

Package ‘bfpwr’

June 13, 2024

Version 0.1

Date 2024-06-13

Author Samuel Pawel [aut, cre] (<<https://orcid.org/0000-0003-2779-320X>>)

Maintainer Samuel Pawel <samuel.pawel@uzh.ch>

Title Power and Sample Size Calculations for Bayes Factor Analysis

Description Provides functionality for performing power and sample size calculations for Bayes factor analysis.

License GPL-3

Encoding UTF-8

Suggests roxygen2, tinytest

NeedsCompilation no

RoxygenNote 7.3.1

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

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

Contents

bf01	2
nbf01	3
ntbf01	4
pbf01	6
plot.power.bftest	7
powerbf01	8
powertbf01	10
print.power.bftest	11
ptbf01	12
tb01	14

Index	17
--------------	-----------

bf01*Bayes factor under normality*

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.

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 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 > 1 indicates evidence for the null hypothesis, whereas BF < 1 indicates evidence for the alternative)

Author(s)

Samuel Pawel

Examples

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

Description

This function computes the required sample size to obtain a Bayes factor ([bf01](#)) less or greater than a threshold k with a specified target power.

Usage

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

Arguments

<code>k</code>	Bayes factor threshold
<code>power</code>	Target power
<code>sd</code>	Standard deviation of one unit
<code>null</code>	Parameter value under the point null hypothesis. Defaults to 0
<code>pm</code>	Mean of the normal prior assigned to the parameter under the alternative in the analysis
<code>psd</code>	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
<code>dpm</code>	Mean of the normal design prior assigned to the parameter. Defaults to the same value as specified for the analysis prior <code>pm</code>
<code>dpsd</code>	Standard deviation of the normal design prior assigned to the parameter. Set to 0 to obtain a point prior at the prior mean. Defaults to the same value as specified for the analysis prior <code>psd</code>
<code>nrange</code>	Sample size search range over which numerical search is performed. Defaults to <code>c(1, 10^5)</code>
<code>lower.tail</code>	Logical indicating whether $\Pr(\text{BF} \leq k)$ (TRUE) or $\Pr(\text{BF} > k)$ (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 <code>stats::uniroot</code>

Value

The required sample size to achieve the specified power

Author(s)

Samuel Pawel

See Also

[pbf01](#), [powerbfb01](#)

Examples

```
## point alternative (analytical and numerical solution available)
ntbf01(k = 1/10, power = 0.9, sd = 1, null = 0, pm = 0.5, psd = 0,
      analytical = c(TRUE, FALSE), integer = FALSE)
```

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](#)) less or greater than a threshold *k* with a specified target power.

Usage

```
ntbf01(
  k = 1/10,
  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. Defaults to 1/10, Jeffreys' threshold for 'strong evidence' against the null hypothesis
power	Target power
null	Standardized mean difference under the point null hypothesis. Defaults to 0
plocation	Analysis t prior location. Defaults to 0
pscale	Analysis t prior scale. Defaults to 1/sqrt(2)
pdf	Analysis t prior degrees of freedom. Defaults to 1 (a Cauchy prior)
type	The type of test. One of "two.sample", "one.sample", "paired". Defaults to "two.sample"
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
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 $\Pr(\text{BF} \leq k)$ (TRUE) or $\Pr(\text{BF} > k)$ (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

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

Note

An error 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](#), [ptbf01](#), [powertbf01](#)

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 = 0.5, dpsd = 0, alternative = "greater",
       lower.tail = FALSE, nrange = c(2, 10000))
```

pbf01

Cumulative distribution function of the Bayes factor under normality

Description

This function computes the probability of obtaining a Bayes factor ([bf01](#)) smaller (or larger) than a threshold k with a specified sample size.

Usage

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

Arguments

<code>k</code>	Bayes factor threshold
<code>n</code>	Sample size
<code>sd</code>	Standard deviation of one unit
<code>null</code>	Parameter value under the point null hypothesis. Defaults to 0
<code>pm</code>	Mean of the normal prior assigned to the parameter under the alternative in the analysis
<code>psd</code>	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
<code>dpm</code>	Mean of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior <code>pm</code>
<code>dpsd</code>	Standard deviation of the normal design prior assigned to the parameter. Defaults to the same value as the analysis prior <code>psd</code>
<code>lower.tail</code>	Logical indicating whether $\Pr(\text{BF} \leq k)$ (TRUE) or $\Pr(\text{BF} > k)$ (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[nbf01](#), [powerbftest](#)**Examples**

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

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

## design prior is the null hypothesis (dpm = 0, dpsd = 0)
pbf01(k = 10, n = 1000, sd = 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, sd = 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)
```

plot.power.bftest	<i>Plot method for class "power.bftest"</i>
-------------------	---

Description

Plot method for class "power.bftest"

Usage

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

Arguments

x	Object of class "power.bftest"
nlim	Range of samples sizes over which the power should be computed. Defaults to c(2, 500)
plot	Logical indicating whether data should be plotted. If FALSE only the data used for plotting are returned.
nullplot	Logical 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](#)

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))
```

powerbf01

Power and sample size calculations for Bayes factor under normality

Description

Compute probability that Bayes factor under normality 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. 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)

Value

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

Note

An error 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](#)

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)
```

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(
  k = 1/10,
  n = NULL,
  power = NULL,
  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

k	Bayes factor threshold. Defaults to 1/10, Jeffreys' threshold for 'strong evidence' against the null hypothesis
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
null	Standardized mean difference under the point null hypothesis. Defaults to 0
plocation	Analysis <i>t</i> prior location. Defaults to 0
pscale	Analysis <i>t</i> prior scale. Defaults to 1/sqrt(2)
pdf	Analysis <i>t</i> prior degrees of freedom. Defaults to 1 (a Cauchy prior)
type	The type of test. One of "two.sample", "one.sample", "paired". Defaults to "two.sample"
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
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)

Value

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

Note

An error 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.bfctest](#), [ptbf01](#)

Examples

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

## determine sample size
plot(powertbf01(k = 1/6, power = 0.95, dpm = 0.5, dps = 0, alternative = "greater"),
     nlim = c(5, 300))

## TODO implement possibility to power for null?
```

```
print.power.bfctest      Print method for class "power.bfctest"
```

Description

Print method for class "power.bfctest"

Usage

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

Arguments

<code>x</code>	Object of class "power.bftest"
<code>digits</code>	Number of digits for formatting of numbers
<code>...</code>	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](#)) smaller (or larger) than a threshold *k* with a specified sample size.

Usage

```
ptbf01(
  k = 1/10,
  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,
...
)

```

Arguments

k	Bayes factor threshold. Defaults to 1/10, Jeffreys' threshold for 'strong evidence' against the null hypothesis
n	Sample size (per group)
n1	Sample size in group 1 (only required for two-sample <i>t</i> -test with unequal group sizes)
n2	Sample size in group 2 (only required for two-sample <i>t</i> -test with unequal group sizes)
null	Standardized mean difference under the point null hypothesis. Defaults to 0
plocation	Analysis <i>t</i> prior location. Defaults to 0
pscale	Analysis <i>t</i> prior scale. Defaults to 1/sqrt(2)
pdf	Analysis <i>t</i> prior degrees of freedom. Defaults to 1
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	The type of test. One of "two.sample", "one.sample", "paired". Defaults to "two.sample"
alternative	Direction of the test. Can be either "two.sided" (default), "less", or "greater"
lower.tail	Logical indicating whether $\Pr(\text{BF} \leq k)$ (TRUE) or $\Pr(\text{BF} > k)$ (FALSE) should be computed. Defaults to TRUE
...	Other arguments passed to <code>stats::uniroot</code>

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](#)

Examples

```
## example from Schönbrodt and Wagenmakers (2018, p. 135)
ptbfb01(k = 1/6, n = 146, dpm = 0.5, dps = 0, alternative = "greater")
ptbfb01(k = 6, n = 146, dpm = 0, dpsd = 0, alternative = "greater",
        lower.tail = FALSE)

## two-sided
ptbfb01(k = 1/6, n = 146, dpm = 0.5, dpsd = 0)
ptbfb01(k = 60, n = 150, dpm = 0.5, dpsd = 0.1, lower.tail = TRUE)

## one-sample test
ptbfb01(k = 1/6, n = 5000, dpm = -0.25, dpsd = 0, alternative = "less", type = "one.sample")
```

tbfb01

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 *t*-distribution is assumed for the SMD under the alternative. 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

```
tbfb01(
  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

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

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 ($BF > 1$ indicates evidence for the null hypothesis, whereas $BF < 1$ indicates evidence for the alternative)

Author(s)

Samuel Pawel

References

- Rouder, J. N., Speckman, P. L., Sun, D., Morey, R. D., Iverson, G. (2014). Bayesian *t* tests for accepting and rejecting the null hypothesis. *Psychonomic Bulletin & Review*, 16(2):225-237. [doi:10.3758/PBR.16.2.225](https://doi.org/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](https://doi.org/10.1080/00031305.2018.1562983)

Examples

```
## analyses from Rouder et al. (2009):
## values from Table 1
tbft01(t = c(0.69, 3.20), n = 100, pscale = 1, type = "one.sample")
## examples from p. 232
tbft01(t = c(2.24, 2.03), n = 80, pscale = 1, type = "one.sample")
```

```
## analyses from Gronau et al. (2020) section 3.2:  
## informed prior  
tbft01(t = -0.90, n1 = 53, n2 = 57, plocation = 0.350, pscale = 0.102, pdf = 3,  
       alternative = "greater", type = "two.sample")  
## default (one-sided) prior  
tbft01(t = -0.90, n1 = 53, n2 = 57, plocation = 0, pscale = 1/sqrt(2), pdf = 1,  
       alternative = "greater", type = "two.sample")
```


Index

bf01, [2](#), [3](#), [6](#)

nbf01, [3](#), [7](#), [9](#)

ntbf01, [4](#)

pbf01, [4](#), [6](#), [9](#)

plot.power.bftest, [6](#), [7](#), [9](#), [11](#)

powerbf01, [4](#), [7](#), [8](#), [8](#), [12](#)

powertbf01, [6](#), [10](#)

print.power.bftest, [11](#)

ptbf01, [6](#), [11](#), [12](#)

tbf01, [4](#), [12](#), [13](#), [14](#)