Package ‘Superpower’

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Title Simulation-Based Power Analysis for Factorial Designs

Version 0.0.3

Description Functions to perform simulations of ANOVA designs of up to three factors. Calculates the observed power and average observed effect size for all main effects and interactions in the ANOVA, and all simple comparisons between conditions. Includes functions for analytic power calculations and additional helper functions that compute effect sizes for ANOVA designs, observed error rates in the simulations, and functions to plot power curves. Please see Lakens, D., & Caldwell, A. R. (2019). "Simulation-Based Power-Analysis for Factorial ANOVA Designs". <doi:10.31234/osf.io/baxsf>.

URL https://arcaldwell49.github.io/SuperpowerBook/

BugReports https://github.com/arcaldwell49/Superpower/issues

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Author Aaron Caldwell [aut, cre],
  Daniel Lakens [aut],
  Lisa DeBruine [ctb],
  Jonathon Love [ctb]

Maintainer Aaron Caldwell <arcaldwell49@gmail.com>

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ANOVA_design            Design function used to specify the parameters to be used in simulations

Description
Design function used to specify the parameters to be used in simulations

Usage
ANOVA_design(
  design,
  n,
  mu,
  sd,
  r = 0,
  labelnames = NULL,
  plot = Superpower_options("plot")
)

Arguments
design            String specifying the ANOVA design.
n            Sample size in each condition
mu            Vector specifying mean for each condition
sd            standard deviation for all conditions (or a vector specifying the sd for each condition)
r            Correlation between dependent variables (single value or matrix)
labelnames            Optional vector to specifying factor and condition names (recommended, if not used factors and levels are indicated by letters and numbers)
plot            Should means plot be printed (defaults to TRUE)
ANOVA\_design

Value

Returns single list with simulated data, design, design list, factor names, formulas for ANOVA, means, sd, correlation, sample size per condition, correlation matrix, covariance matrix, design string, labelnames, labelnameslist, factor names, meansplot

"dataframe" A sample dataframe of what data could look like given the proposed parameters.
"design" aov The design string, e.g. "2b*2w".
"design\_list" The list of variables in the design.
"frml1" The first formula created for this design.
"frml2" The second formula created for this design.
"mu" Vector of means.
"sd" Vector of standard deviations.
"r" Common correlation coefficient.
"n" Sample size per cell. Can be entered as a single value or list of sample sizes for each condition.
If unequal n is entered then the design can only be passed onto ANOVA\_power.
"cor\_mat" The correlation matrix.
"sigmatrix" The variance-covariance matrix.
"design\_factors" Total number of within-subjects factors.
"labelnames" List of the label names.
"labelnameslist" Secondary list of labelnames
"factornames" List of the factor titles.
"meansplot" Plot of the experimental design.

Warnings

Varying the sd or r (e.g., entering multiple values) violates assumptions of homoscedascity and sphericity respectively

Examples

## Set up a within design with 2 factors, each with 2 levels,## with correlation between observations of 0.8,## 40 participants (who do all conditions), and standard deviation of 2## with a mean pattern of 1, 0, 1, 0, conditions labeled 'condition' and## 'voice', with names for levels of "cheerful", "sad", and "human", "robot"ANOVA\_design(design = "2w*2w", n = 40, mu = c(1, 0, 1, 0), sd = 2, r = 0.8, labelnames = c("condition", "cheerful", "sad", "voice", "human", "robot"))
ANOVA_exact

Simulates an exact dataset (mu, sd, and r represent empirical not population mean and covariance matrix) from the design to calculate power

Description

Simulates an exact dataset (mu, sd, and r represent empirical not population mean and covariance matrix) from the design to calculate power

Usage

ANOVA_exact(
  design_result,
  correction = Superpower_options("correction"),
  alpha_level = Superpower_options("alpha_level"),
  verbose = Superpower_options("verbose"),
  emm = Superpower_options("emm"),
  emm_model = Superpower_options("emm_model"),
  contrast_type = Superpower_options("contrast_type"),
  emm_comp
)

Arguments

design_result  Output from the ANOVA_design function

correction     Set a correction of violations of sphericity. This can be set to "none", "GG" Greenhouse-Geisser, and "HF" Huynh-Feldt

alpha_level    Alpha level used to determine statistical significance

verbose        Set to FALSE to not print results (default = TRUE)

emm            Set to FALSE to not perform analysis of estimated marginal means

emm_model      Set model type ("multivariate", or "univariate") for estimated marginal means

contrast_type  Select the type of comparison for the estimated marginal means. Default is pairwise. See ?emmeans::'contrast-methods' for more details on acceptable methods.

emm_comp       Set the comparisons for estimated marginal means comparisons. This is a factor name (a), combination of factor names (a+b), or for simple effects a | sign is needed (a|b)

Value

Returns dataframe with simulation data (power and effect sizes!), anova results and simple effect results, plot of exact data, and alpha_level. Note: Cohen’s f = sqrt(pes/1-pes) and the noncentrality parameter is = f^2*df(error)
"dataframe" A dataframe of the simulation result.
"aov_result" aov object returned from aov_car.
"aov_result" emmeans object returned from emmeans.
"main_result" The power analysis results for ANOVA level effects.
"pc_results" The power analysis results for the pairwise (t-test) comparisons.
"emm_results" The power analysis results of the pairwise comparison results.
"manova_results" Default is "NULL". If a within-subjects factor is included, then the power of
the multivariate (i.e. MANOVA) analyses will be provided.
"alpha_level" The alpha level, significance cut-off, used for the power analysis.
"plot" A plot of the dataframe from the simulation; should closely match the meansplot in ANOVA_design

Warnings
Varying the sd or r (e.g., entering multiple values) violates assumptions of homoscedascity and
sphericity respectively

Examples
## Set up a within design with 2 factors, each with 2 levels,
## with correlation between observations of 0.8,
## 40 participants (who do all conditions), and standard deviation of 2
## with a mean pattern of 1, 0, 1, 0, conditions labeled ‘condition’ and
## ‘voice’, with names for levels of “cheerful”, “sad”, amd “human”, ”robot”
design_result <- ANOVA_design(design = "2w*2w", n = 40, mu = c(1, 0, 1, 0),
sd = 2, r = 0.8, labelnames = c("condition", "cheerful",
"sad", "voice", "human", "robot"))
exact_result <- ANOVA_exact(design_result, alpha_level = 0.05)

ANOVA_power

Simulation function used to estimate power

Description
Simulation function used to estimate power

Usage
ANOVA_power(
  design_result,
  alpha_level = Superpower_options("alpha_level"),
  correction = Superpower_options("correction"),
  p_adjust = "none",
  nsims = 1000,
  seed = NULL,
  verbose = Superpower_options("verbose"),
  emm = Superpower_options("emm"),
)
```r
emm_model = Superpower_options("emm_model"),
contrast_type = Superpower_options("contrast_type"),
emm_p_adjust = "none",
emm_comp = NULL
)
```

**Arguments**

- `design_result` Output from the `ANOVA_design` function
- `alpha_level` Alpha level used to determine statistical significance
- `correction` Set a correction of violations of sphericity. This can be set to "none", "GG" Greenhouse-Geisser, and "HF" Huynh-Feldt
- `p_adjust` Correction for multiple comparisons. This will adjust p values for ANOVA/MANOVA level effects; see `?p.adjust` for options
- `nsims` number of simulations to perform
- `seed` Set seed for reproducible results
- `verbose` Set to FALSE to not print results (default = TRUE)
- `emm` Set to FALSE to not perform analysis of estimated marginal means
- `emm_model` Set model type ("multivariate", or "univariate") for estimated marginal means
- `contrast_type` Select the type of comparison for the estimated marginal means. Default is pairwise. See `?emmeans::'contrast-methods'` for more details on acceptable methods.
- `emm_p_adjust` Correction for multiple comparisons; default is "none". See `?summary.emmGrid` for more details on acceptable methods.
- `emm_comp` Set the comparisons for estimated marginal means comparisons. This is a factor name (a), combination of factor names (a+b), or for simple effects a | sign is needed (a|b)

**Value**

Returns dataframe with simulation data (p-values and effect sizes), anova results (type 3 sums of squares) and simple effect results, and plots of p-value distribution.

- "sim_data" Output from every iteration of the simulation
- "main_result" The power analysis results for ANOVA effects.
- "pc_results" The power analysis results for pairwise comparisons.
- "manova_results" Default is "NULL". If a within-subjects factor is included, then the power of the multivariate (i.e. MANOVA) analyses will be provided.
- "emm_results" The power analysis results of the estimated marginal means.
- "plot1" Distribution of p-values from the ANOVA results.
- "plot2" Distribution of p-values from the pairwise comparisons results.
- "correction" The correction for sphericity applied to the simulation results.
- "p_adjust" The p-value adjustment applied to the simulation results for ANOVA/MANOVA omnibus tests and t-tests.
"emm_p_adjust" The p-value adjustment applied to the simulation results for the estimated marginal means.

"nsims" The number of simulations run.

"alpha_level" The alpha level, significance cut-off, used for the power analysis.

References

too be added

Examples

## Set up a within design with 2 factors, each with 2 levels,
## with correlation between observations of 0.8,
## 40 participants (who do all conditions), and standard deviation of 2
## with a mean pattern of 1, 0, 1, 0, conditions labeled 'condition' and
## 'voice', with names for levels of "cheerful", "sad", and "human", "robot"
design_result <- ANOVA_design(design = "2w*2w", n = 40, mu = c(1, 0, 1, 0),
  sd = 2, r = 0.8, labelnames = c("condition", "cheerful",
  "sad", "voice", "human", "robot"))
power_result <- ANOVA_power(design_result, alpha_level = 0.05,
  p_adjust = "none", seed = 2019, nsims = 10)

mu_from_ES

Convenience function to calculate the means for between designs with
one factor (One-Way ANOVA). Can be used to determine the means
that should yield a specified effect sizes (expressed in Cohen’s f).

Description

Convenience function to calculate the means for between designs with one factor (One-Way ANOVA). Can be used to determine the means that should yield a specified effect sizes (expressed in Cohen’s f).

Usage

mu_from_ES(K, ES)

Arguments

K Number of groups (2, 3, or 4)
ES Effect size (eta-squared)

Value

Returns vector of means
plot_power

Convenience function to plot power across a range of sample sizes.

Description

Convenience function to plot power across a range of sample sizes.

Usage

plot_power(
  design_result,  # Output from the ANOVA_design function
  alpha_level = Superpower_options("alpha_level"),  # Alpha level used to determine statistical significance
  min_n = 7,  # Minimum sample size in power curve.
  max_n = 100,  # Maximum sample size in power curve.
  plot = Superpower_options("plot"),  # Should power plot be printed automatically (defaults to FALSE)
  emm = Superpower_options("emm"),  # Set to FALSE to not perform analysis of estimated marginal means
  emm_model = Superpower_options("emm_model"),  # Set model type ("multivariate", or "univariate") for estimated marginal means
  contrast_type = Superpower_options("contrast_type"),  # Select the type of comparison for the estimated marginal means
  emm_comp
)

Arguments

design_result  # Output from the ANOVA_design function
alpha_level  # Alpha level used to determine statistical significance
min_n  # Minimum sample size in power curve.
max_n  # Maximum sample size in power curve.
plot  # Should power plot be printed automatically (defaults to FALSE)
emm  # Set to FALSE to not perform analysis of estimated marginal means
emm_model  # Set model type ("multivariate", or "univariate") for estimated marginal means
contrast_type  # Select the type of comparison for the estimated marginal means
emm_comp  # Set the comparisons for estimated marginal means comparisons. This is a factor name (a), combination of factor names (a+b), or for simple effects a l sign is needed (a1b)

References


Examples

# Medium effect size (eta-squared), 2 groups
ES <- 0.0588
K <- 2
mu_from_ES(K = K, ES = ES)
Value

Returns plot with power curves for the ANOVA, and a dataframe with the summary data.

"plot_ANOVA" Plot of power curves from ANOVA results.

"plot_MANOVA" Plot of power curves from MANOVA results. Returns NULL if no within-subject factors.

"plot_emm" Plot of power curves from MANOVA results. Returns NULL if emm = FALSE.

"power_df" The tabulated ANOVA power results.

"power_df_manova" The tabulated MANOVA power results. Returns NULL if no within-subject factors.

"power_df_emm" The tabulated Estimated Marginal Means power results. Returns NULL if emm = FALSE.

"effect_sizes" Effect sizes (partial eta-squared) from ANOVA results.

"effect_sizes_manova" Effect sizes (Pillai’s Trace) from MANOVA results. Returns NULL if no within-subject factors.

"effect_sizes_emm" Effect sizes (cohen’s f) estimated marginal means results. Returns NULL if emm = FALSE.

References

too be added

Examples

design_result <- ANOVA_design(design = "3b",
   n = 20,
   mu = c(0,0,0.3),
   sd = 1,
   labelnames = c("condition",
                 "cheerful", "neutral", "sad"))

plot_power(design_result, min_n = 50, max_n = 70)
power_oneway_within

Arguments

   design_result  Output from the ANOVA_design function
   alpha_level    Alpha level used to determine statistical significance

Value

   mu = means
   sigma = standard deviation
   n = sample size
   alpha_level = alpha level
   Cohen_f = Cohen f
   f_2 = Cohen’s f^2
   lambda = lambda
   F_critical = Critical F-value
   power = power
   df1 = degrees of freedom for the effect
   df2 = degrees of freedom of the error
   eta_p_2 = partial eta-squared
   mean_mat = matrix of the means

References

too be added

Examples

## Set up a within design with one factor with 2 levels,
## 40 participants (woh do all conditions), and standard deviation of 2
## with a mean pattern of 1, 0, 1, conditions labeled 'condition'
## with names for levels of "cheerful", "neutral", "sad"

design_result <- ANOVA_design(design = "3b", n = 40, mu = c(1, 0, 1),
                               sd = 2, labelnames = c("condition", "cheerful", "neutral", "sad"))

power_result <- power_oneway_between(design_result, alpha_level = 0.05)

---

title: Analytic power calculation for one-way within designs.

Description

Analytic power calculation for one-way within designs.

Usage

   power_oneway_within(design_result, alpha_level = 0.05)
Arguments

design_result  Output from the ANOVA_design function
alpha_level  Alpha level used to determine statistical significance

Value

mu = means
sigma = standard deviation
n = sample size
alpha_level = alpha level
Cohen_f = Cohen’s f
f_2 = Cohen’s f squared
lambda = lambda
F_critical = Critical F-value
power = power
df1 = degrees of freedom for the effect
df2 = degrees of freedom of the error
eta_p_2 = partial eta-squared
mean_mat = matrix of the means

References

too be added

Examples

## Set up a within design with 3 factors,
## with correlation between observations of 0.8,
## 40 participants (who do all conditions), and standard deviation of 2
## with a mean pattern of 1, 0, 1, conditions labeled 'condition' and
## 'voice', with names for levels of "cheerful", "neutral", "sad".
design_result <- ANOVA_design(design = "3w", n = 40, r = 0.8,
mu = c(1, 0, 1), sd = 2,
labelnames = c("condition", "cheerful", "neutral", "sad"))
power_result <- power_oneway_within(design_result, alpha_level = 0.05)
Analytic power calculation for three-way between designs.

Usage

```
power_threeway_between(design_result, alpha_level = 0.05)
```

Arguments

- `design_result`: Output from the ANOVA_design function
- `alpha_level`: Alpha level used to determine statistical significance (default to 0.05)

Value

- `mu`: means
- `sigma`: standard deviation
- `n`: sample size
- `alpha_level`: alpha level
- `Cohen_f_A`: Cohen’s f for main effect A
- `Cohen_f_B`: Cohen’s f for main effect B
- `Cohen_f_C`: Cohen’s f for main effect C
- `Cohen_f_AB`: Cohen’s f for the A*B interaction
- `Cohen_f_AC`: Cohen’s f for the A*C interaction
- `Cohen_f_BC`: Cohen’s f for the B*C interaction
- `Cohen_f_ABC`: Cohen’s f for the A*B*C interaction
- `f_2_A`: Cohen’s f squared for main effect A
- `f_2_B`: Cohen’s f squared for main effect B
- `f_2_C`: Cohen’s f squared for main effect C
- `f_2_AB`: Cohen’s f squared for A*B interaction
- `f_2_AC`: Cohen’s f squared for A*C interaction
- `f_2_BC`: Cohen’s f squared for B*C interaction
- `f_2_ABC`: Cohen’s f squared for A*B*C interaction
- `lambda_A`: lambda for main effect A
- `lambda_B`: lambda for main effect B
- `lambda_C`: lambda for main effect C
lambda_AB = lambda for A*B interaction
da("lambda_AB")

lambda_AC = lambda for A*C interaction
da("lambda_AC")

lambda_BC = lambda for B*C interaction
da("lambda_BC")

lambda_ABC = lambda for A*B*C interaction
da("lambda_ABC")

critical_F_A = critical F-value for main effect A
da("critical_F_A")

critical_F_B = critical F-value for main effect B
da("critical_F_B")

critical_F_C = critical F-value for main effect C
da("critical_F_C")

critical_F_AB = critical F-value for A*B interaction
da("critical_F_AB")

critical_F_AC = critical F-value for A*C interaction
da("critical_F_AC")

critical_F_BC = critical F-value for B*C interaction
da("critical_F_BC")

critical_F_ABC = critical F-value for A*B*C interaction
da("critical_F_ABC")

power_A = power for main effect A
da("power_A")

power_B = power for main effect B
da("power_B")

power_C = power for main effect C
da("power_C")

power_AB = power for A*B interaction
da("power_AB")

power_AC = power for A*C interaction
da("power_AC")

power_BC = power for B*C interaction
da("power_BC")

power_ABC = power for A*B*C interaction
da("power_ABC")

df_A = degrees of freedom for main effect A
da("df_A")

df_B = degrees of freedom for main effect B
da("df_B")

df_C = degrees of freedom for main effect C
da("df_C")

df_AB = degrees of freedom for A*B interaction
da("df_AB")

df_AC = degrees of freedom for A*C interaction
da("df_AC")

df_BC = degrees of freedom for B*C interaction
da("df_BC")

df_ABC = degrees of freedom for A*B*C interaction
da("df_ABC")

df_error = degrees of freedom for error term
da("df_error")

eta_p_2_A = partial eta-squared for main effect A
da("eta_p_2_A")

eta_p_2_B = partial eta-squared for main effect B
da("eta_p_2_B")

eta_p_2_C = partial eta-squared for main effect C
da("eta_p_2_C")

eta_p_2_AB = partial eta-squared for A*B interaction
da("eta_p_2_AB")

eta_p_2_AC = partial eta-squared for A*C interaction
da("eta_p_2_AC")

eta_p_2_BC = partial eta-squared for B*C interaction
da("eta_p_2_BC")

eta_p_2_ABC = partial eta-squared for A*B*C interaction
da("eta_p_2_ABC")

mean_mat = matrix of the means

data("mean_mat")

References

to be added
Examples

design_result <- ANOVA_design(design = "2b*2b*2b", n = 40,
mu = c(1, 0, 1, 0, 1, 1, 1, 0), sd = 2,
labelnames = c("condition", "cheerful", "sad",
"voice", "human", "robot", "color", "green", "red"))
power_result <- power_threeway_between(design_result, alpha_level = 0.05)

design_result <- ANOVA_design(design = "2b*2b*2b", n = 40,
mu = c(1, 0, 1, 0, 1, 1, 1, 0), sd = 2,
labelnames = c("condition", "cheerful", "sad",
"voice", "human", "robot", "color", "green", "red"))
power_result <- power_threeway_between(design_result, alpha_level = 0.05)

power_twoway_between

Analytic power calculation for two-way between designs.

Description

Analytic power calculation for two-way between designs.

Usage

power_twoway_between(design_result, alpha_level = 0.05)

Arguments

design_result Output from the ANOVA_design function
alpha_level Alpha level used to determine statistical significance

Value

mu = means
sigma = standard deviation
n = sample size
alpha_level = alpha level
Cohen_f_A = Cohen’s f for main effect A
Cohen_f_B = Cohen’s f for main effect B
Cohen_f_AB = Cohen’s f for the A*B interaction
f_2_A = Cohen’s f squared for main effect A
f_2_B = Cohen’s f squared for main effect B
f_2_AB = Cohen’s f squared for A*B interaction
lambda_A = lambda for main effect A
lambda_B = lambda for main effect B
lambda_AB = lambda for A*B interaction
critical_F_A = critical F-value for main effect A
critical_F_B = critical F-value for main effect B
critical_F_AB = critical F-value for A*B interaction
power_A = power for main effect A
Superpower_options

    power_B = power for main effect B
    power_AB = power for A*B interaction
    df_A = degrees of freedom for main effect A
    df_B = degrees of freedom for main effect B
    df_AB = degrees of freedom for A*B interaction
    df_error = degrees of freedom for error term
    eta_p_2_A = partial eta-squared for main effect A
    eta_p_2_B = partial eta-squared for main effect B
    eta_p_2_AB = partial eta-squared for A*B interaction
    mean_mat = matrix of the means

References

too be added

Examples

design_result <- ANOVA_design(design = "2b*2b", n = 40, mu = c(1, 0, 1, 0),
    sd = 2, labelnames = c("condition", "cheerful", "sad",
    "voice", "human", "robot"))
power_result <- power_twoway_between(design_result, alpha_level = 0.05)

Superpower_options

Set/get global Superpower options

Description

Global Superpower options are used, for example, by ANOVA_exact (et al.) and ANOVA_power. But
 can be changed in each functions directly using an argument (which has precedence over the global
options).

Usage

    Superpower_options(...)  

Arguments

...  

One of four: (1) nothing, then returns all options as a list; (2) a name of an
option element, then returns its’ value; (3) a name-value pair which sets the cor-
responding option to the new value (and returns nothing), (4) a list with option-
value pairs which sets all the corresponding arguments. The example show all
possible cases.
Superpower_options

Details

The following arguments are currently set:

- verbose should verbose (printed results) be set to true? Default is TRUE.
- emm Option to perform analysis of estimated marginal means. Default is FALSE.
- emm_model Model type ("multivariate", or "univariate") for estimated marginal means. Default is "multivariate".
- contrast_type The type of comparison for the estimated marginal means. Default is "pairwise". See ?emmeans::'contrast-methods' for more details on acceptable methods.
- plot Option to automatically print plots. Default is FALSE.
- alpha_level Alpha level used to determine statistical significance. Default is .05.
- correction Option to set a correction for sphericity violations. Default is no correction. This can be set to "none", "GG" Greenhouse-Geisser, and "HF" Huynh-Feldt

Value

depends on input, see above.

Note

All options are saved in the global R options with prefix Superpower.
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