

# Package ‘RLRsim’

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**Type** Package

**Title** Exact (Restricted) Likelihood Ratio Tests for Mixed and Additive Models

**Version** 3.1-6

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**Description** Rapid, simulation-based exact (restricted) likelihood ratio tests for testing the presence of variance components/nonparametric terms for models fit with nlme::lme(), lme4::lmer(), lmeTest::lmer(), gamm4::gamm4(), mgcv::gamm() and SemiPar::spm().

**License** GPL

**URL** <https://github.com/fabian-s/RLRsim>

**BugReports** <https://github.com/fabian-s/RLRsim/issues>

**Depends** R (>= 2.14.0)

**Imports** Rcpp (>= 0.11.1), lme4 (>= 1.1), mgcv, nlme

**LinkingTo** Rcpp

**Enhances** SemiPar, lmerTest

**RoxygenNote** 7.0.2

**NeedsCompilation** yes

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**Repository** CRAN

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RLRsim-package	<i>R package for fast and exact (restricted) likelihood ratio tests for mixed and additive models.</i>
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### Description

RLRsim implements fast simulation-based exact tests for variance components in mixed and additive models for conditionally Gaussian responses – i.e., tests for questions like:

- is the variance of my random intercept significantly different from 0?
- is this smooth effect significantly nonlinear?
- is this smooth effect significantly different from a constant effect?

The convenience functions `exactRLRT` and `exactLRT` can deal with fitted models from packages **lme4**, **nlme**, **gamm4**, **SemiPar** and from **mgcv**'s `gamm()`-function. Workhorse functions `LRTSim` and `RLRTSim` accept design matrices as inputs directly and can thus be used more generally to generate exact critical values for the corresponding (restricted) likelihood ratio tests.

The theory behind these tests was first developed in:

Crainiceanu, C. and Ruppert, D. (2004) **Likelihood ratio tests in linear mixed models with one variance component**, *Journal of the Royal Statistical Society: Series B*, **66**, 165–185.

Power analyses and sensitivity studies for **RLRsim** can be found in:

Scheipl, F., Greven, S. and Kuechenhoff, H. (2008) **Size and power of tests for a zero random effect variance or polynomial regression in additive and linear mixed models**. *Computational Statistics and Data Analysis*, **52**(7), 3283–3299.

### Author(s)

Fabian Scheipl (<fabian.scheipl@stat.uni-muenchen.de>), Ben Bolker

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exactLRT	<i>Likelihood Ratio Tests for simple linear mixed models</i>
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### Description

This function provides an exact likelihood ratio test based on simulated values from the finite sample distribution for simultaneous testing of the presence of the variance component and some restrictions of the fixed effects in a simple linear mixed model with known correlation structure of the random effect and i.i.d. errors.

**Usage**

```
exactLRT(
  m,
  m0,
  seed = NA,
  nsim = 10000,
  log.grid.hi = 8,
  log.grid.lo = -10,
  gridlength = 200,
  parallel = c("no", "multicore", "snow"),
  ncpus = 1L,
  cl = NULL
)
```

**Arguments**

<code>m</code>	The fitted model under the alternative; of class <code>lme</code> , <code>lmerMod</code> or <code>spm</code>
<code>m0</code>	The fitted model under the null hypothesis; of class <code>lm</code>
<code>seed</code>	Specify a seed for <code>set.seed</code>
<code>nsim</code>	Number of values to simulate
<code>log.grid.hi</code>	Lower value of the grid on the log scale. See <a href="#">exactLRT</a> .
<code>log.grid.lo</code>	Lower value of the grid on the log scale. See <a href="#">exactLRT</a> .
<code>gridlength</code>	Length of the grid. See <a href="#">LRTSim</a> .
<code>parallel</code>	The type of parallel operation to be used (if any). If missing, the default is "no parallelization".
<code>ncpus</code>	integer: number of processes to be used in parallel operation: typically one would chose this to the number of available CPUs. Defaults to 1, i.e., no parallelization.
<code>cl</code>	An optional parallel or snow cluster for use if <code>parallel = "snow"</code> . If not supplied, a cluster on the local machine is created for the duration of the call.

**Details**

The model under the alternative must be a linear mixed model  $y = X\beta + Zb + \varepsilon$  with a *single* random effect  $b$  with known correlation structure and error terms that are i.i.d. The hypothesis to be tested must be of the form

$$H_0 : \beta_{p+1-q} = \beta_{p+1-q}^0, \dots, \beta_p = \beta_p^0;$$

$$Var(b) = 0$$

versus

$$H_A : \beta_{p+1-q} \neq \beta_{p+1-q}^0 \text{ or } \dots$$

$$\text{or } \beta_p \neq \beta_p^0 \text{ or } Var(b) > 0$$

We use the exact finite sample distribution of the likelihood ratio test statistic as derived by Crainiceanu & Ruppert (2004).

**Value**

A list of class `hstest` containing the following components:

- `statistic` the observed likelihood ratio
- `p` p-value for the observed test statistic
- `method` a character string indicating what type of test was performed and how many values were simulated to determine the critical value
- `sample` the samples from the null distribution returned by [LRTSim](#)

**Author(s)**

Fabian Scheipl, updates for **lme4.0**-compatibility by Ben Bolker

**References**

Crainiceanu, C. and Ruppert, D. (2004) Likelihood ratio tests in linear mixed models with one variance component, *Journal of the Royal Statistical Society: Series B*, **66**, 165–185.

**See Also**

[LRTSim](#) for the underlying simulation algorithm; [RLRTSim](#) and [exactRLRT](#) for restricted likelihood based tests

**Examples**

```
library(nlme);
data(Orthodont);

##test for Sex:Age interaction and Subject-Intercept
mA<-lme(distance ~ Sex * I(age - 11), random = ~ 1| Subject,
  data = Orthodont, method = "ML")
m0<-lm(distance ~ Sex + I(age - 11), data = Orthodont)
summary(mA)
summary(m0)
exactLRT(m = mA, m0 = m0)
```

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exactRLRT

*Restricted Likelihood Ratio Tests for additive and linear mixed models*

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**Description**

This function provides an (exact) restricted likelihood ratio test based on simulated values from the finite sample distribution for testing whether the variance of a random effect is 0 in a linear mixed model with known correlation structure of the tested random effect and i.i.d. errors.

**Usage**

```

exactRLRT(
  m,
  mA = NULL,
  m0 = NULL,
  seed = NA,
  nsim = 10000,
  log.grid.hi = 8,
  log.grid.lo = -10,
  gridlength = 200,
  parallel = c("no", "multicore", "snow"),
  ncpus = 1L,
  cl = NULL
)

```

**Arguments**

<code>m</code>	The fitted model under the alternative or, for testing in models with multiple variance components, the reduced model containing only the random effect to be tested (see Details), an <code>lme</code> , <code>lmerMod</code> or <code>spm</code> object
<code>mA</code>	The full model under the alternative for testing in models with multiple variance components
<code>m0</code>	The model under the null for testing in models with multiple variance components
<code>seed</code>	input for <code>set.seed</code>
<code>nsim</code>	Number of values to simulate
<code>log.grid.hi</code>	Lower value of the grid on the log scale. See <a href="#">exactRLRT</a> .
<code>log.grid.lo</code>	Lower value of the grid on the log scale. See <a href="#">exactRLRT</a> .
<code>gridlength</code>	Length of the grid. See <a href="#">exactLRT</a> .
<code>parallel</code>	The type of parallel operation to be used (if any). If missing, the default is "no parallelization".
<code>ncpus</code>	integer: number of processes to be used in parallel operation: typically one would chose this to the number of available CPUs. Defaults to 1, i.e., no parallelization.
<code>cl</code>	An optional parallel or snow cluster for use if <code>parallel = "snow"</code> . If not supplied, a cluster on the local machine is created for the duration of the call.

**Details**

Testing in models with only a single variance component require only the first argument `m`. For testing in models with multiple variance components, the fitted model `m` must contain **only** the random effect set to zero under the null hypothesis, while `mA` and `m0` are the models under the alternative and the null, respectively. For models with a single variance component, the simulated distribution is exact if the number of parameters (fixed and random) is smaller than the number of observations. Extensive simulation studies (see second reference below) confirm that the application

of the test to models with multiple variance components is safe and the simulated distribution is correct as long as the number of parameters (fixed and random) is smaller than the number of observations and the nuisance variance components are not superfluous or very small. We use the finite sample distribution of the restricted likelihood ratio test statistic as derived by Crainiceanu & Ruppert (2004).

No simulation is performed if the observed test statistic is 0. (i.e., if the fit of the model fitted under the alternative is indistinguishable from the model fit under  $H_0$ ), since the p-value is always 1 in this case.

### Value

A list of class `htest` containing the following components:

A list of class `htest` containing the following components:

- `statistic` the observed likelihood ratio
- `p` p-value for the observed test statistic
- `method` a character string indicating what type of test was performed and how many values were simulated to determine the critical value
- `sample` the samples from the null distribution returned by [RLRTSim](#)

### Author(s)

Fabian Scheipl, bug fixes by Andrzej Galecki, updates for **lme4**-compatibility by Ben Bolker

### References

Crainiceanu, C. and Ruppert, D. (2004) Likelihood ratio tests in linear mixed models with one variance component, *Journal of the Royal Statistical Society: Series B*, **66**, 165–185.

Greven, S., Crainiceanu, C., Kuechenhoff, H., and Peters, A. (2008) Restricted Likelihood Ratio Testing for Zero Variance Components in Linear Mixed Models, *Journal of Computational and Graphical Statistics*, **17** (4): 870–891.

Scheipl, F., Greven, S. and Kuechenhoff, H. (2008) Size and power of tests for a zero random effect variance or polynomial regression in additive and linear mixed models. *Computational Statistics & Data Analysis*, **52**(7):3283–3299.

### See Also

[RLRTSim](#) for the underlying simulation algorithm; [exactLRT](#) for likelihood based tests

### Examples

```
data(sleepstudy, package = "lme4")
mA <- lme4::lmer(Reaction ~ I(Days-4.5) + (1|Subject) + (0 + I(Days-4.5)|Subject),
  data = sleepstudy)
m0 <- update(mA, . ~ . - (0 + I(Days-4.5)|Subject))
m.slope <- update(mA, . ~ . - (1|Subject))
#test for subject specific slopes:
```

```
exactRLRT(m.slope, mA, m0)

library(mgcv)
data(trees)
#test quadratic trend vs. smooth alternative
m.q<-gamm(I(log(Volume)) ~ Height + s(Girth, m = 3), data = trees,
  method = "REML")$lme
exactRLRT(m.q)
#test linear trend vs. smooth alternative
m.l<-gamm(I(log(Volume)) ~ Height + s(Girth, m = 2), data = trees,
  method = "REML")$lme
exactRLRT(m.l)
```

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extract.lmeDesign      *Extract the Design of a linear mixed model*

---

## Description

These functions extract various elements of the design of a fitted lme-, mer or lmerMod-Object. They are called by exactRLRT and exactLRT.

## Usage

```
extract.lmeDesign(m)
```

## Arguments

m                    a fitted lme- or merMod-Object

## Value

a a list with components

- Vr estimated covariance of the random effects divided by the estimated variance of the residuals
- X design of the fixed effects
- Z design of the random effects
- sigmasq variance of the residuals
- lambda ratios of the variances of the random effects and the variance of the residuals
- y response variable

## Author(s)

Fabian Scheipl, extract.lmerModDesign by Ben Bolker. Many thanks to Andrzej Galecki and Tomasz Burzykowski for bug fixes.

## Examples

```
library(nlme)
design <- extract.lmeDesign(lme(distance ~ age + Sex, data = Orthodont,
                             random = ~ 1))
str(design)
```

---

LRTSim

*Simulation of the (Restricted) Likelihood Ratio Statistic*


---

## Description

These functions simulate values from the (exact) finite sample distribution of the (restricted) likelihood ratio statistic for testing the presence of the variance component (and restrictions of the fixed effects) in a simple linear mixed model with known correlation structure of the random effect and i.i.d. errors. They are usually called by `exactLRT` or `exactRLRT`.

## Usage

```
LRTSim(
  X,
  Z,
  q,
  sqrt.Sigma,
  seed = NA,
  nsim = 10000,
  log.grid.hi = 8,
  log.grid.lo = -10,
  gridlength = 200,
  parallel = c("no", "multicore", "snow"),
  ncpus = 1L,
  cl = NULL
)
```

## Arguments

<code>X</code>	The fixed effects design matrix of the model under the alternative
<code>Z</code>	The random effects design matrix of the model under the alternative
<code>q</code>	The number of parameters restrictions on the fixed effects (see <a href="#">Details</a> )
<code>sqrt.Sigma</code>	The upper triangular Cholesky factor of the correlation matrix of the random effect
<code>seed</code>	Specify a seed for <code>set.seed</code>
<code>nsim</code>	Number of values to simulate
<code>log.grid.hi</code>	Lower value of the grid on the log scale. See <a href="#">Details</a>



<code>log.grid.lo</code>	Lower value of the grid on the log scale. See <b>Details</b>
<code>gridlength</code>	Length of the grid for the grid search over lambda. See <b>Details</b>
<code>parallel</code>	The type of parallel operation to be used (if any). If missing, the default is "no parallelization").
<code>ncpus</code>	integer: number of processes to be used in parallel operation: typically one would chose this to the number of available CPUs. Defaults to 1, i.e., no parallelization.
<code>cl</code>	An optional parallel or snow cluster for use if <code>parallel = "snow"</code> . If not supplied, a cluster on the local machine is created for the duration of the call.

### Details

The model under the alternative must be a linear mixed model  $y = X\beta + Zb + \varepsilon$  with a single random effect  $b$  with known correlation structure  $\Sigma$  and i.i.d errors. The simulated distribution of the likelihood ratio statistic was derived by Crainiceanu & Ruppert (2004). The simulation algorithm uses a grid search over a log-regular grid of values of  $\lambda = \frac{\text{Var}(b)}{\text{Var}(\varepsilon)}$  to maximize the likelihood under the alternative for `nsim` realizations of  $y$  drawn under the null hypothesis. `log.grid.hi` and `log.grid.lo` are the lower and upper limits of this grid on the log scale. `gridlength` is the number of points on the grid. These are just wrapper functions for the underlying C code.

### Value

A vector containing the the simulated values of the (R)LRT under the null, with attribute 'lambda' giving  $\arg \min(f(\lambda))$  (see Crainiceanu, Ruppert (2004)) for the simulations.

### Author(s)

Fabian Scheipl; parallelization code adapted from boot package

### References

- Crainiceanu, C. and Ruppert, D. (2004) Likelihood ratio tests in linear mixed models with one variance component, *Journal of the Royal Statistical Society: Series B*, **66**, 165–185.
- Scheipl, F. (2007) Testing for nonparametric terms and random effects in structured additive regression. Diploma thesis (unpublished).
- Scheipl, F., Greven, S. and Kuechenhoff, H (2008) Size and power of tests for a zero random effect variance or polynomial regression in additive and linear mixed models, *Computational Statistics & Data Analysis*, **52**(7):3283-3299

### See Also

[exactLRT](#), [exactRLRT](#) for tests

**Examples**

```
library(lme4)
g <- rep(1:10, e = 10)
x <- rnorm(100)
y <- 0.1 * x + rnorm(100)
m <- lmer(y ~ x + (1|g), REML=FALSE)
m0 <- lm(y ~ 1)

(obs.LRT <- 2*(logLik(m)-logLik(m0)))
X <- getME(m, "X")
Z <- t(as.matrix(getME(m, "Zt")))
sim.LRT <- LRTSim(X, Z, 1, diag(10))
(pval <- mean(sim.LRT > obs.LRT))
```

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