator for tau^2
```

```

pimeta::cima(sbp$y, sbp$sigma_k, method = "DL")

# A Wald-type t-distribution confidence interval
# The Hartung variance estimator & REML estimator for tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "HK")

# A Wald-type t-distribution confidence interval
# The Sidik-Jonkman variance estimator & REML estimator for tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "SJ")

# A Wald-type t-distribution confidence interval
# The Kenward-Roger approach & REML estimator for tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "KR")

# A Wald-type t-distribution confidence interval
# An approximate variance estimator & REML estimator for tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "APX")

# Profile likelihood confidence interval
# Maximum likelihood estimators of variance for the average effect & tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "PL")

# Profile likelihood confidence interval with a Bartlett-type correction
# Maximum likelihood estimators of variance for the average effect & tau^2
pimeta::cima(sbp$y, sbp$sigma_k, method = "BC")

```

 convert_bin

Converting binary data

Description

Converting binary outcome data to the effect size estimates and the within studies standard errors vector

Usage

```
convert_bin(m1, n1, m2, n2, type = c("logOR", "logRR", "RD"))
```

Arguments

m1	the number of successes in treatment group 1
n1	the number of patients in treatment group 1
m2	the number of successes in treatment group 2
n2	the number of patients in treatment group 2
type	the outcome measure for binary outcome data (default = "logOR").

- logOR: logarithmic odds ratio, which is defined by $= \log \frac{(m1+0.5)(n2-m2+0.5)}{(n1-m1+0.5)(m2+0.5)}$.
- logRR: logarithmic relative risk, which is defined by $= \log \frac{(m1+0.5)(n2+0.5)}{(n1+0.5)(m2+0.5)}$.
- RD: risk difference, which is defined by $= \frac{m1}{n1} - \frac{m2}{n2}$.

Details

This function implements methods for logarithmic odds ratio, logarithmic relative risk, and risk difference described in Hartung & Knapp (2001).

Value

- y: the effect size estimates vector.
- se: the within studies standard errors vector.

References

Hartung, J., and Knapp, G. (2001). A refined method for the meta-analysis of controlled clinical trials with binary outcome. *Stat Med.* **20**(24): 3875-3889. <https://doi.org/10.1002/sim.1009>

Examples

```
m1 <- c(15,12,29,42,14,44,14,29,10,17,38,19,21)
n1 <- c(16,16,34,56,22,54,17,58,14,26,44,29,38)
m2 <- c( 9, 1,18,31, 6,17, 7,23, 3, 6,12,22,19)
n2 <- c(16,16,34,56,22,55,15,58,15,27,45,30,38)
dat <- pimeta::convert_bin(m1, n1, m2, n2, type = "logOR")
pimeta::pima(dat$y, dat$se)
```

hyp

Hypertension data

Description

The hypertension data (Wang et al., 2005) included 7 studies comparing the treatment effect of anti-hypertensive treatment versus control on reducing diastolic blood pressure (DBP) in patients with hypertension. Negative estimates indicate the reduction of DBP in the anti-hypertensive treatment group.

Usage

```
data(hyp)
```

Format

A data frame with 10 rows and 2 variables

Details

- y: Standardized mean difference
- se: Standard error
- label: Labels for each study

References

Wang, J. G., Staessen, J. A., Franklin, S. S., Fagard, R., and Gueyffier, F. (2005). Systolic and diastolic blood pressure lowering as determinants of cardiovascular outcome. *Hypertension*. **45**(5): 907-913. <https://doi.org/10.1161/01.HYP.0000165020.14745.79>

i2h	I^2 heterogeneity measure
-----	-----------------------------

Description

Returns the estimator for (Higgins & Thompson, 2002).

Usage

```
i2h(se, tau2h)
```

Arguments

se	the within studies standard errors vector
tau2h	the estimate of τ^2

Value

- i2h: the estimate for I^2 .

References

Higgins, J. P. T., and Thompson, S. G. (2002). Quantifying heterogeneity in a meta-analysis. *Stat Med*. **21**(11): 1539-1558. <https://doi.org/10.1002/sim.1186>

Examples

```
data(sbp, package = "pimeta")
tau2h <- pimeta::tau2h(sbp$y, sbp$sigma)
pimeta::i2h(sbp$sigma, tau2h$tau2h)
```

pain

Pain data

Description

The pain data (Riley et al., 2011; Hauser et al., 2009) included 22 studies comparing the treatment effect of antidepressants on reducing pain in patients with fibromyalgia syndrome. The treatment effects were summarized using standardized mean differences on a visual analog scale for pain between the antidepressant group and control group. Negative estimates indicate the reduction of pain in the antidepressant group.

Usage

```
data(pain)
```

Format

A data frame with 22 rows and 2 variables

Details

- y: Standardized mean difference
- sigma_k: Standard error

References

- Hauser, W., Bernardy, K., Uceyler, N., and Sommer, C. (2009). Treatment of fibromyalgia syndrome with antidepressants: a meta-analysis. *JAMA*. **301**(2): 198-209. <https://doi.org/10.1001/jama.2008.944>
- Riley, R. D., Higgins, J. P. T., and Deeks, J. J. (2011). Interpretation of random effects meta-analyses. *BMJ*. **342**: d549. <https://doi.org/10.1136/bmj.d549>

pima

Calculating Prediction Intervals

Description

This function can estimate prediction intervals (PIs) as follows: A parametric bootstrap PI based on confidence distribution (Nagashima et al., 2018). A parametric bootstrap confidence interval is also calculated based on the same sampling method for bootstrap PI. The Higgins–Thompson–Spiegelhalter (2009) prediction interval. The Partlett–Riley (2017) prediction intervals.

Usage

```
pima(y, se, v = NULL, alpha = 0.05, method = c("boot", "HTS", "HK",
  "SJ", "KR", "CL", "APX"), B = 25000, parallel = FALSE, seed = NULL,
  maxit1 = 1e+05, eps = 10^(-10), lower = 0, upper = 1000,
  maxit2 = 1000, tol = .Machine$double.eps^0.25, rnd = NULL,
  maxiter = 100)
```

Arguments

y	the effect size estimates vector
se	the within studies standard error estimates vector
v	the within studies variance estimates vector
alpha	the alpha level of the prediction interval
method	the calculation method for the pretiction interval (default = "boot"). <ul style="list-style-type: none"> • boot: A parametric bootstrap prediction interval (Nagashima et al., 2018). • HTS: the Higgins–Thompson–Spiegelhalter (2009) prediction interval / (the DerSimonian & Laird estimator for τ^2 with an approximate variance estimator for the average effect, $(1/\sum \hat{w}_i)^{-1}$, $df = K - 2$). • HK: Partlett–Riley (2017) prediction interval (the REML estimator for τ^2 with the Hartung (1999)'s variance estimator [the Hartung and Knapp (2001)'s estimator] for the average effect, $df = K - 2$). • SJ: Partlett–Riley (2017) prediction interval / (the REML estimator for τ^2 with the Sidik and Jonkman (2006)'s bias coreccted variance estimator for the average effect, $df = K - 2$). • KR: Partlett–Riley (2017) prediction interval / (the REML estimator for τ^2 with the Kenward and Roger (1997)'s approach for the average effect, $df = \nu - 1$). • APX: Partlett–Riley (2017) prediction interval / (the REML estimator for τ^2 with an approximate variance estimator for the average effect, $df = K - 2$).
B	the number of bootstrap samples
parallel	the number of threads used in parallel computing, or FALSE that means single threading
seed	set the value of random seed
maxit1	the maximum number of iteration for the exact distribution function of Q
eps	the desired level of accuracy for the exact distribution function of Q
lower	the lower limit of random numbers of τ^2
upper	the upper limit of random numbers of τ^2
maxit2	the maximum number of iteration for numerical inversions
tol	the desired level of accuracy for numerical inversions
rnd	a vector of random numbers from the exact distribution of τ^2
maxiter	the maximum number of iteration for REML estimation

Details

The functions `bootPI`, `pima_boot`, `pima_hts`, `htsdl`, `pima_htsreml`, `htsreml` are deprecated, and integrated to the `pima` function.

Value

- `K`: the number of studies.
- `muhat`: the average treatment effect estimate $\hat{\mu}$.
- `lci`, `uci`: the lower and upper confidence limits $\hat{\mu}_l$ and $\hat{\mu}_u$.
- `lpi`, `upi`: the lower and upper prediction limits \hat{c}_l and \hat{c}_u .
- `tau2h`: the estimate for τ^2 .
- `i2h`: the estimate for I^2 .
- `nup`: degrees of freedom for the prediction interval.
- `nuc`: degrees of freedom for the confidence interval.
- `vmuhat`: the variance estimate for $\hat{\mu}$.

References

- Higgins, J. P. T, Thompson, S. G., Spiegelhalter, D. J. (2009). A re-evaluation of random-effects meta-analysis. *J R Stat Soc Ser A Stat Soc.* **172**(1): 137-159. <https://doi.org/10.1111/j.1467-985X.2008.00552.x>
- Partlett, C, and Riley, R. D. (2017). Random effects meta-analysis: Coverage performance of 95 confidence and prediction intervals following REML estimation. *Stat Med.* **36**(2): 301-317. <https://doi.org/10.1002/sim.7140>
- Nagashima, K., Noma, H., and Furukawa, T. A. (2018). Prediction intervals for random-effects meta-analysis: a confidence distribution approach. *Stat Methods Med Res. In press.* <https://doi.org/10.1177/0962280218773520>.
- Hartung, J. (1999). An alternative method for meta-analysis. *Biom J.* **41**(8): 901-916. [https://doi.org/10.1002/\(SICI\)1521-4036\(199912\)41:8<901::AID-BIMJ901>3.0.CO;2-W](https://doi.org/10.1002/(SICI)1521-4036(199912)41:8<901::AID-BIMJ901>3.0.CO;2-W).
- Hartung, J., and Knapp, G. (2001). On tests of the overall treatment effect in meta-analysis with normally distributed responses. *Stat Med.* **20**(12): 1771-1782. <https://doi.org/10.1002/sim.791>.
- Sidik, K., and Jonkman, J. N. (2006). Robust variance estimation for random effects meta-analysis. *Comput Stat Data Anal.* **50**(12): 3681-3701. <https://doi.org/10.1016/j.csda.2005.07.019>.
- Kenward, M. G., and Roger, J. H. (1997). Small sample inference for fixed effects from restricted maximum likelihood. *Biometrics.* **53**(3): 983-997. <https://www.ncbi.nlm.nih.gov/pubmed/9333350>.
- DerSimonian, R., and Laird, N. (1986). Meta-analysis in clinical trials. *Control Clin Trials.* **7**(3): 177-188.

See Also

[print.pima](#), [plot.pima](#), [cima](#).

Examples

```

data(sbp, package = "pimeta")

# Nagashima-Noma-Furukawa prediction interval
# is sufficiently accurate when I^2 >= 10% and K >= 3
pimeta::pima(sbp$y, sbp$sigma_k, seed = 3141592, parallel = 4)

# Higgins-Thompson-Spiegelhalter prediction interval and
# Partlett-Riley prediction intervals
# are accurate when I^2 > 30% and K > 25
pimeta::pima(sbp$y, sbp$sigma_k, method = "HTS")
pimeta::pima(sbp$y, sbp$sigma_k, method = "HK")
pimeta::pima(sbp$y, sbp$sigma_k, method = "SJ")
pimeta::pima(sbp$y, sbp$sigma_k, method = "KR")
pimeta::pima(sbp$y, sbp$sigma_k, method = "APX")

```

plot.cima

Plot Results

Description

A function for plotting of ‘cima’ objects.

Usage

```

## S3 method for class 'cima'
plot(x, y = NULL, title = "Forest plot",
     base_size = 16, base_family = "", digits = 3, studylabel = NULL,
     ntick = NULL, trans = c("identity", "exp"), ...)

```

Arguments

x	‘cima’ object to plot
y	is not used
title	graph title
base_size	base font size
base_family	base font family
digits	a value for digits specifies the minimum number of significant digits to be printed in values.
studylabel	labels for each study
ntick	the number of x-axis ticks
trans	transformation for logarithmic scale outcomes ("identity" [default] or "exp").
...	further arguments passed to or from other methods.

Examples

```
data(sbp, package = "pimeta")
ciex <- pimeta::cima(sbp$y, sbp$sigma_k, method = "DL")
cairo_pdf("forestplot.pdf", width = 6, height = 3, family = "Arial")
plot(ciex, digits = 2, base_size = 10, studylabel = sbp$label)
dev.off()
```

plot.pima

Plot Results

Description

A function for plotting of 'pima' objects.

Usage

```
## S3 method for class 'pima'
plot(x, y = NULL, title = "Forest plot",
     base_size = 16, base_family = "", digits = 3, studylabel = NULL,
     ntick = NULL, trans = c("identity", "exp"), ...)
```

Arguments

x	'pima' object to plot
y	is not used
title	graph title
base_size	base font size
base_family	base font family
digits	a value for digits specifies the minimum number of significant digits to be printed in values.
studylabel	labels for each study
ntick	the number of x-axis ticks
trans	transformation for logarithmic scale outcomes ("identity" [default] or "exp").
...	further arguments passed to or from other methods.

Examples

```
data(sbp, package = "pimeta")
piex <- pimeta::pima(sbp$y, sbp$sigma_k, method = "HTS")
cairo_pdf("forestplot.pdf", width = 6, height = 3, family = "Arial")
plot(piex, digits = 2, base_size = 10, studylabel = sbp$label)
dev.off()
```

`print.cima`*Print Results*

Description

`print` prints its argument and returns it invisibly (via `invisible(x)`).

Usage

```
## S3 method for class 'cima'
print(x, digits = 4, trans = c("identity", "exp"), ...)
```

Arguments

<code>x</code>	print to display
<code>digits</code>	a value for <code>digits</code> specifies the minimum number of significant digits to be printed in values.
<code>trans</code>	transformation for logarithmic scale outcomes ("identity" [default] or "exp").
<code>...</code>	further arguments passed to or from other methods.

`print.pima`*Print Results*

Description

`print` prints its argument and returns it invisibly (via `invisible(x)`).

Usage

```
## S3 method for class 'pima'
print(x, digits = 4, trans = c("identity", "exp"), ...)
```

Arguments

<code>x</code>	print to display
<code>digits</code>	a value for <code>digits</code> specifies the minimum number of significant digits to be printed in values.
<code>trans</code>	transformation for logarithmic scale outcomes ("identity" [default] or "exp").
<code>...</code>	further arguments passed to or from other methods.

```
print.pima_tau2h      Print Results
```

Description

print prints its argument and returns it invisibly (via invisible(x)).

Usage

```
## S3 method for class 'pima_tau2h'
print(x, digits = 3, ...)
```

Arguments

x	print to display
digits	a value for digits specifies the minimum number of significant digits to be printed in values.
...	further arguments passed to or from other methods.

```
pwchisq      The Distribution of a Positive Linear Combination of Chiqaure Random Variables
```

Description

The cumulative distribution function for the distribution of a positive linear combination of χ^2 random variables with the weights $(\lambda_1, \dots, \lambda_K)$, degrees of freedom (ν_1, \dots, ν_K) , and non-centrality parameters $(\delta_1, \dots, \delta_K)$.

Usage

```
pwchisq(x, lambda = 1, nu = 1, delta = 0, mode = 1,
        maxit1 = 1e+05, eps = 10^(-10))
```

Arguments

x	numeric; value of $x > 0$ ($P[X \leq x]$).
lambda	numeric vector; weights $(\lambda_1, \dots, \lambda_K)$.
nu	integer vector; degrees of freedom (ν_1, \dots, ν_K) .
delta	numeric vector; non-centrality parameters $(\delta_1, \dots, \delta_K)$.
mode	numeric; the mode of calculation (see Farabrother, 1984)
maxit1	integer; the maximum number of iteration.
eps	numeric; the desired level of accuracy.

Value

- prob: the distribution function.

References

Farebrother, R. W. (1984). Algorithm AS 204: the distribution of a positive linear combination of χ^2 random variables. *J R Stat Soc Ser C Appl Stat.* **33**(3): 332–339. <https://rss.onlinelibrary.wiley.com/doi/10.2307/2347721>.

Examples

```
# Table 1 of Farabrother (1984)
# Q6 (The target values are 0.0061, 0.5913, and 0.9779)

pimeta::pwchisq( 20, lambda = c(7,3), nu = c(6,2), delta = c(6,2))
pimeta::pwchisq(100, lambda = c(7,3), nu = c(6,2), delta = c(6,2))
pimeta::pwchisq(200, lambda = c(7,3), nu = c(6,2), delta = c(6,2))
# [1] 0.006117973
# [1] 0.5913421
# [1] 0.9779184
```

sbp

Systolic blood pressure (SBP) data

Description

Riley et al. (2011) analyzed a hypothetical meta-analysis. They generated a data set of 10 studies examining the same antihypertensive drug. Negative estimates suggested reduced blood pressure in the treatment group.

Usage

```
data(sbp)
```

Format

A data frame with 10 rows and 2 variables

Details

- y: Standardized mean difference
- sigma_k: Standard error
- label: Labels for each generated study

References

Riley, R. D., Higgins, J. P. T, and Deeks, J. J. (2011). Interpretation of random effects meta-analyses. *BMJ.* **342**: d549. <https://doi.org/10.1136/bmj.d549>

 setshift

Set-shifting data

Description

Higgins et al. (2009) re-analyzed data (Roberts et al., 2007) that included 14 studies evaluating the set-shifting ability in people with eating disorders by using a prediction interval. Standardized mean differences in the time taken to complete Trail Making Test between subjects with eating disorders and healthy controls were collected. Positive estimates indicate impairment in set shifting ability in people with eating disorders.

Usage

```
data(setshift)
```

Format

A data frame with 14 rows and 2 variables

Details

- y: Standardized mean difference
- sigma_k: Standard error

References

Roberts, M. E., Tchanturia, K., Stahl, D., Southgate, L., and Treasure, J. (2007). A systematic review and meta-analysis of set-shifting ability in eating disorders. *Psychol Med.* **37**(8): 1075-1084. <https://doi.org/10.1017/S0033291707009877>

Higgins, J. P. T, Thompson, S. G., Spiegelhalter, D. J. (2009). A re-evaluation of random-effects meta-analysis. *J R Stat Soc Ser A Stat Soc.* **172**(1): 137-159. <https://doi.org/10.1111/j.1467-985X.2008.00552.x>

 tau2h

Calculating Heterogeneity Variance

Description

Returns a heterogeneity variance estimate and its confidence interval.

Usage

```
tau2h(y, se, maxiter = 100, method = c("DL", "VC", "PM", "HM", "HS",
  "ML", "REML", "AREML", "SJ", "SJ2", "EB", "BM"), methodci = c("NA", "ML",
  "REML"), alpha = 0.05)
```


Arguments

y	the effect size estimates vector
se	the within studies standard errors vector
maxiter	the maximum number of iterations
method	the calculation method for heterogeneity variance (default = "DL"). <ul style="list-style-type: none"> • DL: DerSimonian–Laird estimator (DerSimonian & Laird, 1986). • VC: Variance component type estimator (Hedges, 1983). • PM: Paule–Mandel estimator (Paule & Mandel, 1982). • HM: Hartung–Makambi estimator (Hartung & Makambi, 2003). • HS: Hunter–Schmidt estimator (Hunter & Schmidt, 2004). This estimator has negative bias (Viechtbauer, 2005). • ML: Maximum likelihood (ML) estimator (e.g., DerSimonian & Laird, 1986). • REML: Restricted maximum likelihood (REML) estimator (e.g., DerSimonian & Laird, 1986). • AREML: Approximate restricted maximum likelihood estimator (Thompson & Sharp, 1999). • SJ: Sidik–Jonkman estimator (Sidik & Jonkman, 2005). • SJ2: Sidik–Jonkman improved estimator (Sidik & Jonkman, 2007). • EB: Empirical Bayes estimator (Morris, 1983). • BM: Bayes modal estimator (Chung, et al., 2013).
methodci	the calculation method for a confidence interval of heterogeneity variance (default = NA). <ul style="list-style-type: none"> • NA: a confidence interval will not be calculated. • ML: Wald confidence interval with a ML estimator (Biggerstaff & Tweedie, 1997). • REML: Wald confidence interval with a REML estimator (Biggerstaff & Tweedie, 1997).
alpha	the alpha level of the confidence interval

Details

Excellent reviews of heterogeneity variance estimation have been published (Sidik & Jonkman, 2007; Veroniki, et al., 2016; Langan, et al., 2018).

Value

- tau2h: the estimate for τ^2 .
- lci, uci: the lower and upper confidence limits $\hat{\tau}_l^2$ and $\hat{\tau}_u^2$.

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Examples

```
data(sbp, package = "pimeta")
pimeta::tau2h(sbp$y, sbp$sigma_k)
```

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