

Package ‘power4mome’

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Title Power Analysis for Moderation and Mediation

Version 0.1.1

Description Power analysis and sample size determination for moderation, mediation, and moderated mediation in models fitted by structural equation modelling using the 'lavaan' package by Rosseel (2012) <[doi:10.18637/jss.v048.i02](https://doi.org/10.18637/jss.v048.i02)> or by multiple regression. The package 'manymome' by Cheung and Cheung (2024) <[doi:10.3758/s13428-023-02224-z](https://doi.org/10.3758/s13428-023-02224-z)> is used to specify the indirect paths or conditional indirect paths to be tested.

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do_test	<i>Do a Test on Each Replication</i>
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Description

Do a test on each replication in the output of `sim_out()`.

Usage

```
do_test(
  sim_all,
  test_fun,
  test_args = list(),
  map_names = c(fit = "fit"),
  results_fun = NULL,
  results_args = list(),
  parallel = FALSE,
  progress = FALSE,
  ncores = max(1, parallel::detectCores(logical = FALSE) - 1)
)
```

Arguments

sim_all	The output of <code>sim_out()</code> .
test_fun	A function to do the test. See 'Details' for the requirement of this function. There are some built-in test functions in <code>power4mome</code> , described in 'Details'.
test_args	A list of arguments to be passed to the <code>test_fun</code> function. Default is <code>list()</code> .
map_names	A named character vector specifying how the content of the element <code>extra</code> in each replication of <code>sim_all</code> map to the argument of <code>test_fun</code> . Default is <code>c(fit = "fit")</code> , indicating that the element <code>fit</code> in the element <code>extra</code> is set to the argument <code>fit</code> of <code>test_fun</code> . That is, for the first replication, <code>fit = sim_out[[1]]\$extra\$fit</code> when calling <code>test_fun</code> .
results_fun	The function to be used to extract the test results. See Details for the requirements of this function. Default is <code>NULL</code> , assuming that the output of <code>test_fun</code> can be used directly.
results_args	A list of arguments to be passed to the <code>results_fun</code> function. Default is <code>list()</code> .
parallel	If <code>TRUE</code> , parallel processing will be used to do the tests. Default is <code>FALSE</code> .
progress	If <code>TRUE</code> , the progress of tests will be displayed. Default is <code>'FALSE'</code> .
ncores	The number of CPU cores to use if parallel processing is used.

Details

The function `do_test()` does an arbitrary test in each replication using the function set to `test_fun`.

Value

An object of the class `test_out`, which is a list of length equal to `sim_all`, one element for each replication. Each element of the list has two elements:

- `test`: The output of the function set to `test_fun`.
- `test_results`: The output of the function set to `results_fun`.

The role of do_test()

The function `do_test()` is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to develop other functions for power analysis, or to build their own workflows to do the power analysis.

Major Test-Related Arguments

The test function (test_fun):

The function set to `test_fun`, the *test function*, usually should work on the output of `lavaan::sem()`, `lmhelpers::many_lm()`, or `stats::lm()`, but can also be a function that works on the output of the function set to `fit_function` when calling `fit_model()` or `power4test()` (see `fit_model_args`).

The function has two default requirements.

First, it has an argument `fit`, to be set to the output of `lavaan::sem()` or another output stored in the element `extra$fit` of a replication in the `sim_all` object. (This requirement can be relaxed; see the section on `map_names`.)

That is, the function definition should be of this form: `FUN(fit, ...)`. This is the form of all `test_*` functions in `power4mome`.

If other arguments are to be passed to the test function, they can be set to `test_args` as a named list.

Second, the test function must return an output that (a) can be processed by the results function (see below), or (b) is of the required format for the output of a results function (see the next section). If it already returns an output of the required format, then there is no need to set the results function.

The results function (results_fun):

The test results will be extracted from the output of `test_fun` by the function set to `results_fun`, the *results function*. If the `test_fun` already returns an output of the expected format (see below), then set `results_fun` to `NULL`, the default. The output of `test_fun` will be used for estimating power.

The function set to `results_fun` must accept the output of `test_fun`, as the first argument, and return a named list (which can be a data frame) or a named vector with some of the following elements:

- `est`: Optional. The estimate of a parameter, if applicable.
- `se`: Optional. The standard error of the estimate, if applicable.
- `cilo`: Optional. The lower limit of the confidence interval, if applicable.
- `cihi`: Optional. The upper limit of the confidence interval, if applicable.
- `sig`: Required. If 1, the test is significant. If 0, the test is not significant. If the test cannot be done for any reason, it should be `NA`.

The results can then be used to estimate the power or Type I error of the test.

For example, if the null hypothesis is false, then the proportion of significant, that is, the mean of the values of `sig` across replications, is the power.

Built-in test functions:

The package `power4mome` has some ready-to-use test functions:

- `test_indirect_effect()`

- [test_cond_indirect\(\)](#)
- [test_cond_indirect_effects\(\)](#)
- [test_moderation\(\)](#)
- [test_index_of_mome\(\)](#)
- [test_parameters\(\)](#)

Please refer to their help pages for examples.

The argument `map_names`:

This argument is for developers using a test function that has a different name for the argument of the fit object ("fit", the default).

If `test_fun` is set to a function that works on an output of, say, `lavaan::sem()` but the argument name for the output is not `fit`, the mapping can be changed by `map_names`.

For example, `lavaan::parameterEstimates()` receives an output of `lavaan::sem()` and reports the test results of model parameters. However, the argument name for the lavaan output is `object`. To instruct `do_test()` to do the test correctly when setting `test_fun` to `lavaan::parameterEstimates`, add `map_names = c(object = "fit")`. The element `fit` in a replication will then set to the argument object of `lavaan::parameterEstimates()`.

The background for having the `results_fun` argument

In the early development of `power4mome`, `test_fun` is designed to accept existing functions from other packages, such as `manymome::indirect_effect()`. Their outputs are not of the required format for power analysis, and so results functions are needed to process their outputs. In the current version of `power4mome`, some ready-to-use test functions, usually wrappers of these existing functions from other packages, have been developed, and they no longer need results functions to process the output. The argument `results_fun` is kept for backward compatibility and advanced users to use test functions from other packages.

See Also

See `power4test()` for the all-in-one function that uses this function. See `test_indirect_effect()`, `test_cond_indirect()`, `test_cond_indirect_effects()`, `test_moderation()`, `test_index_of_mome()`, and `test_parameters()` for examples of test functions.

Examples

```
# Specify the population model

mod <-
"
m ~ x
y ~ m + x
"

# Specify the effect sizes (population parameter values)

es <-
"
y ~ m: m
```

```

m ~ x: m
y ~ x: n
"

# Generate several simulated datasets

data_all <- sim_data(nrep = 5,
                    model = mod,
                    pop_es = es,
                    n = 100,
                    iseed = 1234)

# Fit the population model to each datasets

fit_all <- fit_model(data_all)

# Generate Monte Carlo estimates for forming Monte Carlo confidence intervals

mc_all <- gen_mc(fit_all,
                R = 50,
                iseed = 4567)

# Combine the results to a 'sim_all' object
sim_all <- sim_out(data_all = data_all,
                  fit = fit_all,
                  mc_out = mc_all)

# Test the indirect effect in each replication
# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

test_all <- do_test(sim_all,
                   test_fun = test_indirect_effect,
                   test_args = list(x = "x",
                                    m = "m",
                                    y = "y",
                                    mc_ci = TRUE),
                   parallel = FALSE,
                   progress = FALSE)

# The result for each dataset
lapply(test_all, function(x) x$test_results)

```

fit_model

Fit a Model to a List of Datasets

Description

Get the output of `sim_data()` and fit a model to each of the stored datasets.

Usage

```
fit_model(
  data_all = NULL,
  model = NULL,
  fit_function = "lavaan",
  arg_data_name = "data",
  arg_model_name = "model",
  arg_group_name = "group",
  ...,
  fit_out = NULL,
  parallel = FALSE,
  progress = FALSE,
  ncores = max(1, parallel::detectCores(logical = FALSE) - 1)
)
```

Arguments

<code>data_all</code>	The output of <code>sim_data()</code> , or a <code>sim_data</code> class object.
<code>model</code>	The model to be fitted. If <code>NULL</code> , the default, the model stored in <code>data_all</code> , which should be the data generation model, will be used.
<code>fit_function</code>	The function to be used to fit the model. Can also be a string: "lavaan" (the default) for <code>lavaan::sem()</code> , and "lm" or <code>many_lm</code> for <code>lmhelpers::many_lm()</code> . Other functions can also be used if necessary.
<code>arg_data_name</code>	The name of the argument of <code>fit_function</code> expecting the dataset. Default is "data".
<code>arg_model_name</code>	The name of the argument of <code>fit_function</code> expecting the model definition. Default is "model".
<code>arg_group_name</code>	The name of the argument of <code>fit_function</code> expecting the name of the group variable. Used only for multigroup models. Default is "group".
<code>...</code>	Optional arguments to be passed to <code>fit_function</code> when fitting the model.
<code>fit_out</code>	If set to a <code>fit_out</code> object (the output of <code>fit_model()</code>), then all missing arguments will be retrieved from <code>fit_out</code> . That is, users can use <code>fit_model(data_all = new_data, fit_out = old_out)</code> to re-fit a model originally fitted in <code>old_out</code> on a new list of dataset (<code>new_data</code>). No need to include all other arguments.
<code>parallel</code>	If <code>TRUE</code> , parallel processing will be used to fit the models. Default is <code>FALSE</code> .
<code>progress</code>	If <code>TRUE</code> , the progress of model fitting will be displayed. Default is <code>FALSE</code> .
<code>ncores</code>	The number of CPU cores to use if parallel processing is used.

Details

By default, the function `fit_model()`

- extracts the model stored in the output of `sim_data()`,
- fits the model to each dataset simulated using `fit_function`, default to "lavaan" and `lavaan::sem()` will be called,

- and returns the results.

If the datasets were generated from a multigroup model when calling `sim_data()`, a multigroup model is fitted.

Value

An object of the class `fit_out`, which is a list of the output of `fit_function` (`lavaan::sem()` by default). If an error occurred when fitting the model to a dataset, then this element will be the error message from the fit function.

The role of `fit_model()`

This function is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to customize the model fitting step in power analysis.

See Also

See `power4test()` for the all-in-one function that uses this function, and `sim_data()` for the function generating datasets for this function.

Examples

```
# Specify the population model

mod <-
"m ~ x
 y ~ m + x"

# Specify the effect sizes (population parameter values)

es <-
"
y ~ m: m
m ~ x: m
y ~ x: n
"

# Generate several simulated datasets

data_all <- sim_data(nrep = 5,
                    model = mod,
                    pop_es = es,
                    n = 100,
                    iseed = 1234)

# Fit the population model to each datasets

fit_all <- fit_model(data_all)
fit_all[[1]]
```



```

# Fit the population model using the MLR estimator

fit_all_mlr <- fit_model(data_all,
                        estimator = "MLR")
fit_all_mlr[[1]]

# Fit a model different from the population model,
# with the MLR estimator

mod2 <-
  "m ~ x
  y ~ m"

fit_all_mlr2 <- fit_model(data_all,
                        mod2,
                        estimator = "MLR")
fit_all_mlr2[[1]]

```

gen_boot

Generate Bootstrap Estimates

Description

Get a list of the output of `lavaan::sem()` or `lmhelpers::many_lm()` and generate bootstrap estimates of model parameters.

Usage

```

gen_boot(
  fit_all,
  R = 100,
  ...,
  iseed = NULL,
  parallel = FALSE,
  progress = FALSE,
  ncores = max(1, parallel::detectCores(logical = FALSE) - 1),
  compute_implied_stats = FALSE
)

```

Arguments

<code>fit_all</code>	The output of <code>fit_model()</code> or an object of the class <code>fit_out</code> .
<code>R</code>	The number of replications to generate the bootstrap estimates for each fit output.
<code>...</code>	Optional arguments to be passed to <code>manymome::do_boot()</code> when generating the bootstrap estimates.

iseed	The seed for the random number generator. Default is NULL and the seed is not changed.
parallel	If TRUE, parallel processing will be used to generate bootstrap estimates for the fit outputs. Default is FALSE.
progress	If TRUE, the progress will be displayed. Default is 'FALSE'.
ncores	The number of CPU cores to use if parallel processing is used.
compute_implied_stats	Whether implied statistics are computed in each bootstrap samples. Usually not needed and so default to FALSE

Details

The function `gen_boot()` simply calls `manymome::do_boot()` on each output of `lavaan::sem()` or `lmhelpers::many_lm()` in `fit_all`. The simulated estimates can then be used to test effects such as indirect effects, usually by functions from the `manymome` package, such as `manymome::indirect_effect()`.

Value

A `boot_list` object, which is a list of the output of `manymome::do_boot()`.

The role of `gen_boot()`

This function is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to customize the workflow of the power analysis.

See Also

See `power4test()` for the all-in-one function that uses this function.

Examples

```
# Specify the population model

mod <-
"m ~ x
 y ~ m + x"

# Specify the effect sizes (population parameter values)

es <-
"
y ~ m: m
m ~ x: m
y ~ x: n
"

# Generate several simulated datasets

data_all <- sim_data(nrep = 2,
```

```

        model = mod,
        pop_es = es,
        n = 50,
        iseed = 1234)

# Fit the population model to each datasets

fit_all <- fit_model(data_all)

# Generate bootstrap estimates for each replication

boot_all <- gen_boot(fit_all,
                    R = 10,
                    iseed = 4567)

boot_all

```

gen_mc

Generate Monte Carlo Estimates

Description

Get a list of the output of `lavaan::sem()` and generate Monte Carlo estimates of model parameters.

Usage

```

gen_mc(
  fit_all,
  R = 100,
  ...,
  iseed = NULL,
  parallel = FALSE,
  progress = FALSE,
  ncores = max(1, parallel::detectCores(logical = FALSE) - 1),
  compute_implied_stats = FALSE
)

```

Arguments

<code>fit_all</code>	The output of <code>fit_model()</code> or an object of the class <code>fit_out</code> .
<code>R</code>	The number of replications to generate the Monte Carlo estimates for each fit output.
<code>...</code>	Optional arguments to be passed to <code>manymome::do_mc()</code> when generating the Monte Carlo estimates.
<code>iseed</code>	The seed for the random number generator. Default is <code>NULL</code> and the seed is not changed.

parallel	If TRUE, parallel processing will be used to generate Monte Carlo estimates for the fit outputs. Default is FALSE.
progress	If TRUE, the progress will be displayed. Default is 'FALSE.
ncores	The number of CPU cores to use if parallel processing is used.
compute_implied_stats	Whether implied statistics are computed in each Monte Carlo replication. Usually not needed and so default to FALSE.

Details

The function `gen_mc()` simply calls `manymome::do_mc()` on each output of `lavaan::sem()` in `fit_all`. The simulated estimates can then be used to test effects such as indirect effects, usually by functions from the `manymome` package, such as `manymome::indirect_effect()`.

Value

An `mc_list` object, which is a list of the output of `manymome::do_mc()`.

The role of `gen_mc()`

This function is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to customize the workflow of the power analysis.

See Also

See `power4test()` for the all-in-one function that uses this function.

Examples

```
# Specify the population model

mod <-
  "m ~ x
  y ~ m + x"

# Specify the effect sizes (population parameter values)

es <-
  "
  y ~ m: m
  m ~ x: m
  y ~ x: n
  "

# Generate several simulated datasets

data_all <- sim_data(nrep = 5,
                    model = mod,
                    pop_es = es,
                    n = 100,
```

```

iseed = 1234)

# Fit the population model to each datasets

fit_all <- fit_model(data_all)

# Generate Monte Carlo estimates for each replication

mc_all <- gen_mc(fit_all,
                 R = 100,
                 iseed = 4567)

mc_all

```

plot.power_curve *Plot a Power Curve*

Description

Plotting the results in a 'power_curve' object, such as the estimated power against sample size, or the results of `power4test_by_n()` or `power4test_by_es()`.

Usage

```

## S3 method for class 'power_curve'
plot(
  x,
  what = c("ci", "power_curve"),
  main = paste0("Power Curve ", "(Predictor: ", switch(x$predictor, n = "Sample Size", es
    = "Effect Size"), ")"),
  xlab = switch(x$predictor, n = "Sample Size", es = "Effect Size"),
  ylab = "Estimated Power",
  pars_ci = list(),
  type = "l",
  ylim = c(0, 1),
  ci_level = 0.95,
  ...
)

## S3 method for class 'power4test_by_n'
plot(
  x,
  what = c("ci", "power_curve"),
  main = "Estimated Power vs. Sample Size",
  xlab = "Sample Size",
  ylab = "Estimated Power",
  pars_ci = list(),

```

```

    type = "l",
    ylim = c(0, 1),
    ci_level = 0.95,
    ...
)

## S3 method for class 'power4test_by_es'
plot(
  x,
  what = c("ci", "power_curve"),
  main = paste0("Estimated Power vs. Effect Size / Parameter (", attr(x[[1]]),
    "pop_es_name"), ")"),
  xlab = paste0("Effect Size / Parameter (", attr(x[[1]], "pop_es_name"), ")"),
  ylab = "Estiamted Power",
  pars_ci = list(),
  type = "l",
  ylim = c(0, 1),
  ci_level = 0.95,
  ...
)

```

Arguments

x	The object to be plotted. It can be a <code>power_curve</code> object, the output of <code>power_curve()</code> . It can also be the output of <code>power4test_by_n()</code> or <code>power4test_by_es()</code> .
what	A character vector of what to include in the plot. Possible values are "ci" (confidence intervals for the estimated sample size) and "power_curve" (the crude power curve, if available). The default values depend on the type of x.
main	The title of the plot.
xlab, ylab	The labels for the horizontal and vertical axes, respectively.
pars_ci	A named list of arguments to be passed to <code>arrows()</code> to customize the drawing of the confidence intervals.
type	An argument of the default plot method <code>plot.default()</code> . Default is "l". See <code>plot.default()</code> for other options.
ylim	A two-element numeric vector of the range of the vertical axis.
ci_level	The level of confidence of the confidence intervals, if requested. Default is .95, denoting 95%.
...	Optional arguments. Passed to <code>plot()</code> when drawing the base plot.

Details

The `plot` method of `power_curve` objects currently plots the relation between estimated power and the predictor. Other elements can be requested (see the argument `what`), and they can be customized individually.

Value

The `plot`-methods return `x` invisibly. They are called for their side effects.

See Also

[power_curve\(\)](#), [power4test_by_n\(\)](#), and [power4test_by_es\(\)](#).

Examples

```
# Specify the population model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the effect sizes (population parameter values)

model_simple_med_es <-
"
y ~ m: l
m ~ x: m
y ~ x: s
"

# Simulate datasets to check the model

sim_only <- power4test(nrep = 10,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 50,
                      fit_model_args = list(fit_function = "lm"),
                      do_the_test = FALSE,
                      iseed = 1234,
                      parallel = FALSE,
                      progress = FALSE)

# By n: Do a test for different sample sizes
# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

out1 <- power4test_by_n(sim_only,
                       nrep = 10,
                       test_fun = test_parameters,
                       test_args = list(par = "y~x"),
                       n = c(25, 50, 100),
                       by_seed = 1234,
                       parallel = FALSE,
                       progress = FALSE)

pout1 <- power_curve(out1)
pout1
plot(pout1)

# By pop_es: Do a test for different population values of a model parameter
```

```

# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

out2 <- power4test_by_es(sim_only,
                        nrep = 10,
                        test_fun = test_parameters,
                        test_args = list(par = "y~x"),
                        pop_es_name = "y ~ x",
                        pop_es_values = c(0, .3, .5),
                        by_seed = 1234,
                        parallel = FALSE,
                        progress = FALSE)

pout2 <- power_curve(out2)
plot(pout2)

```

plot.x_from_power

Plot The Results of 'x_from_power'

Description

It plots the results of 'x_from_power', such as the estimated power against sample size.

Usage

```

## S3 method for class 'x_from_power'
plot(
  x,
  what = c("ci", "power_curve", "final_x", "final_power", "target_power", switch(x$x, n =
    "sig_area", es = NULL)),
  text_what = c("final_x", "final_power", switch(x$x, n = "sig_area", es = NULL)),
  digits = 3,
  main = paste0("Power Curve ", "(Target Power: ", formatC(x$target_power, digits =
    digits, format = "f"), ")"),
  xlab = NULL,
  ylab = "Estimated Power",
  ci_level = 0.95,
  pars_ci = list(),
  pars_power_curve = list(),
  pars_ci_final_x = list(lwd = 2, length = 0.2, col = "blue"),
  pars_target_power = list(lty = "dashed", lwd = 2, col = "black"),
  pars_final_x = list(lty = "dotted"),
  pars_final_power = list(lty = "dotted", col = "blue"),
  pars_text_final_x = list(y = 0, pos = 3, cex = 1),
  pars_text_final_power = list(pos = 3, cex = 1),
  pars_sig_area = list(col = adjustcolor("lightblue", alpha.f = 0.1)),
  pars_text_sig_area = list(cex = 1),

```



```

    ...
  )

## S3 method for class 'n_region_from_power'
plot(
  x,
  what = c("ci", "power_curve", "final_x", "final_power", "target_power", "sig_area"),
  text_what = c("final_x", "final_power", "sig_area"),
  digits = 3,
  main = paste0("Power Curve ", "(Target Power: ", formatC(x$below$target_power, digits =
    digits, format = "f"), ")"),
  xlab = NULL,
  ylab = "Estimated Power",
  ci_level = 0.95,
  pars_ci = list(),
  pars_power_curve = list(),
  pars_ci_final_x = list(lwd = 2, length = 0.2, col = "blue"),
  pars_target_power = list(lty = "dashed", lwd = 2, col = "black"),
  pars_final_x = list(lty = "dotted"),
  pars_final_power = list(lty = "dotted", col = "blue"),
  pars_text_final_x = list(y = 0, pos = 3, cex = 1),
  pars_text_final_power = list(cex = 1),
  pars_sig_area = list(col = adjustcolor("lightblue", alpha.f = 0.1)),
  pars_text_sig_area = list(cex = 1),
  ...
)

```

Arguments

<code>x</code>	An <code>x_from_power</code> object, the output of <code>x_from_power()</code> .
<code>what</code>	A character vector of what to include in the plot. Possible values are "ci" (confidence intervals for the estimated value of the predictor), "power_curve" (the crude power curve, if available), "final_x" (a vertical line for the value of the predictor with estimated power close enough to the target power by confidence interval), "final_power" (a horizontal line for the estimated power of the final value of the predictor), "target_power" (a horizontal line for the target power), and "sig_area" (the area significantly higher or lower than the target power, if goal is "close_enough" and what is "lb" or "ub"). By default, all these elements will be plotted.
<code>text_what</code>	A character vector of what numbers to be added as labels. Possible values are "final_x" (the value of the predictor with estimated power close enough to the target power by confidence interval) "final_power" (the estimated power of the final value of the predictor), and "sig_area" (labeling the area significantly higher or lower than the target power, if goal is "close_enough" and what is "lb" or "ub"). By default, all these labels will be added.
<code>digits</code>	The number of digits after the decimal that will be used when adding numbers.
<code>main</code>	The title of the plot.

<code>xlab, ylab</code>	The labels for the horizontal and vertical axes, respectively.
<code>ci_level</code>	The level of confidence of the confidence intervals, if requested. Default is <code>.95</code> , denoting 95%.
<code>pars_ci</code>	A named list of arguments to be passed to <code>arrows()</code> to customize the drawing of the confidence intervals.
<code>pars_power_curve</code>	A named list of arguments to be passed to <code>points()</code> to customize the drawing of the power curve.
<code>pars_ci_final_x</code>	A named list of arguments to be passed to <code>arrows()</code> to customize the drawing of the confidence interval of the final value of the predictor.
<code>pars_target_power</code>	A named list of arguments to be passed to <code>abline()</code> when drawing the horizontal line for the target power.
<code>pars_final_x</code>	A named list of arguments to be passed to <code>abline()</code> when drawing the vertical line for the final value of the predictor.
<code>pars_final_power</code>	A named list of arguments to be passed to <code>abline()</code> when drawing the horizontal line for the estimated power at the final value of the predictor.
<code>pars_text_final_x</code>	A named list of arguments to be passed to <code>text()</code> when adding the label for the final value of the predictor.
<code>pars_text_final_power</code>	A named list of arguments to be passed to <code>text()</code> when adding the label for the estimated power of final value of the predictor.
<code>pars_sig_area</code>	A named list of arguments to be passed to <code>rect()</code> when shading the area significantly higher or lower than the target power.
<code>pars_text_sig_area</code>	A named list of arguments to be passed to <code>text()</code> when labelling the area significantly higher or lower than the target power.
<code>...</code>	Optional arguments. Passed to <code>plot()</code> when drawing the estimated power against the predictor.

Details

The `plot` method of `x_from_power` objects currently plots the relation between estimated power and the values examined by `x_from_power()`. Other elements can be requested (see the argument `what`), and they can be customized individually.

The `plot`-method for `n_region_from_power` objects is a modified version of the `plot`-method for `x_from_power`. It plots the results of two runs of `n_from_power()` in one plot. It is otherwise similar to the `plot`-method for `x_from_power`.

Value

The `plot`-method of `x_from_power` returns `x` invisibly. It is called for its side effect.

The `plot`-method of `n_region_from_power` returns `x` invisibly. It is called for its side effect.

 pop_es_yaml

Parse YAML-Style Values For 'pop_es'

Description

Convert a YAML string to a vector or list of pop_es specification.

Usage

```
pop_es_yaml(text)
```

Arguments

`text` The multiline string to be parsed to a specification of population values.

Details

The function `pop_es_yaml()` allows users to specify population values of a model using one single string, as in 'lavaan' model syntax.

Value

Either a named vector (for a single-group model) or a list of named vector (for a multigroup model) of the population values of the parameters (the effect sizes).

Specify 'pop_es' Using a Multiline String

When setting the argument `pop_es`, instead of using a named vector or named list for `pop_es`, the population values of model parameters can also be specified using a multiline string, as illustrated below, to be parsed by `pop_es_yaml()`.

Single-Group Model:

This is an example of the multiline string for a single-group model:

```
y ~ m: 1
m ~ x: m
y ~ x: nil
```

The string must follow this format:

- Each line starts with `tag:`.
 - `tag` can be the name of a parameter, in lavaan model syntax format.
 - * For example, `m ~ x` denotes the path from `x` to `m`.
 - A tag in lavaan model syntax can specify more than one parameter using `+`.
 - * For example, `y ~ m + x` denotes the two paths from `m` and `x` to `y`.
 - Alternatively, the tag can be either `.beta.` or `.cov.`.
 - * Use `.beta.` to set the default values for all regression coefficients.

* Use `.cov.` to set the default values for all correlations of exogenous variables (e.g., predictors).

- After each tag is the value of the population value:
 - nil for nil (zero),
 - s for small,
 - m for medium, and
 - l for large.
 - si, mi, and li for small, medium, and large a standardized indirect effect, respectively.

Note: `n` cannot be used in this mode.

The value for each label is determined by `es1` and `es2` as described in `ptable_pop()`.

- The value can also be set to a numeric value, such as `.30` or `-.30`.

This is another example:

```
.beta.: s
y ~ m: l
```

In this example, all regression coefficients are small, while the path from `m` to `y` is large.

Multigroup Model:

This is an example of the string for a multigroup model:

```
y ~ m: l
m ~ x:
  - nil
  - s
y ~ x: nil
```

The format is similar to that for a single-group model. If a parameter has the same value for all groups, then the line can be specified as in the case of a single-group model: `tag: value`.

If a parameter has different values across groups, then it must be in this format:

- A line starts with the tag, followed by two or more lines. Each line starts with a hyphen `-` and the value for a group.

For example:

```
m ~ x:
  - nil
  - s
```

This denotes that the model has two groups. The values of the path from `x` to `m` for the two groups are 0 (`nil`) and small (`s`), respectively.

Another equivalent way to specify the values are using `[]`, on the same line of a tag.

For example:

```
m ~ x: [nil, s]
```

The number of groups is inferred from the number of values for a parameter. Therefore, if a tag has more than one value, each tag must have the same number of values, or only one value.

The tag `.beta.` and `.cov.` can also be used for multigroup models.

Which Approach To Use:

Note that using named vectors or named lists is more reliable. However, using a multiline string is more user-friendly. If this method failed, please use named vectors or named list instead.

Technical Details:

The multiline string is parsed by `yaml::read_yaml()`. Therefore, the format requirement is actually that of YAML. Users knowledgeable of YAML can use other equivalent way to specify the string.

See Also

[ptable_pop\(\)](#), [power4test\(\)](#), and other functions that have the `pop_es` argument.

Examples

```
mod_es <- c("y ~ m" = "1",
           "m ~ x" = "m",
           "y ~ x" = "nil")

mod_es_yaml <-
"
y ~ m: 1
m ~ x: m
y ~ x: nil
"

pop_es_yaml(mod_es_yaml)
```

power4test

Estimate the Power of a Test

Description

An all-in-one function that receives a model specification, generates datasets, fits a model, does the target test, and returns the test results.

Usage

```
power4test(
  object = NULL,
  nrep = NULL,
  ptable = NULL,
  model = NULL,
  pop_es = NULL,
  standardized = TRUE,
  n = NULL,
```

```

    number_of_indicators = NULL,
    reliability = NULL,
    x_fun = list(),
    e_fun = list(),
    process_data = NULL,
    fit_model_args = list(),
    R = NULL,
    ci_type = "mc",
    gen_mc_args = list(),
    gen_boot_args = list(),
    test_fun = NULL,
    test_args = list(),
    map_names = c(fit = "fit"),
    results_fun = NULL,
    results_args = list(),
    test_name = NULL,
    test_note = NULL,
    do_the_test = TRUE,
    sim_all = NULL,
    iseed = NULL,
    parallel = FALSE,
    progress = TRUE,
    ncores = max(1, parallel::detectCores(logical = FALSE) - 1),
    es1 = c(n = 0, nil = 0, s = 0.1, m = 0.3, l = 0.5, si = 0.141, mi = 0.361, li = 0.51),
    es2 = c(n = 0, nil = 0, s = 0.05, m = 0.1, l = 0.15),
    es_ind = c("si", "mi", "li"),
    n_std = 1e+05,
    std_force_monte_carlo = FALSE
)

## S3 method for class 'power4test'
print(
  x,
  what = c("data", "test"),
  digits = 3,
  digits_descriptive = 2,
  data_long = FALSE,
  test_long = FALSE,
  fit_to_all_args = list(),
  ...
)

```

Arguments

object	Optional. If set to a power4test object, it will be updated using the value(s) in n, pop_es, and/or nrep if they changed, or a new test will be conducted and added to objet. See the help page for details. Default is NULL.
nrep	The number of replications to generate the simulated datasets. Default is NULL.

	Must be set when called to create a <code>power4test</code> object.
<code>ptable</code>	The output of <code>ptable_pop()</code> , which is a <code>ptable_pop</code> object, representing the population model. If <code>NULL</code> , the default, <code>ptable_pop()</code> will be called to generate the <code>ptable_pop</code> object using <code>model</code> and <code>pop_es</code> .
<code>model</code>	The lavaan model syntax of the population model, to be used by <code>ptable_pop()</code> . See 'Details' of on how to specify the model. Ignored if <code>ptable</code> is specified.
<code>pop_es</code>	The character vector or multiline string to specify population effect sizes (population values of parameters). See the help page on how to specify this argument. Ignored if <code>ptable</code> is specified.
<code>standardized</code>	Logical. If <code>TRUE</code> , the default, variances and error variances are scaled to ensure the population variances of the endogenous variables are close to one, and hence the effect sizes (population values) are standardized effect sizes if the variances of the continuous exogenous variables are also equal to one.
<code>n</code>	The sample size for each dataset. Default is 100.
<code>number_of_indicators</code>	A named vector to specify the number of indicators for each factors. See the help page on how to set this argument. Default is <code>NULL</code> and all variables in the model syntax are observed variables. See the help page on how to use this argument.
<code>reliability</code>	A named vector (for a single-group model) or a named list of named vectors (for a multigroup model) to set the reliability coefficient of each set of indicators. Default is <code>NULL</code> . See the help page on how to use this argument.
<code>x_fun</code>	The function(s) used to generate the exogenous variables or error terms. If not supplied, or set to <code>list()</code> , the default, the variables are generated from a multivariate normal distribution. See the help page on how to use this argument.
<code>e_fun</code>	The function(s) used to generate the error terms of indicators, if any. If not supplied, or set to <code>list()</code> , the default, the error terms of indicators are generated from a multivariate normal distribution. Specify in the same way as <code>x_fun</code> . Refer to the help page on <code>x_fun</code> on how to use this argument.
<code>process_data</code>	If not <code>NULL</code> , it must be a named list with these elements: <code>fun</code> (required), the function to further processing the simulated data, such as generating missing data using functions such as <code>mice::ampute()</code> ; <code>args</code> (optional), a named list of arguments to be passed to <code>fun</code> , except the one for the source data; <code>sim_data_name</code> (required) the name of the argument to receive the simulated data (e.g., <code>data</code> for <code>mice::ampute()</code>); <code>processed_data_name</code> (optional), the name of the data frame after being processed by <code>fun</code> , such as the data frame with missing data in the output of <code>fun</code> (e.g., <code>"amp"</code> for <code>mice::ampute()</code>), if omitted, the output of <code>fun</code> should be the data frame with missing data.
<code>fit_model_args</code>	A list of the arguments to be passed to <code>fit_model()</code> when fitting the model. Should be a named list with names being the names of the arguments.
<code>R</code>	The number of replications to generate the Monte Carlo or bootstrapping estimates for each fit output. No Monte Carlo nor bootstrapping estimates will be generated if <code>R</code> is set to <code>NULL</code> .
<code>ci_type</code>	The type of simulation-based confidence intervals to use. Can be either <code>"mc"</code> for Monte Carlo method (the default) or <code>"boot"</code> for nonparametric bootstrapping method. Relevant for test functions that make use of estimates generate by <code>gen_boot()</code> or <code>gen_mc()</code> , such as <code>test_indirect_effect()</code> .

gen_mc_args	A list of arguments to be passed to <code>manymome::do_mc()</code> when generating the Monte Carlo estimates. Should be a named argument with names being the names of the arguments. Used only if <code>ci_type</code> is "mc".
gen_boot_args	A list of arguments to be passed to <code>manymome::do_boot()</code> when generating the bootstrap estimates. Should be a named argument with names being the names of the arguments. Used only if <code>ci_type</code> is "boot".
test_fun	A function to do the test. See 'Details' for the requirement of this function. There are some built-in test functions in <code>power4mome</code> , described in 'Details'.
test_args	A list of arguments to be passed to the <code>test_fun</code> function. Default is <code>list()</code> .
map_names	A named character vector specifying how the content of the element <code>extra</code> in each replication of <code>sim_all</code> map to the argument of <code>test_fun</code> . Default is <code>c(fit = "fit")</code> , indicating that the element <code>fit</code> in the element <code>extra</code> is set to the argument <code>fit</code> of <code>test_fun</code> . That is, for the first replication, <code>fit = sim_out[[1]]\$extra\$fit</code> when calling <code>test_fun</code> .
results_fun	The function to be used to extract the test results. See <code>Details</code> for the requirements of this function. Default is <code>NULL</code> , assuming that the output of <code>test_fun</code> can be used directly.
results_args	A list of arguments to be passed to the <code>results_fun</code> function. Default is <code>list()</code> .
test_name	String. The name of the test. Default is <code>NULL</code> , and the name will be created from <code>test_fun</code> . Note that if <code>sim_out</code> is a <code>power4test</code> object and already has a test of this name stored, it will be replaced by the new results.
test_note	String. An optional note for the test, stored in the attribute <code>test_note</code> of the output of <code>do_test()</code> . Default is <code>NULL</code> .
do_the_test	If <code>TRUE</code> , <code>do_test()</code> will be called to do the test specified by <code>test_fun</code> on the fit output of each dataset.
sim_all	If set to either a <code>sim_out</code> object (the output of <code>sim_out()</code>) or a <code>power4test</code> object (the output of <code>power4test()</code>), the stored datasets and fit outputs will be used for doing the test. Setting object to the output of <code>power4test()</code> is now the preferred method, but this argument is kept for backward compatibility.
iseed	The seed for the random number generator. Default is <code>NULL</code> and the seed is not changed. This seed will be set only once, when calling <code>sim_data()</code> .
parallel	If <code>TRUE</code> , parallel processing will be used when calling other functions, if appropriate. Default is <code>FALSE</code> .
progress	If <code>TRUE</code> , the progress of each step will be displayed. Default is <code>TRUE</code> .
ncores	The number of CPU cores to use if parallel processing is used.
es1	Set the values for each label of the effect size (population value) for correlations and regression paths. Used only if <code>pop_es</code> is a named vector or a multiline string. See the help page on how to specify this argument.
es2	Set the values for each label of the effect size (population value) for product term. Used only if <code>pop_es</code> is a named vector or a multiline string. See the help page on how to specify this argument.
es_ind	The names of labels denoting the effect size of an indirect effect. They will be used to determine the population values of the component paths along an indirect path.

n_std	The sample size used to determine the error variances by simulation when <code>std_force_monte_carlo</code> is TRUE.
std_force_monte_carlo	Logical. If FALSE, the default, standardization is done analytically if the model has no product terms, and by simulation if the model has product terms. That is, error variances required to ensure implied variances equal to one are determined by simulation. If TRUE, simulation will be used whether the model has product terms or not. Always fall back to simulation if analytical standardization failed.
x	The object to be printed.
what	A string vector of what to print, "data" for simulated data and "test" for stored test(s). Default is <code>c("data", "test")</code> .
digits	The numbers of digits displayed after the decimal.
digits_descriptive	The number of digits displayed after the decimal for the descriptive statistics table.
data_long	If TRUE, detailed results will be printed when printing the simulated data.
test_long	If TRUE, detailed results will be printed when printing test(s).
fit_to_all_args	A named list of arguments to be passed to <code>lavaan::sem()</code> when the model is fitted to a sample combined from
...	Optional arguments to be passed to other print methods

Details

The function `power4test()` is an all-in-one function for estimating the power of a test for a model, given the sample size and effect sizes (population values of model parameters).

Value

An object of the class `power4test`, which is a list with two elements:

- `sim_all`: The output of `sim_out()`.
- `test_all`: A named list of the output of `do_test()`. The names are the values of `test_name`. This list can have more than one test because a call to `power4test()` can add new tests to a `power4test` object.

The print method of `power4test` returns `x` invisibly. Called for its side effect.

Workflow

This is the workflow:

- If object is an output of the output of a previous call to `power4test()` with `do_the_test` set to FALSE and so has only the model and the simulated data, the following steps will be skipped and go directly to doing the test.
 - Call `sim_data()` to determine the population model and generate the datasets, using arguments such as `model` and `pop_es`.

- Call `fit_model()` to fit a model to each of the datasets, which is the population model by default.
- If `R` is not `NULL` and `ci_type = "mc"`, call `gen_mc()` to generate Monte Carlo estimates using `manymome::do_mc()`. The estimates can be used by supported functions such as `test_indirect_effect()`.
- If `R` is not `NULL` and `ci_type = "boot"`, call `gen_boot()` to generate bootstrap estimates using `manymome::do_boot()`. The estimates can be used by supported functions such as `test_indirect_effect()`.
- Merge the results into a `sim_out` object by calling `sim_out()`.
- If `do_the_test` is `FALSE`, skip the remaining steps and return a `power4test` object, which contains only the data generated and optionally the Monte Carlo or bootstrap estimates.
- If `do_the_test` is `TRUE`, do the test.
 - `do_test()` will be called to do the test in the fit output of each dataset.
- Return a `power4test` object which include the output of `sim_out` and, if `do_the_test` is `TRUE`, the output of `do_test()`.

This function is to be used when users are interested only in the power of one or several tests on a particular aspect of the model, such as a parameter, given a specific effect sizes and sample sizes.

Detailed description on major arguments can be found in sections below.

NOTE: The technical internal workflow of `power4test()` can be found in this page: https://sfcheung.github.io/power4mome/articles/power4test_workflow.html.

Updating a Condition

The function `power4test()` can also be used to update a condition when only some selected aspects is to be changed.

For example, instead of calling this function with all the arguments set just to change the sample size, it can be called by supplying an existing `power4test` object and set only `n` to a new sample size. The data and the tests will be updated automatically. See the examples for an illustration.

Adding Another Test

The function `power4test()` can also be used to add a test to the output from a previous call to `power4test()`.

For example, after simulating the datasets and doing one test, the output can be set to object of `power4test()`, and set only `test_fun` and, optionally, `test_fun_args` to do one more test on the generated datasets. The output will be the original object with the results of the new test added. See the examples for an illustration.

Model Fitting Arguments ('fit_model_args')

For power analysis, usually, the population model (`model`) is to be fitted, and there is no need to set `fit_model_args`.

If power analysis is to be conducted for fitting a model that is not the population model, or if non-default settings are desired when fitting a model, then the argument `fit_model_args` needed to be set to customize the call to `fit_model()`.

For example, users may want to examine the power of a test when a misspecified model is fitted, or the power of a test when MLR is used as the estimator when calling `lavaan::sem()`.

See the help page of `fit_model()` for some examples.

Specify the Population Model by 'model'

Single-Group Model:

For a single-group model, `model` should be a lavaan model syntax string of the *form* of the model. The population values of the model parameters are to be determined by `pop_es`.

If the model has latent factors, the syntax in `model` should specify only the *structural model* for the *latent factors*. There is no need to specify the measurement part. Other functions will generate the measurement part on top of this model.

For example, this is a simple mediation model:

```
"m ~ x
y ~ m + x"
```

Whether `m`, `x`, and `y` denote observed variables or latent factors are determined by other functions, such as `power4test()`.

Multigroup Model:

Because the model is the population model, equality constraints are irrelevant and the model syntax specifies only the *form* of the model. Therefore, `model` is specified as in the case of single group models.

Specify 'pop_es' Using Named Vectors

The argument `pop_es` is for specifying the population values of model parameters. This section describes how to do this using named vectors.

Single-Group Model:

If `pop_es` is specified by a named vector, it must follow the convention below.

- The names of the vectors are lavaan names for the selected parameters. For example, `m ~ x` denotes the path from `x` to `m`.
- Alternatively, the names can be either `".beta."` or `".cov."`. Use `".beta."` to set the default values for all regression coefficients. Use `".cov."` to set the default values for all correlations of exogenous variables (e.g., predictors).
- The names can also be of this form: `".ind.<path>"`, whether `<path>` denote path in the model. For example, `".ind.(x->m->y)"` denotes the path from `x` through `m` to `y`. Alternatively, the lavaan symbol `~` can also be used: `".ind.(y~m~x)"`. This form is used to set the indirect effect (standardized, by default) along this path. The value for this name will override other settings.
- If using lavaan names, can specify more than one parameter using `+`. For example, `y ~ m + x` denotes the two paths from `m` and `x` to `y`.
- The value of each element can be the label for the effect size: `n` for nil, `s` for small, `m` for medium, and `l` for large. The value for each label is determined by `es1` and `es2`. See the section on specifying these two arguments.

- The value of `pop_es` can also be set to a value, but it must be quoted as a string, such as `"y ~ x" = ".31"`.

This is an example:

```
c(".beta." = "s",
  "m1 ~ x" = "-m",
  "m2 ~ m1" = "1",
  "y ~ x:w" = "s")
```

In this example,

- All regression coefficients are set to small (s) by default, unless specified otherwise.
- The path from x to m1 is set to medium and negative (-m).
- The path from m1 to m2 is set to large (1).
- The coefficient of the product term x:w when predicting y is set to small (s).

Indirect Effect:

When setting an indirect effect to a symbol (default: "si", "mi", "li", with "i" added to differentiate them from the labels for a direct path), the corresponding value is used to determine the population values of *all* component paths along the pathway. All the values are assumed to be equal. Therefore, `".ind. (x->m->y)" = ".20"` is equivalent to setting `m ~ x` and `y ~ m` to the square root of .20, such that the corresponding indirect effect is equal to the designated value.

This behavior, though restricted, is for quick manipulation of the indirect effect. If different values along a pathway, set the value for each path directly.

Only nonnegative value is supported. Therefore, `".ind. (x->m->y)" = "-si"` and `".ind. (x->m->y)" = "-.20"` will throw an error.

Multigroup Model:

The argument `pop_es` also supports multigroup models.

For `pop_es`, instead of named vectors, named *list* of named vectors should be used.

- The names are the parameters, or keywords such as `.beta.` and `.cov.`, like specifying the population values for a single group model.
- The elements are character vectors. If it has only one element (e.g., a single string), then it is the the population value for all groups. If it has more than one element (e.g., a vector of three strings), then they are the population values of the groups. For a model of *k* groups, each vector must have either *k* elements or one element.

This is an example:

```
list("m ~ x" = "m",
     "y ~ m" = c("s", "m", "1"))
```

In this model, the population value of the path `m ~ x` is medium (m) for all groups, while the population values for the path `y ~ m` are small (s), medium (m), and large (1), respectively.

Specify 'pop_es' Using a Multiline String

When setting the argument `pop_es`, instead of using a named vector or named list for `pop_es`, the population values of model parameters can also be specified using a multiline string, as illustrated below, to be parsed by `pop_es_yaml()`.

Single-Group Model:

This is an example of the multiline string for a single-group model:

```
y ~ m: l
m ~ x: m
y ~ x: nil
```

The string must follow this format:

- Each line starts with tag:
 - tag can be the name of a parameter, in lavaan model syntax format.
 - * For example, $m \sim x$ denotes the path from x to m .
 - A tag in lavaan model syntax can specify more than one parameter using +.
 - * For example, $y \sim m + x$ denotes the two paths from m and x to y .
 - Alternatively, the tag can be either `.beta.` or `.cov.`
 - * Use `.beta.` to set the default values for all regression coefficients.
 - * Use `.cov.` to set the default values for all correlations of exogenous variables (e.g., predictors).
- After each tag is the value of the population value:
 - `-nil` for nil (zero),
 - `s` for small,
 - `m` for medium, and
 - `l` for large.
 - `si`, `mi`, and `li` for small, medium, and large a standardized indirect effect, respectively.

Note: `n` cannot be used in this mode.

The value for each label is determined by `es1` and `es2` as described in `ptable_pop()`.

- The value can also be set to a numeric value, such as `.30` or `-.30`.

This is another example:

```
.beta.: s
y ~ m: l
```

In this example, all regression coefficients are small, while the path from m to y is large.

Multigroup Model:

This is an example of the string for a multigroup model:

```
y ~ m: l
m ~ x:
  - nil
  - s
y ~ x: nil
```

The format is similar to that for a single-group model. If a parameter has the same value for all groups, then the line can be specified as in the case of a single-group model: tag: value.

If a parameter has different values across groups, then it must be in this format:

- A line starts with the tag, followed by two or more lines. Each line starts with a hyphen `-` and the value for a group.

For example:

```
m ~ x:
  - nil
  - s
```

This denotes that the model has two groups. The values of the path from x to m for the two groups are 0 (nil) and small (s), respectively.

Another equivalent way to specify the values are using [], on the same line of a tag.

For example:

```
m ~ x: [nil, s]
```

The number of groups is inferred from the number of values for a parameter. Therefore, if a tag has more than one value, each tag must have the same number of value, or only one value.

The tag `.beta.` and `.cov.` can also be used for multigroup models.

Which Approach To Use:

Note that using named vectors or named lists is more reliable. However, using a multiline string is more user-friendly. If this method failed, please use named vectors or named list instead.

Technical Details:

The multiline string is parsed by `yaml::read_yaml()`. Therefore, the format requirement is actually that of YAML. Users knowledgeable of YAML can use other equivalent way to specify the string.

Set the Values for Effect Size Labels ('es1' and 'es2')

The vector `es1` is for correlations, regression coefficients, and indirect effect, and the vector `es2` is for standardized moderation effect, the coefficients of a product term. These labels are to be used in interpreting the specification in `pop_es`.

Set 'number_of_indicators' and 'reliability'

The arguments `number_of_indicators` and `reliability` are used to specify the number of indicators (e.g., items) for each factor, and the population reliability coefficient of each factor, if the variables in the model syntax are latent variables.

Single-Group Model:

If a variable in the model is to be replaced by indicators in the generated data, set `number_of_indicators` to a named numeric vector. The names are the variables of variables with indicators, as appeared in the model syntax. The value of each name is the number of indicators.

The argument `reliability` should then be set a named numeric vector (or list, see the section on multigroup models) to specify the population reliability coefficient ("omega") of each set of indicators. The population standardized factor loadings are then computed to ensure that the population reliability coefficient is of the target value.

These are examples for a single group model:

```
number of indicator = c(m = 3, x = 4, y = 5)
```

The numbers of indicators for m, x, and y are 3, 4, and 5, respectively.

```
reliability = c(m = .90, x = .80, y = .70)
```

The population reliability coefficients of *m*, *x*, and *y* are .90, .80, and .70, respectively.

Multigroup Models:

Multigroup models are supported. The number of groups is inferred from `pop_es` (see the help page of `ptable_pop()`), or directly from `ptable`.

For a multigroup model, the number of indicators for each variable must be the same across groups.

However, the population reliability coefficients can be different across groups. For a multigroup model of *k* groups, with one or more population reliability coefficients differ across groups, the argument `reliability` should be set to a named list. The names are the variables to which the population reliability coefficients are to be set. The element for each name is either a single value for the common reliability coefficient, or a numeric vector of the reliability coefficient of each group.

This is an example of `reliability` for a model with 2 groups:

```
reliability = list(x = .80, m = c(.70, .80))
```

The reliability coefficients of *x* are .80 in all groups, while the reliability coefficients of *m* are .70 in one group and .80 in another.

Equal Numbers of Indicators and/or Reliability Coefficients:

If all variables in the model has the same number of indicators, `number_of_indicators` can be set to one single value.

Similarly, if all sets of indicators have the same population reliability in all groups, `reliability` can also be set to one single value.

Specify The Distributions of Exogenous Variables Or Error Terms Using 'x_fun'

By default, variables and error terms are generated from a multivariate normal distribution. If desired, users can supply the function used to generate an exogenous variable and error term by setting `x_fun` to a named list.

The names of the list are the variables for which a user function will be used to generate the data.

Each element of the list must also be a list. The first element of this list, can be unnamed, is the function to be used. If other arguments need to be supplied, they should be included as named elements of this list.

For example:

```
x_fun = list(x = list(power4mome::rexp_rs),
             w = list(power4mome::rbinary_rs,
                     p1 = .70))
```

The variables *x* and *w* will be generated by user-supplied functions.

For *x*, the function is `power4mome::rexp_rs`. No additional argument when calling this function.

For *w*, the function is `power4mome::rbinary_rx`. The argument `p1 = .70` will be passed to this function when generating the values of *w*.

If a variable is an endogenous variable (e.g., being predicted by another variable in a model), then `x_fun` is used to generate its *error term*. Its implied population distribution may still be different from that generated by `x_fun` because the distribution also depends on the distribution of other variables predicting it.

These are requirements for the user-functions:

- They must return a numeric vector.
- They must have an argument `n` for the number of values.
- The *population* mean and standard deviation of the generated values must be 0 and 1, respectively.

The package `power4mome` has helper functions for generating values from some common nonnormal distributions and then scaling them to have population mean and standard deviation equal to 0 and 1 (by default), respectively. These are some of them:

- `rbinary_rs()`.
- `rexp_rs()`.
- `rbeta_rs()`.
- `rlnorm_rs()`.
- `rpgnorm_rs()`.

To use `x_fun`, the variables must have zero covariances with other variables in the population. It is possible to generate nonnormal multivariate data but we believe this is rarely needed when estimating power *before* having the data.

Major Test-Related Arguments

The test function (`test_fun`):

The function set to `test_fun`, the *test function*, usually should work on the output of `lavaan::sem()`, `lmhelpers::many_lm()`, or `stats::lm()`, but can also be a function that works on the output of the function set to `fit_function` when calling `fit_model()` or `power4test()` (see `fit_model_args`).

The function has two default requirements.

First, it has an argument `fit`, to be set to the output of `lavaan::sem()` or another output stored in the element `extra$fit` of a replication in the `sim_all` object. (This requirement can be relaxed; see the section on `map_names`.)

That is, the function definition should be of this form: `FUN(fit, ...)`. This is the form of all `test_*` functions in `power4mome`.

If other arguments are to be passed to the test function, they can be set to `test_args` as a named list.

Second, the test function must return an output that (a) can be processed by the results function (see below), or (b) is of the required format for the output of a results function (see the next section). If it already returns an output of the required format, then there is no need to set the results function.

The results function (`results_fun`):

The test results will be extracted from the output of `test_fun` by the function set to `results_fun`, the *results function*. If the `test_fun` already returns an output of the expected format (see below),

then set `results_fun` to `NULL`, the default. The output of `test_fun` will be used for estimating power.

The function set to `results_fun` must accept the output of `test_fun`, as the first argument, and return a named list (which can be a data frame) or a named vector with some of the following elements:

- `est`: Optional. The estimate of a parameter, if applicable.
- `se`: Optional. The standard error of the estimate, if applicable.
- `cilo`: Optional. The lower limit of the confidence interval, if applicable.
- `cihi`: Optional. The upper limit of the confidence interval, if applicable.
- `sig`: Required. If 1, the test is significant. If 0, the test is not significant. If the test cannot be done for any reason, it should be `NA`.

The results can then be used to estimate the power or Type I error of the test.

For example, if the null hypothesis is false, then the proportion of significant, that is, the mean of the values of `sig` across replications, is the power.

Built-in test functions:

The package `power4mome` has some ready-to-use test functions:

- `test_indirect_effect()`
- `test_cond_indirect()`
- `test_cond_indirect_effects()`
- `test_moderation()`
- `test_index_of_mome()`
- `test_parameters()`

Please refer to their help pages for examples.

The argument `map_names`:

This argument is for developers using a test function that has a different name for the argument of the fit object (`"fit"`, the default).

If `test_fun` is set to a function that works on an output of, say, `lavaan::sem()` but the argument name for the output is not `fit`, the mapping can be changed by `map_names`.

For example, `lavaan::parameterEstimates()` receives an output of `lavaan::sem()` and reports the test results of model parameters. However, the argument name for the lavaan output is `object`. To instruct `do_test()` to do the test correctly when setting `test_fun` to `lavaan::parameterEstimates`, add `map_names = c(object = "fit")`. The element `fit` in a replication will then set to the argument object of `lavaan::parameterEstimates()`.

Examples

```
# Specify the model

model_simple_med <-
"
m ~ x
y ~ m + x
"
```

```
# Specify the population values

model_simple_med_es <-
"
m ~ x: m
y ~ m: l
y ~ x: n
"

# Set nrep to a large number in real analysis, such as 400
# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

out <- power4test(nrep = 10,
                  model = model_simple_med,
                  pop_es = model_simple_med_es,
                  n = 100,
                  test_fun = test_parameters,
                  test_args = list(pars = "m~x"),
                  iseed = 1234,
                  parallel = FALSE,
                  progress = TRUE)

print(out,
      test_long = TRUE)

# Change the sample size

out1 <- power4test(out,
                   n = 200,
                   iseed = 1234,
                   parallel = FALSE,
                   progress = TRUE)

print(out1,
      test_long = TRUE)

# Add one more test

out2 <- power4test(out,
                   test_fun = test_parameters,
                   test_args = list(pars = "y~x"),
                   parallel = FALSE,
                   progress = TRUE)

print(out2,
      test_long = TRUE)
```

Description

Estimate power for a set of effect sizes (population values of a model parameter).

Usage

```
power4test_by_es(
  object,
  pop_es_name = NULL,
  pop_es_values = NULL,
  progress = TRUE,
  ...,
  by_seed = NULL,
  by_nrep = NULL,
  save_sim_all = TRUE
)

## S3 method for class 'power4test_by_es'
c(..., sort = TRUE, skip_checking_models = FALSE)

as.power4test_by_es(original_object, pop_es_name)

## S3 method for class 'power4test_by_es'
print(x, print_all = FALSE, digits = 3, ...)
```

Arguments

object	A <code>power4test</code> object, or a <code>power4test_by_es</code> object. If it is a <code>power4test_by_es</code> object, the first element, which is a <code>power4test</code> object, will be used as the value of this argument.
pop_es_name	The name of the parameter. See the help page of <code>ptable_pop()</code> on the names for the argument <code>pop_es</code> .
pop_es_values	A numeric vector of the population values of the parameter specified in <code>pop_es_names</code> .
progress	Logical. Whether progress of the simulation will be displayed.
...	For <code>power4test_by_es()</code> , they are arguments to be passed to <code>power4test()</code> . For <code>c.power4test_by_es()</code> , they are <code>power4test_by_es()</code> outputs to be combined together. For the <code>print</code> method of the output of <code>power4test_by_es()</code> , they are arguments to be passed to the <code>print</code> method of the output of <code>power4test()</code> (<code>print.power4test()</code>).
by_seed	If set to a number, it will be used to generate the seeds for each call to <code>power4test()</code> . If <code>NULL</code> , the default, then seeds will still be randomly generated but the results cannot be easily reproduced.
by_nrep	If set to a number, it will be used to generate the number of replications (<code>nrep</code>) for each call to <code>power4test()</code> . If set to a numeric vector of the same length as <code>pop_es_values</code> , then these are the <code>nrep</code> values for each of the calls, allowing for different numbers of replications for the population values. If <code>NULL</code> , the default, then the original <code>nrep</code> will be used. This argument is used by <code>x_from_power()</code> for efficiency, and is rarely used when calling this function directly.

save_sim_all	If FALSE, the dataset in the power4test objects are not saved, to reduce the size of the output. Default is TRUE.
sort	When combining the objects, whether they will be sorted by population values. Default is TRUE.
skip_checking_models	Whether the check of the data generation model will be checked. Default is TRUE. Should be set to FALSE only when users are certain they are based on the same model, or when the model is not saved (e.g., save_sim_all set to FALSE when the objects were generated). This argument is used by x_from_power() for efficiency, and is rarely used when calling the c method directly.
original_object	The object to be converted to a power4test_by_es object.
x	The object to be printed.
print_all	If TRUE, all elements in x, that is, the results of all sample sizes examined, will be printed. If FALSE, then only those of the first value of the parameter will be printed.
digits	The numbers of digits displayed after the decimal.

Details

The function [power4test_by_es\(\)](#) regenerates datasets for a set of effect sizes (population values of a model parameter) and does the stored tests in each of them.

Optionally, it can also be run on a object with no stored tests. In this case, additional arguments must be set to instruct [power4test\(\)](#) on the tests to be conducted.

It is usually used to examine the power over a sets of effect sizes (population values).

The c method of power4test_by_es objects is used to combine tests from different runs of [power4test_by_es\(\)](#).

The function [as.power4test_by_es\(\)](#) is used to convert a power4test object to a power4test_by_es object, if it is not already one. Useful when concatenating power4test objects with power4test_by_es objects.

Value

The function [power4test_by_es\(\)](#) returns a power4test_by_es object, which is a list of power4test objects, one for each population value of the parameter.

The method [c.power4test_by_es\(\)](#) returns a power4test_by_es object with all the elements (tests for different values of pop_es_values) combined.

The function [as.power4test_by_es\(\)](#) returns a power4test_by_es object converted from the input object.

The print-method of power4test_by_es objects returns the object invisibly. It is called for its side-effect.

See Also

[power4test\(\)](#)

Examples

```

# Specify the model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the population values

model_simple_med_es <-
"
m ~ x: m
y ~ m: l
y ~ x: n
"

sim_only <- power4test(nrep = 2,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 100,
                      R = 40,
                      ci_type = "boot",
                      fit_model_args = list(fit_function = "lm"),
                      do_the_test = FALSE,
                      iseed = 1234)

test_out <- power4test(object = sim_only,
                      test_fun = test_indirect_effect,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       boot_ci = TRUE,
                                       mc_ci = FALSE))

out <- power4test_by_es(test_out,
                       pop_es_name = "y ~ m",
                       pop_es_values = c(.10, .20))

out_reject <- rejection_rates(out)
out_reject

```

power4test_by_n

Power By Sample Sizes

Description

Estimate power for a set of sample sizes.

Usage

```

power4test_by_n(
  object,
  n = NULL,
  progress = TRUE,
  ...,
  by_seed = NULL,
  by_nrep = NULL,
  save_sim_all = TRUE
)

## S3 method for class 'power4test_by_n'
c(..., sort = TRUE, skip_checking_models = FALSE)

as.power4test_by_n(original_object)

## S3 method for class 'power4test_by_n'
print(x, print_all = FALSE, ...)

```

Arguments

object	A <code>power4test</code> object, or a <code>power4test_by_n</code> object. If it is a <code>power4test_by_n</code> object, the first element, which is a <code>power4test</code> object, will be used as the value of this argument.
n	A numeric vector of sample sizes for which the simulation will be conducted.
progress	Logical. Whether progress of the simulation will be displayed.
...	For <code>power4test_by_n()</code> , they are arguments to be passed to <code>power4test()</code> . For <code>c.power4test_by_n()</code> , they are <code>power4test_by_n()</code> outputs to be combined together. For the print method of the output of <code>power4test_by_n()</code> , they are arguments to be passed to the print method of the output of <code>power4test()</code> (<code>print.power4test()</code>).
by_seed	If set to a number, it will be used to generate the seeds for each call to <code>power4test()</code> . If NULL, the default, then seeds will still be randomly generated but the results cannot be easily reproduced.
by_nrep	If set to a number, it will be used to generate the number of replications (<code>nrep</code>) for each call to <code>power4test()</code> . If set to a numeric vector of the same length as <code>n</code> , then these are the <code>nrep</code> values for each of the calls, allowing for different numbers of replications for the sample sizes. If NULL, the default, then the original <code>nrep</code> will be used. This argument is used by <code>x_from_power()</code> for efficiency, and is rarely used when calling this function directly.
save_sim_all	If FALSE, the dataset in the <code>power4test</code> objects are not saved, to reduce the size of the output. Default is TRUE.
sort	When combining the objects, whether they will be sorted by sample sizes. Default is TRUE.
skip_checking_models	Whether the check of the data generation model will be checked. Default is TRUE. Should be set to FALSE only when users are certain they are based

on the same model, or when the model is not saved (e.g., `save_sim_all` set to `FALSE` when the objects were generated). This argument is used by `x_from_power()` for efficiency, and is rarely used when calling the `c` method directly.

<code>original_object</code>	The object to be converted to a <code>power4test_by_n</code> object.
<code>x</code>	The object to be printed.
<code>print_all</code>	If <code>TRUE</code> , all elements in <code>x</code> , that is, the results of all sample sizes examined, will be printed. If <code>FALSE</code> , then only those of the first sample size will be printed.

Details

The function `power4test_by_n()` regenerates datasets for a set of sample sizes and does the stored tests in each of them.

Optionally, it can also be run on a object with no stored tests. In this case, additional arguments must be set to instruct `power4test()` on the tests to be conducted.

It is usually used to examine the power over a set of sample sizes.

The `c` method of `power4test_by_n` objects is used to combine tests from different runs of `power4test_by_n()`.

The function `as.power4test_by_n()` is used to convert a `power4test` object to a `power4test_by_n` object, if it is not already one. Useful when concatenating `power4test` objects with `power4test_by_n` objects.

Value

The function `power4test_by_n()` returns a `power4test_by_n` object, which is a list of `power4test` objects, one for each sample size.

The method `c.power4test_by_n()` returns a `power4test_by_n` object with all the elements (tests for different sample sizes) combined.

The function `as.power4test_by_n()` returns a `power4test_by_n` object converted from the input object.

The `print`-method of `power4test_by_n` objects returns the object invisibly. It is called for its side-effect.

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the population values
```



```

model_simple_med_es <-
"
m ~ x: m
y ~ m: l
y ~ x: n
"

sim_only <- power4test(nrep = 2,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 100,
                      R = 40,
                      ci_type = "boot",
                      fit_model_args = list(fit_function = "lm"),
                      do_the_test = FALSE,
                      iseed = 1234)

test_out <- power4test(object = sim_only,
                      test_fun = test_indirect_effect,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       boot_ci = TRUE,
                                       mc_ci = FALSE))

out <- power4test_by_n(test_out,
                      n = c(100, 110, 120))
out_reject <- rejection_rates(out)
out_reject

```

power_curve

Power Curve

Description

Estimate the relation between power and a characteristic, such as sample size or population effect size (population value of a model parameter).

Usage

```

power_curve(
  object,
  formula = NULL,
  start = NULL,
  lower_bound = NULL,
  upper_bound = NULL,
  nls_args = list(),
  nls_control = list(),

```

```

    verbose = FALSE,
    models = c("nls", "logistic", "lm")
  )

  ## S3 method for class 'power_curve'
  print(x, data_used = FALSE, digits = 3, right = FALSE, row.names = FALSE, ...)

```

Arguments

object	An object of the class <code>power4test_by_n</code> or <code>power4test_by_es</code> , which is the output of <code>power4test_by_n()</code> or <code>power4test_by_es()</code> .
formula	A formula of the model for <code>stats::nls()</code> . It can also be a list of formulas, and the models will be fitted successively by <code>stats::nls()</code> , with the first model fitted successfully adopted. The response variable in the formula must be named <code>reject</code> , and the predictor named <code>x</code> . Whether <code>x</code> represents <code>n</code> or <code>es</code> depends on the class of object. If <code>NULL</code> , the default, it will be determined internally based on the type of object.
start	Either a named vector of the start value(s) of parameter(s) in <code>formula</code> , or a list of named vectors of the starting value(s) of the list of <code>formula(s)</code> . If <code>NULL</code> , the default, they will be determined internally.
lower_bound	Either a named vector of the lower bound(s) of parameter(s) in <code>formula</code> , or a list of named vectors of the lower bound(s) for the list of <code>formula(s)</code> . They will be passed to <code>lower</code> of <code>stats::nls()</code> . If <code>NULL</code> , the default, it will be determined internally based on the type of object.
upper_bound	Either a named vector of the upper bound(s) of parameter(s) in <code>formula</code> , or a list of named vectors of the upper bound(s) for the list of <code>formula(s)</code> . They will be passed to <code>upper</code> of <code>stats::nls()</code> . If <code>NULL</code> , the default, it will be determined internally based on the type of object.
nls_args	A named list of arguments to be used when calling <code>stats::nls()</code> . Used to override internal default, such as the algorithm (default is "port"). Use this argument with cautions.
nls_control	A named list of arguments to be passed the <code>control</code> argument of <code>stats::nls()</code> . The values will override internal default values, and also override <code>nls_args</code> . Use this argument with cautions.
verbose	Logical. Whether messages will be printed when trying different models.
models	Models to try. Support "nls" (fitted by <code>nls()</code>), "logistic" (fitted by <code>glm()</code>), and "lm" (fitted by <code>lm()</code>). By default, all three models will be attempted, in this order.
x	A <code>power_curve</code> object.
data_used	Logical. Whether the rejection rates data frame used to fit the model is printed.
digits, right, row.names	Arguments of the same names used by the <code>print</code> method of a <code>data.frame</code> object. Used when <code>data_used</code> is <code>TRUE</code> and the rejection rates data frame is printed.
...	For the <code>print</code> method of <code>power_curve</code> objects, they are optional arguments to be passed to <code>print.data.frame()</code> when printing the rejection rates data frame.

Details

The function `power_curve()` retrieves the information from the output of `power4test_by_n()` or `power4test_by_es()`, and estimate the power curve: the relation between the characteristic varied, sample size for `power4test_by_n()` and the population effect size for `power4test_by_es()`, and the rejection rate of the test conducted by `power4test_by_n()` or `power4test_by_es()`. This rejection rate is the power when the null hypothesis is false (e.g., the population value of the effect size being tested is nonzero).

The model fitted is *not* intended to be a precise model for the relation across a wide range. It is only a crude estimate based on the limited number of values of the characteristic (e.g., sample size) examined, which can be as small as four or even smaller. The model is intended to be used for only for the range covered, and for estimating the probable sample size or effect size with a desirable level of power. This value should then be studied by higher precision through simulation using functions such as `power4test()`.

These are the models to be tried, in the following order:

- One or nonlinear models, to be fitted by `stats::nls()`. If several models are specified, all will be fitted and the one with the smallest deviance will be used.
- If all the nonlinear models failed, for whatever reason, a logistic regression will be fitted by `stats::glm()` to predict the binary significant test results.
- If the logistic model also failed, for whatever reason, a simple linear regression model will be fitted. Although the power curve is nonlinear across a wide range of, say, sample size, a linear model can still be a good enough approximation for a narrow range of the predictor.

The output can then be plotted to visualize the power curve, using the `plot` method (`plot.power_curve()`) for the output of `power_curve()`.

This function can be used directly, but is also used internally by functions such as `x_from_power()`.

Value

It returns a list which is a `power_curve` object, with the following elements:

- `fit`: The model fitted, which is the output of `stats::nls()`, `stats::glm()`, or `stats::lm()`.
- `reject_df`: The table of reject rates and other characteristics, which is generated by `rejection_rates()`.
- `predictor`: The predictor or the power curve, either "n" (sample size) or "es" (population effect size).
- `call`: The call used to run this function.

The `print` method of `power_curve` object returns `x` invisibly. Called for its side-effect.

See Also

`power4test_by_n()` and `power4test_by_es()` for the output supported by `power_curve()`, `plot.power_curve()` for the `plot` method and `predict.power_curve()` for the `predict` method of the output of `power_curve()`.

Examples

```

# Specify the population model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the effect sizes (population parameter values)

model_simple_med_es <-
"
y ~ m: l
m ~ x: m
y ~ x: s
"

# Simulate datasets to check the model
# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

sim_only <- power4test(nrep = 10,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 50,
                      fit_model_args = list(fit_function = "lm"),
                      do_the_test = FALSE,
                      iseed = 1234,
                      parallel = FALSE,
                      progress = FALSE)

# By n: Do a test for different sample sizes

out1 <- power4test_by_n(sim_only,
                       nrep = 10,
                       test_fun = test_parameters,
                       test_args = list(par = "y~x"),
                       n = c(25, 50, 100),
                       by_seed = 1234,
                       parallel = FALSE,
                       progress = FALSE)

pout1 <- power_curve(out1)
pout1
plot(pout1)

# By pop_es: Do a test for different population values of a model parameter

out2 <- power4test_by_es(sim_only,
                        nrep = 10,
                        test_fun = test_parameters,

```

```

      test_args = list(par = "y~x"),
      pop_es_name = "y ~ x",
      pop_es_values = c(0, .3, .5),
      by_seed = 1234,
      parallel = FALSE,
      progress = FALSE)

pout2 <- power_curve(out2)
pout2
plot(pout2)

```

predict.power_curve *Predict Method for a 'power_curve' Object*

Description

Compute the predicted values in a model fitted by `power_curve()`.

Usage

```
## S3 method for class 'power_curve'
predict(object, newdata, ...)
```

Arguments

<code>object</code>	A <code>power_curve</code> object.
<code>newdata</code>	A data frame with a column named <code>x</code> . It can also be a named list, with one element named <code>x</code> and is a vector of the values. If not supplied, values of <code>x</code> stored in <code>object</code> will be used.
<code>...</code>	Additional arguments. Passed to the corresponding <code>predict</code> method.

Details

The `predict` method of `power_curve` objects works in two modes.

If new data is not supplied (through `newdata`), it retrieves the stored results and calls the corresponding methods to compute the predicted values, which are the predicted rejection rates (power levels if the null hypothesis is false, e.g., the population effect size is equal to zero).

If new data is supplied, such as a named list with a vector of sample sizes, they will be used to compute the predicted rejection rates.

Value

It returns a numeric vector of the predicted rejection rates.

See Also

[power_curve\(\)](#).

Examples

```

# Specify the population model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the effect sizes (population parameter values)

model_simple_med_es <-
"
y ~ m: l
m ~ x: m
y ~ x: s
"

# Simulate datasets to check the model
# Set `parallel` to TRUE for faster, usually much faster, analysis
# Set `progress` to TRUE to display the progress of the analysis

sim_only <- power4test(nrep = 10,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 50,
                      fit_model_args = list(fit_function = "lm"),
                      do_the_test = FALSE,
                      iseed = 1234,
                      parallel = FALSE,
                      progress = FALSE)

# By n: Do a test for different sample sizes

out1 <- power4test_by_n(sim_only,
                       nrep = 10,
                       test_fun = test_parameters,
                       test_args = list(par = "y~x"),
                       n = c(25, 100, 200, 1000),
                       by_seed = 1234,
                       parallel = FALSE,
                       progress = FALSE)

pout1 <- power_curve(out1)
pout1
predict(pout1,
       newdata = list(x = c(150, 250, 500)))

# By pop_es: Do a test for different population values of a model parameter

out2 <- power4test_by_es(sim_only,
                        nrep = 10,

```

```

      test_fun = test_parameters,
      test_args = list(par = "y~x"),
      pop_es_name = "y ~ x",
      pop_es_values = seq(0, .7, .15),
      by_seed = 1234,
      parallel = FALSE,
      progress = FALSE)

pout2 <- power_curve(out2)
pout2
predict(pout2,
        newdata = list(x = c(.25, .55)))

```

ptable_pop

Generate the Population Model

Description

Generate the complete population model using the model syntax and user-specified effect sizes (population parameter values).

Usage

```

ptable_pop(
  model = NULL,
  pop_es = NULL,
  es1 = c(n = 0, nil = 0, s = 0.1, m = 0.3, l = 0.5, si = 0.141, mi = 0.361, li = 0.51),
  es2 = c(n = 0, nil = 0, s = 0.05, m = 0.1, l = 0.15),
  es_ind = c("si", "mi", "li"),
  standardized = TRUE,
  n_std = 1e+05,
  std_force_monte_carlo = FALSE,
  add_cov_for_moderation = TRUE
)

```

```

model_matrices_pop(x, ..., drop_list_single_group = TRUE)

```

Arguments

model	String. The model defined by lavaan model syntax. See 'Details'.
pop_es	It can be a data frame with these columns: lhs, op, rhs, and pop. The first three columns correspond to those in a lavaan parameter table. The column pop stores the population values. The column es stores the original labels, for reference. It can also be a named character vector (named list for multigroup models) or a multiline string, which are the preferred approaches. See the help page on how to specify this vector.

es1	Set the values for each label of the effect size (population value) for correlations and regression paths. Used only if pop_es is a named vector or a multiline string. See the help page on how to specify this argument.
es2	Set the values for each label of the effect size (population value) for product term. Used only if pop_es is a named vector or a multiline string. See the help page on how to specify this argument.
es_ind	The names of labels denoting the effect size of an indirect effect. They will be used to determine the population values of the component paths along an indirect path.
standardized	Logical. If TRUE, the default, variances and error variances are scaled to ensure the population variances of the endogenous variables are close to one, and hence the effect sizes (population values) are standardized effect sizes if the variances of the continuous exogenous variables are also equal to one.
n_std	The sample size used to determine the error variances by simulation when std_force_monte_carlo is TRUE.
std_force_monte_carlo	Logical. If FALSE, the default, standardization is done analytically if the model has no product terms, and by simulation if the model has product terms. That is, error variances required to ensure implied variances equal to one are determined by simulation. If TRUE, simulation will be used whether the model has product terms or not. Always fall back to simulation if analytical standardization failed.
add_cov_for_moderation	Logical. If TRUE, the default, for a model in which one or product terms for moderation involve one or more mediator, covariances between their error terms and the product terms will be added automatically. If these covariances are not added, the model may not be invariant to linear transformation of some variables in the model.
x	It can be a 'lavaan' model syntax, to be passed to ptable_pop() , or a parameter table with the column start set to the population values, such as the output of ptable_pop() .
...	If x is a model syntax, these are arguments to be passed to ptable_pop() .
drop_list_single_group	If TRUE and the number of groups is equal to one, the output will be a list of matrices of one group only. Default if TRUE.

Details

The function [ptable_pop\(\)](#) generates a lavaan parameter table that can be used to generate data based on the population values of model parameters.

Value

The function [ptable_pop\(\)](#) returns a lavaan parameter table of the model, with the column start set to the population values.

The function [model_matrices_pop\(\)](#) returns a lavaan LISREL-style model matrices (like the output of [lavaan::lavInspect\(\)](#) with what set to "free"), with matrix elements set to the population

values. If x is the model syntax, it will be stored in the attributes `model`. If the model is a multigroup model with k groups (k greater than 1), then it returns a list of k lists of lavaan LISREL-style model matrices unless `drop_list_single_group` is TRUE.

The role of `ptable_pop()`

The function `ptable_pop()` is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to develop other functions for power analysis, or to build their own workflows to do the power analysis.

Specify the Population Model by 'model'

Single-Group Model:

For a single-group model, `model` should be a lavaan model syntax string of the *form* of the model. The population values of the model parameters are to be determined by `pop_es`.

If the model has latent factors, the syntax in `model` should specify only the *structural model* for the *latent factors*. There is no need to specify the measurement part. Other functions will generate the measurement part on top of this model.

For example, this is a simple mediation model:

```
"m ~ x
y ~ m + x"
```

Whether m , x , and y denote observed variables or latent factors are determined by other functions, such as `power4test()`.

Multigroup Model:

Because the model is the population model, equality constraints are irrelevant and the model syntax specifies only the *form* of the model. Therefore, `model` is specified as in the case of single group models.

Specify 'pop_es' Using Named Vectors

The argument `pop_es` is for specifying the population values of model parameters. This section describes how to do this using named vectors.

Single-Group Model:

If `pop_es` is specified by a named vector, it must follow the convention below.

- The names of the vectors are lavaan names for the selected parameters. For example, $m \sim x$ denotes the path from x to m .
- Alternatively, the names can be either `".beta."` or `".cov."`. Use `".beta."` to set the default values for all regression coefficients. Use `".cov."` to set the default values for all correlations of exogenous variables (e.g., predictors).
- The names can also be of this form: `".ind.<path>"`, whether `<path>` denote path in the model. For example, `".ind.(x->m->y)"` denotes the path from x through m to y . Alternatively, the lavaan symbol \sim can also be used: `".ind.(y~m~x)"`. This form is used to set the indirect effect (standardized, by default) along this path. The value for this name will override other settings.

- If using lavaan names, can specify more than one parameter using +. For example, $y \sim m + x$ denotes the two paths from m and x to y .
- The value of each element can be the label for the effect size: n for nil, s for small, m for medium, and l for large. The value for each label is determined by `es1` and `es2`. See the section on specifying these two arguments.
- The value of `pop_es` can also be set to a value, but it must be quoted as a string, such as $"y \sim x" = ".31"$.

This is an example:

```
c(".beta." = "s",
  "m1 ~ x" = "-m",
  "m2 ~ m1" = "l",
  "y ~ x:w" = "s")
```

In this example,

- All regression coefficients are set to small (s) by default, unless specified otherwise.
- The path from x to $m1$ is set to medium and negative ($-m$).
- The path from $m1$ to $m2$ is set to large (l).
- The coefficient of the product term $x:w$ when predicting y is set to small (s).

Indirect Effect:

When setting an indirect effect to a symbol (default: $"si"$, $"mi"$, $"li"$, with $"i"$ added to differentiate them from the labels for a direct path), the corresponding value is used to determine the population values of *all* component paths along the pathway. All the values are assumed to be equal. Therefore, $".ind.(x \rightarrow m \rightarrow y) = ".20"$ is equivalent to setting $m \sim x$ and $y \sim m$ to the square root of $.20$, such that the corresponding indirect effect is equal to the designated value.

This behavior, though restricted, is for quick manipulation of the indirect effect. If different values along a pathway, set the value for each path directly.

Only nonnegative value is supported. Therefore, $".ind.(x \rightarrow m \rightarrow y) = "-si"$ and $".ind.(x \rightarrow m \rightarrow y) = "-.20"$ will throw an error.

Multigroup Model:

The argument `pop_es` also supports multigroup models.

For `pop_es`, instead of named vectors, named *list* of named vectors should be used.

- The names are the parameters, or keywords such as `.beta.` and `.cov.`, like specifying the population values for a single group model.
- The elements are character vectors. If it has only one element (e.g., a single string), then it is the the population value for all groups. If it has more than one element (e.g., a vector of three strings), then they are the population values of the groups. For a model of k groups, each vector must have either k elements or one element.

This is an example:

```
list("m ~ x" = "m",
     "y ~ m" = c("s", "m", "l"))
```

In this model, the population value of the path $m \sim x$ is medium (m) for all groups, while the population values for the path $y \sim m$ are small (s), medium (m), and large (l), respectively.

Specify 'pop_es' Using a Multiline String

When setting the argument `pop_es`, instead of using a named vector or named list for `pop_es`, the population values of model parameters can also be specified using a multiline string, as illustrated below, to be parsed by `pop_es_yaml()`.

Single-Group Model:

This is an example of the multiline string for a single-group model:

```
y ~ m: l
m ~ x: m
y ~ x: nil
```

The string must follow this format:

- Each line starts with tag:
 - tag can be the name of a parameter, in lavaan model syntax format.
 - * For example, `m ~ x` denotes the path from `x` to `m`.
 - A tag in lavaan model syntax can specify more than one parameter using `+`.
 - * For example, `y ~ m + x` denotes the two paths from `m` and `x` to `y`.
 - Alternatively, the tag can be either `.beta.` or `.cov.`.
 - * Use `.beta.` to set the default values for all regression coefficients.
 - * Use `.cov.` to set the default values for all correlations of exogenous variables (e.g., predictors).
- After each tag is the value of the population value:
 - `-nil` for nil (zero),
 - `s` for small,
 - `m` for medium, and
 - `l` for large.
 - `si`, `mi`, and `li` for small, medium, and large a standardized indirect effect, respectively.

Note: `n` *cannot* be used in this mode.

The value for each label is determined by `es1` and `es2` as described in `ptable_pop()`.

- The value can also be set to a numeric value, such as `.30` or `-.30`.

This is another example:

```
.beta.: s
y ~ m: l
```

In this example, all regression coefficients are small, while the path from `m` to `y` is large.

Multigroup Model:

This is an example of the string for a multigroup model:

```
y ~ m: l
m ~ x:
  - nil
  - s
y ~ x: nil
```

The format is similar to that for a single-group model. If a parameter has the same value for all groups, then the line can be specified as in the case of a single-group model: `tag: value`.

If a parameter has different values across groups, then it must be in this format:

- A line starts with the tag, followed by two or more lines. Each line starts with a hyphen `-` and the value for a group.

For example:

```
m ~ x:
- nil
- s
```

This denotes that the model has two groups. The values of the path from `x` to `m` for the two groups are 0 (`nil`) and small (`s`), respectively.

Another equivalent way to specify the values are using `[],` on the same line of a tag.

For example:

```
m ~ x: [nil, s]
```

The number of groups is inferred from the number of values for a parameter. Therefore, if a tag has more than one value, each tag must have the same number of values, or only one value.

The tag `.beta.` and `.cov.` can also be used for multigroup models.

Which Approach To Use:

Note that using named vectors or named lists is more reliable. However, using a multiline string is more user-friendly. If this method failed, please use named vectors or named list instead.

Technical Details:

The multiline string is parsed by `yaml::read_yaml()`. Therefore, the format requirement is actually that of YAML. Users knowledgeable of YAML can use other equivalent way to specify the string.

Set the Values for Effect Size Labels ('es1' and 'es2')

The vector `es1` is for correlations, regression coefficients, and indirect effect, and the vector `es2` is for standardized moderation effect, the coefficients of a product term. These labels are to be used in interpreting the specification in `pop_es`.

The role of `model_matrices_pop()`

The function `model_matrices_pop()` generates models matrices with population values, used by `ptable_pop()`. Users usually do not call this function directly, though developers can use this build their own workflows to generate the data.

See Also

`power4test()`, and `pop_es_yaml()` on an alternative way to specify population values.

Examples

```

# Specify the model

model1 <-
"
m1 ~ x + c1
m2 ~ m1 + x2 + c1
y ~ m2 + m1 + x + w + x:w + c1
"

# Specify the population values

model1_es <- c("m1 ~ x" = "-m",
              "m2 ~ m1" = "s",
              "y ~ m2" = "1",
              "y ~ x" = "m",
              "y ~ w" = "s",
              "y ~ x:w" = "s",
              "x ~~ w" = "s")

ptable_final1 <- ptable_pop(model1,
                           pop_es = model1_es)

ptable_final1

# Use a multiline string, illustrated by a simpler model

model2 <-
"
m ~ x
y ~ m + x
"

model2_es_a <- c("m ~ x" = "s",
                "y ~ m" = "m",
                "y ~ x" = "nil")

model2_es_b <-
"
m ~ x: s
y ~ m: m
y ~ x: nil
"

ptable_model2_a <- ptable_pop(model2,
                              pop_es = model2_es_a)
ptable_model2_b <- ptable_pop(model2,
                              pop_es = model2_es_b)

ptable_model2_a
ptable_model2_b

identical(ptable_model2_a,

```

```
        ptable_model2_b)

# model_matrices_pop

model_matrices_pop(ptable_final1)

model_matrices_pop(model1,
                    pop_es = model1_es)
```

rbeta_rs

Random Variable From a Beta Distribution

Description

Generate random numbers from a beta distribution, rescaled to have user-specified population mean and standard deviation.

Usage

```
rbeta_rs(n = 10, shape1 = 0.5, shape2 = 0.5, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
shape1	shape1 for <code>stats::rbeta()</code> .
shape2	shape2 for <code>stats::rbeta()</code> .
pmean	Population mean.
psd	Population standard deviation.

Details

First, specify the two parameters, shape1 and shape2, and the desired population mean and standard deviation. The random numbers, drawn from a beta distribution by `stats::rbeta()` will then be rescaled with the desired population mean and standard deviation.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rbeta_rs(n = 5000,
              shape1 = .5,
              shape2 = .5,
              pmean = 3,
              psd = 1)
```

```
mean(x)
sd(x)
hist(x)
```

rbeta_rs2

Random Variable From a Beta Distribution (User Range)

Description

Generate random numbers from a beta distribution, rescaled to have user-specified population mean and standard deviation, and within a specific range.

Usage

```
rbeta_rs2(n = 10, bmean, bsd, blow = 0, bhigh = 1)
```

Arguments

n	The number of random numbers to generate.
bmean	The population mean.
bsd	The population standard deviation. If bsd is zero or negative, all random numbers will be equal to bmean.
blow	The lower bound of the target range.
bhigh	The upper bound of the target range.

Details

First, specify the two parameters, shape1 and shape2, and the desired population mean and standard deviation. The random numbers, drawn from a beta distribution by `stats::rbeta()` will then be rescaled to the desired population range.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rbeta_rs2(n = 5000,
              bmean = .80,
              bsd = .10,
              blow = .00,
              bhigh = .95)

mean(x)
sd(x)
hist(x)
y <- rbeta_rs2(n = 5000,
```

```
          bmean = 4,  
          bsd = 3,  
          blow = -10,  
          bhigh = 10)  
mean(y)  
sd(y)  
hist(y)
```

rbinary_rs

Random Binary Variable

Description

Generate random numbers from a distribution of 0 or 1, rescaled to have user-specified population mean and standard deviation.

Usage

```
rbinary_rs(n = 10, p1 = 0.5, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
p1	The probability of being 1, before rescaling.
pmean	Population mean.
psd	Population standard deviation.

Details

First, specify probability of 1 ($p1$), and the desired population mean and standard deviation. The random numbers, drawn from a distribution of 0 ($1 - p1$ probability) and 1 ($p1$ probability), will then be rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)  
x <- rbinary_rs(n = 5000,  
               p1 = .5,  
               pmean = 3,  
               psd = 1)  
mean(x)  
sd(x)  
hist(x)
```

rejection_rates	<i>Rejection Rates</i>
-----------------	------------------------

Description

Get all rejection rates of all tests stored in a power4test object or other supported objects.

Usage

```
rejection_rates(object, ...)  
  
## Default S3 method:  
rejection_rates(object, ...)  
  
## S3 method for class 'power4test'  
rejection_rates(  
  object,  
  all_columns = FALSE,  
  ci = TRUE,  
  level = 0.95,  
  se = FALSE,  
  collapse = c("none", "all_sig", "at_least_one_sig", "at_least_k_sig"),  
  at_least_k = 1,  
  ...  
)  
  
## S3 method for class 'power4test_by_es'  
rejection_rates(  
  object,  
  all_columns = FALSE,  
  ci = TRUE,  
  level = 0.95,  
  se = FALSE,  
  ...  
)  
  
## S3 method for class 'power4test_by_n'  
rejection_rates(  
  object,  
  all_columns = FALSE,  
  ci = TRUE,  
  level = 0.95,  
  se = FALSE,  
  ...  
)  
  
## S3 method for class 'rejection_rates_df'
```

```
print(x, digits = 3, annotation = TRUE, abbreviate_col_names = TRUE, ...)
```

Arguments

object	The object from which the rejection rates are to be computed, such as a <code>power4test</code> object, a <code>power4test_by_n</code> object, or a <code>power4test_by_es</code> object.
...	Optional arguments. For the <code>print</code> method, these arguments will be passed to the <code>print</code> method of <code>data.frame</code> objects <code>print.data.frame()</code> . Not used by other methods.
all_columns	If <code>TRUE</code> , all columns stored by a test will be extracted. Default is <code>FALSE</code> and only essential columns related to power will be printed.
ci	If <code>TRUE</code> , confidence intervals for the rejection rates (column <code>reject</code> or <code>sig</code>) will be computed. Normal approximation is used in forming the confidence intervals.
level	The level of confidence for the confidence intervals, if <code>ci</code> is <code>TRUE</code> . Default is <code>.95</code> , denoting 95%.
se	If <code>TRUE</code> , standard errors for the rejection rates (column <code>reject</code> or <code>sig</code>) will be computed. Normal approximation is used to compute the standard errors.
collapse	Whether a single decision (significant vs. not significant) is made across all tests for a test that consists of several tests (e.g., the tests of several parameters). If <code>"none"</code> , tests will be summarized individually. If <code>"all_sig"</code> , then the set of tests is considered significant if all individual tests are significant. If <code>"at_least_one_sig"</code> , then the set of tests is considered significant if at least one of the tests is significant. If <code>"at_least_k_sig"</code> , then the set of tests is considered significant if at least <code>k</code> tests are significant, <code>k</code> set by the argument <code>at_least_k</code> .
at_least_k	Used by <code>collapse</code> , the number of tests required to be significant for the set of tests to be considered significant.
x	The <code>rejection_rates_df</code> object to be printed.
digits	The number of digits to be printed after the decimal.
annotation	Logical. Whether additional notes will be printed.
abbreviate_col_names	Logical. Whether some column names will be abbreviated.

Details

For a `power4test` object, `rejection_rates` loops over the tests stored in a `power4test` object and retrieves the rejection rate of each test.

The `rejection_rates` method for `power4test_by_es` objects is used to compute the rejection rates from a `power4test_by_es` object, with effect sizes added to the output.

The `rejection_rates` method for `power4test_by_n` objects is used to compute the rejection rates, with sample sizes added to the output.

Value

The `rejection_rates` method returns a `rejection_rates_df` object, with a `print` method.

If the input (object) is a `power4test` object, the `rejection_rates_df` object is a data-frame like object with the number of rows equal to the number of tests. Note that some tests, such as the test by `test_parameters()`, conduct one test for each parameter. Each such test is counted as one test.

The data frame has at least these columns:

- `test`: The name of the test.
- `label`: The label for each test, or "Test" if a test only does one test (e.g., `test_indirect_effect()`).
- `pvalid`: The proportion of valid tests across all replications.
- `reject`: The rejection rate for each test. If the null hypothesis is false, then this is the power.

The `rejection_rates` method for `power4test_by_es` objects returns an object of the class `rejection_rates_df_by_es`, which is a subclass of `rejection_rates_df`. It is a data frame which is similar to the output of `rejection_rates()`, with two columns added for the effect size (`pop_es_name` and `pop_es_values`) for each test.

The `rejection_rates` method for `power4test_by_n` objects returns an object of the class `rejection_rates_df_by_n`, which is a subclass of `rejection_rates_df`. It is a data frame which is similar to the output of a `power4test` object, with a column `n` added for the sample size for each test.

The `print` method of a `rejection_rates_df` object returns the object invisibly. It is called for its side-effect.

See Also

`power4test()`, `power4test_by_n()`, and `power4test_by_es()`, which are supported by this method.

Examples

```
# Specify the population model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the effect sizes (population parameter values)

model_simple_med_es <-
"
y ~ m: l
m ~ x: m
y ~ x: n
"

# Generate some datasets to check the model

sim_only <- power4test(nrep = 4,
                      model = model_simple_med,
```

```

        pop_es = model_simple_med_es,
        n = 100,
        R = 50,
        ci_type = "boot",
        fit_model_args = list(fit_function = "lm"),
        do_the_test = FALSE,
        iseed = 1234)

# Do the test 'test_indirect_effect' on each datasets

test_out <- power4test(object = sim_only,
                      test_fun = test_indirect_effect,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       boot_ci = TRUE,
                                       mc_ci = FALSE))

# Do the test 'test_parameters' on each datasets
# and add the results to 'test_out'

test_out <- power4test(object = test_out,
                      test_fun = test_parameters)

# Compute and print the rejection rates for stored tests

rejection_rates(test_out)

# See the help pages of power4test_by_n() and power4test_by_es()
# for other examples.

```

rexp_rs

Random Variable From an Exponential Distribution

Description

Generate random numbers from an exponential distribution, rescaled to have user-specified population mean and standard deviation.

Usage

```
rexp_rs(n = 10, rate = 1, pmean = 0, psd = 1, rev = FALSE)
```

Arguments

n	The number of random numbers to generate.
rate	rate for <code>stats::rexp()</code> .
pmean	Population mean.

psd	Population standard deviation.
rev	If TRUE, the distribution is reversed to generate a negatively skewed distribution. Default is FALSE.

Details

First, specify the parameter, rate, and the desired population mean and standard deviation. The random numbers, drawn from an exponential distribution by `stats::rexp()`, will then be rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rexp_rs(n = 5000,
             rate = 4,
             pmean = 3,
             psd = 1)

mean(x)
sd(x)
hist(x)
```

rlnorm_rs

Random Variable From a Lognormal Distribution

Description

Generate random numbers from a lognormal distribution, rescaled to have user-specified population mean and standard deviation.

Usage

```
rlnorm_rs(n = 10, mui = 0, sigma = 1, rev = FALSE, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
mui	The parameter mui to be used by <code>stats::rlnorm()</code> .
sigma	The parameter sigma to be used by <code>stats::rlnorm()</code> .
rev	If TRUE, the distribution is reversed to generate a negatively skewed distribution. Default is FALSE.
pmean	Population mean.
psd	Population standard deviation.

Details

First, specify the parameter, μ and σ , and the desired population mean and standard deviation. The random numbers, drawn from a lognormal distribution by `stats::rlnorm()`, will then be rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rlnorm_rs(n = 5000,
              mui = 0,
              sigma = 1,
              pmean = 0,
              psd = 1)

mean(x)
sd(x)
hist(x)
```

rpgnorm_rs

Random Variable From a Generalized Normal Distribution

Description

Generate random numbers from generalized normal distribution, rescaled to have user-specified population mean and standard deviation.

Usage

```
rpgnorm_rs(n = 10, p = 2, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
p	The parameter of the distribution. Must be a positive non-zero number. Default is 2, resulting in a normal distribution. Higher than 2 results in negative excess kurtosis. Lower than 2 results in positive excess kurtosis.
pmean	Population mean.
psd	Population standard deviation.

Details

First, specify the parameter p and the desired population mean and standard deviation. The random numbers, drawn from a generalized normal distribution by `pgnorm::rpgnorm()`, will then be rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rpgnorm_rs(n = 5000,
               p = 2,
               pmean = 0,
               psd = 1)

mean(x)
sd(x)
hist(x)
x_kurt <- function(p) {gamma(5/p)*gamma(1/p)/(gamma(3/p)^2) - 3}

p <- 6
x <- rpgnorm_rs(n = 50000,
               p = p,
               pmean = 0,
               psd = 1)

mean(x)
sd(x)
x_kurt(p)
qqnorm(x); qqline(x)

p <- 1
x <- rpgnorm_rs(n = 50000,
               p = p,
               pmean = 0,
               psd = 1)

mean(x)
sd(x)
x_kurt(p)
qqnorm(x); qqline(x)
```

 rt_rs

Random Variable From a t Distribution

Description

Generate random numbers from a t distribution, rescaled to have user-specified population mean and standard deviation.

Usage

```
rt_rs(n = 10, df = 5, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
df	df for <code>stats::rt()</code> .
pmean	Population mean.
psd	Population standard deviation.

Details

First, specify the parameter df and the desired population mean and standard deviation. The random numbers, drawn from the generalized normal distribution by `stats::rt()`, will then be rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- rt_rs(n = 5000,
           df = 5,
           pmean = 3,
           psd = 1)

mean(x)
sd(x)
hist(x)
```

runif_rs

Random Variable From a Uniform Distribution

Description

Generate random numbers from a uniform distribution, with user-specified population mean and standard deviation.

Usage

```
runif_rs(n = 10, min = 0, max = 1, pmean = 0, psd = 1)
```

Arguments

n	The number of random numbers to generate.
min	min for runif.
max	max for runif.
pmean	Population mean.
psd	Population standard deviation.

Details

First, the user specifies the parameters, min and max, and the desired population mean and standard deviation. Then the random numbers will be generated and rescaled with the desired population mean and standard.

Value

A vector of the generated random numbers.

Examples

```
set.seed(90870962)
x <- runif_rs(n = 5000,
             min = 2,
             max = 4,
             pmean = 3,
             psd = 1)

mean(x)
sd(x)
hist(x)
```

sim_data

Simulate Datasets Based on a Model

Description

Get a model matrix and effect size specification and simulate a number of datasets, along with other information.

The function

Usage

```
sim_data(
  nrep = 10,
  ptable = NULL,
  model = NULL,
  pop_es = NULL,
  ...,
  n = 100,
  iseed = NULL,
  number_of_indicators = NULL,
  reliability = NULL,
  x_fun = list(),
  e_fun = list(),
  process_data = NULL,
  parallel = FALSE,
```

```

    progress = FALSE,
    ncores = max(1, parallel::detectCores(logical = FALSE) - 1)
  )

## S3 method for class 'sim_data'
print(
  x,
  digits = 3,
  digits_descriptive = 2,
  data_long = TRUE,
  fit_to_all_args = list(),
  est_type = "standardized",
  variances = NULL,
  pure_x = TRUE,
  pure_y = TRUE,
  ...
)

pool_sim_data(object, as_list = FALSE)

```

Arguments

nrep	The number of replications to generate the simulated datasets. Default is 10.
ptable	The output of <code>ptable_pop()</code> , which is a <code>ptable_pop</code> object, representing the population model. If <code>NULL</code> , the default, <code>ptable_pop()</code> will be called to generate the <code>ptable_pop</code> object, using arguments such as <code>model</code> and <code>pop_es</code> .
model	The lavaan model syntax of the population model. Ignored if <code>ptable</code> is specified. See <code>ptable_pop</code> on how to specify this argument.
pop_es	The character to specify population effect sizes. See <code>ptable_pop</code> on how to specify this argument. Ignored if <code>ptable</code> is specified.
...	For <code>sim_data</code> , parameters to be passed to <code>ptable_pop()</code> . For <code>print.sim_data()</code> , these arguments are ignored.
n	The sample size for each dataset. Default is 100.
iseed	The seed for the random number generator. Default is <code>NULL</code> and the seed is not changed.
number_of_indicators	A named vector to specify the number of indicators for each factors. See the help page on how to set this argument. Default is <code>NULL</code> and all variables in the model syntax are observed variables. See the help page on how to use this argument.
reliability	A named vector (for a single-group model) or a named list of named vectors (for a multigroup model) to set the reliability coefficient of each set of indicators. Default is <code>NULL</code> . See the help page on how to use this argument.
x_fun	The function(s) used to generate the exogenous variables or error terms. If not supplied, or set to <code>list()</code> , the default, the variables are generated from a multivariate normal distribution. See the help page on how to use this argument.

e_fun	The function(s) used to generate the error terms of indicators, if any. If not supplied, or set to <code>list()</code> , the default, the error terms of indicators are generated from a multivariate normal distribution. Specify in the same way as <code>x_fun</code> . Refer to the help page on <code>x_fun</code> on how to use this argument.
process_data	If not NULL, it must be a named list with these elements: <code>fun</code> (required), the function to further processing the simulated data, such as generating missing data using functions such as <code>mice::ampute()</code> ; <code>args</code> (optional), a named list of arguments to be passed to <code>fun</code> , except the one for the source data; <code>sim_data_name</code> (required) the name of the argument to receive the simulated data (e.g., <code>data</code> for <code>mice::ampute()</code>); <code>processed_data_name</code> (optional), the name of the data frame after being processed by <code>fun</code> , such as the data frame with missing data in the output of <code>fun</code> (e.g., <code>"amp"</code> for <code>mice::ampute()</code>), if omitted, the output of <code>fun</code> should be the data frame with missing data.
parallel	If TRUE, parallel processing will be used to simulate the datasets. Default is FALSE.
progress	If TRUE, the progress of data simulation will be displayed. Default is FALSE.
ncores	The number of CPU cores to use if parallel processing is used.
x	The <code>sim_data</code> object to be printed.
digits	The numbers of digits displayed after the decimal.
digits_descriptive	The number of digits displayed after the decimal for the descriptive statistics table.
data_long	If TRUE, detailed information will be printed.
fit_to_all_args	A named list of arguments to be passed to <code>lavaan::sem()</code> when the model is fitted to a sample combined from all samples stored.
est_type	The type of estimates to be printed. Can be a character vector of one to two elements. If only <code>"standardized"</code> , then the standardized estimates are printed. If only <code>"unstandardized"</code> , then the unstandardized estimates are printed. If a vector like <code>c("standardized", "unstandardized")</code> , then both unstandardized and standardized estimates are printed.
variances	Logical. Whether variances and error variances are printed. Default depends on <code>est_type</code> . If <code>"unstandardized"</code> is in <code>est_type</code> , then default is TRUE. If only <code>"standardized"</code> is in <code>est_type</code> , then default is FALSE.
pure_x, pure_y	When Logical. When printing indirect effects, whether only "pure" x-variables (variables not predicted by another other variables) and/or "pure" y-variables (variables that do not predict any other variables other than indicators) will be included in enumerating the paths.
object	Either a <code>sim_data</code> object or a <code>power4test</code> object. It extracts the simulated data and return them, combined to one single data frame or, if <code>as_list</code> is TRUE, as a list of data frames.
as_list	Logical. If TRUE, the simulated datasets is returned as one single data frame. If FALSE, they are returned as a list of data frames.

Details

The function `sim_data()` generates a list of datasets based on a population model.

Value

The function `sim_out()` returns a list of the class `sim_data`, with length `nrep`. Each element is a `sim_data_i` object, with the following major elements:

- `ptable`: A lavaan parameter table of the model, with population values set in the column `start`. (It is the output of the function `ptable_pop()`.)
- `mm_out`: The population model represented by model matrices as in lavaan. (It is the output of the function `model_matrices_pop()`.)
- `mm_lm_out`: A list of regression model formula, one for each endogenous variable. (It is the output of the internal function `mm_lm()`.)
- `mm_lm_dat_out`: A simulated dataset generated from the population model. (It is the output of the internal function `mm_lm_data()`.)
- `model_original`: The original model syntax (i.e., the argument `model`).
- `model_final`: A modified model syntax if the model is a latent variable model. Indicators are added to the syntax.
- `fit0`: The output of `lavaan::sem()` with `ptable` as the model and `do.fit` set to `FALSE`. Used for the easy retrieval of information about the model.

The print method of `sim_data` returns `x` invisibly. It is called for its side effect.

The function `pool_sim_data()` returns either one data frame or a list of data frames, depending on the argument `as_list`

The role of `sim_data()`

The function `sim_data()` is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to develop other functions for power analysis, or to build their own workflows to do the power analysis.

Workflow

The function `sim_data()` does two tasks:

- Determine the actual population model with population values based on:
 - A model syntax for the observed variables (for a path model) or the latent factors (for a latent variable model).
 - A textual specification of the effect sizes of parameters.
 - The number of indicators for each latent factor if the model is a latent variable model.
 - The reliability of each latent factor as measured by the indicators if the model is a latent factor model.
- Generate `nrep` simulated datasets from the population model.

The simulated datasets can then be used to fit a model, test parameters, and estimate power.

The output is usually used by `fit_model()` to fit a target model, by default the population model, to each of the dataset.

Set 'number_of_indicators' and 'reliability'

The arguments `number_of_indicators` and `reliability` are used to specify the number of indicators (e.g., items) for each factor, and the population reliability coefficient of each factor, if the variables in the model syntax are latent variables.

Single-Group Model:

If a variable in the model is to be replaced by indicators in the generated data, set `number_of_indicators` to a named numeric vector. The names are the variables of variables with indicators, as appeared in the `model` syntax. The value of each name is the number of indicators.

The argument `reliability` should then be set a named numeric vector (or list, see the section on multigroup models) to specify the population reliability coefficient ("omega") of each set of indicators. The population standardized factor loadings are then computed to ensure that the population reliability coefficient is of the target value.

These are examples for a single group model:

```
number_of_indicators = c(m = 3, x = 4, y = 5)
```

The numbers of indicators for `m`, `x`, and `y` are 3, 4, and 5, respectively.

```
reliability = c(m = .90, x = .80, y = .70)
```

The population reliability coefficients of `m`, `x`, and `y` are .90, .80, and .70, respectively.

Multigroup Models:

Multigroup models are supported. The number of groups is inferred from `pop_es` (see the help page of `ptable_pop()`), or directly from `ptable`.

For a multigroup model, the number of indicators for each variable must be the same across groups.

However, the population reliability coefficients can be different across groups. For a multigroup model of k groups, with one or more population reliability coefficients differ across groups, the argument `reliability` should be set to a named list. The names are the variables to which the population reliability coefficients are to be set. The element for each name is either a single value for the common reliability coefficient, or a numeric vector of the reliability coefficient of each group.

This is an example of `reliability` for a model with 2 groups:

```
reliability = list(x = .80, m = c(.70, .80))
```

The reliability coefficients of `x` are .80 in all groups, while the reliability coefficients of `m` are .70 in one group and .80 in another.

Equal Numbers of Indicators and/or Reliability Coefficients:

If all variables in the model has the same number of indicators, `number_of_indicators` can be set to one single value.

Similarly, if all sets of indicators have the same population reliability in all groups, `reliability` can also be set to one single value.

Specify The Distributions of Exogenous Variables Or Error Terms Using 'x_fun'

By default, variables and error terms are generated from a multivariate normal distribution. If desired, users can supply the function used to generate an exogenous variable and error term by setting `x_fun` to a named list.

The names of the list are the variables for which a user function will be used to generate the data.

Each element of the list must also be a list. The first element of this list, can be unnamed, is the function to be used. If other arguments need to be supplied, they should be included as named elements of this list.

For example:

```
x_fun = list(x = list(power4mome::rexp_rs),
            w = list(power4mome::rbinary_rs,
                    p1 = .70))
```

The variables `x` and `w` will be generated by user-supplied functions.

For `x`, the function is `power4mome::rexp_rs`. No additional argument when calling this function.

For `w`, the function is `power4mome::rbinary_rx`. The argument `p1 = .70` will be passed to this function when generating the values of `w`.

If a variable is an endogenous variable (e.g., being predicted by another variable in a model), then `x_fun` is used to generate its *error term*. Its implied population distribution may still be different from that generate by `x_fun` because the distribution also depends on the distribution of other variables predicting it.

These are requirements for the user-functions:

- They must return a numeric vector.
- They must have an argument `n` for the number of values.
- The *population* mean and standard deviation of the generated values must be 0 and 1, respectively.

The package `power4mome` has helper functions for generating values from some common nonnormal distributions and then scaling them to have population mean and standard deviation equal to 0 and 1 (by default), respectively. These are some of them:

- `rbinary_rs()`.
- `rexp_rs()`.
- `rbeta_rs()`.
- `rlnorm_rs()`.
- `rpgnorm_rs()`.

To use `x_fun`, the variables must have zero covariances with other variables in the population. It is possible to generate nonnormal multivariate data but we believe this is rarely needed when estimating power *before* having the data.

Specify the Population Model by 'model'

Single-Group Model:

For a single-group model, `model` should be a lavaan model syntax string of the *form* of the model. The population values of the model parameters are to be determined by `pop_es`.

If the model has latent factors, the syntax in `model` should specify only the *structural model* for the *latent factors*. There is no need to specify the measurement part. Other functions will generate the measurement part on top of this model.

For example, this is a simple mediation model:

```
"m ~ x
y ~ m + x"
```

Whether `m`, `x`, and `y` denote observed variables or latent factors are determined by other functions, such as `power4test()`.

Multigroup Model:

Because the model is the population model, equality constraints are irrelevant and the model syntax specifies only the *form* of the model. Therefore, `model` is specified as in the case of single group models.

Specify 'pop_es' Using Named Vectors

The argument `pop_es` is for specifying the population values of model parameters. This section describes how to do this using named vectors.

Single-Group Model:

If `pop_es` is specified by a named vector, it must follow the convention below.

- The names of the vectors are lavaan names for the selected parameters. For example, `m ~ x` denotes the path from `x` to `m`.
- Alternatively, the names can be either `".beta."` or `".cov."`. Use `".beta."` to set the default values for all regression coefficients. Use `".cov."` to set the default values for all correlations of exogenous variables (e.g., predictors).
- The names can also be of this form: `".ind.<path>"`, whether `<path>` denote path in the model. For example, `".ind.(x->m->y)"` denotes the path from `x` through `m` to `y`. Alternatively, the lavaan symbol `~` can also be used: `".ind.(y~m~x)"`. This form is used to set the indirect effect (standardized, by default) along this path. The value for this name will override other settings.
- If using lavaan names, can specify more than one parameter using `+`. For example, `y ~ m + x` denotes the two paths from `m` and `x` to `y`.
- The value of each element can be the label for the effect size: `n` for nil, `s` for small, `m` for medium, and `l` for large. The value for each label is determined by `es1` and `es2`. See the section on specifying these two arguments.
- The value of `pop_es` can also be set to a value, but it must be quoted as a string, such as `"y ~ x" = ".31"`.

This is an example:

```
c(".beta." = "s",
  "m1 ~ x" = "-m",
  "m2 ~ m1" = "1",
  "y ~ x:w" = "s")
```

In this example,

- All regression coefficients are set to small (s) by default, unless specified otherwise.
- The path from x to m1 is set to medium and negative (-m).
- The path from m1 to m2 is set to large (1).
- The coefficient of the product term x:w when predicting y is set to small (s).

Indirect Effect:

When setting an indirect effect to a symbol (default: "si", "mi", "li", with "i" added to differentiate them from the labels for a direct path), the corresponding value is used to determine the population values of *all* component paths along the pathway. All the values are assumed to be equal. Therefore, ".ind.(x->m->y)" = ".20" is equivalent to setting $m \sim x$ and $y \sim m$ to the square root of .20, such that the corresponding indirect effect is equal to the designated value.

This behavior, though restricted, is for quick manipulation of the indirect effect. If different values along a pathway, set the value for each path directly.

Only nonnegative value is supported. Therefore, ".ind.(x->m->y)" = "-si" and ".ind.(x->m->y)" = "-.20" will throw an error.

Multigroup Model:

The argument pop_es also supports multigroup models.

For pop_es, instead of named vectors, named *list* of named vectors should be used.

- The names are the parameters, or keywords such as .beta. and .cov., like specifying the population values for a single group model.
- The elements are character vectors. If it has only one element (e.g., a single string), then it is the the population value for all groups. If it has more than one element (e.g., a vector of three strings), then they are the population values of the groups. For a model of k groups, each vector must have either k elements or one element.

This is an example:

```
list("m ~ x" = "m",
     "y ~ m" = c("s", "m", "1"))
```

In this model, the population value of the path $m \sim x$ is medium (m) for all groups, while the population values for the path $y \sim m$ are small (s), medium (m), and large (1), respectively.

Specify 'pop_es' Using a Multiline String

When setting the argument pop_es, instead of using a named vector or named list for pop_es, the population values of model parameters can also be specified using a multiline string, as illustrated below, to be parsed by `pop_es_yaml()`.

Single-Group Model:

This is an example of the multiline string for a single-group model:


```

y ~ m: l
m ~ x: m
y ~ x: nil

```

The string must follow this format:

- Each line starts with tag:
 - tag can be the name of a parameter, in lavaan model syntax format.
 - * For example, $m \sim x$ denotes the path from x to m .
 - A tag in lavaan model syntax can specify more than one parameter using +.
 - * For example, $y \sim m + x$ denotes the two paths from m and x to y .
 - Alternatively, the tag can be either `.beta.` or `.cov.`
 - * Use `.beta.` to set the default values for all regression coefficients.
 - * Use `.cov.` to set the default values for all correlations of exogenous variables (e.g., predictors).
- After each tag is the value of the population value:
 - nil for nil (zero),
 - s for small,
 - m for medium, and
 - l for large.
 - si, mi, and li for small, medium, and large a standardized indirect effect, respectively.

Note: `n` *cannot* be used in this mode.

The value for each label is determined by `es1` and `es2` as described in `ptable_pop()`.

- The value can also be set to a numeric value, such as `.30` or `-.30`.

This is another example:

```

.beta.: s
y ~ m: l

```

In this example, all regression coefficients are small, while the path from m to y is large.

Multigroup Model:

This is an example of the string for a multigroup model:

```

y ~ m: l
m ~ x:
- nil
- s
y ~ x: nil

```

The format is similar to that for a single-group model. If a parameter has the same value for all groups, then the line can be specified as in the case of a single-group model: `tag: value`.

If a parameter has different values across groups, then it must be in this format:

- A line starts with the tag, followed by two or more lines. Each line starts with a hyphen – and the value for a group.

For example:

```
m ~ x:
- nil
- s
```

This denotes that the model has two groups. The values of the path from x to m for the two groups are 0 (`nil`) and small (`s`), respectively.

Another equivalent way to specify the values are using `[]`, on the same line of a tag.

For example:

```
m ~ x: [nil, s]
```

The number of groups is inferred from the number of values for a parameter. Therefore, if a tag has more than one value, each tag must have the same number of value, or only one value.

The tag `.beta.` and `.cov.` can also be used for multigroup models.

Which Approach To Use:

Note that using named vectors or named lists is more reliable. However, using a multiline string is more user-friendly. If this method failed, please use named vectors or named list instead.

Technical Details:

The multiline string is parsed by `yaml::read_yaml()`. Therefore, the format requirement is actually that of YAML. Users knowledgeable of YAML can use other equivalent way to specify the string.

Set the Values for Effect Size Labels ('es1' and 'es2')

The vector `es1` is for correlations, regression coefficients, and indirect effect, and the vector `es2` is for standardized moderation effect, the coefficients of a product term. These labels are to be used in interpreting the specification in `pop_es`.

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

mod <-
"m ~ x
 y ~ m + x"

# Specify the population values

es <-
"
y ~ m: m
m ~ x: m
y ~ x: n
"
```

```
# Generate the simulated datasets

data_all <- sim_data(nrep = 5,
                    model = mod,
                    pop_es = es,
                    n = 100,
                    iseed = 1234)

data_all
```

sim_out	<i>Create a 'sim_out' Object</i>
---------	----------------------------------

Description

Combine the outputs of `sim_data()`, `fit_model()`, and optionally `gen_mc()` and/or `gen_boot()` to one single object.

Usage

```
sim_out(data_all, ...)

## S3 method for class 'sim_out'
print(x, digits = 3, digits_descriptive = 2, fit_to_all_args = list(), ...)
```

Arguments

data_all	The output of <code>sim_data()</code> .
...	Named arguments of objects to be added to each replication under the element <code>extra</code> . For example, if set to <code>fit = fit_all</code> , where <code>fit_all</code> is the output of <code>fit_model()</code> , then <code>data_all[[1]]\$extra\$fit</code> will be set to the first output in <code>fit_all</code> .
x	The <code>sim_out</code> object to be printed.
digits	The numbers of digits displayed after the decimal.
digits_descriptive	The number of digits displayed after the decimal for the descriptive statistics table.
fit_to_all_args	A named list of arguments to be passed to <code>lavaan::sem()</code> when the model is fitted to a sample combined from

Details

It merges into one object the output of `sim_data()`, which is a list of `nrep` simulated datasets, `fit_model()`, which is a list of the `lavaan::sem()` output for the `nrep` datasets, and optionally the output of `gen_mc()` or `gen_boot()`, which is a list of the `R` sets of Monte Carlo or bootstrap estimates based on the results of `fit_model()`. The list has `nrep` elements, each element with the data, the model fit results, and optionally the Monte Carlo estimates matched.

This object can then be used for testing effects of interests, which are further processed to estimate the power of this test.

The function `sim_out()` is used by the all-in-one function `power4test()`. Users usually do not call this function directly, though developers can use this function to develop other functions for power analysis, or to build their own workflows to do the power analysis.

Value

The function `sim_out()` returns a `sim_out` object, which is a list of length equal to the length of `data_all`. Each element of the list is a `sim_data` object with the element `extra` added to it. Other named elements will be added under this name. For example, the output of `fit_model()` for this replication can be added to `fit`, under `extra`. See the description of the argument `...` for details.

The print method of `sim_out` returns `x` invisibly. Called for its side effect.

See Also

`power4test()`

Examples

```
# Specify the model

mod <-
"m ~ x
 y ~ m + x"

# Specify the population values

es <-
"
y ~ m: m
m ~ x: m
y ~ x: n
"

# Generate the simulated datasets

dats <- sim_data(nrep = 5,
                 model = mod,
                 pop_es = es,
                 n = 100,
                 iseed = 1234)

# Fit the population model to each dataset
```

```

fits <- fit_model(dats)

# Combine the results to one object

sim_out_all <- sim_out(data_all = dats,
                      fit = fits)
sim_out_all

# Verify that the elements of fits are set to extra$fit

library(lavaan)
parameterEstimates(fits[[1]])
parameterEstimates(sim_out_all[[1]]$extra$fit)
parameterEstimates(fits[[2]])
parameterEstimates(sim_out_all[[2]]$extra$fit)

```

summarize_tests

Summarize Test Results

Description

Extract and summarize test results.

Usage

```

summarize_tests(
  object,
  collapse = c("none", "all_sig", "at_least_one_sig", "at_least_k_sig"),
  at_least_k = 1
)

## S3 method for class 'test_summary_list'
print(x, digits = 3, ...)

## S3 method for class 'test_summary'
print(x, digits = 2, ...)

## S3 method for class 'test_out_list'
print(x, digits = 3, test_long = FALSE, ...)

```

Arguments

object	A power4test object or the element test_all in a power4test object.
collapse	Whether a single decision (significant vs. not significant) is made across all tests for a test that consists of several tests (e.g., the tests of several parameters). If "none", tests will be summarized individually. If "all_sig", then

the set of tests is considered significant if all individual tests are significant. If "at_least_one_sig", then the set of tests is considered significant if at least one of the tests is significant. If "at_least_k_sig", then the set of tests is considered significant if at least k tests are significant, k set by the argument at_least_k.

at_least_k	Used by collapse, the number of tests required to be significant for the set of tests to be considered significant.
x	The object to be printed.
digits	The numbers of digits after the decimal when printing numeric results.
...	Optional arguments. Not used.
test_long	If TRUE, a detailed report will be printed.

Details

The function `summarize_tests()` is used to extract information from each test stored in a `power4test` object.

The method `print.test_out_list()` is used to print the content of a list of test stored in a `power4test` object, with the option to print just the names of tests.

Value

The function `summarize_tests()` returns a list of the class `test_summary_list`. Each element contains a summary of a test stored. The elements are of the class `test_summary`, with these elements:

- `test_attributes`: The stored information of a test, for printing.
- `nrep`: The number of datasets (replications).
- `mean`: The means of numeric information. For significance tests, these are the rejection rates.
- `nvalid`: The number of non-NA replications used to compute each mean.

The print methods returns x invisibly. They are called for their side effects.

The role of `summarize_tests()` and related functions

The function `summarize_tests()` and related print methods are used by the all-in-one function `power4test()` and its summary method. Users usually do not call them directly, though developers can use this function to develop other functions for power analysis, or to build their own workflows to do the power analysis.

See Also

`power4test()`

Examples

```
# Specify the model

mod <-
"
m ~ x
y ~ m + x
"

# Specify the population values

es <-
"
y ~ m: 1
m ~ x: m
y ~ x: n
"

# Simulated datasets

sim_only <- power4test(nrep = 2,
                      model = mod,
                      pop_es = es,
                      n = 100,
                      do_the_test = FALSE,
                      iseed = 1234)

# Test the parameters in each dataset

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters)

# Print the summary

summarize_tests(test_out)
```

summary.x_from_power *Summarize 'x_from_power' Results*

Description

The summary method of the output of `x_from_power()`.

Usage

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

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

## S3 method for class 'summary.x_from_power'
print(x, digits = 3, ...)

## S3 method for class 'summary.n_region_from_power'
print(x, digits = 3, ...)
```

Arguments

object	An <code>x_from_power</code> -class object, such as the output of <code>x_from_power()</code> , or an object of the class <code>n_region_from_power</code> , such as the output of <code>n_region_from_power()</code> .
...	Additional arguments. Not used for now.
x	The output of <code>summary.x_from_power()</code> , the summary method of an <code>x_from_power</code> object, which is the output of <code>x_from_power()</code> , or the output of <code>summary.n_region_from_power()</code> , the summary method of an <code>n_region_from_power</code> object (the output of <code>n_region_from_power()</code>).
digits	The number of digits after the decimal when printing the results.

Details

The summary method simply prepares the results of `x_from_power()` to be printed in details.

Value

The summary method for `x_from_power` objects returns an object of the class `summary.x_from_power`, which is simply the output of `x_from_power()`, with a `print` method dedicated for detailed summary. Please refer to `x_from_power()` for the contents.

The `print`-method of `summary.x_from_power` objects returns the object `x` invisibly. It is called for its side effect.

The `print`-method of `summary.n_region_from_power` objects returns the object `x` invisibly. It is called for its side effect.

See Also

`x_from_power()`, `n_region_from_power()`

Examples

```
# Specify the population model

mod <-
"
m ~ x
y ~ m + x
"

# Specify the population values
```



```

mod_es <-
"
m ~ x: m
y ~ m: l
y ~ x: n
"

# Generate the datasets

sim_only <- power4test(nrep = 5,
                      model = mod,
                      pop_es = mod_es,
                      n = 100,
                      do_the_test = FALSE,
                      iseed = 2345)

# Do a test

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters,
                      test_args = list(pars = "m~x"))

# Determine the sample size with a power of .80 (default)

power_vs_n <- x_from_power(test_out,
                          x = "n",
                          progress = TRUE,
                          target_power = .80,
                          final_nrep = 5,
                          max_trials = 1,
                          seed = 1234)

summary(power_vs_n)

```

test_cond_indirect *Test a Conditional Indirect Effect*

Description

Test a conditional indirect effect for a power4test object.

Usage

```

test_cond_indirect(
  fit = fit,
  x = NULL,
  m = NULL,
  y = NULL,
  wvalues = NULL,
  mc_ci = TRUE,

```

```

mc_out = NULL,
boot_ci = FALSE,
boot_out = NULL,
check_post_check = TRUE,
...,
fit_name = "fit",
get_map_names = FALSE,
get_test_name = FALSE
)

```

Arguments

fit	The fit object, to be passed to <code>manymome::cond_indirect()</code> .
x	The name of the x-variable, the predictor.
m	A character vector of the name(s) of mediator(s). The path moves from the first mediator in the vector to the last mediator in the vector. Can be NULL and the path is a direct path without mediator.
y	The name of the y-variable, the outcome variable.
wvalues	A numeric vector of named elements. The names are the variable names of the moderators, and the values are the values to which the moderators will be set to. Default is NULL.
mc_ci	Logical. If TRUE, the default, Monte Carlo confidence intervals will be formed. This argument and <code>boot_ci</code> cannot be both TRUE.
mc_out	The pre-generated Monte Carlo estimates generated by <code>manymome::do_mc</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
boot_ci	Logical. If TRUE, the default, nonparametric bootstrap confidence intervals will be formed. This argument and <code>mc_ci</code> cannot be both TRUE.
boot_out	The pre-generated bootstrap estimates generated by <code>manymome::do_boot</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
check_post_check	Logical. If TRUE, the default, and the model is fitted by <code>lavaan</code> , the test will be conducted only if the model passes the <code>post.check</code> conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>manymome::cond_indirect()</code> .
fit_name	The name of the model fit object to be extracted. Default is "fit". Used only when more than one model is fitted in each replication. This should be the name of the model on which the test is to be conducted.
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing a conditional indirect effect, by setting it to the `test_fun` argument.

It uses `manymome::cond_indirect()` to do the test. It can be used on models fitted by `lavaan::sem()` or fitted by a sequence of calls to `stats::lm()`, although only nonparametric bootstrap confidence interval is supported for models fitted by regression using `stats::lm()`.

It can also be used to test a conditional effect on a direct path with no mediator. Just omit `m` when calling the function.

Value

In its normal usage, it returns a named numeric vector with the following elements:

- `est`: The mean of the estimated indirect effect across datasets.
- `cilo` and `cihi`: The means of the lower and upper limits of the confidence interval (95% by default), respectively.
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

model_simple_mod <-
"
m ~ x + w + x:w
y ~ m + x
"

# Specify the population values

model_simple_mod_es <-
"
y ~ m: 1
y ~ x: n
m ~ x: m
m ~ w: n
m ~ x:w: 1
"

# Simulate the data

sim_only <- power4test(nrep = 5,
                      model = model_simple_mod,
                      pop_es = model_simple_mod_es,
                      n = 100,
                      R = 100,
```

```

do_the_test = FALSE,
iseed = 1234)

# Do the test in each replication

test_ind <- power4test(object = sim_only,
  test_fun = test_cond_indirect,
  test_args = list(x = "x",
    m = "m",
    y = "y",
    wvalues = c(w = 1),
    mc_ci = TRUE))

print(test_ind,
  test_long = TRUE)

```

```
test_cond_indirect_effects
```

Test Several Conditional Indirect Effects

Description

Test several conditional indirect effects for a `power4test` object.

Usage

```

test_cond_indirect_effects(
  fit = fit,
  x = NULL,
  m = NULL,
  y = NULL,
  wlevels = NULL,
  mc_ci = TRUE,
  mc_out = NULL,
  boot_ci = FALSE,
  boot_out = NULL,
  check_post_check = TRUE,
  ...,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)

```

Arguments

<code>fit</code>	The fit object, to be passed to <code>manymome::cond_indirect_effects()</code> .
<code>x</code>	The name of the x-variable, the predictor.

m	A character vector of the name(s) of mediator(s). The path moves from the first mediator in the vector to the last mediator in the vector. Can be NULL and the path is a direct path without mediator.
y	The name of the y-variable, the outcome variable.
wlevels	The output of <code>manymome::merge_mod_levels()</code> , or the moderator(s) to be passed to <code>manymome::mod_levels_list()</code> . If all the moderators can be represented by one variable, that is, each moderator is (a) a numeric variable, (b) a dichotomous categorical variable, or (c) a factor or string variable used in <code>stats::lm()</code> in fit, then it is a vector of the names of the moderators as appeared in the data frame. If at least one of the moderators is a categorical variable represented by more than one variable, such as user-created dummy variables used in <code>lavaan::sem()</code> , then it must be a list of the names of the moderators, with such moderators represented by a vector of names. For example: <code>list("w1", c("gpgp2", "gpgp3"))</code> , the first moderator w1 and the second moderator a three-category variable represented by gpgp2 and gpgp3. See the help page of <code>manymome::cond_indirect_effects()</code> for further details.
mc_ci	Logical. If TRUE, the default, Monte Carlo confidence intervals will be formed. This argument and <code>boot_ci</code> cannot be both TRUE.
mc_out	The pre-generated Monte Carlo estimates generated by <code>manymome::do_mc</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
boot_ci	Logical. If TRUE, the default, nonparametric bootstrap confidence intervals will be formed. This argument and <code>mc_ci</code> cannot be both TRUE.
boot_out	The pre-generated bootstrap estimates generated by <code>manymome::do_boot</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
check_post_check	Logical. If TRUE, the default, and the model is fitted by <code>lavaan</code> , the test will be conducted only if the model passes the <code>post.check</code> conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>manymome::cond_indirect_effects()</code> .
fit_name	The name of the model fit object to be extracted. Default is "fit". Used only when more than one model is fitted in each replication. This should be the name of the model on which the test is to be conducted.
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing several conditional indirect effects, by setting it to the `test_fun` argument.

It uses `manymome::cond_indirect_effects()` to do the test. It can be used on models fitted by `lavaan::sem()` or fitted by a sequence of calls to `stats::lm()`, although only nonparametric bootstrap confidence interval is supported for models fitted by regression using `stats::lm()`.

It can also be used to test conditional effects on a direct path with no mediator. Just omit `m` when calling the function.

Value

In its normal usage, it returns the output returned by `manymome::cond_indirect_effects()`, with the following modifications:

- `est`: The estimated conditional indirect effects.
- `cilo` and `cihi`: The lower and upper limits of the confidence interval (95% by default), respectively.
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).
- `test_label`: A column of labels generated to label the conditional effects.

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

model_simple_mod <-
"
m ~ x + w + x:w
y ~ m + x
"

# Specify the population values

model_simple_mod_es <-
"
y ~ m: 1
y ~ x: n
m ~ x: m
m ~ w: n
m ~ x:w: 1
"

# Simulate the data

# Set nrep to a larger value in real analysis, such as 400
sim_only <- power4test(nrep = 5,
  model = model_simple_mod,
  pop_es = model_simple_mod_es,
  n = 100,
  R = 100,
  do_the_test = FALSE,
  iseed = 1234)

# Do the tests in each replication
```

```

test_out <- power4test(object = sim_only,
                      test_fun = test_cond_indirect_effects,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       wlevels = c("w"),
                                       mc_ci = TRUE))

print(test_out,
      test_long = TRUE)

```

test_index_of_mome *Test a Moderated Mediation Effect*

Description

Test a moderated mediation effect for a power4test object.

Usage

```

test_index_of_mome(
  fit = fit,
  x = NULL,
  m = NULL,
  y = NULL,
  w = NULL,
  mc_ci = TRUE,
  mc_out = NULL,
  boot_ci = FALSE,
  boot_out = NULL,
  check_post_check = TRUE,
  ...,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)

```

Arguments

fit	The fit object, to be passed to <code>manymome::index_of_mome()</code> .
x	The name of the x-variable, the predictor.
m	A character vector of the name(s) of mediator(s). The path moves from the first mediator in the vector to the last mediator in the vector. Can be NULL and the path is a direct path without mediator.
y	The name of the y-variable, the outcome variable.
w	The name of the moderator.

mc_ci	Logical. If TRUE, the default, Monte Carlo confidence intervals will be formed. This argument and boot_ci cannot be both TRUE.
mc_out	The pre-generated Monte Carlo estimates generated by <code>manymome::do_mc</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
boot_ci	Logical. If TRUE, the default, nonparametric bootstrap confidence intervals will be formed. This argument and mc_ci cannot be both TRUE.
boot_out	The pre-generated bootstrap estimates generated by <code>manymome::do_boot</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
check_post_check	Logical. If TRUE, the default, and the model is fitted by <code>lavaan</code> , the test will be conducted only if the model passes the <code>post.check</code> conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>manymome::index_of_mome()</code> .
fit_name	The name of the model fit object to be extracted. Default is "fit". Used only when more than one model is fitted in each replication. This should be the name of the model on which the test is to be conducted.
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing a moderated mediation effect, by setting it to the `test_fun` argument.

It uses `manymome::index_of_mome()` to do the test. It can be used on models fitted by `lavaan::sem()` or fitted by a sequence of calls to `stats::lm()`, although only nonparametric bootstrap confidence interval is supported for models fitted by regression using `stats::lm()`.

Value

In its normal usage, it returns a named numeric vector with the following elements:

- `est`: The mean of the estimated indirect effect across datasets.
- `ci_lo` and `ci_hi`: The means of the lower and upper limits of the confidence interval (95% by default), respectively.
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).

See Also

`power4test()`

Examples

```
# Specify the model

mod <-
"
m ~ x + w + x:w
y ~ m
"

# Specify the population values

mod_es <-
"
m ~ x: n
y ~ x: m
m ~ w: l
m ~ x:w: l
"

# Simulate the data

sim_only <- power4test(nrep = 2,
                      model = mod,
                      pop_es = mod_es,
                      n = 100,
                      R = 100,
                      do_the_test = FALSE,
                      iseed = 1234)

# Do the test in each replication

test_out <- power4test(object = sim_only,
                      test_fun = test_index_of_mome,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       w = "w",
                                       mc_ci = TRUE))

print(test_out,
      test_long = TRUE)
```

test_indirect_effect *Test an Indirect Effect*

Description

Test an indirect effect for a power4test object.

Usage

```
test_indirect_effect(
  fit = fit,
  x = NULL,
  m = NULL,
  y = NULL,
  mc_ci = TRUE,
  mc_out = NULL,
  boot_ci = FALSE,
  boot_out = NULL,
  check_post_check = TRUE,
  ...,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)
```

Arguments

fit	The fit object, to be passed to manymome::indirect_effect() .
x	The name of the x-variable, the predictor.
m	A character vector of the name(s) of mediator(s). The path moves from the first mediator in the vector to the last mediator in the vector. Can be NULL and the path is a direct path without mediator.
y	The name of the y-variable, the outcome variable.
mc_ci	Logical. If TRUE, the default, Monte Carlo confidence intervals will be formed. This argument and <code>boot_ci</code> cannot be both TRUE.
mc_out	The pre-generated Monte Carlo estimates generated by manymome::do_mc , stored in a <code>power4test</code> object. Users should not set this argument and should let power4test() to set it automatically.
boot_ci	Logical. If TRUE, the default, nonparametric bootstrap confidence intervals will be formed. This argument and <code>mc_ci</code> cannot be both TRUE.
boot_out	The pre-generated bootstrap estimates generated by manymome::do_boot , stored in a <code>power4test</code> object. Users should not set this argument and should let power4test() to set it automatically.
check_post_check	Logical. If TRUE, the default, and the model is fitted by <code>lavaan</code> , the test will be conducted only if the model passes the <code>post.check</code> conducted by lavaan::lavInspect() (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to manymome::indirect_effect() .
fit_name	The name of the model fit object to be extracted. Default is "fit". Used only when more than one model is fitted in each replication. This should be the name of the model on which the test is to be conducted.
get_map_names	Logical. Used by power4test() to determine how to extract stored information and assign them to this function. Users should not use this argument.

`get_test_name` Logical. Used by `power4test()` to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing an indirect effect, by setting it to the `test_fun` argument.

It uses `manymome::indirect_effect()` to do the test. It can be used on models fitted by `lavaan::sem()` or fitted by a sequence of calls to `stats::lm()`, although only nonparametric bootstrap confidence interval is supported for models fitted by regression using `stats::lm()`.

Value

In its normal usage, it returns a named numeric vector with the following elements:

- `est`: The mean of the estimated indirect effect across datasets.
- `cilo` and `cihi`: The means of the lower and upper limits of the confidence interval (95% by default), respectively.
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

model_simple_med <-
"
m ~ x
y ~ m + x
"

# Specify the population values

model_simple_med_es <-
"
y ~ m: l
m ~ x: m
y ~ x: n
"

# Simulate the data

sim_only <- power4test(nrep = 5,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 100,
                      R = 100,
                      do_the_test = FALSE,
```

```

iseed = 1234)

# Do the test in each replication

test_ind <- power4test(object = sim_only,
                      test_fun = test_indirect_effect,
                      test_args = list(x = "x",
                                       m = "m",
                                       y = "y",
                                       mc_ci = TRUE))

print(test_ind,
      test_long = TRUE)

```

test_k_indirect_effects

Test Several Indirect Effects

Description

Test several indirect effects for a power4test object.

Usage

```

test_k_indirect_effects(
  fit = fit,
  x = NULL,
  m = NULL,
  y = NULL,
  mc_ci = TRUE,
  mc_out = NULL,
  boot_ci = FALSE,
  boot_out = NULL,
  check_post_check = TRUE,
  ...,
  omnibus = c("no", "all_sig", "at_least_one_sig", "at_least_k_sig"),
  at_least_k = 1,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)

```

Arguments

fit	The fit object, to be passed to <code>manymome::indirect_effect()</code> .
x	The name of the x-variable, the predictor.

m	Must be a list of character vectors. Each character vector stores the name(s) of mediator(s) along a path. The path moves from the first mediator in the vector to the last mediator in the vector. If NULL, the stored paths will be used, which are all the indirect paths in the model between x and y, by default.
y	The name of the y-variable, the outcome variable.
mc_ci	Logical. If TRUE, the default, Monte Carlo confidence intervals will be formed. This argument and boot_ci cannot be both TRUE.
mc_out	The pre-generated Monte Carlo estimates generated by <code>manymome::do_mc</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
boot_ci	Logical. If TRUE, the default, nonparametric bootstrap confidence intervals will be formed. This argument and mc_ci cannot be both TRUE.
boot_out	The pre-generated bootstrap estimates generated by <code>manymome::do_boot</code> , stored in a <code>power4test</code> object. Users should not set this argument and should let <code>power4test()</code> to set it automatically.
check_post_check	Logical. If TRUE, the default, and the model is fitted by lavaan, the test will be conducted only if the model passes the <code>post.check</code> conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>manymome::many_indirect_effects()</code> .
omnibus	If "no", the default, then the test results for all paths are stored. If "all_sig", then only one row of test is stored, and the test is declared significant if <i>all</i> paths are significant. If "at_least_one_sig", then only one row of test is stored, and the test is declared significant if at least one of the paths is significant. If "at_least_k_sig", then only one row of test is stored, and the test is declared significant if at least k of the paths is significant, k determined by the argument <code>at_least_k</code> .
at_least_k	The minimum number of paths required to be significant for the omnibus test to be considered significant. Used when omnibus is "at_least_k_sig".
fit_name	The name of the model fit object to be extracted. Default is "fit". Used only when more than one model is fitted in each replication. This should be the name of the model on which the test is to be conducted.
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing an indirect effect, by setting it to the `test_fun` argument.

It uses `manymome::many_indirect_effects()` to do the test. It can be used on models fitted by `lavaan::sem()` or fitted by a sequence of calls to `stats::lm()`, although only nonparametric bootstrap confidence interval is supported for models fitted by regression using `stats::lm()`.

Value

In its normal usage, it returns a data frame with the following columns:

- `est`: The estimated indirect effect for each path.
- `cilo` and `cihi`: The lower and upper limits of the confidence interval (95% by default), respectively, for each indirect effect
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).
- `test_label`: A column of labels generated to label the indirect effects.

If `omnibus` is `"all_sig"` or `"at_least_one_sig"`, then the data frame has only one row, and the columns `"est"`, `"cilo"`, and `"cihi"` are NA. The column `sig` is determined by whether all paths are significant (`"all_sig"`) or whether at least one path is significant (`"at_least_one_sig"`).

See Also

[power4test\(\)](#)

Examples

```
# Specify the model

model_simple_med <-
"
m1 ~ x
m2 ~ x
y ~ m1 + m2 + x
"

# Specify the population values

model_simple_med_es <-
"
y ~ m1: s
m1 ~ x: m
y ~ m2: s
m2 ~ x: l
y ~ x: n
"

# Simulate the data

sim_only <- power4test(nrep = 5,
                      model = model_simple_med,
                      pop_es = model_simple_med_es,
                      n = 100,
                      R = 100,
                      do_the_test = FALSE,
                      iseed = 1234)

# Do the test in each replication
```

```

test_ind <- power4test(object = sim_only,
                      test_fun = test_k_indirect_effects,
                      test_args = list(x = "x",
                                       y = "y",
                                       mc_ci = TRUE))

print(test_ind,
      test_long = TRUE)

# Set omnibus = "all_sig" to declare
# significant only if all paths are
# significant

test_ind_all_sig <- power4test(
  object = sim_only,
  test_fun = test_k_indirect_effects,
  test_args = list(x = "x",
                   y = "y",
                   mc_ci = TRUE,
                   omnibus = "all_sig"))

print(test_ind_all_sig,
      test_long = TRUE)

```

test_moderation	<i>Test All Moderation Effects</i>
-----------------	------------------------------------

Description

Test all moderation effects by testing all product terms for a `power4test` object.

Usage

```

test_moderation(
  fit = fit,
  standardized = FALSE,
  check_post_check = TRUE,
  ...,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)

```

Arguments

<code>fit</code>	The fit object, to be passed to <code>lavaan::parameterEstimates()</code> , <code>lavaan::standardizedSolution()</code> , or <code>lmhelpers::lm_list_to_partable()</code> .
<code>standardized</code>	Logical. If TRUE, <code>lavaan::standardizedSolution()</code> will be used. Can be used only with models fitted by lavaan.

check_post_check	Logical. If TRUE, the default, and the model is fitted by lavaan, the test will be conducted only if the model passes the post.check conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>lavaan::parameterEstimates()</code> , <code>lavaan::standardizedSolutions()</code> or <code>lmhelpers::lm_list_to_partable()</code> .
fit_name	The name of the fit results for which the parameter names will be displayed. Default is "fit".
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.

Details

This function is to be used in `power4test()` for testing all product terms, by setting it to the `test_fun` argument.

It is just a wrapper to `test_parameters()`. It will first identifies all product terms (terms with `:` in the names), and then call `test_parameters()`, with `pars` set to select the regression coefficients of these terms.

Value

In its normal usage, it returns the output returned by `lavaan::parameterEstimates()` or `lmhelpers::lm_list_to_partable()` with the following modifications:

- `est`: The parameter estimates, even if standardized estimates are requested (not `est.std`).
- `ci.lo` and `ci.hi`: The lower and upper limits of the confidence interval (95% by default), respectively (not `ci.lower` and `ci.upper`).
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).
- `test_label`: A column of labels generated by `lavaan::lav_partable_labels()`, which are usually the labels used by `coef()` to label the parameters.

See Also

`power4test()`, `test_parameters()`

Examples

```
# Specify the model

mod <-
"
m ~ x + w1 + x:w1
y ~ m + x
"

# Specify the population values
```



```

mod_es <-
"
m ~ x: n
y ~ x: m
m ~ w1: n
m ~ x:w1: 1
"

# Simulate the data

sim_only <- power4test(nrep = 4,
                      model = mod,
                      pop_es = mod_es,
                      n = 100,
                      do_the_test = FALSE,
                      iseed = 1234)

# Do the test in each replication

test_out <- power4test(object = sim_only,
                      test_fun = test_moderation)

print(test_out,
      test_long = TRUE)

```

test_parameters	<i>Test All Free Parameters</i>
-----------------	---------------------------------

Description

Test all free parameters, including user-defined parameters, for a `power4test` object.

Usage

```

test_parameters(
  fit = fit,
  standardized = FALSE,
  pars = NULL,
  op = NULL,
  remove.nonfree = TRUE,
  check_post_check = TRUE,
  ...,
  omnibus = c("no", "all_sig", "at_least_one_sig", "at_least_k_sig"),
  at_least_k = 1,
  fit_name = "fit",
  get_map_names = FALSE,
  get_test_name = FALSE
)

```

```
)
find_par_names(object, fit_name = "fit")
```

Arguments

fit	The fit object, to be passed to <code>lavaan::parameterEstimates()</code> , <code>lavaan::standardizedSolution()</code> , or <code>lmhelpers::lm_list_to_partable()</code> .
standardized	Logical. If TRUE, <code>lavaan::standardizedSolution()</code> will be used. Can be used only with models fitted by lavaan.
pars	Optional. If set to a character vector, only parameters with <code>test_label</code> equal to values in <code>pars</code> will be returned. See the help page on valid names.
op	Optional. If set to a character vector, only parameters with operators (e.g., " <code>~</code> ", " <code>=~</code> ") will be returned. If both <code>pars</code> and <code>op</code> are specified, only parameters meeting <i>both</i> requirements will be returned.
remove.nonfree	Logical. If TRUE, the default, only free parameters will be returned. Ignored if <code>standardized</code> is TRUE or if the model is not fitted by lavaan.
check_post_check	Logical. If TRUE, the default, and the model is fitted by lavaan, the test will be conducted only if the model passes the <code>post.check</code> conducted by <code>lavaan::lavInspect()</code> (with <code>what = "post.check"</code>).
...	Additional arguments to be passed to <code>lavaan::parameterEstimates()</code> , <code>lavaan::standardizedSolution()</code> , or <code>lmhelpers::lm_list_to_partable()</code> .
omnibus	If " <code>no</code> ", the default, then the test results for all paths are stored. If " <code>all_sig</code> ", then only one row of test is stored, and the test is declared significant if <i>all</i> paths are significant. If " <code>at_least_one_sig</code> ", then only one row of test is stored, and the test is declared significant if at least one of the paths is significant. If " <code>at_least_k_sig</code> ", then only one row of test is stored, and the test is declared significant if at least <code>k</code> of the paths is significant, <code>k</code> determined by the argument <code>at_least_k</code> .
at_least_k	The minimum number of paths required to be significant for the omnibus test to be considered significant. Used when <code>omnibus</code> is " <code>at_least_k_sig</code> ".
fit_name	The name of the fit results for which the parameter names will be displayed. Default is " <code>fit</code> ".
get_map_names	Logical. Used by <code>power4test()</code> to determine how to extract stored information and assign them to this function. Users should not use this argument.
get_test_name	Logical. Used by <code>power4test()</code> to get the default name of this test. Users should not use this argument.
object	A <code>power4test</code> object.

Details

This function is to be used in `power4test()` for testing all free and user-defined model parameters, by setting it to the `test_fun` argument.

For models fitted by lavaan, it uses `lavaan::parameterEstimates()` to do the test. If bootstrapping was requested (by setting `se = "boot"`), then it supports bootstrap confidence intervals returned by `lavaan::parameterEstimates()`.

It has preliminary, though limited, support for models fitted by `stats::lm()` (through `lmhelpers::many_lm()`). Tests are conducted by ordinary least squares confidence intervals based on the t statistic, reported by `stats::confint()` applied to the output of `stats::lm()`.

Value

In its normal usage, it returns the output returned by `lavaan::parameterEstimates()` or `lmhelpers::lm_list_to_partable` with the following modifications:

- `est`: The parameter estimates, even if standardized estimates are requested (not `est.std`).
- `ci.lo` and `ci.hi`: The lower and upper limits of the confidence interval (95% by default), respectively (not `ci.lower` and `ci.upper`).
- `sig`: Whether a test by confidence interval is significant (1) or not significant (0).
- `test_label`: A column of labels generated by `lavaan::lav_partable_labels()`, which are usually the labels used by `coef()` to label the parameters.

Find the names of parameters

To use the argument `pars`, the names as appeared in the function `coef()` must be used. For the output of lavaan, this can usually be inferred from the parameter syntax (e.g., `y~x`, no space). If not sure, call `coef()` on the output of lavaan. If a parameter is labelled, then the label should be used in `par`.

If not sure, the function `find_par_names()` can be used to find valid names.

See Also

`power4test()`

Examples

```
# Specify the model

mod <-
"
m ~ x
y ~ m + x
"

# Specify the population values

mod_es <-
"
y ~ m: 1
m ~ x: m
y ~ x: n
"
```

```
# Simulate the data

sim_only <- power4test(nrep = 2,
                      model = mod,
                      pop_es = mod_es,
                      n = 100,
                      do_the_test = FALSE,
                      iseed = 1234)

# Do the tests in each replication

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters)

print(test_out,
      test_long = TRUE)

# Do the tests in each replication: Standardized solution
# Delta method SEs will be used to do the tests

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters,
                      test_args = list(standardized = TRUE))

print(test_out,
      test_long = TRUE)

# Do the tests in each replication: Parameters with the selected operator

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters,
                      test_args = list(op = "~"))

print(test_out,
      test_long = TRUE)

# Finding valid parameter names

find_par_names(sim_only)
```

x_from_power

Sample Size and Effect Size Determination

Description

It searches by simulation the sample size (given other factors, such as effect sizes) or effect size (given other factors, such as sample size) with power to detect an effect close to a target value.

Usage

```
x_from_power(  
  object,  
  x,  
  pop_es_name = NULL,  
  target_power = 0.8,  
  what = c("point", "ub", "lb"),  
  goal = switch(what, point = "ci_hit", ub = "close_enough", lb = "close_enough"),  
  ci_level = 0.95,  
  tolerance = 0.02,  
  x_interval = switch(x, n = c(50, 2000), es = NULL),  
  extendInt = NULL,  
  progress = TRUE,  
  simulation_progress = TRUE,  
  max_trials = 10,  
  final_nrep = 400,  
  final_R = 1000,  
  seed = NULL,  
  x_include_interval = FALSE,  
  check_es_interval = TRUE,  
  power_curve_args = list(power_model = NULL, start = NULL, lower_bound = NULL,  
    upper_bound = NULL, nls_control = list(), nls_args = list()),  
  save_sim_all = FALSE,  
  algorithm = NULL,  
  control = list()  
)
```

```
n_from_power(  
  object,  
  pop_es_name = NULL,  
  target_power = 0.8,  
  what = c("point", "ub", "lb"),  
  goal = switch(what, point = "ci_hit", ub = "close_enough", lb = "close_enough"),  
  ci_level = 0.95,  
  tolerance = 0.02,  
  x_interval = c(50, 2000),  
  extendInt = NULL,  
  progress = TRUE,  
  simulation_progress = TRUE,  
  max_trials = 10,  
  final_nrep = 400,  
  final_R = 1000,  
  seed = NULL,  
  x_include_interval = FALSE,  
  check_es_interval = TRUE,  
  power_curve_args = list(power_model = NULL, start = NULL, lower_bound = NULL,  
    upper_bound = NULL, nls_control = list(), nls_args = list()),  
  save_sim_all = FALSE,
```

```

    algorithm = NULL,
    control = list()
  )

n_region_from_power(
  object,
  pop_es_name = NULL,
  target_power = 0.8,
  ci_level = 0.95,
  tolerance = 0.02,
  x_interval = c(50, 2000),
  extendInt = NULL,
  progress = TRUE,
  simulation_progress = TRUE,
  max_trials = 10,
  final_nrep = 400,
  final_R = 1000,
  seed = NULL,
  x_include_interval = FALSE,
  check_es_interval = TRUE,
  power_curve_args = list(power_model = NULL, start = NULL, lower_bound = NULL,
    upper_bound = NULL, nls_control = list(), nls_args = list()),
  save_sim_all = FALSE,
  algorithm = NULL,
  control = list()
)

## S3 method for class 'x_from_power'
print(x, digits = 3, ...)

## S3 method for class 'n_region_from_power'
print(x, digits = 3, ...)

```

Arguments

object	A <code>power4test</code> object, which is the output of <code>power4test()</code> . Can also be a <code>power4test_by_n</code> object, the output of <code>power4test_by_n()</code> , or a <code>power4test_by_es</code> object, the output of <code>power4test_by_es()</code> . For these two types of objects, the attempt with power closest to the <code>target_power</code> will be used as object, and all other attempts in them will be included in the estimation of subsequent attempts and the final output. Last, it can also be the output of a previous call to <code>x_from_power()</code> , and the stored trials will be retrieved.
x	For <code>x_from_power()</code> , x set the value to be searched. Can be "n", the sample size, or "es", the population value of a parameter (set by <code>pop_es_name</code>). For the print method of <code>x_from_power</code> objects, this is the output of <code>x_from_power()</code> .
pop_es_name	The name of the parameter. Required if x is "es". See the help page of <code>ptable_pop()</code> on the names for the argument <code>pop_es</code> .
target_power	The target power, a value greater than 0 and less than one.

what	The value for which is searched: the estimate power ("point"), the upper bound of the confidence interval ("ub"), or the lower bound of the confidence interval ("lb").
goal	The goal of the search. If "ci_hit", then the goal is to find a value of x with the confidence interval of the estimated power including the target power. If "close_enough", then the goal is to find a value of x with the value in what "close enough" to the target power, defined by having an absolute difference with the target power less than tolerance.
ci_level	The level of confidence of the confidence intervals computed for the estimated power. Default is .95, denoting 95%.
tolerance	Used when the goal is "close_enough".
x_interval	A vector of two values, the minimum value and the maximum values of x, in the search for the values (sample sizes or population values). If NULL, default when x = "es", it will be determined internally.
extendInt	Whether x_interval can be expanded when estimating the the values to try. The value will be passed to the argument of the same name in <code>stats::uniroot()</code> . If x is "n", then the default value is "upX". That is, a value higher than the maximum in x_interval is allowed, if predicted by the tentative model. Otherwise, the default value is "no". See the help page of <code>stats::uniroot()</code> for further information.
progress	Logical. Whether the searching progress is reported.
simulation_progress	Logical. Whether the progress in each call to <code>power4test()</code> , <code>power4test_by_n()</code> , or <code>power4test_by_es()</code> is shown. To be passed to the progress argument of these functions.
max_trials	The maximum number of trials in searching the value with the target power. Rounded up if not an integer.
final_nrep	The number of replications in the final stage, also the maximum number of replications in each call to <code>power4test()</code> , <code>power4test_by_n()</code> , or <code>power4test_by_es()</code> .
final_R	The number of Monte Carlo simulation or bootstrapping samples in the final stage. The R in calling <code>power4test()</code> , <code>power4test_by_n()</code> , or <code>power4test_by_es()</code> will be stepped up to this value when approaching the target power. Do not need to be very large because the goal is to estimate power by replications, not for high precision in one single replication.
seed	If not NULL, <code>set.seed()</code> will be used to make the process reproducible. This is not always possible if many stages of parallel processing is involved.
x_include_interval	Logical. Whether the minimum and maximum values in x_interval are mandatory to be included in the values to be searched.
check_es_interval	If TRUE, the default, and x is "es", a conservative probable range of valid values for the selected parameter will be determined, and it will be used instead of x_interval. If the range spans both positive and negative values, only the interval of the same sign as the population value in object will be used.

power_curve_args	A named list of arguments to be passed <code>power_curve()</code> when estimating the relation between power and x (sample size or effect size). Please refer to <code>power_curve()</code> on available arguments. There is one except: <code>power_model</code> is mapped to the formula argument of <code>power_curve()</code> .
save_sim_all	If FALSE, the default, the data in each <code>power4test</code> object for each value of x is not saved, to reduce the size of the output. If set to TRUE, the size of the output can be very large in size.
algorithm	The algorithm for finding x. Can be "power_curve" or "bisection". The default algorithm depends on x.
control	A named list of additional arguments to be passed to the algorithm to be used. For advanced users.
digits	The number of digits after the decimal when printing the results.
...	Optional arguments. Not used for now.

Details

This is how to use `x_from_power()`:

- Specify the model by `power4test()`, with `do_the_test = FALSE`, and set the magnitude of the effect sizes to the minimum levels to detect.
- Add the test using `power4test()` using `test_fun` and `test_args` (see the help page of `power4test()` for details). Run it on the starting sample size or effect size.
- Call `x_from_power()` on the output of `power4test()` returned from the previous step. This function will iteratively repeat the analysis on either other sample sizes, or other values for a selected model parameter (the effect sizes), trying to achieve a goal (`goal`) for a value of interest (`what`).

If the goal is "ci_hit", the search will try to find a value (a sample size, or a population value of the selected model parameter) with a power level close enough to the target power, defined by having its confidence interval for the power including the target power.

If the goal is "close_enough", then the search will try to find a value of x with its level of power ("point"), the upper bound of the confidence interval for this level of power ("ub"), or the lower bound of the confidence interval from this level of power ("lb") "close enough" to the target level of power, defined by having an absolute difference less than the tolerance.

If several values of x (sample size or the population value of a model parameter) have already been examined by `power4test_by_n()` or `power4test_by_es()`, the output of these two functions can also be used as object by `x_from_power()`.

Usually, the default values of the arguments should be sufficient.

The results can be viewed using `summary()`, and the output has a `plot` method (`plot.x_from_power()`) to plot the relation between power and values (of x) examined.

A detailed illustration on how to use this function for sample size can be found from this page:

https://sfcheung.github.io/power4mome/articles/x_from_power_for_n.html

The function `n_from_power()` is just a wrapper of `x_from_power()`, with x set to "n".

The function `n_region_from_power()` is just a wrapper of `x_from_power()`, with `x` set to "n", with two passes, one with `what = "ub"` and one with `what = "lb"`.

The print method only prints basic information. Call the `summary` method of `x_from_power` objects (`summary.x_from_power()`) and its print method for detailed results

Value

The function `x_from_power()` returns an `x_from_power` object, which is a list with the following elements:

- `power4test_trials`: The output of `power4test_by_n()` for all sample sizes examined, or of `power4test_by_es()` for all population values of the selected parameter examined.
- `rejection_rates`: The output of `rejection_rates()`.
- `x_tried`: The sample sizes or population values examined.
- `power_tried`: The estimated rejection rates for all the values examined.
- `x_final`: The sample size or population value in the solution. NA if a solution not found.
- `power_final`: The estimated power of the value in the solution. NA if a solution not found.
- `i_final`: The position of the solution in `power4test_trials`. NA if a solution not found.
- `ci_final`: The confidence interval of the estimated power in the solution, formed by normal approximation. NA if a solution not found.
- `ci_level`: The level of confidence of `ci_final`.
- `nrep_final`: The number of replications (`nrep`) when estimating the power in the solution.
- `power_curve`: The output of `power_curve()` when estimating the power curve.
- `target_power`: The requested target power.
- `power_tolerance`: The allowed difference between the solution's estimated power and the target power. Determined by the number of replications and the level of confidence of the confidence intervals.
- `x_estimated`: The value (sample size or population value) with the target power, estimated by `power_curve`. This is used, when solution not found, to determine the range of the values to search when calling the function again.
- `start`: The time and date when the process started.
- `end`: The time and date when the process ended.
- `time_spent`: The time spent in doing the search.
- `args`: A named list of the arguments of `x_from_power()` used in the search.
- `call`: The call when this function is called.

The function `n_region_from_power()` returns a named list of two output of `n_from_power()`, of the class `n_region_from_power`. The output with `what = "ub"` is named "below", and the output with `what = "lb"` is named "above".

The print-method of `x_from_power` objects returns the object `x` invisibly. It is called for its side effect.

The print-method of `x_from_power_region` objects returns the object `x` invisibly. It is called for its side effect.

Algorithms

Two algorithms are currently available, the simple (though inefficient) bisection method, and a method that makes use of the estimated crude power curve.

Unlike typical root-finding problems, the prediction of the level of power is stochastic. Moreover, the computational cost is high when Monte Carlo or bootstrap confidence intervals are used to do a test because the estimation of the power for one single value of x can sometimes take one minute or longer. Therefore, in addition to the simple bisection method, a method, named *power curve* method, was also specifically developed for this scenario.

Bisection Method:

This method, `algorithm = "bisection"`, basically starts with an interval that probably encloses the value of x that meets the goal, and then successively narrows this interval. The mid-point of this interval is used as the estimate. Though simple, there are cases in which it can be slow. Nevertheless, preliminary examination suggests that this method is good enough for common scenarios. Therefore, this method is the default algorithm when x is n .

Power Curve Method:

This method, `algorithm = "power_curve"`, starts with a crude power curve based on a few points. This tentative model is then used to suggest the values to examine in the next iteration. The form, not just the parameters, of the model can change across iterations, as more and more data points are available.

This method can be used only with the goal `"ci_hit"`. This method is the default method for $x = "es"$ with goal = `"ci_hit"` because the relation between the power and the population value of a parameter varies across parameters, unlike the relation between power and sample size. Therefore, taking into account the working power curve may help finding the desired value of x .

The technical internal workflow of this method implemented in `x_from_power()` can be found in this page: https://sfcheung.github.io/power4mome/articles/x_from_power_workflow.html.

See Also

[power4test\(\)](#), [power4test_by_n\(\)](#), and [power4test_by_es\(\)](#).

Examples

```
# Specify the population model

mod <-
"
m ~ x
y ~ m + x
"

# Specify the population values

mod_es <-
"
m ~ x: m
y ~ m: 1
```

```
y ~ x: n
"

# Generate the datasets

sim_only <- power4test(nrep = 5,
                      model = mod,
                      pop_es = mod_es,
                      n = 100,
                      do_the_test = FALSE,
                      iseed = 2345)

# Do a test

test_out <- power4test(object = sim_only,
                      test_fun = test_parameters,
                      test_args = list(pars = "m~x"))

# Determine the sample size with a power of .80 (default)

# In real analysis, to have more stable results:
# - Use a larger final_nrep (e.g., 400).

# If the default values are OK, this call is sufficient:
# power_vs_n <- x_from_power(test_out,
#                            x = "n",
#                            seed = 4567)
power_vs_n <- x_from_power(test_out,
                          x = "n",
                          progress = TRUE,
                          target_power = .80,
                          final_nrep = 5,
                          max_trials = 1,
                          seed = 1234)

summary(power_vs_n)
plot(power_vs_n)
```

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