

Package ‘MANOVA.RM’

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Type Package

Title Analysis of Multivariate Data and Repeated Measures Designs

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Depends R (>= 3.4.0)

Description Implemented are various tests for semi-parametric repeated measures and general MANOVA designs that do neither assume multivariate normality nor covariance homogeneity, i.e., the procedures are applicable for a wide range of general multivariate factorial designs. Furthermore, post-hoc comparisons are provided for the multivariate analyses.

Friedrich, S., Konietschke, F. and Pauly, M. (2018) <arXiv:1801.08002>.

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Imports plyr (>= 1.8.3), MASS (>= 7.3-43), Matrix (>= 1.2-2), magic (>= 1.5-6), plotrix (>= 3.5-12), parallel, methods, ellipse, multcomp

LazyData TRUE

Suggests RGtk2 (>= 2.20.31), knitr, rmarkdown, HSAUR, tidy, GFD, testthat

RoxygenNote 6.1.0

VignetteBuilder knitr, rmarkdown

URL <http://github.com/smn74/MANOVA.RM>

BugReports <http://github.com/smn74/MANOVA.RM/issues>

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conf.reg	<i>The conf.reg() function calculates confidence regions for contrasts in multivariate factorial designs. In the two-dimensional case, confidence ellipsoids can be plotted via the generic plot() function.</i>
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Description

The conf.reg() function calculates confidence regions for contrasts in multivariate factorial designs. In the two-dimensional case, confidence ellipsoids can be plotted via the generic plot() function.

Usage

```
conf.reg(object, nullhypo)
```

Arguments

object	A MANOVA object.
nullhypo	In scenarios with more than one factor, the null hypothesis, i.e., the contrast of interest must be specified.

Value

A confreg object containing the following components:

center	The center of the confidence ellipsoid.
scale	The scaling factors for the axis of the confidence ellipsoid calculated as $\sqrt{\lambda * c/N}$, where λ are the eigenvalues, c denotes the bootstrap quantile and N is the total sample size. See Friedrich and Pauly (2018) for details.
eigenvectors	The corresponding eigenvectors, which determine the axes of the ellipsoid.

References

Friedrich, S., and Pauly, M. (2018). MATS: Inference for potentially singular and heteroscedastic MANOVA. *Journal of Multivariate Analysis*, 165, 166-179.

Examples

```
data(EEG)
EEG_mod <- MANOVA(resp ~ sex * diagnosis,
                  data = EEG, subject = "id", resampling = "paramBS",
                  alpha = 0.05, iter = 100, CPU = 1)
conf.reg(EEG_mod, nullhypo = "sex")
```

 EEG

EEG Measurements in Patients with Alzheimer's Disease (long format)

Description

At the Department of Neurology, University Clinic of Salzburg, 160 patients were diagnosed with either AD, MCI, or SCC, based on neuropsychological diagnostics. This data set contains z-scores for brain rate and Hjorth complexity, each measured at frontal, temporal and central electrode positions and averaged across hemispheres. In addition to standardization, complexity values were multiplied by -1 in order to make them more easily comparable to brain rate values: For brain rate we know that the values decrease with age and pathology, while Hjorth complexity values are known to increase with age and pathology. The three between-subjects factors considered were sex (men vs. women), diagnosis (AD vs. MCI vs. SCC), and age (< 70 vs. >= 70 years). Additionally, the within-subjects factors region (frontal, temporal, central) and feature (brain rate, complexity) structure the response vector.

Usage

```
data(EEG)
```

Format

A data frame with 960 rows and 7 variables:

resp EEG measurements

sex sex of the patient

age age of the patient, coded as 0 for less than 70 years and 1 for ≥ 70 years

diagnosis neuropsychological diagnosis, AD for Alzheimer's Disease, MCI for mild cognitive impairment or SCC for subjective cognitive complaints without clinically significant deficits

region brain region of the EEG measurements, one of "temporal", "frontal" and "central"

feature feature of the EEG measurements, either "brainrate" or "complexity"

id Subject id

Source

Bathke, A., Friedrich, S., Konietschke, F., Pauly, M., Staffen, W., Strobl, N. and Hoeller, Y. (2018). Testing Mean Differences among Groups: Multivariate and Repeated Measures Analysis with Minimal Assumptions. *Multivariate Behavioral Research*. Doi: 10.1080/00273171.2018.1446320.

EEGwide

EEG Measurements in Patients with Alzheimer's Disease (wide format)

Description

At the Department of Neurology, University Clinic of Salzburg, 160 patients were diagnosed with either AD, MCI, or SCC, based on neuropsychological diagnostics. This data set contains z-scores for brain rate and Hjorth complexity, each measured at frontal, temporal and central electrode positions and averaged across hemispheres. In addition to standardization, complexity values were multiplied by -1 in order to make them more easily comparable to brain rate values: For brain rate we know that the values decrease with age and pathology, while Hjorth complexity values are known to increase with age and pathology. The three between-subjects factors considered were sex (men vs. women), diagnosis (AD vs. MCI vs. SCC), and age (< 70 vs. ≥ 70 years). Additionally, the within-subjects factors region (frontal, temporal, central) and feature (brain rate, complexity) structure the response vector.

Usage

`data(EEGwide)`

Format

A data frame with 160 rows and 9 variables:

brainrate_temporal EEG measurements for brainrate in temporal regions

brainrate_frontal EEG measurements for brainrate in frontal regions

brainrate_central EEG measurements for brainrate in central regions
complexity_temporal EEG measurements for complexity in temporal regions
complexity_frontal EEG measurements for complexity in frontal regions
complexity_central EEG measurements for complexity in central regions
sex sex of the patient
age age of the patient
diagnosis neuropsychological diagnosis, AD for Alzheimer's Disease, MCI for mild cognitive impairment or SCC for subjective cognitive complaints without clinically significant deficits
AgeGroup categorized age, coded as 0 for less than 70 years and 1 for ≥ 70 years

Source

Bathke, A., Friedrich, S., Konietschke, F., Pauly, M., Staffen, W., Strobl, N. and Hoeller, Y. (2018). Testing Mean Differences among Groups: Multivariate and Repeated Measures Analysis with Minimal Assumptions. *Multivariate Behavioral Research*. Doi: 10.1080/00273171.2018.1446320.

GUI.MANOVA

A graphical user interface for the MANOVA() function

Description

This function provides a graphical user interface for calculating statistical tests for multivariate data.

Usage

GUI.MANOVA()

Details

The function produces a GUI for the calculation of the test statistics. Data can be loaded via the "load data" button. The formula, number of resampling iterations (default: 10,000) and the significance level alpha (default: 0.05) need to be specified. Furthermore, the column name specifying the subjects in the data needs to be provided. For the resampling methods, the user can choose between a parametric bootstrap approach (see e.g. Konietschke et al. (2015)) and a Wild bootstrap using Rademacher weights (see e.g. Bathke et al. (2016)).

`GUI.MANOVAwide`*A graphical user interface for the MANOVA.wide() function*

Description

This function provides a graphical user interface for calculating statistical tests for multivariate data.

Usage`GUI.MANOVAwide()`**Details**

The function produces a GUI for the calculation of the test statistics. Data can be loaded via the "load data" button. The formula, number of resampling iterations (default: 10,000) and the significance level alpha (default: 0.05) need to be specified. For the resampling methods, the user can choose between a parametric bootstrap approach (see e.g. Konietzschke et al. (2015)) and a Wild bootstrap using Rademacher weights (see e.g. Bathke et al. (2016)).

`GUI.RM`*A graphical user interface for the RM() function*

Description

This function provides a graphical user interface for calculating statistical tests in repeated measures designs.

Usage`GUI.RM()`**Details**

The function produces a GUI for the calculation of the test statistics and for plotting. Data can be loaded via the "load data" button. The formula, number of resampling iterations (default: 10,000) and the significance level alpha (default: 0.05) need to be specified. Furthermore, the number of sub-plot factors and the column name specifying the subjects in the data need to be provided. For the resampling methods, the user can choose between a permutation approach (Friedrich et al. (2017)), a parametric bootstrap approach (Konietzschke et al. (2015)) and a Wild bootstrap using Rademacher weights (Bathke et al. (2016)). If the plot option is chosen, an additional window opens containing information on the plots.

Description

The MANOVA function calculates the Wald-type statistic (WTS) and a modified ANOVA-type statistic (MATS) as well as resampling versions of these test statistics for semi-parametric multivariate data.

Usage

```
MANOVA(formula, data, subject, iter = 10000, alpha = 0.05,
       resampling = "paramBS", CPU, seed, nested.levels.unique = FALSE,
       dec = 3)
```

Arguments

formula	A model <code>formula</code> object. The left hand side contains the response variable and the right hand side contains the factor variables of interest. An interaction term must be specified.
data	A <code>data.frame</code> , list or environment containing the variables in <code>formula</code> . Data must be in long format and must not contain missing values.
subject	The column name of the subjects in the data.
iter	The number of iterations used for calculating the resampled statistic. The default option is 10,000.
alpha	A number specifying the significance level; the default is 0.05.
resampling	The resampling method to be used, one of "paramBS" (parametric bootstrap approach) and "WildBS" (wild bootstrap approach with Rademacher weights).
CPU	The number of cores used for parallel computing. If omitted, cores are detected via <code>detectCores</code> .
seed	A random seed for the resampling procedure. If omitted, no reproducible seed is set.
nested.levels.unique	A logical specifying whether the levels of the nested factor(s) are labeled uniquely or not. Default is FALSE, i.e., the levels of the nested factor are the same for each level of the main factor. For an example and more explanations see the GFD package and the corresponding vignette.
dec	Number of decimals the results should be rounded to. Default is 3.

Details

The `MANOVA()` function provides the Wald-type statistic (WTS) as well as the modified ANOVA-type statistic (MATS) for multivariate designs with metric data as described in Konietzke et al. (2015) and Friedrich and Pauly (2018), respectively. The MATS is invariant under scale transformations of the components and applicable to designs with singular covariance matrices. Both tests

are applicable for non-normal error terms, different sample sizes and/or heteroscedastic variances. They are implemented for designs with an arbitrary number of crossed factors or for nested designs. In addition to the asymptotic p-values, the function also provides p-values based on resampling approaches.

Value

A MANOVA object containing the following components:

Descriptive	Some descriptive statistics of the data for all factor level combinations. Displayed are the number of individuals per factor level combination and the vector of means (one column per dimension).
Covariance	The estimated covariance matrix.
WTS	The value of the WTS along with degrees of freedom of the central chi-square distribution and p-value.
MATS	The value of the MATS.
resampling	p-values for the test statistic based on the chosen resampling approach.

NOTE

The number of resampling iterations has been set to 10 in the examples due to run time restrictions on CRAN. Usually it is recommended to use at least 1000 iterations. For more information and detailed examples also refer to the package vignette.

References

- Konietschke, F., Bathke, A. C., Harrar, S. W. and Pauly, M. (2015). Parametric and nonparametric bootstrap methods for general MANOVA. *Journal of Multivariate Analysis*, 140, 291-301.
- Friedrich, S., Brunner, E. and Pauly, M. (2017). Permuting longitudinal data in spite of the dependencies. *Journal of Multivariate Analysis*, 153, 255-265.
- Bathke, A., Friedrich, S., Konietschke, F., Pauly, M., Staffen, W., Strobl, N. and Hoeller, Y. (2018). Testing Mean Differences among Groups: Multivariate and Repeated Measures Analysis with Minimal Assumptions. *Multivariate Behavioral Research*, 53(3), 348-359, Doi: 10.1080/00273171.2018.1446320.
- Friedrich, S., Konietschke, F., Pauly, M. (2017). GFD - An R-package for the Analysis of General Factorial Designs. *Journal of Statistical Software*, 79(1), 1-18.
- Friedrich, S., and Pauly, M. (2018). MATS: Inference for potentially singular and heteroscedastic MANOVA. *Journal of Multivariate Analysis*, 165, 166-179.

See Also

[RM](#)

Examples

```
data(EEG)
EEG_mod <- MANOVA(resp ~ sex * diagnosis,
                  data = EEG, subject = "id", resampling = "paramBS",
                  alpha = 0.05, iter = 10, CPU = 1)
```



```
summary(EEG_mod)
```

MANOVA.wide

Tests for Multivariate Data in Semi-Parametric Factorial Designs

Description

The MANOVA.wide function calculates the Wald-type statistic (WTS) and a modified ANOVA-type statistic (MATS) as well as resampling versions of these test statistics for semi-parametric multivariate data provided in wide format.

Usage

```
MANOVA.wide(formula, data, iter = 10000, alpha = 0.05,
  resampling = "paramBS", CPU, seed, nested.levels.unique = FALSE,
  dec = 3)
```

Arguments

formula	A model formula object. The left hand side contains the matrix of response variables and the right hand side contains the factor variables of interest. An interaction term must be specified.
data	A data.frame, list or environment containing the variables in formula. Data must be in wide format. Note: Lines containing missing values will be removed.
iter	The number of iterations used for calculating the resampled statistic. The default option is 10,000.
alpha	A number specifying the significance level; the default is 0.05.
resampling	The resampling method to be used, one of "paramBS" (parametric bootstrap approach) and "WildBS" (wild bootstrap approach with Rademacher weights). The Wild Bootstrap is calculated for all test statistics.
CPU	The number of cores used for parallel computing. If omitted, cores are detected via detectCores .
seed	A random seed for the resampling procedure. If omitted, no reproducible seed is set.
nested.levels.unique	A logical specifying whether the levels of the nested factor(s) are labeled uniquely or not. Default is FALSE, i.e., the levels of the nested factor are the same for each level of the main factor. For an example and more explanations see the GFD package and the corresponding vignette.
dec	Number of decimals the results should be rounded to. Default is 3.

Value

See [MANOVA](#)

NOTE

The number of resampling iterations has been set to 100 in the examples due to run time restrictions on CRAN. Usually it is recommended to use at least 1000 iterations.

See Also

[MANOVA](#)

Examples

```
#Example on producing plastic film from Krzanowski (1998, p. 381), see \link{manova.summary}
tear <- c(6.5, 6.2, 5.8, 6.5, 6.5, 6.9, 7.2, 6.9, 6.1, 6.3,
          6.7, 6.6, 7.2, 7.1, 6.8, 7.1, 7.0, 7.2, 7.5, 7.6)
gloss <- c(9.5, 9.9, 9.6, 9.6, 9.2, 9.1, 10.0, 9.9, 9.5, 9.4,
           9.1, 9.3, 8.3, 8.4, 8.5, 9.2, 8.8, 9.7, 10.1, 9.2)
opacity <- c(4.4, 6.4, 3.0, 4.1, 0.8, 5.7, 2.0, 3.9, 1.9, 5.7,
             2.8, 4.1, 3.8, 1.6, 3.4, 8.4, 5.2, 6.9, 2.7, 1.9)
rate    <- gl(2,10, labels = c("Low", "High"))
additive <- gl(2, 5, length = 20, labels = c("Low", "High"))
example <- data.frame(tear, gloss, opacity, rate, additive)
fit <- MANOVA.wide(cbind(tear, gloss, opacity) ~ rate * additive,
                  data = example, iter = 100, CPU = 1)
summary(fit)
```

MANOVARM

MANOVA.RM: A package for calculating test statistics and their resampling versions for heteroscedastic semi-parametric multivariate data or repeated measures designs.

Description

The MANOVA.RM package provides two important functions: `MANOVA()` and `RM()` which will be explained in detail below.

MANOVA and MANOVA.wide function

The `MANOVA()` and `MANOVA.wide()` functions provide the Wald-type statistic (WTS) as well as a modified ANOVA-type statistic (MATS) as in Friedrich and Pauly (2018) for multivariate designs with metric data as described in Konietzschke et al. (2015). These are applicable for non-normal error terms, different sample sizes and/or heteroscedastic variances. The MATS can even handle designs involving singular covariance matrices. The tests are implemented for designs with an arbitrary number of crossed factors or for nested designs. In addition to the asymptotic p-values, they also provide p-values based on resampling approaches (parametric or wild bootstrap). The difference between the two functions is the format of the data: For `MANOVA()`, the data needs to be in long format, while `MANOVA.wide()` is for data in wide format. For further details, see `MANOVA` and `MANOVA.wide`.

RM function

The RM() function provides the Wald-type statistic (WTS) as well as the ANOVA-type statistic (ATS) for repeated measures designs with metric data as described in Friedrich et al. (2017). These are even applicable for non-normal error terms and/or heteroscedastic variances. It is implemented for designs with an arbitrary number of whole-plot and sub-plot factors and allows for different sample sizes. In addition to the asymptotic p-values, it also provides p-values based on resampling approaches (Permutation, parametric bootstrap, Wild bootstrap). For further details, see RM.

References

- Konietschke, F., Bathke, A. C., Harrar, S. W. and Pauly, M. (2015). Parametric and nonparametric bootstrap methods for general MANOVA. *Journal of Multivariate Analysis*, 140, 291-301.
- Friedrich, S., Brunner, E. and Pauly, M. (2017). Permuting longitudinal data in spite of the dependencies. *Journal of Multivariate Analysis*, 153, 255-265.
- Friedrich, S., Konietschke, F., Pauly, M. (2016). GFD - An R-package for the Analysis of General Factorial Designs. *Journal of Statistical Software*, 79(1), 1-18.
- Bathke, A., Friedrich, S., Konietschke, F., Pauly, M., Staffen, W., Strobl, N. and Hoeller, Y. (2018). Testing Mean Differences among Groups: Multivariate and Repeated Measures Analysis with Minimal Assumptions. *Multivariate Behavioral Research*. Doi: 10.1080/00273171.2018.1446320.
- Friedrich, S., and Pauly, M. (2018). MATS: Inference for potentially singular and heteroscedastic MANOVA. *Journal of Multivariate Analysis*, 165, 166-179.

o2cons

Oxygen Consumption of Leukocytes

Description

A dataset containing measurements on the oxygen consumption of leukocytes in the presence and absence of inactivated staphylococci.

Usage

```
data(o2cons)
```

Format

A data frame with 144 rows and 5 variables:

O2 oxygen consumption of leukocytes in μl

Staphylococci whether or not inactivated staphylococci were added, 1 denotes yes, 0 no

Time the measurements were taken after 6, 12 and 18 minutes

Group the treatment group, either P for Placebo or V for Verum

Subject the subject id

Source

Friedrich, S., Brunner, E. & Pauly, M. (2017). Permuting longitudinal data in spite of the dependencies. *Journal of Multivariate Analysis*, 153, 255-265.

plot.RM	<i>Plot function for an RM object</i>
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Description

Generic plot function for RM objects: Returns a plot of the mean values along with confidence intervals for a factor (combination) specified by the user.

Usage

```
## S3 method for class 'RM'
plot(x, CI.info = FALSE, ...)
```

Arguments

x	An object of class RM
CI.info	If CI.info = TRUE, the mean values and confidence limits of the considered contrast are printed.
...	Additional parameters to be passed to plot()

Details

An additional argument factor can be used to specify the factor(s) used for plotting in two- and higher-way layouts. See the examples for details.

print.MANOVA	<i>Display MANOVA object</i>
--------------	------------------------------

Description

Returns a short summary of the results (test statistics with p-values)

Usage

```
## S3 method for class 'MANOVA'
print(x, ...)
```

Arguments

x	A MANOVA object
...	Additional parameters (currently not used)

print.RM	<i>Display an RM object</i>
----------	-----------------------------

Description

Returns a short summary of the results (test statistics with p-values)

Usage

```
## S3 method for class 'RM'
print(x, ...)
```

Arguments

x	An RM object
...	Additional parameters (currently not used)

RM	<i>Tests for Repeated Measures in Semi-Parametric Factorial Designs</i>
----	---

Description

The RM() function calculates the Wald-type statistic (WTS), the ANOVA-type statistic (ATS) as well as resampling versions of these test statistics for semi-parametric repeated measures designs.

Usage

```
RM(formula, data, subject, no.subf = 1, iter = 10000, alpha = 0.05,
    resampling = "Perm", CPU, seed, CI.method = "t-quantile", dec = 3)
```

Arguments

formula	A model formula object. The left hand side contains the response variable and the right hand side contains the factor variables of interest. An interaction term must be specified. The time variable must be the last factor in the formula.
data	A data.frame, list or environment containing the variables in formula. Data must be in long format and must not contain missing values.
subject	The column name of the subjects in the data.
no.subf	The number of sub-plot factors in the data, default is 1.
iter	The number of iterations used for calculating the resampled statistic. The default option is 10,000.
alpha	A number specifying the significance level; the default is 0.05.

resampling	The resampling method to be used, one of "Perm" (randomly permute all observations), "paramBS" (parametric bootstrap approach) and "WildBS" (wild bootstrap approach with Rademacher weights). Except for the Wild Bootstrap, all methods are applied to the WTS only.
CPU	The number of cores used for parallel computing. If omitted, cores are detected via <code>detectCores</code> .
seed	A random seed for the resampling procedure. If omitted, no reproducible seed is set.
CI.method	The method for calculating the quantiles used for the confidence intervals, either "t-quantile" (the default) or "resampling" (the quantile of the resampled WTS).
dec	Number of decimals the results should be rounded to. Default is 3.

Details

The `RM()` function provides the Wald-type statistic as well as the ANOVA-type statistic for repeated measures designs with metric data as described in Friedrich et al. (2017). These are even applicable for non-normal error terms and/or heteroscedastic variances. It is implemented for designs with an arbitrary number of between-subject (whole-plot) and within-subject (sub-plot) factors and allows for different sample sizes. In addition to the asymptotic p-values, it also provides p-values based on resampling approaches. NOTE: The number of within-subject factors needs to be specified in the function call. If only one factor is present, it is assumed that this is a within-subjects factor (e.g. time).

Value

An RM object containing the following components:

Descriptive	Some descriptive statistics of the data for all factor level combinations. Displayed are the number of individuals per factor level combination, the mean and $100 \cdot (1 - \alpha)\%$ confidence intervals (based on t-quantiles).
Covariance	The estimated covariance matrix.
WTS	The value of the WTS along with degrees of freedom of the central chi-square distribution and corresponding p-value.
ATS	The value of the ATS, degrees of freedom of the central F distribution and the corresponding p-value.
resampling	p-values for the test statistics based on the chosen resampling approach.

References

- Friedrich, S., Brunner, E. and Pauly, M. (2017). Permuting longitudinal data in spite of the dependencies. *Journal of Multivariate Analysis*, 153, 255-265.
- Bathke, A., Friedrich, S., Konietschke, F., Pauly, M., Staffen, W., Strobl, N. and Hoeller, Y. (2018). Testing Mean Differences among Groups: Multivariate and Repeated Measures Analysis with Minimal Assumptions. *Multivariate Behavioral Research*, 53(3), 348-359, Doi: 10.1080/00273171.2018.1446320.
- Friedrich, S., Konietschke, F., Pauly, M. (2017). GFD - An R-package for the Analysis of General Factorial Designs. *Journal of Statistical Software*, 79(1), 1-18.

See Also

[GFD](#), [nparLD](#), [MANOVA](#)

Examples

```
data(o2cons)
## Not run:
oxy <- RM(O2 ~ Group * Staphylococci * Time, data = o2cons,
          subject = "Subject", no.subf = 2, iter = 1000, resampling = "Perm", CPU = 1)
summary(oxy)
plot(oxy, factor = "Group")

# For more details including the output of the examples also refer to the
# package vignette.

# using the EEG data, consider additional within-subjects factors 'brain region'
# and 'feature'
data(EEG)
EEG_model <- RM(resp ~ sex * diagnosis * feature * region,
                data = EEG, subject = "id", no.subf = 2, resampling = "WildBS",
                iter = 1000, alpha = 0.01, CPU = 4, seed = 987, dec = 2)
summary(EEG_model)

## End(Not run)
```

simCI

Multivariate post-hoc comparisons and simultaneous confidence intervals for contrasts in multivariate factorial designs

Description

Multivariate post-hoc comparisons and simultaneous confidence intervals for contrasts in multivariate factorial designs

Usage

```
simCI(object, contrast = c("pairwise", "user-defined"), contmat = NULL,
      type = NULL, base = 1, ...)
```

Arguments

object	A MANOVA object.
contrast	The contrast matrix of interest, can either be "pairwise" or "user-defined".
contmat	If contrast = "user-defined", the contrast matrix must be specified here. Note that its rows must sum to zero.

type	If contrast is "pairwise", the type of the pairwise comparison must be specified here. Calculation is based on the <code>contrMat</code> function in package <code>multcomp</code> , see the corresponding help page for details on the types of contrasts available.
base	an interger specifying which group is considered the baseline group for Dunnett contrasts, see <code>contrMat</code> .
...	Not used yet.

Details

The `simCI()` function computes the multivariate p-values for the chosen contrast of the multivariate mean vector based on the bootstrap version of the sum statistic. Details on this test can be found in Friedrich and Pauly (2018). Furthermore, confidence intervals for summary effects (i.e., averaged over each dimension), also based on the bootstrap version of the sum statistic, are returned as well.

Value

Multivariate p-values and simultaneous confidence intervals for the chosen contrasts.

References

Friedrich, S., and Pauly, M. (2018). MATS: Inference for potentially singular and heteroscedastic MANOVA. *Journal of Multivariate Analysis*, 165, 166-179.

See Also

[contrMat](#)

summary.MANOVA

Summarizing a MANOVA object

Description

Returns a summary of the results including mean vectors and sample sizes for all groups as well as test statistics with degrees of freedom and p-values

Usage

```
## S3 method for class 'MANOVA'
summary(object, ...)
```

Arguments

object	A MANOVA object
...	Additional parameters (currently not used)

`summary.RM`*Summarizing an RM object*

Description

Returns a summary of the results including mean values, variances and sample sizes for all groups as well as test statistics with degrees of freedom and p-values

Usage

```
## S3 method for class 'RM'  
summary(object, ...)
```

Arguments

<code>object</code>	An RM object
<code>...</code>	Additional parameters (currently not used)

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