Package 'lcsm'

July 28, 2026

Type Package

Title Univariate and Bivariate Latent Change Score Modelling

Date 2026-07-28

Version 0.3.3

Description Helper functions to implement univariate and bivariate latent change score models in R using the 'lavaan' package.
For details about Latent Change Score Modeling (LCSM) see McArdle (2009) <doi:10.1146/annurev.psych.60.110707.163612> and Grimm, An, McArdle, Zonderman and Resnick (2012) <doi:10.1080/10705511.2012.659627>.
The package automatically generates 'lavaan' syntax for different model specifications and varying timepoints.
The 'lavaan' syntax generated by this package can be returned and further specifications can be added manually.
Longitudinal plots as well as simplified path diagrams can be created to visualise data and model specifications.
Estimated model parameters and fit statistics can be extracted as data frames.
Data for different univariate and bivariate LCSM can be simulated by specifying estimates for model parameters to explore their effects.
This package combines the strengths of other R packages like 'lavaan', 'broom', and 'semPlot' by generating 'lavaan' syntax that helps these packages work together.

Depends R (>= 3.5.0)

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Encoding UTF-8

URL https://milanwiedemann.github.io/lcsm/

BugReports https://github.com/milanwiedemann/lcsm/issues

LazyData true

Imports lavaan (>= 0.6.2), dplyr (>= 0.7.4), tibble (>= 1.4.2), magrittr (>= 1.5), rlang (>= 0.1.6), tidyr (>= 0.8.0), ggplot2 (>= 2.2.1), broom (>= 0.5.1), semPlot (>= 1.1), stats (>= 3.5.2), stringr (>= 1.4.0), purrr (>= 0.3.4)

Suggests testthat (>= 3.0.0), knitr (>= 1.22), rmarkdown (>= 1.12), shiny (>= 1.4.0)

VignetteBuilder knitr

Config/testthat/edition 3

Config/roxygen2/version 8.0.0

NeedsCompilation no

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Repository CRAN

Date/Publication 2026-07-28 15:40:02 UTC

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`data_bi_lcsm` *Longitudinal dataset with repeated measures of two constructs*

Description

Example dataset with repeated measures of two constructs to illustrate how the package works.

Usage

```
data(data_bi_lcsm)
```

Format

A longitudinal dataset in wide format:

- `id`: ID variable, unique identifier for each person
- `x1`: x value at time point 1
- `x2`: x value at time point 2
- `x3`: x value at time point 3
- `x4`: x value at time point 4
- `x5`: x value at time point 5
- `x6`: x value at time point 6
- `x7`: x value at time point 7
- `x8`: x value at time point 8
- `x9`: x value at time point 9
- `x10`: x value at time point 10
- `y1`: y value at time point 1
- `y2`: y value at time point 2
- `y3`: y value at time point 3
- `y4`: y value at time point 4
- `y5`: y value at time point 5
- `y6`: y value at time point 6
- `y7`: y value at time point 7
- `y8`: y value at time point 8
- `y9`: y value at time point 9
- `y10`: y value at time point 10

Examples

```
# Load data into global environment
data(data_bi_lcsm)
```

---

data_uni_lcsm *Longitudinal dataset with repeated measures of one constructs*

Description

Example dataset with repeated measures of one constructs to illustrate how the package works.

Usage

```
data(data_uni_lcsm)
```

Format

A longitudinal dataset in wide format:

- `id`: ID variable, unique identifier for each person
- `x1`: x value at time point 1
- `x2`: x value at time point 2
- `x3`: x value at time point 3
- `x4`: x value at time point 4
- `x5`: x value at time point 5
- `x6`: x value at time point 6
- `x7`: x value at time point 7
- `x8`: x value at time point 8
- `x9`: x value at time point 9
- `x10`: x value at time point 10

Examples

```
# Load data into global environment
data(data_uni_lcsm)
```

`extract_fit` *Extract fit statistics of lavaan objects*

Description

Extract fit statistics of lavaan objects

Usage

```
extract_fit(..., details = FALSE)
```

Arguments

`...`	lavaan object(s)
`details`	Logical, if TRUE return all fit statistics. By default this is set to FALSE, a selection (chisq, npar, aic, bic, cfi, rmsea, srmr) of fit statistics is returned.

Value

This function returns a tibble.

References

David Robinson and Alex Hayes (2019). broom: Convert Statistical Analysis Objects into Tidy Tibbles. R package version 0.5.2. https://CRAN.R-project.org/package=broom/.

Examples

```
# First create a lavaan object
## Not run:
bi_lcsm_01 <- fit_bi_lcsm(data = data_bi_lcsm,
                          var_x = names(data_bi_lcsm)[2:4],
                          var_y = names(data_bi_lcsm)[12:14],
                          model_x = list(alpha_constant = TRUE,
                                         beta = TRUE,
                                         phi = FALSE),
                          model_y = list(alpha_constant = TRUE,
                                         beta = TRUE,
                                         phi = TRUE),
                          coupling = list(delta_lag_xy = TRUE,
                                          xi_lag_yx = TRUE)
                                          )

# Now extract fit statistics

extract_fit(bi_lcsm_01)

## End(Not run)
```

`extract_param` *Extract labelled parameters of lavaan objects*

Description

Extract labelled parameters of lavaan objects

Usage

```
extract_param(lavaan_object, printp = FALSE)
```

Arguments

`lavaan_object`	lavaan object.
`printp`	If TRUE convert into easily readable p values.

Value

This function returns a tibble with labelled parameters.

References

David Robinson and Alex Hayes (2019). broom: Convert Statistical Analysis Objects into Tidy Tibbles. R package version 0.5.2. https://CRAN.R-project.org/package=broom/

Examples

```
# First create a lavaan object
bi_lcsm_01 <- fit_bi_lcsm(data = data_bi_lcsm,
                          var_x = names(data_bi_lcsm)[2:4],
                          var_y = names(data_bi_lcsm)[12:14],
                          model_x = list(alpha_constant = TRUE,
                                         beta = TRUE,
                                         phi = FALSE),
                          model_y = list(alpha_constant = TRUE,
                                         beta = TRUE,
                                         phi = TRUE),
                          coupling = list(delta_lag_xy = TRUE,
                                          xi_lag_yx = TRUE)
                                          )

# Now extract parameter estimates
extract_param(bi_lcsm_01)
```

`fit_bi_lcsm` *Fit bivariate latent change score models*

Description

Fit bivariate latent change score models.

Usage

```
fit_bi_lcsm(
  data,
  var_x,
  var_y,
  model_x,
  model_y,
  coupling,
  add = NULL,
  mimic = "Mplus",
  estimator = "MLR",
  missing = "FIML",
  return_lavaan_syntax = FALSE,
  ...
)
```

Arguments

`data`	Wide dataset.
`var_x`	List of variables measuring one construct of the model.
`var_y`	List of variables measuring another construct of the model.

`model_x` List of model specifications (logical) for variables specified in `var_x`.

- `alpha_constant`: Constant change factor
- `alpha_piecewise`: Piecewise constant change factors
- `alpha_piecewise_num`: Changepoint of piecewise constant change factors. In an example with 10 repeated measurements, setting `alpha_piecewise_num` to 5 would estimate two seperate constant change factors, a first one for changes up to timepoint 5, and a second one for changes from timepoint 5 onwards (in this example timepoint 10).
- `alpha_linear`: Linear change factor
- `beta`: Proportional change factor
- `phi`: Autoregression of change scores

`model_y` List of model specifications for variables specified in `var_y`.

- `alpha_constant`: Constant change factor
- `alpha_piecewise`: Piecewise constant change factors
- `alpha_piecewise_num`: Changepoint of piecewise constant change factors. In an example with 10 repeated measurements, setting `alpha_piecewise_num` to 5 would estimate two seperate constant change factors, a first one for changes up to timepoint 5, and a second one for changes from timepoint 5 onwards (in this example timepoint 10).
- `alpha_linear`: Linear change factor
- `beta`: Proportional change factor
- `phi`: Autoregression of change scores

`coupling` List of model specifications (logical) for coupling parameters.

- `coupling_piecewise`: Piecewise coupling parameters
- `coupling_piecewise_num`: Changepoint of piecewise coupling parameters
- `delta_xy`: True score y predicting subsequent change score x
- `delta_yx`: True score x predicting subsequent change score y
- `xi_xy`: Change score y predicting subsequent change score x
- `xi_yx`: Change score x predicting subsequent change score y

`add` String, lavaan syntax to be added to the model

`mimic` See `mimic` argument in lavOptions.

`estimator` See `estimator` argument in lavOptions.

`missing` See `missing` argument in lavOptions.

`return_lavaan_syntax`
Logical, if TRUE return the lavaan syntax used for simulating data. To make it look beautiful use the function cat.

`...` Additional arguments to be passed to lavOptions.

Value

This function returns a lavaan class object.

References

Ghisletta, P., & McArdle, J. J. (2012). Latent Curve Models and Latent Change Score Models Estimated in R. Structural Equation Modeling: A Multidisciplinary Journal, 19(4), 651–682. doi:10.1146/annurev.psych.60.110707.163612.

Grimm, K. J., Ram, N., & Estabrook, R. (2017). Growth Modeling—Structural Equation and Multilevel Modeling Approaches. New York: The Guilford Press.

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. Annual Review of Psychology, 60(1), 577–605. doi:10.1146/annurev.psych.60.110707.163612.

Yves Rosseel (2012). lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1-36. doi:10.18637/jss.v048.i02.

Examples

```
# Fit
fit_bi_lcsm(data = data_bi_lcsm,
            var_x = names(data_bi_lcsm)[2:4],
            var_y = names(data_bi_lcsm)[12:14],
            model_x = list(alpha_constant = TRUE,
                           beta = TRUE,
                           phi = FALSE),
            model_y = list(alpha_constant = TRUE,
                           beta = TRUE,
                           phi = TRUE),
            coupling = list(delta_lag_xy = TRUE,
                            xi_lag_yx = TRUE)
                            )
```

`fit_uni_lcsm` *Fit univariate latent change score models*

Description

Fit univariate latent change score models.

Usage

```
fit_uni_lcsm(
  data,
  var,
  model,
  add = NULL,
  mimic = "Mplus",
  estimator = "MLR",
  missing = "FIML",
  return_lavaan_syntax = FALSE,
  ...
)
```

Arguments

`data`	A data frame in "wide" format, i.e. one column for each measurement point and one row for each observation.
`var`	Vector, specifying the variable names of each measurement point sequentially.
`model`	List of model specifications (logical) for variables specified in `var`. • `alpha_constant`: Constant change factor • `alpha_piecewise`: Piecewise constant change factors • `alpha_piecewise_num`: Changepoint of piecewise constant change factors. In an example with 10 repeated measurements, setting `alpha_piecewise_num` to 5 would estimate two seperate constant change factors, a first one for changes up to timepoint 5, and a second one for changes from timepoint 5 onwards (in this example timepoint 10). • `alpha_linear`: Linear change factor • `beta`: Proportional change factor • `phi`: Autoregression of change scores
`add`	String, lavaan syntax to be added to the model
`mimic`	See `mimic` argument in lavOptions.
`estimator`	See `estimator` argument in lavOptions.
`missing`	See `missing` argument in lavOptions.
`return_lavaan_syntax`	Logical, if TRUE return the lavaan syntax used for simulating data. To make it look beautiful use the function cat.
`...`	Additional arguments to be passed to lavOptions.

Value

This function returns a lavaan class object.

References

Ghisletta, P., & McArdle, J. J. (2012). Latent Curve Models and Latent Change Score Models Estimated in R. Structural Equation Modeling: A Multidisciplinary Journal, 19(4), 651-682. 10.1080/10705511.2012.713275.

Grimm, K. J., Ram, N., & Estabrook, R. (2017). Growth Modeling—Structural Equation and Multilevel Modeling Approaches. New York: The Guilford Press.

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. Annual Review of Psychology, 60(1), 577–605. doi:10.1146/annurev.psych.60.110707.163612.

Yves Rosseel (2012). lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1-36. doi:10.18637/jss.v048.i02.

Examples

```
# Fit univariate latent change score model
fit_uni_lcsm(data = data_uni_lcsm,
             var = names(data_uni_lcsm)[2:4],
             model = list(alpha_constant = TRUE,
                          beta = FALSE,
                          phi = FALSE))
```

`lcsm_data` *Longitudinal dataset with repeated measures of two constructs*

Description

Example dataset with 5 repeated measures of two constructs to illustrate how the package works.

Usage

```
data(lcsm_data)
```

Format

A longitudinal dataset in wide format:

- `id`: ID variable, unique identifier for each person
- `x1`: x value at time point 1
- `x2`: x value at time point 2
- `x3`: x value at time point 3
- `x4`: x value at time point 4
- `x5`: x value at time point 5
- `y1`: y value at time point 1
- `y2`: y value at time point 2
- `y3`: y value at time point 3
- `y4`: y value at time point 4
- `y5`: y value at time point 5

Examples

```
# Load data into global environment
data(lcsm_data)
```

`plot_lcsm` *Plot simplified path diagram of univariate and bivariate latent change score models*

Description

Note that the following three arguments are needed to create a plot (see below for more details):

- `lavaan_object`: the lavaan fit object needs to be specified together with a
- `lcsm`: a string indicating whether the latent change score model is "univariate" or "bivariate", and
- `lavaan_syntax`: a separate object with the lavaan syntax as a string

Usage

```
plot_lcsm(
  lavaan_object,
  layout = NULL,
  lavaan_syntax = NULL,
  return_layout_from_lavaan_syntax = FALSE,
  lcsm = c("univariate", "bivariate"),
  lcsm_colours = FALSE,
  curve_covar = 0.5,
  what = "path",
  whatLabels = "est",
  edge.width = 1,
  node.width = 1,
  border.width = 1,
  fixedStyle = 1,
  freeStyle = 1,
  residuals = FALSE,
  label.scale = FALSE,
  sizeMan = 3,
  sizeLat = 5,
  intercepts = FALSE,
  fade = FALSE,
  nCharNodes = 0,
  nCharEdges = 0,
  edge.label.cex = 0.5,
  ...
)
```

Arguments

`lavaan_object`	lavaan object of a univariate or bivariate latent change score model.
`layout`	Matrix, specifying number and location of manifest and latent variables of LCS model specified in `lavaan_object`.

lavaan_syntax	String, lavaan syntax of the lavaan object specified in lavaan_object. If lavaan_syntax is provided a layout matrix will be generated automatically.
return_layout_from_lavaan_syntax	Logical, if TRUE and lavaan_syntax is provided, the layout matrix generated for semPaths will be returned for inspection of further customisation.
lcsm	String, specifying whether lavaan_object represent a "univariate" or "bivariate" LCS model.
lcsm_colours	Logical, if TRUE the following colours will be used to highlight different parts of the model: Observed variables (White); Latent true scores (Green); Latent change scores (Blue) ; Change factors (Yellow).
curve_covar	See semPaths.
what	See semPlot. "path" to show unweighted grey edges, "par" to show parameter estimates as weighted (green/red) edges
whatLabels	See semPaths. "label" to show edge names as label, "est" for parameter estimates, "hide" to hide edge labels.
edge.width	See semPaths.
node.width	See semPaths.
border.width	See semPaths.
fixedStyle	See semPaths.
freeStyle	See semPaths.
residuals	See semPaths.
label.scale	See semPaths.
sizeMan	See semPaths.
sizeLat	See semPaths.
intercepts	See semPaths.
fade	See semPaths.
nCharNodes	See semPaths.
nCharEdges	See semPaths.
edge.label.cex	See semPaths.
...	Other arguments passed on to semPaths.

Value

Plot

References

Sacha Epskamp (2019). semPlot: Path Diagrams and Visual Analysis of Various SEM Packages' Output. R package version 1.1.1. https://CRAN.R-project.org/package=semPlot/

Examples

```
# Simplified plot of univariate lcsm
lavaan_syntax_uni <- fit_uni_lcsm(
  data = data_bi_lcsm,
  var = c("x1", "x2", "x3", "x4", "x5"),
  model = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  ),
  return_lavaan_syntax = TRUE,
  return_lavaan_syntax_string = TRUE
)

lavaan_object_uni <- fit_uni_lcsm(
  data = data_bi_lcsm,
  var = c("x1", "x2", "x3", "x4", "x5"),
  model = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  )
)

plot_lcsm(
  lavaan_object = lavaan_object_uni,
  what = "cons", whatLabels = "invisible",
  lavaan_syntax = lavaan_syntax_uni,
  lcsm = "univariate"
)
## Not run:
# Simplified plot of bivariate lcsm
lavaan_syntax_bi <- fit_bi_lcsm(
  data = data_bi_lcsm,
  var_x = c("x1", "x2", "x3", "x4", "x5"),
  var_y = c("y1", "y2", "y3", "y4", "y5"),
  model_x = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  ),
  model_y = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  ),
  coupling = list(
    delta_lag_xy = TRUE,
    delta_lag_yx = TRUE
  ),
  return_lavaan_syntax = TRUE,
  return_lavaan_syntax_string = TRUE
```

```
)

lavaan_object_bi <- fit_bi_lcsm(
  data = data_bi_lcsm,
  var_x = c("x1", "x2", "x3", "x4", "x5"),
  var_y = c("y1", "y2", "y3", "y4", "y5"),
  model_x = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  ),
  model_y = list(
    alpha_constant = TRUE,
    beta = TRUE,
    phi = TRUE
  ),
  coupling = list(
    delta_lag_xy = TRUE,
    delta_lag_yx = TRUE
  )
)

plot_lcsm(
  lavaan_object = lavaan_object_bi,
  what = "cons", whatLabels = "invisible",
  lavaan_syntax = lavaan_syntax_bi,
  lcsm = "bivariate"
)

## End(Not run)
```

`plot_trajectories` *Plot individual trajectories*

Description

Plot individual trajectories

Usage

```
plot_trajectories(
  data,
  id_var,
  var_list,
  line_colour = "blue",
  group_var = NULL,
  point_colour = "black",
  line_alpha = 0.2,
```

```
  point_alpha = 0.2,
  point_size = 1,
  smooth = FALSE,
  smooth_method = "loess",
  smooth_se = FALSE,
  xlab = "X",
  ylab = "Y",
  scale_x_num = FALSE,
  scale_x_num_start = 1,
  random_sample_frac = 1,
  seed = 1234,
  title_n = FALSE,
  connect_missing = TRUE
)
```

Arguments

data	Dataset in wide format.
id_var	String, specifying id variable.
var_list	Vector, specifying variable names to be plotted in sequential order.
line_colour	String, specifying colour of lines.
group_var	String, specifying variable name of group, each group will get individual colour lines. This overwrites the line_colour argument. Also consider other options to look at trajectories like facet_wrap which may be more appropriate.
point_colour	String, specifying, colour of points.
line_alpha	Numeric, specifying alpha of lines.
point_alpha	Numeric, specifying alpha of points.
point_size	Numeric, size of point
smooth	Logical, add smoothed conditional means using geom_smooth.
smooth_method	String, specifying method to be used for calculating average line, see geom_smooth.
smooth_se	Logical, specifying whether to add standard error of average line or not.
xlab	String for x axis label.
ylab	String for y axis label.
scale_x_num	Logical, if TRUE print sequential numbers starting from 1 as x axis labels, if FALSE use variable names.
scale_x_num_start	Numeric, if scale_x_num = TRUE this is the starting value of the x axis.
random_sample_frac	The fraction of rows to select (from wide dataset), default is set to 1 (100 percent) of the sample.
seed	Set seed for random sample if random_sample_frac argument is used.
title_n	Logical, specifying whether to print title with number and percentage of cases used for the plot.
connect_missing	Logical, specifying whether to connect points by id_var across missing values.

Value

ggplot2 object

Examples

```
# Create plot for construct x
plot_trajectories(data = data_bi_lcsm,
                  id_var = "id",
                  var_list = c("x1", "x2", "x3", "x4", "x5",
                               "x6", "x7", "x8", "x9", "x10"))

# Create plot for construct y specifying some ather arguments
plot_trajectories(data = data_bi_lcsm,
                  id_var = "id",
                  var_list = c("y1", "y2", "y3", "y4", "y5",
                               "y6", "y7", "y8", "y9", "y10"),
                  xlab = "Time", ylab = "Y Score",
                  connect_missing = FALSE, random_sample_frac = 0.5)
```

---

rename_lcsm_vars *Rename variables for univariate and bivariate latent change score models*

Description

Rename variables for univariate and bivariate latent change score models

Usage

```
rename_lcsm_vars(data, var_x, var_y)
```

Arguments

data	Dataset in wide format
var_x	List of variables measuring first construct
var_y	List of variables measuring second construct

Value

Dataset in wide format with renamed variables

`select_bi_cases` *Select cases based on minimum number of available session scores on two longitudinal measures*

Description

Select cases based on minimum number of available session scores on two longitudinal measures

Usage

```
select_bi_cases(data, id_var, var_list_x, var_list_y, min_count_x, min_count_y)
```

Arguments

`data`	A data frame in "wide" format, i.e. one column for each measurement point and one row for each observation.
`id_var`	String, specifying id variable.
`var_list_x`	Vector, specifying variable names of construct X in sequential order.
`var_list_y`	Vector, specifying variable names of construct Y in sequential order.
`min_count_x`	Numeric, specifying minimum number of available scores for construct X.
`min_count_y`	Numeric, specifying minimum number of available scores for construct Y.

Value

tibble

Examples

```
select_bi_cases(data_bi_lcsm,
  id_var = "id",
  var_list_x = names(data_bi_lcsm)[2:11],
  var_list_y = names(data_bi_lcsm)[12:21],
  min_count_x = 7,
  min_count_y = 7
)
```

select_uni_cases — *Select cases based on minimum number of available session scores on one longitudinal measure*

Description

Select cases based on minimum number of available session scores on one longitudinal measure

Usage

```
select_uni_cases(data, id_var, var_list, min_count, return_id_only = FALSE)
```

Arguments

data	Dataset in wide format.
id_var	String, specifying id variable.
var_list	Vector, specifying variable names in sequential order.
min_count	Numeric, specifying minimum number of available scores
return_id_only	Logical, if TRUE only return ID. This is needed for select_bi_cases

Value

tibble

Examples

```
select_uni_cases(data_uni_lcsm,
  id_var = "id",
  var_list = names(data_uni_lcsm)[-1],
  min_count = 7
)
```

sim_bi_lcsm — *Simulate data from bivariate latent change score model parameter estimates*

Description

This function simulate data from bivariate latent change score model parameter estimates using simulateData.

Usage

```
sim_bi_lcsm(
  timepoints,
  model_x,
  model_x_param = NULL,
  model_y,
  model_y_param = NULL,
  coupling,
  coupling_param = NULL,
  sample.nobs = 500,
  na_x_pct = 0,
  na_y_pct = 0,
  seed = NULL,
  ...,
  var_x = "x",
  var_y = "y",
  change_letter_x = "g",
  change_letter_y = "j",
  return_lavaan_syntax = FALSE
)
```

Arguments

`timepoints`	See specify_bi_lcsm
`model_x`	See specify_bi_lcsm
`model_x_param`	List, specifying parameter estimates for the LCSM that has been specified in the argument 'model_x': • `gamma_lx1`: Mean of latent true scores x (Intercept), • `sigma2_lx1`: Variance of latent true scores x, • `sigma2_ux`: Variance of observed scores x, • `alpha_g2`: Mean of change factor (g2), • `alpha_g3`: Mean of change factor (g3), • `sigma2_g2`: Variance of change factor (g2). • `sigma2_g3`: Variance of change factor (g3), • `sigma_g2lx1`: Covariance of change factor (g2) with the initial true score x (lx1), • `sigma_g3lx1`: Covariance of change factor (g3) with the initial true score x (lx1), • `sigma_g2g3`: Covariance of change factors (g2 and g2), • `phi_x`: Autoregression of change scores x.
`model_y`	See specify_bi_lcsm
`model_y_param`	List, specifying parameter estimates for the LCSM that has been specified in the argument 'model_y': • `gamma_ly1`: Mean of latent true scores y (Intercept), • `sigma2_ly1`: Variance of latent true scores y,

- sigma2_uy: Variance of observed scores y,
- alpha_j2: Mean of change factor (j2),
- alpha_j3: Mean of change factor (j3),
- sigma2_j2: Variance of change factor (j2).
- sigma2_j3: Variance of change factor (j3),
- sigma_j2ly1: Covariance of change factor (j2) with the initial true score x (ly1),
- sigma_j3ly1: Covariance of change factor (j3) with the initial true score x (ly1),
- sigma_j2j3: Covariance of change factors (j2 and j2),
- phi_y: Autoregression of change scores y.

coupling — See specify_bi_lcsm

coupling_param — List, specifying parameter estimates coupling parameters that have been specified in the argument 'coupling':

- sigma_su: Covariance of residuals x and y,
- sigma_ly1lx1: Covariance of intercepts x and y,
- sigma_g2ly1: Covariance of change factor x (g2) with the initial true score y (ly1),
- sigma_g3ly1: Covariance of change factor x (g3) with the initial true score y (ly1),
- sigma_j2lx1: Covariance of change factor y (j2) with the initial true score x (lx1),
- sigma_j3lx1: Covariance of change factor y (j3) with the initial true score x (lx1),
- sigma_j2g2: Covariance of change factors y (j2) and x (g2),
- sigma_j2g3: Covariance of change factors y (j2) and x (g3),
- sigma_j3g2: Covariance of change factors y (j3) and x (g2),,
- delta_con_xy: Change score x (t) determined by true score y (t),
- delta_con_yx: Change score y (t) determined by true score x (t),
- delta_lag_xy: Change score x (t) determined by true score y (t-1),
- delta_lag_yx: Change score y (t) determined by true score x (t-1),
- xi_con_xy: Change score x (t) determined by change score y (t),
- xi_con_yx: Change score y (t) determined by change score x (t),
- xi_lag_xy: Change score x (t) determined by change score y (t-1),
- xi_lag_yx: Change score y (t) determined by change score x (t-1)

sample.nobs — Numeric, number of cases to be simulated, see specify_uni_lcsm

na_x_pct — Numeric, percentage of random missing values in the simulated dataset (0 to 1)

na_y_pct — Numeric, percentage of random missing values in the simulated dataset (0 to 1)

seed — Set seed for data simulation, see simulateData

... — Arguments to be passed on to simulateData

var_x — See specify_bi_lcsm

var_y — See specify_bi_lcsm

`change_letter_x`
: See specify_bi_lcsm

`change_letter_y`
: See specify_bi_lcsm

`return_lavaan_syntax`
: Logical, if TRUE return the lavaan syntax used for simulating data. To make it look beautiful use the function cat.

Value

tibble

References

Ghisletta, P., & McArdle, J. J. (2012). Latent Curve Models and Latent Change Score Models Estimated in R. Structural Equation Modeling: A Multidisciplinary Journal, 19(4), 651-682. 10.1080/10705511.2012.713275.

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Kievit, R. A., Brandmaier, A. M., Ziegler, G., van Harmelen, A.-L., de Mooij, S. M. M., Moutoussis, M., ... Dolan, R. J. (2018). Developmental cognitive neuroscience using latent change score models: A tutorial and applications. Developmental Cognitive Neuroscience, 33, 99–117. doi:10.1016/j.dcn.2017.11.007.

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. Annual Review of Psychology, 60(1), 577–605. doi:10.1146/annurev.psych.60.110707.163612.

Yves Rosseel (2012). lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1-36. doi:10.18637/jss.v048.i02.

Examples

```
# Simulate data from bivariate LCSM parameters
sim_bi_lcsm(timepoints = 12,
            na_x_pct = .05,
            na_y_pct = .1,
            model_x = list(alpha_constant = TRUE, beta = TRUE, phi = FALSE),
            model_x_param = list(gamma_lx1 = 21,
                                 sigma2_lx1 = .5,
                                 sigma2_ux = .2,
                                 alpha_g2 = -.4,
                                 sigma2_g2 = .4,
                                 sigma_g2lx1 = .2,
                                 beta_x = -.1),
            model_y = list(alpha_constant = TRUE, beta = TRUE, phi = TRUE),
            model_y_param = list(gamma_ly1 = 5,
                                 sigma2_ly1 = .2,
                                 sigma2_uy = .2,
                                 alpha_j2 = -.2,
                                 sigma2_j2 = .1,
                                 sigma_j2ly1 = .02,
```

```
                      beta_y = -.2,
                      phi_y = .1),
coupling = list(delta_lag_xy = TRUE,
                xi_lag_yx = TRUE),
coupling_param =list(sigma_su = .01,
                      sigma_ly1lx1 = .2,
                      sigma_g2ly1 = .1,
                      sigma_j2lx1 = .1,
                      sigma_j2g2 = .01,
                      delta_lag_xy = .13,
                      xi_lag_yx = .4),
return_lavaan_syntax = FALSE)
```

`sim_uni_lcsm` *Simulate data from univariate latent change score model parameter estimates*

Description

This function simulate data from univariate latent change score model parameter estimates using simulateData.

Usage

```
sim_uni_lcsm(
  timepoints,
  model,
  model_param = NULL,
  var = "x",
  change_letter = "g",
  sample.nobs = 500,
  na_pct = 0,
  seed = NULL,
  ...,
  return_lavaan_syntax = FALSE
)
```

Arguments

`timepoints`	See specify_uni_lcsm
`model`	See specify_uni_lcsm
`model_param`	List, specifying parameter estimates for the LCSM that has been specified in the argument 'model'

- `gamma_lx1`: Mean of latent true scores x (Intercept),
- `sigma2_lx1`: Variance of latent true scores x,
- `sigma2_ux`: Variance of observed scores x,

- alpha_g2: Mean of change factor (g2),
- alpha_g3: Mean of change factor (g3),
- sigma2_g2: Variance of constant change factor (g2).
- sigma2_g3: Variance of constant change factor (g3),
- sigma_g2lx1: Covariance of constant change factor (g2) with the initial true score x (lx1),
- sigma_g3lx1: Covariance of constant change factor (g3) with the initial true score x (lx1),
- sigma_g2g3: Covariance of change factors (g2 and g2),
- phi_x: Autoregression of change scores x.

var — See specify_uni_lcsm

change_letter — See specify_uni_lcsm

sample.nobs — Numeric, number of cases to be simulated, see specify_uni_lcsm

na_pct — Numeric, percentage of random missing values in the simulated dataset (0 to 1)

seed — Set seed for data simulation, see simulateData

... — Arguments to be passed on to simulateData

return_lavaan_syntax — Logical, if TRUE return the lavaan syntax used for simulating data. To make it look beautiful use the function cat.

Value

tibble

Examples

```
# Simulate data from univariate LCSM parameters
sim_uni_lcsm(timepoints = 10,
             model = list(alpha_constant = TRUE, beta = FALSE, phi = TRUE),
             model_param = list(gamma_lx1 = 21,
                                sigma2_lx1 = 1.5,
                                sigma2_ux = .2,
                                alpha_g2 = -.93,
                                sigma2_g2 = .1,
                                sigma_g2lx1 = .2,
                                phi_x = .2),
             return_lavaan_syntax = FALSE,
             sample.nobs = 1000,
             na_pct = .3)
```

specify_bi_lcsm *Specify lavaan model for bivariate latent change score models*

Description

Specify lavaan model for bivariate latent change score models

Usage

```
specify_bi_lcsm(
  timepoints,
  var_x,
  model_x,
  var_y,
  model_y,
  coupling,
  add = NULL,
  change_letter_x = "g",
  change_letter_y = "j"
)
```

Arguments

timepoints	Number of timepoints.
var_x	Vector, specifying variables measuring one construct of the model.
model_x	List, specifying model specifications (logical) for variables specified in var_x. • alpha_constant: Constant change factor • alpha_piecewise: Piecewise constant change factors • alpha_piecewise_num: Changepoint of piecewise constant change factors • alpha_linear: Linear change factor • beta: Proportional change factor • phi: Autoregression of change scores
var_y	Vector, specifying variables measuring another construct of the model.
model_y	List, specifying model specifications (logical) for variables specified in var_y. • alpha_constant: Constant change factor • alpha_piecewise: Piecewise constant change factors • alpha_piecewise_num: Changepoint of piecewise constant change factors • alpha_linear: Linear change factor • beta: Proportional change factor • phi: Autoregression of change scores
coupling	List, specifying coupling parameters. • coupling_piecewise: Piecewise coupling parameters

- coupling_piecewise_num: Changepoint of piecewise coupling parameters
- delta_con_xy: True score y predicting concurrent change score x
- delta_lag_xy: True score y predicting subsequent change score x
- delta_con_yx: True score x predicting concurrent change score y
- delta_lag_yx: True score x predicting subsequent change score y
- xi_con_xy: Change score y predicting concurrent change score x
- xi_lag_xy: Change score y predicting subsequent change score x
- xi_con_yx: Change score x predicting concurrent change score y
- xi_lag_yx: Change score x predicting subsequent change score y

add String, lavaan syntax to be added to the model

change_letter_x
String, specifying letter to be used as change factor for construct x in lavaan syntax.

change_letter_y
String, specifying letter to be used as change factor for construct y in lavaan syntax.

Value

Lavaan model syntax including comments.

References

Ghisletta, P., & McArdle, J. J. (2012). Latent Curve Models and Latent Change Score Models Estimated in R. Structural Equation Modeling: A Multidisciplinary Journal, 19(4), 651-682. 10.1080/10705511.2012.713275.

Grimm, K. J., Ram, N., & Estabrook, R. (2017). Growth Modeling—Structural Equation and Multilevel Modeling Approaches. New York: The Guilford Press.

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. Annual Review of Psychology, 60(1), 577–605. doi:10.1146/annurev.psych.60.110707.163612.

Yves Rosseel (2012). lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1-36. doi:10.18637/jss.v048.i02.

Examples

```
# Specify bivariate LCSM
lavaan_bi_lcsm_01 <- specify_bi_lcsm(timepoints = 10,
                                     var_x = "x",
                                     model_x = list(alpha_constant = TRUE,
                                                    beta = TRUE,
                                                    phi = TRUE),
                                     var_y = "y",
                                     model_y = list(alpha_constant = TRUE,
                                                    beta = TRUE,
                                                    phi = TRUE),
                                     coupling = list(delta_lag_xy = TRUE,
```

```
                                        delta_lag_yx = TRUE),
                                change_letter_x = "g",
                                change_letter_y = "j")

# To look at string simply return the object
lavaan_bi_lcsm_01

# To get a readable output use cat() function
cat(lavaan_bi_lcsm_01)
```

`specify_uni_lcsm` *Specify lavaan model for univariate latent change score models*

Description

Specify lavaan model for univariate latent change score models

Usage

```
specify_uni_lcsm(timepoints, var, model, add = NULL, change_letter = "g")
```

Arguments

`timepoints`	Number if timepoints.
`var`	String, specifying letter to be used for of variables (Usually x or y).
`model`	List of model specifications (logical) for the variables specified in `variable`.
	• `alpha_constant`: Constant change factor, • `alpha_piecewise`: Piecewise constant change factors, • `alpha_piecewise_num`: Changepoint of piecewise constant change factors, • `alpha_linear`: Linear change factor, • `beta`: Proportional change factor, • `phi`: Autoregression of change scores.
`add`	String, lavaan syntax to be added to the model
`change_letter`	String, specifying letter to be used for change factor (Usually g or j).

Value

Lavaan model syntax including comments.

References

Ghisletta, P., & McArdle, J. J. (2012). Latent Curve Models and Latent Change Score Models Estimated in R. Structural Equation Modeling: A Multidisciplinary Journal, 19(4), 651–682. doi:10.1080/10705511.2012.713275.

Grimm, K. J., Ram, N., & Estabrook, R. (2017). Growth Modeling—Structural Equation and Multilevel Modeling Approaches. New York: The Guilford Press.

McArdle, J. J. (2009). Latent variable modeling of differences and changes with longitudinal data. Annual Review of Psychology, 60(1), 577–605. doi:10.1146/annurev.psych.60.110707.163612.

Yves Rosseel (2012). lavaan: An R Package for Structural Equation Modeling. Journal of Statistical Software, 48(2), 1-36. doi:10.18637/jss.v048.i02.

Examples

```
# Specify univariate LCSM
lavaan_uni_lcsm_01 <- specify_uni_lcsm(timepoints = 10,
                                       model = list(alpha_constant = TRUE,
                                                    beta = TRUE,
                                                    phi = TRUE),
                                       var = "x",
                                       change_letter = "g")

#' # To look at string simply return the object
lavaan_uni_lcsm_01

# To get a readable output use cat() function
cat(lavaan_uni_lcsm_01)
```

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