Package 'WebPower'

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Description This is a collection of tools for conducting both basic and advanced statistical power analysis including correlation, proportion, t-test, one-way ANOVA, two-way ANOVA, linear regression, logistic regression, Poisson regression, mediation analysis, longitudinal data analysis, structural equation modeling and multilevel modeling. It also serves as the engine for conducting power analysis online at <https://webpower.psychstat.org>.

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`WebPower-package` *Basic and Advanced Statistical Power Analysis*

Description

This is a collection of tools for conducting both basic and advanced statistical power analysis including correlation, proportion, t-test, one-way ANOVA, two-way ANOVA, linear regression, logistic regression, Poisson regression, mediation analysis, longitudinal data analysis, structural equation modeling and multilevel modeling. It also serves as the engineer for conducting power analysis online at https://webpower.psychstat.org.

Details

This is a collection of tools for conducting both basic and advanced statistical power analysis including correlation, proportion, t-test, one-way ANOVA, two-way ANOVA, linear regression, logistic regression, Poisson regression, mediation analysis, longitudinal data analysis, structural equation modeling and multilevel modeling. It also serves as the engineer for conducting power analysis online at https://webpower.psychstat.org.

References

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

`CRT2` *Example Data For CRT With 2 Arms*

Description

- ID. The identification number of the subjects.
- cluster. The cluster number.
- score. The score of the subject.
- group. The group number.

Usage

```
CRT2
```

Format

An object of class `data.frame` with 8 rows and 4 columns.

Examples

```
#  ID cluster score group
#  1 1 6 0
#  2 1 2 0
#  3 2 6 1
#  4 2 5 1
#  5 3 1 0
#  6 3 4 0
#  7 4 6 1
#  8 4 4 1
```

CRT3 *Example Data For CRT With 3 Arms*

Description

- ID. The identification number of the subjects.
- cluster. The cluster number.
- score. The score of the subject.
- group. The group number.

Usage

```
CRT3
```

Format

An object of class `data.frame` with 30 rows and 4 columns.

Examples

```
#   id cluster score group
#   1 1 1.93 0
#   2 1 1.51 0
#   3 1 2.13 0
#   4 1 2.96 0
#   5 1 3.84 0
#   6 2 3.36 1
#   7 2 3.13 1
#   8 2 1.71 1
#   9 2 3.1 1
#   10 2 2.53 1
#   11 3 2.01 2
#   12 3 4.73 2
#   13 3 3.34 2
#   14 3 0.11 2
#   15 3 3.6 2
#   16 4 2 0
#   17 4 1.99 0
#   18 4 1.89 0
#   19 4 2.25 0
#   20 4 1.83 0
#   21 5 3.03 1
#   22 5 2.08 1
#   23 5 1.5 1
#   24 5 3.18 1
#   25 5 1.92 1
#   26 6 3.49 2
#   27 6 3.08 2
#   28 6 4.54 2
```

```
#   29 6 2.34 2
#   30 6 4.33 2
```

`estCRT2arm` *Estimate multilevel effect size from data*

Description

Estimate multilevel effect size from data

Usage

```
estCRT2arm(file)
estCRT3arm(file)
estMRT2arm(file)
estMRT3arm(file)
```

Arguments

`file`	a data file

`MRT2` *Example Data For MRT With 2 Arms*

Description

- ID. The identification number of the subjects.
- cluster. The cluster number.
- score. The score of the subject.
- group. The group number.

Usage

```
MRT2
```

Format

An object of class `data.frame` with 16 rows and 4 columns.

Examples

```
#Example data for MRT with 2 arms
#  id cluster score group
#  1 1 6 0
#  2 1 2 0
#  3 1 3 1
#  4 1 3 1
#  5 2 6 0
#  6 2 10 0
#  7 2 7 1
#  8 2 6 1
#  9 3 6 0
#  10 3 5 0
#  11 3 4 1
#  12 3 4 1
#  13 4 1 0
#  14 4 8 0
#  15 4 10 1
#  16 4 -2 1
```

MRT3 *Example Data For MRT With 3 Arms*

Description

- ID. The identification number of the subjects.
- cluster. The cluster number.
- score. The score of the subject.
- group. The group number.

Usage

```
MRT3
```

Format

An object of class `data.frame` with 24 rows and 4 columns.

Examples

```
#  id cluster score group
#  1 1 2 0
#  2 1 3 0
#  3 1 2 1
#  4 1 0 1
#  5 1 3 2
#  6 1 2 2
#  7 2 1 0
```

```
#   8 2 4 0
#   9 2 2 1
#   10 2 3 1
#   11 2 3 2
#   12 2 1 2
#   13 3 1 0
#   14 3 4 0
#   15 3 1 1
#   16 3 1 1
#   17 3 2 2
#   18 3 0 2
#   19 4 4 0
#   20 4 3 0
#   21 4 1 1
#   22 4 3 1
#   23 4 3 2
#   24 4 3 2
```

---

nuniroot *Solve A Single Equation*

Description

The function searches in an interval for a root (i.e., zero) of the function f with respect to its first argument. The argument interval is for the input of x, the corresponding outcome interval will be used as the interval to be searched in.

Usage

```
nuniroot(f, interval, maxlength = 100)
```

Arguments

f	Function for which the root is sought.
interval	A vector containing the end-points of the interval to be searched for the root.
maxlength	The number of vaulue points in the interval to be searched. It is 100 by default.

Value

A list with at least four components: root and f.root give the location of the root and the value of the function evaluated at that point. iter and estim.prec give the number of iterations used and an approximate estimated precision for root. (If the root occurs at one of the endpoints, the estimated precision is NA.)

Examples

```
f <- function(x) 1+x-0.5*x^2
interval <- c(-3,6)
nuniroot(f,interval)
```

`plot.lcs.power` *Plot the power curve for Latent Change Score Models*

Description

This function is used to plot the power analysis results for Latent Change Score Models.

Usage

```
## S3 method for class 'lcs.power'
plot(x, parameter, ...)
```

Arguments

`x`	Data to plot.
`parameter`	Parameters for features of the plot.
`...`	Extra arguments. It is not required.

References

Zhang, Z., & Liu, H. (2018). Sample Size and Measurement Occasion Planning for Latent Change Score Models through Monte Carlo Simulation. In E. Ferrer, S. M. Boker, and K. J. Grimm (Eds.) Advances in Longitudinal Models for Multivariate Psychology: A Festschrift for Jack McArdle.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

`plot.webpower` *To plot Statistical Power Curve*

Description

This function is used to plot the power curves generated by webpower.

Usage

```
## S3 method for class 'webpower'
plot(x, xvar = NULL, yvar = NULL, xlab = NULL,
  ylab = NULL, ...)
```

Arguments

`x`	Objects of power analysis.
`xvar`	The variable name used as the x (horizontal) axis. It is not required.
`yvar`	The variable name used as the y (vertical) axis. It is not required.
`xlab`	The label for the x axis. It is not required.
`ylab`	The label for the y axis. It is not required.
`...`	Extra arguments. It is not required.

Value

The plot.

Examples

```
res <- wp.correlation(n=seq(50,100,10),r=0.3, alternative="two.sided")
plot(res)
```

`print.webpower` *To Print Statistical Power Analysis Results*

Description

This function is used to summary the power analysis results.

Usage

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

Arguments

x	Object of power analysis. It is an object returned by a webpower function such as wp.anova().
...	Extra arguments. It is not required.

Value

The printing of the input object of power analysis.

Examples

```
res <- wp.correlation(n=50,r=0.3, alternative="two.sided")
print(res)
```

sem.effect.size *Calculate the Effect Size for SEM*

Description

This function is for calculating SEM effect size.

Usage

```
sem.effect.size(full.model.pop, reduced.model)
```

Arguments

full.model.pop	Full model (under the alternative hypothesis) with population parameters.
reduced.model	Reduced model (under the null hypothesis) lavaan specification.

Value

An object of the power analysis.

delta	Effect size.
df	Degrees of freedom
RMSEA	RMSEA

References

Demidenko, E. (2007). Sample size determination for logistic regression revisited. Statistics in medicine, 26(18), 3385-3397.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
full.model.pop <-'
y1 ~ 0.4*x
y2 ~ 0.5*x + 0.2*y1
y3 ~ 0.4*x
y4 ~ 0.4*y1 + 0.4*y2 + 0.4*y3
y1 ~~ 0.84*y1
y2 ~~ 0.61*y2
y3 ~~ 0.84*y3
y4 ~~ 0.27*y4
'

reduced.model <-'
y1 ~ x
y2 ~ x
y3 ~ x
```

```
y4 ~ y1 + y3
'

sem.effect.size(full.model.pop, reduced.model)
```

---

summary.power *Summary Statistical Power Analysis Results*

Description

This function is used to summary the power analysis results.

Usage

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

Arguments

object	Object of power analysis. It is an object returned by a webpower function for SEM based on Monte Carlo methods with class = 'power'.
...	Extra arguments. It is not required.

Value

The summary of the input object of power analysis.

---

wp.anova *Statistical Power Analysis for One-way ANOVA*

Description

One-way analysis of variance (one-way ANOVA) is a technique used to compare means of two or more groups (e.g., *Maxwell & Delaney, 2003*). The ANOVA tests the null hypothesis that samples in two or more groups are drawn from populations with the same mean values. The ANOVA analysis typically produces an F-statistic, the ratio of the bewteen-group variance to the within-group variance.

Usage

```
wp.anova(k = NULL, n = NULL, f = NULL, alpha = 0.05, power = NULL,
  type = c("overall", "two.sided", "greater", "less"))
```

Arguments

- `k` Number of groups.
- `n` Sample size.
- `f` Effect size. We use the statistic f as the measure of effect size for one-way ANOVA as in *Cohen (1988)*. Cohen defined the size of effect as: small 0.1, medium 0.25, and large 0.4.
- `alpha` Significance level chosed for the test. It equals 0.05 by default.
- `power` Statistical power.
- `type` Type of test ("`overall`" or "`two.sided`" or "`greater`" or "`less`"). The default is "two.sided". The option "overall" is for the overall test of anova; "two.sided" is for a contrast anova; "greater" is testing the between-group vairance greater than the within-group, while "less" is vis versus.

Value

An object of the power analysis.

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Maxwell, S. E., & Delaney, H. D. (2004). Designing experiments and analyzing data: A model comparison perspective (Vol. 1). Psychology Press.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power for the overall test of one-way ANOVA:
wp.anova(f=0.25,k=4, n=100, alpha=0.05)
#  Power for One-way ANOVA
#
#    k   n    f alpha     power
#    4 100 0.25  0.05 0.5181755
#
#  NOTE: n is the total sample size (overall)
#  URL: http://psychstat.org/anova

#To calculate the power curve with a sequence of sample sizes:
res <- wp.anova(f=0.25, k=4, n=seq(100,200,10), alpha=0.05)
res
#  Power for One-way ANOVA
#
#    k   n    f alpha     power
#    4 100 0.25  0.05 0.5181755
#    4 110 0.25  0.05 0.5636701
#    4 120 0.25  0.05 0.6065228
#    4 130 0.25  0.05 0.6465721
```

```
#    4 140 0.25  0.05 0.6837365
#    4 150 0.25  0.05 0.7180010
#    4 160 0.25  0.05 0.7494045
#    4 170 0.25  0.05 0.7780286
#    4 180 0.25  0.05 0.8039869
#    4 190 0.25  0.05 0.8274169
#    4 200 0.25  0.05 0.8484718
#
#  NOTE: n is the total sample size (overall)
#  URL: http://psychstat.org/anova

#To plot the power curve:
plot(res, type='b')

#To estimate the sample size with a given power:
wp.anova(f=0.25,k=4, n=NULL, alpha=0.05, power=0.8)
#  Power for One-way ANOVA
#
#    k        n    f alpha power
#    4 178.3971 0.25  0.05   0.8
#
#  NOTE: n is the total sample size (overall)
#  URL: http://psychstat.org/anova

#To estimate the minimum detectable effect size with a given power:
wp.anova(f=NULL,k=4, n=100, alpha=0.05, power=0.8)
#  Power for One-way ANOVA
#
#    k   n         f alpha power
#    4 100 0.3369881  0.05   0.8
#
#  NOTE: n is the total sample size (overall)
#  URL: http://psychstat.org/anova

#To conduct power analysis for a contrast one-way ANOVA:
wp.anova(f=0.25,k=4, n=100, alpha=0.05, type='two.sided')
#  Power for One-way ANOVA
#
#    k   n    f alpha     power
#    4 100 0.25  0.05 0.6967142
#
#  NOTE: n is the total sample size (contrast, two.sided)
#  URL: http://psychstat.org/anova

#To calculate the power curve with a sequence of sample sizes:
res <- wp.anova(f=seq(0.1, 0.8, 0.1), k=4, n=100, alpha=0.05)
res
#  Power for One-way ANOVA
#
#    k   n   f alpha     power
#    4 100 0.1  0.05 0.1128198
#    4 100 0.2  0.05 0.3452612
#    4 100 0.3  0.05 0.6915962
```

```
#    4 100 0.4  0.05 0.9235525
#    4 100 0.5  0.05 0.9911867
#    4 100 0.6  0.05 0.9995595
#    4 100 0.7  0.05 0.9999908
#    4 100 0.8  0.05 0.9999999
#
#  NOTE: n is the total sample size (overall)
#  URL: http://psychstat.org/anova
```

wp.anova.binary — *Statistical Power Analysis for One-way ANOVA with Binary Data*

Description

The power analysis procedure for one-way ANOVA with binary data is introduced by *Mai and Zhang (2017)*. One-way ANOVA with binary data is used for comparing means of three or more groups of binary data. Its outcome variable is supposed to follow Bernoulli distribution. And its overall test uses a likelihood ratio test statistics.

Usage

```
wp.anova.binary(k = NULL, n = NULL, V = NULL, alpha = 0.05,
  power = NULL)
```

Arguments

k	Number of groups.
n	Sample size.
V	Effect size. See the research by *Mai and Zhang (2017)* for details.
alpha	Significance level chosed for the test. It equals 0.05 by default.
power	Statistical power.

Value

An object of the power analysis.

References

Mai, Y., & Zhang, Z. (2017). Statistical Power Analysis for Comparing Means with Binary or Count Data Based on Analogous ANOVA. In L. A. van der Ark, M. Wiberg, S. A. Culpepper, J. A. Douglas, & W.-C. Wang (Eds.), Quantitative Psychology - The 81st Annual Meeting of the Psychometric Society, Asheville, North Carolina, 2016: Springer.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power for one-way ANOVA (overall test) with binary data:
wp.anova.binary(k=4,n=100,V=0.15,alpha=0.05)
#  One-way Analogous ANOVA with Binary Data
#
#     k   n    V alpha     power
#     4 100 0.15  0.05 0.5723443
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovabinary

#To generate a power curve given a sequence of sample sizes:
res <- wp.anova.binary(k=4,n=seq(100,200,10),V=0.15,alpha=0.05,power=NULL)
res
#  One-way Analogous ANOVA with Binary Data
#
#     k   n    V alpha     power
#     4 100 0.15  0.05 0.5723443
#     4 110 0.15  0.05 0.6179014
#     4 120 0.15  0.05 0.6601594
#     4 130 0.15  0.05 0.6990429
#     4 140 0.15  0.05 0.7345606
#     4 150 0.15  0.05 0.7667880
#     4 160 0.15  0.05 0.7958511
#     4 170 0.15  0.05 0.8219126
#     4 180 0.15  0.05 0.8451603
#     4 190 0.15  0.05 0.8657970
#     4 200 0.15  0.05 0.8840327
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovabinary

#To plot the power curve:
plot(res)

#To calculate the required sample size for one-way ANOVA (overall test) with binary data:
wp.anova.binary(k=4,n=NULL,V=0.15,power=0.8, alpha=0.05)
#  One-way Analogous ANOVA with Binary Data
#
#     k        n    V alpha power
#     4 161.5195 0.15  0.05   0.8
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovabinary

#To calculate the minimum detectable effect size for one-way ANOVA (overall test) with binary data:
wp.anova.binary(k=4,n=100,V=NULL,power=0.8, alpha=0.05)
#  One-way Analogous ANOVA with Binary Data
#
#     k   n         V alpha power
#     4 100 0.1906373  0.05   0.8
#
```

```
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovabinary

#To generate a power curve given a sequence of effect sizes:
wp.anova.binary(k=4,n=100,V=seq(0.1,0.5,0.05),alpha=0.05,power=NULL)
#  One-way Analogous ANOVA with Binary Data
#
#    k   n    V alpha     power
#    4 100 0.10  0.05 0.2746396
#    4 100 0.15  0.05 0.5723443
#    4 100 0.20  0.05 0.8402271
#    4 100 0.25  0.05 0.9659434
#    4 100 0.30  0.05 0.9961203
#    4 100 0.35  0.05 0.9997729
#    4 100 0.40  0.05 0.9999933
#    4 100 0.45  0.05 0.9999999
#    4 100 0.50  0.05 1.0000000
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovabinary
```

`wp.anova.count` *Statistical Power Analysis for One-way ANOVA with Count Data*

Description

The power analysis procedure for one-way ANOVA with count data is introduced by *Mai and Zhang (2017)*. One-way ANOVA with count data is used for comparing means of three or more groups of binary data. Its outcome variable is supposed to follow Poisson distribution. And its overall test uses a likelihood ratio test statistics.

Usage

```
wp.anova.count(k = NULL, n = NULL, V = NULL, alpha = 0.05,
  power = NULL)
```

Arguments

`k`	Number of groups.
`n`	Sample size.
`V`	Effect size. See the research by *Mai and Zhang (2017)* for details.
`alpha`	Significance level chosed for the test. It equals 0.05 by default.
`power`	Statistical power.

Value

An object of the power analysis.

References

Mai, Y., & Zhang, Z. (2017). Statistical Power Analysis for Comparing Means with Binary or Count Data Based on Analogous ANOVA. In L. A. van der Ark, M. Wiberg, S. A. Culpepper, J. A. Douglas, & W.-C. Wang (Eds.), Quantitative Psychology - The 81st Annual Meeting of the Psychometric Society, Asheville, North Carolina, 2016: Springer.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power for one-way ANOVA (overall test) with count data:
wp.anova.count(k=4,n=100,V=0.148,alpha=0.05)
#  One-way Analogous ANOVA with Count Data
#
#    k   n     V alpha     power
#    4 100 0.148  0.05 0.5597441
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovacount

#To generate a power curve given sequence of sample sizes:
res <- wp.anova.count(k=4,n=seq(100,200,10),V=0.148,alpha=0.05,power=NULL)
res
#  One-way Analogous ANOVA with Count Data
#
# k   n     V alpha     power
# 4 100 0.148  0.05 0.5597441
# 4 110 0.148  0.05 0.6049618
# 4 120 0.148  0.05 0.6470911
# 4 130 0.148  0.05 0.6860351
# 4 140 0.148  0.05 0.7217782
# 4 150 0.148  0.05 0.7543699
# 4 160 0.148  0.05 0.7839101
# 4 170 0.148  0.05 0.8105368
# 4 180 0.148  0.05 0.8344142
# 4 190 0.148  0.05 0.8557241
# 4 200 0.148  0.05 0.8746580
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovacount

#To plot the power curve:
plot(res)

#To calculate the required sample size for one-way ANOVA (overall test) with count data:
wp.anova.count(k=4,n=NULL,V=0.148,power=0.8, alpha=0.05)
#  One-way Analogous ANOVA with Count Data
#
#    k        n     V alpha power
#    4 165.9143 0.148  0.05   0.8
```

```
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovacount

#To calculate the minimum detectable effect size for one-way ANOVA (overall test) with count data:
wp.anova.count(k=4,n=100,V=NULL,power=0.8, alpha=0.05)
#  One-way Analogous ANOVA with Count Data
#
#     k   n         V alpha power
#     4 100 0.1906373  0.05   0.8
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovacount

#To generate a power curve given a sequence of effect sizes:
res <- wp.anova.count(k=5,n=100,V=seq(0.1,0.5,0.05),alpha=0.05,power=NULL)
res
#  One-way Analogous ANOVA with Count Data
#
#     k   n    V alpha     power
#     5 100 0.10  0.05 0.3200744
#     5 100 0.15  0.05 0.6634861
#     5 100 0.20  0.05 0.9118531
#     5 100 0.25  0.05 0.9893643
#     5 100 0.30  0.05 0.9994549
#     5 100 0.35  0.05 0.9999887
#     5 100 0.40  0.05 0.9999999
#     5 100 0.45  0.05 1.0000000
#     5 100 0.50  0.05 1.0000000
#
#  NOTE: n is the total sample size
#  URL: http://psychstat.org/anovacount
```

`wp.blcsm` *Statistical Power Curve for Bivariate Latent Change Score Models based on Monte Carlo Simulation*

Description

A longitudinal design often involves data collection on multiple variables from multiple participants at multiple times. Growth curve models (GCM) are structural equation models for longitudinal data analysis (*McArdle & Epstein, 1987; McArdle & Nesselroade, 2014*). Latent change score models (LCSM) combine difference equations with growth curves to investigate change in longitudinal studies . LCSM provied an efficient way to model nonlinear trajectory (e.g., *McArdle, 2000; McArdle & Hamagami, 2001; Hamagami et al., 2010*). This function is used to conduct power analysis for bivariate LCSMs based on a Monte Carlo method (a method also used by *Muthén & Muthén, 2002; Thoemmes et al., 2010; Zhang & Wang, 2009; Zhang, 2014*). For each Monte Carlo replication, the Maximum likelihood ratio test is used for the model, while the Wald test is used for the parameter test. The method can obtain the power for testing each individual parameter of the models such as the change rate and coupling parameters.

Usage

```
wp.blcsm(N = 100, T = 5, R = 1000, betay = 0, my0 = 0, mys = 0,
  varey = 1, vary0 = 1, varys = 1, vary0ys = 0, alpha = 0.05,
  betax = 0, mx0 = 0, mxs = 0, varex = 1, varx0 = 1, varxs = 1,
  varx0xs = 0, varx0y0 = 0, varx0ys = 0, vary0xs = 0, varxsys = 0,
  gammax = 0, gammay = 0, ...)
```

Arguments

N	Sample size. It is 100 by default.
T	Number of measurement occasions. It is 5 by default.
R	Number of replications for the Monte Carlo simulation. It is 1000 by default.
betay	Parameter in the model: The compound rate of change for variable y. Its default value is 0.
my0	Parameter in the model: Mean of the initial latent score for variable y. Its default value is 0.
mys	Parameter in the model: Mean of the linear constant effect for variable y. Its default value is 0.
varey	Parameter in the model: Variance of the measurement error/uniqueness score for variable y. Its default value is 1.
vary0	Parameter in the model: Variance of the initial latent score for variable y. Its default value is 1.
varys	Parameter in the model: Variance of the linear constant effect for variable y. Its default value is 0.
vary0ys	Parameter in the model: Covariance of the initial latent score and the linear constant effect for variable y. Its default value is 0.
alpha	significance level chosed for the test. It equals 0.05 by default.
betax	Parameter in the model: The compound rate of change for variable x. Its default value is 0.
mx0	Parameter in the model: Mean of the initial latent score for variable x. Its default value is 0.
mxs	Parameter in the model: Mean of the linear constant effect for variable x. Its default value is 0.
varex	Parameter in the model: Variance of the measurement error/uniqueness score for variable x. Its default value is 1.
varx0	Parameter in the model: Variance of the initial latent score for variable x. Its default value is 1.
varxs	Parameter in the model: Variance of the linear constant effect for variable x. Its default value is 0.

varx0xs	Parameter in the model: Covariance of the initial latent score and the linear constant effect for variable x. Its default value is 0.
varx0y0	Parameter in the model: Covariance of the initial latent scores for y and x. Its default value is 0.
varx0ys	Parameter in the model: Covariance of the initial latent score for x and the linear constant effect for y. Its default value is 0.
vary0xs	Parameter in the model: Covariance of the initial latent score for y and the linear constant effect for x. Its default value is 0.
varxsys	Parameter in the model: Covariance of the linear constant effects for y and x. Its default value is 0.
gammax	Coupling parameter in the model: The effect of variable x on the change score of variable y. Its default value is 0.
gammay	Coupling parameter in the model: The effect of variable y on the change score of variable x. Its default value is 0.
...	Extra arguments. It is not required.

Value

An object of the power analysis. The output of the R function includes 4 main pieces of information for each parameter in the model. The first is the Monte Carlo estimate (mc.est). It is calculated as the mean of the R sets of parameter estimates from the simulated data. Note that the Monte Carlo estimates should be close to the population parameter values used in the model. The second is the Monte Carlo standard deviation (mc.sd), which is calculated as the standard deviation of the R sets of parameter estimates. The third is the Monte Carlo standard error (mc.se), which is obtained as the average of the R sets of standard error estimates of the parameter estimates. Lastly, mc.power is the statistical power for each parameter.

References

Zhang, Z., & Liu, H. (2018). Sample Size and Measurement Occasion Planning for Latent Change Score Models through Monte Carlo Simulation. In E. Ferrer, S. M. Boker, and K. J. Grimm (Eds.) Advances in Longitudinal Models for Multivariate Psychology: A Festschrift for Jack McArdle.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
## Not run:
#To conduct power analysis for a bivariate LCSM with sample size equal to 100:
wp.blcsm(N=100, T=5, R=1000, betay=0.08, my0=20, mys=1.5, varey=9,
     vary0=3, varys=1, vary0ys=0, alpha=0.05, betax=0.2, mx0=20, mxs=5,
         varex=9, varx0=3, varxs=1, varx0xs=0, varx0y0=1, varx0ys=0,
                           vary0xs=0, varxsys=0, gammax=0, gammay=-.1)
#             pop.par mc.est  mc.sd  mc.se  mc.power N T
#    betax    0.20     0.230  0.260  0.187  0.241   100 5
#    betay    0.08     0.164  0.572  0.435  0.081   100 5
#    gammax   0.00    -0.033  0.234  0.178  0.112   100 5
#    gammay  -0.10    -0.175  0.641  0.458  0.075   100 5
```

```
#    mx0     20.00    20.004  0.336  0.326  1.000   100 5
#    mxs      5.00     5.933  7.848  5.615  0.167   100 5
#    my0     20.00    20.019  0.346  0.326  1.000   100 5
#    mys      1.50     0.451  6.933  5.321  0.156   100 5
#    varex    9.00     8.941  0.744  0.732  1.000   100 5
#    varey    9.00     8.939  0.749  0.720  1.000   100 5
#    varx0    3.00     3.029  1.243  1.222  0.739   100 5
#    varx0xs  0.00    -0.210  0.768  0.767  0.030   100 5
#    varx0y0  1.00     1.052  0.840  0.835  0.226   100 5
#    varx0ys  0.00    -0.012  0.668  0.601  0.017   100 5
#    varxs    0.60     2.343  6.805  2.687  0.090   100 5
#    varxsys  0.00     0.072  3.559  1.740  0.019   100 5
#    vary0    3.00     2.951  1.423  1.245  0.684   100 5
#    vary0xs  0.00     0.198  2.263  1.629  0.031   100 5
#    vary0ys  0.00    -0.371  1.970  1.511  0.106   100 5
#    varys    0.05     1.415  3.730  2.096  0.024   100 5

#To conduct power analysis for a bivariate LCSM with sample size equal to 500:
wp.blcsm(N=500, T=5, R=1000, betay=0.08, my0=20, mys=1.5, varey=9,
      vary0=3, varys=1, vary0ys=0, alpha=0.05, betax=0.2, mx0=20
           , mxs=5, varex=9, varx0=3, varxs=1, varx0xs=0, varx0y0=1,
                 varx0ys=0, vary0xs=0, varxsys=0, gammax=0, gammay=-.1)
#            pop.par mc.est mc.sd mc.se  mc.power N  T
#    betax    0.20  0.2009 0.031 0.031   1.000  500 5
#    betay    0.08  0.0830 0.070 0.068   0.199  500 5
#    gammax   0.00 -0.0014 0.030 0.029   0.057  500 5
#    gammay  -0.10 -0.1022 0.072 0.073   0.271  500 5
#    mx0     20.00 19.9911 0.145 0.145   1.000  500 5
#    mxs      5.00  5.0308 0.939 0.942   1.000  500 5
#    my0     20.00 19.9999 0.143 0.146   1.000  500 5
#    mys      1.50  1.4684 0.889 0.885   0.420  500 5
#    varex    9.00  8.9836 0.340 0.328   1.000  500 5
#    varey    9.00  8.9961 0.341 0.328   1.000  500 5
#    varx0    3.00  3.0052 0.524 0.523   1.000  500 5
#    varx0xs  0.00 -0.0144 0.222 0.230   0.047  500 5
#    varx0y0  1.00  1.0064 0.360 0.360   0.808  500 5
#    varx0ys  0.00 -0.0012 0.199 0.201   0.051  500 5
#    varxs    1.00  1.0312 0.180 0.189   1.000  500 5
#    varxsys  0.00  0.0028 0.161 0.163   0.045  500 5
#    vary0    3.00  2.9777 0.519 0.547   1.000  500 5
#    vary0xs  0.00  0.0072 0.286 0.294   0.035  500 5
#    vary0ys  0.00 -0.0135 0.252 0.257   0.043  500 5
#    varys    1.00  1.0246 0.260 0.253   0.999  500 5

## End(Not run)
```

---

wp.correlation *Statistical Power Analysis for Correlation*

Description

This function is for power analysis for correlation. Correlation measures whether and how a pair of variables are related. The Pearson Product Moment correlation coefficient (r) is adopted here. The power calculation for correlation is conducted based on Fisher's z transformation of Pearson correlation coefficent *(Fisher, 1915, 1921)*.

Usage

```
wp.correlation(n = NULL, r = NULL, power = NULL, p = 0, rho0 = 0,
  alpha = 0.05, alternative = c("two.sided", "less", "greater"))
```

Arguments

`n`	Sample size.
`r`	Effect size or correlation. According to *Cohen (1988)*, a correlation coefficient of 0.10, 0.30, and 0.50 are considered as an effect size of "small", "medium", and "large", respectively.
`power`	Statistical power.
`p`	Number of variables to partial out.
`rho0`	Null correlation coefficient.
`alpha`	Significance level chosed for the test. It equals 0.05 by default.
`alternative`	Direction of the alternative hypothesis (`"two.sided"` or `"less"` or `"greater"`). The default is "two.sided".

Value

An object of the power analysis.

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Fisher, R. A. (1915). Frequency distribution of the values of the correlation coefficient in samples from an indefinitely large population. Biometrika, 10(4), 507-521.

Fisher, R. A. (1921). On the probable error of a coefficient of correlation deduced from a small sample. Metron, 1, 3-32.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
wp.correlation(n=50,r=0.3, alternative="two.sided")
#  Power for correlation
#
#     n   r alpha     power
#    50 0.3  0.05 0.5728731
#
```

```
#  URL: http://psychstat.org/correlation

#To calculate the power curve with a sequence of sample sizes:
res <- wp.correlation(n=seq(50,100,10),r=0.3, alternative="two.sided")
res
#  Power for correlation
#
#      n   r alpha     power
#     50 0.3  0.05 0.5728731
#     60 0.3  0.05 0.6541956
#     70 0.3  0.05 0.7230482
#     80 0.3  0.05 0.7803111
#     90 0.3  0.05 0.8272250
#    100 0.3  0.05 0.8651692
#
#  URL: http://psychstat.org/correlation

#To plot the power curve:
plot(res, type='b')

#To estimate the sample size with a given power:
wp.correlation(n=NULL, r=0.3, power=0.8, alternative="two.sided")
#  Power for correlation
#
#           n   r alpha power
#    83.94932 0.3  0.05   0.8
#
#  URL: http://psychstat.org/correlation

#To estimate the minimum detectable effect size with a given power:
wp.correlation(n=NULL,r=0.3, power=0.8, alternative="two.sided")
#  Power for correlation
#
#           n   r alpha power
#    83.94932 0.3  0.05   0.8
#
#  URL: http://psychstat.org/correlation
#
#To calculate the power curve with a sequence of effect sizes:
res <- wp.correlation(n=100,r=seq(0.05,0.8,0.05), alternative="two.sided")
res
#  Power for correlation
#
#      n    r alpha      power
#    100 0.05  0.05 0.07854715
#    100 0.10  0.05 0.16839833
#    100 0.15  0.05 0.32163978
#    100 0.20  0.05 0.51870091
#    100 0.25  0.05 0.71507374
#    100 0.30  0.05 0.86516918
#    100 0.35  0.05 0.95128316
#    100 0.40  0.05 0.98724538
#    100 0.45  0.05 0.99772995
```

```
#    100 0.50  0.05 0.99974699
#    100 0.55  0.05 0.99998418
#    100 0.60  0.05 0.99999952
#    100 0.65  0.05 0.99999999
#    100 0.70  0.05 1.00000000
#    100 0.75  0.05 1.00000000
#    100 0.80  0.05 1.00000000
#
#  URL: http://psychstat.org/correlation
```

`wp.crt2arm` *Statistical Power Analysis for Cluster Randomized Trials with 2 Arms*

Description

Cluster randomized trials (CRT) are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a contral arm *(Liu, 2013).* The data from CRT can be analyzed in a two-level hierachical linear model, where the indicator variable for treatment assignment is included in second level. If a study contains multiple treatments, then mutiple indicators will be used. This function is for designs with 2 arms (i.e., a treatment and a control). Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013).*

Usage

```
wp.crt2arm(n = NULL, f = NULL, J = NULL, icc = NULL, power = NULL,
  alpha = 0.05, alternative = c("two.sided", "one.sided"), interval = NULL)
```

Arguments

`n`	Sample size. It is the number of individuals within each cluster.
`f`	Effect size. It specifies either the main effect of treatment, or the mean difference between the treatment clusters and the control clusters.
`J`	Number of clusters / sides. It tells how many clusters are considered in the study design. At least two clusters are required.
`icc`	Intra-class correlation. ICC is calculated as the ratio of between-cluster variance to the total variance. It quantifies the degree to which two randomly drawn observations within a cluster are correlated.
`power`	Statistical power.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`alternative`	Type of the alternative hypothesis (`"two.sided"` or `"one.sided"`). The default is "two.sided". The option "one.sided" can be either "less" or "greater".
`interval`	A vector containing the end-points of the interval to be searched for the root.

Value

An object of the power analysis.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.crt2arm(f = 0.6, n = 20, J = 10, icc = 0.1, alpha = 0.05, power = NULL)
#  Cluster randomized trials with 2 arms
#
#     J  n   f icc     power alpha
#    10 20 0.6 0.1 0.5901684  0.05
#
#  NOTE: n is the number of subjects per cluster.
#  URL: http://psychstat.org/crt2arm

#To generate a power curve given a sequence of sample sizes:
res <- wp.crt2arm(f = 0.6, n = seq(20,100,10), J = 10,
                       icc = 0.1, alpha = 0.05, power = NULL)
res
#  Cluster randomized trials with 2 arms
#
#     J   n   f icc     power alpha
#    10  20 0.6 0.1 0.5901684  0.05
#    10  30 0.6 0.1 0.6365313  0.05
#    10  40 0.6 0.1 0.6620030  0.05
#    10  50 0.6 0.1 0.6780525  0.05
#    10  60 0.6 0.1 0.6890755  0.05
#    10  70 0.6 0.1 0.6971076  0.05
#    10  80 0.6 0.1 0.7032181  0.05
#    10  90 0.6 0.1 0.7080217  0.05
#    10 100 0.6 0.1 0.7118967  0.05
#
#  NOTE: n is the number of subjects per cluster.
#  URL: http://psychstat.org/crt2arm

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.crt2arm(f = 0.8, n = NULL, J = 10,
                 icc = 0.1, alpha = 0.05, power = 0.8)
#  Cluster randomized trials with 2 arms
#
#     J        n   f icc power alpha
#    10 16.02558 0.8 0.1   0.8  0.05
#
```

```
# NOTE: n is the number of subjects per cluster.
# URL: http://psychstat.org/crt2arm
```

---

wp.crt3arm *Statistical Power Analysis for Cluster Randomized Trials with 3 Arms*

Description

Cluster randomized trials (CRT) are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a control arm *(Liu, 2013)*. The data from CRT can be analyzed in a two-level hierarchical linear model, where the indicator variable for treatment assignment is included in second level. If a study contains multiple treatments, then multiple indicators will be used. This function is for designs with 3 arms (i.e., two treatments and a control). Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*.

Usage

```
wp.crt3arm(n = NULL, f = NULL, J = NULL, icc = NULL, power = NULL,
  alpha = 0.05, alternative = c("two.sided", "one.sided"),
  type = c("main", "treatment", "omnibus"), interval = NULL)
```

Arguments

`n`	Sample size. It is the number of individuals within each cluster.
`f`	Effect size. It specifies one of the three types of effects: the main effect of treatment, the mean difference between the treatment clusters, and the control clusters.
`J`	Number of clusters / sides. It tells how many clusters are considered in the study design. At least two clusters are required.
`icc`	Intra-class correlation. ICC is calculated as the ratio of between-cluster variance to the total variance. It quantifies the degree to which two randomly drawn observations within a cluster are correlated.
`power`	Statistical power.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`alternative`	Type of the alternative hypothesis (`"two.sided"` or `"one.sided"`). The default is "two.sided". The option "one.sided" can be either "less" or "greater".
`type`	Type of effect (`"main"` or `"treatment"` or `"omnibus"`) with "main" as default. The type "main" tests the difference between the average treatment arms and the control arm; Type "treatment" tests the difference between the two treatment arms; and Type "omnibus" tests whether the tree arms are all equivalent.
`interval`	A vector containing the end-points of the interval to be searched for the root.

Value

An object of the power analysis.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.crt3arm(f = 0.5, n = 20, J = 10, icc = 0.1, alpha = 0.05, power = NULL)
#  Cluster randomized trials with 3 arms
#
#      J  n   f icc     power alpha
#     10 20 0.5 0.1 0.3940027  0.05
#
#  NOTE: n is the number of subjects per cluster.
#  URL: http://psychstat.org/crt3arm

#To generate a power curve given a sequence of sample sizes:
res <- wp.crt3arm(f = 0.5, n = seq(20, 100, 10), J = 10,
                       icc = 0.1, alpha = 0.05, power = NULL)
res
#  Cluster randomized trials with 3 arms
#
#      J   n   f icc     power alpha
#     10  20 0.5 0.1 0.3940027  0.05
#     10  30 0.5 0.1 0.4304055  0.05
#     10  40 0.5 0.1 0.4513376  0.05
#     10  50 0.5 0.1 0.4649131  0.05
#     10  60 0.5 0.1 0.4744248  0.05
#     10  70 0.5 0.1 0.4814577  0.05
#     10  80 0.5 0.1 0.4868682  0.05
#     10  90 0.5 0.1 0.4911592  0.05
#     10 100 0.5 0.1 0.4946454  0.05
#
#  NOTE: n is the number of subjects per cluster.
#  URL: http://psychstat.org/crt3arm

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.crt3arm(f = 0.8, n = NULL, J = 10, icc = 0.1, alpha = 0.05, power = 0.8)
#  Cluster randomized trials with 3 arms
#
#      J        n   f icc power alpha
#     10 27.25145 0.8 0.1   0.8  0.05
#
#  NOTE: n is the number of subjects per cluster.
```

```
# URL: http://psychstat.org/crt3arm
```

`wp.effect.CRT2arm` *Effect size calculatator based on raw data for Cluster Randomized Trials with 2 Arms*

Description

This function is for effect size and ICC calculation for CRT with 2 arms based on empirical data. Cluster randomized trials (CRT) are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a contral arm *(Liu, 2013)*. The data from CRT can be analyzed in a two-level hierachical linear model, where the indicator variable for treatment assignment is included in second level. If a study contains multiple treatments, then mutiple indicators will be used. This function is for designs with 3 arms (i.e., two treatments and a control). Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*. The Effect size f specifies the main effect of treatment, the mean difference between the treatment clusters and the control clusters. This function is used to calculate the effect size with a input data set.

Usage

```
wp.effect.CRT2arm(file)
```

Arguments

`file`	The input data set. The first column of the data is the ID variable, the second column represents cluster, the third column is the outcome variable, and the fourth column is the condition variable (0 for control, 1 for condition).

Value

A list including effect size f and ICC.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Examples

```
#Empirical data set CRT2:
CRT2
#ID cluster score group
#1 1 6 0
#2 1 2 0
#3 2 6 1
```

```
#4 2 5 1
#5 3 1 0
#6 3 4 0
#7 4 6 1
#8 4 4 1

#To calculate the effect size and ICC based on empirical data
wp.effect.CRT2arm (CRT2)
#  Effect size for CRT2arm
#
#         f  ICC
#  1.264911 -0.5
#
#  NOTE: f is the effect size.
#  URL: http://psychstat.org/crt2arm
```

---

wp.effect.CRT3arm — *Effect size calculatator based on raw data for Cluster Randomized Trials with 3 Arms*

Description

This function is for effect size and ICC calculation for Cluster randomized trials (CRT) with 3 arms based on empirical data. CRT are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a contral arm *(Liu, 2013)*. The data from CRT can be analyzed in a two-level hierachical linear model, where the indicator variable for treatment assignment is included in second level. If a study contains multiple treatments, then mutiple indicators will be used. This function is for designs with 3 arms (i.e., two treatments and a control). Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*. The Effect size f specifies the main effect of treatment, the mean difference between the treatment clusters and the control clusters. This function is used to calculate the effect size with a input data set.

Usage

```
wp.effect.CRT3arm(file)
```

Arguments

`file`	The input data set. The first column of the data is the ID variable, the second column represents cluster, the third column is the outcome variable, and the fourth column is the condition variable (0 for control, 1 for treatment1, 2 for treatment2).

Value

A list including effect size f1, f2, f3, and ICC.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Examples

```
#To calculate the effect sizes based on empirical data
wp.effect.CRT3arm (CRT3)
#  Effect size for CRT3arm
#
#  f1         f2        f3       ICC
#  0.6389258 -0.6189113 0.3931397 -0.019794
#
#  NOTE: f1 for treatment main effect;
#        f2 for difference between two treatments;
#        f3 for effect size of omnibus test.
#  URL: http://psychstat.org/crt3arm
```

`wp.effect.MRT2arm` *Effect size calculatator based on raw data for Multisite Randomized Trials with 2 Arms*

Description

This function is for effect size calculation for Multisite randomized trials (MRT) with 2 arms based on empirical data. MRTs are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a contral arm *(Liu, 2013)*. The data from MRT can be analyzed in a two-level hierachical linear model, where the indicator variable for treatment assignment is included in first level. If a study contains multiple treatments, then mutiple indicators will be used. Three types of tests are considered in the function: (1) The "main" type tests treatment main effect; (2) The "site" type tests the variance of cluster/site means; and (3) The "variance" type tests variance of treatment effects. Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*. This function is used to calculate the effect size with a input data set.

Usage

```
wp.effect.MRT2arm(file)
```

Arguments

`file` The input data set. The first column of the data is the ID variable, the second column represents cluster, the third column is the outcome variable, and the fourth column is the condition variable (0 for control, 1 for condition).

Value

A list including effect size f.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Examples

```
#To calculate the effect size based on empirical data
wp.effect.MRT2arm (MRT2)
#  Effect size for MRT2arm
#
#  f
#  -0.2986755
#
#  NOTE: f is the effect size.
#  URL: http://psychstat.org/mrt2arm
```

---

wp.effect.MRT3arm *Effect size calculatator based on raw data for Multisite Randomized Trials with 3 Arms*

Description

This function is for effect size calculation for Multisite randomized trials (MRT) with 3 arms based on empirical data. MRTs are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a contral arm *(Liu, 2013)*. The data from MRT can be analyzed in a two-level hierachical linear model, where the indicator variable for reatment assignment is included in first level. If a study contains multiple treatments, then mutiple indicators will be used. This function is for designs with 3 arms (i.e., two treatments and a control). Three types of tests are considered in the function: (1) The "main" type tests treatment main effect; (2) The "treatment" type tests the difference between the two treaments; and (3) The "omnibus" type tests whether the three arms are all equivalent. Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*. This function is used to calculate the effect size with a input data set.

Usage

```
wp.effect.MRT3arm(file)
```

Arguments

`file` The input data set. The first column of the data is the ID variable, the second column represents cluster, the third column is the outcome variable, and the fourth column is the condition variable (0 for control, 1 for treatment1, 2 for treatment2).

Value

A list including effect size f.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Examples

```
#To calculate the effect size and ICC based on empirical data
#  wp.effect.MRT3arm(MRT3)
#  Effect size for MRT3arm
#
#  f1        f2
#  -0.6214215 -0.355098
#
#  NOTE: f1 for treatment main effect;
#        f2 for comparing the two treatments.
#  URL: http://psychstat.org/mrt3arm
```

---

wp.kanova — *Power analysis for two-way, three-way and k-way ANOVA*

Description

Power analysis for two-way, three-way and k-way ANOVA

Usage

```
wp.kanova(n = NULL, ndf = NULL, f = NULL, ng = NULL, alpha = 0.05, power = NULL)
```

Arguments

`n`	Sample size
`ndf`	Numerator degrees of freedom
`f`	Effect size
`ng`	Number of groups
`alpha`	Significance level
`power`	Statistical power

References

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
########## Chapter 6. two-way and three-way ANOVA  #############
## Main effect of two-way ANOVA
wp.kanova(n=120, ndf=2, f=0.2, alph=0.05, ng=6)

## Interaction effect of two-way ANOVA
wp.kanova(n=120, ndf=2, f=0.4, alph=0.05, ng=6)

## Interaction effect of three-way ANOVA
wp.kanova(n=360, ndf=4, f=0.3, alph=0.05, ng=18)
```

`wp.lcsm` *Statistical Power Curve for Univariate Latent Change Score Models based on Monte Carlo Simulation*

Description

A longitudinal design often involves data collection on multiple variables from multiple participants at multiple times. Growth curve models (GCM) are structural equation models for longitudinal data analysis (*McArdle & Epstein, 1987; McArdle & Nesselroade, 2014*). Latent change score models (LCSM) combine difference equations with growth curves to investigate change in longitudinal studies . LCSM provied an efficient way to model nonlinear trajectory (e.g., *McArdle, 2000; McArdle & Hamagami, 2001; Hamagami et al., 2010*). This function is used to conduct power analysis for univariate LCSMs based on a Monte Carlo method (a method also used by *Muthén & Muthén, 2002; Thoemmes et al., 2010; Zhang & Wang, 2009; Zhang, 2014*). For each Monte Carlo replication, the Maximum likelihood ratio test is used for the model, while the Wald test is used for the parameter test. The method can obtain the power for testing each individual parameter of the models such as the change rate and coupling parameters.

Usage

```
wp.lcsm(N = 100, T = 5, R = 1000, betay = 0, my0 = 0, mys = 0,
  varey = 1, vary0 = 1, varys = 1, vary0ys = 0, alpha = 0.05, ...)
```

Arguments

N	Sample size. It is 100 by default.
T	Number of measurement occasions. It is 5 by default.
R	Number of replications for the Monte Carlo simulation. It is 1000 by default.
betay	Parameter in the model: The compound rate of change. Its default value is 0.
my0	Parameter in the model: Mean of the initial latent score. Its default value is 0.
mys	Parameter in the model: Mean of the linear constant effect. Its default value is 0.
varey	Parameter in the model: Variance of the measurement error/uniqueness score. Its default value is 1.
vary0	Parameter in the model: Variance of the initial latent score. Its default value is 1.
varys	Parameter in the model: Variance of the linear constant effect. Its default value is 0.
vary0ys	Parameter in the model: Covariance of the initial latent score and the linear constant effect. Its default value is 0.
alpha	significance level chosed for the test. It equals 0.05 by default.
...	Extra arguments. It is not required.

Value

An object of the power analysis. The output of the R function includes 4 main pieces of information for each parameter in the model. The first is the Monte Carlo estimate (mc.est). It is calculated as the mean of the R sets of parameter estimates from the simulated data. Note that the Monte Carlo estimates should be close to the population parameter values used in the model. The second is the Monte Carlo standard deviation (mc.sd), which is calculated as the standard deviation of the R sets of parameter estimates. The third is the Monte Carlo standard error (mc.se), which is obtained as the average of the R sets of standard error estimates of the parameter estimates. Lastly, mc.power is the statistical power for each parameter.

References

Zhang, Z., & Liu, H. (2018). Sample Size and Measurement Occasion Planning for Latent Change Score Models through Monte Carlo Simulation. In E. Ferrer, S. M. Boker, and K. J. Grimm (Eds.) Advances in Longitudinal Models for Multivariate Psychology: A Festschrift for Jack McArdle.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
## Not run:
#Power analysis for a univariate LCSM
#Power for each parameter given sample size, number of measurement occasions,
# true effect (true values of parameters), and significance level:
wp.lcsm(N = 100, T = 5, R = 1000, betay = 0.1, my0 = 20, mys = 1.5,
```

```
        varey = 9, vary0 = 2.5, varys = .05, vary0ys = 0, alpha = 0.05)
#           pop.par mc.est mc.sd mc.se mc.power  N  T
#    betay   0.10   0.103  0.043 0.044  0.664   100 5
#    my0    20.00  19.999  0.324 0.319  1.000   100 5
#    mys     1.50   1.418  1.106 1.120  0.274   100 5
#    varey   9.00   8.961  0.724 0.732  1.000   100 5
#    vary0   2.50   2.463  1.151 1.139  0.583   100 5
#    vary0ys 0.00  -0.004  0.408 0.403  0.048   100 5
#    varys   0.05   0.053  0.173 0.175  0.050   100 5
#
#  #To calculate the Type I error rate and power for parameters
  wp.lcsm(N = 100, T = 5, R = 1000, betay = 0, my0 = 0, mys = 0,
              varey = 1, vary0 = 1, varys = 1, vary0ys = 0,alpha = 0.05)
#           pop.par mc.est mc.sd mc.se mc.power N T
#    betay   0 0.001 0.056 0.056 0.046 100 5
#    my0 0 0.001 0.129 0.126 0.056 100 5
#    mys 0 0.002 0.105 0.105 0.044 100 5
#    varey   1 0.994 0.083 0.081 1.000 100 5
#    vary0   1 0.990 0.236 0.230 1.000 100 5
#    vary0ys 0 -0.005 0.136 0.136 0.044 100 5
#    varys   1 1.006 0.227 0.227 1.000 100 5

# To generate a power curve for different sample sizes for a univariate LCSM
res <- wp.lcsm(N = seq(100, 200, 10), T = 5, R = 1000, betay = 0.1,
                          my0 = 20, mys = 1.5, varey = 9, vary0 = 2.5,
                               varys = .05, vary0ys = 0, alpha = 0.05)
#plot(res, parameter='betay')
#plot(res, parameter='mys')

# To generate a power curve for different numbers of occasions for a univariate LCSM
res <- wp.lcsm(N = 100, T = 4:10, R = 1000, betay = 0.1, my0 = 20, mys = 1.5,
                varey = 9, vary0 = 2.5, varys = .05, vary0ys = 0, alpha = 0.05)
#plot(res, parameter='betay')
#plot(res, parameter='mys')

## End(Not run)
```

`wp.logistic` *Statistical Power Analysis for Logistic Regression*

Description

This function is for Logistic regression models. Logistic regression is a type of generalized linear models where the outcome variable follows Bernoulli distribution. Here, Maximum likelihood methods is used to estimate the model parameters. The estimated regression coefficent is assumed to follow a normal distribution. A Wald test is use to test the mean difference between the estimated parameter and the null parameter (tipically the null hypothesis assumes it equals 0). The procedure introduced by *Demidenko (2007)* is adopted here for computing the statistical power.

Usage

```
wp.logistic(n = NULL, p0 = NULL, p1 = NULL, alpha = 0.05,
  power = NULL, alternative = c("two.sided", "less", "greater"),
  family = c("Bernoulli", "exponential", "lognormal", "normal", "Poisson",
  "uniform"), parameter = NULL)
```

Arguments

n	Sample size.
p0	Prob(*Y=1|X=0*): the probobility of observieng 1 for the outcome variable Y when the predictor X equals 0.
p1	Prob(*Y=1|X=1*): the probobility of observieng 1 for the outcome variable Y when the predictor X equals 1.
alpha	significance level chosed for the test. It equals 0.05 by default.
power	Statistical power.
alternative	Direction of the alternative hypothesis ("two.sided" or "less" or "greater"). The default is "two.sided".
family	Distribution of the predictor ("Bernoulli","exponential", "lognormal", "normal", "Poisson", "uniform"). The default is "Bernoulli".
parameter	Corresponding parameter for the predictor's distribution. The default is 0.5 for "Bernoulli", 1 for "exponential", (0,1) for "lognormal" or "normal", 1 for "Poisson", and (0,1) for "uniform".

Value

An object of the power analysis.

References

Demidenko, E. (2007). Sample size determination for logistic regression revisited. Statistics in medicine, 26(18), 3385-3397.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.logistic(n = 200, p0 = 0.15, p1 = 0.1, alpha = 0.05,
            power = NULL, family = "normal", parameter = c(0,1))
#  Power for logistic regression
#
#      p0  p1     beta0      beta1   n alpha     power
#    0.15 0.1 -1.734601 -0.4626235 200  0.05 0.6299315
#
#  URL: http://psychstat.org/logistic
```

```
#To generate a power curve given a sequence of sample sizes:
res <- wp.logistic(n = seq(100,500,50), p0 = 0.15, p1 = 0.1, alpha = 0.05,
                power = NULL, family = "normal", parameter = c(0,1))
res
#  Power for logistic regression
#
#      p0  p1     beta0      beta1   n alpha     power
#    0.15 0.1 -1.734601 -0.4626235 100  0.05 0.3672683
#    0.15 0.1 -1.734601 -0.4626235 150  0.05 0.5098635
#    0.15 0.1 -1.734601 -0.4626235 200  0.05 0.6299315
#    0.15 0.1 -1.734601 -0.4626235 250  0.05 0.7264597
#    0.15 0.1 -1.734601 -0.4626235 300  0.05 0.8014116
#    0.15 0.1 -1.734601 -0.4626235 350  0.05 0.8580388
#    0.15 0.1 -1.734601 -0.4626235 400  0.05 0.8998785
#    0.15 0.1 -1.734601 -0.4626235 450  0.05 0.9302222
#    0.15 0.1 -1.734601 -0.4626235 500  0.05 0.9518824
#
#  URL: http://psychstat.org/logistic

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.logistic(n = NULL, p0 = 0.15, p1 = 0.1, alpha = 0.05,
              power = 0.8, family = "normal", parameter = c(0,1))
#  Power for logistic regression
#
#      p0  p1     beta0      beta1        n alpha power
#    0.15 0.1 -1.734601 -0.4626235 298.9207  0.05   0.8
#
#  URL: http://psychstat.org/logistic
```

`wp.mc.chisq.diff` *Statistical Power Analysis for SEM Based on Chi-square Difference Test*

Description

This function is for SEM power analysis based on the chi-square difference test.

Usage

```
wp.mc.chisq.diff(full.model.pop, full.model,
reduced.model, N=100, R=1000, alpha=0.05)
```

Arguments

full.model.pop	Full model (under the alternative hypothesis) with population parameters.
full.model	Full model (under the alternative hypothesis) lavaan specification.
reduced.model	Reduced model (under the null hypothesis) lavaan specification.
N	Sample size.
R	Number of Monte Carlo replications.
alpha	significance level chosed for the test. It equals 0.05 by default.

Value

An object of the power analysis.

power	Statistical power.
df	Degrees of freedom
chi.diff	Chi-square differences between the reduced model and the full model

References

Demidenko, E. (2007). Sample size determination for logistic regression revisited. Statistics in medicine, 26(18), 3385-3397.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
set.seed(20220722)

full.model.pop <-'
y1 ~ 0.4*x
y2 ~ 0.5*x + 0.2*y1
y3 ~ 0.4*x
y4 ~ 0.4*y1 + 0.4*y2 + 0.4*y3
y1 ~~ 0.84*y1
y2 ~~ 0.61*y2
y3 ~~ 0.84*y3
y4 ~~ 0.27*y4
'

full.model <-'
y1 ~ x
y2 ~ x + y1
y3 ~ x
y4 ~ y1 + y2 + y3
'

reduced.model <-'
y1 ~ x
```

```
y2 ~ x
y3 ~ x
y4 ~ y1 + y3
'

wp.mc.chisq.diff(full.model.pop, full.model, reduced.model)
```

---

wp.mc.sem.basic *Statistical Power Analysis for Structural Equation Modeling / Mediation based on Monte Carlo Simulation*

Description

Structural equation modeling (SEM) is a multivariate technique used to analyze relationships among observed and latent variables. It can be viewed as a combination of factor analysis and multivariate regression analysis. A mediation model can be viewed as a SEM model. Funtions *wp.sem.chisq* and *wp.sem.rmsea* provide anlytical solutions of power analysis for SEM. Function *wp.mediation* provides anlytical solutions of power analysis for a simple mediatoin model. This function provides a solution based on Monte Carlo simulation (see *Zhang, 2014*). If the model is a mediation, Sobel test is used for the mediation / indirect effects. The solution is extended from the general framework for power analysis for complex mediation models using Monte Carlo simulation in Mplus *(Muthén & Muthén, 2011)* proposed by *Thoemmes et al. (2010)*. We extended the framework in two ways. First, the method allows the specification of nonnormal data in the Monte Carlo simulation and can thereby reflect more closely practical data collection. Second, the function *wp.mc.sem.basic* of a free, open-source R package, WebPower, is developed to ease power anlysis for mediation models using the proposed method.

Usage

```
wp.mc.sem.basic(model, indirect = NULL, nobs = 100, nrep = 1000,
  alpha = 0.95, skewness = NULL, kurtosis = NULL, ovnames = NULL,
  se = "default", estimator = "default", parallel = "no",
  ncore = Sys.getenv("NUMBER_OF_PROCESSORS"), cl = NULL, ...)
```

Arguments

model	Model specified using lavaan syntax. More about model specification can be found in *Rosseel (2012)*.
indirect	Indirect effect difined using lavaan syntax.
nobs	Sample size.
nrep	Number of replications for the Monte Carlo simulation.
alpha	significance level chosed for the test. It equals 0.05 by default.
skewness	A sequence of skewnesses of the observed variables.
kurtosis	A sequence of kurtosises of the observed variables.

ovnames Names of the observed variables in the model.

se The method for calculatating the standard errors. Its default method "default" is regular standard errors. More about methods specification standard errors calculatationcan be found in *Rosseel (2012).*

estimator Estimator. It is Maxmum likelihood estimator by default. More about estimator specification can be found in *Rosseel (2012).*

parallel Parallel computing ("no" or "parallel" or "snow"). It is "no" by default, which means it will not use parallel computing. The option "parallel" is to use multiple cores in a computer for parallel computing. It is used with the number of cores (*ncore*). The option "snow" is to use clusters for parallel computing. It is used with the number of clusters (*cl*).

ncore Number of processors used for parallel computing. By default, ncore = Sys.getenv('NUMBER_OF_PROC

cl Number of clusters. It is NULL by default. When it is NULL, the program will detect the number of clusters automatically.

... Extra arguments. It is not required.

Value

An object of the power analysis. The power for all parameters in the model as well as the indirect effects if specified.

References

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. Psychological methods, 1(2), 130.

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). Ghent, Belgium: Ghent University.

Satorra, A., & Saris, W. E. (1985). Power of the likelihood ratio test in covariance structure analysis. Psychometrika, 50(1), 83-90.

Thoemmes, F., MacKinnon, D. P., & Reiser, M. R. (2010). Power analysis for complex mediational designs using Monte Carlo methods. Structural Equation Modeling, 17(3), 510-534.

Zhang, Z. (2014). Monte Carlo based statistical power analysis for mediation models: Methods and software. Behavior research methods, 46(4), 1184-1198.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
set.seed(20220722)

#To calculate power for mediation based on Monte Carlo simulation when Sobel test is used:
#To specify the model
demo ="
y ~ cp*x + start(0)*x + b*m + start(0.39)* m
m ~ a*x + start(0.39)*x
```

```
x ~~ start(1)*x
m ~~ start(1)*m
y ~~ start(1)*y
"
#To specify the indirect effects
mediation = "
ab := a*b
abc:= a*b + cp
"
#To calculate power for mediation using regular standard errors
## change nrep to at least 1,000 in real data analysis
sobel.regular = wp.mc.sem.basic(model=demo, indirect=mediation, nobs=100, nrep=10,
       skewness=c(0, 0, 1.3), kurtosis=c(0,0,10), ovnames=c("x","m","y"))

#To calculate power for mediation using robust standard errors
sobel.robust = wp.mc.sem.basic(model=demo, indirect=mediation, nobs=100, nrep=10,
   skewness=c(0, 0, 1.3), kurtosis=c(0,0,10), ovnames=c("x","m","y"), se="robust")

#To print the power for mediation based on Sobel test using regular standard errors:
summary(sobel.regular)
#    Basic information:
#
#      Esimation method                                  ML
#      Standard error                              standard
#      Number of requested replications                1000
#      Number of successful replications               1000
#
#                            True  Estimate      MSE      SD     Power Coverage
#    Regressions:
#      y ~
#        x        (cp)      0.000    0.003    0.106    0.107    0.045    0.955
#        m         (b)      0.390    0.387    0.099    0.113    0.965    0.919
#      m ~
#        x         (a)      0.390    0.389    0.100    0.101    0.976    0.953
#    Variances:
#        x                  1.000    0.995    0.141    0.139    1.000    0.936
#        m                  1.000    0.981    0.139    0.137    1.000    0.923
#        y                  1.000    0.968    0.137    0.330    1.000    0.560
#
#    Indirect/Mediation effects:
#        ab                 0.152    0.150    0.056    0.060    0.886    0.928
#        abc                0.152    0.153    0.106    0.109    0.305    0.948

#To print the power analysis results for mediation based on Sobel test using robust standard errors:
summary(sobel.robust)
#    Basic information:
#
#      Esimation method                                  ML
#      Standard error                            robust.sem
#      Number of requested replications                1000
#      Number of successful replications               1000
#
#                            True  Estimate      MSE      SD     Power Coverage
```

```
#    Regressions:
#      y ~
#        x        (cp)      0.000   -0.003    0.106    0.113    0.055    0.945
#        m         (b)      0.390    0.398    0.111    0.119    0.972    0.927
#      m ~
#        x         (a)      0.390    0.389    0.099    0.101    0.974    0.939
#
#    Intercepts:
#        y                  0.000    0.000    0.100    0.104    0.058    0.942
#        m                  0.000    0.000    0.100    0.105    0.054    0.946
#        x                  0.000   -0.004    0.100    0.104    0.066    0.934
#
#    Variances:
#        x                  1.000    0.991    0.138    0.140    1.000    0.930
#        m                  1.000    0.976    0.135    0.135    1.000    0.915
#        y                  1.000    1.002    0.281    0.365    0.981    0.805
#
#    Indirect/Mediation effects:
#        ab                 0.152    0.156    0.060    0.064    0.870    0.900
#        abc                0.152    0.153    0.108    0.117    0.303    0.936
```

`wp.mc.sem.boot` *Statistical Power Analysis for Structural Equation Modeling / Mediation based on Monte Carlo Simulation: bootstrap method*

Description

Structural equation modeling (SEM) is a multivariate technique used to analyze relationships among observed and latent variables. It can be viewed as a combination of factor analysis and multivariate regression analysis. A mediation model can be viewed as a SEM model. Funtions *wp.sem.chisq* and *wp.sem.rmsea* provide anlytical solutions of power analysis for SEM. Function *wp.mediation* provides anlytical solutions of power analysis for a simple mediatoin model. This function provides a solution based on Monte Carlo simulation (see *Zhang, 2014*) and a bootstrap method for testing the indirect /mediation effects. The solution is extended from the general framework for power analysis for complex mediation models using Monte Carlo simulation in Mplus *(Muthén & Muthén, 2011)* proposed by *Thoemmes et al. (2010)*. We extended the framework in three ways. First, we proposes a general method to conduct power analysis for mediation models based on the bootstrap method. The method is still based on Monte Carlo simulation but uses the bootstrap method to test mediation effects. Second, the method allows the specification of nonnormal data in the Monte Carlo simulation and can thereby reflect more closely practical data collection. Third, the function *wp.mc.sem.boot* of a free, open-source R package, WebPower, is developed to ease power anlysis for mediation models using the proposed method.

Usage

```
wp.mc.sem.boot(model, indirect = NULL, nobs = 100, nrep = 1000,
  nboot = 1000, alpha = 0.95, skewness = NULL, kurtosis = NULL,
```

```
ovnames = NULL, se = "default", estimator = "default",
parallel = "no", ncore = Sys.getenv("NUMBER_OF_PROCESSORS"), cl = NULL,
...)
```

Arguments

model	Model specified using lavaan syntax. More about model specification can be found in *Rosseel (2012).*
indirect	Indirect effect difined using lavaan syntax.
nobs	Sample size. It is 100 by default.
nrep	Number of replications for the Monte Carlo simulation. It is 1000 by default.
nboot	Number of replications for the bootstrap to test the specified parameter (e.g., mediation). It is 1000 by default.
alpha	significance level chosed for the test. It equals 0.05 by default.
skewness	A sequence of skewnesses of the observed variables. It is not required.
kurtosis	A sequence of kurtosises of the observed variables. It is not required.
ovnames	Names of the observed variables in the model. It is not required.
se	The method for calculatating the standard errors. Its default method "default" is regular standard errors. More about methods specification standard errors calculatationcan be found in *Rosseel (2012).*
estimator	Estimator. It is Maxmum likelihood estimator by default. More about estimator specification can be found in *Rosseel (2012).*
parallel	Parallel computing (`"no"` or `"parallel"` or `"snow"`). It is "no" by default, which means it will not use parallel computing. The option "parallel" is to use multiple cores in a computer for parallel computing. It is used with the number of cores (*ncore*). The option "snow" is to use clusters for parallel computing. It is used with the number of clusters (*cl*).
ncore	Number of processors used for parallel computing. By default, ncore = Sys.getenv('NUMBER_OF_PROC
cl	Number of clusters. It is NULL by default. When it is NULL, the program will detect the number of clusters automatically.
...	Extra arguments. It is not required.

Value

An object of the power analysis. The power for all parameters in the model as well as the indirect effects if specified.

References

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). Ghent, Belgium: Ghent University.

Thoemmes, F., MacKinnon, D. P., & Reiser, M. R. (2010). Power analysis for complex mediational designs using Monte Carlo methods. Structural Equation Modeling, 17(3), 510-534.

Zhang, Z. (2014). Monte Carlo based statistical power analysis for mediation models: Methods and software. Behavior research methods, 46(4), 1184-1198.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
set.seed(20220722)

#To specify the model
demo ="
y ~ cp*x + start(0)*x + b*m + start(0.39)* m
m ~ a*x + start(0.39)*x
x ~~ start(1)*x
m ~~ start(1)*m
y ~~ start(1)*y
"
#To specify the indirect effects
mediation = "
ab := a*b
abc:= a*b + cp
"
#Power for mediation based on MC method when bootstrap method is used to test the effects:
# change nrep and nboot to at least 1,000 in real analysis

mediation.boot = wp.mc.sem.boot(model=demo, indirect=mediation, nobs=100,
                               nrep=10, nboot=10,
             skewness=c(0, 0, 1.3), kurtosis=c(0,0,10), ovnames=c("x","m","y"))

#To print the power analysis results
summary(mediation.boot)

#Example: Power for Simple Mediation Analysis
ex1model <- "
math ~ c*ME + start(0)*ME + b*HE + start(0.39)*HE
HE ~ a*ME + start(0.39)*ME
"

indirect <- "ab:=a*b"

# change nrep and nboot to at least 1,000 in real analysis
boot.normal <- wp.mc.sem.boot(ex1model,indirect, 50, nrep=10, nboot=10)
summary(boot.normal)

boot.non.normal <- wp.mc.sem.boot(ex1model,indirect, 100, nrep=10, nboot=10,
                              skewness=c(-0.3, -0.7, 1.3),
                              kurtosis=c(1.5, 0, 5), ovnames=c('ME','HE','math'))
summary(boot.non.normal)

#Example: Multiple Group Mediation Analysis (Moderated Mediation)
ex3model <- "
y ~ start(c(0.283, 0.283))*x + c(c1,c2)*x + start(c(0.36, 0.14))*m + c(b1,b2)*m
m ~ start(c(0.721, 0.721))*x + c(a1,a2)*x
m =~ c(1,1)*m1 + start(c(0.8, 0.8))*m2 + start(c(0.8, 0.8))*m3
```

```
x ~~ start(c(0.25, 0.25))*x
y ~~ start(c(0.81, 0.95))*y
m ~~ start(c(0.87, 0.87))*m
m1 ~~ start(c(0.36, 0.36))*m1
m2 ~~ start(c(0.36, 0.36))*m2
m3 ~~ start(c(0.36, 0.36))*m3
"

# med1 and med2 are the mediation effect for group1 and group2, respectively.
indirect <- "
med1 := a1*b1
med2 := a2*b2
diffmed := a1*b1 - a2*b2
"

# change nrep and nboot to at least 1,000 in real analysis
bootstrap <- wp.mc.sem.boot(ex3model, indirect, nobs=c(400,200),
                              nrep=10, nboot=10)
summary(bootstrap)

#Example: A Longitudinal Mediation Model
ex4model <- "
x2 ~ start(.9)*x1 + x*x1
x3 ~ start(.9)*x2 + x*x2
m2 ~ start(.3)*x1 + a*x1 + start(.3)*m1 + m*m1
m3 ~ start(.3)*x2 + a*x2 + start(.3)*m2 + m*m2
y2 ~ start(.3)*m1 + b*m1 + start(.7)*y1 + y*y1
y3 ~ start(.3)*m2 + b*m2 + start(.7)*y2 + y*y2 + start(0)*x1 + c*x1
x1 ~~ start(.37)*m1
x1 ~~ start(.27)*y1
y1 ~~ start(.2278)*m1
x2 ~~ start(.19)*x2
x3 ~~ start(.19)*x3
m2 ~~ start(.7534)*m2
m3 ~~ start(.7534)*m3
y2 ~~ start(.3243)*y2
y3 ~~ start(.3243)*y3
"

indirect <- "ab := a*b"

# change nrep and nboot to at least 1,000 in real analysis
set.seed(10)
bootstrap <- wp.mc.sem.boot(ex4model, indirect, nobs=500, nrep=10, nboot=10)
summary(bootstrap)
```

wp.mc.sem.power.curve *Statistical Power Curve for Structural Equation Modeling / Mediation based on Monte Carlo Simulation*

Description

A power curve is useful to graphically display how power changes with sample size (e.g., *Zhang & Wang*). This function is to generate a power curve for SEM based on Monte Carlo simulation, either using Sobel test or bootstrap method to test the indirect / mediation effects if applicable.

Usage

```
wp.mc.sem.power.curve(model, indirect = NULL, nobs = 100, type = "basic",
  nrep = 1000, nboot = 1000, alpha = 0.95, skewness = NULL,
  kurtosis = NULL, ovnames = NULL, se = "default",
  estimator = "default", parallel = "no",
  ncore = Sys.getenv("NUMBER_OF_PROCESSORS"), cl = NULL, ...)
```

Arguments

`model`	Model specified using lavaan syntax. More about model specification can be found in *Rosseel (2012).*
`indirect`	Indirect effect difined using lavaan syntax.
`nobs`	Sample size. It is 100 by default.
`type`	The method used to test the indirect effects (`'basic'` or `'boot'`). By default type='basic'. The type 'basic' is to use Sobel test (see also *wp.mc.sem.basic*), while 'boot' is to use bootstrap method (see also *wp.mc.sem.boot*).
`nrep`	Number of replications for the Monte Carlo simulation. It is 1000 by default.
`nboot`	Number of replications for the bootstrap to test the specified parameter (e.g., mediation). It is 1000 by default.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`skewness`	A sequence of skewnesses of the observed variables. It is not required.
`kurtosis`	A sequence of kurtosises of the observed variables. It is not required.
`ovnames`	Names of the observed variables in the model. It is not required.
`se`	The method for calculatating the standard errors. Its default method "default" is regular standard errors. More about methods specification standard errors calculatationcan be found in *Rosseel (2012).*
`estimator`	Estimator. It is Maxmum likelihood estimator by default. More about estimator specification can be found in *Rosseel (2012).*
`parallel`	Parallel computing (`"no"` or `"parallel"` or `"snow"`). It is "no" by default, which means it will not use parallel computing. The option "parallel" is to use multiple cores in a computer for parallel computing. It is used with the number of cores (*ncore*). The option "snow" is to use clusters for parallel computing. It is used with the number of clusters (*cl*).
`ncore`	Number of processors used for parallel computing. By default, ncore = Sys.getenv('NUMBER_OF_PROC
`cl`	Number of clusters. It is NULL by default. When it is NULL, the program will detect the number of clusters automatically.
`...`	Extra arguments. It is not required.

Value

An object of the power analysis. The power for all parameters in the model as well as the indirect effects if specified.

References

Rosseel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). Ghent, Belgium: Ghent University.

Thoemmes, F., MacKinnon, D. P., & Reiser, M. R. (2010). Power analysis for complex mediational designs using Monte Carlo methods. Structural Equation Modeling, 17(3), 510-534.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
set.seed(20220722)

#To specify the model
ex2model ="
ept ~ start(0.4)*hvltt + b*hvltt + start(0)*age + start(0)*edu + start(2)*R
hvltt ~ start(-0.35)*age + a*age +c*edu + start(0.5)*edu
R ~ start(-0.06)*age + start(0.2)*edu
R =~ 1*ws + start(0.8)*ls + start(0.5)*lt
age ~~ start(30)*age
edu ~~ start(8)*edu
age ~~ start(-2.8)*edu
hvltt ~~ start(23)*hvltt
R ~~ start(14)*R
ws ~~ start(3)*ws
ls ~~ start(3)*ls
lt ~~ start(3)*lt
ept ~~ start(3)*ept
"
#To specify the indirect effects
indirect = "ind1 := a*b + c*b"
nobs <- seq(100, 2000, by =200)
#To calculate power curve:
# change nrep and nboot to at least 1,000 in real analysis
power.curve = wp.mc.sem.power.curve(model=ex2model, indirect=indirect,
                              nobs=nobs, type='boot',
  nrep=10, nboot=10)
```

wp.mc.t *Power analysis for t-test based on Monte Carlo simulation*

Description

Power analysis for t-test based on Monte Carlo simulation

Usage

```
wp.mc.t(n = NULL, R0 = 1e+05, R1 = 1000, mu0 = 0, mu1 = 0,
sd = 1, skewness = 0, kurtosis = 3, alpha = 0.05,
type = c("two.sample", "one.sample", "paired"),
alternative = c("two.sided", "less", "greater"))
```

Arguments

n	Sample size
R0	Number of replications under the null
R1	Number of replications
mu0	Population mean under the null
mu1	Population mean under the alternative
sd	Standard deviation
skewness	Skewness
kurtosis	kurtosis
alpha	Significance level
type	Type of anlaysis
alternative	alternative hypothesis

References

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
set.seed(20220722)
########## Chapter 16. Monte Carlo t-test #############
wp.mc.t(n=20 , mu0=0, mu1=0.5, sd=1, skewness=0,
kurtosis=3, type = c("one.sample"), alternative = c("two.sided"))

wp.mc.t(n=40 , mu0=0, mu1=0.3, sd=1, skewness=1,
kurtosis=6, type = c("paired"), alternative = c("greater"))

wp.mc.t(n=c(15, 15), mu1=c(0.2, 0.5), sd=c(0.2, 0.5),
```

```
skewness=c(1, 2), kurtosis=c(4, 6), type = c("two.sample"), alternative = c("less"))
```

`wp.mediation` *Statistical Power Analysis for Simple Mediation*

Description

This function is for mediation models. Mediation models can be used to investigate the underlying mechanisms related to why an input variable x influences an output variable y (e.g., *Hayes, 2013; MacKinnon, 2008*). The mediation effect is calculated as *a*b*, where *a* is the path coefficent from the predictor x to the mediator m, and *b* is the path coefficent from the mediator m to the outcome variable y. Sobel test statistic *(Sobel, 1982)* is used to test whether the mediation effect is significantly different from zero.

Usage

```
wp.mediation(n = NULL, power = NULL, a = 0.5, b = 0.5, varx = 1,
  vary = 1, varm = 1, alpha = 0.05, interval = NULL)
```

Arguments

`n`	Sample size.
`power`	Statistical power.
`a`	Coefficient from x to m. The default value is 0.5.
`b`	Coefficient from m to y. The default value is 0.5.
`varx`	Variance of x. The default value is 1.
`vary`	Variance of y. The default value is 1.
`varm`	Variance of m. The default value is 1.
`alpha`	significance level chosen for the test. It equals 0.05 by default.
`interval`	A vector containing the end-points of the interval to be searched for the root.

Value

An object of the power analysis.

References

Hayes, A. F. (2013). Introduction to mediation, moderation, and conditional process analysis: A regression-based approach. Guilford Press.

MacKinnon, D. P. (2008). Introduction to statistical mediation analysis. Routledge.

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. Sociological methodology, 13, 290-312.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.mediation(n = 100, power = NULL, a = 0.5, b = 0.5,
                  varx = 1, vary = 1, varm = 1, alpha = 0.05)
#    Power for simple mediation
#
#        n     power   a   b varx varm vary alpha
#      100 0.9337271 0.5 0.5    1    1    1  0.05
#
#    URL: http://psychstat.org/mediation

#To generate a power curve given a sequence of sample sizes:
res <- wp.mediation(n = seq(50,100,5), power = NULL, a = 0.5, b = 0.5,
                            varx = 1, vary = 1, varm = 1, alpha = 0.05)
res
#    Power for simple mediation
#
#        n     power   a   b varx varm vary alpha
#       50 0.6877704 0.5 0.5    1    1    1  0.05
#       55 0.7287681 0.5 0.5    1    1    1  0.05
#       60 0.7652593 0.5 0.5    1    1    1  0.05
#       65 0.7975459 0.5 0.5    1    1    1  0.05
#       70 0.8259584 0.5 0.5    1    1    1  0.05
#       75 0.8508388 0.5 0.5    1    1    1  0.05
#       80 0.8725282 0.5 0.5    1    1    1  0.05
#       85 0.8913577 0.5 0.5    1    1    1  0.05
#       90 0.9076417 0.5 0.5    1    1    1  0.05
#       95 0.9216744 0.5 0.5    1    1    1  0.05
#      100 0.9337271 0.5 0.5    1    1    1  0.05
#
#    URL: http://psychstat.org/mediation

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.mediation(n = NULL, power = 0.9, a = 0.5, b = 0.5,
                varx = 1, vary = 1, varm = 1, alpha = 0.05)
#    Power for simple mediation
#
#             n power   a   b varx varm vary alpha
#      87.56182   0.9 0.5 0.5    1    1    1  0.05
#
#    URL: http://psychstat.org/mediation

#To calculate the minimum detectable effect size of one coefficent given power and sample size:
wp.mediation(n = 100, power = 0.9, a = NULL, b = 0.5,
               varx = 1, vary = 1, varm = 1, alpha = 0.05)
#    Power for simple mediation
#
#                     n power         a   b varx varm vary alpha
#      100   0.9 0.7335197 0.5    1    1    1  0.05
```

```
#
#    URL: http://psychstat.org/mediation
```

wp.mmrm *Power analysis for longitudinal data analysis*

Description

The two functions are adapted from the R package longpower by Michael C. Donohue. More will be added later.

Usage

```
wp.mmrm(N = NULL, Ra = NULL, ra = NULL, sigmaa = NULL,
Rb = NULL, rb = NULL, sigmab = NULL, lambda = 1,
delta = NULL, alpha = 0.05, power = NULL,
alternative = c("two.sided", "one.sided"))
wp.mmrm.ar1(N = NULL, rho = NULL, ra = NULL, sigmaa = NULL,
rb = NULL, sigmab = NULL, lambda = 1, times = 1:length(ra),
delta = NULL, alpha = 0.05, power = NULL,
alternative = c("two.sided", "one.sided"))
```

Arguments

N	N
Ra	Ra
ra	ra
sigmaa	sigmaa
Rb	Rb
rb	rb
sigmab	sigmab
lambda	lambda
delta	delta
alpha	Significance level
power	Statistical power
alternative	alternative hypothesis
rho	rho
times	times

References

Lu, K., Luo, X., Chen, P.-Y. (2008) Sample size estimation for repeated measures analysis in randomized clinical trials with missing data. International Journal of Biostatistics, 4, (1)

wp.mrt2arm — *Statistical Power Analysis for Multisite Randomized Trials with 2 Arms*

Description

Multisite randomized trials (MRT) are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a control arm *(Liu, 2013)*. The data from MRT can be analyzed in a two-level hierarchical linear model, where the indicator variable for treatment assignment is included in first level. If a study contains multiple treatments, then multiple indicators will be used. This function is for designs with 2 arms (i.e., a treatment and a control). Three types of tests are considered in the function: (1) The "main" type tests treatment main effect; (2) The "site" type tests the variance of cluster/site means; and (3) The "variance" type tests variance of treatment effects. Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*.

Usage

```
wp.mrt2arm(n = NULL, f = NULL, J = NULL, tau00 = NULL, tau11 = NULL,
  sg2 = NULL, power = NULL, alpha = 0.05, alternative = c("two.sided",
  "one.sided"), type = c("main", "site", "variance"), interval = NULL)
```

Arguments

`n`	Sample size. It is the number of individuals within each cluster.
`f`	Effect size. It specifies the main effect of treatment, the mean difference between the treatment clusters/sites and the control clusters/sites. Effect size must be positive.
`J`	Number of clusters / sites. It tells how many clusters are considered in the study design. At least two clusters are required.
`tau00`	Variance of cluster/site means. It is one of the residual variances in the second level. Its value must be positive.
`tau11`	Variance of treatment effects across sites. It is one of the residual variances in the second level. Its value must be positive.
`sg2`	Level-one error Variance. The residual variance in the first level.
`power`	Statistical power.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`alternative`	Type of the alternative hypothesis (`"two.sided"` or `"one.sided"`). The default is "two.sided". The option "one.sided" can be either "less" or "greater".
`type`	Type of effect (`"main"` or `"site"` or `"variance"`) with "main" as default. The type "main" tests treatment main effect, no tau00 needed; Type "site" tests the variance of cluster/site means, no tau11 or f needed; and Type "variance" tests variance of treatment effects, no tau00 or f needed.
`interval`	A vector containing the end-points of the interval to be searched for the root.

Value

An object of the power analysis.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
#For main effect
wp.mrt2arm(n = 45, f = 0.5, J = 20, tau11 = 0.5,
            sg2 = 1.25, alpha = 0.05, power = NULL)
#  Power analysis for Multileve model Multisite randomized trials with 2 arms
#
#      J  n   f tau11  sg2     power alpha
#      20 45 0.5   0.5 1.25 0.8583253  0.05
#
#  NOTE: n is the number of subjects per cluster
#  URL: http://psychstat.org/mrt2arm

#For variance of treament effect
wp.mrt2arm(n = 45, f = 0.5, J = 20, tau11 = 0.5,
               sg2 = 1.25, alpha = 0.05, power = NULL, type = "variance")
#  Power analysis for Multileve model Multisite randomized trials with 2 arms
#
#     J  n   f tau11  sg2     power alpha
#    20 45 0.5   0.5 1.25 0.9987823  0.05
#
#  NOTE: n is the number of subjects per cluster
#  URL: http://psychstat.org/mrt2arm

#For testing site variablity
res<- wp.mrt2arm(n = 45, f = 0.5, J = 20, tau11 = 0.5,
                 sg2 = 1.25, alpha = 0.05, power = NULL, type = "site")
#  Power analysis for Multileve model Multisite randomized trials with 2 arms
#
#     J  n   f tau11  sg2 alpha
#    20 45 0.5   0.5 1.25  0.05
#
#  NOTE: n is the number of subjects per cluster
#  URL: http://psychstat.org/mrt2arm

#To generate a power curve given a sequence of sample sizes:
res <- wp.mrt2arm(n = seq(10,50,5), f = 0.5, J = 20, tau11 = 0.5,
                          sg2 = 1.25, alpha = 0.05, power = NULL)
```

```
#  Power analysis for Multileve model Multisite randomized trials with 2 arms
#
#       J  n   f tau11  sg2     power alpha
#      20 10 0.5   0.5 1.25 0.6599499  0.05
#      20 15 0.5   0.5 1.25 0.7383281  0.05
#      20 20 0.5   0.5 1.25 0.7818294  0.05
#      20 25 0.5   0.5 1.25 0.8090084  0.05
#      20 30 0.5   0.5 1.25 0.8274288  0.05
#      20 35 0.5   0.5 1.25 0.8406659  0.05
#      20 40 0.5   0.5 1.25 0.8506049  0.05
#      20 45 0.5   0.5 1.25 0.8583253  0.05
#      20 50 0.5   0.5 1.25 0.8644864  0.05
#
#  NOTE: n is the number of subjects per cluster
#  URL: http://psychstat.org/mrt2arm

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.mrt2arm(n = NULL, f = 0.5, J = 20, tau11 = 0.5,
                      sg2 = 1.25, alpha = 0.05, power = 0.8)
#  Power analysis for Multileve model Multisite randomized trials with 2 arms
#
#     J        n   f tau11  sg2 power alpha
#    20 23.10086 0.5   0.5 1.25   0.8  0.05
#
#  NOTE: n is the number of subjects per cluster
#  URL: http://psychstat.org/mrt2arm
```

---

wp.mrt3arm   *Statistical Power Analysis for Multisite Randomized Trials with 3 Arms*

Description

Multisite randomized trials (MRT) are a type of multilevel design for the situation when the entire cluster is randomly assigned to either a treatment arm or a control arm *(Liu, 2013)*. The data from MRT can be analyzed in a two-level hierarchical linear model, where the indicator variable for treatment assignment is included in first level. If a study contains multiple treatments, then multiple indicators will be used. This function is for designs with 3 arms (i.e., two treatments and a control). Three types of tests are considered in the function: (1) The "main" type tests treatment main effect; (2) The "treatment" type tests the difference between the two treatments; and (3) The "omnibus" type tests whether the three arms are all equivalent. Details leading to power calculation can be found in *Raudenbush (1997)* and *Liu (2013)*.

Usage

```
wp.mrt3arm(n = NULL, f1 = NULL, f2 = NULL, J = NULL, tau = NULL,
  sg2 = NULL, power = NULL, alpha = 0.05, alternative = c("two.sided",
  "one.sided"), type = c("main", "treatment", "omnibus"), interval = NULL)
```

Arguments

`n`	Sample size. It is the number of individuals within each cluster.
`f1`	Effect size for treatment main effect. Effect size must be positive.
`f2`	Effect size for the difference between two treatments. Effect size must be positive.
`J`	Number of clusters / sites. It tells how many clusters are considered in the study design. At least two clusters are required.
`tau`	Variance of treatment effects across sites/clusters.
`sg2`	Level-one error Variance. The residual variance in the first level.
`power`	Statistical power.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`alternative`	Type of the alternative hypothesis (`"two.sided"` or `"one.sided"`). The default is "two.sided". The option "one.sided" can be either "less" or "greater".
`type`	Type of effect (`"main"` or `"treatment"` or `"omnibus"`) with "main" as default. The type "main" tests the difference between the average treatment arms and the control arm; Type "treatment" tests the difference between the two treatment arms; and Type "omnibus" tests whether the three arms are all equivalent.
`interval`	A vector containing the end-points of the interval to be searched for the root.

Value

An object of the power analysis.

References

Liu, X. S. (2013). Statistical power analysis for the social and behavioral sciences: basic and advanced techniques. Routledge.

Raudenbush, S. W. (1997). Statistical analysis and optimal design for cluster randomized trials. Psychological Methods, 2(2), 173.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
#For main effect
wp.mrt3arm(n = 30, f1 = 0.43, J = 20, tau = 0.4,
               sg2 = 2.25, alpha = 0.05, power = NULL)
#    Multisite randomized trials with 3 arms
#
#       J  n   f1 tau  sg2     power alpha
#      20 30 0.43 0.4 2.25 0.8066964  0.05
#
#    NOTE: n is the number of subjects per cluster
#    URL: http://psychstat.org/mrt3arm
```

```
#For tesing difference between effects
wp.mrt3arm(n = 30, f2 = 0.2, J = 20, tau = 0.4, sg2 = 2.25,
                      alpha = 0.05, power = NULL, type="treatment")
#    Multisite randomized trials with 3 arms
#
#      J  n  f2 tau  sg2     power alpha
#     20 30 0.2 0.4 2.25 0.2070712  0.05
#
#    NOTE: n is the number of subjects per cluster
#    URL: http://psychstat.org/mrt3arm

#For testing site variablity
wp.mrt3arm(n = 30, f1=0.43, f2 = 0.2, J = 20, tau = 0.4, sg2 = 2.25,
                          alpha = 0.05, power = NULL, type="omnibus")
#    Multisite randomized trials with 3 arms
#
#       J  n   f1  f2 tau  sg2     power alpha
#      20 30 0.43 0.2 0.4 2.25 0.7950757  0.05
#
#    NOTE: n is the number of subjects per cluster
#    URL: http://psychstat.org/mrt3arm

#To generate a power curve given a sequence of numbers of sites/clusters:
res <- wp.mrt3arm(n = 30, f2 = 0.2, J = seq(20,120,10), tau = 0.4,
            sg2 = 2.25, alpha = 0.05, power = NULL, type="treatment")
res
#    Multisite randomized trials with 3 arms
#
#       J  n  f2 tau  sg2     power alpha
#      20 30 0.2 0.4 2.25 0.2070712  0.05
#      30 30 0.2 0.4 2.25 0.2953799  0.05
#      40 30 0.2 0.4 2.25 0.3804554  0.05
#      50 30 0.2 0.4 2.25 0.4603091  0.05
#      60 30 0.2 0.4 2.25 0.5337417  0.05
#      70 30 0.2 0.4 2.25 0.6001544  0.05
#      80 30 0.2 0.4 2.25 0.6593902  0.05
#      90 30 0.2 0.4 2.25 0.7116052  0.05
#     100 30 0.2 0.4 2.25 0.7571648  0.05
#     110 30 0.2 0.4 2.25 0.7965644  0.05
#     120 30 0.2 0.4 2.25 0.8303690  0.05
#
#    NOTE: n is the number of subjects per cluster
#    URL: http://psychstat.org/mrt3arm

#To plot the power curve:
plot(res, "J", "power")

#To calculate the required sample size given power and effect size:
wp.mrt3arm(n = NULL, f1 = 0.43, J = 20, tau = 0.4,
                sg2 = 2.25, alpha = 0.05, power = 0.8)
#    Multisite randomized trials with 3 arms
#
#       J        n   f1 tau  sg2 power alpha
```

```
#      20 28.61907 0.43 0.4 2.25   0.8  0.05
#
#    NOTE: n is the number of subjects per cluster
#    URL: http://psychstat.org/mrt3arm
```

---

wp.poisson *Statistical Power Analysis for Poisson Regression*

Description

This function is for Poisson regression models. Poisson regression is a type of generalized linear models where the outcomes are usually count data. Here, Maximum likelihood methods is used to estimate the model parameters. The estimated regression coefficent is assumed to follow a normal distribution. A Wald test is used to test the mean difference between the estimated parameter and the null parameter (tipically the null hypothesis assumes it equals 0). The procedure introduced by *Demidenko (2007)* is adopted here for computing the statistical power.

Usage

```
wp.poisson(n = NULL, exp0 = NULL, exp1 = NULL, alpha = 0.05,
  power = NULL, alternative = c("two.sided", "less", "greater"),
  family = c("Bernoulli", "exponential", "lognormal", "normal", "Poisson",
  "uniform"), parameter = NULL, subdivisions=200L,
  i.method=c("numerical", "MC"), mc.iter=20000)
```

Arguments

`n`	Sample size.
`exp0`	The base rate under the null hypothesis. It always takes positive value. See the article by *Demidenko (2007)* for details.
`exp1`	The relative increase of the event rate. It is used for calculatation of the effect size. See the article by *Demidenko (2007)* for details.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`power`	Statistical power.
`alternative`	Direction of the alternative hypothesis (`"two.sided"` or `"less"` or `"greater"`). The default is "two.sided".
`family`	Distribution of the predictor (`"Bernoulli"`,`"exponential"`, `"lognormal"`, `"normal"`, `"Poisson"`, `"uniform"`). The default is "Bernoulli".
`parameter`	Corresponding parameter for the predictor's distribution. The default is 0.5 for "Bernoulli", 1 for "exponential", (0,1) for "lognormal" or "normal", 1 for "Poisson", and (0,1) for "uniform".
`subdivisions`	Number of divisions for integration
`i.method`	Integration method
`mc.iter`	Number of iterations for Monte Carlo integration

Value

An object of the power analysis.

References

Demidenko, E. (2007). Sample size determination for logistic regression revisited. Statistics in medicine, 26(18), 3385-3397.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.poisson(n = 4406, exp0 = 2.798, exp1 = 0.8938, alpha = 0.05,
                 power = NULL, family = "Bernoulli", parameter = 0.53)
#  Power for Poisson regression
#
#       n     power alpha  exp0   exp1    beta0      beta1 paremeter
#    4406 0.9999789  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#
#  URL: http://psychstat.org/poisson

#To generate a power curve given a sequence of sample sizes:
res <- wp.poisson(n = seq(800, 1500, 100), exp0 = 2.798, exp1 = 0.8938,
      alpha = 0.05, power = NULL, family = "Bernoulli", parameter = 0.53)
res
#  Power for Poisson regression
#
#       n     power alpha  exp0   exp1    beta0      beta1 paremeter
#     800 0.7324097  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#     900 0.7813088  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1000 0.8224254  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1100 0.8566618  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1200 0.8849241  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1300 0.9080755  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1400 0.9269092  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#    1500 0.9421344  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
#
#  URL: http://psychstat.org/poisson

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.poisson(n = NULL, exp0 = 2.798, exp1 = 0.8938, alpha = 0.05,
            power = 0.8, family = "Bernoulli", parameter = 0.53)
#  Power for Poisson regression
#
#           n power alpha  exp0   exp1    beta0      beta1 paremeter
#    943.2628   0.8  0.05 2.798 0.8938 1.028905 -0.1122732      0.53
```

```
#
#  URL: http://psychstat.org/poisson
```

---

wp.popPar *Extract Population Value Table*

Description

This function is used to extract population value table for parameters form an power analysis object for SEM based on Monte Carlo methods (class = 'power').

Usage

```
wp.popPar(object)
```

Arguments

object	Object of power analysis. It is an object returned by a webpower function for SEM based on Monte Carlo methods with class = 'power'.

Value

Population value table of parameters from the input object of power analysis.

---

wp.prop *Statistical Power Analysis for Tests of Proportions*

Description

Tests of proportions are a technique used to compare proportions of success or agreement in one or two samples. The one-sample test of proportion tests the null proportion of success, usually 0.5. The two-sample test of proportions tests the null hypothesis that the two samples are drawn from populations with the same proportion of success. A z-test is used to evaluate whether the given difference in proportions is statistical significantly different from the null hypothesis. The power calculation is based on the arcsine transformation of the proportion (see *Cohen, 1988, p.548*).

Usage

```
wp.prop(h = NULL, n1 = NULL, n2 = NULL, alpha = 0.05, power = NULL,
  type = c("1p", "2p", "2p2n"), alternative = c("two.sided", "less",
  "greater"))
```

Arguments

`h`	Effect size of the proportion comparison. *Cohen (1992)* suggested that effect size values of 0.2, 0.5, and 0.8 represent "small", "medium", and "large" effect sizes, repectively.
`n1`	Sample size of the first group.
`n2`	Sample size of the second group if applicable.
`alpha`	Significance level chosed for the test. It equals 0.05 by default.
`power`	Statistical power.
`type`	Type of comparison (`"1p"` or `"2p"` or `"2p2n"`). The default is "1p". 1p: one sample; 2p: two sample with equal sample size; 2p2n: two sample with unequal sample size.
`alternative`	Direction of the alternative hypothesis (`"two.sided"` or `"less"` or `"greater"`). The default is "two.sided".

Value

An object of the power analysis.

References

Cohen, J. (1992). A power primer. Psychological bulletin, 112(1), 155.

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the power for two groups of proportion with unequal sample size:
wp.prop(h=0.52,n1=35,n2=50,alternative="greater",type="2p2n")
#  Power for two-sample proportion (unequal n)
#
#       h n1 n2 alpha     power
#    0.52 35 50  0.05 0.7625743
#
#  NOTE: Sample size for each group
#  URL: http://psychstat.org/prop2p2n

#To calculate the power curve with a sequence of sample sizes:
res <- wp.prop(h=0.52,n1=seq(10,100,10),alternative="greater",type="1p")
res
#  Power for one-sample proportion test
#
#       h   n alpha     power
#    0.52  10  0.05 0.4998128
#    0.52  20  0.05 0.7519557
#    0.52  30  0.05 0.8855706
#    0.52  40  0.05 0.9499031
```

```
#     0.52  50  0.05 0.9789283
#     0.52  60  0.05 0.9914150
#     0.52  70  0.05 0.9965928
#     0.52  80  0.05 0.9986772
#     0.52  90  0.05 0.9994960
#     0.52 100  0.05 0.9998111
#
#  URL: http://psychstat.org/prop

#To plot the power curve:
plot(res, type='b')

#To estimate the sample size with a given power:
wp.prop(h=0.52,n1=NULL,power=0.8,alternative="greater",type="1p")
#  Power for one-sample proportion test
#
#        h        n alpha power
#     0.52 22.86449  0.05   0.8
#
#  URL: http://psychstat.org/prop

#To estimate the minimum detectable effect size with a given power:
wp.prop(h=NULL,n1=35,power=0.8,alternative="greater",type="1p")
#  Power for one-sample proportion test
#
#             h  n alpha power
#     0.4202907 35  0.05   0.8
#
#  URL: http://psychstat.org/prop

#To calculate the power curve with a sequence of effect sizes:
wp.prop(h=seq(0.1, 0.8, 0.1),n1=100,alternative="greater",type="1p")
#  Power for one-sample proportion test
#
#       h   n alpha     power
#     0.1 100  0.05 0.2595110
#     0.2 100  0.05 0.6387600
#     0.3 100  0.05 0.9123145
#     0.4 100  0.05 0.9907423
#     0.5 100  0.05 0.9996034
#     0.6 100  0.05 0.9999934
#     0.7 100  0.05 1.0000000
#     0.8 100  0.05 1.0000000
#
#  URL: http://psychstat.org/prop
```

wp.regression   *Statistical Power Analysis for Linear Regression*

Description

This function is for power analysis for regression models. Regression is a statistical technique for examining the relationship between one or more independent variables (or predictors) and one dependent variable (or the outcome). Regression provides an F-statistic that can be formulated using the ratio between variation in the outcome variable that is explained by the predictors and the unexplained variation *(Cohen, 1988))*. The test statistc can also be experessed in terms of caomparison between Full and Reduced models *(Maxwell & Delaney, 2003)*.

Usage

```
wp.regression(n = NULL, p1 = NULL, p2 = 0, f2 = NULL, alpha = 0.05,
  power = NULL, type=c("regular", "Cohen"))
```

Arguments

`n`	Sample size.
`p1`	Number of predictors in the full model.
`p2`	Number of predictors in the reduced moedel, it is 0 by default. See the book by *Maxwell and Delaney (2003)* for the definition of the reduced model.
`f2`	Effect size. We use the statistic f2 as the measure of effect size for linear regression proposed by *Cohen(1988, p.410)*. *Cohen* discussed the effect size in three different cases. The calculation of f2 can be generalized using the idea of a full model and a reduced model by *Maxwell and Delaney (2003)*.
`alpha`	significance level chosen for the test. It equals 0.05 by default.
`power`	Statistical power.
`type`	If set to "Cohen", the formula used in the Cohen's book will be used (not recommended).

Value

An object of the power analysis

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Maxwell, S. E., & Delaney, H. D. (2004). Designing experiments and analyzing data: A model comparison perspective (Vol. 1). Psychology Press.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.regression(n = 100, p1 = 3, f2 = 0.1, alpha = 0.05, power = NULL)
#  Power for multiple regression
#
```

```
#      n p1 p2  f2 alpha     power
#    100  3  0 0.1  0.05 0.7420463
#
#  URL: http://psychstat.org/regression

#To generate a power curve given a sequence of sample sizes:
res <- wp.regression(n = seq(50,300,50), p1 = 3, f2 = 0.1,
                                 alpha = 0.05, power = NULL)
res
#  Power for multiple regression
#
#      n p1 p2  f2 alpha     power
#    50  3  0 0.1  0.05 0.4077879
#    100  3  0 0.1  0.05 0.7420463
#    150  3  0 0.1  0.05 0.9092082
#    200  3  0 0.1  0.05 0.9724593
#    250  3  0 0.1  0.05 0.9925216
#    300  3  0 0.1  0.05 0.9981375
#
#  URL: http://psychstat.org/regression

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.regression(n = NULL, p1 = 3, f2 = 0.1, alpha = 0.05, power = 0.8)
#  Power for multiple regression
#
#           n p1 p2  f2 alpha power
#    113.0103  3  0 0.1  0.05   0.8
#
#  URL: http://psychstat.org/regression

#The statistical power given sample size and effect size when controling two predictors:
wp.regression(n = 100, p1 = 3, p2 = 2, f2 = 0.1429, alpha = 0.05, power = NULL)
#  Power for multiple regression
#
#      n p1 p2     f2 alpha     power
#    100  3  2 0.1429  0.05 0.9594695
#
#  URL: http://psychstat.org/regression

# To generate a power curve given a sequence of effect sizes:
res <- wp.regression(n = 50, p1 = 3, f2 = seq(0.05,0.5,0.05),
                                  alpha = 0.05, power = NULL)
res
#  Power for multiple regression
#
#     n p1 p2   f2 alpha     power
#    50  3  0 0.05  0.05 0.2164842
#    50  3  0 0.10  0.05 0.4077879
#    50  3  0 0.15  0.05 0.5821296
#    50  3  0 0.20  0.05 0.7210141
```

```
#    50  3  0 0.25  0.05 0.8220164
#    50  3  0 0.30  0.05 0.8906954
#    50  3  0 0.35  0.05 0.9350154
#    50  3  0 0.40  0.05 0.9624324
#    50  3  0 0.45  0.05 0.9788077
#    50  3  0 0.50  0.05 0.9883012
#
#  URL: http://psychstat.org/regression
```

`wp.rmanova` *Statistical Power Analysis for Repeated Measures ANOVA*

Description

Repeated-measures ANOVA can be used to compare the means of a sequence of measurements (e.g., *O'brien & Kaiser, 1985*). In a repeated-measures design, evey subject is exposed to all different treatments, or more commonly measured across different time points. Power analysis for (1) the within-effect test about the mean difference among measurements by default. If the subjects are from more than one group,the power analysis is also available for (2) the between-effect test about mean difference among groups and (3) the interaction effect test of the measurements and groups.

Usage

```
wp.rmanova(n = NULL, ng = NULL, nm = NULL, f = NULL, nscor = 1,
  alpha = 0.05, power = NULL, type = 0)
```

Arguments

`n`	Sample size.
`ng`	Number of groups.
`nm`	Number of measurements.
`f`	Effect size. We use the statistic f as the measure of effect size for repeated-measures ANOVA as in *Cohen(1988, p.275)*.
`nscor`	Nonsphericity correction coefficient. The nonsphericity correction coefficient is a measure of the degree of sphericity in the population. A coefficient of 1 means sphericity is met, while a coefficient less than 1 means not met. The samller value of the coefficient means the further departure from sphericity. The lowest value of the coefficient is 1/(nm-1) where nm is the total number of measurements. Two viable approaches for computing the empirical nonsphericity correction coefficient are sggested. One is by *Greenhouse and Geisser (1959)*, the other is by *Huynh and Feldt (1976)*.
`alpha`	significance level chosed for the test. It equals 0.05 by default.
`power`	Statistical power.
`type`	Type of analysis (`0` or `1` or `2`). The value "0" is for between-effect; "1" is for within-effect; and "2" is for interaction effect.

Value

An object of the power analysis

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. Psychometrika, 24(2), 95-112.

Huynh, H., & Feldt, L. S. (1976). Estimation of the Box correction for degrees of freedom from sample data in randomized block and split-plot designs. Journal of educational statistics, 1(1), 69-82.

O'brien, R. G., & Kaiser, M. K. (1985). MANOVA method for analyzing repeated measures designs: an extensive primer. Psychological bulletin, 97(2), 316.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power for repeated-measures ANOVA:
wp.rmanova(n=30, ng=3, nm=4, f=0.36, nscor=0.7)
#  Repeated-measures ANOVA analysis
#
#    n    f ng nm nscor alpha     power
#    30 0.36  3  4   0.7  0.05 0.2674167
#
#  NOTE: Power analysis for between-effect test
#  URL: http://psychstat.org/rmanova

#To generate a power curve given a sequence of sample sizes:
res <- wp.rmanova(n=seq(30,150,20), ng=3, nm=4, f=0.36, nscor=0.7)
#  Repeated-measures ANOVA analysis
#
#      n    f ng nm nscor alpha     power
#     30 0.36  3  4   0.7  0.05 0.2674167
#     50 0.36  3  4   0.7  0.05 0.4386000
#     70 0.36  3  4   0.7  0.05 0.5894599
#     90 0.36  3  4   0.7  0.05 0.7110142
#    110 0.36  3  4   0.7  0.05 0.8029337
#    130 0.36  3  4   0.7  0.05 0.8691834
#    150 0.36  3  4   0.7  0.05 0.9151497
#
#  NOTE: Power analysis for between-effect test
#  URL: http://psychstat.org/rmanova

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.rmanova(n=NULL, ng=3, nm=4, f=0.36, power=0.8, nscor=0.7)
```

```
#  Repeated-measures ANOVA analysis
#
#           n    f ng nm nscor alpha power
#    109.2546 0.36  3  4   0.7  0.05   0.8
#
#  NOTE: Power analysis for between-effect test
#  URL: http://psychstat.org/rmanova

#To calculate the minimum detectable effect size given power and sample size:
wp.rmanova(n=30, ng=3, nm=4, f=NULL, power=0.8, nscor=0.7)
#  Repeated-measures ANOVA analysis
#
#     n        f ng nm nscor alpha power
#    30 0.716768  3  4   0.7  0.05   0.8
#
#  NOTE: Power analysis for between-effect test
#  URL: http://psychstat.org/rmanova

# To generate a power curve given a sequence of effec sizes:
wp.rmanova(n=30, ng=3, nm=4, f=seq(0.1,0.5,0.05), nscor=0.7)
#  Repeated-measures ANOVA analysis
#
#     n    f ng nm nscor alpha      power
#    30 0.10  3  4   0.7  0.05 0.06442235
#    30 0.15  3  4   0.7  0.05 0.08327886
#    30 0.20  3  4   0.7  0.05 0.11101678
#    30 0.25  3  4   0.7  0.05 0.14853115
#    30 0.30  3  4   0.7  0.05 0.19640404
#    30 0.35  3  4   0.7  0.05 0.25460008
#    30 0.40  3  4   0.7  0.05 0.32223192
#    30 0.45  3  4   0.7  0.05 0.39746082
#    30 0.50  3  4   0.7  0.05 0.47757523
#
#  NOTE: Power analysis for between-effect test
#  URL: http://psychstat.org/rmanova
```

`wp.sem.chisq` *Statistical Power Analysis for Structural Equation Modeling based on Chi-Squared Test*

Description

Structural equation modeling (SEM) is a multivariate technique used to analyze relationships among observed and latent variables. It can be viewed as a combination of factor analysis and multivariate regression analysis. Two methods are widely used in power analysis for SEM. One is based on the likelihood ratio test proposed by *Satorra and Saris (1985)*. The other is based on RMSEA proposed by *MacCallum et al. (1996)*. This function is for SEM power analysis based on the likelihood ratio test.

Usage

```
wp.sem.chisq(n = NULL, df = NULL, effect = NULL, power = NULL,
  alpha = 0.05)
```

Arguments

- `n` Sample size.
- `df` Degrees of freedom. The degrees of freedom of the chi-squared test.
- `effect` Effect size. It specifies the population misfit of a SEM model, which is the difference between two SEM models: a full model (Mf) and a reduced model (Mr). A convienient way to get the effect size is to fit the reduced model using SEM software such R package 'lavaan' *(Rossel, 2012)*. Then the effect size is calculated as the chi-squared statistics dividing by the sample size.
- `power` Statistical power.
- `alpha` significance level chosed for the test. It equals 0.05 by default.

Value

An object of the power analysis.

References

Satorra, A., & Saris, W. E. (1985). Power of the likelihood ratio test in covariance structure analysis. Psychometrika, 50(1), 83-90.

Rossel, Y. (2012). Lavaan: An R package for structural equation modeling and more. Version 0.5–12 (BETA). Retrieved from http://users. ugent. be/~ yrosseel/lavaan/lavaanIntroduction.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.sem.chisq(n = 100, df = 4, effect = 0.054, power = NULL, alpha = 0.05)
#    Power for SEM (Satorra & Saris, 1985)
#
#        n df effect     power alpha
#      100  4  0.054 0.4221152  0.05
#
#    URL: http://psychstat.org/semchisq

#To generate a power curve given a sequence of sample sizes:
res <- wp.sem.chisq(n = seq(100,600,100), df = 4,
           effect = 0.054, power = NULL, alpha = 0.05)
res
#    Power for SEM (Satorra & Saris, 1985)
#
#        n df effect     power alpha
#      100  4  0.054 0.4221152  0.05
```

```
#      200  4  0.054 0.7510630  0.05
#      300  4  0.054 0.9145660  0.05
#      400  4  0.054 0.9750481  0.05
#      500  4  0.054 0.9935453  0.05
#      600  4  0.054 0.9984820  0.05
#
#    URL: http://psychstat.org/semchisq

#To plot the power curve:
plot(res)

#To generate a power curve given a sequence of alphas:
res <- wp.sem.chisq(n = 100, df = 4, effect = 0.054, power = NULL,
                            alpha = c(0.001, 0.005, 0.01, 0.025, 0.05))
res
#    Power for SEM (Satorra & Saris, 1985)
#
#        n df effect      power alpha
#      100  4  0.054 0.06539478 0.001
#      100  4  0.054 0.14952768 0.005
#      100  4  0.054 0.20867087 0.010
#      100  4  0.054 0.31584011 0.025
#      100  4  0.054 0.42211515 0.050
#
#    URL: http://psychstat.org/semchisq

#To calculate the required sample size given power and effect size:
wp.sem.chisq(n = NULL, df = 4, effect = 0.054, power = 0.8, alpha = 0.05)
#  Power for SEM (Satorra & Saris, 1985)
#
#           n df effect power alpha
#    222.0238  4  0.054   0.8  0.05
#
#  URL: http://psychstat.org/semchisq

#To calculate the minimum detectable effect size of one coefficent given power and sample size:
wp.sem.chisq(n = 100, df = 4, effect = NULL, power = 0.8, alpha = 0.05)
#    Power for SEM (Satorra & Saris, 1985)
#
#        n df    effect power alpha
#      100  4 0.1205597   0.8  0.05
#
#    URL: http://psychstat.org/semchisq
```

`wp.sem.rmsea` *Statistical Power Analysis for Structural Equation Modeling based on RMSEA*

Description

Structural equation modeling (SEM) is a multivariate technique used to analyze relationships among observed and latent variables. It can be viewed as a combination of factor analysis and multivariate regression analysis. Two methods are widely used in power analysis for SEM. One is based on the likelihood ratio test proposed by *Satorra and Saris (1985)*. The other is based on RMSEA proposed by *MacCallum et al. (1996)*. This function is for SEM power analysis based on RMSEA.

Usage

```
wp.sem.rmsea(n = NULL, df = NULL, rmsea0 = NULL, rmsea1 = NULL,
  power = NULL, alpha = 0.05, type = c("close", "notclose"))
```

Arguments

n	Sample size.
df	Degrees of freedom. The degrees of freedom of the chi-squared test.
rmsea0	RMSEA for H0. It usually euquals zero.
rmsea1	RMSEA for H1.
power	Statistical power.
alpha	significance level chosed for the test. It equals 0.05 by default.
type	Close fit or non-clase fit (`'close'` or `'notclose'`). It is 'close' by default.

Value

An object of the power analysis.

References

MacCallum, R. C., Browne, M. W., & Sugawara, H. M. (1996). Power analysis and determination of sample size for covariance structure modeling. Psychological methods, 1(2), 130.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the statistical power given sample size and effect size:
wp.sem.rmsea (n = 100, df = 4, rmsea0 = 0,
               rmsea1 = 0.116,  power = NULL, alpha = 0.05)
#    Power for SEM based on RMSEA
#
#        n df rmsea0 rmsea1     power alpha
#      100  4      0  0.116 0.4208173  0.05
#
#    URL: http://psychstat.org/rmsea

#To generate a power curve given a sequence of sample sizes:
res <- wp.sem.rmsea (n = seq(100,600,100), df = 4, rmsea0 = 0,
                        rmsea1 = 0.116,  power = NULL, alpha = 0.05)
res
#    Power for SEM based on RMSEA
#
#        n df rmsea0 rmsea1     power alpha
```

```
#      100  4      0  0.116 0.4208173  0.05
#      200  4      0  0.116 0.7494932  0.05
#      300  4      0  0.116 0.9135968  0.05
#      400  4      0  0.116 0.9746240  0.05
#      500  4      0  0.116 0.9933963  0.05
#      600  4      0  0.116 0.9984373  0.05
#
#    URL: http://psychstat.org/rmsea

#To plot the power curve:
plot(res)

#To calculate the required sample size given power and effect size:
wp.sem.rmsea (n = NULL, df = 4, rmsea0 = 0,
              rmsea1 = 0.116,  power = 0.8, alpha = 0.05)
#    Power for SEM based on RMSEA
#
#             n df rmsea0 rmsea1 power alpha
#      222.7465  4      0  0.116   0.8  0.05
#
#    URL: http://psychstat.org/rmsea

#  #To calculate the minimum detectable effect size of rmsea1 given power and sample size:
wp.sem.rmsea (n = 100, df = 4, rmsea0 = 0,
             rmsea1 = NULL,  power = 0.8, alpha = 0.05)
#    Power for SEM based on RMSEA
#
#        n df rmsea0    rmsea1 power alpha
#      100  4      0 0.1736082   0.8  0.05
#
#    URL: http://psychstat.org/rmsea
```

---

wp.t *Statistical Power Analysis for t-Tests*

Description

A t-test is a statistical hypothesis test in which the test statistic follows a Student's t distribution if the null hypothesis is true and follows a non-central t distribution if the alternative hypothesis is true. The t test can assess the statistical significance of (1) the difference between population mean and a specific value, (2) the difference between two independent populaion means, and (3) difference between means of matched paires.

Usage

```
wp.t(n1 = NULL, n2 = NULL, d = NULL, alpha = 0.05, power = NULL,
  type = c("two.sample", "one.sample", "paired", "two.sample.2n"),
  alternative = c("two.sided", "less", "greater"),
  tol = .Machine$double.eps^0.25)
```

Arguments

n1	Sample size of the first group.
n2	Sample size of the second group if applicable.
d	Effect size. See the book by *Cohen (1988)* for details.
alpha	Significance level chosed for the test. It equals 0.05 by default.
power	Statistical power.
type	Type of comparison ("one.sample" or "two.sample" or "two.sample.2n" or "two.sample.2n" or "paired"). "two.sample" is two-sample t-test with equal sample sizes, two.sample.2n" is two-sample t-test with unequal sample sizes, "paired" is paired t-test
alternative	Direction of the alternative hypothesis ("two.sided" or "less" or "greater"). The default is "two.sided".
tol	tolerance in root solver.

Value

An object of the power analysis.

References

Cohen, J. (1988). Statistical power analysis for the behavioral sciences (2nd Ed). Hillsdale, NJ: Lawrence Erlbaum Associates.

Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press.

Examples

```
#To calculate the power for one sample t-test given sample size and effect size:
wp.t(n1=150, d=0.2, type="one.sample")
#  One-sample t-test
#
# n   d alpha    power
# 150 0.2 0.05 0.682153
#
#  URL: http://psychstat.org/ttest

#To calculate the power for paired t-test given sample size and effect size:
wp.t(n1=40, d=-0.4, type="paired", alternative="less")
#  Paired t-test
#
#     n    d alpha     power
#    40 -0.4  0.05 0.7997378
#
#  NOTE: n is number of *pairs*
#  URL: http://psychstat.org/ttest

#To estimate the required sample size given power and effect size for paired t-test :
wp.t(d=0.4, power=0.8, type="paired", alternative="greater")
```

```
#  Paired t-test
#
#           n   d alpha power
#    40.02908 0.4  0.05   0.8
#
#  NOTE: n is number of *pairs*
#  URL: http://psychstat.org/ttest

#To estimate the power for balanced two-sample t-test given sample size and effect size:
wp.t(n1=70, d=0.3, type="two.sample", alternative="greater")
#  Two-sample t-test
#
#     n   d alpha     power
#    70 0.3  0.05 0.5482577
#
#  NOTE: n is number in *each* group
#  URL: http://psychstat.org/ttest

#To estimate the power for unbalanced two-sample t-test given sample size and effect size:
wp.t(n1=30, n2=40, d=0.356, type="two.sample.2n", alternative="two.sided")
#  Unbalanced two-sample t-test
#
#    n1 n2     d alpha     power
#    30 40 0.356  0.05 0.3064767
#
#  NOTE: n1 and n2 are number in *each* group
#  URL: http://psychstat.org/ttest2n

#To estimate the power curve for unbalanced two-sample t-test given a sequence of effect sizes:
res <- wp.t(n1=30, n2=40, d=seq(0.2,0.8,0.05), type="two.sample.2n",
                                             alternative="two.sided")
res
#  Unbalanced two-sample t-test
#
#    n1 n2    d alpha     power
#    30 40 0.20  0.05 0.1291567
#    30 40 0.25  0.05 0.1751916
#    30 40 0.30  0.05 0.2317880
#    30 40 0.35  0.05 0.2979681
#    30 40 0.40  0.05 0.3719259
#    30 40 0.45  0.05 0.4510800
#    30 40 0.50  0.05 0.5322896
#    30 40 0.55  0.05 0.6121937
#    30 40 0.60  0.05 0.6876059
#    30 40 0.65  0.05 0.7558815
#    30 40 0.70  0.05 0.8151817
#    30 40 0.75  0.05 0.8645929
#    30 40 0.80  0.05 0.9040910
#
#  NOTE: n1 and n2 are number in *each* group
#  URL: http://psychstat.org/ttest2n

#To plot a power curve:
```

```
plot(res, xvar='d', yvar='power')
```

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