

# Package ‘harmonious’

July 15, 2024

**Type** Package

**Title** Explanatory Item Response modeling in CmdStanR

**Version** 0.1.0

**Author** Nathan DePuy

**Maintainer** Nathan DePuy <depy@uiowa.edu>

**Description** A package for performing Bayesian inference on Explanatory Item Repsonse models in CmdStanR

**Depends** R (>= 4.0.0),

bayesplot,

Cairo,

ggplot2,

pander,

mathjaxr,

loo,

remotes,

cmdstanr

**Suggests** testthat (>= 3.0.0)

**Additional\_repositories** <https://mc-stan.org/r-packages/>

**SystemRequirements** CmdStan (<https://mc-stan.org/users/interfaces/cmdstan>)

**Encoding** UTF-8

**LazyData** true

**Config/testthat/edition** 3

**RoxygenNote** 7.3.2

**Roxygen** list(markdown=TRUE)

**RdMacros** mathjaxr

**Remotes** stan-dev/cmdstanr

## Contents

CreateMod . . . . .	2
genData . . . . .	3
genReport . . . . .	4
initialize . . . . .	5
rCorr . . . . .	5
rhatCheck . . . . .	6
sample . . . . .	7

**Index****8**

CreateMod

*Create Adjunct CmdStan Model Environment***Description**

Creates an environment to estimate the  $p \times i$  interaction model with CmdStan.

**Usage**

```
CreateMod(
  coef_hyper,
  sd_hyper,
  nWarmup_init,
  nSamples_init,
  nWarmup_run,
  nSamples_run,
  aux_envir
)
```

**Arguments**

<code>coef_hyper</code>	Hyperparameter value for the standard deviation of normally distributed parameters
<code>sd_hyper</code>	Hyperparameter value for the shape parameter of gamma distributed parameters
<code>nWarmup_init</code>	Number of burn-in draws for the fixed $\theta$ model
<code>nWarmup_run</code>	Number of burn-in draws for the free $\theta$ model
<code>nSamples_run</code>	Number of sampled posterior values for the free $\theta$ model (after burn-in has completed)
<code>aux_envir</code>	An environment object that contains objects to be loaded into the CreateMod environment (such as is returned by the <a href="#">genData</a> function)
<code>nSampels_init</code>	Number of posterior draws for the fixed $\theta$ model (after burn-in has completed)

**Details**

Creates an environment with methods for fitting the fixed  $\theta$  and free  $\theta$  models. Additionally, CreateMod includes a method for recursively checking  $\hat{R}$  convergence.

**Value**

an environment object containing fixed  $\theta$  and free  $\theta$  model results

**See Also**

[initialize](#), [sample](#), [rhatCheck](#)

genData

*Data Generating Function for the  $p \times i$  Interaction Model***Description**

Generates data for a  $p \times i$  Interaction Model under the Explanatory Item Response theoretical framework.

**Usage**

```
genData(P, I, J, K, seed = NULL, isCorrI = TRUE)
```

**Arguments**

P	Number of examinees
I	Number of items
J	Number of potential item feature categories
K	Number of potential person feature categories
seed	Integer seed for replication (if NULL, a random seed will be generated)
isCorrI	Draw Cholesky-factorized lower triangular matrix for modeling structured item residuals?

**Details**

Let a model of the log-odds transformed outcome ( $\eta_{pi}$ ) be defined as:

$$\eta_{pi} = \theta_p \lambda_i + \tau_i + \sum_{k=1}^K \sum_{j=1}^J \beta_{jk(\eta)} x_{ik} z_{pj}$$

where the linear predictor of latent trait measurements  $\theta_p$  is defined as:

$$\theta_p = \sum_{j=1}^J \beta_{j(\theta)} z_{pj} + u_{p(\theta)}$$

where the linear predictor of item slope/discrimination terms ( $\lambda_i$ ) is defined as:

$$\lambda_i = \sum_{k=1}^K \beta_{k(\lambda)} x_{ik} + u_{i(\lambda)}$$

and where the linear predictor of item intercept/easiness terms ( $\tau_i$ ) is defined as:

$$\tau_i = \sum_{k=1}^K \beta_{k(\tau)} x_{ik} + u_{i(\tau)}$$

For the linear predictor of latent trait measurements, the following assumption is made on its residual terms for the purposes of model identification:

$$u_{p(\theta)} \sim \mathcal{N}(0, 1)$$

If an assumption is made that there is no structured dependency between the residual terms for the linear predictors of item intercepts and item slopes (`isCorrI = FALSE`), then:

$$u_{i_{(\lambda)}} \sim \mathcal{N}(0, \sigma_{\lambda}^2)$$

$$u_{i_{(\tau)}} \sim \mathcal{N}(0, \sigma_{\tau}^2)$$

Whereas if it is assumed that the residuals of the linear predictors of item intercepts and item slopes is assumed to have a predictable underlying structure (`isCorrI = TRUE`), then:

$$\begin{bmatrix} u_{i_{(\lambda)}} \\ u_{i_{(\tau)}} \end{bmatrix} \sim \mathcal{MVN}\left(\mu = \begin{bmatrix} 0 \\ 0 \end{bmatrix}, \Sigma = \begin{bmatrix} \sigma_{\lambda}^2 & \sigma_{\lambda}\sigma_{\tau} \\ \sigma_{\tau}\sigma_{\lambda} & \sigma_{\tau}^2 \end{bmatrix}\right)$$

### Value

an environment containing simulated data

---

genReport

*Generate Text Report of Free  $\theta$  Model Results*

---

### Description

Helper function that generates a text document in the user-specified save directory

### Usage

```
genReport(saveDir, fileDetails, ...)
```

### Arguments

saveDir	Path to directory where report is saved
fileDetails	string identifier for name of saved report
...	additional arguments passed from parent frame

### Details

Model results include posterior descriptives and simulated data information

### Value

a .txt file of the free  $\theta$  results

---

initialize	<i>Run Fixed <math>\theta</math> Model</i>
------------	--

---

**Description**

Runs the first step in the two-step estimation framework

**Usage**

```
initialize(...)
```

**Arguments**

... arguments passed from parent frame

**Details**

The first step in the two-step estimation framework for the  $p \times i$  model

**Value**

Model results for the standardized  $\theta$  model added to the environment rendered by [CreateMod](#)

**See Also**

[CreateMod](#)

---

rCorr	<i>Randomly Sample a Cholesky Factorized, Lower Triangular Matrix from a Lewandowski-Kurowicka-Joe Distribution</i>
-------	---

---

**Description**

Generates a lower triangular, invertible, positive-definite matrix

**Usage**

```
rCorr(nDim, eta = 1)
```

**Arguments**

nDim	desired dimension of the sampled $n \times n$ matrix
eta	concentration hyperparameter

**Details**

Using the onion method (Ghosh & Henderson, 2003), samples a Cholesky factorized lower-triangular matrix  $L$  from a Lewandowski-Kurowicka-Joe (LKJ) distribution given the concentration hyperparameter  $\eta$ , such that:

$$A = LL^{\top}$$

where  $A$  is a  $n \times n$  matrix and is a member of the set of all symmetric, positive-definite matrices.

**Value**

a lower triangular  $n \times n$  matrix

**References**

Ghosh, S. and Henderson, S. G. (2003). Behavior of the norta method for correlated random vector generation as the dimension increases. *ACM Transactions on Modeling and Computer Simulation*, 13(3), 276-294. <https://doi.org/10.1145/937332.937336>

---

rhatCheck

---

*Recursive Validation for Rhat Convergence*


---

**Description**

Helper function that validates  $\hat{R}$  convergence.

**Usage**

```
rhatCheck(...)
```

**Arguments**

... arguments passed from parent frame

**Details**

```
Input: CmdStan model,  $N_{\max}$ ,  $\hat{R}_1$ 
Sample CmdStan model
while  $\hat{R}_n \leq \hat{R}_{thresh}$  or  $n \leq N_{\max}$  do
  Sample CmdStan model
   $n += 1$ 
end do
end while
```

**Value**

modified free  $\theta$  model that is added to an environment created by [CreateMod](#)

**References**

Vehtari, A., Gelman, A., Simpson, D., Carpenter, B., & Bürkner, P. (2021). Rank-normalization, folding, and localization: an improved  $\hat{r}^2$  for assessing convergence of mcmc (with discussion). *Bayesian Analysis*, 16(2). <https://doi.org/10.1214/20-ba1221>

**See Also**

[CreateMod](#)

---

`sample`*Run Free  $\theta$  Model*

---

**Description**

Runs the second step of the two-step estimation framework

**Usage**

```
sample(...)
```

**Arguments**

... arguments passed from parent frame

**Details**

The second step treating latent trait measurements ( $\theta_p$ ) as freely estimated parameters in the two-step estimation framework for the  $p \times i$  model

**Value**

Model results for the full model added to the environment rendered by [CreateMod](#)

**See Also**

[CreateMod](#)

# Index

CreateMod, [2](#), [5–7](#)

genData, [2](#), [3](#)

genReport, [4](#)

initialize, [2](#), [5](#)

rCorr, [5](#)

rhatCheck, [2](#), [6](#)

sample, [2](#), [7](#)