Package 'MEI'

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Type Package

Title Measurement Equivalence/Invariance Test

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Description

This package provides a collection of functions for testing configural, metric, and scalar invariance, as well as comparing latent means and defined parameters. Applied to multiple groups, multiple times in longitudinal studies, multiple sources in congruence research, and multi-level confirmatory factor analysis. Notes: (1) Use 2,000 bootstrapped samples or one million sets of factor loadings and intercepts generated by Monte Carlo simulation based on the parameter estimates and the variance-covariance matrix of the freely estimated factor loadings and intercepts in the configural invariance model (or partial metric invariance model), and the confidence intervals of differences in factor loadings and intercepts between groups are calculated. (2) When more than two groups are tested for ME/I, for each combination of reference item and argument, first compares each pair of groups using a Type I error rate of 0.01 or 0.001, then applies the list-and-delete method to identify the set of invariant groups. (3) After identifying the sets of groups with invariant factor loadings or intercepts in each pair of reference and argument items, the model with the least number of freely estimated factor loadings and intercepts (the most parsimonious model with the largest number of invariant items) will be selected. (4) When multiple models have the same number of estimated parameters, the model with the best fit will be selected. (5) Missing values are handled with full-information maximum likelihood. (6) All non-converged and non-admissible bootstrapped samples are removed from the calculations. (7) All the identification of invariant sets is correct up to a maximum of 25 groups. If there are more than 12 sets of invariant groups, the remaining groups will be considered as non-invariant.

License GPL-3

Encoding UTF-8

LazyData TRUE

Depends R (>= 3.5.0),
lavaan (>= 0.6-5),
MASS (>= 7.3-60),
semTools (>= 0.5-6)

Imports MASS (>= 7.3-60),
semTools (>= 0.5-6),
lavaan (>= 0.6-5), parallel

URL https://github.com/gche935/MEI

BugReports https://github.com/gche935/MEI/issues

RoxygenNote 7.3.3

Contents

`CompareLoadings` *Metric Invariance Test*

Description

Conduct a full metric invariance test and identify a partial metric invariance model.

Usage

```
CompareLoadings(
  model,
  data.source,
  Groups,
  Cluster = "NULL",
  Bootstrap = 0,
  alpha = 0.01
)
```

Arguments

`model`	User-specified CFA model.
`data.source`	A data frame containing the observed variables used in the model.
`Groups`	Grouping variable for cross-group comparisons.
`Cluster`	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
`Bootstrap`	Number of bootstrap samples, must be between 500 and 5,000. If not specified, the Monte Carlo simulation (default) will be used.
`alpha`	Type I error rate (default is 0.01) for identifying non-invariant items in the List and Delete method. Can also use Bonferroni adjustment (Type I error /No. of comparisons).

Details

Reference: Measurement Equivalence/Invariance Test based on "Cheung, G. W. & Lau, R. S. (2012). A direct comparison approach for testing measurement invariance. Organizational Research Methods, 15, 167-198."

Value

Partial metric invariance model in the PMI.txt file.

Examples

```
## -- Example A: Measurement Invariance Test Across Groups -- ##

# Data file is "Example.A"

# Specify the measurement model - Model.A
Model.A <- '
       WorkLifeConflict =~ R45a + R45b + R45c + R45d + R45e
       Engagement =~ R90a + R90b + R90c
       Wellbeing =~ R87a + R87b + R87c + R87d + R87e
'

## Not run:
## ===== Full Measurement Invariance Test ===== ##
Full_MEI(Model.A, Example.A, Groups = "Region")
## End (Not run)

## ===== Compare Loadings ===== ##
CompareLoadings(Model.A, Example.A, Groups = "Region", alpha = 0.001)
```

`CompareMeans` *Scalar Invariance Test and Compare Latent Means*

Description

Conduct scalar invariance test, identify partial scalar invariance model, and compare latent means.

Usage

```
CompareMeans(
  model.PMI,
  data.source,
  Groups,
  Cluster = "NULL",
  Bootstrap = 0,
  alpha = 0.01
)
```

Arguments

model.PMI	Partial metric invariance model (PMI.Model.R from CompareLoadings() or user-specified).
data.source	A data frame containing the observed variables used in the model.
Groups	Grouping variable for cross-group comparisons.
Cluster	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
Bootstrap	Number of bootstrap samples, must be between 500 and 5,000. If not specified, the Monte Carlo simulation (default) will be used.
alpha	Type I error rate (default is 0.01) for identifying non-invariant items in the List and Delete method. Can also use Bonferroni adjustment (Type I error /No. of comparisons).

Details

Reference: Measurement Equivalence/Invariance Test based on "Cheung, G. W. & Lau, R. S. (2012). A direct comparison approach for testing measurement invariance. Organizational Research Methods, 15, 167-198."

Value

Partial scalar invariance model in PSI.txt file and results of latent means comparisons.

Examples

```
## Not run:
## ===== Full Measurement Invariance Test ===== ##
Full_MEI(Model.A, Example.A, Groups = "Region")

## ===== Compare Loadings ===== ##
CompareLoadings(Model.A, Example.A, Groups = "Region", alpha = 0.001)
## End (Not run)

## ===== Compare Intercepts and Latent Means ===== ##
CompareMeans(PMI.Model.R, Example.A, Groups = "Region", alpha = 0.001)
```

CompareParameters *Compare Defined Parameters Across Groups*

Description

Conduct defined parameters across groups, e.g., direct, indirect and total effects.

Usage

```
CompareParameters(
  model.PMI,
  model.PATH,
  data.source,
  Groups,
  Cluster = "NULL",
  Bootstrap = 0
)
```

Arguments

model.PMI	Partial metric invariance model (PMI.Model.R from CompareLoadings() or user-specified).
model.PATH	model with defined parameters.
data.source	A data frame containing the observed variables used in the model.
Groups	Grouping variable for cross-group comparisons.
Cluster	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
Bootstrap	Number of bootstrap samples, must be between 500 and 5,000. If not specified, the Monte Carlo simulation (default) will be used.

Details

Reference: Lau, R. S. & Cheung, G. W. (2012). Estimating and comparing specific mediation effects in complex latent variable models. Organizational Research Methods, 15, 3-16.

Value

Estimates and confidence intervals for defined parameters in each group and comparisons of defined parameters across groups.

Examples

```
## Specify the measurement model - Model.A
Model.A <- '
       WorkLifeConflict =~ R45a + R45b + R45c + R45d + R45e
       Engagement =~ R90a + R90b + R90c
       Wellbeing =~ R87a + R87b + R87c + R87d + R87e
'

## Not run:
## ===== Full Measurement Invariance Test ===== ##
Full_MEI(Model.A, Example.A, Groups = "Region")

## ===== Compare Loadings ===== ##
CompareLoadings(Model.A, Example.A, Groups = "Region", alpha = 0.001)
## End (Not run)

## ===== Compare Paths ===== ##
# -- Specify Path model - model.PATH (model.DP) [OrgSize and Tenure are control variables] -- #
model.DP <- '
```

```
  Wellbeing ~ Xb1*Engagement + Xc1*WorkLifeConflict + Xd1*OrgSize + Xe1*Tenure
  Engagement ~ Xa1*WorkLifeConflict

 # Defined Parameters #
 IndirectP := Xa1*Xb1  # Indirect effect
 DirectP := Xc1  # Direct effect
 Total := Xa1*Xb1 + Xc1  # Total effect
'

# -- Run function CompareParmeters using  Monte Carlo simulation -- #
CompareParameters(PMI.Model.R, model.DP, Example.A, Groups = "Region")
```

`Example.A` *Example.A dataset*

Description

Simulated dataset for demonstrating Full_MEI(), CompareLoadings(), CompareMeans(), and CompareParameters().

Usage

```
Example.A
```

Format

A data frame with 2800 rows and 17 variables:

ID Numeric, case ID number.

Region Character, Grouping variable for Groups: European region ("North West", "Nordic", "Continental", "Southern", "Central East", "North East" and "South East").

Org Size Numeric, control variable - organization size.

Tenure Numeric, control variable - tenure in years.

R45a Numeric, Reverse-coded work-life conflict item 45a: from 1 (never) to 5 (always).

R45b Numeric, Reverse-coded work-life conflict item 45b: from 1 (never) to 5 (always).

R45c Numeric, Reverse-coded work-life conflict item 45c: from 1 (never) to 5 (always).

R45d Numeric, Reverse-coded work-life conflict item 45d: from 1 (never) to 5 (always).

R45e Numeric, Reverse-coded work-life conflict item 45e: from 1 (never) to 5 (always).

R90a Numeric, Reverse-coded engagement item 90a: from 1 (never) to 5 (always).

R90b Numeric, Reverse-coded engagement item 90b: from 1 (never) to 5 (always).

R90c Numeric, Reverse-coded engagement item 90c: from 1 (never) to 5 (always).

R87a Numeric, Reverse-coded psychological wellbeing item 87a: from 1 (at no time) to 6 (all of the time).

R87b Numeric, Reverse-coded psychological wellbeing item 87b: from 1 (at no time) to 6 (all of the time).

R87c Numeric, Reverse-coded psychological wellbeing item 87c: from 1 (at no time) to 6 (all of the time).

R87d Numeric, Reverse-coded psychological wellbeing item 87d: from 1 (at no time) to 6 (all of the time).

R87e Numeric, Reverse-coded psychological wellbeing item 87e: from 1 (at no time) to 6 (all of the time).

Source

Simulated dataset (400 observations for each region) based on the 6th European Working Conditions Survey (EWCS 2015; Eurofound, 2024) – Examined the life and working conditions of 43,850 respondents in 35 European countries, which were divided into seven regions: North West, Nordic, Continental, Southern, Central East, North East and South East.

`Example.B` *Example.B dataset*

Description

Simulated dataset for demonstrating LGCompareLoadings() and LGCompareMeans() in longitudinal studies.

Usage

```
Example.B
```

Format

A data frame with 242 rows and 16 variables:

ID Numeric, case ID number.

x1_T1 Numeric, Satisfaction with life scale Item 1 (SWLS1) at T1 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x2_T1 Numeric, Satisfaction with life scale Item 2 (SWLS1) at T1 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x3_T1 Numeric, Satisfaction with life scale Item 3 (SWLS1) at T1 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x4_T1 Numeric, Satisfaction with life scale Item 4 (SWLS1) at T1 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x5_T1 Numeric, Satisfaction with life scale Item 5 (SWLS1) at T1 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x1_T2 Numeric, Satisfaction with life scale Item 1 (SWLS1) at T2 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x2_T2 Numeric, Satisfaction with life scale Item 2 (SWLS1) at T2 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x3_T2 Numeric, Satisfaction with life scale Item 3 (SWLS1) at T2 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x4_T2 Numeric, Satisfaction with life scale Item 4 (SWLS1) at T2 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x5_T2 Numeric, Satisfaction with life scale Item 5 (SWLS1) at T2 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x1_T3 Numeric, Satisfaction with life scale Item 1 (SWLS1) at T3 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x2_T3 Numeric, Satisfaction with life scale Item 2 (SWLS1) at T3 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x3_T3 Numeric, Satisfaction with life scale Item 3 (SWLS1) at T3 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x4_T3 Numeric, Satisfaction with life scale Item 4 (SWLS1) at T3 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

x5_T3 Numeric, Satisfaction with life scale Item 5 (SWLS1) at T3 from 1 (lowest satisfaction) to 6 (greatest satisfaction).

Source

Simulated dataset with 242 observations across three time points based on Study 2 in Wu, C., Chen, L. H., & Tsai, Y. (2009). Longitudinal invariance analysis of the satisfaction with life scale. Personality and Individual Differences, 46, 396-401.

`Example.C` *Example.C dataset*

Description

Simulated dataset for demonstrating LGCompareLoadings() and LGCompareMeans() in congruence studies.

Usage

```
Example.C
```

Format

A data frame with 332 rows and 21 variables:

ID Numeric, case ID number.

x1_T1 Numeric, Self-ratings of managerial role item 1 from 1 (not at all effective) to 7 (extremely effective).

x2_T1 Numeric, Self-ratings of managerial role item 2 from 1 (not at all effective) to 7 (extremely effective).

x3_T1 Numeric, Self-ratings of managerial role item 3 from 1 (not at all effective) to 7 (extremely effective).

x4_T1 Numeric, Self-ratings of managerial role item 4 from 1 (not at all effective) to 7 (extremely effective).

x5_T1 Numeric, Self-ratings of managerial role item 5 from 1 (not at all effective) to 7 (extremely effective).

x6_T1 Numeric, Self-ratings of managerial role item 6 from 1 (not at all effective) to 7 (extremely effective).

x7_T1 Numeric, Self-ratings of managerial role item 7 from 1 (not at all effective) to 7 (extremely effective).

x8_T1 Numeric, Self-ratings of managerial role item 8 from 1 (not at all effective) to 7 (extremely effective).

x9_T1 Numeric, Self-ratings of managerial role item 9 from 1 (not at all effective) to 7 (extremely effective).

x10_T1 Numeric, Self-ratings of managerial role item 10 from 1 (not at all effective) to 7 (extremely effective).

x1_T2 Numeric, Supervisor-ratings of managerial role item 1 from 1 (not at all effective) to 7 (extremely effective).

x2_T2 Numeric, Supervisor-ratings of managerial role item 2 from 1 (not at all effective) to 7 (extremely effective).

x3_T2 Numeric, Supervisor-ratings of managerial role item 3 from 1 (not at all effective) to 7 (extremely effective).

x4_T2 Numeric, Supervisor-ratings of managerial role item 4 from 1 (not at all effective) to 7 (extremely effective).

x5_T2 Numeric, Supervisor-ratings of managerial role item 5 from 1 (not at all effective) to 7 (extremely effective).

x6_T2 Numeric, Supervisor-ratings of managerial role item 6 from 1 (not at all effective) to 7 (extremely effective).

x7_T2 Numeric, Supervisor-ratings of managerial role item 7 from 1 (not at all effective) to 7 (extremely effective).

x8_T2 Numeric, Supervisor-ratings of managerial role item 8 from 1 (not at all effective) to 7 (extremely effective).

x9_T2 Numeric, Supervisor-ratings of managerial role item 9 from 1 (not at all effective) to 7 (extremely effective).

x10_T2 Numeric, Supervisor-ratings of managerial role item 10 from 1 (not at all effective) to 7 (extremely effective).

Source

Simulated dataset with 332 dyads of mid-level executives and their supervisors based on Ashford, S. J., & Tsui A. S. (1991). Self-regulation for managerial effectiveness: The role of active feedback seeking. Academy of Management Journal, 34, 251-280.

`Example.D` *Example.D dataset*

Description

Simulated dataset for demonstrating MLCompareLoadings() for multi-level confirmatory factor analysis.

Usage

```
Example.D
```

Format

A data frame with 2500 rows and 9 variables:

ID Numeric, Cluster variable

x1 Numeric, Negatively worded item 1 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x2 Numeric, Negatively worded item 2 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x3 Numeric, Negatively worded item 3 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x4 Numeric, Negatively worded item 4 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x5 Numeric, Negatively worded item 5 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x6 Numeric, Negatively worded item 6 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x7 Numeric, Negatively worded item 7 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

x8 Numeric, Negatively worded item 8 of Oldenburg Burnout Inventory from 1 (completely disagree) to 5 (completely agree).

Source

Simulated dataset based on Gruszczynska, E., Basinska, B. A., & Schaufeli, W. B. 2021. Within- and between-person factor structure of the Oldenburg Burnout Inventory: Analysis of a diary study using multilevel confirmatory factor analysis. PLoS ONE 16(5):e0251257. doi: 10.1371/journal.pone.0251257 – Eight negatively-worded items of the Oldenburg Burnout Inventory (OLBI) to measure burnout of 250 employees for 10 consecutive working days.

`Full_MEI` *Full Measurement Invariance Test*

Description

Conduct configural invariance, full metric invariance and full scalar invariance tests.

Usage

```
Full_MEI(model, data.source, Groups, Cluster = "NULL")
```

Arguments

`model`	User-specified CFA model.
`data.source`	A data frame containing the observed variables used in the model.
`Groups`	Grouping variable for cross-group comparisons.
`Cluster`	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.

Value

lavaan outputs, model fit for configural, metric and scalar invariance models, summary of fit statistics for each model.

Examples

```
## -- Example A: Measurement Invariance Test Across Groups -- ##

# Data file is "Example.A"

# Specify the measurement model - Model.A
Model.A <- '
       WorkLifeConflict =~ R45a + R45b + R45c + R45d + R45e
       Engagement =~ R90a + R90b + R90c
       Wellbeing =~ R87a + R87b + R87c + R87d + R87e
'

## ===== Full Measurement Invariance Test ===== ##
Full_MEI(Model.A, Example.A, Groups = "Region")
```

LGCompareLoadings *Metric Invariance Test Across Time or Sources*

Description

Conduct metric invariance test and identify non-invariant items across time or different sources.

Usage

```
LGCompareLoadings(
  model,
  data.source,
  Cluster = "NULL",
  no.waves = 3,
  Bootstrap = 0,
  alpha = 0.01
)
```

Arguments

model	User-specified measurement model.
data.source	A data frame containing the observed variables used in the model.
Cluster	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
no.waves	Number of waves/sources for comparisons.
Bootstrap	Number of bootstrap samples, must be between 500 and 5,000. If not specified, the Monte Carlo simulation (default) will be used.
alpha	Type I error rate (default is 0.01) for identifying non-invariant items in the List and Delete method. Can also use Bonferroni adjustment (Type I error /No. of comparisons).

Details

Requires defining the measurement model only once. All indicators should have the suffix _T1, _T2 and _T3 (e.g., x1_T1, x1_T2, x1_T3) in the data file to indicate when the item was measured.

Residuals of indicators are covaried across time/sources automatically.

Value

Estimates and confidence intervals for defined parameters in each group and comparisons of defined parameters across groups.

Examples

```
## == Example B - Panel Data in Longitudinal Studies == ##

# Data file is "Example.B"

## Specify the measurement model - Model.B ##
Model.B <- '
  SWLS =~ x1 + x2 + x3 + x4 + x5
'

## ===== Compare Factor Loadings ===== ##
LGCompareLoadings(Model.B, Example.B, no.waves = 3, alpha =  0.01)


## == Example C - Non-independent Data from two sources == ##

# Data file is "Example.C"

## Specify the measurement model - Model.C ##
Model.C <- '
     External =~ x1 + x2 + x3 + x4 + x5 + x6
     Internal =~ x7 + x8 + x9 + x10
'

## ===== Compare Factor Loadings ===== ##
LGCompareLoadings(Model.C, Example.C, no.waves = 2, alpha = 0.01)
```

`LGCompareMeans` *Scalar Invariance Test and Compare Latent Means in Longitudinal Models*

Description

Conduct scalar invariance test, identify partial scalar invariance model, and compare latent means across time/sources.

Usage

```
LGCompareMeans(
  model.PMI,
  data.source,
```

```
  Cluster = "NULL",
  no.waves = 3,
  Bootstrap = 0,
  alpha = 0.01
)
```

Arguments

model.PMI	Partial metric invariance model (PMI.Model.R from LGCompareLoadings() or user-specified).
data.source	A data frame containing the observed variables used in the model.
Cluster	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
no.waves	Number of waves/sources for comparisons.
Bootstrap	Number of bootstrap samples, must be between 500 and 5,000. If not specified, the Monte Carlo simulation (default) will be used.
alpha	Type I error rate(default is 0.01) for identifying non-invariant items in the List and Delete method. Can also use Bonferroni adjustment (Type I error /No. of comparisons).

Details

Requires defining the measurement model only once. All indicators should have the suffix _T1, _T2 and _T3 (e.g., x1_T1, x1_T2, x1_T3) in the data file to indicate when the item was measured.

Residuals of indicators are covaried across time/sources automatically.

Value

Partial scalar invariance model in PSI.txt file and results of latent means comparisons.

Examples

```
## == Example B - Panel Data in Longitudinal Studies == ##

# Data file is "Example.B"

## Not run:
## Specify the measurement model - Model.B ##
Model.B <- '
  SWLS =~ x1 + x2 + x3 + x4 + x5
'

## ===== Compare Factor Loadings ===== ##
LGCompareLoadings(Model.B, Example.B, no.waves = 3, alpha =  0.01)
## End (Not run)

## ===== Compare Means ===== ##
LGCompareMeans(PMI.Model.R, Example.B, no.waves = 3, alpha = 0.01)


## == Example C - Non-independent Data from two sources == ##
```

```
# Data file is "Example.C"

## Not run:
## Specify the measurement model - Model.C ##
Model.C <- '
     External =~ x1 + x2 + x3 + x4 + x5 + x6
     Internal =~ x7 + x8 + x9 + x10
'

## ===== Compare Factor Loadings ===== ##
LGCompareLoadings(Model.C, Example.C, no.waves = 2, alpha = 0.01)
## End (Not run)

## ===== Compare Means ===== ##
LGCompareMeans(PMI.Model.R, Example.C, no.waves = 2, alpha = 0.01)
```

`MLCompareLoadings` *Metric Invariance Test Between Level 1 and Level 2*

Description

Conduct configural invariance and full metric invariance test, and identify the partial metric invariance model

Usage

```
MLCompareLoadings(model, data.source, Cluster = "NULL", alpha = 0.05)
```

Arguments

`model`	User-specified measurement model.
`data.source`	A data frame containing the observed variables used in the model.
`Cluster`	Cluster variable for nested data. The Monte Carlo simulation method should be used for nested data.
`alpha`	Type I error rate (default is 0.05) for identifying non-invariant items in the List and Delete method for multi-level models.

Details

Reference: Measurement Equivalence/Invariance Test based on "Cheung, G. W. & Lau, R. S. (2012). A direct comparison approach for testing measurement invariance. Organizational Research Methods, 15, 167-198."

Since all Level 1 (within-group) variables are group-mean centered, intercepts and latent means of all variables at Level 1 are set to zero. Hence, only configural and metric invariance across levels are tested. Bootstrapping is not available for a multi-level model.

Define the measurement model only once without specifying the level, and the function will compare the model across levels.

Value

Partial metric invariance model in PMI.txt file.

Examples

```
## == Example D - Multilevel Confirmatory Factor Analysis == ##
# Data file is "Example.A"; cluster variable is "ID"

## Specify the measurement model - Model.D ##
Model.D <- 'OLBI =~ x1 + x2 + x3 + x4 + x5 + x6 + x7 + x8'

## ===== Compare Loadings ===== ##
MLCompareLoadings(Model.D, Example.D, Cluster = "ID", alpha = 0.05)
```

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