Package 'AOboot'

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Type Package

Title Bootstrapping in Different One-Way and Two-Way ANOVA

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Depends R (>= 4.3.0), afex, emmeans, lsr, methods, carData

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Description To address the violation of the assumption of normally distributed variables, researchers frequently employ bootstrapping. Building upon established packages for R (Sigmann et al. (2024) <doi:10.32614/CRAN.package.afex>, Lenth (2024) <doi:10.32614/CRAN.package.emmeans>), we provide bootstrapping functions to approximate a normal distribution of the parameter estimates for between-subject, within-subject, and mixed one-way and two-way ANOVA.

License GPL (>= 2)

Encoding UTF-8

RoxygenNote 7.3.2

NeedsCompilation no

Author Lisa-Marie Segbert [aut],
Christian Blötner [aut, cre]

Maintainer Christian Blötner <c.bloetner@gmail.com>

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Contents

AObootBetween *Bootstrapped ANOVA for Between-Subject Designs*

Description

In case of violations of the assumption of the normal distribution, researchers usually employ bootstrapping. Based on the R packages afex and emmeans, this function computes bootstrapped confidence intervals for the effect sizes, estimated marginal means, and post hoc tests for one-way and two-way ANOVAs following a between-subject design. Furthermore, the p-values of the F-statistic are adjusted to reflect the probability to obtain equal or higher values than the raw, non-bootstrapped ANOVA (Stine, 1989 <doi:10.1177/0049124189018002003>; see also this tutorial by Nadine Spychala.).

Usage

```
AObootBetween(var.between,
              var.dv,
              var.id,
              levels.b1,
              levels.b2 = NULL,
              eff.si = c("pes", "ges"),
              data,
              silence = FALSE,
              n.sim = 1000,
              alpha = .05,
              seed = 1234,
              n.round = 2)
```

Arguments

var.between	Variable(s) reflecting the between-subject level.
var.dv	Dependent variable.
var.id	Unique person specifier.
levels.b1	Levels of the first-named independent variable. Must be identical with the levels in the dataset.
levels.b2	For two-way ANOVAs. Levels of the second-named independent variable. Must be identical with the levels in the dataset.
eff.si	Effect size for the F-tests. "pes" reflects partial eta-squared, "ges" reflects eta-squared.
data	Name of the dataframe.
silence	Logical. If FALSE, progress of the bootstrapping procedure will be displayed.
n.sim	Number of bootstrap samples to be drawn.
alpha	Type I error.

seed	To make the results reproducible, it is recommended to set a random seed parameter.
n.round	Number of digits in the output.

Details

The p-value of the F-test ('Pr(>F)') in the output reflects the probability to obtain an F-value as high as or higher than the F-value from the raw, non-bootstrapped ANOVA. Thus, it should not be mistaken as a p-value in the sense of a null hypothesis significance test. More information about this can be found in this tutorial by Nadine Spychala.

Value

type.aov	Type of ANOVA conducted.
factor	Name of the groups in the factor (in one-way ANOVA).
factor1	Name of the groups in the first factor (in two-way ANOVA).
factor2	Name of the groups in the second factor (in two-way ANOVA).
anova	Results of the conducted ANOVA (i.e., degrees of freedom, F-test, p-value, effect size with bootstrap confidence interval, and numbers of tests for which convergence was achieved.
em	Estimated marginal means in one-way ANOVA.
em.1	Estimated marginal means for factor 1 in two-way ANOVA.
em.2	Estimated marginal means for factor 2 in two-way ANOVA.
em.3	Estimated marginal means for factor 1 by factor 2 in two-way ANOVA.
em.4	Estimated marginal means for factor 2 by factor 1 in two-way ANOVA.
no.test	Number of post hoc tests in one-way ANOVAs for which convergence was achieved.
no.test1	Number of post hoc tests for factor 1 in two-way ANOVAs for which convergence was achieved.
no.test2	Number of post hoc tests for factor 2 in two-way ANOVAs for which convergence was achieved.
no.test3	Number of post hoc tests for factor 1 by factor 2 in two-way ANOVAs for which convergence was achieved.
no.test4	Number of post hoc tests for factor 2 by factor 1 in two-way ANOVAs for which convergence was achieved.
ph	Post hoc tests in one-way ANOVAs.
ph.1	Post hoc tests for factor 1 in two-way ANOVAs.
ph.2	Post hoc tests for factor 2 in two-way ANOVAs.
ph.3	Post hoc tests for factor 1 by factor 2 in two-way ANOVAs.
ph.4	Post hoc tests for factor 2 by factor 1 in two-way ANOVAs.

Author(s)

Lisa-Marie Segbert, Christian Blötner <c.bloetner@gmail.com>

References

Stine, R. (1989). An introduction to bootstrap methods: Examples and ideas. Sociological Methods & Research, 18(2-3), 243–291. <https://doi.org/10.1177/0049124189018002003>

Examples

```
library(carData)

# The OBrienKaiser dataset from the carData package

ao <- OBrienKaiser

# Add a unique person identifier to the dataset

ao$pers <- 1:nrow(OBrienKaiser)

# One-way between-subjects ANOVA

AObootBetween(
  var.between = "treatment",
  var.dv = "pre.1",
  var.id = "pers",
  levels.b1 = c("control", "A", "B"),
  eff.si = "ges",
  data = ao,
  n.sim = 1000,
  alpha = .05,
  seed = 1234,
  n.round = 2)


# Two-way between-subjects ANOVA

AObootBetween(
  var.between = c("treatment", "gender"),
  var.dv = "pre.1",
  var.id = "pers",
  levels.b1 = c("control", "A", "B"),
  levels.b2 = c("M", "F"),
  eff.si = "pes",
  data = ao,
  n.sim = 1000,
  alpha = .05,
  seed = 1236,
  n.round = 2)
```

AObootMixed *Bootstrapped ANOVA for Mixed Designs*

Description

In case of violations of the assumption of the normal distribution, researchers usually employ bootstrapping. Based on the R packages afex and emmeans, this function computes bootstrapped confidence intervals for the effect sizes, estimated marginal means, and post hoc tests for Mixed ANOVAs. Furthermore, the p-values of the F-statistic are adjusted to reflect the probability to obtain equal or higher values than the raw, non-bootstrapped ANOVA (Stine, 1989 <doi:10.1177/0049124189018002003>; see also this tutorial by Nadine Spychala.).

Usage

```
AObootMixed(var.within,
            var.between,
            var.id,
            levels.w1,
            levels.b1,
            eff.si = c("pes", "ges"),
            data,
            silence = FALSE,
            n.sim = 1000,
            alpha = .05,
            seed = 1234,
            n.round = 2)
```

Arguments

var.within	Variable(s) reflecting the within-subject level.
var.between	Variable(s) reflecting the between-subject level.
var.id	Unique person specifier.
levels.w1	Levels of the within-subjects variable. Must be identical with the levels in the dataset.
levels.b1	Levels of the between-subjects variable. Must be identical with the levels in the dataset.
eff.si	Effect size for the F-tests. pes reflects partial eta-squared, ges reflects eta-squared.
data	Name of the dataframe. The dataset must be in a wide-format, with one row per participant.
silence	Logical. If FALSE, progress of the bootstrapping procedure will be displayed.
n.sim	Number of bootstrap samples to be drawn.
alpha	Type I error.
seed	To make the results reproducible, it is recommended to set a random seed parameter.
n.round	Number of digits in the output.

Details

The p-value of the F-test (`Pr(>F)`) in the output reflects the probability to obtain an F-value as high as or higher than the F-value from the raw, non-bootstrapped ANOVA. Thus, it should not be mistaken as a p-value in the sense of a null hypothesis significance test. More information about this can be found in this tutorial by Nadine Spychala.

Value

`type.aov`	Type of ANOVA conducted.
`factor1`	Name of the groups in the between factor.
`factor2`	Name of the groups in the within factor.
`anova`	Results of the conducted ANOVA (i.e., degrees of freedom, F-test, p-value, effect size with bootstrap confidence interval, and numbers of tests for which convergence was achieved.
`em.1`	Estimated marginal means for between factor.
`em.2`	Estimated marginal means for within factor.
`em.3`	Estimated marginal means for between factor by within factor.
`em.4`	Estimated marginal means for within factor by between factor.
`no.test1`	Number of post hoc tests for the between factor for which convergence was achieved.
`no.test2`	Number of post hoc tests for the within factor for which convergence was achieved.
`no.test3`	Number of post hoc tests for the between factor by within factor for which convergence was achieved.
`no.test4`	Number of post hoc tests for within factor by between factor for which convergence was achieved.
`ph.1`	Post hoc tests for between factor.
`ph.2`	Post hoc tests for within factor.
`ph.3`	Post hoc tests for between factor by within factor.
`ph.4`	Post hoc tests for within factor by between factor.

output <- list(type.aov = "Two-way mixed ANOVA", factor1 = levels.b1, factor2 = levels.w1, anova = round(orig.aov$anova_table, n.round), em.1 = dat.em1, no.test1 = no.test1, ph.1 = dat.ph1, em.2 = dat.em2, no.test2 = no.test2, ph.2 = dat.ph2, em.3 = dat.em3, no.test3 = no.test3, ph.3 = dat.ph3, em.4 = dat.em4, no.test4 = no.test4, ph.4 = dat.ph4)

Author(s)

Lisa-Marie Segbert, Christian Blötner <c.bloetner@gmail.com>

References

Stine, R. (1989). An introduction to bootstrap methods: Examples and ideas. Sociological Methods & Research, 18(2-3), 243–291. <https://doi.org/10.1177/0049124189018002003>

Examples

```
library(carData)

# The OBrienKaiser dataset from the carData package

ao <- OBrienKaiser

# Add a unique person identifier to the dataset

ao$pers <- 1:nrow(OBrienKaiser)

# Mixed ANOVA

AObootMixed(
    var.within = c("pre.1", "post.1", "fup.1"),
    var.between = "treatment",
    var.id = "pers",
    levels.w1 = c("pre", "post", "fup"),
    levels.b1 = c("control", "A", "B"),
    eff.si = "pes",
    data = ao,
    n.sim = 1000,
    alpha = .05,
    seed = 1234,
    n.round = 2)
```

AObootWithin *Bootstrapped ANOVA for Within-Subject Designs*

Description

In case of violations of the assumption of the normal distribution, researchers usually employ bootstrapping. Based on the R packages afex and emmeans, this function computes bootstrapped confidence intervals for the effect sizes, estimated marginal means, and post hoc tests for one-way and two-way ANOVAs following a within-subject design. Furthermore, the p-values of the F-statistic are adjusted to reflect the probability to obtain equal or higher values than the raw, non-bootstrapped ANOVA (Stine, 1989 <doi:10.1177/0049124189018002003>; see also this tutorial by Nadine Spychala.).

Usage

```
AObootWithin(var.within,
             var.id,
             levels.w1,
             levels.w2 = NULL,
             eff.si = c("pes", "ges"),
             data,
```

```
silence = FALSE,
n.sim = 1000,
alpha = .05,
seed = 1234,
n.round = 2)
```

Arguments

var.within	Variable(s) reflecting the within-subject level.
var.id	Unique person specifier.
levels.w1	Levels of the first-named independent variable. Must be identical with the levels in the dataset.
levels.w2	For two-way ANOVAs. Levels of the second-named independent variable. Must be identical with the levels in the dataset.
eff.si	Effect size for the F-tests. pes reflects partial eta-squared, ges reflects eta-squared.
data	Name of the dataframe. The dataset must be in a wide-format, with one row per participant.
silence	Logical. If FALSE, progress of the bootstrapping procedure will be displayed.
n.sim	Number of bootstrap samples to be drawn.
alpha	Type I error.
seed	To make the results reproducible, it is recommended to set a random seed parameter.
n.round	Number of digits in the output.

Details

The p-value of the F-test (Pr(>F)) in the output reflects the probability to obtain an F-value as high as or higher than the F-value from the raw, non-bootstrapped ANOVA. Thus, it should not be mistaken as a p-value in the sense of a null hypothesis significance test. More information about this can be found in this tutorial by Nadine Spychala.

Value

type.aov	Type of ANOVA conducted.
factor	Name of the groups in the factor (in one-way ANOVA).
factor1	Name of the groups in the first factor (in two-way ANOVA).
factor2	Name of the groups in the second factor (in two-way ANOVA).
anova	Results of the conducted ANOVA (i.e., degrees of freedom, F-test, p-value, effect size with bootstrap confidence interval, and numbers of tests for which convergence was achieved.
em	Estimated marginal means in one-way ANOVA.
em.1	Estimated marginal means for factor 1 in two-way ANOVA.

em.2	Estimated marginal means for factor 2 in two-way ANOVA.
em.3	Estimated marginal means for factor 1 by factor 1 in two-way ANOVA.
em.4	Estimated marginal means for factor 2 by factor 1 in two-way ANOVA.
no.test	Number of post hoc tests in one-way ANOVAs for which convergence was achieved.
no.test1	Number of post hoc tests for factor 1 in two-way ANOVAs for which convergence was achieved.
no.test2	Number of post hoc tests for factor 2 in two-way ANOVAs for which convergence was achieved.
no.test3	Number of post hoc tests for factor 1 by factor 2 in two-way ANOVAs for which convergence was achieved.
no.test4	Number of post hoc tests for factor 2 by factor 1 in two-way ANOVAs for which convergence was achieved.
ph	Post hoc tests in one-way ANOVAs.
ph.1	Post hoc tests for factor 1 in two-way ANOVAs.
ph.2	Post hoc tests for factor 2 in two-way ANOVAs.
ph.3	Post hoc tests for factor 1 by factor 2 in two-way ANOVAs.
ph.4	Post hoc tests for factor 2 by factor 1 in two-way ANOVAs.

Author(s)

Lisa-Marie Segbert, Christian Blötner <c.bloetner@gmail.com>

References

Stine, R. (1989). An introduction to bootstrap methods: Examples and ideas. Sociological Methods & Research, 18(2-3), 243–291. <https://doi.org/10.1177/0049124189018002003>

Examples

```
library(carData)

# The OBrienKaiser dataset from the carData package

ao <- OBrienKaiser

# Add a unique person identifier to the dataset

ao$pers <- 1:nrow(OBrienKaiser)

# One-way within-subjects ANOVA

AObootWithin(
    var.within = c("pre.1", "post.1", "fup.1"),
    var.id = "pers",
    levels.w1 = c("pre", "post", "fup"),
    eff.si = "ges",
```

```
    data = ao,
    n.sim = 1000,
    alpha = .05,
    seed = 1234,
    n.round = 2)


# Two-way within-subjects ANOVA

AObootWithin(
  var.within = c("pre.1", "pre.2", "pre.3", "pre.4", "pre.5",
                 "post.1", "post.2", "post.3", "post.4", "post.5",
                 "fup.1", "fup.2", "fup.3", "fup.4", "fup.5"),
  var.id = "pers",
  levels.w1 = c("pre", "post", "fup"),
  levels.w2 = c("1", "2", "3", "4", "5"),
  eff.si = "pes",
  data = ao,
  n.sim = 1000,
  alpha = .05,
  seed = 1234,
  n.round = 2)
```

AOboot_one *AOboot.one Class*

Description

A S3 class to represent one-way ANOVAs.

Usage

```
AOboot_one(type.aov, factor, anova, em, no.test, ph)
```

Arguments

type.aov	Character string giving the type of ANOVA computed.
factor	Names of groups in the entered factor.
anova	Results of the ANOVA.
em	Bootstrapped estimated marginal means.
no.test	Number of tests conducted that did not produce errors.
ph	Bootstrapped post hoc tests.

Value

An object of class "AOboot.one".

AOboot_two *AOboot.two Class*

Description

A S3 class to represent two-way ANOVAs.

Usage

```
AOboot_two(
  type.aov,
  factor1,
  factor2,
  anova,
  em.1,
  no.test1,
  ph.1,
  em.2,
  no.test2,
  ph.2,
  em.3,
  no.test3,
  ph.3,
  em.4,
  no.test4,
  ph.4
)
```

Arguments

type.aov	Character string giving the type of ANOVA computed.
factor1	Names of groups in the first factor.
factor2	Names of groups in the second factor.
anova	Results of the ANOVA.
em.1	Bootstrapped estimated marginal means for factor 1.
no.test1	Number of bootstrapped tests conducted for factor 1 that did not produce errors.
ph.1	Bootstrapped post hoc tests for factor 1.
em.2	Bootstrapped estimated marginal means for factor 2.
no.test2	Number of bootstrapped tests conducted for factor 2 that did not produce errors.
ph.2	Bootstrapped post hoc tests for factor 2.
em.3	Bootstrapped estimated marginal means for factor 1 by factor 2.
no.test3	Number of bootstrapped tests conducted for factor 1 by factor 2 that did not produce errors.

ph.3	Bootstrapped post hoc tests for factor 1 by factor 2.
em.4	Bootstrapped estimated marginal means for factor 2 by factor 1.
no.test4	Number of bootstrapped tests conducted for factor 2 by factor 1 that did not produce errors.
ph.4	Bootstrapped post hoc tests for factor 2 by factor 1.

Value

An object of class "AOboot.two".

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