

# Package ‘lmerTest’

June 23, 2016

**Type** Package

**Title** Tests in Linear Mixed Effects Models

**Version** 2.0-32

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**Depends** R (>= 3.0.0), Matrix, stats, methods, lme4 (>= 1.0)

**Imports** plyr, MASS, Hmisc, ggplot2

**Suggests** pbkrtest, nlme, estimability

**Description** Different kinds of tests for linear mixed effects models as implemented in 'lme4' package are provided. The tests comprise types I - III F tests for fixed effects, LR tests for random effects. The package also provides the calculation of population means for fixed factors with confidence intervals and corresponding plots. Finally the backward elimination of non-significant effects is implemented.

**LazyData** TRUE

**License** GPL (>= 2)

**Repository** CRAN

**NeedsCompilation** no

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lmerTest-package	<i>The package performs different kinds of tests on lmer objects, such as F tests of types I - III hypotheses for the fixed part, likelihood ratio tests for the random part, least squares means (population means) and differences of least squares means for the factors of the fixed part with corresponding plots. The package also provides with a function step, that preforms backward elimination of non-significant effects, starting from the random effects, and then fixed ones.</i>
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## Description

The package provides anova function, that gives data frame similar to what gives **lme4** package but with p-values calculated from F statistics of types I - III hypotheses. There are two options for denominator degrees of freedom of F statistics: "Satterthwaite" and "Kenward-Roger". The calculation of anova with Kenward-Roger's approximation is based on function from **pbkrtest** package, the calculation of Satterthwaite's approximation is based on SAS proc mixed theory (see reference). The package also provides summary function, which gives the same as **lme4** package summary function but with p-values and degrees of freedom added for the t-test (based on Satterthwaite approximation for denominator degrees of freedom). The tests on random effects are performed using likelihood ratio tests.

## Details

Package: lmerTest  
 Type: Package  
 Version: 1.0  
 Date: 2012-01-10  
 License: GPL

The calculation of statistics for the fixed part was developed according to SAS Proc Mixed Theory (see reference).

## Author(s)

Alexandra Kuznetsova <alku@dtu.dk>, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

## References

SAS Technical Report R-101 1978 Tests of Hypotheses in Fixed-Effects Linear Models *Copyright (C)* (SAS Institute Inc., Cary, NC, USA)

Goodnight, J.H. 1976 General Linear Models Procedure (S.A.S. Institute, Inc.)

Schaalje G.B., McBride J.B., Fellingham G.W. 2002 Adequacy of approximations to distributions of test Statistics in complex mixed linear models

## Examples

```
## import lmerTest package
library(lmerTest)

## an object of class merModLmerTest
m <- lmer(Informed.liking ~ Gender+Information+Product +(1|Consumer), data=ham)

## gives summary of lmer object. The same as of class merMod but with
## additional p-values calculated based on Satterthwaite's approximations
summary(m)

## anova table the same as of class merMod but with additional F statistics and
## and denominator degrees of freedom and
## p-values calculated based on Satterthwaite's approximations
anova(m)

## anova table the same as of class merMod but with additional F statistics and
## denominator degrees of freedom and
## p-values calculated based on Kenward-Roger's approximations
## Not run:
if(requireNamespace("pbkrtest", quietly = TRUE))
  anova(m, ddf = "Kenward-Roger")

## End(Not run)

## anova table of class merMod
anova(m, ddf="lme4")

## backward elimination of non-significant effects of model m
st <- step(m)

plot(st)
```

---

anova-methods

*Methods for function anova in package **lmerTest***

---

## Description

Methods for Function anova in Package **lmerTest**

**Usage**

```
## S4 method for signature 'merModLmerTest'
anova(object, ... , ddf="Satterthwaite",
type=3)
```

**Arguments**

object	object of class "merModLmerTest"
...	object of class "merModLmerTest". Then the model comparison statistic will be calculated
ddf	By default the Satterthwaite's approximation to degrees of freedom is calculated. If ddf="Kenward-Roger", then the Kenward-Roger's approximation is calculated using KRmodcomp function from <b>pbkrtest</b> package. If ddf="lme4" then the anova table that comes from <b>lme4</b> package is returned.
type	type of hypothesis to be tested. Could be type=3 or type=2 or type = 1 (The definition comes from SAS theory)

**Details**

According to (Goodnight, J.H. 1976) the behaviour of the type 3 hypothesis is not fully studied for the situations with missing cells (where observations are missing at some factor-level combination). A warning is returned in such cases.

**References**

SAS Technical Report R-101 1978 Tests of Hypotheses in Fixed-Effects Linear Models *Copyright (C)* (SAS Institute Inc., Cary, NC, USA)

Goodnight, J.H. 1976 General Linear Models Procedure (S.A.S. Institute, Inc.)

Schaalje G.B., McBride J.B., Fellingham G.W. 2002 Adequacy of approximations to distributions of test Statistics in complex mixed linear models

**Examples**

```
#import lmerTest package
library(lmerTest)

m.ham <- lmer(Informed.liking ~ Product*Information*Gender
+ (1|Consumer), data = ham)

# type 3 anova table with denominator degrees of freedom
# calculated based on Satterthwaite's approximation
anova(m.ham)

# type 1 anova table with denominator degrees of freedom
# calculated based on Satterthwaite's approximation
## Not run:
anova(m.ham, type = 1)

## End(Not run)
```

```

# type3 anova table with additional F statistics and denominator degrees of freedom
# calculated based on Kenward-Roger's approximation
if(require(pbkrtest))
anova(m.ham, ddf = "Kenward-Roger")

## Not run:
# anova table, that is returned by lme4 package
anova(m.ham, ddf = "lme4")

## End(Not run)

```

---

calcSatterth	<i>F-test based on the Satterthwaite's approximation for denominator degrees of freedom.</i>
--------------	--

---

### Description

Produces a list with the values for an approximate F-test based on the Satterthwaite's approximation.

### Usage

```
calcSatterth(model, L)
```

### Arguments

model	linear mixed effects model (lmer object).
L	hypothesis contrast matrix or a vector
...	other potential arguments.

### Details

F test for the null hypothesis  $H_0 : L\beta = 0$ , where  $\beta$  is a vector of the same length as `fixef(model)`

### Value

A list with the results from the F test

denom	numeric. Denominator degrees of freedom, calculated with the Satterthwaite's approximation
Fstat	numeric. F statistic
pvalue	numeric. p-value of the corresponding F test
ndf	numeric. Numerator degrees of freedom

**Author(s)**

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

**References**

Schaalje G.B., McBride J.B., Fellingham G.W. 2002 Adequacy of approximations to distributions of test Statistics in complex mixed linear models

**See Also**

[anova](#)

**Examples**

```
## import lme4 package and lmerTest package
library(lmerTest)

## specify lmer model for the sleepstudy data from the lme4 package
m <- lmer(Reaction ~ Days + (1 + Days|Subject), sleepstudy)

L <- cbind(0,1) ## specify contrast vector
calcSatterth(m, L) ## calculate F test

## specify model for the ham data
m.ham <- lmer(Informed.liking ~ Product + (1|Consumer), data = ham)

## specify contrast vector for testing product effect
L <- matrix(0, ncol = 4, nrow = 3)
L[1,2] <- L[2,3] <- L[3,4] <- 1
calcSatterth(m.ham, L)

## by using anova function we get the same result
anova(m.ham)
```

---

carrots

*Consumer preference mapping of carrots*

---

**Description**

In a consumer study 103 consumers scored their preference of 12 danish carrot types on a scale from 1 to 7. Moreover the consumers scored the degree of sweetness, bitterness and crispiness in the products. The carrots were harvested in autumn 1996 and tested in march 1997. In addition to the consumer survey, the carrot products were evaluated by a trained panel of tasters, the sensory panel, with respect to a number of sensory (taste, odour and texture) properties. Since usually a high number of (correlated) properties(variables) are used, in this case 14, it is a common procedure to use a few, often 2, combined variables that contain as much of the information in the sensory variables as possible. This is achieved by extracting the first two principal components in a principal components analysis(PCA) on the product-by-property panel average data matrix. In this data set the variables for the first two principal components are named (sens1 and sens2).

**Usage**

carrots

**Format**

Consumer factor with 103 levels: numbering identifying consumers

Frequency factor with 5 levels; "How often do you eat carrots?" 1: once a week or more, 2: once every two weeks, 3: once every three weeks, 4: at least once month, 5: less than once a month

Gender factor with 2 levels. 1: male, 2:female

Age factor with 4 levels. 1: less than 25 years, 2: 26-40 years, 3: 41-60 years, 4 more than 61 years

Homesize factor with two levels. Number of persons in the household. 1: 1 or 2 persons, 2: 3 or more persons

Work factor with 7 levels. different types of employment. 1: unskilled worker(no education), 2: skilled worker(with education), 3: office worker, 4: housewife (or man), 5: independent businessman/ self-employment, 6: student, 7: retired

Income factor with 4 levels. 1: <150000, 2: 150000-300000, 3: 300000-500000, 4: >500000

**Source**

Per Bruun Brockhoff, The Royal Veterinary and Agricultural University, Denmark.

**Examples**

```
#import lme4 package and lmerTest package
library(lmerTest)

m.carrots <- lmer(Preference ~ sens2 + Homesize
+(1+sens2|Consumer), data=carrots)

# only elimination of the random part is required.
#approximation of ddf is Satterthwaite
step(m.carrots, reduce.random = FALSE)
```

---

difflsmeans

*Calculates Differences of Least Squares Means and Confidence Intervals for the factors of a fixed part of mixed effects model of lmer object.*

---

**Description**

Produces a data frame which resembles to what SAS software gives in proc mixed statement. The approximation for degrees of freedom is Satterthwaite's.

**Usage**

```
difflsmeans(model, test.offs=NULL, ddf="Satterthwaite",...)
```

## Arguments

model	linear mixed effects model (lmer object).
test. effs	character vector specifying names of terms to be tested. If NULL all the terms are tested.
ddf	By default the Satterthwaite's approximation to degrees of freedom is calculated. If ddf="Kenward-Roger", then the Kenward-Roger's approximation is calculated using KRmodcomp function from <b>pbkrtest</b> package. If ddf="lme4" then the anova table that comes from <b>lme4</b> package is returned
...	other potential arguments.

## Value

Produces Differences of Least Squares Means (population means) table with p-values and Confidence intervals.

## Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

## See Also

[lsmeans](#), [step](#), [rand](#)

## Examples

```
## import lme4 package and lmerTest package
library(lmerTest)

## specify lmer model
m1 <- lmer(Informed.liking ~ Gender*Information +(1|Consumer), data=ham)

## calculate least squares means for interaction Gender:Information
diffsmeans(m1, test. effs="Gender:Information")

m <- lmer(Coloursaturation ~ TVset*Picture + (1|Assessor), data=TVbo)
plot(diffsmeans(m, test. effs="TVset"))
```



---

ham *Conjoint study of dry cured ham*

---

### Description

One of the purposes of the study was to investigate the effect of information given to the consumers measured in hedonic liking for the hams. Two of the hams were Spanish and two were Norwegian, each origin representing different salt levels and different aging time. The information about origin was given in such way that both true and false information was given. essentially a 4\*2 design with 4 samples and 2 information levels. A total of 81 Consumers participated in the study.

### Usage

ham

### Format

Consumer factor with 81 levels: numbering identifying consumers

Product factor with four levels

Informed.liking numeric: hedonic liking for the products

Information factor with two levels

Gender factor with two levels (gender)

Age numeric: age of Consumer

### References

"Alternative methods for combining design variables and consumer preference with information about attitudes and demographics in conjoint analysis" . T. Naes, V.Lengard, S. Bolling Johansen, M. Hersleth

### Examples

```
#import lmerTest package
library(lmerTest)

m <- lmer(Informed.liking ~ Product*Information*Gender
+ (1|Product:Consumer) , data=ham)

#anova table with p-values with Satterthwaite's approximation for denominator
#degrees of freedom
anova(m)

#analysis of random and fixed parts and post hoc
#analysis of Product and Information effects
step(m, reduce.random=FALSE, reduce.fixed=FALSE,
test.offs=c("Product", "Information"))
```

---

 lmer

*Fit Linear Mixed-Effects Models*


---

**Description**

Fit a linear mixed model

**Details**

This lmer function is an overloaded function of lmer (merMod class from **lme4** package).

**Value**

An object of class "[merModLmerTest](#)"

**See Also**

[merModLmerTest](#) class

**Examples**

```
library(lmerTest)

## linear mixed models
fm1 <- lmer(Reaction ~ Days + (Days|Subject), sleepstudy)
fm2 <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject), sleepstudy)

# anova table the same as of class merMod but with additional F statistics and
# p-values calculated based on Satterthwaite's approximations
anova(fm1)

# anova table the same as of class merMod but with additional F statistics and
# p-values calculated based on Kenward-Roger's approximations
## Not run:
if(requireNamespace("pbkrtest", quietly = TRUE))
  anova(fm1, ddf="Kenward-Roger")

# anova table the same as of class merMod
anova(fm1, ddf="lme4")

## End(Not run)

# gives summary of merModLmerTest class. The same as of class merMod but with
# additional p-values calculated based on Satterthwaite's approximations
summary(fm1)

## multiple comparisons statistics. The one from lme4 package
## Not run:
anova(fm1, fm2)
```

```
## End(Not run)
```

---

lsmeans	<i>Calculates Least Squares Means and Confidence Intervals for the factors of a fixed part of mixed effects model of lmer object.</i>
---------	---

---

### Description

Produces a data frame which resembles to what SAS software gives in proc mixed statement. The approximation of degrees of freedom is Satterthwaite's.

### Usage

```
lsmeans(model, test.terms = NULL, ddf="Satterthwaite", ...)
```

### Arguments

model	linear mixed effects model (lmer object).
test.terms	character vector specifying the names of terms to be tested. If NULL all the terms are tested.
ddf	By default the Satterthwaite's approximation to degrees of freedom is calculated. If ddf="Kenward-Roger", then the Kenward-Roger's approximation is calculated using KRmodcomp function from <b>pbkrtest</b> package. If ddf="lme4" then the anova table that comes from <b>lme4</b> package is returned
...	other potential arguments.

### Value

Produces Least Squares Means (population means) table with p-values and Confidence intervals.

### Note

For construction of the contrast matrix popMatrix function from **doBy** package was used.

### Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

### References

**doBy** package, **gplots** package

### See Also

[step](#), [rand](#), [diff](#)lsmeans

**Examples**

```
## import lme4 package and lmerTest package
library(lmerTest)

## specify lmer model
m1 <- lmer(Informed.liking ~ Gender*Information +(1|Consumer), data=ham)

## calculate least squares means for interaction Gender:Information
lsmeans(m1, test.effs="Gender:Information")

m <- lmer(Coloursaturation ~ TVset*Picture + (1|Assessor), data=TVbo)
plot(lsmeans(m))
lsmeans(m, test.effs="TVset")
```

---

merModLmerTest-class *Mixed Model Representations*

---

**Description**

The merModLmerTest *contains* merMod class of **lme4** package and overloads anova and summary functions.

**Objects from the Class**

Objects can be created via the [lmer](#) functions.

**See Also**

[lmer\(\)](#)

**Examples**

```
(m <- lmer(Reaction ~ Days + (1|Subject) + (0+Days|Subject),
          data = sleepstudy))

## type 3 anova table with denominator degrees of freedom
## calculated based on Satterthwaite's approximation
anova(m)

## type 1 anova table with denominator degrees of freedom
## calculated based on Satterthwaite's approximation
## Not run:
anova(m, type=1)

## End(Not run)
```

```

## type3 anova table with additional F statistics and denominator degrees of freedom
## calculated based on Kenward-Roger's approximation
## Not run:
if(requireNamespace("pbkrtest", quietly = TRUE))
anova(m, ddf="Kenward-Roger")

## End(Not run)

## anova table, that is returned by lme4 package
anova(m, ddf="lme4")

## summary of merModLmerTest object. Returns the same as merMod object but with an
## additional column of p values for the t test.
summary(m)

```

---

rand	<i>Performs likelihood ratio test on random effects of linear mixed effects model.</i>
------	--

---

### Description

Returns a data frame with values of Chi square statistics and corresponding p-values of likelihood ratio tests.

### Usage

```
rand(model, ...)
```

### Arguments

model	linear mixed effects model (lmer object).
...	other potential arguments.

### Details

The columns of the data are:

Chisq: The value of the chi square statistics

Chi Df: The degrees of freedom for the test

p.value: The p-value of the likelihood ratio test for the effect

### Value

Produces a data frame with LR tests for the random terms.

### Author(s)

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

**See Also**

[step](#), [lsmeans](#), [diffsmeans](#)

**Examples**

```
#import lme4 package and lmerTest package
library(lmerTest)

#lmer model with correlation between intercept and slopes
#in the random part
m <- lmer(Preference ~ sens2+Homesize+(1+sens2|Consumer), data=carrots)

# table with p-values for the random effects
rand(m)
```

---

step	<i>Performs backward elimination of non-significant effects of linear mixed effects model:</i>
------	--

---

**Description**

performs automatic backward elimination of all effects of linear mixed effect model. First backward elimination of the random part is performed following by backward elimination of the fixed part. Finally LSMEANS (population means) and differences of LSMEANS for the fixed part of the model are calculated and the final model is provided. The p-values for the fixed effects are calculated from F test based on Satterthwaite's or Kenward-Roger approximation), p-values for the random effects are based on likelihood ratio test. All analysis may be performed on lmer object of **lme4** package.

**Usage**

```
step(model, ddf = "Satterthwaite", type = 3, alpha.random = 0.1, alpha.fixed = 0.05,
      reduce.fixed = TRUE, reduce.random = TRUE, fixed.calc = TRUE, lsmeans.calc = TRUE,
      diffsmeans.calc = TRUE, test.offs = NULL, keep.offs = NULL, ...)
```

**Arguments**

model	linear mixed effects model (lmer object).
ddf	approximation for denominator degrees of freedom. By default Satterthwaite's approximation. ddf="Kenward-Roger" calculates Kenward-Roger approximation
type	type of hypothesis to be tested (SAS notation). Either type=1 or type=3.
alpha.random	significance level for elimination of the random part (for LRT test)

<code>alpha.fixed</code>	significance level for elimination of the fixed part (for F test and t-test for least squares means)
<code>reduce.fixed</code>	logical for whether the reduction of the fixed part is required
<code>reduce.random</code>	logical for whether the reduction of the random part is required
<code>fixed.calc</code>	logical for whether the calculation of the table for fixed effects is needed. If FALSE then only the analysis of random effects is done
<code>lsmeans.calc</code>	logical for whether the calculation of LSMEANS(population means) is required
<code>diffsmeans.calc</code>	logical for whether the calculation of differences of LSMEANS is required
<code>test.offs</code>	character vector specifying the names of terms to be tested in LSMEANS. If NULL all the terms are tested. If <code>lsmeans.calc==FALSE</code> then LSMEANS are not calculated.
<code>keep.offs</code>	character vector specifying the names of terms to be kept in the model even if being non-significant
<code>...</code>	other potential arguments.

### Details

Elimination of all effects is done one at a time. Elimination of the fixed part is done by the principle of marginality that is: the highest order interactions are tested first: if they are significant, the lower order effects are not tested for significance. The step function of `lmerTest` overrides the one from stats package for `lm` objects. So if the `lmerTest` is attached and one wants to call `step` for `lm` object, then needs to use `stats::step`

### Value

<code>rand.table</code>	data frame with value of Chi square statistics, p-values for the likelihood ratio test for random effects
<code>anova.table</code>	data frame with tests for whether the model fixed terms are significant (Analysis of Variance)
<code>lsmeans.table</code>	Least Squares Means data frame with p-values and Confidence intervals
<code>diffs.lsmeans.table</code>	Differences of Least Squares Means data frame with p-values and Confidence intervals
<code>model</code>	Final model - object of <code>merLmerTest</code> (contains <code>mer</code> class) or <code>gls</code> (after all the required reduction has been performed)

### Note

For the random coefficient models: in the random part if correlation is present between slope and intercept, then the simplified model will contain just an intercept. That is if the random part of the initial model is  $(1+c|f)$ , then this model is compared to  $(1|f)$  by using LRT. If there are multiple slopes, then the the slope with the highest p-value (and higher then alpha level) is eliminated. That is if the random part of the initial model has the following form  $(1+c1+c2|f)$ , then two simplified models are constructed and compared to the initial one: the first one has  $(1+c1|f)$  in the random part and the second one has:  $(1+c2|f)$ .

**Author(s)**

Alexandra Kuznetsova, Per Bruun Brockhoff, Rune Haubo Bojesen Christensen

**See Also**

[rand](#), [lsmeans](#), [difflsmeans](#)

**Examples**

```
#import lme4 package and lmerTest package
library(lmerTest)

## Not run:
m <- lmer(Informed.liking ~ Product*Information*Gender+
(1|Consumer) + (1|Product:Consumer), data=ham)

#elimination of non-significant effects
s <- step(m)

#plot of post-hoc analysis of the final model
plot(s)

m <- lmer(Coloursaturation ~ TVset*Picture+
(1|Assessor)+(1|Assessor:TVset), data=TVbo)

step(m, keep.offs = "Assessor")

## End(Not run)
```

**Description**

Methods for function summary in package **lmerTest**



**Methods**

`signature(object = "merModLmerTest" , ddf = "Satterthwaite" , ...)` summary of the results of linear mixed effects model fitting of object. Returns the same output as `summary` of "merMod" class but with additional columns with the names "df", "t value" and "Pr(>t)" representing degrees of freedom, t-statistics and p-values respectively calculated based on Satterthwaite's or Kenward-Roger's approximations. [summary](#)

**Examples**

```
(fm1 <- lmer(Reaction ~ Days + (Days | Subject), sleepstudy))

## will give you an additional column with p values for the t test
summary(fm1)

##using Kenward-Roger approximations to degrees of freedom
if(require(pbkrtest))
summary(fm1, ddf="Kenward-Roger")

#will give the summary of lme4 package
summary(fm1, ddf="lme4")
```

---

TVbo

*TV dataset*


---

**Description**

The TVbo dataset comes from Bang and Olufsen company. The main purpose was to test products, specified by two attributes Picture and TVset. 15 different response variables (characteristics of the product) were assessed by trained panel list.

**Usage**

TVbo

**Format**

Assessor factor: numbering identifying assessors

TVset factor: attribute of the product

Picture factor: attribute of the product

15 Characteristics of the product numeric variables: Coloursaturation, Colourbalance, Noise, Depth, Sharpness, Lightlevel, Contrast, Sharpnessofmovement, Flickeringstationary, Flickeringmovement, Distortion, Dimlasseffect, Cutting, Flossyedges, Elasticeffect

**Source**

Bang and Olufsen company

**Examples**

```
## import lme4 package and lmerTest package
library(lmerTest)

## Not run:
m <- lmer(Coloursaturation ~ TVset*Picture+
(1|Assessor)+(1|Assessor:TVset), data=TVbo)

step(m, test.offs="TVset", reduce.fixed=FALSE, reduce.random=TRUE)

## End(Not run)
```

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