

Package ‘mokken’

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Title Conducts Mokken Scale Analysis

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Depends R (>= 3.5.0), graphics, polCA

Suggests MASS

Description Contains functions for performing Mokken
scale analysis on test and questionnaire data.
It includes an automated item selection algorithm, and various checks of model assumptions.

License GPL (>= 2)

URL <https://sites.google.com/a/tilburguniversity.edu/avdrark/mokken>

LinkingTo Rcpp

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mokken-package	<i>Mokken Scale Analysis</i>
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Description

Mokken scale analysis (Mokken, 1971; Sijtsma & Molenaar, 2002; Sijtsma & Van der Ark, 2017) is a scaling procedure for both dichotomous and polytomous items. It consists of an item selection algorithm to partition a set of items into Mokken scales and several methods to check the assumptions of two nonparametric item response theory models: the monotone homogeneity model and the double monotonicity model. The output of this R-package resembles the output of the stand-alone program MSP (Molenaar & Sijtsma, 2000).

Details

Package:	mokken
Type:	Package
Version:	3.0.3
Date:	2020-09-15
License:	GPL Version 2 or later

The package contains principal functions for Mokken scale analysis.

The package contains the following data sets

<code>acl</code>	Scores on a personality checklist.
<code>cavalini</code>	Scores on an inventory on industrial malodor
<code>transreas</code>	Scores on a transitive reasoning test
<code>DS14</code>	Scores on a Type D test (bootstrap sample)
<code>autonomySupport</code>	Scores from students on their teacher's autonomy support
<code>SWMD</code>	Scores from pupils nested in classrooms on their well-being with teachers

A guide for Mokken scale analysis in R for people who do not know R (Van der Ark, 2010) is available as a vignette from <https://sites.google.com/a/tilburguniversity.edu/avdrark/mokken>. The Mokken package was created by Andries van der Ark, who is also the maintainer. Significant parts have been developed by Letty Koopman (multilevel analysis) and Don van den Berg and Hendrik Straat (all C and C++ codes). Thanks are due to Michael Allerhand, Geert H. van Kollenburg, Renske E. Kuijpers, Rudy Ligtoet, Hannah E. M. Oosterhuis, Daniel W. van der Palm, and Max Welz for contributing R code; to Geert H. van Kollenburg, Patrick Mair, and Don van Ravenswaaij for testing the software; to Wijbrandt van Schuur for comments on the vignette; to Michael Allerhand, Stephen Cubbellotti, Michael Dewey, Jasmin Durstin, Wilco H. M. Emons, Jue Huang, Michael Kubovy, Ivo Molenaar, Jonathan Rose, Tobias Schlaffer, Klaas Sijtsma, Iris Smits, Jia Jia Syu, Stefan Vermeent, Roger Watson, Max Welz, and Na Yang for reporting comments or bugs; to Diederick Stoel (ProfitWise) for financial support, to Harrie C. M. Vorst, Pierre Cavalini, and Johan Denollet for permission to use their data; to Robert J. Mokken for lending his last name.

Version 0 was introduced in Van der Ark (2007). It included the functions

<code>coefH</code>	Scalability coefficients
<code>coefZ</code>	Test statistics for scalability coefficients
<code>check.monotonicity</code>	Investigate monotonicity assumptions
<code>check.restscore</code>	Investigate nonintersection assumption using Method Restscore
<code>check.pmatrix</code>	Investigate nonintersection assumption using Method Pmatrix
<code>search.normal</code>	Mokken's automated item selection algorithm

The following major modifications have been made.

<code>aisp</code>	More general automated item selection algorithm. Function search has become obsolete (Version 2.0)
<code>check.reliability</code>	Compute reliability coefficients (Version 2.0)
<code>check.iio</code>	Investigate invariant item orderings (Version 2.4)
<code>coefH</code>	Standard errors for scalability coefficients included (Version 2.6)

All updates until version 2.7 are described in Van der Ark (2012). The following modifications have been made in Version 2.7 in comparison to previous versions.

<code>check.errors</code>	Inclusion new function to compute weighted Guttman errors for each person.
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<code>check.iio</code>	plot has been added.
<code>check.monotonicity</code>	Computation of number of active pairs for dichotomous items has been corrected.
<code>check.pmatrix</code>	Summary of the results has been corrected.
<code>check.restscore</code>	Code pertaining to IIO has been deleted. The procedure is now equivalent to MSP.
<code>coefH</code>	Option included to compare scalability coefficients across groups

The following modifications have been made in Version 2.7.1 in comparison to previous versions.

`mokken` Some legal issues

The following modifications have been made in Version 2.7.2 in comparison to previous versions.

`check.iio` Violations of IIO for dichotomous items are now tested using a z-test rather than a t-test.

The following modifications have been made in Version 2.7.3 in comparison to previous versions.

<code>plot.iio.class</code>	Confidence envelopes around estimated response functions
<code>plot.monotonicity.class</code>	Confidence envelopes around estimated response functions
<code>plot.restscore.class</code>	Confidence envelopes around estimated response functions

The following modifications have been made in Version 2.8.1 in comparison to previous versions.

`aisp` Startsets have been added

The following modifications have been made in Version 2.8.2 in comparison to previous versions.

<code>recode</code>	New
<code>check.ca</code>	New
<code>check.norms</code>	New
<code>check.errors</code>	Outlier score O+ has been included

The following modifications have been made in Version 2.8.3 in comparison to previous versions.

<code>twoway</code>	New
<code>DS14</code>	New data set
<code>check.errors</code>	Outlier cutoff scores have been included

The following modifications have been made in Version 2.8.4 in comparison to previous versions.

`check.iio` New code for computing HT for large samples

The following modifications have been made in Version 2.8.5 in comparison to previous versions.

<code>MLcoefH</code>	New code for computing two-level scalability coefficients and standard errors
<code>autonomySupport</code>	New two-level data set.

The following modifications have been made in Version 2.8.9 and 2.8.10 in comparison to previous versions.

<code>coefH</code>	Included possibility to include a fixed item-step order
<code>MLcoefH</code>	Code updated
<code>check.errors</code>	Code updated

The following modifications have been made in Version 2.8.11 in comparison to previous versions.

<code>plot</code>	The level of transparency of the plotted confidence intervals can be adjusted manually
<code>MLcoefH</code>	Code updated

The following modifications have been made in Version 2.8.12 in comparison to previous versions.

<code>check.monotonicity</code>	Z statistic adjusted (Molenaar & Sijtsma, 2000. p. 72)
<code>check.norms</code>	Z Output corrected for <code>nice.output = FALSE</code>

The following modifications have been made in Version 2.9.0 in comparison to previous versions.

<code>coefH</code>	Z Solution of Koopman et al. (2017) implemented to solve the problem of equal item steps and code updated
<code>MLcoefH</code>	Z Solution of Koopman et al. (2017) implemented to solve the problem of equal item steps and code updated

The following modifications have been made in Version 3.0.0 in comparison to previous versions.

<code>aisp</code>	Genetic algorithm has been reprogrammed and is now much faster. Argument lowerbound can now be a vector, enabling the investigation of several lower bounds simultaneously. Extra argument to specify which standard errors should be used in Z-test (Koopman et al., 2020b). Extra argument to indicate which null-hypothesis should be used to test H_i (i.e., $H_i = c$ or $H_i = 0$)(Koopman et al. 2020a). Extra argument to handle nested data (Koopman et al., 2020b).
<code>check.iio</code>	Computation of Coefficient HT for large samples is now much faster.
<code>coefH</code>	New standard errors for nested data (Koopman et al. 2020a).
<code>coefZ</code>	Extra argument to compute the Z-score using lowerbound as the null hypothesis (Koopman et al., 2020b). Extra argument to compute Z-score using delta method standard error, but the original method remains available. Extra argument to compute Z-score in nested data (Koopman et al., 2020b).
<code>ICC</code>	New function for ICCs in two-level Mokken scale analysis (Koopman et al. 2020a)

MLcoefH	Extra argument for weighted proportions. Reduces bias in two-level standard errors (Koopman et al. 2020a) Extra argument for a fixed item-step order
SWMD	New data file (Koopman et al. 2020a)

The following modifications have been made in Version 3.0.3 in comparison to previous versions.

coefZ	Error handling added
	The delta test uses range-preserving asymptotic theory (Koopman, Zijlstra, & Van der Ark, 2020c)
coefH	Range-preserving confidence intervals added (Koopman et al., 2020c) Extra argument to print variance-covariance matrices of estimated coefficients Error handling added for more than 10 response categories
MLcoefH	Range-preserving confidence intervals added (Koopman et al., 2020c) Extra argument to print variance-covariance matrices of estimated coefficients
MLcoefZ	New function for z-scores of two-level scalability coefficients (Koopman et al., 2020c)
aisp	type.se default adjusted and additional error handling added
check.errors	Repaired bug in check.errors
mcmi	New data file (Sijtsma & van der Ark, 2020)
All functions	A warning has been added if items have different numbers of response categories

Author(s)

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References

Koopman, L., Zijlstra, B. J. H., & Van der Ark, L. A. (2020a). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.

Koopman, L., Zijlstra, B. J. H., & Van der Ark, L. A. (2020b). New advances in Mokken scale analysis. Paper presented at the online meeting of the Psychometric Society, July, 2020.

Koopman, L., Zijlstra, B. J. H., & Van der Ark, L. A. (2020c). Range-preserving confidence intervals for scalability coefficients in Mokken scale analysis. Manuscript in preparation.

Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.

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Sijtsma, K., & Van der Ark, L. A. (2017). A tutorial on how to do a Mokken scale analysis on your test and questionnaire data. *British Journal of Mathematical and Statistical Psychology*, 70, 137-158. <https://doi.org/10.1111/bmsp.12078>

Sijtsma, K., & Van der Ark, L. A. (2020), *Measurement models for psychological attributes*. Boca Raton, FL: Chapman and Hall/CRC Press. <https://www.routledge.com/Measurement-Models-for-Psychological-Attributes/Sijtsma-Ark/p/book/9780367424527>

Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*, 20(11), 1-19. <https://www.jstatsoft.org/article/view/v020i11>

Van der Ark, L. A. (2010). Getting started with Mokken scale analysis in **R**. Unpublished manuscript. <https://sites.google.com/a/tilburguniversity.edu/avdrark/mokken>

Van der Ark, L. A. (2012). New developments in Mokken scale analysis in **R**. *Journal of Statistical Software*, 48(5), 1-27. <https://www.jstatsoft.org/article/view/v048i05>

Examples

```
# Personality test
data(acl)

# Select the items of the scale Communality
Communality <- acl[,1:10]

# Compute scalability coefficients
coefH(Communality)

# Investigate the assumption of monotonicity
monotonicity.list <- check.monotonicity(Communality)
summary(monotonicity.list)
plot(monotonicity.list)

# Investigate the assumption of non-intersecting ISRFs using method restscore
restscore.list <- check.restscore(Communality)
summary(restscore.list)
plot(restscore.list)

# Investigate the assumption of non-intersecting ISRFs using method pmatrix
pmatrix.list <- check.pmatrix(Communality)
summary(pmatrix.list)
plot(pmatrix.list)

# Investigate the assumption of IIO using method MIIO
iio.list <- check.iio(Communality)
summary(iio.list)
plot(iio.list)

# Compute the reliability of the scale
check.reliability(Communality)

# Partition the the scale into mokken scales
aisp(Communality)
```

acl

Adjective Checklist Data

Description

Scores of 433 students on 218 items from a Dutch version of the Adjective Checklist.

Usage

```
data(acl)
```

Format

A 433 by 218 matrix containing integers. `dimnames(acl)[[2]]` are adjectives

Details

Each item is an adjective with five ordered answer categories (0 = completely disagree, 1 = disagree, 2 = agree nor disagree, 3 = agree, 4 = completely agree). The respondents were instructed to consider whether an adjective described their personality, and mark the answer category that fits best to this description. The 218 items constitute 22 scales (see table); 77 items of the 218 items that constitute the ten scales were negatively worded. The negatively worded items are indicated by an asterisk in the `dimnames` and their item scores have been reversed. The Deference scale measures in fact the opposite of Deference.

Communality	Items 1-10	Change	Items 111-119
Achievement	Items 11-20	Succorance	Items 120-129
Dominance	Items 21-30	Abasement	Items 130-139
Endurance	Items 31-40	Deference*	Items 140-149
Order	Items 41-50	Personal Adjustment	Items 150-159
Intracception	Items 51-60	Ideal Self	Items 160-169
Nurturance	Items 61-70	Critical parent	Items 170-179
Affiliation	Items 71-80	Nurturant parent	Items 180-189
Exhibition	Items 81-90	Adult	Items 190-199
Autonomy	Items 91-100	Free Child	Items 200-209
Aggression	Items 101-110	Adapted Child	Items 210-218

Source

Data were kindly made available by H. C. M. Vorst from the University of Amsterdam. The original Adjective Checklist was developed by Gough and Heilbrun (1980).

References

Gough, H. G., & Heilbrun, A. B. (1980) *The Adjective Check List, Manual 1980 Edition*. Consulting Psychologists Press.

Van der Ark, L. A. (2007) Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

Examples

```
data(acl)
```

aisp *Automated Item Selection Procedure (AISP) for Mokken Scale Analysis*

Description

Returns a matrix with as many rows as there are items, indicating to which scale an item belongs for each lowerbound.

Usage

```
aisp(X, lowerbound=.3, search="normal", alpha=.05, StartSet=FALSE, popsize=20,
maxgens=default.maxgens, pxover=0.5, pmutation=0.1, verbose=FALSE,
type.se = "Z", test.Hi = FALSE, level.two.var = NULL)
```

Arguments

X	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X)$ items. Missing values are not allowed
search	Type of item selection procedure: "normal": Mokken's automated item selection procedure (Mokken, 1971; Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002); "ga": item selection using a genetic algorithm (Straat, van der Ark, & Sijtsma, 2013). The default is "normal".
lowerbound	Value or vector with numeric scaling criteria; $0 \leq \text{lowerbound} < 1$. The default is 0.3.
alpha	Type I error level. The default is 0.05.
StartSet	Startset of items for the first scale. Vector of item numbers. If StartSet == FALSE no startset is provided (default).
popsize	Size of the population of items in genetic algorithm. The default is 20.
maxgens	Number of generations in genetic algorithm. The default is $10^{(\log_2(ncol(X))/5)} * 1000$.
pxover	Cross-over probability in genetic algorithm. The default is 0.5.
pmutation	Mutation probability in genetic algorithm. The default is 0.1.
verbose	Logical, indicating whether should output to the screen the results of the model. If FALSE, no output is produced. The default is TRUE.
type.se	Indicates which type of standard errors is used in a Z-test whether coefficients meet the scaling criteria: "delta": uses standard errors approximated by the delta method (Kuijpers, Van der Ark, Kroon, 2013; Koopman, Zijlstra, Van der Ark, 2020); "Z": uses original Z-test (Mokken, 1971; Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002). The default is "Z", but is automatically changed to "delta" for test.Hi == TRUE or if a level.two.var is given.
test.Hi	If FALSE: tests if Hi is significantly larger than zero; If TRUE tests if Hi is significantly larger than lowerbound. The default is FALSE.
level.two.var	vector of length $nrow(X)$ or matrix with number of rows equal to $nrow(X)$ that indicates the level two variable for nested data (Koopman et al., 2020).

Details

Each scale must consist of at least two items, hence the number of Mokken scales cannot exceed $\text{ncol}(X)/2$. Procedure may be slow for large data sets. Especially if the genetic algorithm is used. There is not yet an option `search="extended"`. `aisp` replaces the function `search.normal` in earlier versions.

Value

An matrix with `J` rows. Each entry refers to an item. Items with same integer belong to the same Mokken scale. A zero indicates an unscalable item. If n is the largest integer, then n Mokken scales were found.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>, J. H. Straat, L. Koopman

References

- Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.
- Kuijpers, R. E., Van der Ark, L. A., & Croon, M. A. (2013). Standard errors and confidence intervals for scalability coefficients in Mokken scale analysis using marginal models. *Sociological Methodology*, 43, 42-69. <https://doi.org/10.1177/0081175013481958>
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- Van der Ark, L. A. (2012). New developments in Mokken scale analysis in **R**. *Journal of Statistical Software*, 48. <https://www.jstatsoft.org/article/view/v048i05>

See Also

[coefH](#), [check.iio](#), [check.monotonicity](#), [check.pmatrix](#), [check.reliability](#), [check.restscore](#)

Examples

```
data(acl)

# Select the scale Commuality consisting of 10 items.
Commuality <- acl[,1:10]

# Partition these 10 items into mokken scales using Mokken's automated item selection procedure.
```

```

scale <- aisp(Communality)
coefH(Communality[,scale==1])

# Same but using items 1 and 2 in the startset.
scale <- aisp(Communality, StartSet = c(1, 2), verbose = TRUE)
coefH(Communality[,scale==1])

# Perform aisp for increasing lowerbounds

scales <- aisp(Communality, lowerbound = seq(0, .55, .05))
scales

# Use a significant test for criteria  $H_i > c$  (rather than the point estimate)
scale <- aisp(Communality, type.se = "delta", test.Hi = TRUE, verbose = TRUE)
coefH(Communality[,scale==1])

# Partition these 10 items into mokken scales using a genetic algorithm.
scale <- aisp(Communality, search="ga", maxgens=1000)
coefH(Communality[,scale==1])

# Perform aisp on two-level data
data(autonomySupport)
scores <- autonomySupport[, -1]
classes <- autonomySupport[, 1]
scale <- aisp(scores, type.se = "delta", level.two.var = classes)
coefH(scores[, scale==1], level.two.var = classes)

```

autonomySupport

Autonomy Support Data

Description

A two-level dataset with scores of 14 teachers who are rated by a group of pupils on 7 items from a Dutch Autonomy Support questionnaire (group size ranged between 5 and 39 pupils, total number of pupils is 259).

Usage

```
data(autonomySupport)
```

Format

A 259 by 8 data frame containing integers. The first column reflects a teacher indicator, the remaining columns the 7 items, see `colnames(autonomySupport)`.

Details

Each item has five ordered answer categories from *not at all/never* (score 1) to *certainly/always* (score 5). The items reflect several autonomy supportive behaviours from teachers.

<i>Item</i>	<i>Short</i>	<i>Content</i>
Item 1	Choose	The teacher lets me choose what I am going to do
Item 2	Decide	The teacher decides which task I will start with (inversely coded)
Item 3	Task	I get to choose which task I will start with
Item 4	Listen	The teacher listens to me when I disagree with something
Item 5	Help	The teacher helps me when I ask for it
Item 6	Accept	The teacher accepts me for who I am
Item 7	Understand	The teacher helps me when I do not understand a task

Source

The seven items are a subset from a self-constructed 27-item questionnaire on teacher's autonomy support. Data were collected and made available by L. Koopman from the University of Amsterdam.

References

Koopman, L., Zijlstra, B. J. H. & Van der Ark, L. A., (2019). Standard errors of two-level scalability coefficients. *British Journal of Statistical and Mathematical Psychology*, 73, 213-236. <https://doi.org/10.1111/bmsp.12174>

See Also

[MLcoefH](#),

Examples

```
data(autonomySupport)
```

cavalini

Coping Strategies

Description

Data came from 17 polytomous items administered to 828 respondents (Cavalini, 1992) asking them how they coped actively with the bad smell from a factory in the neighborhood of their homes.

Usage

```
data(cavalini)
```

Format

A 828 by 17 matrix containing integers. `attributes(cavalini)` gives details on the items.

Details

Items have four ordered answer categories, *never* (score 0), *seldom* (1), *often* (2), and *always* (3). The 17 items constitute 4 scales (for detailed information, see Sijtsma & Molenaar, 2002, pp. 82-86).

Item1	Keep windows closed
Item2	No laundry outside
Item3	Search source of malodor
Item4	No blankets outside
Item5	Try to find solutions
Item6	Go elsewhere for fresh air
Item7	Call environmental agency
Item8	Think of something else
Item9	File complaint with producer
Item10	Acquiesce in odor annoyance
Item11	Do something to get rid of it
Item12	Say “it might have been worse”
Item13	Experience unrest
Item14	Talk to friends and family
Item15	Seek diversion
Item16	Avoid breathing through the nose
Item17	Try to adapt to situation

References

Cavalini, P. M. (1992). *It's an ill wind that brings no good. Studies on odour annoyance and the dispersion of odorant concentrations from industries*. Unpublished doctoral dissertation. University of Groningen, The Netherlands.

Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.

See Also

[check.iio](#),

Examples

```
data(cavalini)
attributes(cavalini)$labels
```

check.bounds

Check the relative lower bound for scalability coefficients

Description

Returns the relative bounds for Mokken's scalability coefficients for dichotomous items as described by Ellis (2014).

Usage

```
check.bounds(X, quant = .90, lower = TRUE, upper = FALSE)
```

Arguments

X	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X)$ items. Missing values are not allowed
quant	numerical value between 0 and 1 used for the computation of lower bound $L2rij$. The computation deviates somewhat from the proposal in Ellis (2014) because the <code>stats</code> function <code>quantile</code> is used.
lower	Boolean: If TRUE, the lower bounds are given.
upper	Boolean: If TRUE, the upper bounds are given.

Value

List containing two lists `UpperBounds` and `LowerBounds`, each containing a list of two $J \times J$ matrices ($J =$ number of items): $L1rij$ (overestimator of the lower bound for the correlation) and $L2rij$ (underestimator of the lower bound for the correlation).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

Ellis, J. L. (2014). An inequality for correlations in unidimensional monotone latent variable models for binary variables. *Psychometrika*, 79, 303-316. <https://doi.org/10.1007/S11336-013-9341-5>

Examples

```
data(acl)
Communality <- acl[,1:10]
R <- cor(Communality)
res <- check.bounds(Communality, upper = TRUE)
L1rij <- res$LowerBounds$L1rij
L2rij <- res$LowerBounds$L2rij
U1rij <- res$UpperBounds$U1rij
U2rij <- res$UpperBounds$U2rij
# Correlations that meet L1rij (possibly an overestimation of the lower bound).
R >= L1rij
# Correlations that meet U1rij (possibly an overestimation of the upper bound).
R <= U1rij
# Correlations that meet L2rij (possibly an underestimation of the lower bound).
R >= L2rij
# Correlations that meet U2rij (possibly an underestimation of the upper bound).
R <= U2rij
```

check.ca *Check conditional association to indentify local dependence.*

Description

The function uses three special cases of conditional association (CA; Holland & Rosenbaum, 1986) to identify positive and negative local dependence in the monotone homogeneity model. Straat, Van der Ark, and Sijtsma (2016; also, see Sijtsma, Van der Ark, & Straat, 2015) described the procedure.

Usage

```
check.ca(X, Windex = FALSE, MINSIZE = 4, NWEIGHTOPTION = "noweight",
         COVWEIGHTOPTION = "pnorm", MINGROUP = 4)
```

Arguments

X	Matrix of integers, missing values are not allowed
Windex	Boolean. Should output contain indices W1, W2, and W3?
MINSIZE	Minimum sample size of a rest-score group
NWEIGHTOPTION	Weight of sample size on each conditional covariance. Options: "noweight" (each covariance has weight 1, default in Straat et al., 2016) and "sqrt" (each covariance has weight $\sqrt{N_k(x)}$), this option was used in an older, decrepit, version of Straat et al., 2016)
COVWEIGHTOPTION	Weight of each conditional covariance on the computation of W1, W2, and W3. Options: "pnorm" (weight equals $P[\text{cov} < 0]$, default in Straat et al., 2014) and "noweight" (if $\text{cov} < 0$, then weight = 1, and weight = 0, otherwise; this option was used in a previous version of Straat et al., 2014)
MINGROUP	Minimum sample size of the conditioning variable to compute a covariance. Since the term $N-3$ is used in the computation of the standard error, $N = 4$ is the default.

Value

list of three components:

- (1) InScale (vector of booleans with length equal to the number of items): indicates whether an item is still in the scale.
- (2) Index (list): Numerical values of indices W1, W2, and W3 (shown only if Windex = TRUE). Index has three subcomponents: W1, W2, and W3.
- (3) Flagged (list): Boolean indicating whether a value of W1, W2, and W3 is flagged (1) or not (0) (shown only if Windex = TRUE) Index has three subcomponents: F1, F2, and F3, corresponding to the flagging of indices W1, W2, and W3, respectively.

Subcomponents correspond to the iteration. The first subcomponent refers to the situation with all items in the test, the second subcomponent refers to the situation with the worst item deleted, the third subcomponent refers to the situation with the two worst items deleted, etc.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl> and J. H. Straat

References

Straat, J. H., Van der Ark, L. A., & Sijtsma, K. (2016). Using conditional association to identify locally Independent item sets. *Methodology*, *12*, 117-123. <https://doi.org/10.1027/1614-2241/a000115>

Sijtsma, K., van der Ark, L. A., & Straat, J. H. (2015) Goodness of fit methods for nonparametric IRT models. In L. A. van der Ark, D. M. Bolt, W.-C. Wang, J. Douglas, & S.-M. Chow (Eds.), *Quantitative psychology research: The 79th Annual Meeting of the Psychometric Society, Madison, Wisconsin, 2014*. (pp. 109 - 120) Springer. https://doi.org/10.1007/978-3-319-19977-1_9

See Also

[DS14](#), [recode](#), [twoway](#)

Examples

```
data(DS14)

# Handle missing data and recode negatively worded items
X <- DS14[, 3 : 16]
X <- twoway(X)
X <- recode(X, c(1, 3))

# Negative affectivity
Na <- X[, c(1, 3, 6, 8, 10, 11, 14)]

# Social inhibition
Si <- X[, c(2, 4, 5, 7, 9, 12, 13)]

check.ca(Na, TRUE)
```

check.errors

Check the number of Guttman errors (Gplus) and the number of infrequent scores (Oplus) for each respondent

Description

Returns a list containing outlier scores Gplus (number of Guttman errors; Guttman, 1944) and Oplus for each respondent (Zijlstra, van der Ark & Sijtsma, 2007).

Usage

```
check.errors(X, returnGplus = TRUE, returnOplus = FALSE)
```

Arguments

X	matrix or data frame of numeric data containing the responses of nrow(X) respondents to ncol(X) items. Missing values are not allowed
returnGplus	Boolean. If TRUE the output contains outlier score Gplus
returnOplus	Boolean. If TRUE the output contains outlier score Oplus

Value

List. Depending on the values of returnGplus and returnOplus, the output contains outlier score Gplus (the number of Guttman errors) and Oplusfor each respondent

Author(s)

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References

- Guttman, L. (1944) A basis for scaling qualitative data. *American Sociological Review*, 9, 139-150.
- Meijer, R. R. (1994) The number of Guttman errors as a simple and powerful person-fit statistic. *Applied Psychological Measurement*, 18, 311-314. <https://doi.org/10.1177/014662169401800402>
- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in R. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>
- Zijlstra, W. P., Van der Ark, L. A., & Sijtsma, K. (e2007). Outlier detection in test and questionnaire data. *Multivariate Behavioral Research*, 42, 531-555. <https://doi.org/10.1080/00273170701384340>

See Also

[check.ca](#), [check.iio](#), [check.monotonicity](#), [check.pmatrix](#), [check.reliability coefH](#), [plot.restscore.class](#), [summary.restscore.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
Gplus <- check.errors(Communality, TRUE, FALSE)$Gplus
Oplus <- check.errors(Communality, FALSE, TRUE)$Oplus

hist(Gplus, breaks = 0:max(Gplus))
```

check.iio

*Check of Invariant Item Ordering***Description**

Returns a list (of class `iio.class`) with results from the investigation of invariant item ordering. Three methods may be used for the investigation of invariant item ordering. (1) Method MIIO (manifest invariant item ordering: investigates the manifest item response functions for all pairs of items). For polytomous items, t-tests are used to test violations, for dichotomous items z-tests are used to test violations. (2) Method MS-CPM (manifest scale - cumulative probability model: investigates the manifest item step response functions for all pairs of items). Z-tests are used to test violations. (3) Method IT (increasingness in transposition: investigates all bivariate joint probabilities for all pairs of items). Chi-square tests are used to test violations.

For a complete description of Method MIIO, see Ligtvoet, Van der Ark, Te Marvelde, and Sijtsma (2010); for a complete description of the Method MS-CPM and Method IT with reference to Method MIIO, see Ligtvoet, Van der Ark, Bergsma, and Sijtsma (2011).

Usage

```
check.iio(X, method="MIIO", minvi = default.minvi, minsize = default.minsize,
alpha = .05, item.selection=TRUE, verbose=FALSE)
```

Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X)$ items. Missing values are not allowed
<code>method</code>	Either "MIIO" (default), "MSCPM", or "IT". Partial matching is allowed (e.g. <code>method="ms"</code> is equivalent to <code>method="MSCPM"</code>)
<code>minvi</code>	minimum size of a violation that is reported. By default <code>minvi = .03</code> times the number of item step response functions (m) for Method MIIO; <code>minvi = .03</code> for Method IT and Method MSCPM
<code>minsize</code>	minimum size of a rest score group. By default <code>minsize = N/10</code> if $N \geq 500$; <code>minsize = N/5</code> if $250 \leq N < 500$; and <code>minsize = max(N/3, 50)</code> if $N < 250$
<code>alpha</code>	Nominal Type I error for t test (Method MIIO), z test (Method MSCPM), or McNemar test (Method IT). Default <code>alpha = .05</code>
<code>item.selection</code>	Conduct backward item selection procedure (see Ligtvoet et al., 2010). Default <code>item.selection=TRUE</code>
<code>verbose</code>	Show the results of the backward item selection algorithm on screen. Default <code>verbose=FALSE</code>

Details

The output is of class `iio.class`, and is often numerous. Functions `plot` and `summary` can be used to summarize the output. See Van der Ark (2014) for an example.

Value

results	A list with as many components as there are item pairs. Each component itself is also a list containing the results of the investigation of IIO.
violations	A matrix: Summary of the backward item selection (Corresponds to Table 4 in Ligtvoet et al., 2010, and Table 1 in Ligtvoet et al., 2011). The first column gives, for each item, the number of violations of IIO. If the number of violations is nonzero, then the item with the largest number of violations is removed. If two or more items have the maximum number of violations, then from those items the item producing the lowest value of Loevinger's H is removed. The second column shows the number of violations with one item removed, the third column shows the number of violations with two items removed, etc.
items.removed	List of the items removed in chronological order
HT	Coefficient HT for the remaining items. For the use of coefficient HT see Ligtvoet et al. (2010). If the sample size is extremely large coefficient HT is estimated using a random subsample.
method	The argument method
item.mean	The mean item scores

Author(s)

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References

- Ligtvoet, R., L. A. van der Ark, J. M. te Marvelde, & K. Sijtsma (2010). Investigating an invariant item ordering for polytomously scored items. *Educational and Psychological Measurement*, 70, 578-595. <https://doi.org/10.1177/0013164409355697>
- Ligtvoet, R., L. A. van der Ark, W. P. Bergsma, & K. Sijtsma (2011). Polytomous latent scales for the investigation of the ordering of items. *Psychometrika*, 76, 200-216. <https://doi.org/10.1007/s11336-010-9199-8>
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See Also

[check.errors](#), [check.monotonicity](#), [check.pmatrix](#), [check.reliability](#) [check.restscore](#), [coefH](#), [plot.iio.class](#), [summary.iio.class](#),

Examples

```
# Examples from Ligtvoet et al. (2010).

data(acl)

Order <- acl[,41:50]
summary(check.iio(Order))
plot(check.iio(Order))

Autonomy <- acl[,91:100]
summary(check.iio(Autonomy))
plot(check.iio(Autonomy))

# Examples from Ligtvoet et al. (2011).

data(cavalini)
X1 <- cavalini[,c(3,5,6,7,9,11,13,14)]

# Use Method MIIO and remove items violating MIIO
iio.list1 <- check.iio(X1)
summary(iio.list1)
X2 <- X1[,is.na(charmatch(dimnames(X1)[[2]],names(iio.list1$items.removed)))]

# Use Method MSCPM and remove items violating MSCPM
iio.list2 <- check.iio(X2,method="MSCPM")
summary(iio.list2)
X3 <- X2[,is.na(charmatch(dimnames(X2)[[2]],names(iio.list2$items.removed)))]

# Use Method IT
iio.list3 <- check.iio(X3,method="IT")
summary(iio.list3)
```

check.monotonicity *Check of Monotonicity*

Description

Returns a list (of class `monotonicity.class`) with results from the investigation of monotonicity (Junker & Sijtsma, 2000; Mokken, 1971; Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002).

Usage

```
check.monotonicity(X, minvi = 0.03, minsize = default.minsize)
```

Arguments

X	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X)$ items. Missing values are not allowed
minvi	minimum size of a violation that is reported
minsize	minimum size of a rest score group. By default $minsize = N/10$ if $N \geq 500$; $minsize = N/5$ if $250 \leq N < 500$; and $minsize = \max(N/3, 50)$ if $N < 250$

Details

The output is of class `monotonicity.class`, and is often numerous. Functions `plot` and `summary` can be used to summarize the output. See Van der Ark (2007) for an example.

Value

results	A list with as many components as there are items. Each component itself is also a list containing the results of the check of monotonicity.
I.labels	The item labels
Hi	The item scalability coefficients H_i
m	The number of answer categories.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Junker, B.W., & Sijtsma, K. (2000). Latent and manifest monotonicity in item response models. *Applied Psychological Measurement*, 24, 65-81. <https://doi.org/10.1177/01466216000241004>
- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
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- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.errors](#), [check.iio](#), [check.restscore](#), [check.pmatrix](#), [check.reliability](#), [coefH](#), [plot.monotonicity.class](#), [summary.monotonicity.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
monotonicity.list <- check.monotonicity(Communality)
plot(monotonicity.list)
summary(monotonicity.list)
```

`check.norms`*Standard errors for norm statistics*

Description

The function presents standard errors for the mean, standard deviation, standard scores, stanine boundaries, and percentiles based on a vector of test scores (Oosterhuis, Van der Ark, & Sijtsma, 2017).

Usage

```
check.norms(y, nice.output = TRUE)
```

Arguments

<code>y</code>	numerical vector. Typically a numerical vector of length N, representing the test scores of N respondents. Missing values are not allowed
<code>nice.output</code>	Logical: If TRUE, norm statistics and standard errors are combined in an a single object of class <code>noquote</code>

Value

list of five components:

- (1) mean: Sample mean and its standard error (`noquote`).
- (2) sd: Sample standard deviation and its standard error (`noquote`).
- (3) z: For each unique testscore, the test score, its frequency, the corresponding estimated standard score and its standard error (`noquote`).
- (4) sta9: The estimates of the 8 boundaries of the stanines and their standard error (`noquote`).
- (5) z: For each unique testscore, the test score, its frequency, the corresponding estimated percentile rank and its standard error (`noquote`).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl> and H. E. M. Oosterhuis

References

Oosterhuis, H. E. M., Van der Ark, L. A., & Sijtsma, K. (2017). Standard errors and confidence intervals of norm statistics for educational and psychological tests. *Psychometrika*, 82, 559-588. <https://doi.org/10.1007/s11336-016-9535-8>

See Also

[DS14](#), [recode](#), [twoway](#)

Examples

```

data(DS14)

# Handle missing data and recode negatively worded items
X <- DS14[, 3 : 16]
X <- twoway(X)
X <- recode(X, c(1, 3))

# Negative affectivity
Na <- X[, c(1, 3, 6, 8, 10, 11, 14)]

# Social inhibition
Si <- X[, c(2, 4, 5, 7, 9, 12, 13)]

# Norms
check.norms(rowSums(Na))
check.norms(rowSums(Si))

```

check.pmatrix

Check of Nonintersection Using Method Pmatrix

Description

Returns a list (of class `pmatrix.class`) with results from the investigation of nonintersection using method `pmatrix` (Mokken, 1971; Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002).

Usage

```
check.pmatrix(X, minvi = 0.03)
```

Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of <code>nrow(X)</code> respondents to <code>ncol(X)</code> items. Missing values are not allowed
<code>minvi</code>	minimum size of a violation that is reported

Details

The output is often numerous. Functions `plot` and `summary` can be used to summarize the output. See Van der Ark (2007) for an example.

Value

<code>results</code>	A list with as many components as there are item pairs. Each component itself is also a list containing the results of the check of nonintersection using Method <code>pmatrix</code> . The P(++) matrix and P(- -) (Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002) are also included.
<code>I.item</code>	vector indicating to which items the rows and column the P(++) matrix belong

I.step	the labels of the item steps in order of popularity
I.labels	the item labels
Hi	the item scalability coefficients Hi
minvi	the value of minvi

Author(s)

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References

- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.errors](#), [check.iio](#), [check.monotonicity](#), [check.reliability](#) [check.restscore](#), [coefH](#), [plot.pmatrix.class](#), [summary.pmatrix.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
pmatrix.list <- check.pmatrix(Communality)
plot(pmatrix.list)
summary(pmatrix.list)
```

check.reliability *Computation of reliability statistics*

Description

Returns a list of reliability statistics: Molenaar Sijtsma (MS, 1984, 1988) statistic (a.k.a rho; also see, Sijtsma & Molenaar, 1987; Van der Ark, 2010), Cronbach's (1951) alpha, Guttman's (1945) lambda 2, and the latent class reliability coefficient (LCRC; Van der Ark, Van der Palm, & Sijtsma, 2011).

Usage

```
check.reliability(X, MS = TRUE, alpha = TRUE, lambda.2 = TRUE,
LCRC = FALSE, nclass = nclass.default, irc = FALSE)
```

Arguments

X	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X)$ items. Missing values are not allowed
MS	Boolean. If TRUE, The MS statistic is computed.
alpha	Boolean. If TRUE, Cronbach's alpha is computed.
lambda.2	Boolean. If TRUE, Guttman's Lambda 2 is computed.
LCRC	Boolean. If TRUE, the LCRC is computed.
nclass	Integer. Number of latent classes for the computation of LCRC. By default: the number of items minus 1.
irc	Boolean. If TRUE, the item-rest correlation (a.k.a. corrected item-total correlation) is computed.

Details

The computation of LCRC depends on the package `poLCA`, which in its turn depends on the packages `MASS` and `scatterplot3d`. Computation of the LCRC may be time consuming if the number of latent classes is large. The optimal number of latent classes should be determined prior to the computation of the LCRC, using software for latent class analysis (e.g., the R-package `poLCA`).

Value

MS	Molenaar Sijtsma statistic (a.k.a. rho).
alpha	Cronbach's alpha
lambda.2	Guttman's Lambda 2
LCRC	LCRC

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Cronbach, L. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, *16*, 297-334. <https://doi.org/10.1007/BF02310555>
- Guttman, L. (1945). A basis for analyzing test-retest reliability. *Psychometrika*, *10*, 255-282. <https://doi.org/10.1007/BF02288892>
- Molenaar, I. W., & Sijtsma, K. (1984). Internal consistency and reliability in Mokken's non-parametric item response model. *Tijdschrift voor onderwijsresearch*, *9*, 257-268. Retrieved from <https://pure.uvt.nl/ws/portalfiles/portal/1030704/INTERNAL.PDF>
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Van der Ark, L. A., Van der Palm, D. W., & Sijtsma, K. (2011). A latent class approach to estimating test-score reliability. *Applied Psychological Measurement*, *35*, 380-392. <https://doi.org/10.1177/0146621610392911>

Van der Palm, D. W., Van der Ark, L. A. & Sijtsma, K. (2014). A flexible latent class approach to estimating test-score reliability. *Journal of Educational Measurement*, *51*, 339-357. <https://doi.org/10.1111/jedm.12053>

See Also

[check.errors](#), [check.iio](#), [check.monotonicity](#), [check.pmatrix](#) [check.restscore](#), [coefH](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
check.reliability(Communality, LCRC = TRUE)
```

check.restscore

Check of Nonintersection Using Method Restscore

Description

Returns a list (of class `restscore.class`) with results from the investigation of nonintersection using method `restscore` (Mokken, 1971; Molenaar & Sijtsma, 2000; Sijtsma & Molenaar, 2002).

Usage

```
check.restscore(X, minvi = 0.03, minsize = default.minsize)
```

Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of <code>nrow(X)</code> respondents to <code>ncol(X)</code> items. Missing values are not allowed
<code>minvi</code>	minimum size of a violation that is reported
<code>minsize</code>	minimum size of a rest score group. By default <code>minsize = N/10</code> if $N \geq 500$; <code>minsize = N/5</code> if $250 \leq N < 500$; and <code>minsize = max(N/3, 50)</code> if $N < 250$

Details

The output is often numerous. Procedure may be slow for large data sets. Functions `plot` and `summary` can be used to summarize the output. See Van der Ark (2007) for an example.

Value

results	A list with as many components as there are item pairs. Each component itself is also a list containing the results of the check of nonintersection using method <code>restscore</code> .
I.labels	The item labels
Hi	The item scalability coefficients
m	The number of answer categories.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.errors](#), [check.iio](#), [check.monotonicity](#), [check.pmatrix](#), [check.reliability](#) `coefH`, [plot.restscore.class](#), [summary.restscore.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
restscore.list <- check.restscore(Communality)
plot(restscore.list)
summary(restscore.list)
```

coefH

Scalability coefficients H

Description

Computes item-pair scalability coefficients H_{ij} , item scalability coefficients H_i , and scale scalability coefficient H (Loevinger, 1948; Mokken, 1971, pp. 148-153; Molenaar & Sijtsma, 2000, pp. 11-13; Sijtsma & Molenaar, chap. 4; Van der Ark, 2007; 2010), as well as their standard errors (Kuijpers, Van der Ark, & Croon, 2013; also see Van der Ark, Croon, & Sijtsma, 2008). Mokken's coefficients and standard errors can also be estimated in two-level data (Koopman, Zijlstra, & Van der Ark, 2020a). It is also possible to compare scalability coefficients across groups using the item-step ordering of the entire sample (cf. `CHECK=GROUPS` option in `MSP`; Molenaar and Sijtsma, 2000). The estimated variance-covariance matrix of the coefficients are invisible but can be printed by saving the result, see examples.

Usage

```
coefH(X, se = TRUE, ci = FALSE, nice.output = TRUE, level.two.var = NULL,
      group.var = NULL, fixed.itemstep.order = NULL, print.to.screen = TRUE)
```

Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of <code>nrow(X)</code> respondents to <code>ncol(X)</code> items. Missing values are not allowed
<code>se</code>	Logical: If TRUE, the standard errors of the scalability coefficients are given
<code>ci</code>	The confidence level between 0 and 1 of the range-preserving confidence intervals. If FALSE (default), no confidence intervals are printed (Koopman, Zijlstra, & Van der Ark, 2020b).
<code>nice.output</code>	Logical: If TRUE, scalability coefficients and standard errors are combined in an a single object of class <code>noquote</code>
<code>level.two.var</code>	vector of length <code>nrow(X)</code> or matrix with number of rows equal to <code>nrow(X)</code> that indicates the level two variable for nested data to get appropriate standard errors (Koopman et al., 2020a).
<code>group.var</code>	vector of length <code>nrow(X)</code> or matrix with number of rows equal to <code>nrow(X)</code> to be used as grouping variable
<code>fixed.itemstep.order</code>	matrix with number of rows equal to the number of item steps (<code>m</code>) and number of columns equal to the number of items (<code>J</code>). The matrix should consist the integers <code>1 : (m * J)</code> , indicating a predefined order of the items steps with respect to popularity. Value 1 indicates the easiest (most popular) item step, value <code>(m * J)</code> indicates the most difficult item step.
<code>print.to.screen</code>	Logical: If TRUE results are printed to the screen. Option FALSE is useful only for some internal functions

Details

May not work if any of the item variances equals zero. Such items should not be used in a test and removed from the data frame.

If `nice.output = TRUE` and `se = TRUE`, the result is a list of 3 objects of class `noquote`; if `nice.output = FALSE` and `se = TRUE`, the result is a list of 6 matrices (3 for the scalability coefficients and 3 for the standard errors); and if `se = FALSE`, the result is a list of 3 matrices (for the scalability coefficients); if `ci` is specified and `se = TRUE` or `nice.output = FALSE`, there is one additional matrix for the `ci`'s of the `Hij` coefficients; if `level.two.var` is not null the standard errors are adjusted to take the nesting into account; if `group.var = Y` with `Y` having `K` values, an additional element named `Groups` is added to the list. Element `Groups` shows the scalability coefficients per group ordered by means of `sort` (see [Sys.getlocale](#) for details). `group.var` returns coefficients for groups containing at least two case. Computation of standard errors can be slow for a combination of a large sample size and a large number of items.

Value

Hi.j	scalability coefficients of the item pairs (possibly with standard errors; see details)
Hi	vector containing scalability coefficients of the items (possibly with standard errors; see details)
H	scalability coefficient of the entire scale (possibly with standard error; see details)
se.Hi.j	standard errors of the scalability coefficients of the item pairs (only if nice.output = FALSE and se = TRUE; see details)
se.Hi	standard errors of the scalability coefficients of the items (see details)
se.H	standard error of the scalability coefficient of the entire scale (see details)
ci.Hi.j	range-preserving confidence intervals of the scalability coefficients of the item pairs (only if nice.output = FALSE and/or se = TRUE; see details)
ci.Hi	range-preserving confidence intervals of the scalability coefficients of the items (see details)
ci.H	range-preserving confidence intervals of the scalability coefficient of the entire scale (see details)
Groups	Scalability coefficients for subgroups (see details)

Author(s)

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References

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See Also

[coefZ](#), [search.normal](#)

Examples

```

data(acl)
Communality <- acl[,1:10]

# Compute scalability coefficients and standard errors
Hs <- coefH(Communality)

# Compute scalability coefficients, standard errors, and range-preserving confidence intervals
coefH(Communality, ci = .95)

# Scalability coefficients but no standard errors
coefH(Communality, se=FALSE)

# Scalability coefficients for different groups:
subgroup <- ifelse(acl[,11] < 2,1,2)
coefH(Communality, group.var = subgroup)

# Extract variance-covariance matrices
attributes(Hs)
Hs$covHij
Hs$covHi
Hs$covH

# Nested data:
data(autonomySupport)
scores <- autonomySupport[, -1]
classes <- autonomySupport[, 1]
coefH(scores, level.two.var = classes, ci = .95)

```

coefZ

Computation of Z-Values

Description

Computes Zij-values of item pairs, Zi-values of items, and Z-value of the entire scale, which are used to test whether Hij, Hi, and H, respectively, are significantly greater than zero using the original method Z (Molenaar and Sijtsma, 2000, pp. 59-62; Sijtsma and Molenaar, p. 40; Van der Ark, 2007; 2010) or the delta method (Kuijpers, Van der Ark, & Croon, 2013; Koopman, Zijlstra, & Van der Ark, 2020a). The delta method can also handle nested data and can test other lowerbounds than zero. The test uses range-preserving asymptotic theory (Koopman, Zijlstra, & Van der Ark, 2020b)

Used in the function `aisp`

Usage

```
coefZ(X, lowerbound = 0, type.se = "Z", level.two.var = NULL)
```


Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of <code>nrow(X)</code> respondents to <code>ncol(X)</code> items. Missing values are not allowed
<code>lowerbound</code>	Value of the null hypothesis to which the scalability are compared to compute the Z-score (see details), $0 \leq \text{lowerbound} < 1$. The default is 0.
<code>type.se</code>	Indicates which type of standard errors is used to compute the Z-score: "delta": uses standard errors approximated by the delta method (Kuijpers, Van der Ark, Kroon, 2013; Koopman, Zijlstra, Van der Ark, 2020a); "Z": uses original Z-test and is only appropriate to test <code>lowerbound = 0</code> (Mokken, 1971; Molenaar and Sijtsma, 2000; Sijtsma and Molenaar, 2002). The default is "Z".
<code>level.two.var</code>	vector of length <code>nrow(X)</code> or matrix with number of rows equal to <code>nrow(X)</code> that indicates the level two variable for nested data (Koopman et al., 2020a).

Details

The Z-score with `type.se = "delta"` for the estimated item-pair coefficient H_{ij} with standard error $SE(H_{ij})$ is computed as

$$Z = -(\log(1-H_{ij}) - \log(1-\text{lowerbound})) / (SE(H_{ij}) / (1-H_{ij})) \text{ (Koopman, Zijlstra, Vander Ark, 2020b)}$$

Unlike `coefH`, standard errors are not provided.

Value

<code>Zij</code>	matrix containing the Z-values of the item-pairs
<code>Zi</code>	vector containing Z-values of the items
<code>Z</code>	Z-value of the entire scale

Author(s)

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References

- Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020a). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.
- Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020b). *Range-preserving confidence intervals for scalability coefficients in Mokken scale analysis*. Manuscript submitted for publication.
- Kuijpers, R. E., Van der Ark, L. A., & Croon, M. A. (2013). Standard errors and confidence intervals for scalability coefficients in Mokken scale analysis using marginal models. *Sociological Methodology*, 43, 42-69. <https://doi.org/10.1177/0081175013481958>
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
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- Van der Ark, L. A. (2010). Getting started with Mokken scale analysis in **R**. Unpublished manuscript. <https://sites.google.com/a/tilburguniversity.edu/avdrark/mokken>

See Also[coefH, aisp](#)**Examples**

```
data(acl)
Communality <- acl[,1:10]

# Compute the Z-score of each coefficient
coefH(Communality)
coefZ(Communality)

# Using lowerbound .3
coefZ(Communality, lowerbound = .3, type.se = "delta")

# Z-scores for nested data
data(autonomySupport)
scores <- autonomySupport[, -1]
classes <- autonomySupport[, 1]
coefH(scores, level.two.var = classes)
coefZ(scores, type.se = "delta", level.two.var = classes)
```

DS14

DS14

Description

Gender, age, and item scores on the DS14 questionnaire of 541 coronary artery disease patients.

Usage

```
data(DS14)
```

Format

A 541 by 16 matrix containing gender, age, and item scores on the DS14 questionnaire.

Details

The DS14 (Denollet, 2005) is the most accepted and widely used diagnostic instrument for the assessment of the type-D pattern. Type D (distressed) is defined as the joint tendency towards negative affectivity (e.g., worry, irritability, gloom) and social inhibition (e.g., reticence and a lack of self-assurance). DS14 contains 14 items, each having five ordered response categories (0 = completely disagree, 1 = disagree, 2 = agree nor disagree, 3 = agree, 4 = completely agree). Items 2, 4, 5, 7, 9, 12, and 13 measure negative affectivity. Items 1, 3, 6, 8, 10, 11, and 14 measure social inhibition. Items 1 and 3 are negatively worded (indicated by an asterisk in the dimnames).

The data contain the gender (Male) of the patients (1 = male, 0 = female), the age (Age) of the patients in years, and the scores to DS14. Ten item scores are missing. Items 1 and 3 must be recoded before the data can be used meaningfully. The data have been used to investigate predictive value of social inhibition and negative affectivity for cardiovascular events and mortality in patients with coronary artery disease (Denollet et al., 2013), to investigate the relation between Type D and inflammation and endothelial dysfunction' (van Dooren et al., 2016), and to investigate the relation between Type D and increased macrophage activity (Zuccarella-Hackl et al., 2016) These data have also been analyzed in papers on Mokken scale analysis (Sijtsma & Van der Ark, 2016; Straat et al., 2016).

Source

Data were kindly made available by J. Denollet from Tilburg University.

References

- Denollet, J., Pedersen, S. S., Vrints, C. J., & Conraads, V. M. (2013). Predictive value of social inhibition and negative affectivity for cardiovascular events and mortality in patients with coronary artery disease: the Type D personality construct. *Psychosomatic Medicine*, *75*, 873-981. <https://doi.org/10.1097/PSY.000000000000001>
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See Also

[recode](#), [tway](#)

Examples

```
data(DS14)

# Handle missing data and recode negatively worded items
X <- DS14[, 3 : 16]
X <- twoway(X)
X <- recode(X, c(1, 3))
head(X)
```

ICC *Intraclass correlation*

Description

Computes to intraclass correlation for multilevel data (ICC; Snijders & Bosker, 1999, p. 17) for each item and the total scale of a questionnaire (Koopman, Van der Ark, & Zijlstra, 2020) and the F-test for the null hypothesis that the (total scale) ICC is zero (Snijders & Bosker, 2012, p. 22)

Usage

ICC(X)

Arguments

X matrix or data frame of numeric data containing a grouping column and the item scores of $nrow(X)$ respondents to $ncol(X) - 1$ items. Missing values are not allowed

Value

itemICC The ICC per item
 scaleICC The ICC for the total scale and the corresponding results for the F-test

Author(s)

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References

Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.
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See Also

[SWMD](#), [MLcoefH](#),

Examples

```
# Data example (Koopman et al., 2020)
data(SWMD)

# Compute ICC
ICC(SWMD)
```

mcmi

Millon Clinical Multiaxial Inventory

Description

Scores of 1208 patients and inmates on 44 dichotomous items from a Dutch version of the Millon Clinical Multiaxial Inventory-III.

Usage

```
data(mcmi)
```

Format

A 1208 by 44 data frame containing integers.

Details

The data were collected by Gina Rossi (Rossi et al., 2010) as part of a larger project. This subset of 44 items was used to demonstrate diagnostic classification models (cognitive diagnosis models) by de la Torre et al. (2018), Van der Ark et al. (2019), and Sijtsma & Van der Ark (2020). The Q matrix used in the analyses is an attribute. Both the items and the respondents have been deidentified. The deidentified data do allow to replicate the analyses in Sijtsma and Van der Ark (2020, chapter 5), using the code available from <https://osf.io/e9jrz>.

Source

Data were kindly made available by Gina Rossi from the Vrije Universiteit Brussel, Belgium. The original Millon Clinical Multiaxial Inventory-III was developed by Millon (1994).

References

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Examples

```
data(mcmi)

# Q matrix
attributes(mcmi)$Q
```

MLcoefH

*Two-level scalability coefficients H***Description**

Computes all types of two-level scalability coefficients (Snijders, 2001; Crisan et al., 2016), that is, between- and within-rater item-pair scalability coefficients and their ratio (HB_{ij}, HW_{ij}, and BW_{ij}, respectively), between- and within-rater item scalability coefficients and their ratio (HB_i, HW_i, and BW_i, respectively), and between- and within-rater total scale scalability coefficients and their ratio (HB, HW, and BW, respectively). In addition, standard errors are estimated (Koopman, et al., 2019). Note that this version is an adaptation of the estimation methods described in Snijders (1999) and in Koopman et al. (2019), as the group proportions are now by default weighted for group size (Koopman, Zijlstra, & Van der Ark, 2020a). As a result, the estimates for the autonomySupport data differs from the printed table in Koopman et al. (2019). The estimated variance-covariance matrix of the coefficients are invisible but can be printed by saving the result, see examples.

Usage

```
MLcoefH(X, se = TRUE, ci = FALSE, nice.output = TRUE, subject = 1,
        fixed.itemstep.order = NULL, weigh.props = TRUE, cov.mat = FALSE)
```

Arguments

X	matrix or data frame of numeric data containing a subject indicator column and the responses of nrow(X) raters to ncol(X) - 1 items. Missing values are not allowed
se	Logical: If TRUE, the standard errors are printed alongside the scalability coefficients
ci	The confidence level between 0 and 1 of the range-preserving confidence intervals. If FALSE (default), no confidence intervals are printed (Koopman, Zijlstra, & Van der Ark, 2020b).
nice.output	Logical: If TRUE, scalability coefficients and standard errors are combined in a single object of class noquote. Item-pair ratios BW _{ij} are only printed if FALSE
subject	Represents the subject column. Default is column 1.
fixed.itemstep.order	matrix with number of rows equal to the number of item steps (m) and number of columns equal to the number of items (J). The matrix should consist the integers 1 : (m * J), indicating a predefined order of the items steps with respect to popularity. Value 1 indicates the easiest (most popular) item step, value (m * J) indicates the most difficult item step.

weigh.props	If TRUE: Use weighted proportions across groups to estimate coefficients and standard errors, if FALSE: Use averaged proportions across groups to estimate coefficients and standard errors.
cov.mat	Logical: If TRUE, the variance-covariance matrices of the estimated coefficients are printed. Default is FALSE.

Details

If `se = TRUE` and `nice.output = TRUE`, the result is a list of 3 objects of class `noquote`; if `se = TRUE` and `nice.output = FALSE`, the result is a list of 3 matrices, one per set of coefficients; and if `se = FALSE`, the result is a list of 3 matrices containing only the scalability coefficients; if `ci = TRUE` and `nice.output = TRUE`, there is one additional matrix for the `ci`'s of the `Hij` coefficients. Computation of standard errors can be slow for a combination of many subjects and a large number of items; if `cov.mat = TRUE` three additional matrices are printed with the variance-covariances of `Hij`, `Hi`, and `H`.

Value

<code>Hij</code>	Scalability coefficients of the item pairs, upper triangle are the between-rater coefficients, and the lower triangle the within-rater coefficients (possibly with standard errors and/or confidence intervals; see details). If <code>nice.output = FALSE</code> this returns a matrix with the type of coefficients per column
<code>Hi</code>	Between- and within-rater scalability coefficients of the items and their ratio (possibly with standard errors and/or confidence intervals; see details)
<code>H</code>	between- and within-rater scalability coefficients of the entire scale and their ratio (possibly with standard error and/or confidence intervals; see details)

Author(s)

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References

- Crisan, D. R., Van de Pol, J. E., & Van der Ark, L. A. (2016). Scalability coefficients for two-level polytomous item scores: An introduction and an application. In L. A. Van der Ark, D. M. Bolt, W.-C. Wang, & M. Wiberg (Eds.), *Quantitative psychology research*. Springer. https://doi.org/10.1007/978-3-319-38759-8_11
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See Also

[MLcoefZ,coefH](#),

Examples

```
# Small data example (Koopman et al., 2019)
smallData <- data.frame(Subs = c(1, 1, 1, 1, 2, 2, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3),
  Xa = c(0, 0, 1, 0, 1, 1, 1, 1, 2, 1, 0, 1, 2, 0, 0, 0),
  Xb = c(0, 0, 1, 0, 2, 2, 2, 1, 2, 1, 2, 2, 1, 1, 0),
  Xc = c(1, 0, 0, 0, 1, 1, 2, 1, 2, 0, 1, 1, 2, 1, 0))

MLcoefH(smallData)

# Compute also the range-preserving confidence intervals
MLcoefH(smallData, ci = .95)

# Print variance-covariance matrices
MLcoefH(smallData, cov.mat = TRUE)

# Load real data example. Note that due to an estimation adaptation (Koopman et al., 2020)
# the results differ from the table in Koopman et al. (2019).
data(autonomySupport)

# Compute scalability coefficients with or without standard errors, range-preserving
# confidence intervals, nice output

H.se.nice <- MLcoefH(autonomySupport)
H.se.nice

H.se.not <- MLcoefH(autonomySupport, nice.output = FALSE)
H.se.not

H.se.ci.nice <- MLcoefH(autonomySupport, ci = .95)
H.se.ci.nice

H.se.ci.not <- MLcoefH(autonomySupport, ci = .95, nice.output = FALSE)
H.se.ci.not

H.nice <- MLcoefH(autonomySupport, se = FALSE)
H.nice

H.not <- MLcoefH(autonomySupport, se = FALSE, nice.output = FALSE)
H.not
```

MLcoefZ *Computation of Z-Values for two-level scalability coefficients*

Description

Computes Z_{ij} -values of item pairs, Z_i -values of items, and Z -value of the entire scale, which are used to test whether H_{ij} , H_i , and H , respectively (within- and between-rater versions), are significantly greater a specified lowerbound using the delta method (Koopman, Zijlstra, & Van der Ark, 2020a). The test uses range-preserving asymptotic theory (Koopman, Zijlstra, & Van der Ark, 2020b).

Usage

```
MLcoefZ(X, lowerbound = 0)
```

Arguments

X	matrix or data frame of numeric data containing the responses of $nrow(X)$ respondents to $ncol(X) - 1$ items. The first column of X is assumed to be a subject column, see ?MLcoefH() for details. Missing values are not allowed
lowerbound	Value of the null hypothesis to which the scalability are compared to compute the Z-score (see details), $0 \leq \text{lowerbound} < 1$. The default is 0.

Details

The range-preserving Z-score for the estimated item-pair coefficient H_{ij} with standard error $SE(H_{ij})$ is computed as

$$Z = -(\log(1-H_{ij}) - \log(1-\text{lowerbound})) / (SE(H_{ij}) / (1-H_{ij})) \text{ (Koopman, Zijlstra, Vander Ark, 2020b)}$$

Unlike MLcoefH, standard errors are not provided.

Value

Z_{ij}	matrix containing the Z-values of the item-pairs
Z_i	vector containing Z-values of the items
Z	Z-value of the entire scale

Author(s)

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References

Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020a). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.

Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020b). *Range-preserving confidence intervals for scalability coefficients in Mokken scale analysis*. Manuscript submitted for publication.

See Also[MLcoefH](#)**Examples**

```
data(SWMD)

# Compute the Z-score using lowerbound 0
MLcoefZ(SWMD)

# Using lowerbound .1
MLcoefZ(SWMD, lowerbound = .1)
```

MLweight

*Weights for Guttman Errors in two-level test data***Description**

Computes weights for Guttman errors in two-level test data (Koopman, Van der Ark, & Zijlstra, 2017)

Usage

```
MLweight(X, maxx = NULL, minx = NULL, itemstep.order = NULL)
```

Arguments

<code>X</code>	Data matrix with a subject column and two item columns. The subject column is assumed to be the first.
<code>maxx</code>	The highest possible answer category. If not specified it is determined by using the highest item score.
<code>minx</code>	The lowest possible answer category. If not specified it is determined by using the lowest item score.
<code>itemstep.order</code>	The two columns pertaining the two items in question, from a (possibly larger) matrix with number of rows equal to the number of item steps (m) and number of columns equal to the number of items (J). The matrix should consist the integers $1 : (m * J)$, indicating a predefined order of the items steps with respect to popularity. Value 1 indicates the easiest (most popular) item step, value $(m * J)$ indicates the most difficult item step.

Value

Returns a vector with the weights for each item-score pattern of a given item-pair. In case of ties in item popularities the average weights across possible item-orderings are returned.

Author(s)

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References

Koopman, L., Van der Ark, L. A., & Zijlstra, B. J. H. (2017). *Weighted Guttman Errors: Handling Ties and Two-Level Data*. In L. A. Van der Ark, S. Culpepper, J. A. Douglas, W.-C. Wang, & M. Wiberg (Eds.), *Quantitative Psychology: The 81st Annual Meeting of the Psychometric Society, Asheville, North Carolina, 2016* (pp. 183-190). Springer. https://doi.org/10.1007/978-3-319-56294-0_17

See Also

[MLcoefH](#)

Examples

```
smallData <- data.frame(Subs = c(1, 1, 1, 1, 1, 2, 2, 2, 2, 3, 3, 3, 3, 3, 3),
  Xa = c(2, 0, 0, 1, 0, 2, 2, 0, 2, 2, 1, 2, 1, 2, 2),
  Xb = c(1, 1, 1, 0, 1, 2, 2, 1, 2, 2, 1, 0, 2, 2, 2),
  Xc = c(0, 0, 0, 1, 0, 2, 2, 1, 2, 1, 0, 0, 1, 1, 2))

# Compute the weights
I <- 3
for(i in 1:(I - 1)) for(j in (i + 1):I)
  print(MLweight(smallData[, c(1, i + 1, j + 1)], minx = 0, maxx = 2))
```

plot.iio.class *Plot iio.class objects*

Description

S3 Method to plot objects of class iio.class. Graphic display of the checks of iio. One graph for each item plotting the estimated item response functions.

Usage

```
## S3 method for class 'iio.class'
plot(x, item.pairs = all.pairs, ci = TRUE, alpha = .05,
     color = c("black", "blue"), transparency = 20, ask = TRUE, ...)
```

Arguments

x	Object of class iio.class produced by check.iio .
item.pairs	vector containing the numbers of the item pairs for which the results are depicted graphically. For example, item.pairs = 1 prints the results for items 1 and 2, item.pairs = 2 prints the results for items 1 and 3, item.pairs = J prints the results for items 1 and J\$, and item.pairs = J+1 prints the results for items 2 and 3. Default the results for all item pairs are depicted.
ci	Boolean. If TRUE (default), then confidence envelops are plotted around IRFs.

alpha	Type of plotted (1 - alpha) confidence intervals. By default 95-percent confidence intervals are depicted
color	Color of the plotted curves and confidence envelopes. Defaults are black for the first item and blue for the second item.
transparancy	Transparancy of the confidence intervals. Higher values result in more opaque colors for the confidence intervals.
ask	Boolean. If TRUE (default), then <code>par("ask"=TRUE)</code> ; i.e., a hard return between subsequent plots is required. If FALSE, then <code>par("ask"=FALSE)</code> .
...	Optional graphical parameters will be ignored

Details

The plot function corresponds to method MIIO; each graph plots the estimated item response functions (item rest-score functions) for two items. For details of the method, see Ligtoet et al. (2010, 2011); Sijtsma et al. (2012). For details of the confidence envelopes, see Van der Ark (2012b). For the implementation in R, see Van der Ark (2012a). For `ask==FALSE`, the default graphic device in R may only display the last graph.

Value

Returns a graph.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Ligtoet, R., L. A. van der Ark, J. M. te Marvelde, & K. Sijtsma (2010). Investigating an invariant item ordering for polytomously scored items. *Educational and Psychological Measurement*, 70, 578-595. <https://doi.org/10.1177/0013164409355697>
- Ligtoet, R., L. A. van der Ark, W. P. Bergsma, & K. Sijtsma (2011). Polytomous latent scales for the investigation of the ordering of items. *Psychometrika*, 76, 200-216. <https://doi.org/10.1007/s11336-010-9199-8>
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- Van der Ark, L. A. (2014). Visualizing uncertainty of estimated response functions in nonparametric item response theory. In R. E. Millsap, L. A. van der Ark, D. Bolt, & C. M. Woods (Eds.), *New developments in quantitative psychology* (pp. 59-68). New York: Springer. https://doi.org/10.1007/978-1-4614-9348-8_5

See Also

[check.iio](#), [summary.iio.class](#)

Examples

```
data(ac1)
Communality <- ac1[,1:10]
iio.list <- check.iio(Communality)
summary(iio.list)
plot(iio.list)
```

```
plot.monotonicity.class
```

Plot monotonicity.class objects

Description

S3 Method to plot objects of class `monotonicity.class`. Graphic display of the checks of monotonicity. One graph for each item plotting the estimated item step response functions and/or item response function, plus confidence envelopes (Van der Ark, 2012).

Usage

```
## S3 method for class 'monotonicity.class'
plot(x, items = all.items, curves = "both", ci = TRUE,
      alpha = .05, color = "black", transparency = 20, ask = TRUE, ...)
```

Arguments

<code>x</code>	Object of class <code>monotonicity.class</code> produced by check.monotonicity .
<code>items</code>	vector containing the numbers of the items for which the results are depicted graphically. Default the results for all items are depicted.
<code>curves</code>	"ISRF": Item step response functions (ISRFs) are depicted; "IRF": item response functions (IRFs) are depicted; "both": Both ISRFs and IRFs are depicted. Default is "both"
<code>ci</code>	Boolean. If TRUE (default), then confidence envelopes are plotted around IRFs and ISRFs.
<code>alpha</code>	Type of plotted (1 - alpha) confidence intervals. By default 95-percent confidence intervals are depicted
<code>color</code>	Color of the plotted curves and confidence envelopes. Default is black.
<code>transparency</code>	Transparency of the confidence intervals. Higher values result in more opaque colors for the confidence intervals.
<code>ask</code>	Boolean. If TRUE (default), then <code>par("ask")=TRUE</code> ; i.e., a hard return between subsequent plots is required. If FALSE, then <code>par("ask")=FALSE</code> .
<code>...</code>	Optional graphical parameters will be ignored

Details

For details of the method, see Molenaar and Sijtsma (2000) and Sijtsma and Molenaar (2002). For details of the confidence envelopes, see Van der Ark (2012) For the implementation in R, see Van der Ark (2007). For `curves=="both"`, both plots are plotted simultaneously using `layout(matrix(c(1,2),1,2))`. For `ask=="FALSE"`, the default graphic device in R may only display the last graph.

Value

Returns a graph.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.

Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.

Van der Ark, L. A. (2007). Mokken scale analysis in R. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

Van der Ark, L. A. (2014). Visualizing uncertainty of estimated response functions in nonparametric item response theory. In R. E. Millsap, L. A. van der Ark, D. Bolt, & C. M. Woods (Eds.), *New developments in quantitative psychology* (pp. 59-68). New York: Springer. https://doi.org/10.1007/978-1-4614-9348-8_5

See Also

[check.monotonicity](#), [summary.monotonicity.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
monotonicity.list <- check.monotonicity(Communality)
plot(monotonicity.list)
summary(monotonicity.list)
```

plot.pmatrix.class *Plot pmatrix.class objects*

Description

S3 Method to plot objects of class `pmatrix.class`. Graphic display of the checks of `pmatrix`. One graph for each item plotting the rows of the P(++) matrix and rows of the P(-) matrix. If nonintersection holds the lines in the plots of the P(++) matrix must be nondecreasing and the lines in the plots of the P(-) matrix must be nonincreasing.

Usage

```
## S3 method for class 'pmatrix.class'
plot(x, items = all.items, pmatrix = "both", ci = TRUE,
      alpha = .05, color = "black", transparency = 20, ask = TRUE, ...)
```

Arguments

x	Object of class pmatrix.class produced by check.pmatrix .
items	vector containing the numbers of the item pairs for which the results are depicted graphically. Default the results for all items are depicted.
pmatrix	Valid options are "ppp", "pmm", and "both". If pmatrix="ppp", then the P(++) matrix is plotted, if pmatrix="pmm", then the P(-) matrix is plotted, if pmatrix="both", then both the P(++) matrix and P(-) matrix are plotted.
ci	Boolean. If TRUE, then confidence envelops are plotted around IRFs and ISRFs.
alpha	Type of plotted (1 - alpha) confidence intervals. By default 95-percent confidence intervals are depicted
color	Color of the plotted curves and confidence envelops. Default is black.
transparency	Transparency of the confidence intervals. Higher values result in more opaque colors for the confidence intervals.
ask	Boolean. If TRUE (default), then par("ask"=TRUE); i.e., a hard return between subsequent plots is required. If FALSE, then par("ask"=FALSE).
...	Optional graphical parameters will be ignored

Details

The default graphic device in R may only display the last graph.

In the plot of the P(++) matrix and the P(-) matrix, the x-axis contains the $k = (J - 1)m$ item steps not pertaining to item j in order of popularity (ascending). Let $Y_g = 1$ indicate that the g -th item step has been taken: i.e. $X_i \geq y$ and let $Y_g = 0$ indicate that the g -th item step has not been taken: i.e. $X_i < y$. The m lines in the plot of the P(++) matrix connect $P(X_j \geq x, Y_1 = 1), \dots, P(X_j \geq x, Y_k = 1), x = 1, \dots, m$. The m lines in the plot of the P(-) matrix connect $P(X_j < x, Y_1 = 0), \dots, P(X_j < x, Y_k = 0), x = 1, \dots, m$.

If the number of item steps on the x-axis is greater than 10, then the labels are not displayed,

Value

Returns a graph.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.pmatrix](#), [summary.pmatrix.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
pmatrix.list <- check.pmatrix(Communality)
plot(pmatrix.list)
summary(pmatrix.list)
```

plot.restscore.class *Plot restscore.class objects*

Description

S3 Method to plot objects of class restscore.class. Graphic display of the checks of restscore. One graph for each item pair plotting the estimated item step response functions (ISRFs); confidence envelopes are optional. Intersections of the lines indicate violations of nonintersection,

Usage

```
## S3 method for class 'restscore.class'
plot(x, item.pairs = all.pairs, ci = TRUE, alpha = .05,
      color = c("black", "blue"), transparency = 20, ask = TRUE, ...)
```

Arguments

- | | |
|------------|---|
| x | Object of class restscore.class produced by check.restscore . |
| item.pairs | vector containing the numbers of the item pairs for which the results are depicted graphically. For example, item.pairs = 1 prints the results for items 1 and 2, item.pairs = 2 prints the results for items 1 and 3, item.pairs = J prints the results for items 1 and J\$, and item.pairs = J+1 prints the results for items 2 and 3. Default the results for all item pairs are depicted. |
| ci | Boolean. If TRUE (default), then confidence envelopes are plotted around ISRFs. |
| alpha | Type of plotted (1 - alpha) confidence intervals. By default 95-percent confidence intervals are depicted |

color	Color of the plotted lines and confidence envelopes. Defaults are black for the first item and blue for the second item.
transparency	Transparency of the confidence intervals. Higher values result in more opaque colors for the confidence intervals.
ask	Boolean. If TRUE (default), then <code>par("ask"=TRUE)</code> ; i.e., a hard return between subsequent plots is required. If FALSE, then <code>par("ask"=FALSE)</code> .
...	Optional graphical parameters will be ignored

Details

For details of the method, see Molenaar and Sijtsma (2000) and Sijtsma and Molenaar (2002). For details of the confidence envelopes, see Van der Ark (2012). For the implementation in R, see Van der Ark (2007). For `ask==FALSE`, the default graphic device in R may only display the last graph. The default number of plots can increase rapidly for large numbers of items.

Value

Returns a graph.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.

Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.

Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

Van der Ark, L. A. (2014). Visualizing uncertainty of estimated response functions in nonparametric item response theory. In R. E. Millsap, L. A. van der Ark, D. Bolt, & C. M. Woods (Eds.), *New developments in quantitative psychology* (pp. 59-68). New York: Springer. https://doi.org/10.1007/978-1-4614-9348-8_5

See Also

[check.restscore](#), [summary.restscore.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
restscore.list <- check.restscore(Communality)
plot(restscore.list)
summary(restscore.list)
```

recode	<i>Recodes negatively worded items</i>
--------	--

Description

Returns a matrix or data.frame with the indicated items recoded.

Usage

```
recode(X, items = NULL, values = defaultValues)
```

Arguments

<code>X</code>	matrix or data frame of numeric data containing the responses of <code>nrow(X)</code> respondents to <code>ncol(X)</code> items. Missing values are allowed
<code>items</code>	Vector of integers indicating the items to be recoded
<code>values</code>	Vector of possible item scores. By default the range of the observed values is taken

Details

The result is `X` for which columns `items` have been recoded.

Value

The result is `X` for which columns `items` have been recoded.

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

See Also

[DS14](#), [twoway](#)

Examples

```
data(DS14)

# Handle missing data and recode negatively worded items
X <- DS14[, 3 : 16]
X <- twoway(X)
X <- recode(X, c(1, 3))
head(X)
```

summary.iio.class	<i>Summarize iio.class objects</i>
-------------------	------------------------------------

Description

S3 Method for summary of objects of class iio.class. Summarize checks of invariant item ordering.

Usage

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

Arguments

object	list produced by check.iio
...	Optional parameters will be ignored

Value

method	String describing the method used for investigating invariant item ordering: Either "MIIO" (Method Manifest Invariant Item Ordering), "MSCPM" (Method Manifest Scale Cumulative Probability Model), or "IT" (Method Increasingness in Transposition)
item.summary	Matrix with $n_{col}(X)$ rows and 10 columns, showing for each item a summary of the violations of an invariant item ordering: $itemH$ = Item-scalability coefficient; $\#ac$ = number of active pairs that were investigated; $\#vi$ = number of violations in which the item is involved; $\#vi/\#ac$ = proportion of active pairs that is involved in a violation; $maxvi$ = maximum violation; sum = sum of all violations; $tmax$ (for method MIIO), $zmax$ (for method MSCPM), or $xmax$ (for method IT) = maximum t-value, z-value, and chi-square value, respectively; $tsig$ (for method MIIO), $zsig$ (for method MSCPM), or $xsig$ (for method IT) = number of significant t-values, z-values, and chi-square values, respectively; $crit$ = Crit value (Molenaar & Sijtsma, 2000, pp. 49, 74).
backward.selection	Matrix showing the number of violations for each item (rows) at each step of the backward item selection proces (columns). The first column shows the number of violations for each item. Then in an iterative procedure, the item whose removal results in the largest decrease of violations is removed and the number of violations is computed again. If the reduction in the number of violations is undecisive then, from the candidate items, the item having the smallest scalability coefficient is removed. The backward selection procedure stops when there are no more violations.
HT	Numeric: Coefficient HT for the selected items. Given an IIO, coefficient HT expresses the strength of the ordering (Ligtvoet et al., 2010).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

Ligtvoet, R., L. A. van der Ark, J. M. te Marvelde, & K. Sijtsma (2010). Investigating an invariant item ordering for polytomously scored items. *Educational and Psychological Measurement*, 70, 578-595. <https://doi.org/10.1177/0013164409355697>

Ligtvoet, R., L. A. van der Ark, W. P. Bergsma, & K. Sijtsma (2011). Polytomous latent scales for the investigation of the ordering of items. *Psychometrika*, 76, 200-216. <https://doi.org/10.1007/s11336-010-9199-8>

Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.

Sijtsma, K., R. R. Meijer, & Van der Ark, L. A. (2011). Mokken scale analysis as time goes by: An update for scaling practitioners. *Personality and Individual Differences*, 50, 31-37. <https://doi.org/10.1016/j.paid.2010.08.016>

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Van der Ark, L. A. (2012). New developments in Mokken scale analysis in R. *Journal of Statistical Software*, 48(5), 1-27. <https://www.jstatsoft.org/article/view/v048i05>

See Also

[check.iio](#), [plot.iio.class](#)

Examples

```
# Examples from Ligtvoet et al. (2011).

data(cavalini)
X1 <- cavalini[,c(3,5,6,7,9,11,13,14)]

# Use Method MIIO and remove items violating MIIO
iio.list1 <- check.iio(X1)
summary(iio.list1)
plot(iio.list1)
X2 <- X1[,is.na(charmatch(dimnames(X1)[[2]],names(iio.list1$items.removed)))]

# Use Method MSCPM and remove items violating MSCPM
iio.list2 <- check.iio(X2,method="MSCPM")
summary(iio.list2)
X3 <- X2[,is.na(charmatch(dimnames(X2)[[2]],names(iio.list2$items.removed)))]

# Use Method IT
iio.list3 <- check.iio(X3,method="IT")
summary(iio.list3)
```

`summary.monotonicity.class`*Summarize monotonicity.class objects*

Description

S3 Method for summary of objects of class `monotonicity.class`. Summarizes checks of monotonicity

Usage

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

Arguments

<code>object</code>	list produced by check.monotonicity
<code>...</code>	Optional parameters will be ignored

Value

Matrix with $n_{col}(X)$ rows and 10 columns, showing for each item a summary of the violations of monotonicity: `itemH` = Item-scalability coefficient; `#ac` = number of active pairs that were investigated; `#vi` = number of violations in which the item is involved; `#vi/#ac` = proportion of active pairs that is involved in a violation; `maxvi` = maximum violation; `sum` = sum of all violations; `zmax` = maximum z-value; `zsig` = number of significant z-values; `crit` = Crit value (Molenaar & Sijtsma, 2000, pp. 49, 74).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in R. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.monotonicity](#), [plot.monotonicity.class](#)

Examples

```
data(ac1)
Communality <- ac1[,1:10]
monotonicity.list <- check.monotonicity(Communality)
plot(monotonicity.list)
summary(monotonicity.list)
```

summary.pmatrix.class *Summarize pmatrix.class objects*

Description

S3 Method for summary of objects of class pmatrix.class. Summarize checks of nonintersection using method pmatrix.

Usage

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

Arguments

object	list produced by check.pmatrix
...	Optional parameters will be ignored

Details

For obtaining the P++ and P- matrix, see examples.

Value

Matrix with `ncol(X)` rows and 10 columns, showing for each item a summary of the violations of nonintersection using method pmatrix: `itemH` = Item-scalability coefficient; `#ac` = number of active pairs that were investigated; `#vi` = number of violations in which the item is involved; `#vi/#ac` = proportion of active pairs that is involved in a violation; `maxvi` = maximum violation; `sum` = sum of all violations; `zmax` = maximum z-value; `zsig` = number of significant z-values; `crit` = Crit value (Molenaar & Sijtsma, 2000, pp. 49, 74).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in **R**. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.pmatrix](#), [plot.pmatrix.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
pmatrix.list <- check.pmatrix(Communality)
plot(pmatrix.list)
summary(pmatrix.list)

# Small example showing how to retrieve the P++ matrix and the P-- matrix
SmallExample <- acl[,1:4]
pmatrix.list <- check.pmatrix(SmallExample)
pmatrix.list$results$Ppp
pmatrix.list$results$Pmm
```

```
summary.restscore.class
```

Summarize restscore.class objects

Description

S3 Method for summary of objects of class restscore.class. Summarize checks of nonintersection using method restscore.

Usage

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

Arguments

object	list produced by check.restscore
...	Optional parameters will be ignored

Value

Matrix with $ncol(X)$ rows and 10 columns, showing for each item a summary of the violations of nonintersection using method `restscore`: `itemH` = Item-scalability coefficient; `#ac` = number of active pairs that were investigated; `#vi` = number of violations in which the item is involved; `#vi/#ac` = proportion of active pairs that is involved in a violation; `maxvi` = maximum violation; `sum` = sum of all violations; `zmax` = maximum z-value; `zsig` = number of significant z-values; `crit` = Crit value (Molenaar & Sijtsma, 2000, pp. 49, 74).

Author(s)

L. A. van der Ark <L.A.vanderArk@uva.nl>

References

- Mokken, R. J. (1971) *A Theory and Procedure of Scale Analysis*. De Gruyter.
- Molenaar, I.W., & Sijtsma, K. (2000) *User's Manual MSP5 for Windows* [Software manual]. IEC ProGAMMA.
- Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.
- Van der Ark, L. A. (2007). Mokken scale analysis in R. *Journal of Statistical Software*. <https://www.jstatsoft.org/article/view/v020i11>

See Also

[check.restscore](#), [plot.restscore.class](#)

Examples

```
data(acl)
Communality <- acl[,1:10]
restscore.list <- check.restscore(Communality)
plot(restscore.list)
summary(restscore.list)
```

SWMD

SWMD Data Subset

Description

A subset of the COOL5-18 data (see below) with scores of 651 pupils nested in 30 classes on the 7-item Schaal Welbevinden Met Docenten [Scale Well-Being With Teachers] (Peetsma, Wagenaar, & de Kat, 2001; Zijlstra, Keuning, Keizer-Mittelhauser, Naaijer, & Timmermans, 2017). See `attributes(SWMD)` for the original item labels and content. R-code to get this subsample is available as online supplement to Koopman, Zijlstra, & Van der Ark (2020).

Usage

```
data(SWMD)
```


Format

A 651 by 8 data frame containing integers. The first column reflects a classroom indicator, the remaining columns the 7 items, see `colnames(SWMD)`.

Details

Each item has five ordered answer categories from *not true at all* (score 0) to *completely true* (score 4).

<i>Item</i>	<i>Short</i>	<i>Content</i>
Item1	lv_wdo1	The teachers usually know how I feel
Item2	lv_wdo2	I can talk about problems with the teachers
Item3	lv_wdo3	If I feel unhappy, I can talk to the teachers about it
Item4	lv_wdo4	I feel at ease with the teachers
Item5	lv_wdo5	The teachers understand me
Item6	lv_wdo6	I have good contact with the teachers
Item7	lv_wdo7	I would prefer to have other teachers (inversely coded)

The items were translated from Dutch. For the original items, see p. 79 in Zijsling et al. (2017).

Source

Data is a subset of respondents and items from the large-scale cohort study COOL5-18. <http://www.cool5-18.nl/> (Zijsling et al., 2017). For entire dataset see <https://doi.org/10.17026/dans-zfp-egnq> Dataset is accessible after login.

References

- Koopman, L. Zijlstra, B. J. H., & Van der Ark, L. A. (2020). *A two-step procedure for scaling multilevel data using Mokken's scalability coefficients*. Manuscript submitted for publication.
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- Zijsling, D., Keuning, J., Keizer-Mittelhaeuser, M.-A., Naaijer, H., & Timmermans, A. (2017). *Cohortonderzoek COOL5-18: Technisch rapport meting VO-3 in 2014*. Onderwijs/Onderzoek. Retrieved from https://www.rug.nl/research/portal/files/41740853/Cool_afn1314_vo3_techrapport.pdf

See Also

[MLcoefH](#), [ICC](#),

Examples

```
# Data example (Koopman et al., 2020)
data(SWMD)
```

```
# Item content, see labels
attributes(SWMD)$labels

# Compute ICC
ICC(SWMD)
```

transreas *Transitive Reasoning*

Description

Data came from 12 dichotomous items administered to 425 children in grades 2 through 6 (Verweij, Sijtsma, & Koops, 1996). Each item is a transitive reasoning task.

Usage

```
data(transreas)
```

Format

A 425 by 13 (grade and scores on 12 items) matrix containing integers. `attributes(transreas)` gives details on the items

Details

Items have two ordered answer categories, *incorrect* (score 0), *correct* (1). (for detailed information, see Sijtsma & Molenaar, 2002, p. 33).

Item	Task	Property	Format	Objects	Measures
T09L	9	length	YA = YB < YC = YD	sticks	12.5, 12.5, 13, 13 (cm)
T12P	12	pseudo			
T10W	10	weight	YA = YB < YC = YD	balls	60, 60, 100, 100 (g)
T11P	11	pseudo			
T04W	4	weight	YA = YB = YC = YD	cubes	65 (g)
T05W	5	weight	YA < YB < YC	balls	40, 50, 70 (cm)
T02L	2	length	YA = YB = YC = YD	tubes	12 (cm)
T07L	7	length	YA > YB = YC	sticks	28.5, 27.5, 27.5 (cm)
T03W	3	weight	YA > YB > YC	tubes	45, 25, 18 (g)
T01L	1	length	YA > YB > YC	sticks	12, 11.5, 11 (cm)
T08W	8	weight	YA > YB = YC	balls	65, 40, 40 (g)
T06A	6	area	YA > YB > YC	discs	7.5, 7, 6.5 (diameter; cm)

References

Verweij, A. C., Sijtsma, K., & Koops, W. (1996). A Mokken scale for transitive reasoning suited for longitudinal research. *International Journal of Behavioral Development*, 23, 241-264. [https://doi.org/10.1016/0165-0325\(96\)00011-1](https://doi.org/10.1016/0165-0325(96)00011-1)

[//doi.org/10.1177/016502549601900115](https://doi.org/10.1177/016502549601900115)

Sijtsma, K., & Molenaar, I. W. (2002) *Introduction to nonparametric item response theory*. Sage.

Examples

```
# Construction of Table 3.1 in Sijtsma and Molenaar (2002, p. 33)
data(transreas)
grades <- transreas[,1]
item.scores <- transreas[,-1]
Total.group <- round(apply(item.scores,2,mean),2)
for (i in 2:6) assign(paste("Grade.",i,sep=""),
  round(apply(item.scores[grades==i,],2,mean),2))
Task <- c(9,12,10,11,4,5,2,7,3,1,8,6)
Property <- attributes(transreas)$property
Format <- attributes(transreas)$format
Objects <- attributes(transreas)$objects
Measures <- attributes(transreas)$measures
Table.3.1 <- data.frame(Task,Property,Format,Objects,Measures,
  Total.group,Grade.2,Grade.3,Grade.4,Grade.5,Grade.6)
Table.3.1
```

twoway

Two-way imputation

Description

Returns a single or multiple completed data sets using two-way imputation with normally distributed errors.

Usage

```
twoway(X, nCompletedDataSets = 1, minX = defaultMinX, maxX = defaultMaxX, seed = FALSE)
```

Arguments

X	matrix or data frame of integer data containing the score of $n_{row}(X)$ respondents to $n_{col}(X)$ items. Typically X contains missing values.
nCompletedDataSets	Number of completed data sets.
minX	Minimum item score. By default, the minimum item score is the lowest score found in the data.
maxX	Maximum item score. By default, the maximum item score is the highest score found in the data.
seed	Seed for random sampling. If seed = FALSE (default), no seed is given, otherwise seed must be a numeric value. Replications having the same seed result in exactly the same outcome value.

Details

For single imputation (`nCompletedDataSets == 1`, default) the function returns an object of the same class as `X`, for multiple imputation (`nCompletedDataSets > 1`) the function returns a list. References for two-way imputation include Bernaards and Sijtsma (2000), Sijtsma and Van der Ark (2003), and Van Ginkel, Van der Ark, and Sijtsma (2007).

Value

The result is `X` for which the missing values have been replaced by imputed values. For multiple imputations, the result is a list of matrices/data frames. For single imputations, the result is a matrix/data frame.

Author(s)

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References

Bernaards, C. A., & Sijtsma, K. (2000). Influence of simple imputation and EM methods on factor analysis when item nonresponse in questionnaire data is nonignorable *Multivariate Behavioral Research*, 35, 321-364. https://doi.org/10.1207/S15327906MBR3503_03

Sijtsma, K., & Van der Ark, L. A. (2003). Investigation and treatment of missing item scores in test and questionnaire data. *Multivariate Behavioral Research*, 38, 505-528. https://doi.org/10.1207/s15327906mbr3804_4

Van Ginkel, J. R., Van dec Ark, L. A., & Sijtsma, K. (2007). Multiple imputation of item scores in test and questionnaire data, and influence on psychometric results. *Multivariate aBehavioral Research*, 42, 387-414. <https://doi.org/10.1080/00273170701360803>

See Also

[DS14](#), [recode](#)

Examples

```
data(DS14)

# Handle missing data and recode negatively worded items
X <- DS14[, 3 : 16]
X <- twoway(X)
X <- recode(X, c(1, 3))
head(X)
```

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