Package: MIRES (via r-universe)

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Title Measurement Invariance Assessment Using Random Effects Models and Shrinkage

Version 0.1.1

Description Estimates random effect latent measurement models, wherein the loadings, residual variances, intercepts, latent means, and latent variances all vary across groups. The random effect variances of the measurement parameters are then modeled using a hierarchical inclusion model, wherein the inclusion of the variances (i.e., whether it is effectively zero or non-zero) is informed by similar parameters (of the same type, or of the same item). This additional hierarchical structure allows the evidence in favor of partial invariance to accumulate more quickly, and yields more certain decisions about measurement invariance. Martin, Williams, and Rast (2020) <doi:10.31234/osf.io/qbdjt>.

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BugReports https://github.com/stephenSRMMartin/MIRES/issues

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`MIRES-package` *The 'MIRES' package.*

Description

Estimates random effect latent measurement models, wherein the loadings, residual variances, intercepts, latent means, and latent variances all vary across groups. The random effect variances of the measurement parameters are then modeled using a hierarchical inclusion model, wherein the inclusion of the variances (i.e., whether it is effectively zero or non-zero) is informed by similar parameters (of the same type, or of the same item). This additional hierarchical structure allows the evidence in favor of partial invariance to accumulate more quickly, and yields more certain decisions about measurement invariance.

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References

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.1. https://mc-stan.org

Martin, S. R., Williams, D. R., & Rast, P. (2019, June 18). Measurement Invariance Assessment with Bayesian Hierarchical Inclusion Modeling. <doi:10.31234/osf.io/qbdjt>

See Also

Useful links:

- Report bugs at https://github.com/stephenSRMMartin/MIRES/issues

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`mires` *Fit mixed effects measurement model for invariance assessment.*

Description

Fits mixed effects measurement models for measurement invariance assessment.

Usage

```
mires(
  formula,
  group,
  data,
  inclusion_model = c("dependent", "independent"),
  identification = c("sum_to_zero", "hierarchical"),
  save_scores = FALSE,
  prior_only = FALSE,
  prior = c(0, 0.25),
  ...
)
```

Arguments

`formula`	Formula. LHS is the factor name, and RHS contains indicators.
`group`	Grouping variable (symbol). Grouping variable over which to assess invariance.
`data`	data.frame. Must contain the indicators specified in formula, and the grouping variable.

`inclusion_model`
: String (Default: dependent). If dependent, then the regularization of RE-SDs are dependent (See Details). If independent, then regularization is per-parameter. This is useful for comparing a dependent inclusion model to a non-dependent inclusion model. Note that adaptive regularization occurs regardless (until a non-regularized version is implemented).

`identification`
: String (Default: sum_to_zero). If `hierarchical`, then latent means and (log) SDs are identified as zero-centered random effects. If `sum_to_zero`, then latent means are identified by a sum-to-zero constraint, and (log) latent SDs are identified by a sum-to-zero constraint.

`save_scores`
: Logical (Default: FALSE). If TRUE, latent scores for each observation are estimated. If FALSE (Default), latent scores are marginalized out; this can result in more efficient sampling and faster fits, due to the drastic reduction in estimated parameters. Note that the random effects for each group are always estimated, and are not marginalized out.

`prior_only`
: Logical (Default: FALSE). If TRUE, samples are drawn from the prior.

`prior`
: Numeric vector (Default: c(0, .25)). The location and scale parameters for the hierarchical inclusion model.

`...`
: Further arguments to `sampling`.

Details

MIRES stands for Measurement Invariance assessment with Random Effects and Shrinkage. Unlike other measurement invariance approaches, the MIRES model assumes all measurement model parameters (loadings, residual SDs, and intercepts) can randomly vary across groups — It is a mixed effects model on all parameters. Unlike most mixed effects models, the random effect variances are themselves also hierarchically modeled from a half-normal distribution with location zero, and a scaling parameter. This scaling parameter allows for rapid shrinkage of variance toward zero (invariance), while allowing variance if deemed necessary (non-invariance).

The scaling parameter (an estimated quantity) controls whether the RE variance is effectively zero (invariant) or not (non-invariant). Therefore, the random effect variances are regularized. When `inclusion_model` is `dependent` (Default), the scaling parameters are hierarchically modeled. By doing so, the invariance or non-invariance of a parameter is informed by other parameters with shared characteristics. Currently, we assume that each parameter informs the invariance of other similar parameters (presence of variance in some loadings increases the probability of variance in other loadings), and of similar items (non-invariance of item j parameters informs other parameters for item j). This approach increases the information available about presence or absence of invariance, allowing for more certain decisions.

The "Hierarchical inclusion model" on the random effect variance manifests as a hierarchical prior. When a dependent inclusion model is specified, then the hierarchical prior on random effect SDs is:

$$p(\sigma_p|\exp(\tau)) = \mathcal{N}^+(\sigma_p|0, \exp(\tau))$$

$$\tau = \tau_c + \tau_{param} + \tau_{item} + \tau_p$$

$$\tau_* \sim \mathcal{N}(\mu_h, \sigma_h)$$

Therefore, the regularization of each RE-SD is shared between all RE-SDs (tau_c), all RE-SDs of the same parameter type (tau_param), and all RE-SDs of the same item (tau_item).

When an independent inclusion model is specified (`inclusion_model` is "independent"), only the independent regularization term τ_p is included. The prior is then scaled so that the marginal prior on each $p(\sigma_p)$ remains the same. In this case, RE-SDs cannot share regularization intensities between one another.

The inclusion model hyper parameters (mu_h, sigma_h) can be specified, but we recommend the default as a relatively sane, but weakly informative prior.

Value

mires object.

Author(s)

Stephen R. Martin

References

Stan Development Team (2020). RStan: the R interface to Stan. R package version 2.21.1. https://mc-stan.org

Martin, S. R., Williams, D. R., & Rast, P. (2019, June 18). Measurement Invariance Assessment with Bayesian Hierarchical Inclusion Modeling. <doi:10.31234/osf.io/qbdjt>

Examples

```
data(sim_loadings) # Load simulated data set
head(sim_loadings) # 8 indicators, grouping variable is called "group"

# Fit MIRES to simulated data example.
# Assume factor name is, e.g., agreeableness.
fit <- mires(agreeableness ~ x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7 + x_8,
             group = group,
             data = sim_loadings, chains = 2, cores = 2)

# Summarize fit
summary(fit)

# Compare all groups' loadings:
pairwise(fit, param = "lambda")
# Compare groups "2" and "3" only:
pairwise(fit, param = "lambda", groups = c("2", "3"))

# Get random effects:
fit_ranefs <- ranef(fit)
# Look at random effects of loadings:
fit_ranefs$lambda
```

`pairwise` *Pairwise comparisons of random parameters.*

Description

Compute pairwise differences in group-specific measurement parameters.

Usage

```
pairwise(
  mires,
  param = c("lambda", "resid", "nu"),
  prob = 0.95,
  less_than = 0.1,
  groups = NULL,
  ...
)
```

Arguments

`mires`	mires object.
`param`	Character. One of `lambda` (loadings), `resid` (residual standard deviation on the log scale), or `nu` (intercepts).
`prob`	Numeric (0-1). Probability mass contained within the highest density interval.
`less_than`	Numeric (Default: .1; positive). Value at which to assess Pr(|difference| < less_than|D).
`groups`	Character vector (Optional). If specified, will only compute pairwise differences of the specified groups.
`...`	Not used.

Details

For a specified set of parameters, this computes all pairwise differences in the random effects across the posterior. Specifically, this computes the posterior differences of groups' parameters, for all parameters. This is useful for comparing groups' estimates under non-invariance.

Value

Data frame.

Author(s)

Stephen Martin

print.mires *Print function for mires objects.*

Description

Print function for mires objects.

Usage

```
## S3 method for class 'mires'
print(x, ...)
```

Arguments

x	mires object.
...	Not used.

Value

x (Invisibly)

Author(s)

Stephen R. Martin

print.summary.mires *Print method for MIRES summary objects.*

Description

Print method for MIRES summary objects.

Usage

```
## S3 method for class 'summary.mires'
print(x, ...)
```

Arguments

x	summary.mires object.
...	Not used.

Value

x (Invisibly)

Author(s)

Stephen Martin

`ranef.mires` *Extract random effects of each group from MIRES model.*

Description

Extract random effects of each group from MIRES model.

Usage

```
## S3 method for class 'mires'
ranef(object, prob = 0.95, ...)
```

Arguments

`object`	mires object.
`prob`	Numeric (Default: .95). Amount of probability mass to contain within the credible interval.
`...`	Not used.

Value

List containing summaries of lambda, (log) residual SDs, nu, latent mean, and (log) latent SD random effects.

Author(s)

Stephen R Martin

`sim_all` *Simulated data: All parameters vary (Full non-invariance)*

Description

Simulated data: All parameters vary (Full non-invariance)

Usage

```
sim_all
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

sim_intercepts *Simulated data: Intercepts vary*

Description

Simulated data: Intercepts vary

Usage

```
sim_intercepts
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

sim_items *Simulated data: Half the items are non-invariant.*

Description

Simulated data: Half the items are non-invariant.

Usage

```
sim_items
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

sim_loadings *Simulated data: Loadings vary*

Description

Simulated data: Loadings vary

Usage

```
sim_loadings
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

sim_none *Simulated data: No variance (Full invariance)*

Description

Simulated data: No variance (Full invariance)

Usage

```
sim_none
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

sim_resid *Simulated data: Residual variances vary*

Description

Simulated data: Residual variances vary

Usage

```
sim_resid
```

Format

A simulated dataset containing eight indicators for one factor, and one grouping variable.

summary.mires *Summary method for mires object.*

Description

Computes summaries for MIRES objects.

Usage

```
## S3 method for class 'mires'
summary(object, prob = 0.95, less_than = 0.1, ...)
```

Arguments

`object`	mires object.
`prob`	Numeric (Default = .95). Probability mass to be contained in the highest posterior density interval.
`less_than`	Numeric (Default: .1; positive). Value at which to assess Pr(SD < less_than|D).
`...`	Not used.

Details

Computes summary tables for fixed measurement parameters (loadings, residual SDs, and intercepts) and random effect standard deviations (resd). The printed output includes the posterior mean, median, SD, and .95 (Default) highest density intervals. HDIs were chosen instead of quantile intervals because the random effect SDs can be on the boundary of zero if invariance is plausible. Additionally, other columns exist to help aid decisions about invariance:

BF01 Bayes factor of invariance (Variance = 0) to non-invariance (Variance > 0)

BF10 Bayes factor of non-invariance (Variance > 0) to invariance (Variance = 0). The inverse of BF01 for convenience

Pr(SD <= `less_than`) The posterior probability that the random effect SD is less than `less_than` (Default: .1). Set `less_than` to a value below which you would consider the variance to be effectively ignorable.

BF(SD <= `less_than`) The Bayes Factor comparing effectively-invariant (SD < `less_than`) to non-invariant (SD > `less_than`). Set `less_than` to a value below which you would consider variance to be effectively ignorable. This uses the encompassing prior approach.

Value

summary.mires object. List of meta data and summary. Summary is list of summary tables for all fixed effects parameters.

Author(s)

Stephen R. Martin

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