Package ‘CMHNPA’

July 21, 2025

Type Package

Title Cochran-Mantel-Haenszel and Nonparametric ANOVA

Version 1.1.1

Description Cochran-Mantel-Haenszel methods (Cochran (1954) <doi:10.2307/3001616>; Mantel and Haenszel (1959) <doi:10.1093/jnci/22.4.719>; Landis et al. (1978) <doi:10.2307/1402373>) are a suite of tests applicable to categorical data. A competitor to those tests is the procedure of Nonparametric ANOVA which was initially introduced in Rayner and Best (2013) <doi:10.1111/anzs.12041>. The methodology was then extended in Rayner et al. (2015) <doi:10.1111/anzs.12113>. This package employs functions related to both methodologies and serves as an accompaniment to the book: An Introduction to Cochran–Mantel–Haenszel and Non-Parametric ANOVA. The package also contains the data sets used in that text.

License GPL-3

Encoding UTF-8

LazyData true

Depends R (>= 2.10)

RoxygenNote 7.2.1

Imports methods, MASS, car

NeedsCompilation no

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Repository CRAN

Date/Publication 2023-02-08 21:00:05 UTC

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`ARL` *ARL Test*

Description

`ARL` returns the test statistic and p-value for the aligned RL test.

Usage

```
ARL(y, treatment, block1, block2)
```

Arguments

`y`	a numeric vector for the response variable.
`treatment`	a vector giving the treatment type for the corresponding elements of `y`.
`block1`	a vector giving the first blocking variable for the corresponding elements of `y`.
`block2`	a vector giving the second blocking variable for the corresponding elements of `y`.

Details

This test is applicable to Latin square designs. The test is not recommended though as the use of t-1 degrees of freedom in the null distribution results in unsatisfactorily large test sizes.

The `CARL` test uses t+1 degrees of freedom in the null distribution which results is appropriate test size and good power.

Value

A list containing the ARL test statistic adjusted for ties together with the associated p-value using a chi-squared distribution with t-1 degrees of freedom.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

See Also

`CARL()` `PARL()`

Examples

```
attach(peanuts)
ARL(y = yield, treatment = treatment, block1 = row, block2 = col)
```

`asbestos` *Asbestos data*

Description

A data set showing individuals' grade of asbestosis together with their length of expposure to asbestos.

Usage

```
data(asbestos)
```

Format

A data frame with 1117 rows and two columns.

exposure a factor representing the number of years of exposure to asbestos

grade a factor representing the grade of asbestosis. Grade 0 represents none present

Details

Irving J. Selikoff (1915–1992) was a chest physician and researcher who had often been described as America's foremost medical expert on asbestos related diseases between the 1960s and the early 1990s.

Through a lung clinic that he operated in New Jersey, Selikoff collected data from a sample of around 1200 insulation workers in metropolitan New York in 1963.

Source

Selikoff IJ. Household risks with inorganic fibers. Bull N Y Acad Med. 1981 Dec;57(10):947-61.

References

Selikoff IJ. Household risks with inorganic fibers. Bull N Y Acad Med. 1981 Dec;57(10):947-61.

Examples

```
attach(asbestos)
KW(treatment = exposure, response = grade)
```

CARL *CARL Test*

Description

CARL returns the test statistic and p-value for the aligned RL test with empirically fitted degrees of freedom.

Usage

```
CARL(
  y,
  treatment,
  block1,
  block2,
  n_components = 0,
  n_permutations = 0,
  treatment_scores = NULL,
  sig_digits = 4,
  verbose = FALSE
)
```

Arguments

- `y` — a numeric vector for the response variable.
- `treatment` — a vector giving the treatment type for the corresponding elements of `y`.
- `block1` — a vector giving the first blocking variable for the corresponding elements of `y`.
- `block2` — a vector giving the second blocking variable for the corresponding elements of `y`.
- `n_components` — the number of polynomial components you wish to test. The maximum number of components is the number of treatments less one. If the number of components requested is less than `t-2`, a remainder component is created.
- `n_permutations` — the number of permutations you wish to run.
- `treatment_scores` — the scores to be applied to the treatment groups. If not declared these will be set automatically and should be checked.
- `sig_digits` — the number of significant digits the output should show.
- `verbose` — flag for turning on the status bar for permutation tests.

Details

This test is applicable to Latin square designs and is recommended over the RL and ARL test. The test uses t+1 as the degrees of freedom of the chi-squared null distribution and results in appropriate test sizes as well as good power.

Value

The `CARL` test statistic adjusted for ties together with the associated p-value using a chi-squared distribution with t+1 degrees of freedom.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

See Also

`ARL()` `PARL()`

Examples

```
attach(peanuts)
CARL(y = yield, treatment = treatment, block1 = row, block2 = col)
```

`cereal` *Cereal data*

Description

Each of five breakfast cereals are ranked by ten judges, who each taste three cereals. Each cereal is assessed six times.

Usage

```
data(cereal)
```

Format

A data frame with 30 rows and three columns.

rank the rank of the cereal within each judge block

judge the judge that was used

type the type of cereal

Details

The data comes from a Balanced Incomplete Block Design with the number of treatments t = 5, number of blocks b = 10, with k = 3 and r = 6.

Source

Kutner et al. (2005, section 28.1)

References

Kutner, M., Nachtsheim, C., Neter, J. and Li, W. (2005). Applied linear statistical models (5th ed.). Boston: McGraw-Hill Irwin.

Examples

```
attach(cereal)
durbin(y = rank, groups = type, blocks = judge)
```

CMH *CMH Test*

Description

CMH returns the test statistics and p-values for the four CMH tests.

Usage

```
CMH(
  treatment,
  response,
  strata = NULL,
  a_ij = NULL,
  b_hj = NULL,
  test_OPA = TRUE,
  test_GA = TRUE,
  test_MS = TRUE,
  test_C = TRUE,
  cor_breakdown = TRUE
)
```

Arguments

treatment	a factor vector representing the treatment applied.
response	a factor vector giving the response category for the corresponding elements of treatment.
strata	a factor vector giving the strata or block for the corresponding elements of treatment and response.
a_ij	a t x b matrix of treatment scores. The matrix allows for different scores to be used over different strata. If a t x 1 vector of scores is provided, it is assumed that the scores are the same across strata and a warning provided.
b_hj	a c x b matrix of response scores. The matrix allows for different scores to be used over different strata. If a c x 1 vector of scores is provided, it is assumed that the scores are the same across strata and a warning provided.
test_OPA	TRUE or FALSE flag to include the calculation of the OPA test values.
test_GA	TRUE or FALSE flag to include the calculation of the GA test values.
test_MS	TRUE or FALSE flag to include the calculation of the MS test values. If response scores are not included, this test will not be performed.
test_C	TRUE or FALSE flag to include the calculation of the C test values. If response scores and treatment scores are not included, this test will not be performed.
cor_breakdown	TRUE or FALSE flag to indicate if a correlation breakdown over the strata is required.

Details

Provided the required information is used in the function, the function will return all four CMH test results.

Value

The CMH test results for the four tests assuming the required information is supplied.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
CMH(treatment = marriage$religion, response = marriage$opinion,
strata = marriage$education, test_OPA = FALSE, test_MS = FALSE)
```

---

corn *Corn data*

Description

Corn yields when grown by four different methods.

Usage

```
data(corn)
```

Format

A data frame with 34 rows and two columns.

method one of four different methods used to grow corn

outcome corn yield categorised into four levels

Source

Rayner and Best (2001)

References

Rayner, J.C.W. and Best, D.J. (2001). A Contingency Table Approach to Nonparametric Testing. Chapman & Hall/CRC: Boca Raton FL.

Examples

```
attach(corn)
KW(treatment = method, response = outcome)
```

`crossover` *Cross-over data*

Description

A success or fail response variable with three treatments repeated over 11 patients.

Usage

```
data(crossover)
```

Format

A data frame with 33 rows and three columns.

treatment the type of treatment applied. The three treatments are placebo, aspirin and a new drug

success whether the treatment was a success or not

patient the patient the treatment was applied to

Details

In StatXact (2003), three treatment, three period cross-over clinical data for 11 patients are given. This is a CMH design with t = 3, c = 2, and b = 11.

Source

StatXact (2003)

References

StatXact (2003). User Manual Volume 2. CYTEL Software.

Examples

```
attach(crossover)
CMH(treatment = treatment,response = success,strata = patient)
```

`durbin` *Durbin Test*

Description

`durbin` returns the results of Durbin's Rank Sum test.

Usage

```
durbin(
  y,
  groups,
  blocks,
  n_components = 0,
  n_permutations = 0,
  group_scores = NULL,
  sig_digits = 4,
  verbose = FALSE
)
```

Arguments

`y`	a numeric vector for the response variable.
`groups`	a vector giving the group for the corresponding elements of `y`.
`blocks`	a vector giving the block for the corresponding elements of `y`.
`n_components`	the number of polynomial components you wish to test. The maximum number of components is the number of groups less one. If the number of components requested is less than `t-2`, a remainder component is created.
`n_permutations`	the number of permutations you wish to run.
`group_scores`	the scores to be applied to the groups. If not declared these will be set automatically and should be checked.
`sig_digits`	the number of significant digits the output should show.
`verbose`	flag for turning on the status bar for permutation tests.

Details

The test is a generalisation of Friedman's test that can be applied to BIBD.

Value

The Durbin test adjusted for tied results.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(icecream)
durbin(y = rank, groups = variety, blocks = judge)
```

`dynamite` *Dynamite data*

Description

A data set for the explosiveness of five different formulations of explosive.

Usage

```
data(dynamite)
```

Format

A data frame with 25 rows and four columns.

response a numeric vector for the explosiveness of the formulation with corresponding `treatment`, `batch` and `operator`

treatment a factor distinguishing the formulation for the explosive mixture

batch a factor describing the batch the raw materials come from

operator a factor describing the operator who prepares the explosive formulation

Details

The effect of five different formulations of an explosive mixture are assessed. A batch of raw material is large enough for only five formulations. Each formulation is prepared by five operators. The response here is the explosiveness of dynamite formulations. This is a Latin square design.

Source

https://www.fox.temple.edu/cms/wp-content/uploads/2016/05/Randomized-Block-Design.pdf

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(dynamite)
CARL(y = response, treatment = treatment, block1 = batch, block2 = operator)
```

food	*Food data*

Description

Categorical responses made by 15 subjects for two different prices of the same food product. The data is from a CMH design.

Usage

```
data(food)
```

Format

A data frame with 30 rows and three columns.

price a factor showing two price points for the product

decision a factor indicating the decision of either buy, undecided, or not_buy the product

subject a factor showing the individual making a decison about the product

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(food)
b_hj = matrix(1:3,ncol=15,nrow=3)
CMH(treatment = price, response = decision, strata = subject, b_hj = b_hj,
test_OPA = FALSE, test_C = FALSE)
```

friedman	*Friedman Test*

Description

`friedman` returns the test statistic and p-value for the Friedman test.

Usage

```
friedman(
  y,
  groups,
  blocks,
  n_components = 0,
  n_permutations = 0,
  group_scores = NULL,
  sig_digits = 4,
  verbose = FALSE
)
```

Arguments

`y`	a numeric vector for the response variable.
`groups`	a vector giving the group for the corresponding elements of `y`.
`blocks`	a vector giving the block for the corresponding elements of `y`.
`n_components`	the number of polynomial components you wish to test. The maximum number of components is the number of groups less one. If the number of components requested is less than `t-2`, a remainder component is created.
`n_permutations`	the number of permutations you wish to run.
`group_scores`	the scores to be applied to the groups. If not declared these will be set automatically and should be checked.
`sig_digits`	the number of significant digits the output should show.
`verbose`	flag for turning on the status bar for permutation tests.

Value

The Friedman test results statistic adjusted for ties together with the associated p-value.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(jam)
friedman(y = sweetness_ranks, groups = type, blocks = judge)
```

gen_cor *gen_cor Test*

Description

gen_cor returns the generalised correlations and associated p-values together with tests of normality.

Usage

```
gen_cor(
  x,
  y,
  z = NULL,
  U,
  V,
  W = NULL,
  x_scores = NULL,
  y_scores = NULL,
  z_scores = NULL,
  n_perms = 0,
  perms_info = FALSE,
  rounding = 4
)
```

Arguments

x	a numeric vector or factor, commonly a response variable.
y	a numeric vector or factor, commonly a treatment variable.
z	an optional numeric vector or factor, commonly a block variable.
U	the maximum degree of correlation relating to the variable x.
V	the maximum degree of correlation relating to the variable y.
W	the maximum degree of correlation relating to the variable z. Required when z is included.
x_scores	optional scores related to the variable x.
y_scores	optional scores related to the variable y.
z_scores	optional scores related to the variable z.
n_perms	an optional numeric value indicating the number of permutations required.
perms_info	a TRUE of FALSE flag to indicate whether information regarding the progress on the number of permutations should be printed.
rounding	the number of decimal places the output should be rounded to. The default is 4.

Details

This function calculates up to three way generalised correlations. The function calculates three tests by default to test if the correlations are statistically significantly different from 0 with an option to run permuation testing.

Value

This function calculates the generalised correlations for up to three input variables.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(intelligence)
gen_cor(x = rank(score), y = age, U = 2, V = 2)
```

---

hr *HR data*

Description

Human resource ranking data.

Usage

```
data(hr)
```

Format

A data frame with 50 rows and three columns.

applicant the applicant to which ratings are applied

applicant_ranking the ranking from made by the committee member

committee_member member of the selection panel that ranks five candidates

Details

Applications for a position are vetted and ranked by Human Resource (HR) professionals. The top five are interviewed by a selection committee of ten. Each member of the committee gives an initial ranking of the applicants and no one on the committee sees either the ranking by the HR professionals or the initial rankings of the other committee members. Ties are not permitted in any ranking. It is of interest to know if the rankings of the HR professionals and the initial rankings of the selection committee are correlated.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(hr)
a_ij = matrix(1:5,ncol=10,nrow=5)
b_hj = matrix(1:5,ncol=10,nrow=5)
CMH(treatment = applicant, response = applicant_ranking,
    strata = committee_member, a_ij = a_ij, b_hj = b_hj,
    test_OPA = FALSE, test_GA = FALSE, test_MS = FALSE)
```

---

icecream *Ice Cream data*

Description

Ice Cream data

Usage

```
data(icecream)
```

Format

A data frame with 21 rows and three columns.

rank the rank of the ice cream within each judging block

judge the judge that was used

variety the type of ice cream that was tested

Details

The icecream data set comes from a Balanced Incomplete Block Design. There are seven vanilla ice-creams that are the same except for increasing amounts of vanilla flavouring. Seven judges each taste three varieties.

Source

Table 5.1 in Conover (1998, p. 391).

References

Conover, W. J. (1998). Practical nonparametric statistics (3rd ed.). New York: Wiley. Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(icecream)
durbin(y = rank, groups = variety, blocks = judge)
```

`intelligence` *Intelligence data*

Description

Intelligence scores for individuals from different age groups.

Usage

```
data(intelligence)
```

Format

A data frame with 15 rows and two columns.

age age of the respondents

score intelligence score achieved

Source

Rayner and Best (2001, section 8.1)

References

Rayner, J. C. W. and Best, D. J. (2001). A Contingency Table Approach to Nonparametric Testing. Boca Raton: Chapman & Hall/CRC.

Examples

```
attach(intelligence)
gen_cor(x = rank(score), y = age, U = 2, V = 2)
```

jam — *Jam data*

Description

Plum jam sweetness data based on JAR judge scores.

Usage

```
data(jam)
```

Format

A data frame with 24 rows and four columns.

type the type of jam that was tested

judge the judge that was used for tasting

sweetness the judges score for sweetness: 1 denotes not sweet enough, 2 not quite sweet enough, 3 just about right, 4 a little too sweet and 5 too sweet

sweetness_ranks the ranks within judge

Details

Three plum jams, A, B and C are given JAR sweetness codes by eight judges. Here, 1 denotes not sweet enough, 2 not quite sweet enough, 3 just about right, 4 a little too sweet and 5 too sweet.

Source

Rayner and Best (2017, 2018)

References

Rayner, J.C.W. and Best, D.J. (2017). Unconditional analogues of Cochran-Mantel-Haenszel tests. Australian & NZ Journal of Statistics, 59(4), 485-494.

Rayner, J.C.W. and Best, D.J. (2018). Extensions to the Cochran-Mantel-Haenszel mean scores and correlation tests. Journal of Statistical Theory and Practice.

Examples

```
attach(jam)
a_ij = matrix(rep(1:3,8), ncol = 8)
b_hj = matrix(rep(1:5,8), ncol = 8)
CMH(treatment = type, response = sweetness, strata = judge,
    a_ij = a_ij, b_hj = b_hj, test_OPA = FALSE, test_GA = FALSE,
    test_MS = FALSE)
```

job_satisfaction *Job Satisfaction data*

Description

Job satisfaction data based on income and gender.

Usage

```
data(job_satisfaction)
```

Format

A data frame with 104 rows and three columns.

income income level categorised

satisfaction the level of job satisfaction for the respondent

gender gender of the respondent

Details

The data relate job satisfaction and income in males and females. Gender induces two strata; the treatments are income with categories scored 3, 10, 20 and 35 while the response is job satisfaction with categories scored 1, 3, 4, and 5.

Source

Agresti (2003)

References

Agresti, A. (2003). Categorical Data Analysis. Hoboken: John Wiley & Sons.

Examples

```
attach(job_satisfaction)
a_ij = matrix(rep(c(3,10,20,35),2),nrow=4)
b_hj = matrix(rep(c(1,3,4,5),2),nrow=4)
unconditional_CMH(treatment = income, response = satisfaction,
strata = gender, U = 2, V = 2, a_ij = a_ij,
b_hj = b_hj)
```

KW *KW*

Description

KW returns the test statistic and p-value for the Kruskal-Wallis test adjusted for ties.

Usage

```
KW(
  treatment,
  response,
  n_components = 0,
  n_permutations = 0,
  treatment_scores = NULL,
  sig_digits = 4,
  verbose = FALSE
)
```

Arguments

treatment	a factor that defines the group the response belongs to.
response	a numeric variable measuring the response outcome.
n_components	the number of polynomial components you wish to test. The maximum number of components is the number of treatments less one. If the number of components requested is less than t-2, a remainder component is created.
n_permutations	the number of permutations you wish to run.
treatment_scores	the scores to be applied to the treatment groups. If not declared these will be set automatically and should be checked.
sig_digits	the number of significant digits the output should show.
verbose	flag for turning on the status bar for permutation tests.

Details

The Kruskal-Wallis test is a non-parametric equivalent to the one way ANOVA.

Value

The function returns the test result of the Kruskal Wallis test with adjustment for ties and without.

References

Rayner, J.C.W and Livingston Jr, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(whiskey)
KW(treatment = maturity, response = grade)
```

`lemonade` *Lemonade data*

Description

The Lemonade data set comes from a Randomised Block Design. There are four types of lemonades which are all tasted by five tasters.

Usage

```
data(lemonade)
```

Format

A data frame with 20 rows and three columns.

rank the rank of the lemonade within each judging block

type the type of lemonade that was tested

taster the judge that was used for tasting

Source

Thas et al. (2012, section 4.2)

References

Thas, O., Best, D.J. and Rayner, J.C.W. (2012). Using orthogonal trend contrasts for testing ranked data with ordered alternatives. Statisticia Neerlandica, 66(4), 452-471.

Examples

```
attach(lemonade)
friedman(y = rank, groups = type, blocks = taster)
```

lemonade_sugar — *Lemonade Sugar data*

Description

Five lemonades with increasing sugar content are ranked by each of ten judges. They were not permitted to give tied outcomes. This is a randomised block design.

Usage

```
data(lemonade_sugar)
```

Format

A data frame with 50 rows and three columns.

ranks the rank each lemonade based on sugar content

sugar_content type of lemonade ordered by sugar content

judge the judge providing the ranking

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(lemonade_sugar)
gen_cor(x = ranks, y = sugar_content, U = 3, V = 3, rounding = 3)
```

lizard — *Lizard data*

Description

The data come from Manly (2007) and relate to the number of ants consumed by two sizes of Eastern Horned Lizards over a four month period.

Usage

```
data(lizard)
```

Format

A data frame with 24 rows and three columns.

month the month in which the measurements were taken

size the size of the Eastern Horned Lizards

ants the number of ants consumed

Source

Manly (2007)

References

Manly, B. F. J. (2007). Randomization, Bootstrap and Monte Carlo Methods in Biology, Third Edition. Boca Raton: Chapman & Hall/CRC.

Examples

```
attach(lizard)
gen_cor(x = ants, y = month, z = size, U = 3, V = 3, W = 1)
```

`marriage` *Marriage data*

Description

Scores of 1, 2 and 3 are assigned to the responses agree, neutral and disagree respectively to the proposition "Homosexuals should be able to marry" and scores of 1, 2 and 3 are assigned to the religious categories fundamentalist, moderate and liberal respectively.

Usage

```
data(marriage)
```

Format

A data frame with 133 rows and three columns.

education highest level of eduction for the respondent

religion level of religiosity. Scores of 1, 2 and 3 are assigned to the religious categories fundamentalist, moderate and liberal respectively

opinion the response to the proposition: "Homosexuals should be able to marry". Scores of 1, 2 and 3 are assigned to the responses agree, neutral and disagree respectively

Source

Agresti (2002)

References

Agresti, A. (2002). Categorical Data Analysis, 2nd ed; Wiley: New York.

Examples

```
attach(marriage)
lm(as.numeric(opinion)~religion+education)
```

---

milk *Milk data*

Description

In each of four lactation periods each of four cows are fed a different diet. There is a washout period so previous diet does not affect future results. A 4×4 Latin square is used to assess how diet affects milk production.

Usage

```
data(milk)
```

Format

A data frame with 16 rows and four columns.

production a numerical measure of the milk production for the given diet, cow, and period

diet a factor showing which diet the cow was administered

cow a factor indicating the cow

period a factor showing the relevant period

Source

https://www.stat.purdue.edu/~yuzhu/stat514fall05/Lecnot/latinsquarefall05.pdf

Examples

```
attach(milk)
CARL(y = production, treatment = diet, block1 = cow, block2 = period)
```

`mu_r` *mu_r*

Description

`mu_r` returns the estimated rth moment of a vector.

Usage

```
mu_r(x, r)
```

Arguments

`x`	a numeric vector.
`r`	the degree moment requiring calculation

Value

Returns the estimated rth moment of a vector.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
x_vec = rnorm(10)
mu_r(x_vec,2)
```

`np_anova` *np_anova function*

Description

`np_anova` performs a nonparametric ANOVA.

Usage

```
np_anova(ordered_vars, predictor_vars, uvw)
```

Arguments

`ordered_vars`	a data frame for the ordered variables being assessed.
`predictor_vars`	a data frame for the un-ordered variables being assessed.
`uvw`	the degree being assessed. This should be a vector with length equal the number of elements in the `ordered_vars` data frame.

Details

Nonparametric ANOVA is a methodology that is applicable where one as an ordered response variable as well as both ordered response and predictor variables.

Value

Where there is only one ordered variable, the function returns a type III ANOVA table to test for differences of order `uvw` across the levels of the `predictor_vars`.

Where there is more than one ordered variable, the function returns a type III ANOVA table to test for differences in generalised correlations of order `uvw` across the levels of the `predictor_vars`.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(jam)
np_anova(ordered_vars = sweetness, predictor_vars = data.frame(type,judge), uvw = 1)
```

`orthogonal_scores` *orthogonal_scores*

Description

`orthogonal_scores` returns orthogonal scores weighted by prevalence in the data.

Usage

```
orthogonal_scores(x, degree, n_strata = 1)
```

Arguments

`x`	a vector of scores, either a factor or numeric.
`degree`	the degree of orthogonal scores required.
`n_strata`	optional argument for indicating the number of strata to apply the scores to.

Value

Returns a matrix of orthogonal scores.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(jam)
orthogonal_scores(x = sweetness, degree = 2, n_strata = 8)
```

PARL *PARL Test*

Description

`PARL` returns the test statistic and p-value for the aligned RL test performed as a permutation test.

Usage

```
PARL(y, treatment, block1, block2, N_perms = 1000, components = FALSE)
```

Arguments

`y`	a numericc vector for the response variable.
`treatment`	a vector giving the treatment type for the corresponding elements of `y`.
`block1`	a vector giving the first blocking variable for the corresponding elements of `y`.
`block2`	a vector giving the second blocking variable for the corresponding elements of `y`.
`N_perms`	The number of permutations to perform.
`components`	a TRUE or FALSE flag to indicate whether component p-values should be calculated.

Details

This test is applicable to Latin square designs and is recommended over the RL and ARL test. The CARL test is much faster to run.

Value

The PARL test statistic together with the associated p-value. Component p-values may also be calculated and shown.

References

Rayner, J.C.W and Livingston Jr, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

See Also

`ARL()` `CARL()`

Examples

```
attach(peanuts)
PARL(y = yield, treatment = treatment, block1 = row, block2 = col,
components = TRUE)
```

`peanuts` *Peanuts data*

Description

A plant biologist conducted an experiment to compare the yields of four varieties of peanuts, denoted as A, B, C, and D. A plot of land was divided into 16 subplots (four rows and four columns).

Usage

```
data(peanuts)
```

Format

A data frame with 16 rows and four columns.

yield the peanut yield

treatment the variety of peanut plant

row the row the plants were grown in of the plot

col the column the plants were grown in of the plot

Source

http://www.math.montana.edu/jobo/st541/sec3c.pdf

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(peanuts)
CARL(y = yield, treatment = treatment, block1 = row, block2 = col)
```

`Poly` *Poly*

Description

`Poly` returns t-1 orthonormal scores weighted by a weights parameter. The function uses Emerson Recursion.

Usage

```
Poly(x, p)
```

Arguments

`x`	a vector of numeric scores.
`p`	a vector of weights corresponding to the elements of x.

Value

Returns a matrix of orthomornal scores based on the weights provided.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley. Rayner, J.C.W., Thas, O. and De Boeck, B. (2008), A GENERALIZED EMERSON RECURRENCE RELATION. Australian & New Zealand Journal of Statistics, 50: 235-240.

Examples

```
x = 1:5
p = rep(0.2,5)
Poly(x = x, p = p)
```

`RL` *RL Test*

Description

`RL` returns the test statistic and p-value for the RL test. This test is applicable to Latin square designs. The test is not recommended though as block effects contaminate the response variable leading to unacceptable test size.

Usage

```
RL(y, treatment, block1, block2)
```

Arguments

`y`	a numericc vector for the response variable.
`treatment`	a vector giving the treatment type for the corresponding elements of `y`.
`block1`	a vector giving the first blocking variable for the corresponding elements of `y`.
`block2`	a vector giving the second blocking variable for the corresponding elements of `y`.

Value

A list containing the RL test statistic adjusted for ties together with the associated p-value using a chi-squared distribution with t-1 degrees of freedom.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

See Also

`ARL()` `CARL()`

Examples

```
attach(peanuts)
RL(y = yield, treatment = treatment, block1 = row, block2 = col)
```

`row_col_effect` *Row and column effects*

Description

`row_col_effects` returns the values of the row and column effects. This can be used to remove these effects from the response in a process call aligning. This is particularly applicable in LSD data.

Usage

```
row_col_effect(to_align, rows, cols)
```

Arguments

`to_align`	a numeric response vector.
`rows`	a vector giving the row effects for `y`.
`cols`	a vector giving the column effects for `y`.

Value

A vector of row and column effects. The response vector less this is the aligned response variable.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(peanuts)
row_col_effect(to_align = yield, rows = row, cols = col)
```

---

saltiness *Saltiness data*

Description

Three products, A, B and C, were tasted by 107 consumers who gave responses 'not salty enough', 'just about right saltiness' and 'too salty', which were then scored as 1, 2 and 3. The design is randomised blocks.

Usage

```
data(saltiness)
```

Format

A data frame with 321 rows and three columns.

product the type of product being tested

scores the saltiness score. Scores of 1, 2 and 3 correspond to responses 'not salty enough', 'just about right saltiness' and 'too salty'

participant the participant providing the rating

Source

Rayner, J. C. W. and Best, D. J. (2017)

References

Rayner, J. C. W. and Best, D. J. (2017). Unconditional analogues of Cochran-Mantel-Haenszel tests. Australian & New Zealand Journal of Statistics, 59(4):485–494.

Examples

```
attach(saltiness)
CMH(treatment = product, response = scores, strata = participant,
test_OPA = FALSE, test_MS = FALSE, test_C = FALSE)
```

`strawberry` *Strawberry data*

Description

Strawberry growth rates for different pesticides.

Usage

```
data(strawberry)
```

Format

A data frame with 28 rows and four columns.

block the experimental block

pesticide the pesticide applied to the plant. Pesticide O is a control.

response a measure of the growth rate of strawberry plants with `pesticide` applied.

rank rank of the response

Details

Pesticides are applied to strawberry plants to inhibit the growth of weeds. The question is, do they also inhibit the growth of the strawberries? The design is a supplemented balanced design.

Source

Pearce (1960)

References

Pearce, S.C. (1960). Supplemented balanced. Biometrika, 47, 263-271.

Examples

```
attach(strawberry)
lm_strawberry = lm(rank~pesticide+block)
anova(lm_strawberry)
```

`traffic` *Traffic data*

Description

Traffic light data for different light sequences, intersections, and times of day.

Usage

```
data(traffic)
```

Format

A data frame with 25 rows and four columns.

minutes the amount of unused red-light time in minutes

treatment the traffic light sequence

intersection the intersection the `treatment` was applied

time_of_day the time of the day the `treatment` was applied

Details

A traffic engineer conducted a study to compare the total unused red-light time for five different traffic light signal sequences. The experiment was conducted with a Latin square design in which blocking factors were (1) five intersections and (2) five time of day periods.

Source

Kuehl, R. (2000)

References

Kuehl, R. (2000). Design of Experiments: Statistical Principles of Research Design and Analysis. Belmont, California: Duxbury Press.

Best, D. J. and Rayner, J. C. W. (2011). Nonparametric tests for Latin squares. NIASRA Statistics Working Paper Series, 11-11.

Examples

```
attach(traffic)
np_anova(ordered_vars = rank(minutes),
predictor_vars = data.frame(treatment,intersection,time_of_day), uvw = 1)
```

T_Mu *T_Mu statistic*

Description

T_Mu returns the test statistic for an unconditional CMH MS equivalent test of required degree. This function is used in the unconditional_CMH function.

Usage

```
T_Mu(treatment, response, strata = NULL, degree)
```

Arguments

treatment	a vector of treatment values.
response	a vector of response values.
strata	a variable defining the strata.
degree	the degree assessment required.

Value

The function returns the test statistic for an unconditional CMH MS equivalent test of required degree.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

See Also

unconditional_CMH()

Examples

```
attach(job_satisfaction)
T_Mu(treatment = income, response = as.numeric(satisfaction),
strata = gender, degree = 1)
```

unconditional_CMH *Unconditional CMH Test*

Description

unconditional_CMH returns the test statistics and p-values for the equivalent unconditional CMH tests.

Usage

```
unconditional_CMH(
  treatment,
  response,
  strata = NULL,
  U = NULL,
  V = NULL,
  a_ij = NULL,
  b_hj = NULL,
  test_OPA = TRUE,
  test_GA = TRUE,
  test_M = TRUE,
  test_C = TRUE
)
```

Arguments

treatment	a factor vector representing the treatment applied.
response	a factor vector giving the response category for the corresponding elements of treatment.
strata	a factor vector giving the strata or block for the corresponding elements of treatment and response.
U	The degree of assessment relating to the treatment.
V	The degree of assessment relating to the response.
a_ij	a t x b matrix of treatment scores. The matrix allows for different scores to be used over different strata. If a t x 1 vector of scores is provided, it is assumed that the scores are the same across strata and a warning provided.
b_hj	a c x b matrix of response scores. The matrix allows for different scores to be used over different strata. If a c x 1 vector of scores is provided, it is assumed that the scores are the same across strata and a warning provided.
test_OPA	TRUE or FALSE flag to include the calculation of the OPA test values.
test_GA	TRUE or FALSE flag to include the calculation of the GA test values.
test_M	TRUE or FALSE flag to include the calculation of the MS test values. If response scores are not included, this test will not be performed.
test_C	TRUE or FALSE flag to include the calculation of the C test values. If response scores and treatment scores are not included, this test will not be performed.

Value

The unconditional CMH test results.

References

Rayner, J.C.W and Livingston, G. C. (2022). An Introduction to Cochran-Mantel-Haenszel Testing and Nonparametric ANOVA. Wiley.

Examples

```
attach(job_satisfaction)
a_ij = matrix(rep(c(3,10,20,35),2),nrow=4)
b_hj = matrix(rep(c(1,3,4,5),2),nrow=4)
unconditional_CMH(treatment = income, response = satisfaction,
strata = gender, U = 2, V = 2, a_ij = a_ij, b_hj = b_hj)
```

`whiskey` *Whiskey data*

Description

Ratings of different whiskeys of differing maturity.

Usage

```
data(whiskey)
```

Format

A data frame with 8 rows and two columns.

maturity the length of time the whiskey has matured for

grade grade applied to the whiskey. A lower score indicates a better whiskey

Source

O'Mahony (1986, p.363)

References

Rayner, J.C.W. and Best, D.J. (2001). A Contingency Table Approach to Nonparametric Testing. Chapman & Hall/CRC: Boca Raton FL.

O'Mahony, M. (1986). Sensory Evaluation of Food - Statistical Methods and Procedures. Marcel Dekker: New York.

Examples

```
attach(whiskey)
CMH(treatment = maturity, response = grade, a_ij = c(1,5,7),
b_hj = 1:3, test_OPA = FALSE, test_GA = FALSE, test_MS = FALSE)
```

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