

# Package ‘msd’

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**Type** Package

**Title** Method of Successive Dichotomizations

**Version** 0.2.0

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**Imports** stats

**Description** Implements the method of successive dichotomizations by Bradley and Massof (2018) <doi:10.1371/journal.pone.0206106>, which estimates item measures, person measures and ordered rating category thresholds given ordinal rating scale data.

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expdata	<i>Expected Ratings Matrix</i>
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### Description

Expected ratings matrix given item measures, person measures and ordered rating category thresholds.

### Usage

```
expdata(items, persons, thresholds, minRating)
```

### Arguments

items	a numeric vector of item measures with missing values set to NA.
persons	a numeric vector of person measures with missing values set to NA.
thresholds	a numeric vector of ordered rating category thresholds with no NA.
minRating	integer representing the smallest ordinal rating category (see Details).

### Details

It is assumed that the set of ordinal rating categories consists of all integers from the lowest rating category specified by `minRating` to the highest rating category, which is `minRating + length(thresholds)`.

### Value

A numeric matrix of expected ratings.

### Note

Expected ratings are literally the expected value of the ordinal rating categories when treated as integers. Expected ratings that cannot be calculated return as NA (e.g., if either the person or item measure is NA). Intended use is for chi-squared tests or calculating infit and outfit statistics.

### Author(s)

Chris Bradley (cbradley05@gmail.com)

### See Also

[misfit](#)

### Examples

```
# Using randomly generated values with minimum rating set to zero
im <- runif(20, -2, 2)
pm <- runif(50, -2, 2)
th <- sort(runif(5, -2, 2))
m <- expdata(items = im, persons = pm, thresholds = th, minRating = 0)
```

---

`misfit`*Infit and Outfit Statistics*

---

**Description**

Calculates infit and outfit for items and persons.

**Usage**

```
misfit(data, items, persons, thresholds, minRating = NULL)
```

**Arguments**

<code>data</code>	a numeric matrix of ordinal rating scale data whose entries are integers with missing data set to NA. Rows are persons and columns are items. The ordinal rating scale is assumed to go from the smallest to largest integer in integer steps unless <code>minRating</code> is specified.
<code>items</code>	a numeric vector of item measures with missing values set to NA.
<code>persons</code>	a numeric vector of person measures with missing values set to NA.
<code>thresholds</code>	a numeric vector of ordered rating category thresholds with no NA.
<code>minRating</code>	integer representing the smallest ordinal rating category. Default is NULL (see Details).

**Details**

`minRating` must be specified if either the smallest or largest possible rating category is not in data (no person used one of the extreme rating categories). If `minRating` is specified, the ordinal rating scale is assumed to go from `minRating` to `minRating + length(thresholds)`.

**Value**

A list whose elements are:

<code>infit_items</code>	a vector of infit statistics for the items
<code>outfit_items</code>	a vector of outfit statistics for the items
<code>infit_persons</code>	a vector of infit statistics for the persons
<code>outfit_persons</code>	a vector of outfit statistics for the persons

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

## Examples

```
# Using randomly generated values
d <- as.numeric(sample(0:5, 1000, replace = TRUE))
dm <- matrix(d, nrow = 50, ncol = 20)
im <- runif(20, -2, 2)
pm <- runif(50, -2, 2)
th <- sort(runif(5, -2, 2))
m <- misfit(data = dm, items = im, persons = pm, thresholds = th)

# If the lowest or highest rating category is not in \code{data}, specify \code{minRating}
dm[dm == 0] <- NA
m2 <- misfit(data = dm, items = im, persons = pm, thresholds = th, minRating = 0)
```

---

msd

---

*Method of Successive Dichotomizations*


---

## Description

Estimates item measures, person measures, rating category thresholds and their standard errors using the method of successive dichotomizations. Option provided for anchoring certain items and persons while estimating the rest. Option also provided for estimating infit and outfit statistics.

## Usage

```
msd(data, items = NULL, persons = NULL, misfit = FALSE)
```

## Arguments

<code>data</code>	a numeric matrix of ordinal rating scale data whose entries are integers with missing data set to NA. Rows are persons and columns are items. The ordinal rating scale is assumed to go from the smallest integer to the largest integer in data in integer steps.
<code>items</code>	a numeric vector of anchored item measures. Item measures to be estimated are set to NA. Default is NULL (see Details).
<code>persons</code>	a numeric vector of anchored person measures. Person measures to be estimated are set to NA. Default is NULL (see Details).
<code>misfit</code>	logical for calculating infit and outfit statistics. Default is FALSE.

## Details

`items` and `persons` are optional numeric vectors that specify item and person measures that should be "anchored" and not estimated. The length of `items` must equal the number of columns in `data` and the length of `persons` must equal the number of rows in `data`. Only entries set to NA in `items` and `persons` are estimated. Default for both `items` and `persons` is NULL, which is equivalent to a vector of NA so that all items and persons are estimated.

**Value**

A list whose elements are:

item_measures	a vector of item measures for each item
person_measures	a vector of person measures for each person
thresholds	a vector of average rating category thresholds used by the persons when rating the items
item_std_errors	a vector of standard errors for the items
person_std_errors	a vector of standard errors for the persons
threshold_std_errors	a vector of standard errors for the thresholds
item_reliability	reliability of the item measures
person_reliability	reliability of the person measures
infit_items	if misfit = TRUE, a vector of infit statistics for the items
outfit_items	if misfit = TRUE, a vector of outfit statistics for the items
infit_persons	if misfit = TRUE, a vector of infit statistics for the persons
outfit_persons	if misfit = TRUE, a vector of outfit statistics for the persons

**Note**

The axis origin is set by convention at the mean item measure. All item measures and person measures that cannot be estimated will return as NA (e.g., if a person responds with a single rating category to all items, that person's person measure cannot be estimated).

The accuracy of msd can be tested using the simdata function (see Examples).

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**References**

Bradley, C. and Massof, R. W. (2018) Method of successive dichotomizations: An improved method for estimating measures of latent variables from rating scale data. *PLoS One*, **13(10)** doi:10.1371/journal.pone.0206106

**See Also**

[simdata](#)

## Examples

```
# Simple example using a randomly generated ratings matrix
d <- as.numeric(sample(0:5, 1000, replace = TRUE))
dm <- matrix(d, nrow = 50, ncol = 20)
m1 <- msd(dm, misfit = TRUE)

# Anchor first 10 item measures and first 10 person measures
im <- m1$item_measures
im[11:length(im)] <- NA
pm <- m1$person_measures
pm[11:length(pm)] <- NA
m2 <- msd(dm, items = im, persons = pm, misfit = TRUE)

# To test the accuracy of msd using simdata, set the mean item measure to zero
# (axis origin in msd is the mean item measure) and the mean threshold to
# zero (any non-zero mean threshold is reflected in the person measures).
im = runif(100, -2, 2)
im = im - mean(im)
pm = runif(200, -2, 2)
th = sort(runif(5, -2, 2))
th = th - mean(th)
d = simdata(im, pm, th, missingProb = 0.15, minRating = 0)
m = msd(d)

# Compare msd parameters to true values. Linear regression should
# yield a slope very close to 1 and an intercept very close to 0.
lm(m$item_measures ~ im)
lm(m$person_measures ~ pm)
lm(m$thresholds ~ th)
```

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msdprob

*Rating Category Probabilities*


---

## Description

Estimates the probability of observing each rating category.

## Usage

```
msdprob(x, thresholds)
```

## Arguments

x	a real number representing a person minus item measure.
thresholds	a numeric vector of ordered rating category thresholds with no NA.

## Details

It is assumed that thresholds partitions the real line into  $\text{length}(\text{thresholds})+1$  ordered rating categories.

**Value**

A vector of probabilities ordered from lowest to highest rating category.

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**Examples**

```
p <- msdprob(1.4, thresholds = c(-1.1, -0.3, 0.5, 1.7, 2.2))
```

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pms

*Person Measures*

---

**Description**

Estimates person measures assuming all persons use the same rating category thresholds.

**Usage**

```
pms(data, items, thresholds, misfit = FALSE, minRating = NULL)
```

**Arguments**

<code>data</code>	a numeric matrix of ordinal rating scale data whose entries are integers with missing data set to NA. Rows are persons and columns are items. The ordinal rating scale is assumed to go from the smallest to largest integer in integer steps unless <code>minRating</code> is specified.
<code>items</code>	a numeric vector of item measures with missing values set to NA. The length of <code>items</code> must equal the number of columns in <code>data</code> .
<code>thresholds</code>	a numeric vector of ordered rating category thresholds with no NA.
<code>misfit</code>	logical for calculating infit and outfit statistics. Default is FALSE.
<code>minRating</code>	integer representing the smallest ordinal rating category. Default is NULL (see Details).

**Details**

`minRating` must be specified if either the smallest or largest possible rating category is not in data (no person used one of the extreme rating categories). If `minRating` is specified, the ordinal rating scale is assumed to go from `minRating` to `minRating + length(thresholds)`.

**Value**

A list whose elements are:

`person_measures`

a vector of person measures for each person

`person_std_errors`

a vector of standard errors for the persons

`infit_persons` if `misfit = TRUE`, a vector of infit statistics for the persons

`outfit_persons` if `misfit = TRUE`, a vector of outfit statistics for the persons

**Note**

Person measures estimated with `pms` differ from those estimated with `msd` because `pms` assumes all persons use the same rating category thresholds while `msd` does not. Intended use of `pms` is with an anchored set of items and thresholds. Person measures that cannot be estimated will return as NA.

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**See Also**

[msd](#)

**Examples**

```
# Using randomly generated values
d <- as.numeric(sample(0:5, 1000, replace = TRUE))
dm <- matrix(d, nrow = 50, ncol = 20)
im <- runif(20, -2, 2)
th <- sort(runif(5, -2, 2))
p <- pms(data = dm, items = im, thresholds = th, misfit = TRUE)

# If the lowest or highest rating category is not in \code{data}, specify \code{minRating}
dm[dm == 0] <- NA
p2 <- pms(data = dm, items = im, thresholds = th, misfit = TRUE, minRating = 0)
```

---

rasch

*Dichotomous Rasch Model*

---

**Description**

Estimates item measures, person measures and their standard errors using the dichotomous Rasch model. A special case of the function `msd` when the rating scale consists of only two rating categories: 0 and 1. Option provided for anchoring certain items and persons while estimating the rest. Option also provided for estimating infit and outfit statistics.



## Usage

```
rasch(data, items = NULL, persons = NULL, misfit = FALSE)
```

## Arguments

<code>data</code>	a numeric matrix of 0's and 1's with missing data set to NA. Rows are persons and columns are items.
<code>items</code>	a numeric vector of anchored item measures. Item measures to be estimated are set to NA. Default is NULL (see Details).
<code>persons</code>	a numeric vector of anchored person measures. Person measures to be estimated are set to NA. Default is NULL (see Details).
<code>misfit</code>	logical for calculating infit and outfit statistics. Default is FALSE.

## Details

`items` and `persons` are optional numeric vectors that specify item and person measures that should be "anchored" and not estimated. The length of `items` must equal the number of columns in `data` and the length of `persons` must equal the number of rows in `data`. Only entries set to NA in `items` and `persons` are estimated. Default for both `items` and `persons` is NULL, which is equivalent to a vector of NA so that all items and persons are estimated.

## Value

A list whose elements are:

<code>item_measures</code>	a vector of item measures for each item
<code>person_measures</code>	a vector of person measures for each person
<code>item_std_errors</code>	a vector of standard errors for the items
<code>person_std_errors</code>	a vector of standard errors for the persons
<code>item_reliability</code>	reliability value for the items
<code>person_reliability</code>	reliability value for the persons
<code>infit_items</code>	if <code>misfit = TRUE</code> , a vector of infit statistics for the items
<code>outfit_items</code>	if <code>misfit = TRUE</code> , a vector of outfit statistics for the items
<code>infit_persons</code>	if <code>misfit = TRUE</code> , a vector of infit statistics for the persons
<code>outfit_persons</code>	if <code>misfit = TRUE</code> , a vector of outfit statistics for the persons

**Note**

The axis origin is set by convention at the mean item measure. All item measures and person measures that cannot be estimated will return as NA (e.g., if a person responds with a single rating category to all items, that person's person measure cannot be estimated).

rasch is the basis for the "successive dichotomizations" in msd and is repeatedly called by msd when there are three or more rating categories.

The accuracy of rasch can be tested using the simdata function (see Examples).

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**See Also**

[msd](#) [simdata](#)

**Examples**

```
# Simple example using a randomly generated ratings matrix
d <- as.numeric(sample(0:1, 1000, replace = TRUE))
dm <- matrix(d, nrow = 50, ncol = 20)
m1 <- rasch(dm, misfit = TRUE)

# Anchor first 10 item measures and first 10 person measures
im <- m1$item_measures
im[11:length(im)] <- NA
pm <- m1$person_measures
pm[11:length(pm)] <- NA
m2 <- rasch(dm, items = im, persons = pm, misfit = TRUE)

# To test the accuracy of rasch using simdata, set the true mean item measure to
# zero (axis origin in rasch is the mean item measure). Note that the threshold for
# dichotomous data is at 0.
im = runif(100, -2, 2)
im = im - mean(im)
pm = runif(200, -2, 2)
th = 0
d = simdata(im, pm, th, missingProb = 0.15, minRating = 0)
m = rasch(d)

# Compare rasch parameters to true values. Linear regression should
# yield a slope very close to 1 and an intercept very close to 0.
lm(m$item_measures ~ im)
lm(m$person_measures ~ pm)
```

---

`simdata`*Simulated Rating Scale Data*

---

**Description**

Generates simulated rating scale data given item measures, person measures and rating category thresholds.

**Usage**

```
simdata(items, persons, thresholds, missingProb = 0, minRating = 0)
```

**Arguments**

<code>items</code>	a numeric vector of item measures with no NA.
<code>persons</code>	a numeric vector of person measures with no NA.
<code>thresholds</code>	a numeric vector of ordered rating category thresholds with no NA.
<code>missingProb</code>	a number between 0 and 1 specifying the probability of missing data.
<code>minRating</code>	integer representing the smallest ordinal rating category. Default is 0 (see Details).

**Details**

It is assumed that the set of ordinal rating categories consists of all integers from the lowest rating category specified by `minRating` to the highest rating category, which is `minRating + length(thresholds)`.

**Value**

A numeric matrix of simulated rating scale data.

**Note**

`simdata` can be used to test the accuracy of `msd` (see Examples).

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**See Also**

[msd](#)

## Examples

```
# Using randomly generated item measures, person measures and thresholds with
# 15 percent missing data and ordinal rating categories from 0 to 5
im = runif(100, -2, 2)
pm = runif(200, -2, 2)
th = sort(runif(5, -2, 2))
d1 = simdata(im, pm, th, missingProb = 0.15, minRating = 0)

# To test the accuracy of msd using simdata, set the mean item measure to zero
# (axis origin in msd is the mean item measure) and the mean threshold to
# zero (any non-zero mean threshold is reflected in the person measures).
im = runif(100, -2, 2)
im = im - mean(im)
pm = runif(200, -2, 2)
th = sort(runif(5, -2, 2))
th = th - mean(th)
d2 = simdata(im, pm, th, missingProb = 0.15, minRating = 0)
m = msd(d2)

# Compare msd parameters to true values. Linear regression should
# yield a slope very close to 1 and an intercept very close to 0.
lm(m$item_measures ~ im)
lm(m$person_measures ~ pm)
lm(m$thresholds ~ th)
```

---

thresh	<i>Rating Category Thresholds</i>
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---

## Description

Estimates rating category thresholds for msd given rating scale data, item measures and person measures.

## Usage

```
thresh(data, items, persons)
```

## Arguments

data	a numeric matrix of ordinal rating scale data whose entries are integers with missing data set to NA. Rows are persons and columns are items. The ordinal rating scale is assumed to go from the smallest integer to the largest integer in data in integer steps.
items	a numeric vector of item measures with missing values set to NA (see Details).
persons	a numeric vector of person measures with missing values set to NA (see Details).

**Details**

The length of `items` must equal the number of columns in data and the length of `persons` must equal the number of rows in data. Neither `items` nor `persons` can consist of only NA.

**Value**

A list whose elements are:

`thresholds`      a vector of average rating category thresholds used by the persons when rating the items

`threshold_std_errors`  
                  a vector of standard errors for the thresholds

**Note**

`thresh` is a special case of `msd` when item measures and person measures are known.

**Author(s)**

Chris Bradley (cbradley05@gmail.com)

**See Also**

[msd](#)

**Examples**

```
# Using randomly generated values
d <- as.numeric(sample(0:5, 1000, replace = TRUE))
m <- matrix(d, nrow = 50, ncol = 20)
im <- runif(20, -2, 2)
pm <- runif(50, -2, 2)
th1 <- thresh(m, items = im, persons = pm)

# Anchor first 10 item measures and first 10 person measures
im[11:length(im)] <- NA
pm[11:length(pm)] <- NA
th2 <- thresh(m, items = im, persons = pm)
```

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