# Package 'STARTS'

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**Type** Package

**Title** Functions for the STARTS Model

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**Description** Contains functions for estimating the STARTS model of Kenny and Zautra (1995, 2001) <DOI:10.1037/0022-006X.63.1.52>, <DOI:10.1037/10409-008>. Penalized maximum likelihood estimation and Markov Chain Monte Carlo estimation are also provided, see Luedtke, Robitzsch and Wagner (2018) <DOI:10.1037/met0000155>.

**Depends** R (>= 3.1)

**Imports** CDM (>= 7.1-19), graphics, LAM (>= 0.3-27), sirt (>= 2.3), Rcpp, stats, utils

**Suggests** lavaan

**LinkingTo** Rcpp, RcppArmadillo

**URL** https://github.com/alexanderrobitzsch/STARTS, https://sites.google.com/site/alexanderrobitzsch2/software

**License** GPL (>= 2)

**NeedsCompilation** yes

**Repository** CRAN

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# R topics documented:

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`STARTS-package` *Functions for the STARTS Model*

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## Description

Contains functions for estimating the STARTS model of Kenny and Zautra (1995, 2001) <DOI:10.1037/0022-006X.63.1.52>, <DOI:10.1037/10409-008>. Penalized maximum likelihood estimation and Markov Chain Monte Carlo estimation are also provided, see Luedtke, Robitzsch and Wagner (2018) <DOI:10.1037/met0000155>.

## Author(s)

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## References

Kenny, D. A., & Zautra, A. (1995). The trait-state-error model for multiwave data. *Journal of Consulting and Clinical Psychology, 63*, 52-59.

Kenny, D. A., & Zautra, A. (2001). Trait-state models for longitudinal data. In L. M. Collins & A. G. Sayer (Eds.), *New methods for the analysis of change* (pp. 243-263). Washington, DC, US: American Psychological Association.

Luedtke, O., Robitzsch, A., & Wagner, J. (2018). More stable estimation of the STARTS model: A Bayesian approach using Markov Chain Monte Carlo techniques. *Psychological Methods, 23*(3), 570-593.

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`data.starts` *Datasets in the* **STARTS** *Package*

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## Description

Some datasets for illustration used in the examples of the **STARTS** package.

## Usage

```
data(data.starts01a)
data(data.starts01b)
data(data.starts02)
```

## Format

- data.starts01a. A resimulated dataset containing three factors from the Big5 scale measured at five time points used in Luedtke, Robitzsch and Wagner (2018). The dataset only contains observations without missing data.

```
'data.frame':   890 obs. of  16 variables:
$ id: int  100006 100008 100010 100014 100032 100033 100035 100038 100049 100050 ...
$ E1: num  -0.28 1.48 0.12 -1.05 -0.28 ...
$ E2: num  0.12 -0.092 0.495 -0.679 -0.467 ...
$ E3: num  1.08 0.12 0.12 -1.27 -0.28 ...
$ E4: num  0.495 0.12 1.294 -2.229 -0.28 ...
$ E5: num  -0.092 0.707 0.707 -2.041 -0.092 ...
$ N1: num  1.114 -0.173 -0.017 0.958 1.27 ...
$ N2: num  -0.348 0.003 -1.167 1.602 1.758 ...
$ N3: num  -0.192 0.471 -0.348 1.114 0.627 ...
$ N4: num  -0.348 -1.167 -0.504 1.426 1.27 ...
$ N5: num  -0.192 -0.836 -0.192 2.421 1.27 ...
$ O1: num  1.994 -1.82 -0.107 -0.678 -0.792 ...
$ O2: num  1.423 -0.678 -0.678 -0.678 1.423 ...
$ O3: num  1.423 -1.066 -0.678 0.075 0.852 ...
$ O4: num  -0.29 -0.678 -0.29 0.075 -0.107 ...
$ O5: num  1.217 -1.637 -0.29 -0.678 0.646 ...
```

- data.starts01b. Like data.starts01a, but the dataset also contains cases with missing data.

```
'data.frame':   3215 obs. of  17 variables:
$ id  : int  100001 100002 100003 100004 100005 100006 100007 100008 100009 100010 ...
$ patt: Factor w/ 26 levels "P00010","P00011",..: 24 19 20 25 22 26 18 26 19 26 ...
$ E1  : num  0.308 1.67 0.308 0.308 -0.468 ...
$ E2  : num  0.308 0.895 0.707 0.707 0.12 0.12 NA -0.092 -0.28 0.496 ...
$ E3  : num  0.895 NA NA 0.895 NA ...
$ E4  : num  NA NA NA 0.496 0.496 ...
$ E5  : num  0.707 NA 0.308 NA 0.496 -0.092 -0.28 0.707 NA 0.707 ...
$ N1  : num  0.783 -0.017 -0.192 -0.017 -0.504 ...
$ N2  : num  1.114 -0.348 -0.348 -0.348 -0.836 ...
$ N3  : num  -0.348 NA NA -0.348 NA ...
$ N4  : num  NA NA NA -0.504 -1.811 ...
$ N5  : num  0.471 NA -0.192 NA -1.421 ...
$ O1  : num  -0.495 -0.107 -0.495 1.035 -0.792 ...
$ O2  : num  -0.107 -0.107 -0.29 1.035 -0.29 ...
$ O3  : num  0.464 NA NA 1.423 NA ...
$ O4  : num  NA NA NA 1.423 0.281 ...
$ O5  : num  0.646 NA -1.066 NA 0.281 ...
```

- data.starts02 contrains means and covariance matrices of the study of Wu (2016) for the older and the younger cohort (Table 2). Variables a indicate item parcels of negative attitude factor at six occasions. Variable b denotes the performance difficulty factor and variable c the somatic factor.

```
List of 2
$ older_cohort  :List of 3
..$ nobs  : num 630
..$ mean  : Named num [1:18] 3.53 3.46 3.12 2.71 2.8 2.67 2.62 2.69 2.46 2.37 ...
.. ..- attr(*, "names")=chr [1:18] "a1" "a2" "a3" "a4" ...
..$ covmat:'data.frame':      18 obs. of  18 variables:
$ younger_cohort:List of 3
..$ nobs  : num 660
..$ mean  : Named num [1:18] 4.62 4.52 4.46 3.58 3.96 3.21 2.94 3.16 3.03 2.74 ...
.. ..- attr(*, "names")=chr [1:18] "a1" "a2" "a3" "a4" ...
..$ covmat:'data.frame':      18 obs. of  18 variables:
```

## References

Luedtke, O., Robitzsch, A., & Wagner, J. (2018). More stable estimation of the STARTS model: A Bayesian approach using Markov Chain Monte Carlo techniques. *Psychological Methods, 23*(3), 570-593.

Wu, P.-C. (2016). Longitudinal stability of the Beck Depression Inventory II: A latent trait-state-occasion model. *Journal of Psychoeducational Assessment, 34*, 39-53.

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`STARTS-utilities` *Utility Functions in the* **STARTS** *Package*

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## Description

Utlity functions in the **STARTS** package

## Usage

```
## density inverse gamma distribution
digamma2(x, n0, var0)
```

## Arguments

| | |
|---|---|
| `x` | Numeric Vector |
| `n0` | Prior sample size |
| `var0` | Prior variance |

starts_uni *Functions for the Univariate STARTS Model*

## Description

Functions for computing the covariance matrix and simulating data from the univariate STARTS model (Kenny & Zautra, 1995, 2001). The STARTS model can be estimated with maximum likelihood, penalized maximum likelihood (i.e., maximum posterior estimation) or Markov Chain Monte Carlo. See Luedtke, Robitzsch and Wagner (2018) for comparisons among estimation methods.

## Usage

```
## estimation of univariate STARTS model
starts_uni_estimate(data=NULL, covmat=NULL, nobs=NULL, estimator="ML",
    pars_inits=NULL, prior_var_trait=c(3, 0.33), prior_var_ar=c(3, 0.33),
    prior_var_state=c(3, 0.33), prior_a=c(3, 0.5), est_var_trait=TRUE,
    est_var_ar=TRUE, est_var_state=TRUE, var_meas_error=0, constraints=TRUE,
    time_index=NULL, type="stationary", n.burnin=5000, n.iter=20000,
    verbose=FALSE, optim_fct="optim", use_rcpp=TRUE )

## S3 method for class 'starts_uni'
summary(object, digits=3, file=NULL, print_call=TRUE, ...)

## S3 method for class 'starts_uni'
plot(x, ...)

## S3 method for class 'starts_uni'
logLik(object, ...)

## S3 method for class 'starts_uni'
coef(object, ...)

## S3 method for class 'starts_uni'
vcov(object, ...)

## computation of covariance matrix
starts_uni_cov(W, var_trait, var_ar, var_state, a, time_index=NULL,
       add_meas_error=NULL)

## simulation of STARTS model
starts_uni_sim(N, W, var_trait, var_ar, var_state, a, time_index=NULL )

#--- deprecated functions
starts_cov(W, var_trait, var_ar, var_state, a)
starts_sim1dim(N, W, var_trait, var_ar, var_state, a )
```

### Arguments

| | |
|---|---|
| data | Data frame. Missing data must be coded as NA. |
| covmat | Covariance matrix (not necessary if data is provided) |
| nobs | Number of observations (not necessary if data is provided) |
| estimator | Type of estimator: "ML" for maximum likelihood estimation (using LAM::pmle), "PML" for penalized maximum likelihood estimation (using LAM::pmle) and "MCMC" for Markov chain Monte Carlo estimation (using LAM::amh). |
| pars_inits | Optional vector of initial parameters |
| prior_var_trait | Vector of length two specifying the inverse gamma prior for trait variance. The first entry is the prior sample size, the second entry the guess of the proportion of the variance that is attributed to the trait variance. See Luedtke et al. (2018) for further details. |
| prior_var_ar | Prior for autoregressive variance. See prior_var_trait for details. |
| prior_var_state | Prior for state variance. See prior_var_trait for details. |
| prior_a | Vector of length two for specification of the beta prior for stability parameter a. The first entry corresponds to the prior sample size, the second entry corresponds to the prior guess of the stability parameter. |
| est_var_trait | Logical indicating whether the trait variance should be estimated. |
| est_var_ar | Logical indicating whether the autoregressive variance should be estimated. |
| est_var_state | Logical indicating whether the state variance should be estimated. |
| var_meas_error | Value of known measurement variance. Could be based on a reliability estimate of internal consistency, for example. |
| constraints | Logical indicating whether variances should be constrained to be positive |
| time_index | Integer vector of time indices. Time points can be non-equidistant, but must be integer values. |
| type | Type of starts model. Only "stationary" is implemented in this package version. |
| n.burnin | Number of burn-in iterations (if estimator="MCMC") |
| n.iter | Total number of iterations (if estimator="MCMC") |
| verbose | Logical indicating whether iteration progress should be displayed (if estimator="ML" or estimator="PML") |
| optim_fct | Type of optimization function if estimator="ML" or estimator="PML". Can be "optim" for stats::optim or "nlminb" for stats::nlminb. |
| use_rcpp | Logical indicating whether **Rcpp** code should be used in estimation. |
| W | Number of measurement waves. |
| var_trait | Variance of trait component. |
| var_ar | Variance of autoregressive component. |
| var_state | Variance of state component. |

| | |
|---|---|
| N | Sample size of persons |
| a | Stability parameter |
| object | Object of class starts_uni |
| digits | Number of digits after decimal in summary output |
| file | Optional file name for summary output |
| print_call | Logical indicating whether call should be printed in summary output |
| x | Object of class starts_uni |
| ... | Further arguments to be passed. For the plot method, see the plot method for the LAM::amh function for arguments |
| add_meas_error | Optional vector of measurement error variance which should be added to the diagonal of the covariance matrix. |

## Value

Output of starts_uni_estimate

| | |
|---|---|
| coef | Vector of estimated parameters |
| ... | Further values |

Output of starts_uni_cov is a covariance matrix.

Output of starts_uni_sim is a data frame containing simulated values.

## References


Kenny, D. A., & Zautra, A. (1995). The trait-state-error model for multiwave data. *Journal of Consulting and Clinical Psychology, 63*, 52-59.

Kenny, D. A., & Zautra, A. (2001). Trait-state models for longitudinal data. In L. M. Collins & A. G. Sayer (Eds.), *New methods for the analysis of change* (pp. 243-263). Washington, DC, US: American Psychological Association.

Luedtke, O., Robitzsch, A., & Wagner, J. (2018). More stable estimation of the STARTS model: A Bayesian approach using Markov Chain Monte Carlo techniques. *Psychological Methods, 23*(3), 570-593.


## Examples

```
library(sirt)

#############################################################################
# EXAMPLE 1: STARTS model specification using starts_uni_estimate
#############################################################################

## use simulated dataset according to Luedtke et al. (2017)

data(data.starts01a, package="STARTS")
dat <- data.starts01a

#--- covariance matrix and number of observations
```

```
covmat <- stats::cov( dat[, paste0("E",1:5) ] )
nobs <- nrow(dat)

#*** Model 1a: STARTS model with ML estimation
mod1a <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs)
summary(mod1a)

## Not run:
#- estimate model based on input data
mod1a1 <- STARTS::starts_uni_estimate( data=dat[, paste0("E",1:5) ])
summary(mod1a1)

#*** Model 1b: STARTS model with penalized ML estimation using the default priors
mod1b <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, estimator="PML")
summary(mod1b)

#*** Model 1c: STARTS model with MCMC estimation and default priors
set.seed(987)
mod1c <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, estimator="MCMC")

# assess convergence
plot(mod1c)
# summary
summary(mod1c)
# extract more information
logLik(mod1c)
coef(mod1c)
vcov(mod1c)

#*** Model 1d: MCMC estimation with different prior distributions
mod1d <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, estimator="MCMC",
             prior_var_trait=c(10, 0.5), prior_var_ar=c(10, 0.3),
             prior_var_state=c(10, 0.2), prior_a=c(1, 0.5) )
summary(mod1d)

#*** Model 2: remove autoregressive process
mod2 <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, est_var_ar=FALSE)
summary(mod2)

#*** Model 3: remove stable trait factor
mod3 <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, est_var_trait=FALSE)
summary(mod3)

#*** Model 4: remove state variance from the model
mod4 <- STARTS::starts_uni_estimate( covmat=covmat, nobs=nobs, est_var_state=FALSE)
summary(mod4)

## End(Not run)
```

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