Package ‘bfpwr’

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Title Power and Sample Size Calculations for Bayes Factor Analysis

Description Implements z-test, t-test, and normal moment prior Bayes factors based on summary statistics, along with functionality to perform corresponding power and sample size calculations as described in Pawel and Held (2024) <doi:10.48550/arXiv.2406.19940>.

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Encoding UTF-8

Imports lamW

Suggests roxygen2, tinytest, knitr

VignetteBuilder knitr

NeedsCompilation no

RoxygenNote 7.3.1

URL https://github.com/SamCH93/bfpwr

BugReports https://github.com/SamCH93/bfpwr/issues

Contents

`bf01` *z-test Bayes factor*

Description

This function computes the Bayes factor that quantifies the evidence that the data (in the form of an asymptotically normally distributed parameter estimate with standard error) provide for a point null hypothesis with a normal prior assigned to the parameter under the alternative. The standard error is assumed to be known.

Usage

```
bf01(estimate, se, null = 0, pm, psd, log = FALSE)
```

Arguments

`estimate`	Parameter estimate
`se`	Standard error of the parameter estimate
`null`	Parameter value under the point null hypothesis. Defaults to `0`
`pm`	Mean of the normal prior assigned to the parameter under the alternative
`psd`	Standard deviation of the normal prior assigned to the parameter under the alternative. Set to `0` to obtain a point prior at the prior mean
`log`	Logical indicating whether the natural logarithm of the Bayes factor should be returned. Defaults to `FALSE`

Value

Bayes factor in favor of the null hypothesis over the alternative ($\mathrm{BF}_{01} > 1$ indicates evidence for the null hypothesis, whereas $\mathrm{BF}_{01} < 1$ indicates evidence for the alternative)

Author(s)

Samuel Pawel

Examples

```
bf01(estimate = 0.2, se = 0.05, null = 0, pm = 0, psd = 2)
```

`binbf01` *Binomial Bayes factor*

Description

This function computes the Bayes factor for testing a binomial proportion p based on x observed successes out of n trials. Two types of tests are available:

- Test of a point null hypothesis: The Bayes factor quantifies the evidence for $H_0\colon p = p_0$ against $H_1\colon p \neq p_0$. A beta prior is assigned to the proportion p under the alternative hypothesis H_1.
- Test of a directional null hypothesis: The Bayes factor quantifies the evidence for $H_0\colon p \leq p_0$ against $H_1\colon p > p_0$. A beta prior that is truncated to the range $[0, p_0]$ under the null H_0 and to $(p_0, 1]$ under the alternative H_1 is assigned to the proportion p under the corresponding hypothesis.

Usage

```
binbf01(
  x,
  n,
  p0 = 0.5,
  type = c("point", "direction"),
  a = 1,
  b = 1,
  log = FALSE
)
```

Arguments

`x`	Number of successes
`n`	Number of trials
`p0`	Tested binomial proportion. Defaults to `0.5`
`type`	Type of test. Can be `"point"` or `"directional"`. Defaults to `"point"`
`a`	Number of successes parameter of the beta prior distribution. Defaults to `1`
`b`	Number of failures parameter of the beta prior distribution. Defaults to `1`
`log`	Logical indicating whether the natural logarithm of the Bayes factor should be returned. Defaults to `FALSE`

Value

Bayes factor in favor of the null hypothesis over the alternative (BF_{01} > 1 indicates evidence for the null hypothesis, whereas BF_{01} < 1 indicates evidence for the alternative)

Author(s)

Samuel Pawel

See Also

pbinbf01, nbinbf01

Examples

```
## example on Mendelian inheritance from ?stats::binom.test
binbf01(x = 682, n = 925, p0 = 3/4, a = 1, b = 1, type = "point")
## 18.6 => strong evidence for the hypothesized p = 3/4 compared to other p

## with directional hypothesis
binbf01(x = 682, n = 925, p0 = 3/4, a = 1, b = 1, type = "direction")
## 1.5 => only anecdotal evidence for p <= 3/4 over p > 3/4

## Particle-counting experiment from Stone (1997) with point null
binbf01(x = 106298, n = 527135, p0 = 0.2, a = 1, b = 1, type = "point")
## 8.1 => moderate evidence for the alternative over the null

## Coin flip experiment from Bartos et al. (2023) with point null
binbf01(x = 178079, n = 350757 , p0 = 0.5, a = 5100, b = 4900, type = "point")
## => 1/1.72e+17 extreme evidence in favor of the alternative over the null
```

---

nbf01 *Sample size determination for z-test Bayes factor*

Description

This function computes the required sample size to obtain a Bayes factor (bf01) more extreme than a threshold k with a specified target power.

Usage

```
nbf01(
  k,
  power,
  usd,
  null = 0,
  pm,
  psd,
  dpm = pm,
  dpsd = psd,
  nrange = c(1, 10^5),
  lower.tail = TRUE,
  integer = TRUE,
```

```
  analytical = TRUE,
  ...
)
```

Arguments

`k`	Bayes factor threshold
`power`	Target power
`usd`	Unit standard deviation, the (approximate) standard error of the parameter estimate based on $\mathtt{n} = 1$, see details
`null`	Parameter value under the point null hypothesis. Defaults to `0`
`pm`	Mean of the normal prior assigned to the parameter under the alternative in the analysis
`psd`	Standard deviation of the normal prior assigned to the parameter under the alternative in the analysis. Set to `0` to obtain a point prior at the prior mean
`dpm`	Mean of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior `pm`
`dpsd`	Standard deviation of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior `psd`
`nrange`	Sample size search range over which numerical search is performed. Defaults to `c(1, 10^5)`
`lower.tail`	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathtt{k})$ (`TRUE`) or $\Pr(\mathrm{BF}_{01} > \mathtt{k})$ (`FALSE`) should be computed. Defaults to `TRUE`
`integer`	Logical indicating whether only integer valued sample sizes should be returned. If `TRUE` the required sample size is rounded to the next larger integer. Defaults to `TRUE`
`analytical`	Logical indicating whether analytical (if available) or numerical method should be used. Defaults to `TRUE`
`...`	Other arguments passed to `stats::uniroot`

Details

It is assumed that the standard error of the future parameter estimate is of the form $\mathtt{se} = \mathtt{usd}/\sqrt{\mathtt{n}}$. For example, for normally distributed data with known standard deviation `sd` and two equally sized groups of size `n`, the standard error of an estimated standardized mean difference is $\mathtt{se} = \mathtt{sd}\sqrt{2/n}$, so the corresponding unit standard deviation is $\mathtt{usd} = \mathtt{sd}\sqrt{2}$. See the vignette for more information.

Value

The required sample size to achieve the specified power

Note

A warning message will be displayed in case that the specified target power is not achievable under the specified analysis and design priors.

Author(s)

Samuel Pawel

See Also

pbf01, powerbf01, bf01

Examples

```
## point alternative (analytical and numerical solution available)
nbf01(k = 1/10, power = 0.9, usd = 1, null = 0, pm = 0.5, psd = 0,
      analytical = c(TRUE, FALSE), integer = FALSE)

## standardized mean difference (usd = sqrt(2), effective sample size = per group size)
nbf01(k = 1/10, power = 0.9, usd = sqrt(2), null = 0, pm = 0, psd = 1)
## this is the sample size per group (assuming equally sized groups)

## z-transformed correlation (usd = 1, effective sample size = n - 3)
nbf01(k = 1/10, power = 0.9, usd = 1, null = 0, pm = 0.2, psd = 0.5)
## have to add 3 to obtain the actual sample size

## log hazard/odds ratio (usd = 2, effective sample size = total number of events)
nbf01(k = 1/10, power = 0.9, usd = 2, null = 0, pm = 0, psd = sqrt(0.5))
## have to convert the number of events to a sample size
```

---

nbinbf01 *Sample size determination for binomial Bayes factor*

Description

This function computes the required sample size to obtain a Bayes factor (binbf01) more extreme than a threshold k with a specified target power.

Usage

```
nbinbf01(
  k,
  power,
  p0 = 0.5,
  type = c("point", "direction"),
  a = 1,
  b = 1,
  dp = NA,
  da = a,
  db = b,
  dl = 0,
  du = 1,
```

```
  lower.tail = TRUE,
  integer = TRUE,
  nrange = c(1, 10^3),
  ...
)
```

Arguments

k	Bayes factor threshold
power	Target power
p0	Tested binomial proportion. Defaults to 0.5
type	Type of test. Can be "point" or "directional". Defaults to "point"
a	Number of successes parameter of the beta analysis prior distribution. Defaults to 1
b	Number of failures parameter of the beta analysis prior distribution. Defaults to 1
dp	Fixed binomial proportion assumed for the power calculation. Set to NA to use a truncated beta design prior instead (specified via the da, db, dl, and du arguments). Defaults to NA
da	Number of successes parameter of the truncated beta design prior distribution. Is only taken into account if dp = NA. Defaults to the same value a as specified for the analysis prior
db	Number of failures parameter of the truncated beta design prior distribution. Is only taken into account if dp = NA. Defaults to the same value b as specified for the analysis prior
dl	Lower truncation limit of of the truncated beta design prior distribution. Is only taken into account if dp = NA. Defaults to 0
du	Upper truncation limit of of the truncated beta design prior distribution. Is only taken into account if dp = NA. Defaults to 1
lower.tail	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathsf{k})$ (TRUE) or $\Pr(\mathrm{BF}_{01} > \mathsf{k})$ (FALSE) should be computed. Defaults to TRUE
integer	Logical indicating whether only integer valued sample sizes should be returned. If TRUE the required sample size is rounded to the next larger integer. Defaults to TRUE
nrange	Sample size search range over which numerical search is performed. Defaults to c(1, 10^3)
...	Other arguments passed to stats::uniroot

Value

The required sample size to achieve the specified power

Author(s)

Samuel Pawel

See Also

pbinbf01, binbf01

Examples

```
## sample size parameters
pow <- 0.9
p0 <- 3/4
a <- 1
b <- 1
k <- 1/10

## sample sizes for directional testing
(nH1 <- nbinbf01(k = k, power = pow, p0 = p0, type = "direction", a = a,
                 b = b, da = a, db = b, dl = p0, du = 1))
(nH0 <- nbinbf01(k = 1/k, power = pow, p0 = p0, type = "direction", a = a,
                 b = b, da = a, db = b, dl = 0, du = p0, lower.tail = FALSE))
nseq <- seq(1, 1.1*max(c(nH1, nH0)), length.out = 100)
powH1 <- pbinbf01(k = k, n = nseq, p0 = p0, type = "direction", a = a,
                  b = b, da = a, db = b, dl = p0, du = 1)
powH0 <- pbinbf01(k = 1/k, n = nseq, p0 = p0, type = "direction", a = a,
                  b = b, da = a, db = b, dl = 0, du = p0, lower.tail = FALSE)
matplot(nseq, cbind(powH1, powH0), type = "s", xlab = "n", ylab = "Power", lty = 1,
        ylim = c(0, 1), col = c(2, 4), las = 1)
abline(h = pow, lty = 2)
abline(v = c(nH1, nH0), col = c(2, 4), lty = 2)
legend("topleft", legend = c("H1", "H0"), lty = 1, col = c(2, 4))

## sample sizes for point null testing
(nH1 <- nbinbf01(k = k, power = pow, p0 = p0, type = "point", a = a,
                 b = b, da = a, db = b))
(nH0 <- nbinbf01(k = 1/k, power = pow, p0 = p0, type = "point", a = a,
                 b = b, dp = p0, lower.tail = FALSE, nrange = c(1, 10^5)))
nseq <- seq(1, max(c(nH1, nH0)), length.out = 100)
powH1 <- pbinbf01(k = k, n = nseq, p0 = p0, type = "point", a = a,
                  b = b, da = a, db = b, dl = 0, du = 1)
powH0 <- pbinbf01(k = 1/k, n = nseq, p0 = p0, type = "point", a = a,
                  b = b, dp = p0, lower.tail = FALSE)
matplot(nseq, cbind(powH1, powH0), type = "s", xlab = "n", ylab = "Power", lty = 1,
        ylim = c(0, 1), col = c(2, 4), las = 1)
abline(h = pow, lty = 2)
abline(v = c(nH1, nH0), col = c(2, 4), lty = 2)
legend("topleft", legend = c("H1", "H0"), lty = 1, col = c(2, 4))
```

---

nmbf01 *Normal moment prior Bayes factor*

Description

This function computes the Bayes factor that quantifies the evidence that the data (in the form of an asymptotically normally distributed parameter estimate with standard error) provide for a point null hypothesis with a normal moment prior assigned to the parameter under the alternative.

Usage

```
nmbf01(estimate, se, null = 0, psd, log = FALSE)
```

Arguments

`estimate`	Parameter estimate
`se`	Standard error of the parameter estimate
`null`	Parameter value under the point null hypothesis. Defaults to `0`
`psd`	Spread of the normal moment prior assigned to the parameter under the alternative. The modes of the prior are located at $\pm\sqrt{2}\,\texttt{psd}$
`log`	Logical indicating whether the natural logarithm of the Bayes factor should be returned. Defaults to `FALSE`

Details

A normal moment prior has density $f(x \mid \texttt{null}, \texttt{psd}) = N(x \mid \texttt{null}, \texttt{psd}^2) \times (x - \texttt{null})/\texttt{psd}^2$ with $N(x \mid m, v)$ the normal density with mean m and variance v evaluated at x.

Value

Bayes factor in favor of the null hypothesis over the alternative ($\mathrm{BF}_{01} > 1$ indicates evidence for the null hypothesis, whereas $\mathrm{BF}_{01} < 1$ indicates evidence for the alternative)

Author(s)

Samuel Pawel

References

Johnson, V. E. and Rossell, D. (2010). On the use of non-local prior densities in Bayesian hypothesis tests. Journal of the Royal Statistical Society: Series B (Statistical Methodology), 72(2):143–170. doi:10.1111/j.14679868.2009.00730.x

Pramanik, S. and Johnson, V. E. (2024). Efficient alternatives for Bayesian hypothesis tests in psychology. Psychological Methods, 29(2):243–261. doi:10.1037/met0000482

See Also

nmbf01, pnmbf01, nnmbf01, powernmbf01

Examples

```
nmbf01(estimate = 0.25, se = 0.05, null = 0, psd = 0.5/sqrt(2)) # mode at 0.5
```

nnmbf01 *Sample size determination for normal moment prior Bayes factor*

Description

This function computes the required sample size to obtain a normal moment prior Bayes factor (nbf01) more extreme than a threshold k with a specified target power.

Usage

```
nnmbf01(
  k,
  power,
  usd,
  null = 0,
  psd,
  dpm,
  dpsd,
  nrange = c(1, 10^5),
  lower.tail = TRUE,
  integer = TRUE,
  ...
)
```

Arguments

k	Bayes factor threshold
power	Target power
usd	Unit standard deviation, the (approximate) standard error of the parameter estimate based on $n = 1$, see details
null	Parameter value under the point null hypothesis. Defaults to 0
psd	Spread of the normal moment prior assigned to the parameter under the alternative in the analysis. The modes of the prior are located at $\pm\sqrt{2}\,\mathrm{psd}$
dpm	Mean of the normal design prior assigned to the parameter
dpsd	Standard deviation of the normal design prior assigned to the parameter. Set to 0 to obtain a point prior at the design prior mean
nrange	Sample size search range over which numerical search is performed. Defaults to c(1, 10^5)
lower.tail	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathrm{k})$ (TRUE) or $\Pr(\mathrm{BF}_{01} > \mathrm{k})$ (FALSE) should be computed. Defaults to TRUE
integer	Logical indicating whether only integer valued sample sizes should be returned. If TRUE the required sample size is rounded to the next larger integer. Defaults to TRUE
...	Other arguments passed to stats::uniroot

Details

It is assumed that the standard error of the future parameter estimate is of the form $\texttt{se} = \texttt{usd}/\sqrt{\texttt{n}}$. For example, for normally distributed data with known standard deviation sd and two equally sized groups of size n, the standard error of an estimated standardized mean difference is $\texttt{se} = \texttt{sd}\sqrt{2/n}$, so the corresponding unit standard deviation is $\texttt{usd} = \texttt{sd}\sqrt{2}$. See the vignette for more information.

Value

The required sample size to achieve the specified power

Author(s)

Samuel Pawel

See Also

nmbf01, pnmbf01, powernmbf01

Examples

```
nnmbf01(k = 1/10, power = 0.9, usd = 1, null = 0, psd = 0.5/sqrt(2), dpm = 0.5, dpsd = 0)
```

---

ntbf01 *Sample size calculations for t-test Bayes factor*

Description

This function computes the required sample size to obtain a t-test Bayes factor (tbf01) more extreme than a threshold k with a specified target power.

Usage

```
ntbf01(
  k,
  power,
  null = 0,
  plocation = 0,
  pscale = 1/sqrt(2),
  pdf = 1,
  type = c("two.sample", "one.sample", "paired"),
  alternative = c("two.sided", "less", "greater"),
  dpm = plocation,
  dpsd = pscale,
  lower.tail = TRUE,
  integer = TRUE,
  nrange = c(2, 10^4),
  ...
)
```

Arguments

`k`	Bayes factor threshold
`power`	Target power
`null`	Standardized mean difference under the point null hypothesis. Defaults to `0`
`plocation`	t prior location. Defaults to `0`
`pscale`	t prior scale. Defaults to `1/sqrt(2)`
`pdf`	t prior degrees of freedom. Defaults to `1` (a Cauchy prior)
`type`	Type of t-test. Can be `"two.sample"` (default), `"one.sample"`, or `"paired"`
`alternative`	Direction of the test. Can be either `"two.sided"` (default), `"less"`, or `"greater"`. The latter two truncate the analysis prior to negative and positive effects, respectively. If set to `"less"` or `"greater"`, the power is only computed based on data with effect estimates in the direction of the alternative
`dpm`	Mean of the normal design prior assigned to the standardized mean difference. Defaults to the analysis prior location
`dpsd`	Standard deviation of the normal design prior assigned to the standardized mean difference. Set to `0` to obtain a point prior at the design prior mean. Defaults to the analysis prior scale
`lower.tail`	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq$ `k`$)$ (`TRUE`) or $\Pr(\mathrm{BF}_{01} >$ `k`$)$ (`FALSE`) should be computed. Defaults to `TRUE`
`integer`	Logical indicating whether only integer valued sample sizes should be returned. If `TRUE` the required sample size is rounded to the next larger integer. Defaults to `TRUE`
`nrange`	Sample size search range over which numerical search is performed. Defaults to `c(2, 10^4)`
`...`	Other arguments passed to `stats::uniroot`

Value

The required sample size to achieve the specified power

Author(s)

Samuel Pawel

See Also

ptbf01, powertbf01, tbf01

Examples

```
## example from Schönbrodt and Wagenmakers (2018, p.135)
ntbf01(k = 1/6, power = 0.95, dpm = 0.5, dpsd = 0, alternative = "greater")
ntbf01(k = 1/6, power = 0.95, dpm = 0.5, dpsd = 0.1, alternative = "greater")
ntbf01(k = 6, power = 0.95, dpm = 0, dpsd = 0, alternative = "greater",
       lower.tail = FALSE, nrange = c(2, 10000))
```

pbf01 — *Cumulative distribution function of the z-test Bayes factor*

Description

This function computes the probability of obtaining a Bayes factor (bf01) more extreme than a threshold `k` with a specified sample size.

Usage

```
pbf01(k, n, usd, null = 0, pm, psd, dpm = pm, dpsd = psd, lower.tail = TRUE)
```

Arguments

`k`	Bayes factor threshold
`n`	Sample size
`usd`	Unit standard deviation, the (approximate) standard error of the parameter estimate based on $\texttt{n} = 1$, see details
`null`	Parameter value under the point null hypothesis. Defaults to `0`
`pm`	Mean of the normal prior assigned to the parameter under the alternative in the analysis
`psd`	Standard deviation of the normal prior assigned to the parameter under the alternative in the analysis. Set to `0` to obtain a point prior at the prior mean
`dpm`	Mean of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior `pm`
`dpsd`	Standard deviation of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior `psd`
`lower.tail`	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \texttt{k})$ (`TRUE`) or $\Pr(\mathrm{BF}_{01} > \texttt{k})$ (`FALSE`) should be computed. Defaults to `TRUE`

Details

It is assumed that the standard error of the future parameter estimate is of the form $\texttt{se} = \texttt{usd}/\sqrt{\texttt{n}}$. For example, for normally distributed data with known standard deviation `sd` and two equally sized groups of size `n`, the standard error of an estimated standardized mean difference is $\texttt{se} = \texttt{sd}\sqrt{2/n}$, so the corresponding unit standard deviation is $\texttt{usd} = \texttt{sd}\sqrt{2}$. See the vignette for more information.

Value

The probability that the Bayes factor is less or greater (depending on the specified `lower.tail`) than the specified threshold `k`

Author(s)

Samuel Pawel

See Also

nbf01, powerbf01, bf01

Examples

```
## point alternative (psd = 0)
pbf01(k = 1/10, n = 200, usd = 2, null = 0, pm = 0.5, psd = 0)

## normal alternative (psd > 0)
pbf01(k = 1/10, n = 100, usd = 2, null = 0, pm = 0.5, psd = 2)

## design prior is the null hypothesis (dpm = 0, dpsd = 0)
pbf01(k = 10, n = 1000, usd = 2, null = 0, pm = 0.3, psd = 2, dpm = 0, dpsd = 0, lower.tail = FALSE)

## draw a power curve
nseq <- round(exp(seq(log(10), log(10000), length.out = 100)))
plot(nseq, pbf01(k = 1/10, n = nseq, usd = 2, null = 0, pm = 0.3, psd = 0), type = "l",
     xlab = "n", ylab = bquote("Pr(BF"["01"] <= 1/10 * ")"), ylim = c(0, 1),
     log = "x", las = 1)

## standardized mean difference (usd = sqrt(2), effective sample size = per group size)
n <- 30
pbf01(k = 1/10, n = n, usd = sqrt(2), null = 0, pm = 0, psd = 1)

## z-transformed correlation (usd = 1, effective sample size = n - 3)
n <- 100
pbf01(k = 1/10, n = n - 3, usd = 1, null = 0, pm = 0.2, psd = 0.5)

## log hazard/odds ratio (usd = 2, effective sample size = total number of events)
nevents <- 100
pbf01(k = 1/10, n = nevents, usd = 2, null = 0, pm = 0, psd = sqrt(0.5))
```

---

pbinbf01 — *Cumulative distribution function of the binomial Bayes factor*

Description

This function computes the probability of obtaining a binomial Bayes factor (binbf01) more extreme than a threshold k with a specified sample size.

Usage

```
pbinbf01(
  k,
  n,
  p0 = 0.5,
  type = c("point", "direction"),
  a = 1,
```

```
  b = 1,
  dp = NA,
  da = a,
  db = b,
  dl = 0,
  du = 1,
  lower.tail = TRUE
)
```

Arguments

k	Bayes factor threshold
n	Number of trials
p0	Tested binomial proportion. Defaults to `0.5`
type	Type of test. Can be `"point"` or `"directional"`. Defaults to `"point"`
a	Number of successes parameter of the beta analysis prior distribution. Defaults to `1`
b	Number of failures parameter of the beta analysis prior distribution. Defaults to `1`
dp	Fixed binomial proportion assumed for the power calculation. Set to `NA` to use a truncated beta design prior instead (specified via the `da`, `db`, `dl`, and `du` arguments). Defaults to `NA`
da	Number of successes parameter of the truncated beta design prior distribution. Is only taken into account if `dp = NA`. Defaults to the same value `a` as specified for the analysis prior
db	Number of failures parameter of the truncated beta design prior distribution. Is only taken into account if `dp = NA`. Defaults to the same value `b` as specified for the analysis prior
dl	Lower truncation limit of of the truncated beta design prior distribution. Is only taken into account if `dp = NA`. Defaults to `0`
du	Upper truncation limit of of the truncated beta design prior distribution. Is only taken into account if `dp = NA`. Defaults to `1`
lower.tail	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathsf{k})$ (`TRUE`) or $\Pr(\mathrm{BF}_{01} > \mathsf{k})$ (`FALSE`) should be computed. Defaults to `TRUE`

Value

The probability that the Bayes factor is less or greater (depending on the specified `lower.tail`) than the specified threshold `k`

Author(s)

Samuel Pawel

See Also

binbf01, nbinbf01

Examples

```
## compute probability that BF > 10 under the point null
pbinbf01(k = 10, n = 925, p0 = 3/4, type = "point", a = 1, b = 1,
         dp = 3/4, lower.tail = FALSE)

## power curve (weird looking oscillations patterns due to discrete data)
nseq <- seq(100, 500, 1)
pow <- pbinbf01(k = 10, n = nseq, p0 = 3/4, type = "point", a = 1, b = 1,
                dp = 3/4, lower.tail = FALSE)
plot(nseq, pow, type = "s", xlab = "n", ylab = "Power")

## probability that directional BF <= 1/10 under uniform [3/4, 1] design prior
pbinbf01(k = 1/10, n = 925, p0 = 3/4, type = "direction", a = 1, b = 1,
         da = 1, db = 1, dl = 3/4, du = 1)

## power curve
nseq <- seq(15, 200, 1)
pow <- pbinbf01(k = 1/10, n = nseq, p0 = 3/4, type = "direction", a = 1, b = 1,
                da = 1, db = 1, dl = 3/4, du = 1)
plot(nseq, pow, type = "s", xlab = "n", ylab = "Power")
```

`plot.power.bftest` *Plot method for class* `"power.bftest"`

Description

Plot method for class `"power.bftest"`

Usage

```
## S3 method for class 'power.bftest'
plot(x, nlim = c(2, 500), ngrid = 100, plot = TRUE, nullplot = TRUE, ...)
```

Arguments

`x`	Object of class `"power.bftest"`
`nlim`	Range of sample sizes over which the power should be computed. Defaults to `c(2, 500)`
`ngrid`	Number of grid point for which power should be computed. Defaults to 100
`plot`	Logical indicating whether data should be plotted. If `FALSE` only the data used for plotting are returned.
`nullplot`	Logcal indicating whether a second plot with the power in favor of the null (using a Bayes factor threshold of 1/k) should be created. Defaults to `TRUE`
`...`	Other arguments (for consistency with the generic)

Value

Plots power curves (if specified) and invisibly returns a list of data frames containing the data underlying the power curves

Author(s)

Samuel Pawel

See Also

powerbf01, powertbf01, powernmbf01

Examples

```
ssd1 <- powerbf01(k = 1/6, power = 0.95, pm = 0, psd = 1/sqrt(2), dpm = 0.5, dpsd = 0)
plot(ssd1, nlim = c(1, 8000))

power1 <- powerbf01(k = 1/2, n = 120, pm = 0, psd = 1/sqrt(2), dpm = 0.5, dpsd = 0)
plot(power1, nlim = c(1, 1000))
```

---

pnmbf01 — *Cumulative distribution function of the normal moment prior Bayes factor*

Description

This function computes the probability of obtaining a normal moment prior Bayes factor (nmbf01) more extreme than a threshold k with a specified sample size.

Usage

```
pnmbf01(k, n, usd, null = 0, psd, dpm, dpsd, lower.tail = TRUE)
```

Arguments

k	Bayes factor threshold
n	Sample size
usd	Unit standard deviation, the (approximate) standard error of the parameter estimate based on $n = 1$, see details
null	Parameter value under the point null hypothesis. Defaults to 0
psd	Spread of the normal moment prior assigned to the parameter under the alternative in the analysis. The modes of the prior are located at $\pm\sqrt{2}\,\mathsf{psd}$
dpm	Mean of the normal design prior assigned to the parameter
dpsd	Standard deviation of the normal design prior assigned to the parameter. Set to 0 to obtain a point prior at the design prior mean
lower.tail	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathsf{k})$ (TRUE) or $\Pr(\mathrm{BF}_{01} > \mathsf{k})$ (FALSE) should be computed. Defaults to TRUE

Details

It is assumed that the standard error of the future parameter estimate is of the form se $=$ usd$/\sqrt{\text{n}}$. For example, for normally distributed data with known standard deviation sd and two equally sized groups of size n, the standard error of an estimated standardized mean difference is se $=$ sd$\sqrt{2/n}$, so the corresponding unit standard deviation is usd $=$ sd$\sqrt{2}$. See the vignette for more information.

Value

The probability that the Bayes factor is less or greater (depending on the specified `lower.tail`) than the specified threshold k

Author(s)

Samuel Pawel

See Also

nmbf01, nnmbf01, powernmbf01

Examples

```
## point desing prior (psd = 0)
pnmbf01(k = 1/10, n = 200, usd = 2, null = 0, psd = 0.5/sqrt(2), dpm = 0.5, dpsd = 0)

## normal design prior to incorporate parameter uncertainty (psd > 0)
pnmbf01(k = 1/10, n = 200, usd = 2, null = 0, psd = 0.5/sqrt(2), dpm = 0.5, dpsd = 0.25)

## design prior is the null hypothesis (dpm = 0, dpsd = 0)
pnmbf01(k = 10, n = 200, usd = 2, null = 0, psd = 0.5/sqrt(2), dpm = 0, dpsd = 0,
        lower.tail = FALSE)
```

`powerbf01` *Power and sample size calculations for z-test Bayes factor*

Description

Compute probability that z-test Bayes factor is smaller than a specified threshold (the power), or determine sample size to obtain a target power.

Usage

```
powerbf01(
  n = NULL,
  power = NULL,
  k = 1/10,
  sd = 1,
  null = 0,
```

```
  pm,
  psd,
  type = c("two.sample", "one.sample", "paired"),
  dpm = pm,
  dpsd = psd,
  nrange = c(1, 10^5)
)
```

Arguments

`n`	Sample size (per group for two-sample tests). Has to be `NULL` if `power` is specified. Defaults to `NULL`
`power`	Target power. Has to be `NULL` if `n` is specified. Defaults to `NULL`
`k`	Bayes factor threshold. Defaults to `1/10`, Jeffreys' threshold for 'strong evidence' against the null hypothesis
`sd`	Standard deviation of one observation (for `type = "two.sample"` or `type = "one.sample"`) or of one difference within a pair of observations (`type = "paired"`). Is assumed to be known. Defaults to `1`
`null`	Mean difference under the point null hypothesis. Defaults to `0`
`pm`	Mean of the normal prior assigned to the mean difference under the alternative in the analysis
`psd`	Standard deviation of the normal prior assigned to the mean difference under the alternative in the analysis. Set to `0` to obtain a point prior at the prior mean
`type`	The type of test. One of `"two.sample"`, `"one.sample"`, `"paired"`. Defaults to `"two.sample"`
`dpm`	Mean of the normal design prior assigned to the mean difference. Defaults to the same value as the analysis prior `pm`
`dpsd`	Standard deviation of the normal design prior assigned to the mean difference. Defaults to the same value as the analysis prior `psd`
`nrange`	Sample size search range over which numerical search is performed (only taken into account when `n` is `NULL`). Defaults to `c(1, 10^5)`

Details

This function provides a similar interface as `stats::power.t.test`. It also assumes that the data are continuous and that the parameter of interest is either a mean or a (standardized) mean difference. For some users, the low-level functions nbf01 (to directly compute the sample size for a fixed power) and pbf01 (to directly compute the power for a fixed sample size) may also be useful because they can be used for other data and parameter types.

Value

Object of class `"power.bftest"`, a list of the arguments (including the computed one) augmented with `method` and `note` elements

Note

A warning message will be displayed in case that the specified target power is not achievable under the specified analysis and design priors.

Author(s)

Samuel Pawel

See Also

plot.power.bftest, nbf01, pbf01, bf01

Examples

```
## determine power
powerbf01(n = 100, pm = 0, psd = 1, dpm = 0.5, dpsd = 0)

## determine sample size
powerbf01(power = 0.99, pm = 0, psd = 1, dpm = 0.5, dpsd = 0)
```

`powernmbf01` *Power and sample size calculations for normal moment prior Bayes factor*

Description

Compute probability that normal moment prior Bayes factor is smaller than a specified threshold (the power), or determine sample size to obtain a target power.

Usage

```
powernmbf01(
  n = NULL,
  power = NULL,
  k = 1/10,
  sd = 1,
  null = 0,
  psd,
  type = c("two.sample", "one.sample", "paired"),
  dpm,
  dpsd,
  nrange = c(1, 10^5)
)
```

Arguments

`n`	Sample size (per group for two-sample tests). Has to be `NULL` if `power` is specified. Defaults to `NULL`
`power`	Target power. Has to be `NULL` if `n` is specified. Defaults to `NULL`
`k`	Bayes factor threshold. Defaults to `1/10`, Jeffreys' threshold for 'strong evidence' against the null hypothesis
`sd`	Standard deviation of one observation (for `type = "two.sample"` or `type = "one.sample"`) or of one difference within a pair of observations (`type = "paired"`). Is assumed to be known. Defaults to `1`
`null`	Parameter value under the point null hypothesis. Defaults to `0`
`psd`	Spread of the normal moment prior assigned to the parameter under the alternative in the analysis. The modes of the prior are located at $\pm\sqrt{2}$ `psd`
`type`	The type of test. One of `"two.sample"`, `"one.sample"`, `"paired"`. Defaults to `"two.sample"`
`dpm`	Mean of the normal design prior assigned to the parameter
`dpsd`	Standard deviation of the normal design prior assigned to the parameter. Set to 0 to obtain a point prior at the design prior mean
`nrange`	Sample size search range over which numerical search is performed (only taken into account when `n` is `NULL`). Defaults to `c(1, 10^5)`

Details

This function provides a similar interface as `stats::power.t.test`. It also assumes that the data are continuous and that the parameter of interest is either a mean or a (standardized) mean difference. For some users, the low-level functions nnmbf01 (to directly compute the sample size for a fixed power) and pnmbf01 (to directly compute the power for a fixed sample size) may also be useful because they can be used for other data and parameter types.

Value

Object of class `"power.bftest"`, a list of the arguments (including the computed one) augmented with `method` and `note` elements

Author(s)

Samuel Pawel

See Also

plot.power.bftest, nnmbf01, pnmbf01, nmbf01

Examples

```
## determine power
powernmbf01(n = 100, psd = 1, dpm = 0.5, dpsd = 0)

## determine sample size
```

```
powernmbf01(power = 0.99, psd = 1, dpm = 0.5, dpsd = 0)
```

---

powertbf01 *Power and sample size calculations for t-test Bayes factor*

Description

Compute probability that t-test Bayes factor is smaller than a specified threshold (the power), or determine sample size to obtain a target power.

Usage

```
powertbf01(
  n = NULL,
  power = NULL,
  k = 1/10,
  null = 0,
  plocation = 0,
  pscale = 1/sqrt(2),
  pdf = 1,
  type = c("two.sample", "one.sample", "paired"),
  alternative = c("two.sided", "less", "greater"),
  dpm = plocation,
  dpsd = pscale,
  nrange = c(2, 10^4)
)
```

Arguments

`n`	Sample size (per group)
`power`	Target power. Has to be `NULL` if `n` is specified. Defaults to `NULL`
`k`	Bayes factor threshold. Defaults to `1/10`, Jeffreys' threshold for 'strong evidence' against the null hypothesis
`null`	Standardized mean difference under the point null hypothesis. Defaults to `0`
`plocation`	t prior location. Defaults to `0`
`pscale`	t prior scale. Defaults to `1/sqrt(2)`
`pdf`	t prior degrees of freedom. Defaults to `1` (a Cauchy prior)
`type`	Type of t-test. Can be `"two.sample"` (default), `"one.sample"`, or `"paired"`
`alternative`	Direction of the test. Can be either `"two.sided"` (default), `"less"`, or `"greater"`. The latter two truncate the analysis prior to negative and positive effects, respectively. If set to `"less"` or `"greater"`, the power is only computed based on data with effect estimates in the direction of the alternative
`dpm`	Mean of the normal design prior assigned to the standardized mean difference. Defaults to the analysis prior location

`dpsd`	Standard deviation of the normal design prior assigned to the standardized mean difference. Set to `0` to obtain a point prior at the design prior mean. Defaults to the analysis prior scale
`nrange`	Sample size search range over which numerical search is performed (only taken into account when `n` is `NULL`). Defaults to `c(2, 10^4)`

Details

This function provides a similar interface as `stats::power.t.test`. For some users, the low-level functions ntbf01 (to directly compute the sample size for a fixed power) and ptbf01 (to directly compute the power for a fixed sample size) may also be useful.

Value

Object of class `"power.bftest"`, a list of the arguments (including the computed one) augmented with `method` and `note` elements

Author(s)

Samuel Pawel

See Also

plot.power.bftest, ptbf01, ntbf01, tbf01

Examples

```
## determine power
powertbf01(n = 146, k = 1/6, dpm = 0.5, dps = 0, alternative = "greater")

## determine sample size
powertbf01(power = 0.95, k = 1/6, dpm = 0.5, dps = 0, alternative = "greater")
```

`print.power.bftest` *Print method for class* `"power.bftest"`

Description

Print method for class `"power.bftest"`

Usage

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

Arguments

`x`	Object of class `"power.bftest"`
`digits`	Number of digits for formatting of numbers
`...`	Other arguments (for consistency with the generic)

Value

Prints text summary in the console and invisibly returns the `"power.bftest"` object

Note

Function adapted from `stats:::print.power.htest` written by Peter Dalgaard

Author(s)

Samuel Pawel

See Also

powerbf01

Examples

```
powerbf01(power = 0.95, pm = 0, psd = 1, dpm = 0.5, dpsd = 0)
powerbf01(power = 0.95, pm = 0, psd = 1, dpm = 0.5, dpsd = 0, type = "one.sample")
powerbf01(power = 0.95, pm = 0, psd = 1, dpm = 0.5, dpsd = 0, type = "paired")
powerbf01(power = 0.95, pm = 1, psd = 0, dpm = 0.8, dpsd = 0, type = "paired")
```

`ptbf01` *Cumulative distribution function of the t-test Bayes factor*

Description

This function computes the probability of obtaining a t-test Bayes factor (tbf01) more extreme than a threshold `k` with a specified sample size.

Usage

```
ptbf01(
  k,
  n,
  n1 = n,
  n2 = n,
  null = 0,
  plocation = 0,
  pscale = 1/sqrt(2),
```

```
  pdf = 1,
  dpm = plocation,
  dpsd = pscale,
  type = c("two.sample", "one.sample", "paired"),
  alternative = c("two.sided", "less", "greater"),
  lower.tail = TRUE,
  drange = "adaptive",
  ...
)
```

Arguments

`k`	Bayes factor threshold
`n`	Sample size (per group)
`n1`	Sample size in group 1 (only required for two-sample t-test with unequal group sizes)
`n2`	Sample size in group 2 (only required for two-sample t-test with unequal group sizes)
`null`	Standardized mean difference under the point null hypothesis. Defaults to `0`
`plocation`	t prior location. Defaults to `0`
`pscale`	t prior scale. Defaults to `1/sqrt(2)`
`pdf`	t prior degrees of freedom. Defaults to `1` (a Cauchy prior)
`dpm`	Mean of the normal design prior assigned to the standardized mean difference. Defaults to the analysis prior location
`dpsd`	Standard deviation of the normal design prior assigned to the standardized mean difference. Set to `0` to obtain a point prior at the design prior mean. Defaults to the analysis prior scale
`type`	Type of t-test. Can be `"two.sample"` (default), `"one.sample"`, or `"paired"`
`alternative`	Direction of the test. Can be either `"two.sided"` (default), `"less"`, or `"greater"`. The latter two truncate the analysis prior to negative and positive effects, respectively. If set to `"less"` or `"greater"`, the power is only computed based on data with effect estimates in the direction of the alternative
`lower.tail`	Logical indicating whether $\Pr(\mathrm{BF}_{01} \leq \mathtt{k})$ (`TRUE`) or $\Pr(\mathrm{BF}_{01} > \mathtt{k})$ (`FALSE`) should be computed. Defaults to `TRUE`
`drange`	Standardized mean difference search range over which the critical values are searched for. Can be either set to a numerical range or to `"adaptive"` (default) which determines the range in an adaptive way from the other input parameters
`...`	Other arguments passed to `stats::uniroot`

Value

The probability that the Bayes factor is less or greater (depending on the specified `lower.tail`) than the specified threshold `k`

Author(s)

Samuel Pawel

See Also

tbf01, ntbf01, powertbf01

Examples

```
## example from Schönbrodt and Wagenmakers (2018, p. 135)
ptbf01(k = 1/6, n = 146, dpm = 0.5, dpsd = 0, alternative = "greater")
ptbf01(k = 6, n = 146, dpm = 0, dpsd = 0, alternative = "greater",
       lower.tail = FALSE)

## two-sided
ptbf01(k = 1/6, n = 146, dpm = 0.5, dpsd = 0)
ptbf01(k = 6, n = 146, dpm = 0, dpsd = 0, lower.tail = FALSE)

## one-sample test
ptbf01(k = 1/6, n = 146, dpm = 0.5, dpsd = 0, alternative = "greater", type = "one.sample")
```

---

tbf01 *t-test Bayes factor*

Description

This function computes the Bayes factor that forms the basis of the informed Bayesian t-test from Gronau et al. (2020). The Bayes factor quantifies the evidence that the data provide for the null hypothesis that the standardized mean difference (SMD) is zero against the alternative that the SMD is non-zero. A location-scale t-distribution is assumed for the SMD under the alternative hypothesis. The Jeffreys-Zellner-Siow (JZS) Bayes factor (Rouder et al., 2009) is obtained as a special case by setting the location of the prior to zero and the prior degrees of freedom to one, which is the default.

The data are summarized by t-statistics and sample sizes. The following types of t-statistics are accepted:

- Two-sample t-test where the SMD represents the standardized mean difference between two group means (assuming equal variances in both groups)
- One-sample t-test where the SMD represents the standardized mean difference to the null value
- Paired t-test where the SMD represents the standardized mean change score

Usage

```
tbf01(
  t,
  n,
  n1 = n,
  n2 = n,
  plocation = 0,
  pscale = 1/sqrt(2),
  pdf = 1,
  type = c("two.sample", "one.sample", "paired"),
  alternative = c("two.sided", "less", "greater"),
  log = FALSE,
  ...
)
```

Arguments

`t`	t-statistic
`n`	Sample size (per group)
`n1`	Sample size in group 1 (only required for two-sample t-test with unequal group sizes)
`n2`	Sample size in group 2 (only required for two-sample t-test with unequal group sizes)
`plocation`	t prior location. Defaults to `0`
`pscale`	t prior scale. Defaults to `1/sqrt(2)`
`pdf`	t prior degrees of freedom. Defaults to `1` (a Cauchy prior)
`type`	Type of t-test. Can be `"two.sample"` (default), `"one.sample"`, or `"paired"`
`alternative`	Direction of the test. Can be either `"two.sided"` (default), `"less"`, or `"greater"`. The latter two truncate the analysis prior to negative and positive effects, respectively.
`log`	Logical indicating whether the natural logarithm of the Bayes factor should be returned. Defaults to `FALSE`
`...`	Additional arguments passed to `stats::integrate`

Details

The Bayes factor is implemented as in equation (5) in Gronau et al. (2020), and using suitable truncation in case of one-sided alternatives. Integration is performed numerically with `stats::integrate`.

Value

Bayes factor in favor of the null hypothesis over the alternative ($\mathrm{BF}_{01} > 1$ indicates evidence for the null hypothesis, whereas $\mathrm{BF}_{01} < 1$ indicates evidence for the alternative)

Author(s)

Samuel Pawel

References

Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., Iverson, G. (2009). Bayesian t tests for accepting and rejecting the null hypothesis. Psychonomic Bulletin & Review, 16(2):225-237. doi:10.3758/PBR.16.2.225

Gronau, Q. F., Ly., A., Wagenmakers, E.J. (2020). Informed Bayesian t-Tests. The American Statistician, 74(2):137-143. doi:10.1080/00031305.2018.1562983

See Also

powertbf01, ptbf01, ntbf01

Examples

```
## analyses from Rouder et al. (2009):
## values from Table 1
tbf01(t = c(0.69, 3.20), n = 100, pscale = 1, type = "one.sample")
## examples from p. 232
tbf01(t = c(2.24, 2.03), n = 80, pscale = 1, type = "one.sample")

## analyses from Gronau et al. (2020) section 3.2:
## informed prior
tbf01(t = -0.90, n1 = 53, n2 = 57, plocation = 0.350, pscale = 0.102, pdf = 3,
      alternative = "greater", type = "two.sample")
## default (one-sided) prior
tbf01(t = -0.90, n1 = 53, n2 = 57, plocation = 0, pscale = 1/sqrt(2), pdf = 1,
      alternative = "greater", type = "two.sample")
```

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