Package ‘BFpack’

May 11, 2020

Type Package

Title Flexible Bayes Factor Testing of Scientific Expectations

Version 0.2.1

Date 2020-05-11

Maintainer Joris Mulder <j.mulder3@tilburguniversity.edu>

Description Implementation of various default Bayes factors for testing statistical hypotheses. The package is intended for applied quantitative researchers in the social and behavioral sciences, medical research, and related fields. The Bayes factor tests can be executed for statistical models such as univariate and multivariate normal linear models, generalized linear models, special cases of linear mixed models, survival models, relational event models. Parameters that can be tested are location parameters (e.g., regression coefficients), variances (e.g., group variances), and measures of association (e.g,. bivariate correlations). The statistical underpinnings are described in
Mulder, Hoijtink, and Xin (2019) <arXiv:1904.00679>,
Mulder and Gelissen (2019) <arXiv:1807.05819>,
Mulder (2016) <DOI:10.1016/j.jmp.2014.09.004>,
Mulder and Fox (2019) <DOI:10.1214/18-BA1115>,
Mulder and Fox (2013) <DOI:10.1007/s11222-011-9295-3>,
Boeing-Messing, van Assen, Hofman, Hoijtink, and Mulder <DOI:10.1037/met0000116>,
Hoijtink, Mulder, van Lissa, and Gu, (2018) <DOI:10.31234/osf.io/v3shc>,
Gu, Mulder, and Hoijtink, (2018) <DOI:10.1111/bmsp.12110>,
Hoijtink, Gu, and Mulder, (2018) <DOI:10.1111/bmsp.12145>, and
Hoijtink, Gu, Mulder, and Rosseel, (2018) <DOI:10.1037/met0000187>.

License GPL (>= 3)

URL https://github.com/jomulder/BFpack

BugReports https://github.com/jomulder/BFpack/issues

Encoding UTF-8

LazyData true

NeedsCompilation yes

RoxygenNote 6.1.1

Depends R (>= 3.0.0), bain

Imports stats, MASS, Matrix, mvtnorm, pracma, lme4

Suggests testthat, polycor, survival, pscl

Author Joris Mulder [aut, cre],
Caspar van Lissa [aut, ctb],
Xin Gu [aut],
Anton Olsson-Collentine [aut, ctb],
Florian Boeing-Messing [aut, ctb],
Donald R. Williams [aut, ctb],
Jean-Paul Fox [aut, ctb],
Janosch Menke [ctb],
Barry Brown [ctb],
James Lovato [ctb],
Kathy Russell [ctb],
Lapack 3.8 [ctb],
Jack Dongarra [ctb],
Jim Bunch [ctb],
Cleve Moler [ctb],
Gilbert Stewart [ctb],
John Burkandt [ctb],
Ashwith Rego [ctb],
Alexander Godunov [ctb],
Alan Miller [ctb],
Jean-Pierre Moreau [ctb],
The R Core Team [cph]

Repository CRAN

Date/Publication 2020-05-11 17:50:02 UTC

R topics documented:

`actors` *Actors from a consultancy firm*

Description

Information on 25 actors of a consultancy firm for which a sequence of e-mail messages is observed (can be accessed through the 'events' data object). The actor data is simulated based on information provided in Mulder & Leenders (2019). In the original data, 70 actors were involved. The current data is a random sample of 25 actors.

Usage

```
data(actors)
```

Format

dataframe (25 rows, 4 columns)

actors$id	`integer`	ID of the employee, corresponding to the sender and receiver IDs in the events dataframe
actors$position	`numeric`	Hierarchical position of the employee, ranging from 1-4
actors$division	`character`	Categorical variable, indicating the division of the employee
actors$location	`integer`	Categorical variable, indicating the location of the building the employee works in

Details

The related data files 'events', 'same_building', 'same_division' and 'same_hierarchy' contain information on the event sequence and three event statistics respectively.

Source

doi:10.1016/j.chaos.2018.11.027

References

Mulder, J., & Leenders, R. T. (2019). Modeling the evolution of interaction behavior in social networks: A dynamic relational event approach for real-time analysis. Chaos, Solitons and Fractal Nonlinear, 119, 73-85, https://doi.org/10.1016/j.chaos.2018.11.027 doi:10.1016/j.chaos.2018.11.027

attention — *Multiple Sources of Attentional Dysfunction in Adults With Tourette's Syndrome*

Description

Data from a psychological study comparing attentional performances of Tourette's syndrome (TS) patients, ADHD patients, and controls. These data were simulated using the sufficient statistics from Silverstein, Como, Palumbo, West, and Osborn (1995).

Usage

```
data(attention)
```

Format

A data.frame with 51 rows and 2 columns.

Details

accuracy	`numeric`	Participant's accuracy in the attentional task
group	`factor`	Participant's group membership (TS patient, ADHD patient, or control)

Source

DOI:10.1037/0894-4105.9.2.157

References

Silverstein, S. M., Como, P. G., Palumbo, D. R., West, L. L., & Osborn, L. M. (1995). Multiple sources of attentional dysfunction in adults with Tourette's syndrome: Comparison with attention deficit-hyperactivity disorder. Neuropsychology, 9(2), 157-164. https://doi.org/10.1037/0894-4105.9.2.157 DOI:10.1037/0894-4105.9.2.157

bartlett_test — *Bartlett Test of Homogeneity of Variances*

Description

Performs Bartlett's test of the null that the variances in each of the groups (samples) are the same.

Usage

```
bartlett_test(x, g, ...)

## Default S3 method:
bartlett_test(x, g, ...)
```

Arguments

x	a numeric vector of data values, or a list of numeric data vectors representing the respective samples, or fitted linear model objects (inheriting from class "lm").
g	a vector or factor object giving the group for the corresponding elements of x. Ignored if x is a list.
...	further arguments to be passed to or from methods.

Details

x must be a numeric data vector, and g must be a vector or factor object of the same length as x giving the group for the corresponding elements of x.

Value

A list with class "bartlett_htest" containing the following components:

statistic	Bartlett's K-squared test statistic.
parameter	the degrees of freedom of the approximate chi-squared distribution of the test statistic.
p.value	the p-value of the test.
conf.int	a confidence interval for the mean appropriate to the specified alternative hypothesis.
method	the character string "Bartlett test of homogeneity of variances".
data.name	a character string giving the names of the data.
vars	the sample variances across groups (samples).
n	the number of observations per group (sample)

Bain t_test

In order to allow users to enjoy the functionality of bain with the familiar stats-function bartlett.test, we have had to make minor changes to the function bartlett.test.default. All rights to, and credit for, the function bartlett.test.default belong to the R Core Team, as indicated in the original license below. We make no claims to copyright and incur no liability with regard to the changes implemented in bartlett_test.

References

Bartlett, M. S. (1937). Properties of sufficiency and statistical tests. Proceedings of the Royal Society of London Series A 160, 268–282. DOI: 10.1098/rspa.1937.0109.

Examples

```
require(graphics)

plot(count ~ spray, data = InsectSprays)
bartlett_test(InsectSprays$count, InsectSprays$spray)
```

BF *Bayes factors for Bayesian exploratory and confirmatory hypothesis testing*

Description

The BF function can be used for hypothesis testing and model selection using the Bayes factor. By default exploratory hypothesis tests are performed of whether each model parameter equals zero, is negative, or is positive. Confirmatory hypothesis tests can be executed by specifying hypotheses with equality and/or order constraints on the parameters of interest.

Usage

```
BF(x, hypothesis, prior, complement, ...)
```

Arguments

x	An R object containing the outcome of a statistical analysis.
hypothesis	A character string containing the informative hypotheses to evaluate. The default is NULL, which will result in an exploratory analysis.
prior	A vector specifying the prior probabilities of the hypotheses. The default is NULL which will specify equal prior probabilities.
complement	a logical specifying whether the complement should be added to the tested hypothesis under hypothesis.
...	Parameters passed to and from other functions.

Details

The function requires a fitted modeling object. Current analyses that are supported: t_test, bartlett_test, aov, manova, lm, mlm, glm, hetcor, lmer, coxph, survreg, zeroinfl, and polr.

For testing means and regression coefficients of model classes t_test, aov, manova, lm, mlm, adjusted fractional Bayes factors are computed. For testing group variances using bartlett_test, adjusted fractional Bayes factors are computed. For testing measures of association (e.g., correlations) under model class mlm and for testing intraclass correlations under model class lmerMod, default Bayes factors based on uniform priors are computed. For all other model classes an approximate Bayes factor is computed using a Gaussian approximation of the posterior, similar as a classical Wald test.

Value

The output is an object of class BF. The object has elements: BFtu_exploratory, PHP_exploratory, BFtu_confirmatory, PHP_confirmatory, BFmatrix_confirmatory, BFtable_confirmatory, BFtu_main, PHP_main, BFtu_interaction, PHP_interaction, prior, hypotheses, estimates, model, call.

References

Mulder, J., Gu, X., A. Tomarken, F. Böing-Messing, J.A.O.C. Olsson-Collentine, Marlyne Meyerink, D.R. Williams, J. Menke, J.-P. Fox, Y. Rosseel, E.J. Wagenmakers, H. Hoijtink., and van Lissa, C. (submitted). BFpack: Flexible Bayes Factor Testing of Scientific Theories in R.

Examples

```
# EXAMPLE 1. One-sample t test
ttest1 <- bain::t_test(therapeutic,mu=5)
print(ttest1)
# confirmatory Bayesian one sample t test
BF1 <- BF(ttest1,"mu=5")
summary(BF1)
# exploratory Bayesian one sample t test
BF(ttest1)


# EXAMPLE 2. ANOVA
aov1 <- aov(price ~ anchor*motivation,data=tvprices)
# check the names of the model parameters
names(aov1$coefficients)
BF1 <- BF(aov1,hypothesis="anchorrounded=motivationlow;
                           anchorrounded<motivationlow;
                           anchorrounded>motivationlow")
summary(BF1)


# EXAMPLE 3. Logistic regression
fit <- glm(sent ~ ztrust + zfWHR + zAfro + glasses + attract + maturity +
   tattoos, family = binomial(), data = wilson)
```

```
BF1 <- BF(fit, hypothesis = "ztrust > (zfWHR, zAfro) > 0;
                             ztrust > 0 & zfWHR=zAfro= 0")
summary(BF1)

# EXAMPLE 4. Correlation analysis
set.seed(123)
cor1 <- cor_test(memory[1:20,1:3])
BF1 <- BF(cor1)
summary(BF1)
BF2 <- BF(cor1,hypothesis="Wmn_with_Im > Wmn_with_Del > 0;
                          Wmn_with_Im = Wmn_with_Del = 0")
summary(BF2)
```

`cor_test` *Bayesian correlation analysis*

Description

Estimate the unconstrained posterior for the correlations using a joint uniform prior.

Usage

```
cor_test(..., formula = NULL, iter = 5000)
```

Arguments

`...`	matrices (or data frames) of dimensions *n* (observations) by *p* (variables) for different groups (in case of multiple matrices or data frames).
`formula`	an object of class `formula`. This allows for including control variables in the model (e.g., ~ `education`).
`iter`	number of iterations from posterior (default is 5000).

Value

list of class `cor_test`:

- `meanF` posterior means of Fisher transform correlations
- `covmF` posterior covariance matrix of Fisher transformed correlations
- `correstimates` posterior estimates of correlation coefficients
- `corrdraws` list of posterior draws of correlation matrices per group
- `corrnames` names of all correlations

Examples

```
# Bayesian correlation analysis of the 6 variables in 'memory' object
# we consider a correlation analysis of the first three variable of the memory data.
fit <- cor_test(BFpack::memory[,1:3])

# Bayesian correlation of variables in memory object in BFpack while controlling
# for the Cat variable
fit <- cor_test(BFpack::memory[,c(1:4)],formula = ~ Cat)

# Bayesian correlation analysis of first three variables in memory data
# for two different groups
HC <- subset(BFpack::memory[,c(1:3,7)], Group == "HC")[,-4]
SZ <- subset(BFpack::memory[,c(1:3,7)], Group == "SZ")[,-4]
fit <- cor_test(HC,SZ)
```

`fmri` *fMRI data*

Description

fMRI data assessing relation between individual differences in the ability to recognize faces and cars and thickness of the superficial, middle, and deep layers of the fusiform face area, as assessed by high-resolution fMRI recognition (Williams et al, 2019, under review)

Usage

```
data(fmri)
```

Format

A data.frame with 13 rows and 6 columns.

Details

Subject	`numeric`	Particicpant ID number
Face	`numeric`	Standardized score on face recognition battery
Vehicle	`numeric`	Standardized score on vehicle recognition battery
Superficial	`numeric`	Depth in mm of superficial layer of FFA
Middle	`numeric`	Depth in mm of middle layer of FFA
Bform	`numeric`	Depth in mm of deep layer of FFA

References

McGuigin, R.W., Newton, A.T., Tamber-Rosenau, B., Tomarken, A.J, & Gauthier, I. (under review). Thickness of deep layers in the fusiform face area predicts face recognition.

`memory` *Memory data on health and schizophrenic patients*

Description

Data set from study assessing differences between schizophrenic patients and healthy control participants in patterns of correlations among 6 verbal memory tasks (Ichinose et al., 2019).

Im	`numeric`	Percent correct on immediate recall of 3 word lists
Del	`numeric`	Percent correct on delayed recall of 3 word lists
Wmn	`numeric`	Number correct on letter-number span test of auditory working memory
Cat	`numeric`	Number correct on category fluency task
Fas	`numeric`	Number correct on letter fluency task
Rat	`numeric`	Number correct on remote associates task
Group	`factor`	Participant Group (HC = Healthy Control; SZ = Schizophrenia)

Usage

```
data(memory)
```

Format

A data.frame with 40 rows and 8 columns.

References

Ichinose, M.C., Han, G., Polyn, S., Park, S., & Tomarken, A.J. (2019). Verbal memory performance discordance in schizophrenia: A reflection of cognitive dysconnectivity. Unpublished manuscript.

`relevents` *A sequence of innovation-related e-mail messages*

Description

A time-ordered sequence of e-mail messages between employees of a consultancy firm and information on the actors in the relational event sequence. The data is orignally analyzed by Mulder & Leenders (2019), to find drivers of innovation-related e-mail messages exchanged between employees of a large consultancy firm. Originally, the data consist of 2081 e-mail messages exchanged between 70 employees over the course o fa year. The current data is a sample of a simulated data set, based on estimates of the model parameters in Mulder & Leenders (2019).

Usage

```
data(relevents)
```

Format

dataframe (227 rows, 3 columns)

relevents$time	`numeric`	Time of the e-mail message, in seconds since onset of the observation
relevents$sender	`integer`	ID of the sender, corresponding to the employee IDs in the actors dataframe
relevents$receiver	`integer`	ID of the receiver

Details

The related data files actors', 'same_building', 'same_division' and 'same_hierarchy' contain information on the actors and three event statistics respectively.

Source

doi:10.1016/j.chaos.2018.11.027

References

Mulder, J., & Leenders, R. T. (2019). Modeling the evolution of interaction behavior in social networks: A dynamic relational event approach for real-time analysis. Chaos, Solitons and Fractal Nonlinear, 119, 73-85, https://doi.org/10.1016/j.chaos.2018.11.027 doi:10.1016/j.chaos.2018.11.027

`same_building` *Same building event statistic*

Description

A matrix coding whether senders of events (in the rows) and receivers of events (in the column) work in the same building. Related to the 'events' data object, that contains a relational event sequence, and the 'actors' object, that contains information on the 25 actors involved in the relational event sequence.

Usage

```
data(same_building)
```

Format

dataframe (25 rows, 4 columns)

same_building	`integer`	Event statistic. Matrix with senders in the rows and receivers in the columns. The event statistic i

Source

doi:10.1016/j.chaos.2018.11.027

References

Mulder, J., & Leenders, R. T. (2019). Modeling the evolution of interaction behavior in social networks: A dynamic relational event approach for real-time analysis. Chaos, Solitons and Fractal Nonlinear, 119, 73-85, https://doi.org/10.1016/j.chaos.2018.11.027 doi:10.1016/j.chaos.2018.11.027

`same_division` *Same division event statistic*

Description

A matrix coding whether senders of events (in the rows) and receivers of events (in the column) work in the same division. Related to the 'events' data object, that contains a relational event sequence, and the 'actors' object, that contains information on the 25 actors involved in the relational event sequence.

Usage

```
data(same_division)
```

Format

dataframe (25 rows, 4 columns)

same_division `integer` Event statistic. Matrix with senders in the rows and receivers in the columns. The event statistic i

Source

doi:10.1016/j.chaos.2018.11.027

References

Mulder, J., & Leenders, R. T. (2019). Modeling the evolution of interaction behavior in social networks: A dynamic relational event approach for real-time analysis. Chaos, Solitons and Fractal Nonlinear, 119, 73-85, https://doi.org/10.1016/j.chaos.2018.11.027 doi:10.1016/j.chaos.2018.11.027

`same_hierarchy` *Same hierarchical position event statistic*

Description

A matrix coding whether senders of events (in the rows) and receivers of events (in the column) work in the same hierarchical position. Related to the 'events' data object, that contains a relational event sequence, and the 'actors' object, that contains information on the 25 actors involved in the relational event sequence.

Usage

```
data(same_hierarchy)
```

Format

dataframe (25 rows, 4 columns)

same_hierarchy `integer` Event statistic. Matrix with senders in the rows and receivers in the columns. The event statistic

Source

doi:10.1016/j.chaos.2018.11.027

References

Mulder, J., & Leenders, R. T. (2019). Modeling the evolution of interaction behavior in social networks: A dynamic relational event approach for real-time analysis. Chaos, Solitons and Fractal Nonlinear, 119, 73-85, https://doi.org/10.1016/j.chaos.2018.11.027 doi:10.1016/j.chaos.2018.11.027

`sivan` *Wason task performance and morality*

Description

Data from an experimental study, using the Wason selection task (Wason 1968) to examine whether humans have cognitive adaptations for detecting violations of rules in multiple moral domains. Moral domains are operationalized in terms of the five domains of the Moral Foundations Questionnaire (Graham et al. 2011). These data were simulated using the R-package `synthpop`, based on the characteristics of the original data.

Usage

```
data(sivan)
```

Format

A data.frame with 887 rows and 12 columns.

Details

sex	`factor`	Participant sex
age	`integer`	Participant age
nationality	`factor`	Participant nationality
politics	`integer`	How would you define your political opinions? Likert type scale, from 1 (Liberal) to 6 (Conservat
WasonOrder	`factor`	Was the Wason task presented before, or after the MFQ?
Harm	`numeric`	MFQ harm domain.
Fairness	`numeric`	MFQ fairness domain.
Loyalty	`numeric`	MFQ loyalty domain.
Purity	`numeric`	MFQ purity domain.
Tasktype	`ordered`	How was the Wason task framed?
GotRight	`factor`	Did the participant give the correct answer to the Wason task?

Source

DOI:10.1007/s40806-018-0154-8

References

Sivan, J., Curry, O. S., & Van Lissa, C. J. (2018). Excavating the Foundations: Cognitive Adaptations for Multiple Moral Domains. Evolutionary Psychological Science, 4(4), 408–419. https://doi.org/10.1007/s40806-018-0154-8 DOI:10.1007/s40806-018-0154-8

`therapeutic` *Data come from an experimental study (Rosa, Rosa, Sarner, and Barrett, 1998) that were also used in Howell (2012, p.196). An experiment was conducted to investigate if Therapeutic Touch practitioners who were blindfolded can effectively identify which of their hands is below the experimenter¡¯s. Twenty-eight practitioners were involved and tested 10 times in the experiment. Researchers expected an average of 5 correct answers from each practitioner as it is the number by chance if they do not outperform others.*

Description

correct	`integer`	How many correct answers are from each practitioner)

Usage

```
data(therapeutic)
```

Format

A data.frame with 22 rows and 1 column.

References

Howell, D. (2012). Statistical methods for psychology (8th ed.). Belmont, CA: Cengage Learning.

`timssICC` *Trends in International Mathematics and Science Study (TIMSS) 2011-2015*

Description

A stratified sample was drawn by country and school to obtain a balanced sample of p = 15 grade-4 students per school for each of four countries (The Netherlands (NL), Croatia (HR), Germany (DE), and Denmark (DK)) and two measurement occasions (2011, 2015). Achievement scores (first plausible value) of overall mathematics were considered. Performances of fourth and eight graders from more than 50 participating countries around the world can be found at (https://www.iea.nl/timss) The TIMSS achievement scale is centered at 500 and the standard deviation is equal to 100 scale score points. The TIMSS data set has a three-level structure, where students are nested within classrooms/schools, and the classrooms/schools are nested within countries. Only one classroom was sampled per school. Changes in the mathematics achievement can be investigated by examining the grouping of students in schools across countries. Changes in country-specific intraclass correlation coefficient from 2011 to 2015, representing heterogeneity in mathematic achievements within and between schools across years, can be tested. When detecting a decrease in average performance together with an increase of the intraclass correlation, a subset of schools performed worse. For a constant intraclass correlation across years the drop in performance applied to the entire population of schools. For different countries, changes in the intraclass correlation across years can be tested concurrently to examine also differences across countries.

Usage

```
data(timssICC)
```

Format

A data.frame with 16770 rows and 15 columns.

Details

math	`numeric`	math score child
groupNL11	`numeric`	Indicator for child from NL in 2011
groupNL15	`numeric`	Indicator for child from NL in 2015
groupHR11	`numeric`	Indicator for child from HR in 2011
groupHR15	`numeric`	Indicator for child from HR in 2015
groupDE11	`numeric`	Indicator for child from DE in 2011
groupDE15	`numeric`	Indicator for child from DE in 2015

groupDR11	`numeric`	Indicator for child from DK in 2011
groupDR15	`numeric`	Indicator for child from DK in 2015
gender	`numeric`	Female=0,Male=1
weight	`numeric`	Child sampling weight
yeargender	`numeric`	Interaction for occassion and gender
lln	`numeric`	total number of children in school-class
groupschool	`factor`	Nested indicator for school in country
schoolID	`factor`	Unique indicator for school

References

Mulder, J. & Fox, J.-P. (2019). Bayes factor testing of multiple intraclass correlations. Bayesian Analysis. 14, 2, p. 521-552.

`tvprices` *Precision of the Anchor Influences the Amount of Adjustment*

Description

Data from an experimental study where participants have to guess the price of a plasma tv. There were two experimental conditions. These data were simulated using the sufficient statistics from Janiszewski & Uy (2008).

Usage

```
data(tvprices)
```

Format

A data.frame with 59 rows and 3 columns.

Details

price	`numeric`	Participant z-scores of price
anchor	`factor`	Participant anchor
motivation	`factor`	motivation to change

Source

DOI:10.1111/j.1467-9280.2008.02057.x

References

Janiszewski, C., & Uy, D. (2008). Precision of the anchor influences the amount of adjustment. Psychological Science, 19(2), 121–127. https://doi.org/10.1111/j.1467-9280.2008.02057.x DOI:10.1111/j.1467-9280.2008.02057.x

---

`wilson` *Facial trustworthiness and criminal sentencing*

Description

Data from a correlational study in which the correlation between ratings of facial trustworthiness of inmates was correlated with whether they had received the death penalty or not (wilson and Rule, 2015). These data were simulated using the R-package `synthpop`, based on the characteristics of the original data.

Usage

```
data(wilson)
```

Format

A data.frame with 742 rows and 13 columns.

Details

stim	`integer`	Stimulus Number
sent	`integer`	Sentence: 1 = Death, 0 = Life
race	`integer`	Race: 1 = White, -1 = Black
glasses	`integer`	Glasses: 1 = Yes, 0 = No
tattoos	`integer`	Tattoos: 1 = Yes, 0 = No
ztrust	`numeric`	Trustworthiness
trust_2nd	`numeric`	Trustworthiness ratings with 2nd control group; Death targets are same as in primary analysis, Life ta
afro	`numeric`	raw Afrocentricity ratings.
zAfro	`numeric`	Afrocentricity ratings normalized within target race. Analyses in paper were done with this variable.
attract	`numeric`	Attractiveness
fWHR	`numeric`	facial width-to-height
afWHR	`numeric`	fWHR normalized within target race. Analyses in paper were done with this variable
maturity	`numeric`	Maturity

Source

DOI:10.1177/0956797615590992

References

Wilson, J. P., & Rule, N. O. (2015). Facial Trustworthiness Predicts Extreme Criminal-Sentencing Outcomes. Psychological Science, 26(8), 1325–1331.https://doi.org/10.1177/0956797615590992 DOI:10.1177/0956797615590992

Index