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Description Fit Thurstonian Item Response Theory (IRT) models in R. This package supports fitting Thurstonian IRT models and its extensions using 'Stan', 'lavaan', or 'Mplus' for the model estimation. Functionality for extracting results, making predictions, and simulating data is provided as well. References: Brown & Maydeu-Olivares (2011) <doi:10.1177/0013164410375112>; Bürkner et al. (2019) <doi:10.1177/0013164419832063>.

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`thurstonianIRT-package`

The 'thurstonianIRT' package.

Description

This package fits Thurstonian Item Response Theory (IRT) models using 'Stan', 'lavaan', or 'Mplus'. To bring your data into the right format, use the `make_TIRT_data` function. Models can then be fitted via `fit_TIRT_stan`, `fit_TIRT_lavaan`, or `fit_TIRT_mplus` depending on the desired model fitting engine. Data from Thurstonian IRT models can be simulated via `sim_TIRT_data`.

Author(s)

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- Trustees of Columbia University [copyright holder]

References

Brown, A., & Maydeu-Olivares, A. (2011). Item response modeling of forced-choice questionnaires. Educational and Psychological Measurement, 71(3), 460-502. doi:10.1177/0013164410375112

Bürkner P. C., Schulte N., & Holling H. (2019). On the Statistical and Practical Limitations of Thurstonian IRT Models. Educational and Psychological Measurement. doi:10.1177/0013164419832063

See Also

Useful links:

- https://github.com/paul-buerkner/thurstonianIRT
- Report bugs at https://github.com/paul-buerkner/thurstonianIRT/issues

---

cor_matrix *Set up Correlation Matrices*

Description

Set up Correlation Matrices

Usage

```
cor_matrix(cors, dim, dimnames = NULL)
```

Arguments

cors	vector of unique correlations
dim	Dimension of the correlation matrix
dimnames	Optional dimnames of the correlation matrix

Value

A correlation matrix of dimension dim.

Examples

```
cor_matrix(c(0.2, 0.3, 0.5), dim = 3)
```

`fit_TIRT_lavaan` *Fit Thurstonian IRT models in lavaan*

Description

Fit Thurstonian IRT models in lavaan

Usage

```
fit_TIRT_lavaan(data, estimator = "ULSMV", ...)
```

Arguments

`data`	An object of class `'TIRTdata'`. see `make_TIRT_data` for documentation on how to create one.
`estimator`	Name of the estimator that should be used. See `lavOptions`.
`...`	Further arguments passed to `lavaan`.

Value

A `'TIRTfit'` object.

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
          signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
triplets_long <- make_TIRT_data(
  data = triplets, blocks = blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)


# fit the data using lavaan
fit <- fit_TIRT_lavaan(triplets_long)
print(fit)
predict(fit)
```

`fit_TIRT_mplus` *Fit Thurstonian IRT models in Mplus*

Description

Fit Thurstonian IRT models in Mplus

Usage

```
fit_TIRT_mplus(data, ...)
```

Arguments

`data`	An object of class `'TIRTdata'`. see `make_TIRT_data` for documentation on how to create one.
`...`	Further arguments passed to `mplusModeler`.

Value

A `'TIRTfit'` object.

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
          signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
triplets_long <- make_TIRT_data(
  data = triplets, blocks = blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)

## Not run:
# fit the data using Mplus
fit <- fit_TIRT_mplus(triplets_long)
```

```
print(fit)
predict(fit)

## End(Not run)
```

`fit_TIRT_stan` *Fit Thurstonian IRT models in Stan*

Description

Fit Thurstonian IRT models in Stan

Usage

```
fit_TIRT_stan(data, init = 0, ...)
```

Arguments

`data`	An object of class `'TIRTdata'`. see `make_TIRT_data` for documentation on how to create one.
`init`	Initial values of the parameters. Defaults to `0` as it proved to be most stable.
`...`	Further arguments passed to `rstan::sampling`.

Value

A `'TIRTfit'` object.

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
          signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
triplets_long <- make_TIRT_data(
  data = triplets, blocks = blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)
```

```
# fit the data using Stan
fit <- fit_TIRT_stan(triplets_long, chains = 1)
print(fit)
predict(fit)
```

`gof.TIRTfit` *Extract corrected goodness of fit statistics*

Description

By default **lavaan** will return a value for degrees of freedom that ignores redundancies amongst the estimated model thresholds. This function corrects the degrees of freedom, and then recalculates the associated chi-square test statistic p-value and root mean square error of approximation (RMSEA).

Usage

```
## S3 method for class 'TIRTfit'
gof(object, ...)

gof(object, ...)
```

Arguments

`object`	A `TIRTfit` object.
`...`	currently unused.

Details

Note this function is currently only implemented for **lavaan**.

Value

A vector containing the chi-square value, adjusted degrees of freedom, p-value, and RMSEA.

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
```

```
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
triplets_long <- make_TIRT_data(
  data = triplets, blocks = blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)

# fit the data using lavaan
fit <- fit_TIRT_lavaan(triplets_long)
gof(fit)
```

`make_lavaan_code` *Generate lavaan code for Thurstonian IRT models*

Description

Generate lavaan code for Thurstonian IRT models

Usage

```
make_lavaan_code(data)
```

Arguments

`data`	An object of class `'TIRTdata'`. see `make_TIRT_data` for documentation on how to create one.

Value

A character string of lavaan code for a Thurstonian IRT model.

Examples

```
lambdas <- c(runif(6, 0.5, 1), runif(6, -1, -0.5))
sim_data <- sim_TIRT_data(
  npersons = 100,
  ntraits = 3,
  nblocks_per_trait = 4,
  gamma = 0,
  lambda = lambdas,
  Phi = diag(3)
)
cat(make_lavaan_code(sim_data))
```

make_mplus_code *Generate Mplus code for Thurstonian IRT models*

Description

Generate Mplus code for Thurstonian IRT models

Usage

```
make_mplus_code(data, iter = 1000, eta_file = "eta.csv")
```

Arguments

data	An object of class 'TIRTdata'. see make_TIRT_data for documentation on how to create one.
iter	Maximum number of iterations of the model fitting algorithm.
eta_file	optional file name in which predicted trait scores should be stored.

Value

A list of Mplus code snippets to be interpreted by the **MplusAutomation** package.

Examples

```
sim_data <- sim_TIRT_data(
  npersons = 100,
  ntraits = 3,
  nblocks_per_trait = 4,
  gamma = 0,
  lambda = c(runif(6, 0.5, 1), runif(6, -1, -0.5)),
  Phi = diag(3)
)

# show the created Mplus code
lapply(make_mplus_code(sim_data), cat)
```

make_sem_data *Prepare data for Thurstonian IRT models fitted with lavaan or Mplus*

Description

Prepare data for Thurstonian IRT models fitted with lavaan or Mplus

Usage

```
make_sem_data(data)
```

Arguments

data	An object of class 'TIRTdata'. see make_TIRT_data for documentation on how to create one.

Value

A data.frame ready to be passed to **lavaan** or **Mplus**.

Examples

```
# simulate some data
sdata <- sim_TIRT_data(
  npersons = 100,
  ntraits = 3,
  nblocks_per_trait = 4,
  gamma = 0,
  lambda = c(runif(6, 0.5, 1), runif(6, -1, -0.5)),
  Phi = diag(3)
)

# create data ready for use in SEM software
sem_data <- make_sem_data(sdata)
head(sem_data)
```

---

make_stan_data *Prepare data for Thurstonian IRT models fitted with Stan*

Description

Prepare data for Thurstonian IRT models fitted with Stan

Usage

```
make_stan_data(data)
```

Arguments

data	An object of class data.frame containing data of all variables used in the model.

Value

A list of data ready to be passed to **Stan**.

#' @examples # simulate some data sim_data <- sim_TIRT_data(npersons = 100, ntraits = 3, nblocks_per_trait = 4, gamma = 0, lambda = c(runif(6, 0.5, 1), runif(6, -1, -0.5)), Phi = diag(3))

create data ready for use in Stan stan_data <- make_stan_data(sim_data) str(stan_data)

`make_TIRT_data` *Prepare data for Thurstonian IRT models*

Description

Prepare data for Thurstonian IRT models

Usage

```
make_TIRT_data(
  data,
  blocks,
  direction = c("larger", "smaller"),
  format = c("ranks", "pairwise"),
  family = "bernoulli",
  partial = FALSE,
  range = c(0, 1)
)
```

Arguments

`data`	An object of class `data.frame` containing data of all variables used in the model.
`blocks`	Object of class `TIRTblocks` generated by `set_block` indicating which items belong to which block, trait and more. Ignored if data already contains information on the blocks.
`direction`	Indicates if `"larger"` (the default) or `"smaller"` input values are considered as indicating the favored answer.
`format`	Format of the item responses. Either `"ranks"` for responses in ranked format or `"pairwise"` for responses in pairwise comparison format. If `"ranks"`, each item must have its own column in the data frame which contains its ranks within the block. If `"pairwise"`, each existing item combination must have its own column named after the combination of the two compared items.
`family`	Name of assumed the response distribution. Either `"bernoulli"`, `"cumulative"`, or `"gaussian"`.
`partial`	A flag to indicate whether partial comparisons are allowed for responses stored in the `"ranks"` format.
`range`	Numeric vector of length two giving the range of the responses when using the `"pairwise"` format. Defaults to `c(0, 1)` for use with dichotomous responses.

Value

A `data.frame` in a specific format and with attributes ready for use with other functions of the **ThurstonianIRT** package.

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
          signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
triplets_long <- make_TIRT_data(
  data = triplets, blocks = blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)


# fit the data using Stan
fit <- fit_TIRT_stan(triplets_long, chains = 1)
print(fit)
predict(fit)
```

`predict.TIRTfit` *Predict trait scores of Thurstonian IRT models*

Description

Predict trait scores of Thurstonian IRT models

Usage

```
## S3 method for class 'TIRTfit'
predict(object, newdata = NULL, ...)
```

Arguments

`object`	An object of class `TIRTfit`.
`newdata`	Optional `TIRTdata` object (created via `make_TIRT_data`) containing data of new persons for which trait scores should be predicted based on the fitted model. If `NULL` (the default), trait scores are predicted for the persons whose data was used to originally fit the model.
`...`	Further arguments passed to the underlying methods.

Details

When predicting trait scores of new persons (via `newdata`), posterior medians of item parameters are used for predictions. This implies that the uncertainty in the new trait scores is underestimated as the uncertainty in the (posterior distribution of) item parameters is ignored.

Value

A data frame with predicted trait scores.

`set_block` *Prepare blocks of items*

Description

Prepare blocks of items and incorporate information about which item belongs to which trait. A block of items is a set of two or more items presented and answered together by fully ranking them or selecting the most and/or least favorit in a forced choice format. A whole test usually contains several blocks and items may reappear in different blocks.

Usage

```
set_block(items, traits, names = items, signs = 1)

empty_block()
```

Arguments

`items`	Names of item comparisons to be combined into one block. Should correspond to variables in the data.
`traits`	Names of the traits to which each item belongs
`names`	Optional names of the items in the output. Can be used to equate parameters of items across blocks, if the same item was used in different blocks.
`signs`	Expected signs of the item loadings (1 or -1).

See Also

`set_blocks_from_df`

Examples

```
set_block(
  items = c("i1", "i2", "i3"),
  traits = c("A", "B", "C")
) +
set_block(
  items = c("i4", "i5", "i6"),
  traits = c("A", "B", "C")
```

```
)

# Support items i1 and i4 were the same so that they have the same parameters
set_block(
  items = c("i1", "i2", "i3"),
  traits = c("A", "B", "C"),
  names = c("item1", "item2", "item3")
) +
set_block(
  items = c("i4", "i5", "i6"),
  traits = c("A", "B", "C"),
  names = c("item1", "item5", "item6")
)
```

`set_blocks_from_df` *Prepare blocks of items from a data frame*

Description

Prepare blocks of items and incorporate information about which item belongs to which trait from a pre-existing dataframe. This is a wrapper function for `set_block`, eliminating the need to manually set each item, trait, name and sign (loading) info per block.

Usage

```
set_blocks_from_df(
  data,
  blocks = "block",
  items = "item",
  traits = "trait",
  names = items,
  signs = "sign"
)
```

Arguments

`data`	A `data.frame` containing all the required columns (see the arguments below) to specify the item blocks.
`blocks`	Name of column vector denoting the block each item corresponds to. Each block must have an equal number of items.
`items`	Name of column vector denoting items to be combined into one block. Should correspond to variables in the data.
`traits`	Names of column vector denoting the traits to which each item belongs.
`names`	Optional column vector of item names in the output. Can be used to equate parameters of items across blocks, if the same item was used in different blocks.
`signs`	Name of column vector with expected signs of the item loadings (1 or -1).

Details

A block of items is a set of two or more items presented and answered together by fully ranking them or selecting the most and/or least favorite in a forced choice format. A whole test usually contains several blocks and items may reappear in different blocks.

See Also

set_block

Examples

```
block_info <- data.frame(
  block = rep(1:4, each = 3),
  items = c("i1", "i2", "i3", "i4", "i5", "i6",
            "i7", "i8", "i9", "i10", "i11", "i12"),
  traits = rep(c("t1", "t2", "t3"), times = 4),
  signs = c(1, 1, 1, -1, 1, 1, 1, 1, -1, 1, -1, 1)
)

blocks <- set_blocks_from_df(
  data = block_info,
  blocks = "block",
  items = "items",
  traits = "traits",
  signs = "signs"
)
```

---

sim_TIRT_data *Simulate Thurstonian IRT data*

Description

Simulate Thurstonian IRT data

Usage

```
sim_TIRT_data(
  npersons,
  ntraits,
  lambda,
  gamma,
  psi = NULL,
  Phi = NULL,
  eta = NULL,
  family = "bernoulli",
  nblocks_per_trait = 5,
  nitems_per_block = 3,
  comb_blocks = c("random", "fixed")
)
```

Arguments

npersons	Number of persons.
ntraits	Number of traits.
lambda	Item factor loadings.
gamma	Baseline attractiveness parameters of the first item versus the second item in the pairwise comparisons. Can be thought of as intercept parameters.
psi	Optional item uniquenesses. If not provided, they will be computed as psi = 1 - lambda^2 in which case lambda are taken to be the standardized factor loadings.
Phi	Optional trait correlation matrix from which to sample person factor scores. Only used if eta is not provided.
eta	Optional person factor scores. If provided, argument Phi will be ignored.
family	Name of assumed the response distribution. Either "bernoulli", "cumulative", or "gaussian".
nblocks_per_trait	Number of blocks per trait.
nitems_per_block	Number of items per block.
comb_blocks	Indicates how to combine traits to blocks. "fixed" implies a simple non-random design that may combine certain traits which each other disproportionally often. We thus recommend to use a "random" block design (the default) that combines all traits with all other traits equally often on average.

Value

A data.frame of the same structure as returned by make_TIRT_data. Parameter values from which the data were simulated are stored as attributes of the returned object.

Examples

```
# simulate some data
sdata <- sim_TIRT_data(
  npersons = 100,
  ntraits = 3,
  nblocks_per_trait = 4,
  gamma = 0,
  lambda = c(runif(6, 0.5, 1), runif(6, -1, -0.5)),
  Phi = diag(3)
)

# take a look at the data
head(sdata)
str(attributes(sdata))


# fit a Thurstonian IRT model using lavaan
fit <- fit_TIRT_lavaan(sdata)
print(fit)
```

`triplets` *Triplets of Pairwise Comparisons*

Description

This data set contains synthetic data of the first 200 out of a total of 2000 participants on 4 triplets, originally generated as part of Brown and Maydeu-Olivares (2012). In each triplet, participants had to rank the three alternative items according to their preference. Responses were then converted into a set of dichotomous pairwise responses between all the three alternatives. More details can be found in Brown and Maydeu-Olivares (2012).

Usage

```
triplets
```

Format

A data frame of 200 observations containing information on 12 variables. Overall, the 12 items measure 3 different traits. Items 1, 4, 7, and 10 load on trait 1, items 2, 5, 8, and 11 load on trait 2, and items 3, 6, 9, and 12 load on trait 3. Moreover, items 4, 9, and 11 are inverted.

i1i2 Response preferences between item 1 and 2.

i1i3 Response preferences between item 1 and 3.

i2i3 Response preferences between item 2 and 3.

i4i5 Response preferences between item 4 and 5.

i4i6 Response preferences between item 4 and 6.

i5i6 Response preferences between item 5 and 6.

i7i8 Response preferences between item 7 and 8.

i7i9 Response preferences between item 7 and 9.

i8i9 Response preferences between item 8 and 9.

i10i11 Response preferences between item 10 and 11.

i10i12 Response preferences between item 10 and 12.

i11i12 Response preferences between item 11 and 12.

Source

Brown, A. & Maydeu-Olivares, A. (2012). Fitting a Thurstonian IRT model to forced-choice data using Mplus. Behavior Research Methods, 44, 1135–1147. DOI: 10.3758/s13428-012-0217-x

Examples

```
# load the data
data("triplets")

# define the blocks of items
blocks <-
  set_block(c("i1", "i2", "i3"), traits = c("t1", "t2", "t3"),
          signs = c(1, 1, 1)) +
  set_block(c("i4", "i5", "i6"), traits = c("t1", "t2", "t3"),
            signs = c(-1, 1, 1)) +
  set_block(c("i7", "i8", "i9"), traits = c("t1", "t2", "t3"),
            signs = c(1, 1, -1)) +
  set_block(c("i10", "i11", "i12"), traits = c("t1", "t2", "t3"),
            signs = c(1, -1, 1))

# generate the data to be understood by 'thurstonianIRT'
tdat <- make_TIRT_data(
  triplets, blocks, direction = "larger",
  format = "pairwise", family = "bernoulli", range = c(0, 1)
)


# fit the data using Stan
fit <- fit_TIRT_stan(tdat, chains = 1)
print(fit)
predict(fit)
```

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