Package 'CTT'

October 12, 2022

Type Package

Title Classical Test Theory Functions

Version 2.3.3

Date 2018-09-11

Author John T. Willse

Maintainer John T. Willse <willse@uncg.edu>

Description A collection of common test and item analyses from a classical test theory (CTT) framework. Analyses can be applied to both dichotomous and polytomous data. Functions provide reliability analyses (alpha), item statistics, disctractor analyses, disattenuated correlations, scoring routines, and empirical ICCs.

License GPL (>= 2)

NeedsCompilation no

Repository CRAN

Date/Publication 2018-09-12 12:30:06 UTC

R topics documented:

CTT-package *Classical Test Theory Functions*

Description

This package can be used to perform a variety of tasks and analyses associated with classical test theory (CTT): score multiple-choice responses, perform reliability analyses, conduct item analyses, and transform scores onto different scales.

Details

Package:	CTT
Type:	Package
Version:	2.3.3
Date:	2018-09-11
License:	GPL version 2 or newer

The CTT package has the following functions: reliability, score, distractor.analysis, score.transform, spearman.brown, disattenuated.cor, subscales, polyserial.

Author(s)

John T. Willse <willse@uncg.edu>, Zhan Shu

References

Crocker, L. & Algina, J. (1986). Introduction to Classical & Modern Test Theory, New York: Harcourt Brace Jovanovich College Publishers.
Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometika, 16, 297-334.
Gulliksen, H. (1950). Theory of Mental Tests. New York: John Wiley & Sons, Inc.
Olsson, U., Drasgow, F. & Dorans, N. J. (1982). The Polyserial Correlation Coefficient. Psychometika, 47, 337-347.

CTTdata *Example Multiple-Choice Data*

Description

This example data contains 20 unscored multiple-choice items that can be used with the CTT package.

Usage

```
data(CTTdata)
```

Format

A data frame with 100 observations on the following 20 variables.

`i1` a character vector

`i2` a character vector

`i3` a character vector

`i4` a character vector

`i5` a character vector

`i6` a character vector

`i7` a character vector

`i8` a character vector

`i9` a character vector

`i10` a character vector

`i11` a character vector

`i12` a character vector

`i13` a character vector

`i14` a character vector

`i15` a character vector

`i16` a character vector

`i17` a character vector

`i18` a character vector

`i19` a character vector

`i20` a character vector

See Also

CTTkey

Examples

```
data(CTTdata)
```

cttICC *Function for producing theoretical and empirical item characteristic curves.*

Description

This function produces empirical item characteristic curves.

Usage

```
cttICC(scores, itemVector, xlim, ylim, plotTitle, xlab, ylab,
     col = c("black","white"), colTheme, gDevice, file, ...)
```

Arguments

scores	A total measure score, for creating expected mean values of the item.
itemVector	Observed item responses for the item ICC.
xlim	A vector overriding default limits for the x axis.
ylim	A vector overriding default limits for the y axis.
plotTitle	Controls the main plot title.
xlab	The label for the x axis.
ylab	The label for the y axis.
col	A vector of the colors to be used in the plot. The first color will be used for item labels. The second color will be used for shading the area of rejection.
colTheme	Four color themes ("cavaliers", "dukes", "spartans", "greys") are provided. If you provide a color theme, it will override the col paramater.
gDevice	Controls graphics device. Options are "screen" (default), "jpg", or "png".
file	The name of the output file if a device other than "screen" is chosen.
...	Additional parameters passed to the plot command.

Details

The function produces an item characterisic curve plot. The empirical ICC is created by calculating the item mean in between 2 and 20 bins. There must be at least 15 observations per bin, or a smaller number of bins is used.

Author(s)

John T. Willse

Examples

```
library(CTT)# Example data provided with package
data(CTTdata)
data(CTTkey)

# Scores for each preson
myScores <- score(CTTdata,CTTkey, output.scored=TRUE)

# ICC for item 1
cttICC(myScores$score, myScores$scored[,1], colTheme="spartans", cex=1.5)
```

CTTkey *Example Multiple-Choice Key*

Description

This example data contains a key for the 20 unscored multiple-choice items found in CTTdata and can be used with the CTT package.

Usage

```
data(CTTkey)
```

Format

The format is: chr [1:20] "D" "C" "A" "D" "D" "A" "D" "B" "D" "A" ...

See Also

CTTdata

Examples

```
data(CTTkey)
```

---

disattenuated.cor *Function for disattentuated correlation*

Description

This function is used to calculate the disattentuated correlation between two measures given the corresponding test reliabilities.

Usage

```
disattenuated.cor(r.xy, r.xx, new.r.xx = 1)
```

Arguments

r.xy	The correlation between test x and test y
r.xx	Each tests' reliability
new.r.xx	A new reliability for each test (optional)

Details

The data given in r.xy may be a single value or a matrix. A matrix is assumed to be a correlation matrix (square, symmetric).

The data given in r.xx should be a vector, with one reliability for each instrument involved in the correlation, r.xy.

The new.r.xx represents a new reliability for each measure. If these values are less than 1, the returned correlation is the value that would be expected with the new reliability.

Value

If r.xy is a single value a single value is returned. If r.xy is a matrix then a matrix is returned with the reliabilities on the diagonal, the disattenuated correlations in the upper triangle and the original correlations in the lower triangle.

Author(s)

John T. Willse, Zhan Shu

References

Spearman, C. (1904). The proof and measurement of association between two things. American Journal of Psychology, 15, 72-101.
Gulliksen, H. (1950). Theory of Mental Tests. New York: John Wiley & Sons, Inc.

Examples

```
# r.xy=0.6, r.xx=0.7,r.yy=0.8
disattenuated.cor(0.6,c(0.7,0.8))

# if r.xy is a matrix:
cor1 <- matrix(c(1.0000000, 0.24391288, 0.2812319, 0.05251050,
                 0.2439129, 1.00000000, 0.1652985, 0.08126448,
                 0.2812319, 0.16529850, 1.0000000, 0.27971630,
                 0.0525105, 0.08126448, 0.2797163, 1.00000000), byrow=TRUE,
                 ncol=4)

rxx1 <- c(0.8,0.8,0.81,0.9)     # reliability of each test
new.rxx1 <- c(0.9,0.97,0.8,0.7) # projected new reliability of those tests

disattenuated.cor(cor1, rxx1, new.rxx1)
```

`distractor.analysis` *Function for item distractor analysis*

Description

This function is deprecated. Use `distractorAnalysis` for a more complete distractor analysis.

Usage

```
distractor.analysis(items, key, scores, p.table = FALSE, write.csv)
```

Arguments

`items`	The unscored item response from a multiple-choice test
`key`	The answer key for the items
`scores`	An optional set of person scores associated with the item data. If scores are not provided (default) the scores are calculated using the item data and key.
`p.table`	If p.table=FALSE (the default) the function returns the counts of examinees who provide each answer. If p.table=TRUE the function returns the proportion of examinees who provide each answer.
`write.csv`	If the optional file name is provided the function will save a .csv file with the results.

Details

The scores are used to split respondents into terciles. The number (or proportion if p.table=TRUE) of examinees in each tercile giving each response is reported. The correct answer is indicated with an "*".

Value

If p.table=F counts of respondents in each tercile who chose each answer is returned as a list of tables. Each item is a separate element in the list. If p.table=T the tables contain the proportion of respondents who chose each corresponding answer.

Author(s)

John T. Willse, Zhan Shu

References

Allen, M. J. & Yen, W. M. (1979). Introduction to Measurement Theory. Lon Grove, Illinois: Waveland Press, INC.

See Also

`distractorAnalysis`

Examples

```
# Example data provided with package
data(CTTdata)
data(CTTkey)

distractor.analysis(CTTdata,CTTkey)

# Results provided in a .csv file.
distractor.analysis(CTTdata,CTTkey,p.table=TRUE,write.csv="Hello.csv")
```

`distractorAnalysis` *Function for item distractor analysis*

Description

This function provides a distractor analysis.

Usage

```
distractorAnalysis(items, key, scores, nGroups=4, defineGroups, multiKeySep="none",
       multiKeyScore=c("or","poly"), validResp, csvReport, pTable=TRUE, digits)
```

Arguments

`items`	The unscored item response from a multiple-choice test
`key`	The answer key for the items
`scores`	An optional set of person scores associated with the item data. If scores are not provided (default) the scores are calculated using the item data and key.
`nGroups`	Determines the number of groups into which scores are discretized. For example, nGroups=4 (default) performs and analysis based on quartiles.
`defineGroups`	If provided, determines the quantile breakpoints for groups into which scores are discretized. For example, defineGroups=c(.27,.46,.27) performs and analysis with 3 quantiles and 27 percent of examinees in the top and the bottom groups.
`multiKeySep`	If a value other than "none" is provided (e.g., ","), the key and the raw items will be reviewed for the provided delimiter. Using this otion allows for multiple correct responses.
`multiKeyScore`	The first value controls how multiple keys are handled. If "or" any correct response results in score of 1. If "and" all responses must be correct. If the second value is "poly" the returned score is the sum of correct responses. If the second value is "dich" a maximum score of 1 is returned. If the respondent can only provide one response, use "or". If the responded can provide multiple responses and you use c("and", "poly") the score will be 0 or max score.

validResp	A list of vectors providing valid responses for the distractor tables. If no value is provided, valid responses are determined from the data and assumed to be the same across items. If "fromItem" is provided, values are determined from item responses and NOT assumed to be the same across items.
csvReport	If an optional file name is provided the function will save a .csv file with the results.
pTable	If pTable=FALSE the function returns the counts of examinees who provide each answer. If pTable=TRUE (default) the function returns the proportion of examinees who provide each answer.
digits	If digits (an integer) is provided, it specifies the number of decimals to which results will be rounded.

Details

The scores are used to split respondents into groups, with number determine by nGroups. The proportion (or number if pTable=FALSE) of examinees in each group giving each response is reported. The correct answer is indicated with an "*". Additional item statistics are provided. Descriptors of each item are returned as separate elements in a list.

Value

correct	An "*" indicates the correct response
key	The response option being described
n	The number of responsdents choosing that option
rspP	The proportion of respondents with that response
pBis	The point-biserial correlation between that reponse and the total score with that item removed
discrim	The upper proportion minus the lower proportion
lower	The proportion of respondents choosing that response that are from the lowest score group
upper	The proportion of respondents choosing that response that are from the highest score group

Author(s)

John T. Willse

References

Allen, M. J. & Yen, W. M. (1979). Introduction to Measurement Theory. Lon Grove, Illinois: Waveland Press, INC.

Examples

```
# Example data provided with package
data(CTTdata)
data(CTTkey)

distractorAnalysis(CTTdata,CTTkey)

# Results provided in a .csv file.
distractorAnalysis(CTTdata,CTTkey,csvReport="Hello.csv")
```

`itemAnalysis` *Function for item reliability analysis*

Description

This function performs reliability analyses, providing coefficient alpha and classical item statistics. This function improves and replaces the function reliability from previous versions.

Usage

```
itemAnalysis(items, itemReport=TRUE, NA.Delete=TRUE, rBisML=FALSE, hardFlag,
             easyFlag, pBisFlag, bisFlag, flagStyle = c("X",""))
```

Arguments

`items`	The scored response file with "0" (wrong) and "1" (correct) or Likert type data
`itemReport`	If itemReport=TRUE (the default) item analyses are conducted. The function will provide a dataframe containing item names, item means, item total correlations, and alpha if item is removed.
`NA.Delete`	If NA.Delete=TRUE (the default) records are deleted listwise if there are missing responses. If NA.Delete=FALSE all NA values are changed to 0s.
`rBisML`	A logical variable indicating whether the biserial correlation is calculated using a formal maximum likelihood estimator or an ad hoc estimator (default, speeds up analysis with many items).
`hardFlag`	If a numeric value is provided, a flag is added to itemReport for each item with a mean less than the value. itemReport=TRUE must also be set.
`easyFlag`	If a numeric value is provided, a flag is added to itemReport for each item with a mean greater than the value. itemReport=TRUE must also be set.
`pBisFlag`	If a numeric value is provided, a flag is added to itemReport for each item with a point-biserial correlation less than the value. itemReport=TRUE must also be set.
`bisFlag`	If a numeric value is provided, a flag is added to itemReport for each item with a biserial correlation less than the value. itemReport=TRUE must also be set.
`flagStyle`	Determines the values to be used for item flagging. Default uses an "X" when an item is flagged and "" when not. Any value, including booleans can be used.

Details

The input files must be scored files with "0" and "1" or numeric scales (e.g., Likert Type scales). Only basic scale information is returned to the screen. Use str() to view additional statistics that are available. If itemReport is used (preferred) item statistics are provided as part of a dataframe called itemReport. Use function reliability with option itemal (being phased out), for output pre 2.2.

Value

nItem	The number of items
nPerson	The sample size used in calculating the values
alpha	Crobach's alpha
scaleMean	Average total sum socre
scaleSD	Standard deviation of total sum score
itemReport	Returned if itemReport = TRUE. Returns a data frame with key item analysis results: item mean (itemMean), point-biserial (pBis), biserial (bis), Cronbach's alpha if item removed, and any item flags indicated in the function call.

Author(s)

John T. Willse

References

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometika, 16, 297-334.

See Also

score

Examples

```
# Scored input (data frame is preferred)
 x<-data.frame(matrix(c(0,0,0,0,0,
                        0,0,0,0,0,
                        0,0,0,0,1,
                        0,0,0,1,1,
                        0,0,1,1,1,
                        0,1,1,1,1,
                        1,1,1,1,1,
                        1,0,1,1,1,
                        0,0,0,1,1,
                        0,1,1,1,1),nrow=10,ncol=5,byrow=TRUE,
                dimnames=list(c(paste("P",c(1:10),sep="")),c(paste("I",c(1:5),sep="")))))
itemAnalysis(x)

# To see an item report with flags.
iA <- itemAnalysis(x, hardFlag=.25, pBisFlag=.15)
```

```
iA$itemReport

# To see more item statisitics
str(itemAnalysis(x))
```

`polyserial` *Function for calculating polyserial correlations*

Description

This function calculates polyserial correlations using either an ad hoc or ML estimator.

Usage

```
polyserial(x, y, ml = TRUE)
```

Arguments

`x`	A continuous variable.
`y`	An ordinal variable with at least two categories.
`ml`	A logical variable indicating whether to use a formal maximum likelihood estimator (default) or an ad hoc estimator.

Details

The variables should be numeric. The function returns NA is y has only one category.

Value

Returns the polyserial correlation.

Author(s)

John T. Willse

References

Olsson, U., Drasgow, F. & Dorans, N. J. (1982). The Polyserial Correlation Coefficient. Psychometika, 47, 337-347.

Examples

```
x <- rnorm(500, 50,5)
y <- x + rnorm(500,0,2)
x <- x + rnorm(500,0,2)
cor(x,y)

y <- ifelse(y>50,1,0)

cor(x,y)

polyserial(x,y, ml=FALSE)
polyserial(x,y)
```

`reliability` *Function for item reliability analysis*

Description

This function performs reliability analyses, providing coefficient alpha and item statistics.

Usage

```
reliability(items, itemal = TRUE, NA.Delete = TRUE, ml = TRUE)
```

Arguments

`items`	The scored response file with "0" (wrong) and "1" (correct) or Likert type data
`itemal`	If itemal=FALSE (the default) no item analyses are conducted. If itemal=TRUE, the function will provide item means, item total correlations, and alpha if item is removed.
`NA.Delete`	If NA.Delete=TRUE (the default) records are deleted listwise if there are missing responses. If NA.Delete=FALSE all NA values are changed to 0s.
`ml`	A logical variable indicating whether the biserial correlation is calculated using a formal maximum likelihood estimator (default) or an ad hoc estimator.

Details

The input files must be scored files with "0" and "1" or numeric scales (e.g., Likert Type scales). Only basic scale information is returned to the screen. Use str() to view additional statistics that are available.

Value

`nItem`	The number of items
`nPerson`	The sample size used in calculating the values
`alpha`	Crobach's alpha

scaleMean	Average total sum socre
scaleSD	Standard deviation of total sum score
alphaIfDeleted	Cronbach's alpha if the corresponding item were deleted
pBis	The item total correlation, with the item's contribution removed from the total
bis	The item total biserial (or polyserial) correlation, with the item's contribution removed from the total'
itemMean	Average of each item

Author(s)

John T. Willse, Zhan Shu

References

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. Psychometika, 16, 297-334.

See Also

itemAnalysis

Examples

```
# Scored input (data frame is preferred)
 x<-data.frame(matrix(c(0,0,0,0,0,
                        0,0,0,0,0,
                        0,0,0,0,1,
                        0,0,0,1,1,
                        0,0,1,1,1,
                        0,1,1,1,1,
                        1,1,1,1,1,
                        1,0,1,1,1,
                        0,0,0,1,1,
                        0,1,1,1,1),nrow=10,ncol=5,byrow=TRUE,
                dimnames=list(c(paste("P",c(1:10),sep="")),c(paste("I",c(1:5),sep="")))))
reliability(x, itemal=TRUE)

# To see more item statisitics
str(reliability(x,itemal=TRUE))
```

score *Function to score the response files*

Description

This function can score multiple choice item responses. This function can also call and return results from function reliability.

Usage

```
score(items,key,output.scored=FALSE,ID=NA,rel=FALSE,multiKeySep="none",
        multiKeyScore=c("or","poly"))
```

Arguments

items	The item responses to be scored
key	The answer key
output.scored	If output.scored=FALSE (the default) only a vector of scores is returned. If output.scored=TRUE a matrix containing scored items is returned.
ID	If respondent IDs are provided scores are labeled appropriately.
rel	If rel=TRUE, the function will call the function reliability and provide that output as well.
multiKeySep	If a value other than "none" is provided (e.g., ","), the key and the raw items will be reviewed for the provided delimiter. Using this otion allows for multiple correct responses.
multiKeyScore	The first value controls how multiple keys are handled. If "or" any correct response results in score of 1. If "and" all responses must be correct. If the second value is "poly" the returned score is the sum of correct responses. If the second value is "dich" a maximum score of 1 is returned. If the respondent can only provide one response, use "or". If the responded can provide multiple responses and you use c("and", "poly") the score will be 0 or max score.

Author(s)

John T. Willse

See Also

reliability

Examples

```
# Example data provided with package
data(CTTdata)
data(CTTkey)

# Scores for each preson
score(CTTdata,CTTkey)

# Scores, scored file, and relibility
score(CTTdata,CTTkey,output.scored=TRUE,rel=TRUE)
```

`score.transform` *Function for transforming scores onto different scales*

Description

The function transforms the score metric by setting new scales' mean, standard deviation, and normalizing the distribution.

Usage

```
score.transform(scores, mu.new = 0, sd.new = 1, normalize = FALSE)
```

Arguments

`scores`	Vector for examinee scores
`mu.new`	Desired mean of the scale
`sd.new`	Desired standard deviation of scales
`normalize`	If normailize=True, the score will be normalized applying the inverse of the cumulative distribution function of the normal distribution to the respondents percentile score.

Value

The function returns a list with two vectors: new.scores is the transformed score and p.scores is the percentile rank of every examinee. If normalize=TRUE than percentile scores are used to create a roughly normal distribution by applying an inverse cumulative normal distribution function to the p.scores.

Author(s)

John T. Willse, Zhan Shu

Examples

```
# Example data provided with package
data(CTTdata)
data(CTTkey)

# Data scored to demonstrate function
scores <- score(CTTdata,CTTkey)$score # obtain the scores

# the targeted mean=3, standard deviation=1

score.transform(scores,3,1)

# the score should be transformed by normalized precentile
score.transform(scores,3,1,TRUE)
```

`spearman.brown` *Functions for Spearman-Brown "Prophecy" Formula*

Description

This function calculates either a predicted reliability for a measure given the original reliability and a new test length, or the function calculates the required test length to achieve a desired level of reliability.

Usage

```
spearman.brown(r.xx, input = 2, n.or.r = "n")
```

Arguments

`r.xx`	The original relibility
`input`	The new test length or a desired level of reliability, depending on n.or.r
`n.or.r`	If n.or.r="n", the function will return a new reliability; if n.or.r="r", the function will return the factor by which the test length must change to achieve a desired level of reliability.

Details

If n.or.r="n", the function will return a new reliability and input should be the factor by which the test length is to be changed. If n.or.r="r", the function will return the factor by which the test length must change to achieve a desired level of reliability (provided in input).

Author(s)

John Willse, Zhan Shu

References

Spearman, C. (1910). Correlation calculated with faulty data. British Journal of Psychology, 3, 271-295.

Brown,W. (1910). Some experimental results in the correlation of mental abilities. British Journal of Psychology, 3, 296-322.

Examples

```
# old relibility is 0.6, if the measure is lengthened
# by a factor of 2, the relibility of new test is:
spearman.brown(0.6,2,"n")

# old relibility is 0.5, if we want a new measure to
# be 0.8, the new test length is:
spearman.brown(0.5, 0.8, "r")
```

---

subscales *Function to create subscales based on a design matrix*

Description

This convenience function is provided to facilitate extracting subscales from a single set of item responses.

Usage

```
subscales(items, scales, scale.names = NA, score.items = FALSE,
          check.reliability = FALSE, key=NA)
```

Arguments

items	The item response (scored or not)
scales	A design matrix, with items represented in rows and separate subscales represented in columns. An item may appear in more than one subscale.
scale.names	Optional vector of names for the subscales
score.items	If responses are not scored, they may be scored using score.items=TRUE (key must be provided)
check.reliability	If check.reliability=TRUE, the reliability for each subscale will be calculted
key	Optional key, required only if score.scales=TRUE.

Details

This function provides an easy way to create new datasets from a single set of item responses. This function is also a front end for score and reliability, enabling the item responses to be partitioned into separate scales, scored, and reliability analyses performed using this one function.

Value

A list is returned. Results for each subscale (i.e., column in the scales matrix) are provided as sparate objects in that list.

score	Each examinee's score on the associated subscale
reliablity	Reliability results (if requested) for the associated subscale
scored	The scored item responses (if required) for each respondent for the associated subscale

Author(s)

John Willse, Zhan Shu

See Also

reliability, score

Examples

```
# Example data included with package
data(CTTdata)
data(CTTkey)

# design matrix
q <- matrix(c(1,0,
              1,0,
              1,0,
              1,0,
              1,0,
              1,0,
              1,0,
              1,0,
              1,0,
              1,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1,
              0,1), ncol=2, byrow=TRUE)
subscales(CTTdata,q,c("T1","T2"),TRUE,TRUE,CTTkey)
```

Index