validscale: A Stata module to validate subjective measurement scales using Classical Test Theory

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Context

- We use questionnaires to measure non-observable characteristics/traits
  - personality traits
  - aptitudes, intelligence
  - quality of life
  - ...
- The questionnaires are subjective measurement scales providing one or several scores based on the sum (or mean) of responses to items (binary or ordinal variables)

Hospital Anxiety and Depression Scale (Zigmond and Snaith, 1983)

Chart I — Hospital Anxiety and Depression Scale

This questionnaire will help your physician know how you are feeling. Read every sentence. Place an "X" on the answer that best describes how you have been feeling during the LAST WEEK. You do not have to think too much to answer. In this questionnaire, spontaneous answers are more important. Mark only one answer for each question.

A (1) I feel tense or wound up:
- 3 ( ) Most of the time
- 2 ( ) A lot of times
- 1 ( ) From time to time
- 0 ( ) Not at all

D (2) I still enjoy the things I used to:
- 0 ( ) Definitely as much
- 1 ( ) Not quite so much
- 2 ( ) Only a little
- 3 ( ) Hardly at all

A (3) I get a sort of frightened feeling as if something awful is about to happen:
- 3 ( ) Very definitely and quite badly
- 2 ( ) Yes, but not too badly
- 1 ( ) A little, but it doesn't worry me
- 0 ( ) Not at all

D (4) I can laugh and see the funny side of things:
- 0 ( ) As much as I always could
- 1 ( ) Not quite as much now
- 2 ( ) Definitely not so much now
- 3 ( ) Not at all

A (5) Worrying thoughts go through my mind:
- 3 ( ) Most of the time
- 2 ( ) A lot of times
- 1 ( ) From time to time
- 0 ( ) Only occasionally

D (6) I feel cheerful:
- 0 ( ) Most of the time
- 1 ( ) Usually
- 2 ( ) Not often
- 3 ( ) Not at all

A (7) I can seat at ease and feel relaxed:
- 0 ( ) Definitely
- 1 ( ) Usually
- 2 ( ) Not often
- 3 ( ) Not at all

D (8) I feel as I am slowed down:
- 3 ( ) Nearly all the time
- 2 ( ) Very often
- 1 ( ) From time to time
- 0 ( ) Not at all

A (9) I get a sort of frightened feeling like butterflies in the stomach:
- 0 ( ) Not at all
- 1 ( ) From time to time
- 2 ( ) Quite often
- 3 ( ) Very often

D (10) I have lost interest in my appearance:
- 3 ( ) Definitely
- 2 ( ) I don't take so much care as I should
- 1 ( ) I may not take quite as much care
- 0 ( ) I take just as much care as ever

A (11) I feel restless, as if I had to be on the move:
- 3 ( ) Very much indeed
- 2 ( ) Quite a lot
- 1 ( ) Not very much
- 0 ( ) Not at all

D (12) I look forward with enjoyment to things:
- 0 ( ) As much as I ever did
- 1 ( ) A little less than I used to
- 2 ( ) Definitely less than I used to
- 3 ( ) Hardly at all

A (13) I get a sudden feeling of panic:
- 3 ( ) Very often indeed
- 2 ( ) Quite often
- 1 ( ) From time to time
- 0 ( ) Not at all

D (14) I can enjoy a good TV or radio program or book:
- 0 ( ) Often
- 1 ( ) Sometimes
- 2 ( ) Not often
- 3 ( ) Hardly at all

Validity and reliability of a questionnaire

In order to be useful, a questionnaire must be **valid** and **reliable**.

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- structural validity
- convergent validity
- divergent validity
- concurrent validity
- known-groups validity

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- reproducibility
- ("scalability")

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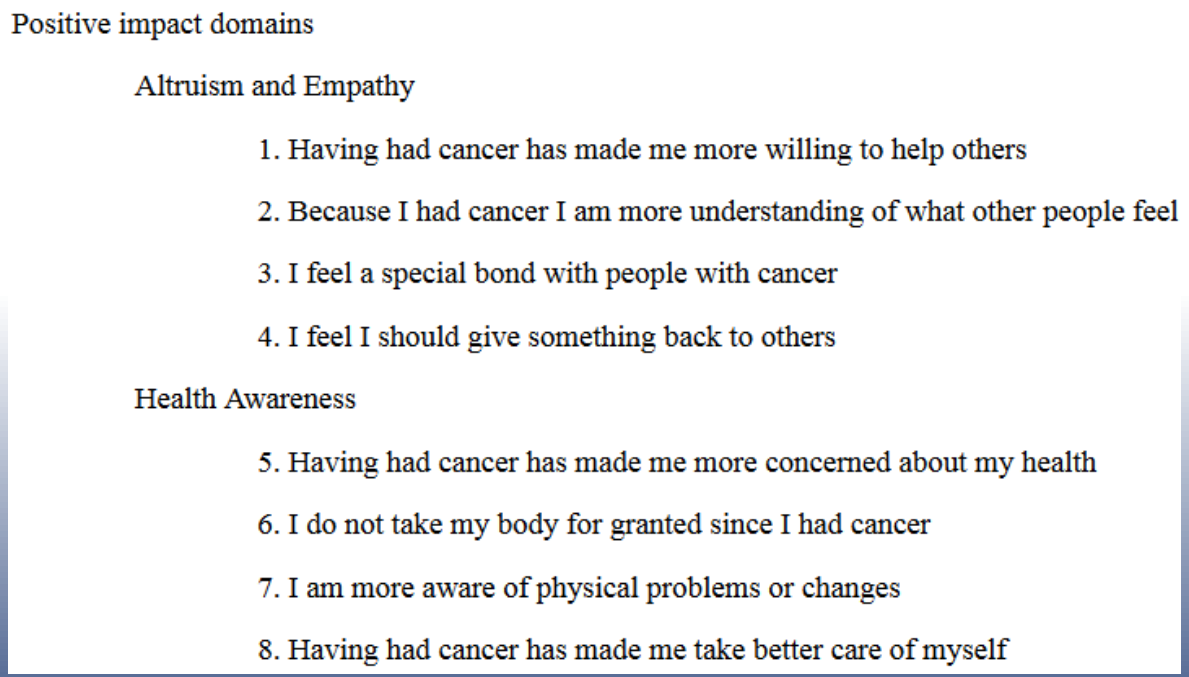
These properties can be assessed using Classical Test Theory (CTT) or Item Response Theory (IRT)

Rationale for `validscale`

- Validity and reliability are assessed using statistical analyses (e.g. Factor Analyses, Intraclass Correlation Coefficients, etc.).
- However, there is currently no statistical software package to perform all these tests in an easy way.
- $\rightarrow$ The objective of `validscale` is to perform the recommended analyses to validate a subjective measurement scale using CTT.

Example dataset : Impact of Cancer Scale (Crespi et al., 2008)

- 37 items (range: 1=strongly disagree to 5=strongly agree) grouped into 8 dimensions measuring impact of cancer
- A French version was administered to a sample of breast cancer survivors (N=371)



Positive impact domains

Altruism and Empathy

1. Having had cancer has made me more willing to help others
2. Because I had cancer I am more understanding of what other people feel
3. I feel a special bond with people with cancer
4. I feel I should give something back to others

Health Awareness

5. Having had cancer has made me more concerned about my health
6. I do not take my body for granted since I had cancer
7. I am more aware of physical problems or changes
8. Having had cancer has made me take better care of myself

- Health Awareness: ioc1-ioc4
- Positive Self-Evaluation: ioc5-ioc8
- Worry: ioc9-ioc15
- Body Change Concerns: ioc16-ioc18
- Appearance Concerns: ioc19-ioc21
- Altruism and Empathy: ioc22-ioc25
- Life Interferences: ioc26-ioc32
- Meaning Of Cancer: ioc33-ioc37

Syntax

`validscale` *varlist*`, partition(`*numlist*`)`

varlist contains the variables (items) used to compute the scores. The first items of *varlist* compose the first dimension, the following items define the second dimension, and so on.

`partition` allows defining in *numlist* the number of items in each dimension. The number of elements in this list indicates the number of dimensions.

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5)
```

Syntax

`validscale` *varlist*, `partition(`*numlist*`)` [`scorename(`*string*`)` `scores(`*varlist*`)` `categories(`*numlist*`)` `impute(`*method*`)` `noround` `compscore(`*method*`)` `descitems` `graphs` `cfa` `cfamethod(`*method*`)` `cfasb` `cfastand` `cfanocovdim` `cfacovs(`*string*`)` `cfarmsea(#)` `cfacfi(#)` `cfaor` `convdiv` `tconvdiv(#)` `convdivboxplots` `alpha(#)` `delta(#)` `h(#)` `hjmin(#)` `repet(`*varlist*`)` `kappa` `ickappa(#)` `scores2(#)` `kgv(`*varlist*`)` `kgvboxplots` `kgvgroupboxplots` `conc(`*varlist*`)` `tconc(#)`]

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Reliability (default output)

- Summary table providing indices for internal consistency (Cronbach's alpha), dicrimination (Feguson's delta), and "scalability" (Loevinger's H coefficients, IRT related)

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MOC) compscore(sum) alpha(0.7) delta(0.9) h(0.3)
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```
Items used to compute the scores

HA : ioc1 ioc2 ioc3 ioc4
PSE : ioc5 ioc6 ioc7 ioc8
W : ioc9 ioc10 ioc11 ioc12 ioc13 ioc14 ioc15
BCC : ioc16 ioc17 ioc18
AC : ioc19 ioc20 ioc21
AE : ioc22 ioc23 ioc24 ioc25
LI : ioc26 ioc27 ioc28 ioc29 ioc30 ioc31 ioc32
MOC : ioc33 ioc34 ioc35 ioc36 ioc37

Number of observations: 371
```

```
Reliability
```

---

	n	alpha	delta	H	Hj_min	
HA	369	0.67	0.94	0.35	0.25	(item ioc1)
PSE	368	0.69	0.96	0.39	0.30	
W	369	0.90	0.99	0.62	0.59	
BCC	369	0.79	0.97	0.61	0.58	
AC	369	0.81	0.97	0.62	0.60	
AE	368	0.71	0.94	0.43	0.34	
LI	367	0.81	0.97	0.42	0.29	(item ioc26)
MOC	363	0.83	0.97	0.53	0.38	

Descriptive table (descitems)

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
MOC) compscore(sum) descitems
```

Description of items

	Missing	N	Response categories 1	2	3	4	5	Alpha - item	Hj	# of NS Hjk
ioc1	3.77%	357	10.08%	12.61%	24.65%	33.05%	19.61%	0.71	0.25	0
ioc2	1.08%	367	3.00%	8.72%	10.90%	39.78%	37.60%	0.52	0.42	0
ioc3	2.16%	363	2.48%	5.79%	11.02%	44.63%	36.09%	0.53	0.43	0
ioc4	2.43%	362	3.31%	8.56%	18.51%	43.09%	26.52%	0.62	0.33	0
ioc5	2.96%	360	9.44%	15.28%	22.78%	28.06%	24.44%	0.70	0.30	0
ioc6	2.96%	360	10.28%	15.28%	24.17%	33.61%	16.67%	0.54	0.47	0
ioc7	2.43%	362	4.97%	8.01%	22.10%	42.27%	22.65%	0.67	0.34	0
ioc8	2.16%	363	14.60%	19.83%	33.06%	20.66%	11.85%	0.58	0.44	0
ioc9	2.43%	362	15.47%	22.65%	14.64%	28.18%	19.06%	0.89	0.63	0
ioc10	3.23%	359	33.43%	27.58%	20.89%	12.26%	5.85%	0.90	0.59	0
ioc11	1.89%	364	5.49%	9.62%	13.74%	42.03%	29.12%	0.89	0.61	0
ioc12	3.23%	359	8.64%	18.94%	19.22%	37.05%	16.16%	0.89	0.63	0
ioc13	3.23%	359	13.65%	24.79%	18.11%	30.36%	13.09%	0.88	0.66	0
ioc14	1.62%	365	12.05%	26.30%	14.25%	28.49%	18.90%	0.89	0.60	0
ioc15	1.08%	367	6.81%	19.62%	18.26%	39.78%	15.53%	0.89	0.64	0

Descriptive graphs (graph)

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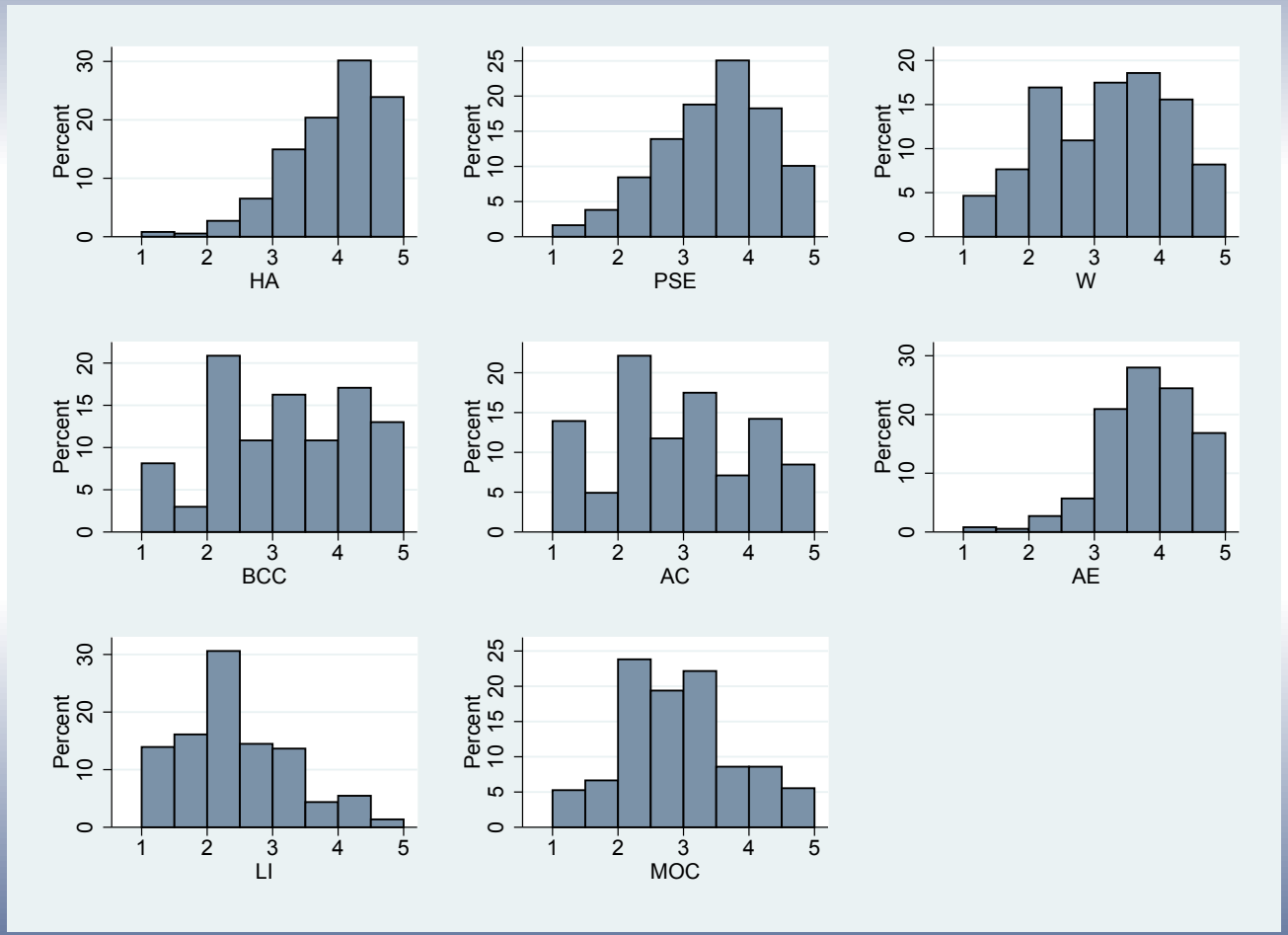

Figure: Histograms of scores

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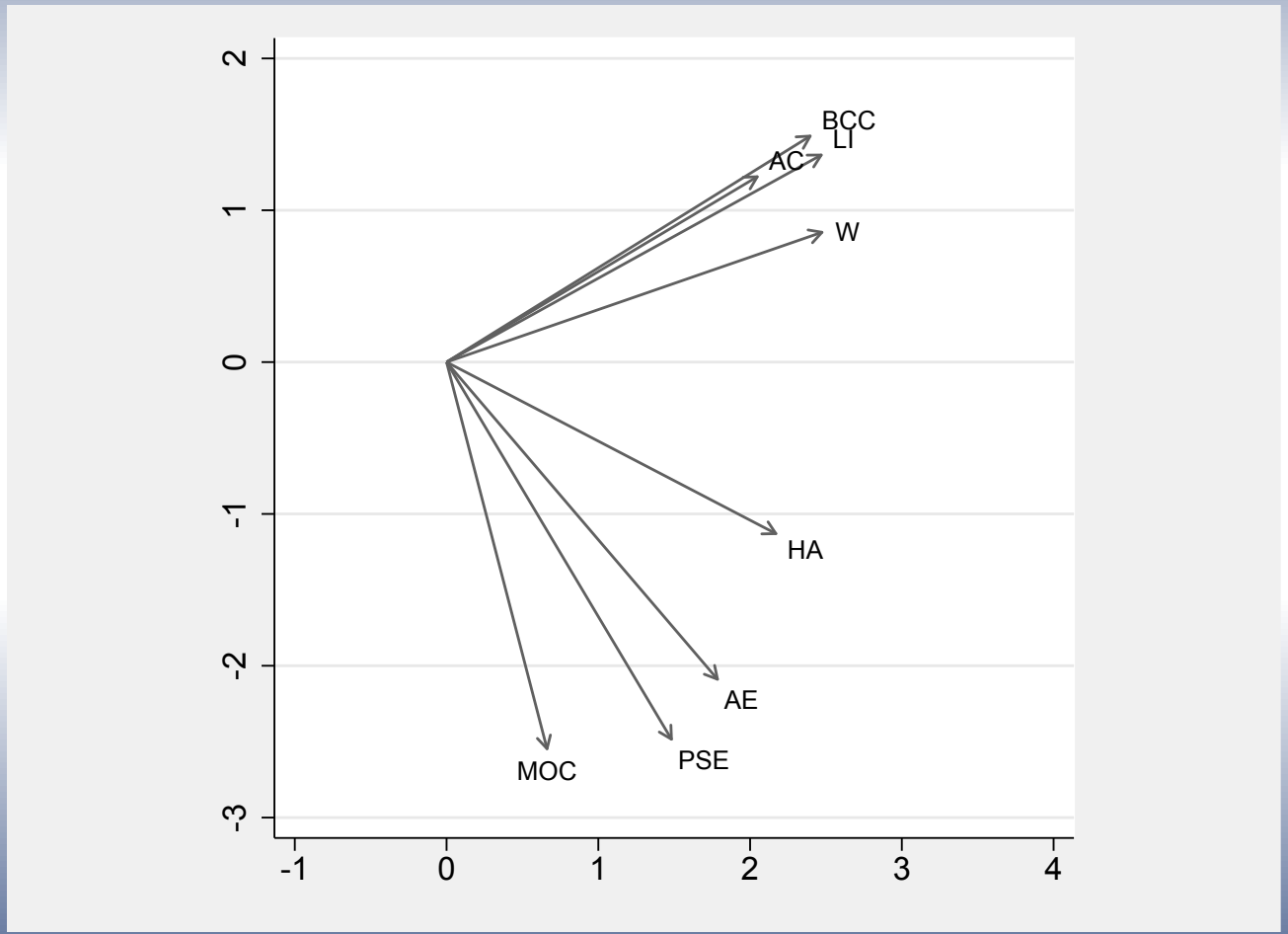

Figure: Correlations between scores

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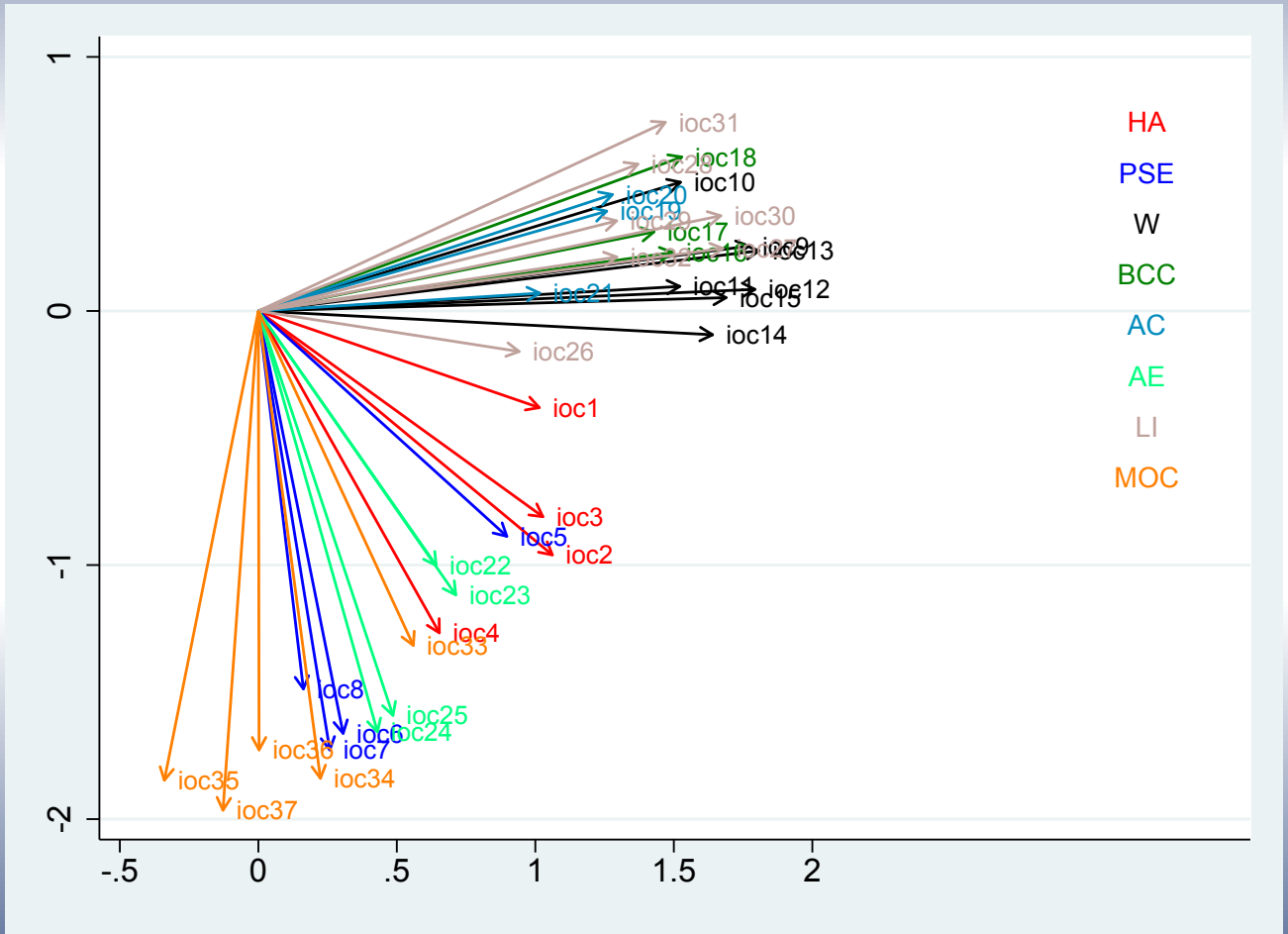

Figure: Correlations between items

Confirmatory Factor Analysis (`cfa`)

- How well the supposed structure (number of dimensions, clustering of items) fit the data ?
- $\rightarrow$ Confirmatory Factor Analysis (based on the `sem` command)
- Some criteria based of fit indices: Root Mean Square Error of Approximation (RMSEA) $<$ 0.06, Comparative Fit Index (CFI) $>$ 0.95

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI MOC) cfa cfacov(ioc1*ioc3)
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```

```
Confirmatory factor analysis

Warning: some items have less than 7 response categories. If multivariate
normality assumption does not hold, maximum likelihood estimation might not
be appropriate. Consider using cfasb in order to apply Satorra-Bentler
adjustment or using cfamethod(adf).

Covariances between errors added: e.ioc1*e.ioc3

Number of used individuals:  292
```

Item	Dimension	Factor loading	Standard error	Intercept	Standard error	Error variance	Variance of dimension
ioc1	HA	1.00	.	3.36	0.07	1.33	0.16
ioc2	HA	2.05	0.46	3.95	0.06	0.45	
ioc3	HA	1.53	0.31	4.01	0.06	0.55	
ioc4	HA	1.47	0.34	3.77	0.06	0.68	
ioc5	PSE	1.00	.	3.42	0.07	1.32	0.32
ioc6	PSE	1.56	0.24	3.27	0.07	0.69	
ioc7	PSE	1.15	0.20	3.70	0.06	0.66	
ioc8	PSE	1.37	0.22	2.91	0.07	0.80	

```
(output omitted)

Goodness of fit:
```

chi2	df	chi2/df	RMSEA [90% CI]	SRMR	NFI
1103.86	600	1.8	0.054 [0.049 ; 0.059]	0.074	0.796

(p-value = 0.000)

RNI	CFI	IFI	MCI
0.894	0.894	0.895	0.421

Convergent and Divergent validities (`convdiv`)

- Are the items correlated enough with the dimension they theoretically belong to ?
- Are they more correlated with their own dimension than with other dimensions ?
- $\rightarrow$ Inspection of correlations between items and scores or rest-scores (i.e. the scores computed without the considered item)

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```

Correlation matrix

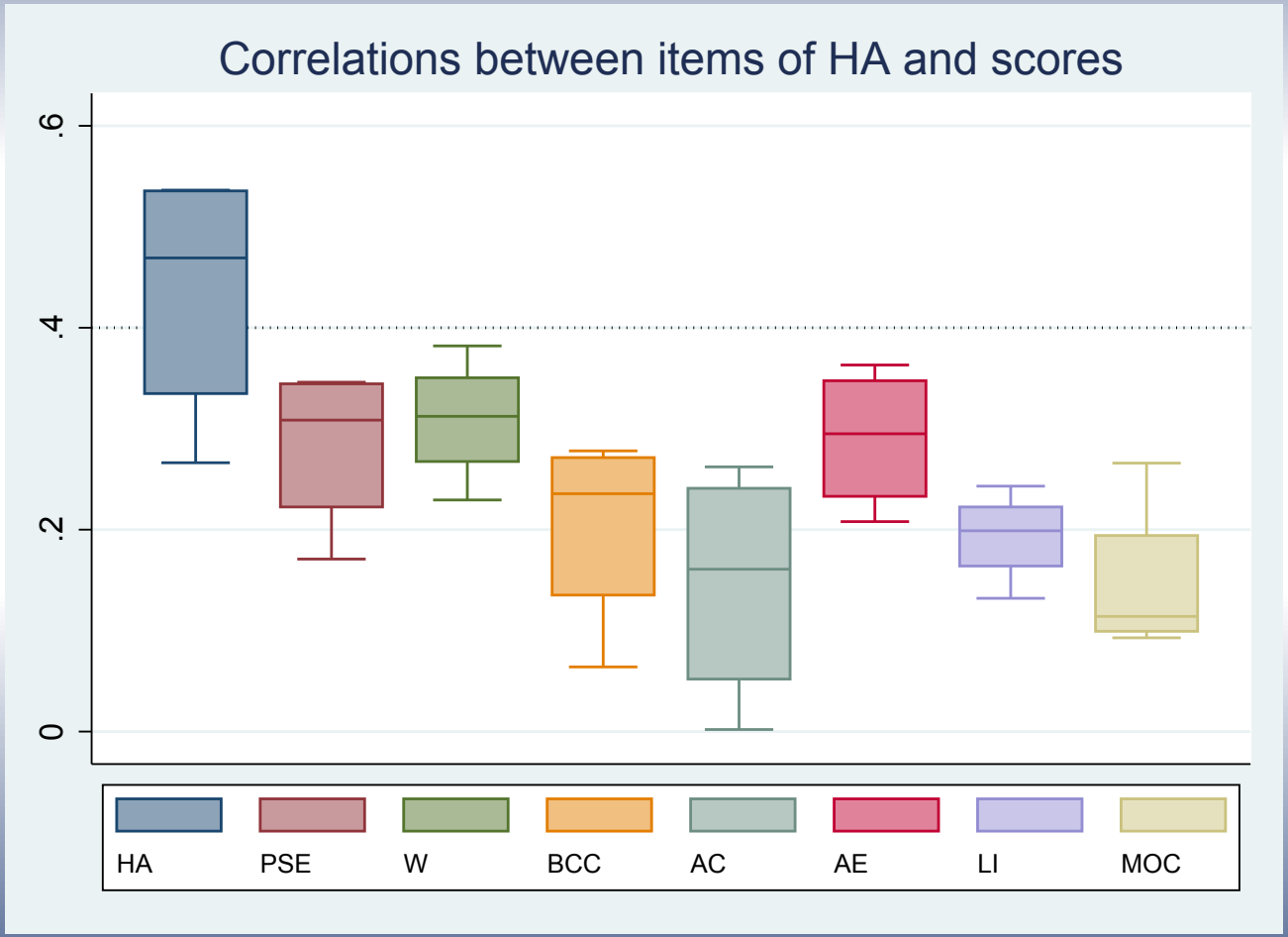
	HA	PSE	W	BCC	AC	AE	LI	MOC
ioc1	0.266	0.171	0.319	0.278	0.262	0.208	0.243	0.093
ioc2	**0.535**	0.343	0.382	0.206	0.102	0.363	0.202	0.122
ioc3	**0.536**	0.346	0.306	0.265	0.220	0.258	0.196	0.106
ioc4	**0.403**	0.274	0.229	0.064	0.002	0.332	0.132	0.266
ioc5	0.359	0.362	0.308	0.172	0.107	0.242	0.174	0.126
ioc6	0.296	**0.609**	0.083	0.013	0.084	0.391	0.077	0.286
ioc7	0.316	**0.418**	0.102	-0.007	0.052	0.423	-0.011	0.382
ioc8	0.157	**0.546**	0.024	0.002	0.077	0.321	0.046	0.253
ioc9	0.364	0.181	**0.743**	0.359	0.280	0.184	0.530	-0.024
ioc10	0.216	0.072	**0.643**	0.364	0.258	0.057	0.466	-0.114
ioc11	0.394	0.045	**0.666**	0.335	0.156	0.166	0.408	-0.010
ioc12	0.411	0.163	**0.734**	0.433	0.327	0.230	0.476	-0.020
ioc13	0.318	0.165	**0.792**	0.389	0.323	0.180	0.524	-0.027
ioc14	0.390	0.191	**0.698**	0.378	0.272	0.186	0.425	0.062
ioc15	0.427	0.145	**0.741**	0.424	0.285	0.185	0.431	0.011

```
Convergent validity: 33/37 items (89.2%) have a correlation coefficient with the score of their own dimension
greater than 0.400

Divergent validity:  33/37 items (89.2%) have a correlation coefficient with the score of their own dimension
greater than those computed with other scores.
```

Convergent and divergent validities (convdiv)

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
  MOC) convdiv convdivboxplot tconc(0.4)
```



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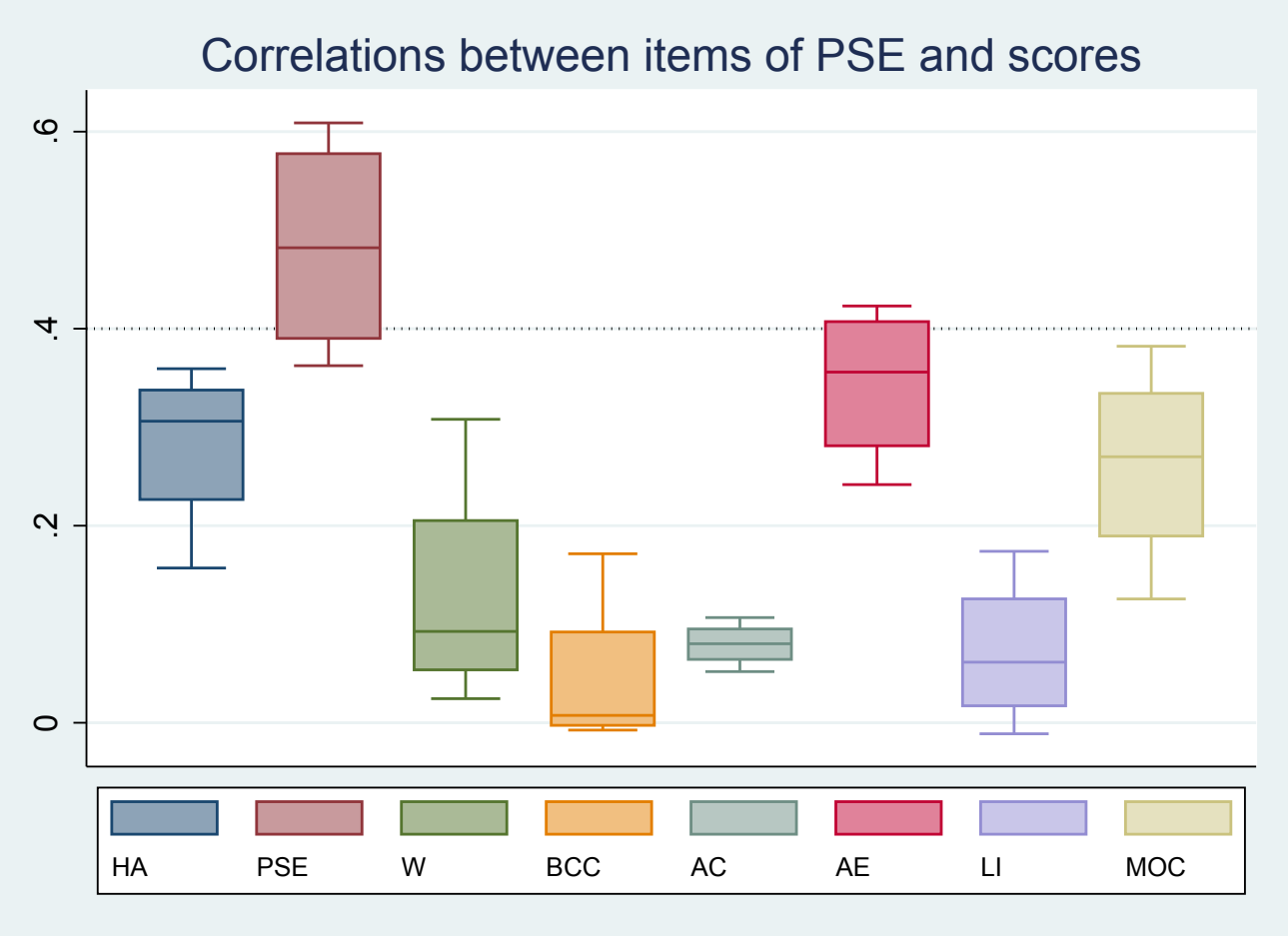

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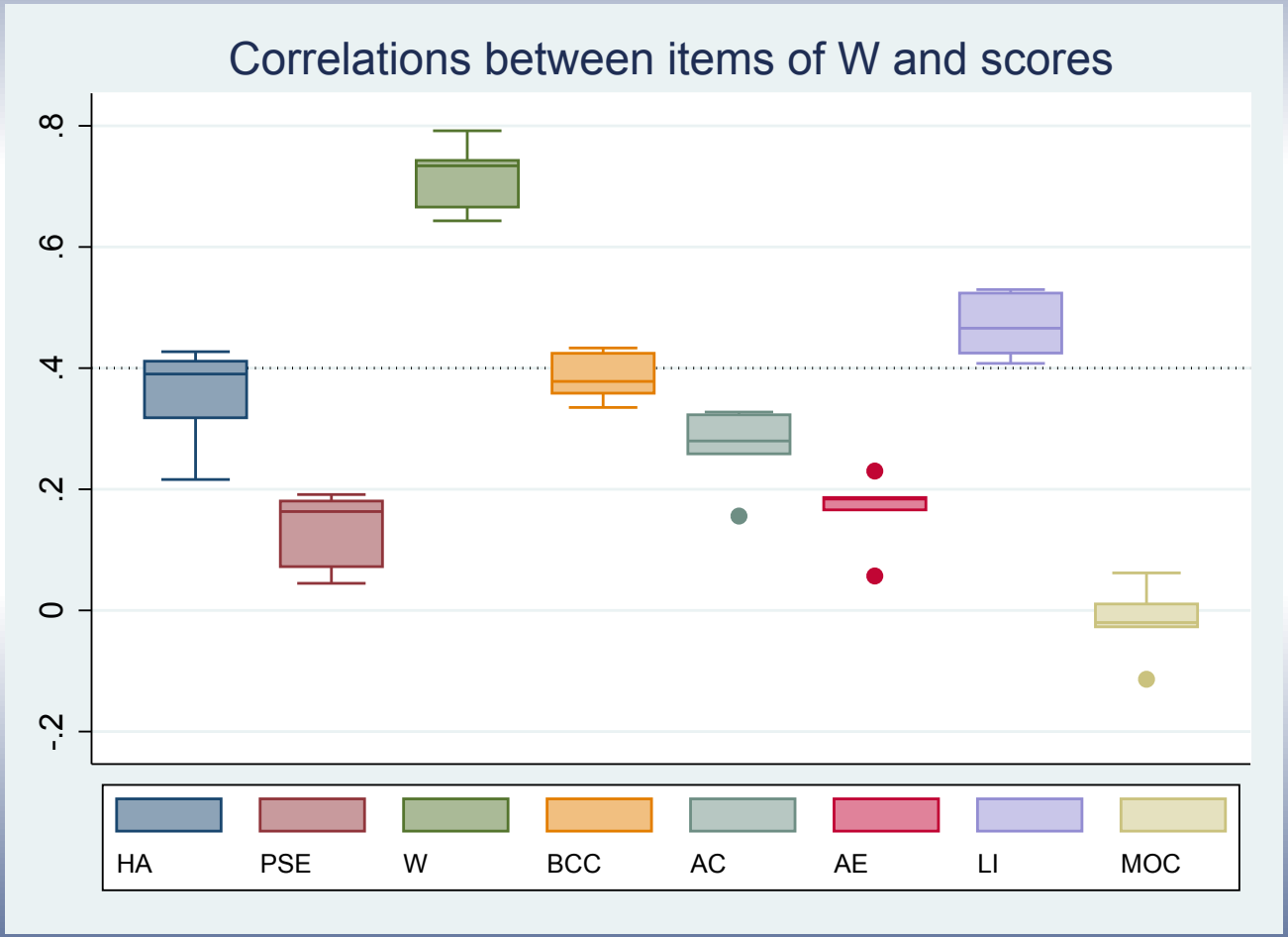

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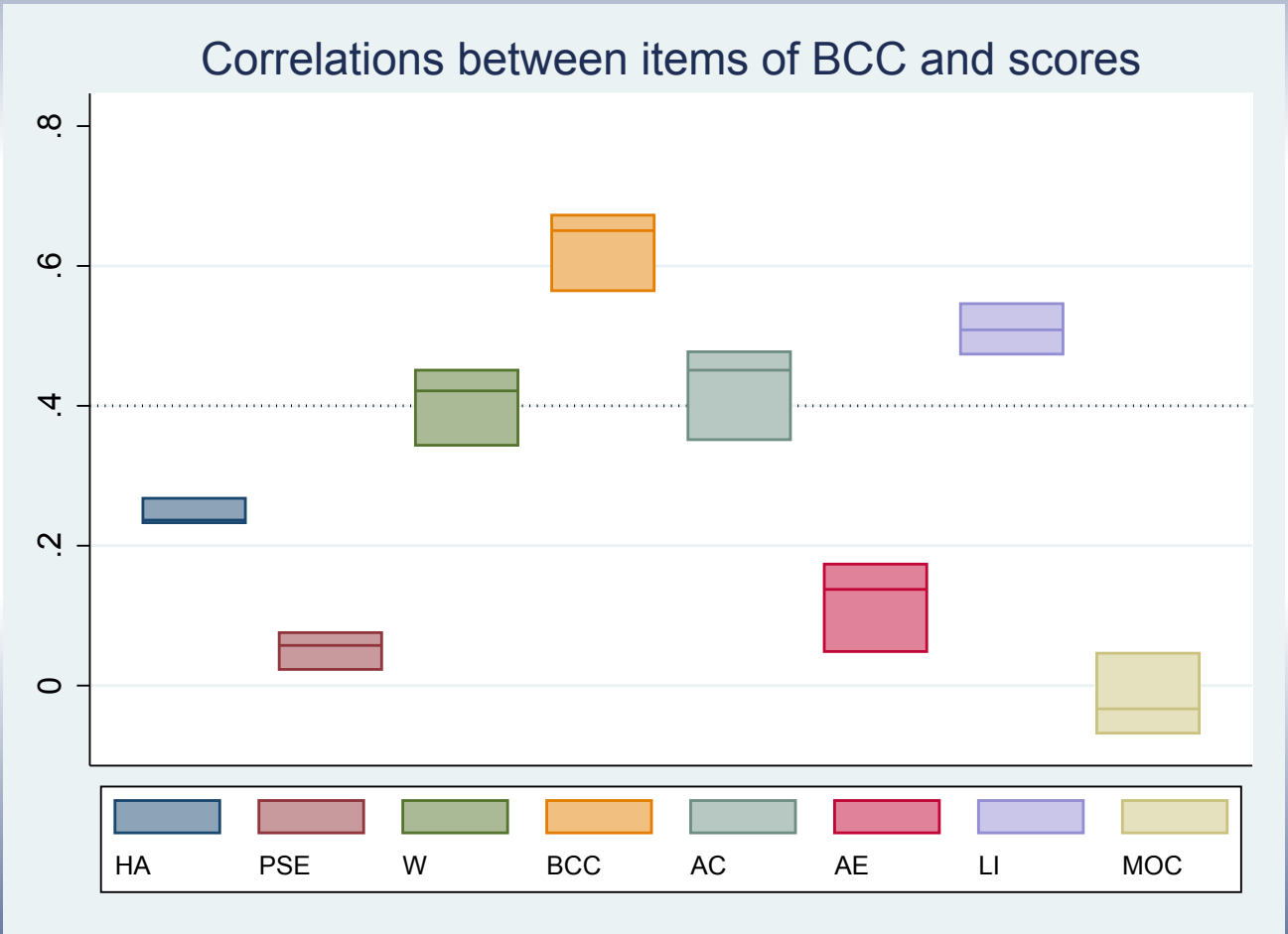

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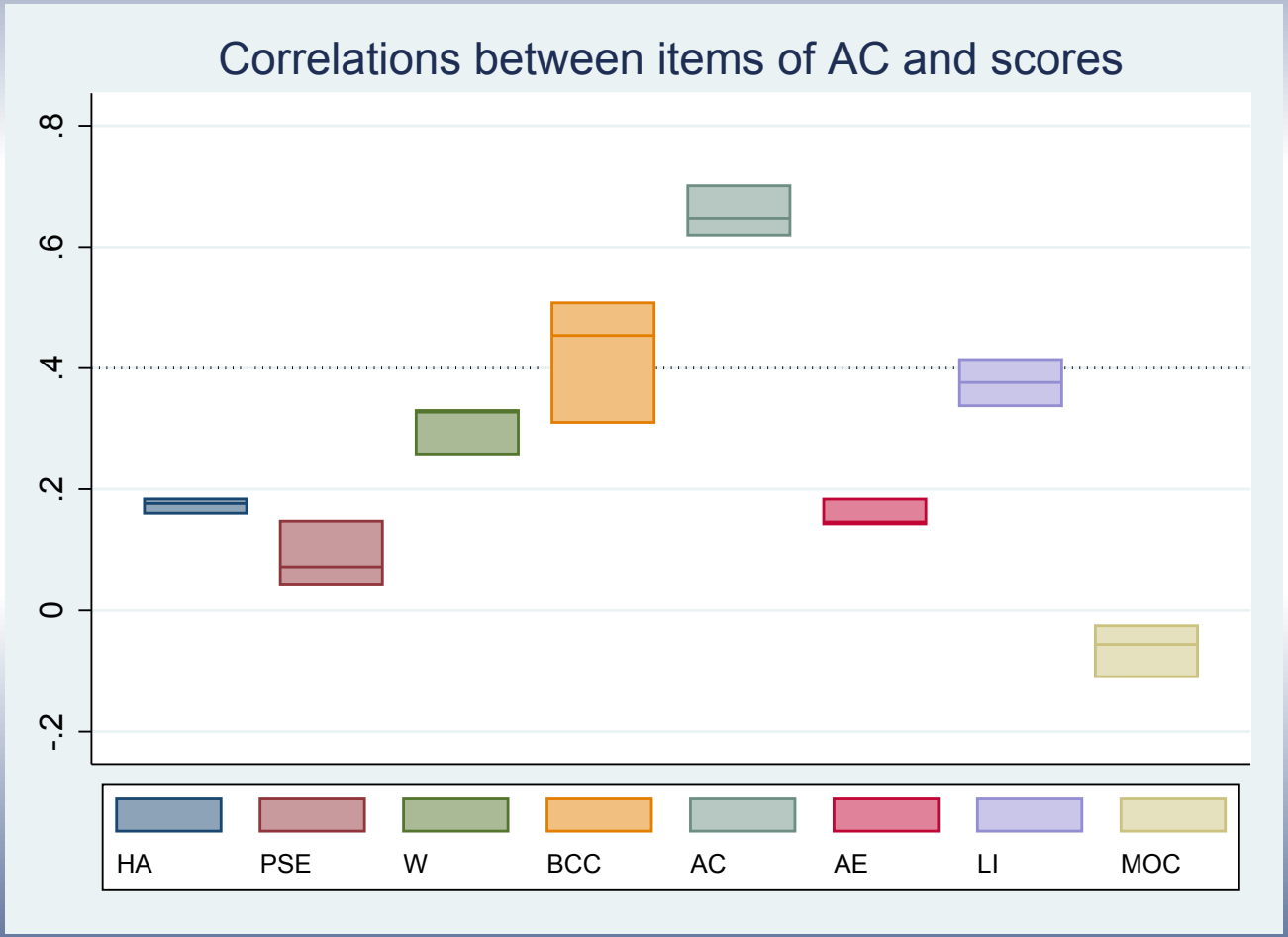

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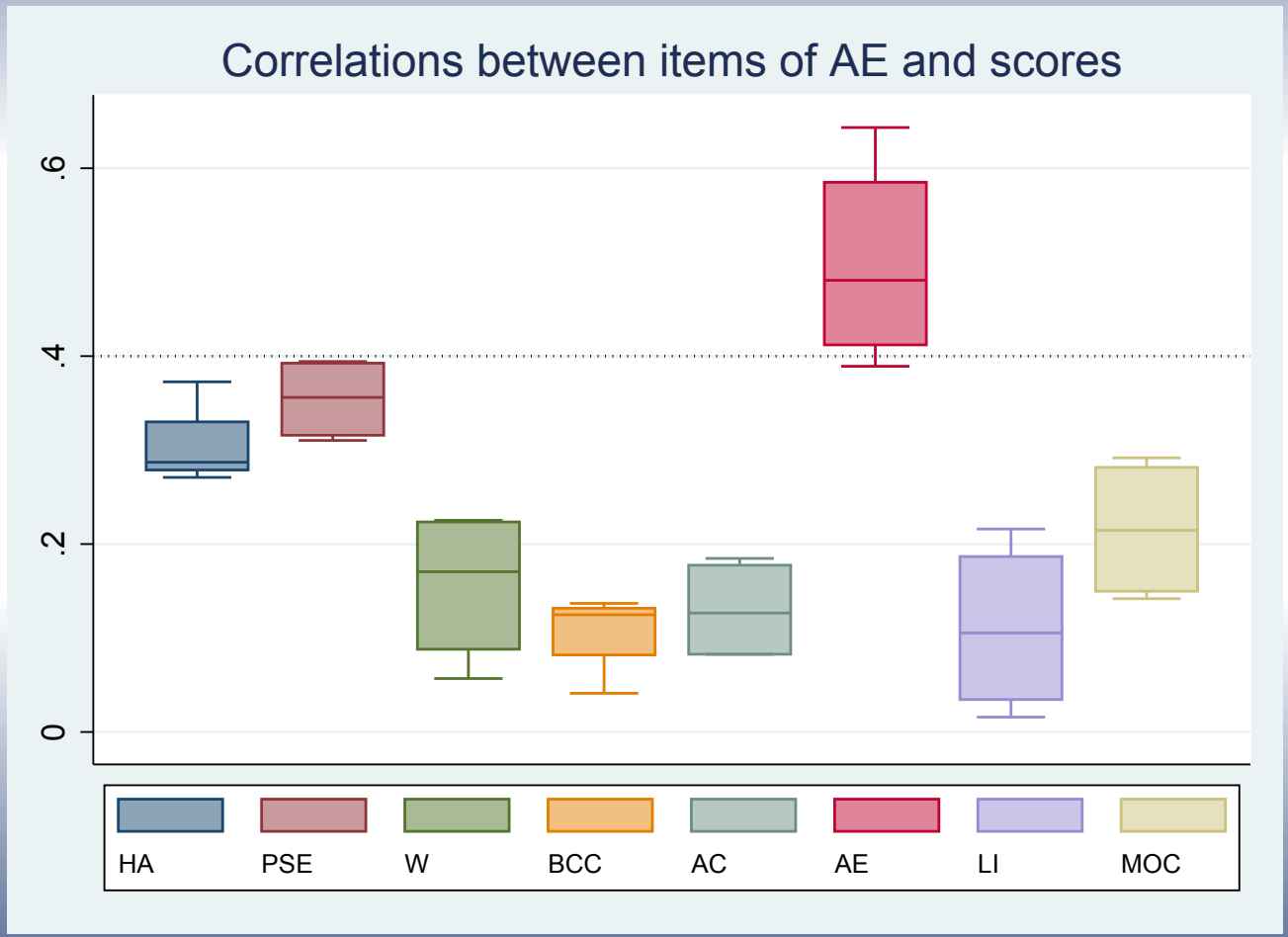

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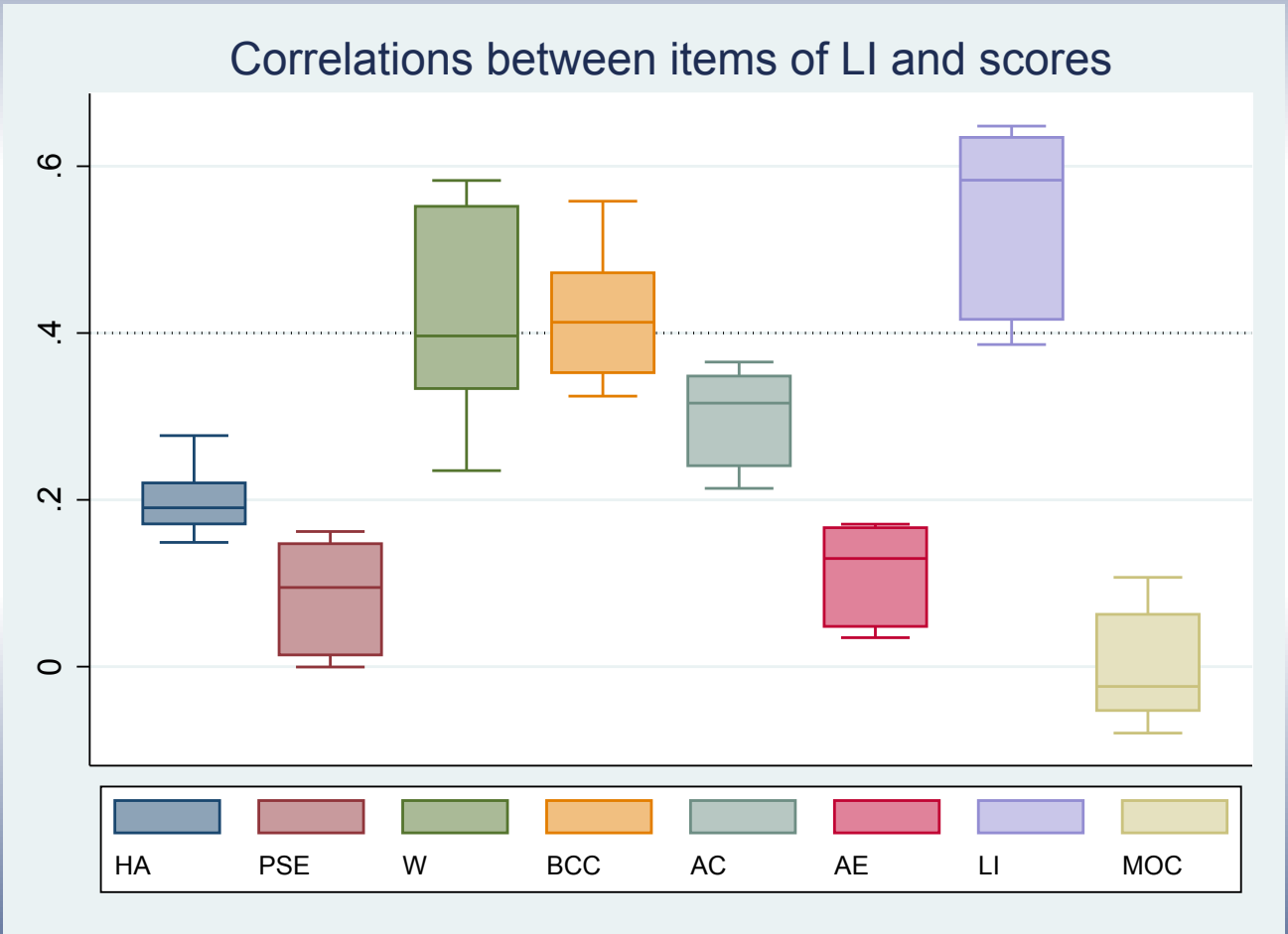

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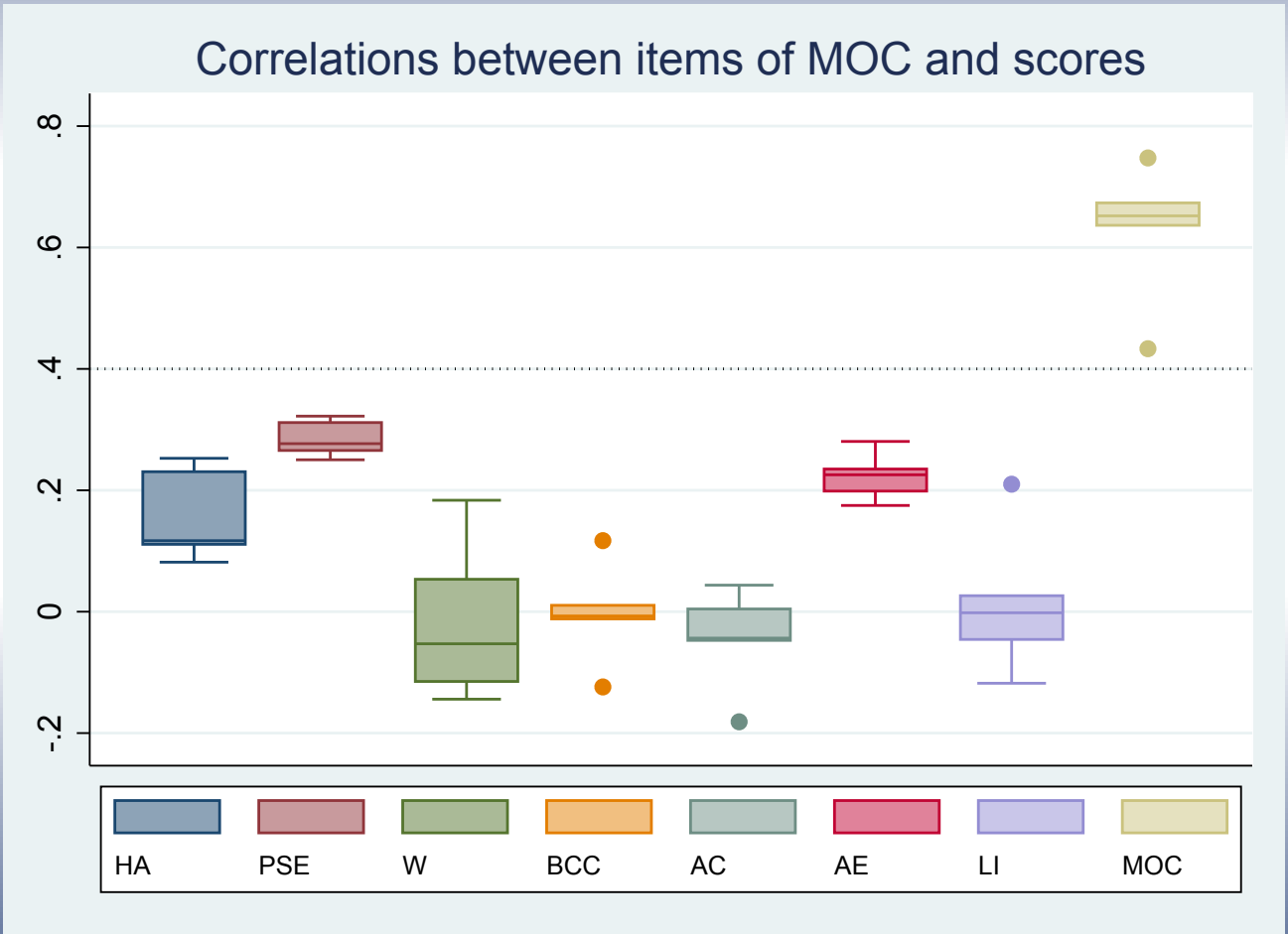

Reproducibility (repet)

- Are the scores and items reproducible in time ?
- → Intraclass Correlation Coefficients (ICC) for reproducibility of scores; kappa's coefficients for reproducibility of items

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
  MOC) repet(ioc1_2-ioc37_2) kappa ickappa(500)
```

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- → Intraclass Correlation Coefficients (ICC) for reproducibility of scores; kappa's coefficients for reproducibility of items

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
  MOC) repet(ioc1_2-ioc37_2) kappa ickappa(500)
```

Reproducibility

Dimension	n	Item	Kappa	95% CI for Kappa (bootstrapped)	ICC	95% CI for ICC
HA	368	ioc1	0.57	[0.50 ; 0.63]	0.93	[0.92 ; 0.95]
		ioc2	0.56	[0.50 ; 0.63]		
		ioc3	0.54	[0.48 ; 0.61]		
		ioc4	0.62	[0.56 ; 0.67]		
PSE	367	ioc5	0.59	[0.50 ; 0.63]	0.94	[0.93 ; 0.95]
		ioc6	0.58	[0.52 ; 0.63]		
		ioc7	0.55	[0.49 ; 0.61]		
		ioc8	0.61	[0.55 ; 0.67]		
W	366	ioc9	0.60	[0.48 ; 0.61]	0.98	[0.97 ; 0.98]
		ioc10	0.55	[0.48 ; 0.61]		
		ioc11	0.56	[0.50 ; 0.63]		
		ioc12	0.62	[0.56 ; 0.68]		
		ioc13	0.65	[0.58 ; 0.71]		
		ioc14	0.63	[0.57 ; 0.69]		
		ioc15	0.56	[0.50 ; 0.62]		

Known-groups validity (kgv)

- Do scores differ as expected between predefined groups of individuals ?
- $\rightarrow$ ANOVAs for comparing mean scores between groups of individuals

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
MOC) kgv(chemo)
```

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```

Known-groups validity

	chemotherapy	mean	sd	p-value	
HA	0 (n=106)	3.71	0.76	0.101	(KW: 0.060)
	1 (n=245)	3.85	0.76		
PSE	0 (n=105)	3.20	0.85	0.042	(KW: 0.029)
	1 (n=245)	3.40	0.85		
W	0 (n=105)	3.10	0.90	0.535	(KW: 0.471)
	1 (n=244)	3.17	1.01		
BCC	0 (n=105)	2.87	1.13	0.009	(KW: 0.011)
	1 (n=247)	3.20	1.06		
AC	0 (n=105)	2.58	1.10	0.011	(KW: 0.014)
	1 (n=245)	2.91	1.13		
AE	0 (n=104)	3.62	0.65	0.187	(KW: 0.095)
	1 (n=247)	3.73	0.74		
LI	0 (n=104)	2.29	0.80	0.157	(KW: 0.215)
	1 (n=246)	2.42	0.85		
MOC	0 (n=103)	2.76	0.83	0.213	(KW: 0.190)
	1 (n=242)	2.90	0.93		

Known-groups validity (kgv)

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
MOC) kgv(chemo) kgvboxplot kgvgroup
```

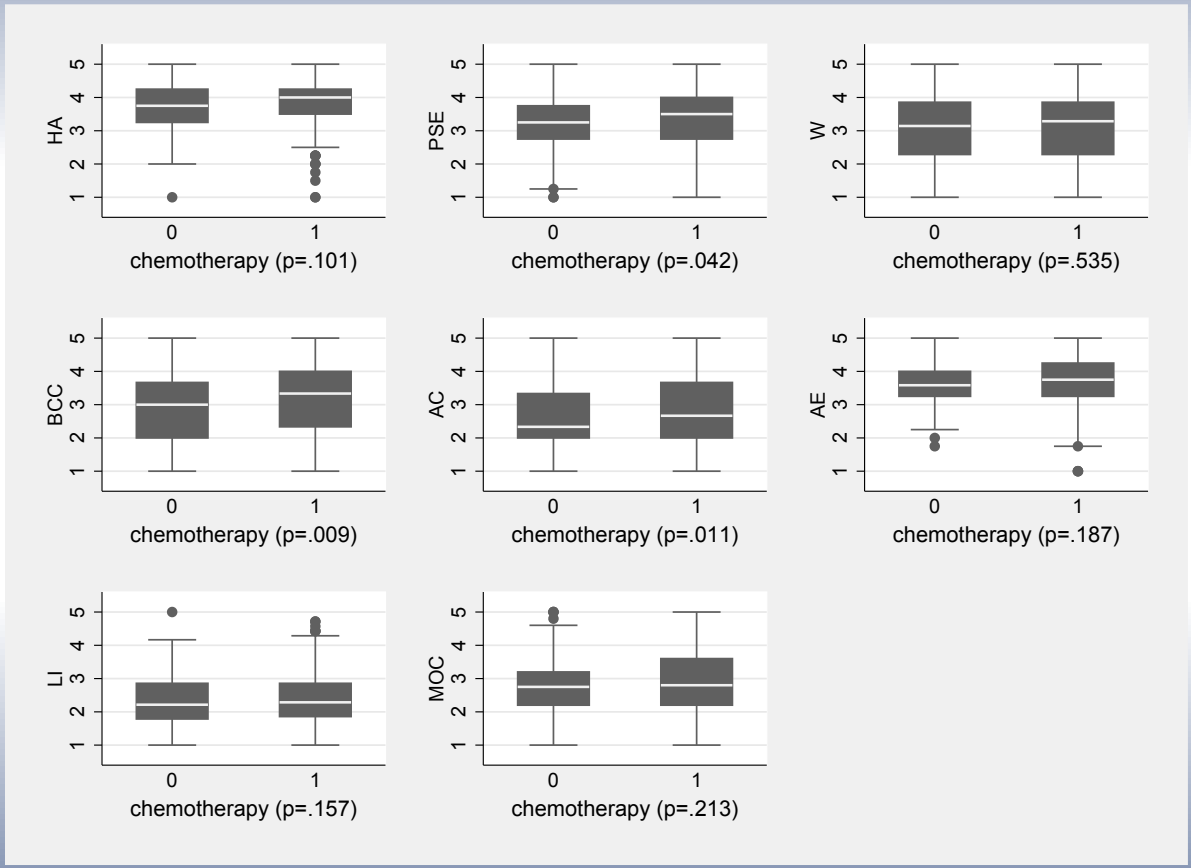


Figure: Known-groups validity: chemotherapy/no chemotherapy.

Concurrent validity (conc)

- Are the scores correlated as expected with other similar validated scores ?
- → Correlation coefficients between scores and other scores measuring similar concepts

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
MOC) conc(sf12mcs sf12pcs)
```

Concurrent validity (conc)

- Are the scores correlated as expected with other similar validated scores ?
- → Correlation coefficients between scores and other scores measuring similar concepts

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE W BCC AC AE LI
MOC) conc(sf12mcs sf12pcs)
```

```
------------------------------------------------------------------------------
Concurrent validity
------------------------------------------------------------------------------

        sf12mcs    sf12pcs
HA      -0.17      -0.14
PSE     -0.04      -0.10
W       -0.44      -0.21
BCC     -0.48      -0.44
AC      -0.26      -0.15
AE      -0.16      -0.07
LI      -0.49      -0.42
MOC      0.12      -0.00
```

sf12mcs: Mental Component Scale of the Short-Form 12
sf12pcs: Physical Component Scale of the Short-Form 12

(Ware Jr et al., 1996)

Example of a complex syntax

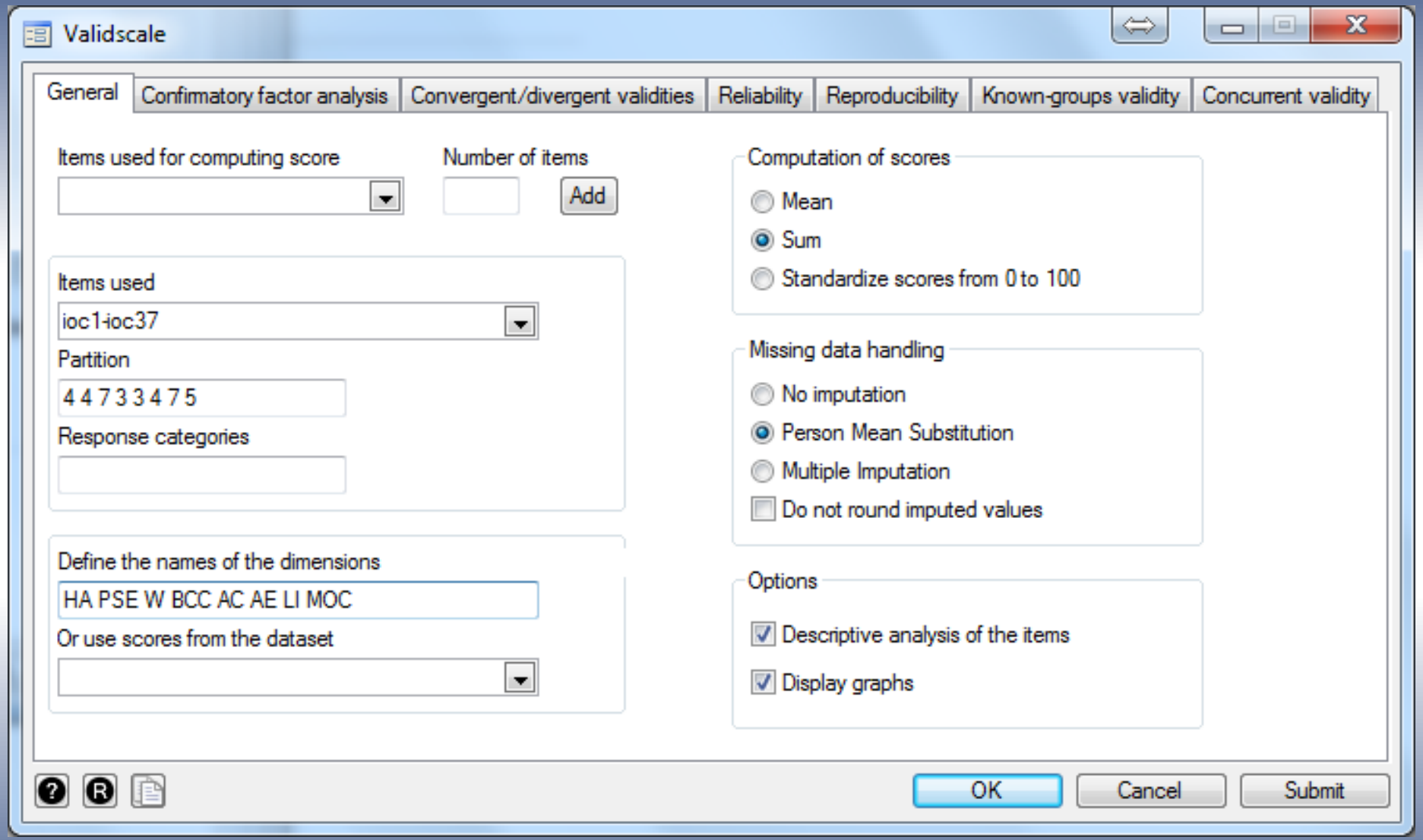
To obtain the above results:

```
. validscale ioc1-ioc37, part(4 4 7 3 3 4 7 5) scorename(HA PSE
W BCC AC AE LI MOC)categories(1 5) impute(pms) noround
compscore(sum) descitems graphs cfa cfamethod(ml) cfastand
cfacov(ioc1*ioc3) convdiv tconvdiv(0.4)convdivboxplots
alpha(0.7) delta(0.9) h(0.3) hjmin(0.3) repet(ioc1_2-ioc37_2)
kappa ickappa(500)kgv(chim) kgvboxplots kgvgroupboxplots
conc(sf12mcs sf12pcs) tconc(0.4)
```

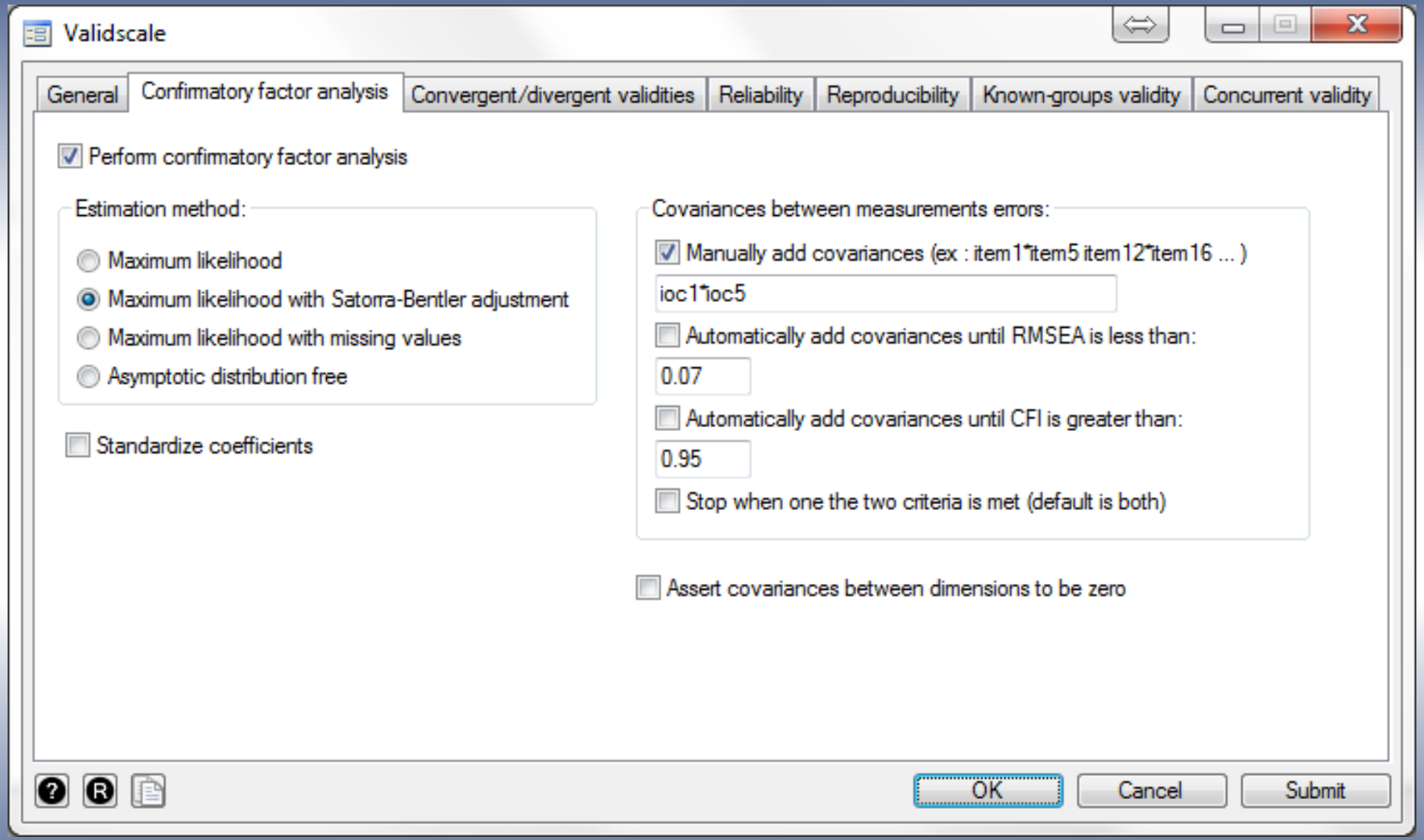
Or use the dialog box:

```
. db validscale
```

Dialog box


Validscale
General
Confirmatory factor analysis
Convergent/divergent validities
Reliability
Reproducibility
Known-groups validity
Concurrent validity
Items used for computing score
Number of items
Add
Items used
ioc1-ioc37
Partition
4 4 7 3 3 4 7 5
Response categories
Define the names of the dimensions
HA PSE W BCC AC AE LI MOC
Or use scores from the dataset
Computation of scores
Mean
Sum
Standardize scores from 0 to 100
Missing data handling
No imputation
Person Mean Substitution
Multiple Imputation
Do not round imputed values
Options
Descriptive analysis of the items
Display graphs
OK
Cancel
Submit

Dialog box


Validscale
General
Confirmatory factor analysis
Convergent/divergent validities
Reliability
Reproducibility
Known-groups validity
Concurrent validity
Perform confirmatory factor analysis
Estimation method:
Maximum likelihood
Maximum likelihood with Satorra-Bentler adjustment
Maximum likelihood with missing values
Asymptotic distribution free
Standardize coefficients
Covariances between measurements errors:
Manually add covariances (ex : item1*item5 item12*item16 ...)
ioc1*ioc5
Automatically add covariances until RMSEA is less than:
0.07
Automatically add covariances until CFI is greater than:
0.95
Stop when one the two criteria is met (default is both)
Assert covariances between dimensions to be zero
OK
Cancel
Submit

Summary

- `validscale` performs the recommended analyses (under CTT) to assess the reliability and validity of a questionnaire
- A dialog box allows using the command in a user-friendly way (type . db validscale)
- Warning/error messages are displayed to help the user during the analysis
- `ssc install validscale`

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