Package: ARTool (via r-universe)

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Title Aligned Rank Transform

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Description The aligned rank transform for nonparametric factorial ANOVAs as described by Wobbrock, Findlater, Gergle, and Higgins (2011) <doi:10.1145/1978942.1978963>. Also supports aligned rank transform contrasts as described by Elkin, Kay, Higgins, and Wobbrock (2021) <doi:10.1145/3472749.3474784>.

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`anova.art` *Aligned Rank Transform Analysis of Variance*

Description

Conduct analyses of variance on aligned rank transformed data.

Usage

```
## S3 method for class 'art'
anova(
  object,
  response = c("art", "aligned"),
  type = c("III", "II", "I", 3, 2, 1),
  factor.contrasts = "contr.sum",
  test = c("F", "Chisq"),
  all.rows = FALSE,
  ...
)

## S3 method for class 'anova.art'
print(x, verbose = FALSE, digits = 5, ...)
```

Arguments

`object`	An object of class `art`.
`response`	Which response to run the ANOVA on: the aligned responses (`"aligned"`) or the aligned and ranked responses (`"art"`). This argument is passed to `artlm`. See 'Details'.

`type` Type of ANOVAs to conduct. If `type` is `1` or `"I"`, then conducts Type I ANOVAs using `anova`. Otherwise, conducts Type II or Type III ANOVAs using `Anova`. The default is Type III *if* the underlying model supports it. Models fit with `Error` terms are fit using `aov`, which only supports Type I ANOVAs.

`factor.contrasts` The name of the contrast-generating function to be applied by default to fixed effect factors. See the first element of `options("contrasts")`. The default is to use `"contr.sum"`, i.e. sum-to-zero contrasts, which is appropriate for Type III ANOVAs (also the default). This argument is passed to `artlm`.

`test` Test statistic to use. Default `"F"`. Note that some models and ANOVA types may not support `"Chisq"`.

`all.rows` Show all rows of the resulting ANOVA tables? By default (`FALSE`), shows only the rows that are relevant depending on the type of `response`.

`...` Additional arguments passed to `Anova` or `anova` by `anova.art` or to `print` by `print.anova.art`.

`x` An object of class `art`.

`verbose` When `TRUE`, sums of squares and residual sum of squares in addition to degrees of freedom are printed in some ANOVA types (e.g. repeated measures ANOVAs). Default `FALSE`, for brevity.

`digits` Digits of output in printed table; see `print`.

Details

This function runs several ANOVAs: one for each fixed effect term in the model `object`. In each ANOVA, the independent variables are the same, but the response is aligned by a different fixed effect term (if response is "aligned") or aligned and ranked by that fixed effect term (if response is "art"). These models are generated using `artlm`.

From each model, only the relevant output rows are kept (unless `all.rows` is `TRUE`, in which case all rows are kept).

When `response` is `"art"` (the default), only one row is kept from each ANOVA: the row corresponding to fixed effect term the response was aligned and ranked by. These results represent nonparametric tests of significance for the effect of each term on the original response variable.

When `response` is `"aligned"`, all rows *except* the row corresponding to the fixed effect term the response was aligned by are kept. If the ART procedure is appropriate for this data, these tests should have all effects "stripped out", and have an F value of ~0. If that is not the case, another analysis should be considered. This diagnostic is tested by `summary.art` and a warning generated if the F values are not all approximately 0.

Value

An object of class `"anova"`, which usually is printed.

Author(s)

Matthew Kay

References

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7–12, 2011). New York: ACM Press, pp. 143–146. doi:10.1145/1978942.1978963

See Also

See `art` for an example. See also `summary.art`, `artlm`.

`art` *Aligned Rank Transform*

Description

Apply the aligned rank transform to a factorial model (with optional grouping terms). Usually done in preparation for a nonparametric analyses of variance on models with numeric or ordinal responses, which can be done by following up with `anova.art`.

Usage

```
art(
  formula,
  data,
  rank.comparison.digits = -floor(log10(.Machine$double.eps^0.5)),
  check.errors.are.factors = TRUE
)
```

Arguments

`formula`	A factorial formula with optional grouping terms or error terms (but not both). Should be a formula with a single response variable (left-hand side) and one or more terms with all interactions on the right-hand side, e.g. `y ~ x` or `y ~ a*b*c` or `y ~ a + b + b:c`. If you want to run a mixed effects ANOVA on the transformed data using `lmer`, you can include grouping terms, as in `y ~ a*b*c + (1|d)`. If you want to run a repeated measures ANOVA using `aov`, you can include error terms, as in `y ~ a*b*c + Error(d)`. See 'Details'.
`data`	An optional data frame containing the variables in the model.
`rank.comparison.digits`	The number of digits to round aligned responses to before ranking (to ensure ties are computed consistently). See the `digits` argument of `round`. The default value is based on the default `tolerance` used for fuzzy comparison in `all.equal`.

check.errors.are.factors
: Should we check to ensure Error() terms are all factors? A common mistake involves coding a categorical variable as numeric and passing it to Error(), yielding incorrect results from aov. Disabling this check is not recommended unless you know what you are doing; the most common uses of Error() (e.g. in repeated measures designs) involve categorical variables (factors).

Details

The aligned rank transform allows a nonparametric analysis of variance to be conducted on factorial models with fixed and random effects (or repeated measures) and numeric or ordinal responses. This is done by first aligning and ranking the fixed effects using this function, then conducting an analysis of variance on linear models built from the transformed data using anova.art (see 'Examples'). The model specified using this function *must* include all interactions of fixed effects.

The formula should contain a single response variable (left-hand side) that can be numeric, an ordered factor, or logical. The right-hand side of the formula should contain one or more fixed effect factors, zero or more grouping terms, and zero or more error terms. Error terms and grouping terms cannot be used simultaneously. All possible interactions of the fixed effect terms must be included. For example, y ~ x and y ~ a*b*c and y ~ a + b + b:c are legal, but y ~ a + b is not, as it omits the interaction a:b. Grouping terms are specified as in lmer, e.g. y ~ a*b*c + (1|d) includes the random intercept term (1|d). Error terms are specified as in aov, e.g. y ~ a*b*c + Error(d). Grouping terms and error terms are not involved in the transformation, but are included in the model when ANOVAs are conducted, see anova.art.

For details on the transformation itself, see Wobbrock *et al.* (2011) or the ARTool website: https://depts.washington.edu/acelab/proj/art/.

Value

An object of class "art":

call
: The call used to generate the transformed data.

formula
: The formula used to generate the transformed data.

cell.means
: A data frame of cell means for each fixed term and interaction on the right-hand side of formula.

estimated.effects
: A data frame of estimated effects for each fixed term and interaction on the right-hand side of formula.

residuals
: A vector of residuals (response - cell mean of highest-order interaction).

aligned
: A data frame of aligned responses for each fixed term and interaction on the right-hand side of formula.

aligned.ranks
: A data frame of aligned and ranked responses for each fixed term and interaction on the right-hand side of formula.

data
: The input data frame

n.grouping.terms
: The number of grouping variables in the input formula.

For a complete description of cell means, estimated effects, aligned ranks, etc., in the above output, see Wobbrock *et al.* (2011).

Author(s)

Matthew Kay

References

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. *ARTool*. https://depts.washington.edu/acelab/proj/art/.

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7–12, 2011). New York: ACM Press, pp. 143–146. doi:10.1145/1978942.1978963

See Also

summary.art, anova.art, artlm, artlm.con, art.con.

Examples

```
data(Higgins1990Table5, package = "ARTool")

## perform aligned rank transform
m <- art(DryMatter ~ Moisture*Fertilizer + (1|Tray), data=Higgins1990Table5)

## see summary data to ensure aligned rank transform is appropriate for this data
summary(m)
## looks good (aligned effects sum to 0 and F values on aligned responses
## not of interest are all ~0)

## we can always look at the anova of aligned data if we want more detail
## to assess the appropriateness of ART.  F values in this anova should all
## be approx 0.
anova(m, response="aligned")

## then we can run an anova on the ART responses (equivalent to anova(m, response="art"))
anova(m)


## if we want contrast tests, we can use art.con():
## Ex 1: pairwise contrasts on Moisture:
art.con(m, "Moisture")
## Ex 2: pairwise contrasts on Moisture:Fertilizer:
art.con(m, "Moisture:Fertilizer")
## Ex 3: difference-of-difference tests on the Moisture:Fertilizer interaction:
art.con(m, "Moisture:Fertilizer", interaction = TRUE)


## The above three examples with art.con() can be constructed manually as well.
## art.con() extracts the appropriate linear model and conducts contrasts
## using emmeans(). If we want to use a specific method for post-hoc tests
## other than emmeans(), artlm.con(m, term) returns the linear model for the
## specified term which we can then examine using our preferred method
```

```
## (emmeans, glht, etc). The equivalent calls for the above examples are:
library(emmeans)

## Ex 1: pairwise contrasts on Moisture:
contrast(emmeans(artlm.con(m, "Moisture"), ~ Moisture), method = "pairwise")

## Ex 2: pairwise contrasts on Moisture:Fertilizer:
## See artlm.con() documentation for more details on the syntax, specifically
## the formula passed to emmeans.
contrast(emmeans(artlm.con(m, "Moisture:Fertilizer"), ~ MoistureFertilizer), method = "pairwise")

## Ex 3: difference-of-difference tests on the Moisture:Fertilizer interaction:
## Note the use of artlm() instead of artlm.con()
contrast(
  emmeans(artlm(m, "Moisture:Fertilizer"), ~ Moisture:Fertilizer),
  method = "pairwise", interaction = TRUE
)


## For a more in-depth explanation and example of contrasts with art and
## differences between interaction types, see vignette("art-contrasts")
```

`art.con` *Aligned Ranked Transform Contrasts*

Description

Conduct contrast tests following an Aligned Ranked Transform (ART) ANOVA (`anova.art`). Conducts contrasts on `art` models using aligned-and-ranked linear models using the ART (Wobbrock et al. 2011) or ART-C (Elkin et al. 2021) alignment procedure, as appropriate to the requested contrast.

Usage

```
art.con(
  m,
  formula,
  response = "art",
  factor.contrasts = "contr.sum",
  method = "pairwise",
  interaction = FALSE,
  adjust,
  ...
)
```

Arguments

m	An object of class art.
formula	Either a character vector or a formula specifying the fixed effects whose levels will be compared. See "Formula" section below.
response	Which response to use: the aligned response ("aligned") or the aligned-and-ranked response ("art"). Default is "art". This argument is passed to artlm.con (when interaction = FALSE) or artlm (when interaction = TRUE).
factor.contrasts	The name of the contrast-generating function to be applied by default to fixed effect factors. Sets the the first element of options("contrasts") for the duration of this function. The default is to use "contr.sum", i.e. sum-to-zero contrasts, which is appropriate for Type III ANOVAs (the default ANOVA type for anova.art). This argument is passed to artlm.con / artlm.
method	Contrast method argument passed to contrast. Note: the default is "pairwise" even though the default for the contrast function is "eff".
interaction	Logical value. If FALSE (the default), conducts contrasts using the ART-C procedure and artlm.con. If TRUE, conducts difference-of-difference contrasts using a model returned by artlm. See the "Interaction Contrasts" section in contrast.
adjust	Character: adjustment method (e.g., "bonferroni") passed to contrast. If not provided, contrast will use its default ("tukey" at the time of publication). All available options are listed in summary.emmGrid in the "P-value adjustments" section.
...	Additional arguments passed to lm or lmer.

Details

An art model m stores the formula and data that were passed to art when m was created. Depending on the requested contrast type, this function either extracts the linear model from m needed to perform that contrast or creates a new linear model on data aligned-and-ranked using the ART-C procedure, then conducts the contrasts specified in parameter formula.

Internally, this function uses artlm.con (when interaction = FALSE) or artlm (when interaction = TRUE) to get the linear model necessary for the requested contrast, computes estimated marginal means on the linear model using emmeans, and conducts contrasts using contrast.

Value

An object of class emmGrid. See contrast for details.

Formula

Contrasts compare combinations of levels from multiple factors. The formula parameter indicates which factors are involved. Two formats are accepted: (1) a character vector as used in artlm and artlm.con, with factors separated by ":"; or (2) a formula as used in emmeans, with factors separated by *. For example, contrasts comparing combinations of levels of factors *X1* and *X2* can be expressed as "X1:X2" (character vector) or as ~ X1*X2 (formula).

Author(s)

Lisa A. Elkin, Matthew Kay, Jacob O. Wobbrock

References

Elkin, L. A., Kay, M, Higgins, J. J., and Wobbrock, J. O. (2021). An aligned rank transform procedure for multifactor contrast tests. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '21)*. Virtual Event (October 10–14, 2021). New York: ACM Press, pp. 754–768. doi:10.1145/3472749.3474784

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7–12, 2011). New York: ACM Press, pp. 143–146. doi:10.1145/1978942.1978963

Examples

```
data(Higgins1990Table5, package = "ARTool")

library(dplyr)

## Perform aligned rank transform
m <- art(DryMatter ~ Moisture*Fertilizer + (1|Tray), data=Higgins1990Table5)

## In a some workflows, contrast tests using ART-C would follow a
## significant omnibus effect found by running an anova on the ART responses
## (equivalent to anova(m, response="art")).
## If conducting planned contrasts, this step can be skipped.
anova(m)

## We can conduct contrasts comparing levels of Moisture using the ART-C procedure.
## If conducting contrasts as a post hoc test, this would follow a significant effect
## of Moisture on DryMatter.

## Using a character vector
art.con(m, "Moisture")
## Or using a formula
art.con(m, ~ Moisture)

## Note: Since the ART-C procedure is mathematically equivalent to the ART procedure
## in the single-factor case, this is the same as
## emmeans(artlm(m, "Moisture"), pairwise ~ Moisture)

## art.con() returns an emmGrid object, which does not print asterisks
## beside "significant" tests (p < 0.05). If you wish to add stars beside
## tests of a particular significant level, you can always do that to the
## data frame returned by the summary() method of emmGrid. For example:
art.con(m, ~ Moisture) %>%
  summary() %>%
  mutate(sig = ifelse(p.value < 0.05, "*", ""))

## Or a more complex example:
```

```
art.con(m, ~ Moisture) %>%
  summary() %>%
  mutate(sig = symnum(p.value, corr = FALSE, na = FALSE,
    cutpoints = c(0, 0.001, 0.01, 0.05, 0.1, 1),
    symbols = c("***", "**", "*", ".", " ")
  ))

## We can conduct contrasts comparing combinations of levels
## of Moisture and Fertilizer using the ART-C procedure.
## If conducting contrasts as a post hoc test, this would follow
## a significant Moisture:Fertlizer interaction effect on Drymatter.

## Using a character vector for formula
art.con(m, "Moisture:Fertilizer")
## Using a formula
art.con(m, ~ Moisture*Fertilizer)

## We can also conduct interaction contrasts (comparing differences of differences)
art.con(m, "Moisture:Fertilizer", interaction = TRUE)

## For more examples, see vignette("art-contrasts")
```

`artlm` *Per-Term Linear Model from Aligned Rank Transformed Data*

Description

Build a linear model for ART data with response aligned or aligned and ranked by the specified term from the model.

Usage

```
artlm(
  m,
  term,
  response = c("art", "aligned"),
  factor.contrasts = "contr.sum",
  ...
)
```

Arguments

`m`	An object of class `art`.
`term`	A character vector indicating the effect term in the transformed data in `m` to use as the aligned or art response.
`response`	Which response to use: the aligned response (`"aligned"`) or the aligned and ranked (`"art"`) response.

`factor.contrasts`
: The name of the contrast-generating function to be applied by default to fixed effect factors. Sets the the first element of `options("contrasts")` for the duration of this function. The default is to use `"contr.sum"`, i.e. sum-to-zero contrasts, which is appropriate for Type III ANOVAs (the default ANOVA type for `anova.art`).

`...`
: Additional arguments passed to `lm` or `lmer`.

Details

This function is used primarily for post-hoc tests. To run an ANOVA, it does not need to be called directly; instead, use `anova.art`, which calls this function as needed.

Value

An object of class `lm` if `formula(m)` does not contain grouping or error terms, an object of class `merMod` (i.e. a model fit by `lmer`) if it contains grouping terms, or an object of class `aovlist` (i.e. a model fit by `aov`) if it contains error terms.

Author(s)

Matthew Kay

See Also

See `art` for an example. See also `anova.art`, which makes use of this function.

`artlm.con` *Per-Term Linear Model on Data Aligned-and-Ranked with ART-C*

Description

Given an `art` model, build a linear model from data aligned or aligned-and-ranked with ART-C alignment procedure by the specified term in the model.

Usage

```
artlm.con(m, term, response = "art", factor.contrasts = "contr.sum", ...)
```

Arguments

`m`
: An object of class `art`.

`term`
: A character vector indicating the effect term in the transformed data in `m` to use as the aligned or art response.

`response`
: Which response to use: the aligned (with ART-C) response (`"aligned"`) or the aligned and ranked (with ART-C) response (`"art"`).

`factor.contrasts`
: The name of the contrast-generating function to be applied by default to fixed effect factors. Sets the the first element of `options("contrasts")` for the duration of this function. The default is to use `"contr.sum"`, i.e. sum-to-zero contrasts, which is appropriate for Type III ANOVAs (the default ANOVA type for `anova.art`).

`...`
: Additional arguments passed to `lm` or `lmer`.

Details

This function is used internally by `art.con` to construct linear models for contrasts using the ART-C procedure (Elkin et al. 2021). It is typically not necessary to use this function directly to conduct contrasts using the ART-C procedure, you can use `art.con` instead, which will ensure that the correct model and contrast test is run. However, should you wish to use the ART-C procedure with a different contrast test than provided by `art.con`, you may with to use this function.

Internally, the ART-C procedure concatenates the variables specified in `term`, and then removes the originals. When specifying the effect terms on which to conduct contrasts, use the concatenation of the effects specified in `term` instead of the original variables. This is demonstrated in the example below.

Value

An object of class `lm` if `formula(m)` does not contain grouping or error terms, an object of class `merMod` (i.e. a model fit by `lmer`) if it does contain grouping terms, or an object of class `aovlist` (i.e. a model fit by `aov`) if it contains error terms.

Author(s)

Lisa A. Elkin

References

Elkin, L. A., Kay, M, Higgins, J. J., and Wobbrock, J. O. (2021). An aligned rank transform procedure for multifactor contrast tests. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '21)*. Virtual Event (October 10–14, 2021). New York: ACM Press, pp. 754–768. doi:10.1145/3472749.3474784

See Also

See also `art.con`, which makes use of this function.

Examples

```
data(Higgins1990Table5, package = "ARTool")

## create an art model
m <- art(DryMatter ~ Moisture*Fertilizer + (1|Tray), data=Higgins1990Table5)

## use emmeans to conduct pairwise contrasts on "Moisture"
library(emmeans)
```

```
contrast(emmeans(artlm.con(m, "Moisture"), ~ Moisture), method = "pairwise")

## use emmeans to conduct pairwise contrasts on "Moisture:Fertilizer"
## N.B. internally, artlm.con concatenates the factors Moisture and Fertilizer
## to create MoistureFertilizer. If you try to use any of Moisture, Fertilizer,
## Moisture:Fertilizer, or Moisture*Fertilizer in the RHS of the formula
## passed to emmeans, you will get an error because the factors Moisture and Fertilizer
## do not exist in the model returned by artlm.con.
contrast(emmeans(artlm.con(m, "Moisture:Fertilizer"), ~ MoistureFertilizer), method = "pairwise")

## Note: art.con uses emmeans internally, and the above examples are equivalent to
## the following calls to art.con, which is the recommended approach as it will
## ensure the model selected and the contrasts extracted from emmeans match.
art.con(m, "Moisture")
art.con(m, "Moisture:Fertilizer")
```

`ElkinAB` *Synthetic 2x2 Within-Subjects Experiment*

Description

Synthetic data from an experiment with two within-subjects factors (`A` and `B`) having two levels each.

Format

A data frame with 32 observations on the following 4 variables.

S a factor representing subjects with levels `"s1"` .. `"s8"`

A a factor with levels `"a1"` `"a2"`

B a factor with levels `"b1"` `"b2"`

Y a numeric vector

Source

Elkin, L. A., Kay, M, Higgins, J. J., and Wobbrock, J. O. (2021). An aligned rank transform procedure for multifactor contrast tests. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '21)*. Virtual Event (October 10–14, 2021). New York: ACM Press, pp. 754–768. doi:10.1145/3472749.3474784

Examples

```
data(ElkinAB, package = "ARTool")

## run contrast using the ART-C procedure on the data.
m <- art(Y ~ A*B + (1|S), data = ElkinAB)
art.con(m, "A:B")
```

ElkinABC *Synthetic 2x2x2 Within-Subjects Experiment*

Description

Synthetic data from an experiment with three within-subjects factors (A, B, and C) having two levels each.

Format

A data frame with 64 observations on the following 5 variables.

S a factor representing subjects with levels "s1" .. "s8"

A a factor with levels "a1" "a2"

B a factor with levels "b1" "b2"

C a factor with levels "c1" "c2"

Y a numeric vector

Source

Elkin, L. A., Kay, M, Higgins, J. J., and Wobbrock, J. O. (2021). An aligned rank transform procedure for multifactor contrast tests. *Proceedings of the ACM Symposium on User Interface Software and Technology (UIST '21)*. Virtual Event (October 10–14, 2021). New York: ACM Press, pp. 754–768. doi:10.1145/3472749.3474784

Examples

```
data(ElkinABC, package = "ARTool")

## run contrast using the ART-C procedure on the data.
m <- art(Y ~ A*B*C + (1|S), data = ElkinABC)
art.con(m, "A:B:C")
```

Higgins1990Table1 *Synthetic 3x3 Factorial Randomized Experiment*

Description

Synthetic data from a balanced 3x3 factorial experiment with main effects, no interaction, and independent and identically distributed (i.i.d.) Normal errors.

Format

A data frame with 36 observations on the following 4 variables.

Subject a factor with levels `"s1"` .. `"s36"`

Row a factor with levels `"r1"` .. `"r3"`

Column a factor with levels `"c1"` .. `"c3"`

Response a numeric vector

Source

Higgins, J. J., Blair, R. C. and Tashtoush, S. (1990). The aligned rank transform procedure. *Proceedings of the Conference on Applied Statistics in Agriculture*. Manhattan, Kansas: Kansas State University, pp. 185-195.

See Also

`art`, `anova.art`.

Examples

```
data(Higgins1990Table1, package = "ARTool")

## run aligned-rank transform and ANOVA on the data
## Note: because there is only one observation per Subject
## in this dataset, we do not need to include Subject as
## a grouping term in this formula. Indeed, if we did,
## lmer would complain when we attempt the ANOVA.
m <- art(Response ~ Row*Column, data=Higgins1990Table1)
anova(m)
```

`Higgins1990Table5` *Split-plot Experiment Examining Effect of Moisture and Fertilizer on Dry Matter in Peat Pots*

Description

This dataset comes from a split-plot experiment examining `Trays` of 4 peat pots each. `Moisture` was varied between `Trays` (i.e. it was the whole-plot treatment) and `Fertilizer` was varied within `Trays` (i.e. it was the sub-plot treatment). The outcome measure was `DryMatter`.

Format

A data frame with 48 observations on the following 4 variables.

Tray a factor with levels `"t1"` .. `"t12"`

Moisture a factor with levels `"m1"` .. `"m4"`

Fertilizer a factor with levels `"f1"` .. `"f4"`

DryMatter a numeric vector

Details

This dataset, originally from Milliken & Johnson (1984), is reproduced here from Higgins *et al.* (1990).

Source

Milliken, G.A., Johnson, D.E. (1984). *Analysis of Messy Data Vol I: Designed Experiments*. Van Nostrand Reinhold Company, New York.

References

Higgins, J. J., Blair, R. C. and Tashtoush, S. (1990). The aligned rank transform procedure. *Proceedings of the Conference on Applied Statistics in Agriculture*. Manhattan, Kansas: Kansas State University, pp. 185-195.

See Also

See `art` for a more complete example. See also `anova.art`.

Examples

```
data(Higgins1990Table5, package = "ARTool")

## run aligned-rank transform and ANOVA on the data
m <- art(DryMatter ~ Moisture*Fertilizer + (1|Tray), data=Higgins1990Table5)
anova(m)
```

HigginsABC *Synthetic 2x2x2 Mixed Design Experiment*

Description

Synthetic data from an experiment with two between-Subjects factors (A and B) having two levels each and one within-Subjects factor (C) with two levels.

Format

A data frame with 16 observations on the following 5 variables.

Subject a factor with levels "s1" .. "s8"

A a factor with levels "a1" "a2"

B a factor with levels "b1" "b2"

C a factor with levels "c1" "c2"

Y a numeric vector

Source

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. *ARTool*. https://depts.washington.edu/acelab/proj/art/.

See Also

art, anova.art.

Examples

```
data(HigginsABC, HigginsABC.art, package = "ARTool")

## run aligned-rank transform and ANOVA on the data
m <- art(Y ~ A*B*C + Error(Subject), data = HigginsABC)
anova(m)
```

InteractionTestData *Synthetic Data Used in the Contrast Test Vignette*

Description

See `vignette("art-contrasts")` for a description of this data.

See Also

`art`, `anova.art`.

Examples

```
## see vignette("art-contrasts")
```

summary.art *Aligned Rank Transform Summary*

Description

Summary and diagnostics for aligned rank transformed data

Usage

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

Arguments

`object`	An object of class `art`.
`...`	Potentially further arguments passed from other methods.

Details

This function gives diagnostic output to help evaluate whether the ART procedure is appropriate for an analysis. It tests that column sums of aligned responses are ~0 and that F values of ANOVAs on aligned responses not of interest are ~0. For more details on these diagnostics see Wobbrock *et al.* (2011).

Value

An object of class `"summary.art"`, which usually is printed.

Author(s)

Matthew Kay

References

Wobbrock, J. O., Findlater, L., Gergle, D., and Higgins, J. J. (2011). The aligned rank transform for nonparametric factorial analyses using only ANOVA procedures. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '11)*. Vancouver, British Columbia (May 7–12, 2011). New York: ACM Press, pp. 143–146. doi:10.1145/1978942.1978963

See Also

See `art` for an example. See also `anova.art`.

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