

Package ‘subscore’

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Title Computing Subscores in Classical Test Theory and Item Response Theory

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Description Functions for computing test subscores using different methods in both classical test theory (CTT) and item response theory (IRT). This package enables three types of subscore methods within the framework of CTT and IRT, including (1) Wainer's augmentation method (Wainer et. al., 2001) <doi:10.4324/9781410604729>, (2) Haberman's subscore methods (Haberman, 2008) <doi:10.3102/1076998607302636>, and (3) Yen's objective performance index (OPI; Yen, 1987) <https://www.ets.org/research/policy_research_reports/publications/paper/1987/hrap>. It also includes functions to compute Proportional Reduction of Mean Squared Errors (PRMSEs) in Haberman's methods which are used to examine whether test subscores are of added value. In addition, the package includes a function to assess the local independence assumption of IRT with Yen's Q3 statistic (Yen, 1984 <doi:10.1177/014662168400800201>; Yen, 1993 <doi:10.1111/j.1745-3984.1993.tb00423.x>).

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CTTsub	<i>This main function estimates true subscores using different methods based on original CTT scores.</i>
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Description

This function estimates true subscores using methods introduced in studies of Haberman (2008) <doi:10.3102/1076998607302636> and Wainer et al. (2001) <doi:10.4324/9781410604729>. Hypothesis tests (i.e., Olkin' Z, Williams's t, and Hedges-Olkin's Z) are used to determine whether a subscore or an augmented subscore has added value. Codes for the hypothesis tests are from Sinharay (2019) <doi: 10.3102/1076998618788862>.

Usage

```
CTTsub(test.data, method = "Haberman")
```

Arguments

test.data	A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.
method	Subscore estimation methods. method="Haberman" (by default) represents the three methods proposed by Haberman (2008) <doi:10.3102/1076998607302636>. method="Wainer" represents Wainer's augmented method.

Value

summary	Summary of estimated subscores (e.g., mean, sd).
PRMSE	(a) PRMSE values of estimated subscores (for Haberman's methods only). (b) Decisions on whether subscores have added value - added.value.s (or added.value.sx) = 1 means subscore.s (or subscore.sx) has added value, and added.value.s (or added.value.sx) = 0 vice versa.

PRMSE.test All information in PRMSE plus results of hypothesis testing based on Sinharay (2019) <doi:10.3102/1076998618788862>.

subscore.original
 Original subscores and total score.

estimated.subscores
 Subscores computed using selected method. Three sets of subscores will be returned if method = "Haberman".

References

Haberman, S. J. (2008). "When can subscores have value?." *Journal of Educational and Behavioral Statistics*, 33(2), 204-229. doi:10.3102/1076998607302636.

Sinharay, S. (2019). "Added Value of Subscores and Hypothesis Testing." *Journal of Educational and Behavioral Statistics*, 44(1), 25-44. doi:10.3102/1076998618788862.

Wainer, H., Vevea, J., Camacho, F., Reeve, R., Rosa, K., Nelson, L., Swygert, K., & Thissen, D. (2001). "Augmented scores - "Borrowing strength" to compute scores based on small numbers of items." In Thissen, D. & Wainer, H. (Eds.), *Test scoring* (pp.343 - 387). Mahwah, NJ: Lawrence Erlbaum Associates, Inc. doi:10.4324/9781410604729.

Examples

```
# Transferring original scored data to a list format
# that can be used in other functions.
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))
#-----
# Estimating subscores using Haberman's methods
CTTsub(test.data,method="Haberman") # Estimating subscores using Haberman's methods

# Obtaining original correlation for the three methods
CTTsub(test.data,method="Haberman")$Correlation

# Obtaining disattenuated correlation for the three methods
CTTsub(test.data,method="Haberman")$Disattenuated.correlation

# Obtaining PRMSEs for the three methods
CTTsub(test.data,method="Haberman")$PRMSE

# Obtaining descriptive statistics summary for estimated subscores
CTTsub(test.data,method="Haberman")$summary

# Obtaining raw subscores
CTTsub(test.data,method="Haberman")$subscore.original

# Obtaining subscores that are estimated as a function of the observed subscores
CTTsub(test.data,method="Haberman")$subscore.s

# Obtaining subscores that are estimated as a function of the observed total score
CTTsub(test.data,method="Haberman")$subscore.x
```

```

# Obtaining subscores that are estimated as a function of
# both the observed subscores and the observed total score.
CTTsub(test.data,method="Haberman")$subscore.sx

#-----
# Estimating subscores using Wainer's method
CTTsub(test.data,method="Wainer")

# Obtaining descriptive statistics summary for subscores
CTTsub(test.data,method="Wainer")$summary

# Obtaining original subscores
CTTsub(test.data,method="Wainer")$subscore.original

# Obtaining subscores that are estimated using Wainer's augmentation method
CTTsub(test.data,method="Wainer")$subscore.augmented

```

data.prep

This function prepares data into a required list format

Description

This function generates a list of data sets using the scored original data set, which can be used as objects in subscore computing functions.

Usage

```
data.prep(scored.data, subtest.infor, subtest.names = NULL)
```

Arguments

scored.data	Original scored data set with rows as individuals and columns as items.
subtest.infor	A numerical vector. The first number indicates the number of subtests, followed by numbers of items on each subscale.
subtest.names	Names of the subscales AND the entire test. The default is NULL. If not provided, names of "subtest.1", "subtest.2",..., will be assigned.

Value

A list that contains item responses of all subtests and the entire test. The list is then used by other functions (e.g., CTTsub) in the package to obtain subscores.

Examples

```

subtest.infor<-c(3,15,15,20)
subtest.names<-c("Algebra","Geometry","Measurement", "Math")
# This math test consists of 3 subtests, which have 15 algebra
# items, 15 geometry items, and 20 measurement items.
test.data<-data.prep(scored.data, subtest.infor, subtest.names)

```

`scored.data`*Sample scored data*

Description

This dataset contains responses of 150 examinees to three subscales. These subscales consist of 15, 15, and 20 items respectively.

Usage

```
data("scored.data")
```

Format

A data frame with 150 observations on the following 50 variables.

V1 Item 1
V2 Item 2
V3 Item 3
V4 Item 4
V5 Item 5
V6 Item 6
V7 Item 7
V8 Item 8
V9 Item 9
V10 Item 10
V11 Item 11
V12 Item 12
V13 Item 13
V14 Item 14
V15 Item 15
V16 Item 16
V17 Item 17
V18 Item 18
V19 Item 19
V20 Item 20
V21 Item 21
V22 Item 22
V23 Item 23
V24 Item 24

V25 Item 25
V26 Item 26
V27 Item 27
V28 Item 28
V29 Item 29
V30 Item 30
V31 Item 31
V32 Item 32
V33 Item 33
V34 Item 34
V35 Item 35
V36 Item 36
V37 Item 37
V38 Item 38
V39 Item 39
V40 Item 40
V41 Item 41
V42 Item 42
V43 Item 43
V44 Item 44
V45 Item 45
V46 Item 46
V47 Item 47
V48 Item 48
V49 Item 49
V50 Item 50

Details

A dataset containing responses of 150 examinees to a total number of 50 items on three subscales (15, 15, and 20 items respectively).

Examples

```
data(scored.data)  
# maybe str(scored.data); plot(scored.data) ...
```

subscore.corr	<i>Computing correlation indices for subscores and the total score.</i>
---------------	---

Description

This function computes Cronbach's Alpha and Stratified Alpha (Cronbach et al., 1965) <doi: 10.1177/001316446502500201>. Disattenuated correlations are also provided.

Usage

```
subscore.corr(test.data)
```

Arguments

test.data	A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.
-----------	--

Value

summary	Summary of obtained subscores (e.g., mean, sd).
correlation	Correlation indices as indicated above.

References

Cronbach, L., Schoneman, P., & McKie, D. (1965). "Alpha coefficients for stratified-parallel tests." *Educational and Psychological Measurement*, 25, 291-282. doi: 10.1177/001316446502500201.

Examples

```
# Transferring scored response data to the required list format
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))

#Estimate true subscores using Haberman's method based on observed subscores
subscore.corr(test.data)

subscore.s(test.data)$summary
subscore.s(test.data)$correlation
```

subscore.s	<i>Computing subscores using Haberman's method based on observed subscores.</i>
------------	---

Description

This function estimate true subscores based on observed subscores, using the method introduced by Haberman (2008) <doi:10.3102/1076998607302636>.

Usage

```
subscore.s(test.data)
```

Arguments

test.data	A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.
-----------	--

Value

summary	Summary of obtained subscores (e.g., mean, sd).
PRMSE	PRMSEs of obtained subscores (for Haberman's methods only).
subscore.original	Original subscores and total score.
subscore.s	Subscores that are estimated based on the observed subscore.

References

Haberman, S. J. (2008). "When can subscores have value?." *Journal of Educational and Behavioral Statistics*, 33(2), 204-229. doi:10.3102/1076998607302636.

Examples

```
# Transferring scored response data to the required list format
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))

# Estimate true subscores using Haberman's method based on observed subscores
subscore.s(test.data)

subscore.s(test.data)$summary
subscore.s(test.data)$Correlation
subscore.s(test.data)$Disattenuated.correlation
subscore.s(test.data)$PRMSE
subscore.s(test.data)$subscore.s
```

subscore.sx	<i>Computing subscores using Haberman's method based on both observed total scores and observed subscores.</i>
-------------	--

Description

This function estimate true subscores based on both observed total scores and observed subscores using the method introduced by Haberman (2008) <doi:10.3102/1076998607302636>.

Usage

```
subscore.sx(test.data)
```

Arguments

test.data	A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.
-----------	--

Value

summary	Summary of obtained subscores (e.g., mean, sd).
PRMSE	PRMSEs of obtained subscores (for Haberman's methods only).
subscore.original	Original observed subscores and total score.
subscore.sx	Subscores that are estimated based on both the observed total score and observed subscore.

References

Haberman, S. J. (2008). "When can subscores have value?." *Journal of Educational and Behavioral Statistics*, 33(2), 204-229. doi:10.3102/1076998607302636.

Examples

```
test.data<-data.prep(scored.data,c(3,15,15,20),
                     c("Algebra","Geometry","Measurement", "Math"))

subscore.sx(test.data)
subscore.s(test.data)$Correlation
subscore.s(test.data)$Disattenuated.correlation
subscore.sx(test.data)$summary
subscore.sx(test.data)$PRMSE
subscore.sx(test.data)$subscore.sx
```

subscore.Wainer

*Estimating true subscores using Wainer's augmentation method***Description**

This function estimates subscores using Wainer's augmentation method (Wainer et. al., 2001) <doi:10.4324/9781410604729>. The central idea of this procedure is that, the estimation of subscores will be improved by shrinking the individual observed subscores towards some aggregate values (i.e., group mean subscores). The extent of the shrinkage depends on the closeness of the subscale being estimated with other subscales as well as reliabilities of all the subscales. Wainer's augmentation is a multivariate version of Kelly's formula (Kelly, 1947) <<https://www.hup.harvard.edu/catalog.php?isbn=978067>>. For details of Wainer's augmentation subscore method, please refer to Wainer et al. (2001) <doi:10.4324/9781410604729>.

Usage

```
subscore.Wainer(test.data)
```

Arguments

`test.data` A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.

Value

`summary` It contains statistical summary of the augmented subscores (mean, sd, and reliability).

`Augmented.subscores`

It contains augmented subscores that are obtained using Wainer's method.

References

Wainer, H., Vevea, J., Camacho, F., Reeve, R., Rosa, K., Nelson, L., Swygert, K., & Thissen, D. (2001). "Augmented scores - "Borrowing strength" to compute scores based on small numbers of items" In Thissen, D. & Wainer, H. (Eds.), *Test scoring* (pp.343 - 387). Mahwah, NJ: Lawrence Erlbaum Associates, Inc. doi:10.4324/9781410604729.

Kelley, T. L. (1947). *Fundamentals of statistics*. Harvard University Press. <https://www.hup.harvard.edu/catalog.php?isbn=97>

Examples

```
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))

subscore.Wainer(test.data)

subscore.Wainer(test.data)$summary
subscore.Wainer(test.data)$subscore.augmented
```

subscore.x	<i>Computing subscores using Haberman's method based on observed total scores.</i>
------------	--

Description

This function estimates true subscores based on observed total scores using the method introduced by Haberman (2008) <doi:10.3102/1076998607302636>.

Usage

```
subscore.x(test.data)
```

Arguments

test.data	A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.
-----------	--

Value

summary	Summary of obtained subscores (e.g., mean, sd).
PRMSE	PRMSEs of obtained subscores (for Haberman's methods only).
subscore.original	Original observed subscores and total score.
subscore.x	Subscores that are estimated based on the observed total score.

References

Haberman, S. J. (2008). "When can subscores have value?." *Journal of Educational and Behavioral Statistics*, 33(2), 204-229.doi:10.3102/1076998607302636

Examples

```
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))

subscore.x(test.data)

subscore.x(test.data)$summary
subscore.x(test.data)$PRMSE
subscore.x(test.data)$Correlation
subscore.x(test.data)$Disattenuated.correlation
subscore.x(test.data)$subscore.x
```

test.data	<i>A list of objects that include both test information and subscores.</i>
-----------	--

Description

This list consists of four objects. The first three objects are item responses on the three subscales (algebra, geometry, and measurement). The fourth object is the response data on the total test.

Usage

```
data("test.data")
```

Format

The format is: A list with 4 objects:

\$ Algebra :'data.frame': 150 obs. of 15 variables:

\$ Geometry :'data.frame': 150 obs. of 15 variables:

\$ Measurement:'data.frame': 150 obs. of 20 variables:

\$ Math :'data.frame': 150 obs. of 50 variables:

Details

Algebra: Responses of 150 participants to 15 items; Geometry: Responses of 150 participants to 15 items. Measurement: Responses of 150 participants to 20 items; Math: Responses of 150 participants to 20 items.

Examples

```
data(test.data)
# maybe str(test.data); plot(test.data) ...
```

TIMSS11G8M.data	<i>The 2011 TIMSS Grade 8 Mathematics Assessment Dataset</i>
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Description

The TIMSS dataset used in Dai, Svetina, and Wang (2017) (doi:10.3102/1076998617716462). It contained responses from 765 students to 32 items with 6 to 9 items on each of the subscales of (1) number (Q1 to Q9), (2) algebra (Q10 to Q18), (3) geometry (Q19 to Q24), and (4) data and chance (Q25 to Q30). Omitted responses were treated as incorrect.

Usage

```
data("TIMSS11G8M.data")
```

Format

A data frame with 765 observations on the following 32 variables.

Q1 a numeric vector
Q2 a numeric vector
Q3 a numeric vector
Q4 a numeric vector
Q5 a numeric vector
Q6 a numeric vector
Q7 a numeric vector
Q8 a numeric vector
Q9 a numeric vector
Q10 a numeric vector
Q11 a numeric vector
Q12 a numeric vector
Q13 a numeric vector
Q14 a numeric vector
Q15 a numeric vector
Q16 a numeric vector
Q17 a numeric vector
Q18 a numeric vector
Q19 a numeric vector
Q20 a numeric vector
Q21 a numeric vector
Q22 a numeric vector
Q23 a numeric vector
Q24 a numeric vector
Q25 a numeric vector
Q26 a numeric vector
Q27 a numeric vector
Q28 a numeric vector
Q29 a numeric vector
Q30 a numeric vector
Q31 a numeric vector
Q32 a numeric vector

Source

Dai, S., Svetina, D., & Wang, X. (2017). "Reporting subscores using R: A software review." *Journal of Educational and Behavioral Statistics*. 42(2), 617-638. doi: 10.3102/1076998617716462.

Examples

```
data(TIMSS11G8M.data)
# maybe str(TIMSS11G8M.data); plot(TIMSS11G8M.data) ...
```

Yen.OPI

*Estimating true subscores using Yen's OPI***Description**

This function estimates subscores using Yen's Objective Performance Index (OPI; Yen, 1987) <https://www.ets.org/research/policy_research_reports/publications/paper/1987/hrap>. Yen's OPI (Yen, 1987) is a procedure combining Bayesian method and item response theory (IRT; Embretson & Reise, 2000 <<https://psycnet.apa.org/record/2000-03918-000>>; Reckase, 1997 <doi: 10.1177/0146621697211002>). This method pulls an examinee's performance on a certain objective (i.e., subscale) towards his/her total test performance in order to get a more stable and precise objective subscore estimate.

Usage

```
Yen.OPI(test.data)
```

Arguments

`test.data` A list that contains item responses of all subtests and the entire test, which can be obtained using function 'data.prep'.

Value

`summary` It contains statistical summary of OPI (mean & sd).
`OPI` Estimated OPI values

References

Embretson, S. E., & Reise, S. P. (2013). "Item response theory". Mahwah, NJ: Lawrence Erlbaum Associates, Inc. <https://psycnet.apa.org/record/2000-03918-000>.

Reckase, M. D. (1997). "The past and future of multidimensional item response theory". *Applied Psychological Measurement*, 21(1), 25-36. doi: 10.1177/0146621697211002.

Yen, W. M. (1987, June). "A Bayesian/IRT index of objective performance". Paper presented at annual meeting of the Psychometric Society, Montreal, Quebec, Canada. https://www.ets.org/research/policy_research_reports/

Examples

```
test.data<-data.prep(scored.data,c(3,15,15,20),
                    c("Algebra","Geometry","Measurement", "Math"))

Yen.OPI(test.data)
```

Yen.Q3 *Computing Yen's Q3 statistic for unidimensional Rasch, 1-, 2-, and 3-PL logistic IRT models*

Description

This function calculates Yen's Q3 statistics as introduced in Yen (1984) <doi: 10.1177/014662168400800201> and Yen (1993) <doi: 10.1111/j.1745-3984.1993.tb00423.x> for unidimensional Rasch, 1-, 2-, and 3-PL logistic IRT models to assess the local independence assumption.

Usage

```
Yen.Q3(scored.data, IRT.model = "2pl")
```

Arguments

scored.data	Item response data with rows as individuals and columns as items.
IRT.model	IRT model ('Rasch', '1pl', '2pl', or '3pl') to be used. The default option is 2pl.

Value

Q3	A matrix of Q3 statistics
Q3.weighted	A matrix of Q3 statistics as obtained by weighting the residual values to reflect the number of examinees with each response pattern.

References

Yen, W. M. (1984). "Effects of local item dependence on the fit and equating performance of the three-parameter logistic model." *Applied Psychological Measurement*, 8(2), 125-145. doi: 10.1177/014662168400800201.

Yen, W. M. (1993). "Scaling performance assessments: Strategies for managing local item dependence." *Journal of educational measurement*, 30(3), 187-213. doi: 10.1111/j.1745-3984.1993.tb00423.x.

Examples

```
Yen.Q3(scored.data, IRT.model="2pl")
```

```
Yen.Q3(scored.data)$Q3
```

```
Yen.Q3(scored.data)$Q3.weighted
```

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