

Tutorial 10: PCA and Factor Analysis

ENVX2001 – Applied Statistical Methods

Semester 1

PCA and Factor Analysis

Students in class gave “Characteristics of a good ecology lecturer”. They scored from 1-10 on a range of characteristics:

- accessible
- attractive
- Wide range of topics
- Do teaching research
- Dress well
- Complex issues
- Example exam questions
- Notes before
- humour
- Easy marking
- Move around lecture
- Detailed lecture notes
- Clear objective to lecture
- Solicit questions
- Use textbook closely
- Focus on primary research
- Use their own research
- Teach in team
- Understand principles of teaching
- Use pointers
- respected

The students also indicated whether they were:

- a gender (male/female)
- studied mainly a system (marine/terrestrial)
- studied mainly an organismal group (plants/animals)

We are going to use principal components analysis and factor analysis to interpret this dataset.

Setup

Load these packages to make the plots look better:

```
CODE
library(FAtools)
library(ggplot2)
library(ggfortify)
```

Load the data

First open your dataset:

```
CODE
lecturers ← read.csv("data/lecturers.csv", header = TRUE)
```

Correlation matrix

Let's first do a correlation matrix:

```
CODE
cor(lecturers[, 8:28])
```


	accessible	attractive	wide_range
accessible	1.00000000	-0.61876084	0.190062066
attractive	-0.61876084	1.00000000	-0.011570169
wide_range	0.19006207	-0.01157017	1.00000000
teaching_based_research	0.24021638	-0.21382943	0.462870058
Dress_nicely	-0.53198037	0.81887024	-0.022848836
focus_on_complex_issues	0.28252341	-0.04447540	0.567443460
gives_example	-0.23669223	0.23435837	0.065815857
gives_out_note	-0.31173854	0.36819405	-0.187661524
sense_of_humour	-0.29068273	0.33747896	0.081503385
mark_easily	-0.34976811	0.44361281	-0.158545138
moves_around	-0.23371225	0.18475768	-0.087292839
offers_lecture_notes	-0.25762452	0.28256570	-0.070931605
clear_objective	-0.21819811	0.14978520	-0.176518448
solicit_questions	0.10349600	-0.076667948	-0.022123679
text_book	0.03170769	0.02849978	-0.241108100
primary_research	0.14147306	-0.06238516	-0.009628388
own_research	-0.01089281	0.15175696	0.157013029
teach_in_team	0.09004589	-0.13904104	0.005163136
understand_principles	-0.08521319	-0.01080764	-0.097173242
use_a_pointer	-0.51717009	0.25526667	-0.131935123
well_respected	-0.12789662	0.04222022	0.037698097
	teaching_based_research	Dress_nicely	
accessible	0.24021638	-0.531980374	
attractive	-0.21382943	0.818870242	
wide_range	0.46287006	-0.022848836	
teaching_based_research	1.00000000	-0.079662581	
Dress_nicely	-0.07966258	1.00000000	
focus_on_complex_issues	0.36612054	-0.074522662	

gives_example	-0.23626944	0.207509283
gives_out_note	-0.13154529	0.349298764
sense_of_humour	-0.37115541	0.326981372
mark_easily	-0.26802282	0.293513890
moves_around	0.35915941	0.175612992
offers_lecture_notes	-0.26062206	0.304730151
clear_objective	-0.10137698	0.162176313
solicit_questions	0.06997014	-0.047353486
text_book	-0.02511112	0.065661794
primary_research	0.08627931	-0.125765210
own_research	0.24450347	0.131114596
teach_in_team	0.05621459	-0.081891992
understand_principles	0.13360929	0.003830791
use_a_pointer	-0.40503932	0.246189390
well_respected	-0.21574299	0.082434616
focus_on_complex_issues gives_example gives_out_note		
accessible	0.28252341	-0.23669223
attractive	-0.04447540	0.23435837
wide_range	0.56744346	0.06581586
teaching_based_research	0.36612054	-0.23626944
Dress_nicely	-0.07452266	0.20750928
focus_on_complex_issues	1.00000000	-0.15606162
gives_example	-0.15606162	1.00000000
gives_out_note	-0.31138949	0.41459959
sense_of_humour	-0.07005663	0.22759892
mark_easily	-0.18475242	0.18880641
moves_around	0.06116819	-0.15496603
offers_lecture_notes	0.04438636	0.67139954
clear_objective	-0.05740760	0.22152350
solicit_questions	0.12547982	-0.10034117
text_book	-0.14904151	0.23189356
primary_research	0.33824172	-0.05502391
own_research	0.21007669	-0.03858742
teach_in_team	-0.05016868	0.22073735
understand_principles	0.12582565	0.06367067
use_a_pointer	-0.19722690	0.29421612
well_respected	-0.15321258	0.20022401
sense_of_humour mark_easily moves_around		
accessible	-0.29068273	-0.349768108
attractive	0.33747896	0.443612809
wide_range	0.08150339	-0.158545138
teaching_based_research	-0.37115541	-0.268022817
Dress_nicely	0.32698137	0.293513890
focus_on_complex_issues	-0.07005663	-0.184752419
gives_example	0.22759892	0.188806413
gives_out_note	0.25028755	0.392596691
sense_of_humour	1.00000000	0.279195853
mark_easily	0.27919585	1.000000000
moves_around	0.14798126	-0.102624026
offers_lecture_notes	0.40350521	0.004540766
clear_objective	0.30494267	0.241714172
solicit_questions	0.22196924	0.221507736
text_book	0.11515826	0.493885950
primary_research	-0.11402253	0.013988221
own_research	0.19400676	-0.136905883
teach_in_team	-0.13889755	-0.029214646
understand_principles	0.08973153	0.029511600
use_a_pointer	0.60147995	0.200483903
well_respected	0.31777004	0.204840208
offers_lecture_notes clear_objective solicit_questions		
accessible	-0.257624516	-0.21819811
attractive	0.282565698	0.14978520
wide_range	-0.070931605	-0.17651845
teaching_based_research	-0.260622062	-0.10137698
Dress_nicely	0.304730151	0.16217631

focus_on_complex_issues	0.044386363	-0.05740760	0.125479819
gives_example	0.671399539	0.22152350	-0.100341166
gives_out_note	0.326501972	0.49329825	0.373066471
sense_of_humour	0.403505211	0.30494267	0.221969236
mark_easily	0.004540766	0.24171417	0.221507736
moves_around	0.116586008	0.32802964	0.357039548
offers_lecture_notes	1.000000000	0.51135418	0.134906607
clear_objective	0.511354179	1.000000000	0.667857876
solicit_questions	0.134906607	0.66785788	1.000000000
text_book	0.241763186	0.50985104	0.514856144
primary_research	0.027238866	-0.05933422	0.008953955
own_research	0.014724611	0.04037952	0.313649567
teach_in_team	0.134589361	0.09431599	0.129502715
understand_principles	0.204933977	0.52773521	0.525180942
use_a_pointer	0.475656687	0.48740938	0.245720968
well_respected	0.173541917	0.20806935	0.217669413
	text_book primary_research own_research		
accessible	0.031707686	0.141473062	-0.01089281
attractive	0.028499784	-0.062385161	0.15175696
wide_range	-0.241108100	-0.009628388	0.15701303
teaching_based_research	-0.025111119	0.086279306	0.24450347
Dress_nicely	0.065661794	-0.125765210	0.13111460
focus_on_complex_issues	-0.149041509	0.338241715	0.21007669
gives_example	0.231893556	-0.050239007	-0.03858742
gives_out_note	0.417052411	-0.002582330	0.11486585
sense_of_humour	0.115158256	-0.114022533	0.19400676
mark_easily	0.493885950	0.013988221	-0.13690588
moves_around	0.018944976	0.201361759	0.52178832
offers_lecture_notes	0.241763186	0.027238866	0.01472461
clear_objective	0.509851042	-0.059334220	0.04037952
solicit_questions	0.514856144	0.008953955	0.31364957
text_book	1.000000000	-0.092231864	-0.11384268
primary_research	-0.092231864	1.000000000	0.35299282
own_research	-0.113842676	0.352992824	1.00000000
teach_in_team	0.176402014	-0.085933891	-0.08668898
understand_principles	0.287773155	0.017218953	0.06370238
use_a_pointer	0.001337384	-0.149851010	0.15399945
well_respected	0.274222528	0.016210854	-0.10140227
	teach_in_team understand_principles use_a_pointer		
accessible	0.090045886	-0.085213191	-0.517170092
attractive	-0.139041035	-0.010807636	0.255266673
wide_range	0.005163136	-0.097173242	-0.131935123
teaching_based_research	0.056214590	0.133609295	-0.405039321
Dress_nicely	-0.081891992	0.003830791	0.246189390
focus_on_complex_issues	-0.050168682	0.125825652	-0.197226905
gives_example	0.220737347	0.063670673	0.294216117
gives_out_note	0.071017950	0.095647419	0.427989355
sense_of_humour	-0.138897546	0.089731525	0.601479950
mark_easily	-0.029214646	0.029511600	0.200483903
moves_around	-0.002012914	0.281044416	0.247735287
offers_lecture_notes	0.134589361	0.204933977	0.475656687
clear_objective	0.094315990	0.527735214	0.487409381
solicit_questions	0.129502715	0.525180942	0.245720968
text_book	0.176402014	0.287773155	0.001337384
primary_research	-0.085933891	0.017218953	-0.149851010
own_research	-0.086688981	0.063702380	0.153999453
teach_in_team	1.000000000	0.101857142	-0.016777680
understand_principles	0.101857142	1.000000000	0.104631048
use_a_pointer	-0.016777680	0.104631048	1.000000000
well_respected	0.545915684	0.207782811	0.318541502
	well_respected		
accessible	-0.12789662		
attractive	0.04222022		
wide_range	0.03769810		
teaching_based_research	-0.21574299		

Dress_nicely	0.08243462
focus_on_complex_issues	-0.15321258
gives_example	0.20022401
gives_out_note	0.24197769
sense_of_humour	0.31777004
mark_easily	0.20484021
moves_around	0.10727553
offers_lecture_notes	0.17354192
clear_objective	0.20806935
solicit_questions	0.21766941
text_book	0.27422253
primary_research	0.01621085
own_research	-0.10140227
teach_in_team	0.54591568
understand_principles	0.20778281
use_a_pointer	0.31854150
well_respected	1.00000000

CODE
`Corrmatrix ← cor(lecturers[, 8:28])`

Bartlett's Test of Sphericity

Now we can do the Bartlett's Test of Sphericity. This test compares the correlation matrix to an identity matrix. If it is significant, it is worth doing a PCA.

CODE
`BARTLETT(Corrmatrix, N = 34, cor_method = c("pearson"))`

OUTPUT

✓ The Bartlett's test of sphericity was significant at an alpha level of .05.
 These data are probably suitable for factor analysis.
 $\chi^2(210) = 355.07$, $p < .001$

Principal Components Analysis

Note: to make this a PCA based on a correlation matrix, we have to scale the variables, hence `scale = TRUE`. There are two main principal components functions, but they are very similar. Note `prcomp` calls the loadings “rotations”, not to be confused with rotations below.

CODE
`pca1 ← prcomp(lecturers[, 8:28], scale = TRUE)`
`pca2 ← princomp(lecturers[, 8:28], cor = TRUE)`

CODE
`summary(pca1)`

OUTPUT

```

Importance of components:
      PC1    PC2    PC3    PC4    PC5    PC6    PC7
Standard deviation   2.2206 1.6616 1.5324 1.29807 1.19561 1.12098 1.08311
Proportion of Variance 0.2348 0.1315 0.1118 0.08024 0.06807 0.05984 0.05586
Cumulative Proportion 0.2348 0.3663 0.4781 0.55833 0.62641 0.68624 0.74211
      PC8    PC9    PC10   PC11   PC12   PC13   PC14
Standard deviation   1.0737 0.95681 0.79545 0.73119 0.7055 0.65580 0.50887
Proportion of Variance 0.0549 0.04359 0.03013 0.02546 0.0237 0.02048 0.01233
Cumulative Proportion 0.7970 0.84060 0.87073 0.89619 0.9199 0.94037 0.95270
      PC15   PC16   PC17   PC18   PC19   PC20   PC21
Standard deviation   0.49817 0.47309 0.42640 0.36970 0.32493 0.24020 0.19872
Proportion of Variance 0.01182 0.01066 0.00866 0.00651 0.00503 0.00275 0.00188
Cumulative Proportion 0.96452 0.97518 0.98384 0.99034 0.99537 0.99812 1.00000

```

```

CODE
summary(pca2)

```

```

OUTPUT
Importance of components:
      Comp.1   Comp.2   Comp.3   Comp.4   Comp.5
Standard deviation   2.2205654 1.6615887 1.5324030 1.29806969 1.19560985
Proportion of Variance 0.2348053 0.1314703 0.1118219 0.08023738 0.06807062
Cumulative Proportion 0.2348053 0.3662756 0.4780975 0.55833484 0.62640546
      Comp.6   Comp.7   Comp.8   Comp.9   Comp.10
Standard deviation   1.12097809 1.08311410 1.07371597 0.95680927 0.79544930
Proportion of Variance 0.05983771 0.05586363 0.05489838 0.04359448 0.03013046
Cumulative Proportion 0.68624317 0.74210679 0.79700517 0.84059965 0.87073010
      Comp.11  Comp.12  Comp.13  Comp.14  Comp.15
Standard deviation   0.73119377 0.70551609 0.65579857 0.50886890 0.49817027
Proportion of Variance 0.02545925 0.02370252 0.02047961 0.01233084 0.01181779
Cumulative Proportion 0.89618936 0.91989188 0.94037149 0.95270232 0.96452011
      Comp.16  Comp.17  Comp.18  Comp.19
Standard deviation   0.4730918 0.426395520 0.369702631 0.324933440
Proportion of Variance 0.0106579 0.008657769 0.006508573 0.005027702
Cumulative Proportion 0.9751780 0.983835781 0.990344355 0.995372057
      Comp.20  Comp.21
Standard deviation   0.240198751 0.198724365
Proportion of Variance 0.002747402 0.001880542
Cumulative Proportion 0.998119458 1.000000000

```

Loadings

Let's look at the loadings. Called "rotations" in prcomp and "loadings" in princomp. They are the Pearson's correlation between that variable and that Principal Component.

```

CODE
pca1

```

```

OUTPUT
Standard deviations (1, .., p=21):
[1] 2.2205654 1.6615887 1.5324030 1.2980697 1.1956099 1.1209781 1.0831141
[8] 1.0737160 0.9568093 0.7954493 0.7311938 0.7055161 0.6557986 0.5088689
[15] 0.4981703 0.4730918 0.4263955 0.3697026 0.3249334 0.2401988 0.1987244

Rotation (n x k) = (21 x 21):
      PC1     PC2     PC3     PC4

```

accessible	-0.27105784	0.21481141	0.22284903	-0.109380126
attractive	0.25953819	-0.19001404	-0.35322829	0.047967149
wide_range	-0.11796047	0.14523503	-0.23536689	-0.465316942
teaching_based_research	-0.17807186	0.33523672	-0.16973235	-0.005540905
Dress_nicely	0.24737662	-0.15550598	-0.32565089	0.019172145
focus_on_complex_issues	-0.13467331	0.28837561	-0.24412817	-0.297540766
gives_example	0.22797978	-0.11739164	0.06984178	-0.437201342
gives_out_note	0.32056620	0.04438472	0.02749136	0.100499687
sense_of_humour	0.27564472	-0.03120757	-0.13957405	-0.145704311
mark_easily	0.23686285	-0.11243202	0.08113616	0.196601185
moves_around	0.13236700	0.32827473	-0.27087444	0.213497862
offers_lecture_notes	0.28307512	0.02357872	-0.01627849	-0.372830743
clear_objective	0.31573398	0.26378859	0.12826236	0.066194937
solicit_questions	0.18991164	0.43659484	0.13380240	0.160366349
text_book	0.21299001	0.16712512	0.33485831	0.124899445
primary_research	-0.05608411	0.19206706	-0.16387602	0.001745603
own_research	0.04318371	0.28387549	-0.37836892	0.056442158
teach_in_team	0.04818137	0.11021896	0.29523823	-0.327405642
understand_principles	0.14556568	0.33936721	0.10777339	0.053017840
use_a_pointer	0.32019196	-0.03811643	-0.08101559	-0.080227102
well_respected	0.19384039	0.06977679	0.22029921	-0.263146206
	PC5	PC6	PC7	PC8
accessible	-0.006862732	0.20175545	0.075192964	0.13471983
attractive	-0.304217305	-0.05278985	-0.006014137	-0.01346850
wide_range	-0.251311171	0.08634713	-0.331523146	0.07096692
teaching_based_research	-0.307853355	-0.22290900	-0.040540304	-0.27328747
Dress_nicely	-0.299180796	-0.12573075	-0.046516486	-0.12380132
focus_on_complex_issues	-0.170654964	0.29340602	-0.050872762	0.07474147
gives_example	-0.075647764	0.06855598	0.364935010	-0.17131172
gives_out_note	-0.125013318	-0.08366732	0.223406707	0.02145305
sense_of_humour	0.216056466	0.21464296	-0.328598912	0.27397871
mark_easily	-0.421810061	0.15983061	-0.046406386	0.38018642
moves_around	0.166526391	-0.35024271	0.055092321	-0.07707096
offers_lecture_notes	0.146235397	0.18757528	0.287000528	-0.27400475
clear_objective	0.060342195	0.17777324	-0.032682046	-0.21837583
solicit_questions	-0.005900941	0.14588578	-0.182965113	0.09074671
text_book	-0.356204508	0.15361788	0.084096939	0.02338965
primary_research	0.039054189	0.06897414	0.592731543	0.45913721
own_research	0.156844077	-0.09496398	0.160942737	0.20826388
teach_in_team	-0.096207102	-0.54758870	0.037625674	0.05473642
understand_principles	0.010243773	0.05372028	-0.114475017	-0.27603888
use_a_pointer	0.411769112	0.01616452	-0.180288938	0.05917537
well_respected	0.013159486	-0.40377696	-0.183055505	0.39655405
	PC9	PC10	PC11	PC12
accessible	0.23711499	0.41979852	0.03945146	0.148881566
attractive	-0.16438427	0.20365082	0.06904042	-0.107432225
wide_range	0.22155409	-0.26438749	-0.03259079	-0.018048262
teaching_based_research	0.19889412	-0.24510749	-0.11135378	0.247899071
Dress_nicely	-0.10406494	0.38639604	0.08377430	0.098387712
focus_on_complex_issues	-0.28979913	0.00432150	0.36226348	-0.066562002
gives_example	0.19510676	-0.15342441	-0.35973985	-0.159175284
gives_out_note	0.41895610	-0.21289394	0.20038838	0.006019332
sense_of_humour	0.09730489	0.19787809	-0.29410062	0.309619454
mark_easily	-0.04288340	-0.25885827	-0.05713892	-0.143735223
moves_around	0.02114182	-0.04788447	0.02682634	0.353171999
offers_lecture_notes	-0.07931457	0.16874959	0.11255136	0.207814735
clear_objective	-0.04989256	-0.08180409	0.29595319	0.009127372
solicit_questions	0.10754501	0.13028684	0.14132328	-0.276862219
text_book	0.12628767	0.17521009	-0.12180066	0.267854799
primary_research	-0.30348754	-0.18921946	0.01954047	0.138689169
own_research	0.28543090	0.27973695	-0.29907250	-0.427500246
teach_in_team	-0.07446630	0.20427502	0.21413563	-0.322896702
understand_principles	-0.49690454	-0.08895650	-0.50033599	-0.189676003
use_a_pointer	0.09757553	-0.27912944	0.22992547	-0.115886008
well_respected	-0.19000184	-0.03498965	-0.08926599	0.276488059

	PC13	PC14	PC15	PC16
accessible	0.29231904	0.29580819	-0.222218786	0.095682695
attractive	0.10512874	0.20004636	0.069413634	-0.326657310
wide_range	0.14339377	-0.15578216	-0.042633744	-0.346118318
teaching_based_research	-0.16129758	-0.08569727	-0.291561886	0.304862272
Dress_nicely	0.22024728	-0.29025496	-0.196064822	0.331319175
focus_on_complex_issues	-0.11651678	0.21121417	0.380088085	0.275036237
gives_example	-0.02596566	0.13003779	0.073844050	-0.048615414
gives_out_note	0.52366782	0.22815294	0.150396690	0.187752138
sense_of_humour	-0.09102492	0.24787583	-0.269328590	0.077361879
mark_easily	-0.30618081	0.26528469	-0.239118638	0.067806707
moves_around	-0.19413727	0.41519824	0.163481854	-0.233951595
offers_lecture_notes	-0.18626080	-0.01943147	-0.008128194	-0.028997162
clear_objective	0.02299500	-0.21161788	-0.392005665	-0.377275931
solicit_questions	0.07959209	-0.06601352	0.067535709	-0.098815936
text_book	-0.31596633	-0.28217199	0.346092878	0.063696048
primary_research	0.11269387	-0.18656539	-0.263215477	-0.012502540
own_research	-0.14671997	-0.23213427	0.082887276	0.001508984
teach_in_team	-0.23420220	0.19002827	-0.271548974	0.056217287
understand_principles	0.29771815	0.14826763	-0.020146024	0.175848894
use_a_pointer	-0.10543967	-0.11603812	-0.008762183	0.433779829
well_respected	0.22357927	-0.22236358	0.251201419	-0.060389007
	PC17	PC18	PC19	PC20
accessible	-0.487523780	-0.092943639	0.11623660	-0.08184741
attractive	-0.106937105	-0.195239242	0.45086924	-0.09762660
wide_range	0.009616636	0.068156323	0.05963088	-0.34244915
teaching_based_research	0.006376281	0.018683190	0.22919635	0.23688191
Dress_nicely	-0.124236446	0.174946567	-0.38290347	-0.11111538
focus_on_complex_issues	0.057689702	-0.197551507	-0.21480326	0.19658872
gives_example	-0.206970055	0.030539850	-0.40647428	-0.01600380
gives_out_note	0.321857496	-0.107588372	0.08121002	0.10250939
sense_of_humour	0.430141107	-0.113398698	-0.08853507	0.02641527
mark_easily	-0.269651092	0.167631153	0.01976224	0.19779113
moves_around	-0.207902119	0.101506396	-0.24054414	-0.20539739
offers_lecture_notes	0.024256519	0.371837654	0.41986631	0.20173823
clear_objective	-0.097333800	-0.419634434	-0.21848656	0.23314508
solicit_questions	0.094290088	0.606166863	-0.05758082	-0.04550053
text_book	0.072364215	-0.254638772	0.07071928	-0.35855399
primary_research	0.130404141	0.041767487	0.01625913	-0.25697656
own_research	-0.068753059	-0.196939862	0.08026083	0.24801010
teach_in_team	0.247146896	-0.095095343	0.00645715	-0.19776650
understand_principles	-0.001605969	-0.075193184	0.12987739	-0.13337875
use_a_pointer	-0.352414119	-0.113600108	0.19774694	-0.34608373
well_respected	-0.231089402	0.008802903	0.03736378	0.36974689
	PC21			
accessible	-0.002932735			
attractive	0.405148279			
wide_range	-0.308435374			
teaching_based_research	0.335322467			
Dress_nicely	-0.150318850			
focus_on_complex_issues	0.045604055			
gives_example	0.338040434			
gives_out_note	-0.184254445			
sense_of_humour	0.144536843			
mark_easily	-0.277239849			
moves_around	-0.151918843			
offers_lecture_notes	-0.289119982			
clear_objective	-0.008051690			
solicit_questions	0.367111373			
text_book	-0.026709294			
primary_research	0.123144467			
own_research	-0.206478451			
teach_in_team	-0.055864220			
understand_principles	-0.183080778			

use_a_pointer	0.121125177
well_respected	0.079347988

CODE
`loadings(pca2)`

OUTPUT

Loadings:

	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8
accessible	0.271	0.215	0.223	0.109		0.202		0.135
attractive	-0.260	-0.190	-0.353			0.304		
wide_range	0.118	0.145	-0.235	0.465	0.251		-0.332	
teaching_based_research	0.178	0.335	-0.170		0.308	-0.223		-0.273
Dress_nicely	-0.247	-0.156	-0.326		0.299	-0.126		-0.124
focus_on_complex_issues	0.135	0.288	-0.244	0.298	0.171	0.293		
gives_example	-0.228	-0.117		0.437			0.365	-0.171
gives_out_note	-0.321			-0.100	0.125		0.223	
sense_of_humour	-0.276		-0.140	0.146	-0.216	0.215	-0.329	0.274
mark_easily	-0.237	-0.112		-0.197	0.422	0.160		0.380
moves_around	-0.132	0.328	-0.271	-0.213	-0.167	-0.350		
offers_lecture_notes	-0.283			0.373	-0.146	0.188	0.287	-0.274
clear_objective	-0.316	0.264	0.128			0.178		-0.218
solicit_questions	-0.190	0.437	0.134	-0.160		0.146	-0.183	
text_book	-0.213	0.167	0.335	-0.125	0.356	0.154		
primary_research		0.192	-0.164				0.593	0.459
own_research		0.284	-0.378		-0.157		0.161	0.208
teach_in_team		0.110	0.295	0.327		-0.548		
understand_principles	-0.146	0.339	0.108			-0.114	-0.276	
use_a_pointer	-0.320				-0.412		-0.180	
well_respected	-0.194		0.220	0.263		-0.404	-0.183	0.397
	Comp.9	Comp.10	Comp.11	Comp.12	Comp.13	Comp.14	Comp.15	
accessible	0.237	0.420		0.149	0.292	0.296	0.222	
attractive	-0.164	0.204		-0.107	0.105	0.200		
wide_range	0.222	-0.264			0.143	-0.156		
teaching_based_research	0.199	-0.245	-0.111	0.248	-0.161		0.292	
Dress_nicely	-0.104	0.386			0.220	-0.290	0.196	
focus_on_complex_issues	-0.290		0.362		-0.117	0.211	-0.380	
gives_example	0.195	-0.153	-0.360	-0.159		0.130		
gives_out_note	0.419	-0.213	0.200		0.524	0.228	-0.150	
sense_of_humour		0.198	-0.294	0.310		0.248	0.269	
mark_easily		-0.259		-0.144	-0.306	0.265	0.239	
moves_around			0.353	-0.194	0.415	-0.163		
offers_lecture_notes		0.169	0.113	0.208	-0.186			
clear_objective			0.296			-0.212	0.392	
solicit_questions	0.108	0.130	0.141	-0.277				
text_book	0.126	0.175	-0.122	0.268	-0.316	-0.282	-0.346	
primary_research	-0.303	-0.189		0.139	0.113	-0.187	0.263	
own_research	0.285	0.280	-0.299	-0.428	-0.147	-0.232		
teach_in_team		0.204	0.214	-0.323	-0.234	0.190	0.272	
understand_principles	-0.497		-0.500	-0.190	0.298	0.148		
use_a_pointer		-0.279	0.230	-0.116	-0.105	-0.116		
well_respected	-0.190			0.276	0.224	-0.222	-0.251	
	Comp.16	Comp.17	Comp.18	Comp.19	Comp.20	Comp.21		
accessible		0.488		0.116				
attractive	-0.327	0.107	0.195	0.451		-0.405		
wide_range	-0.346				0.342	0.308		
teaching_based_research	0.305			0.229	-0.237	-0.335		
Dress_nicely	0.331	0.124	-0.175	-0.383	0.111	0.150		
focus_on_complex_issues	0.275		0.198	-0.215	-0.197			
gives_example		0.207		-0.406		-0.338		
gives_out_note	0.188	-0.322	0.108		-0.103	0.184		

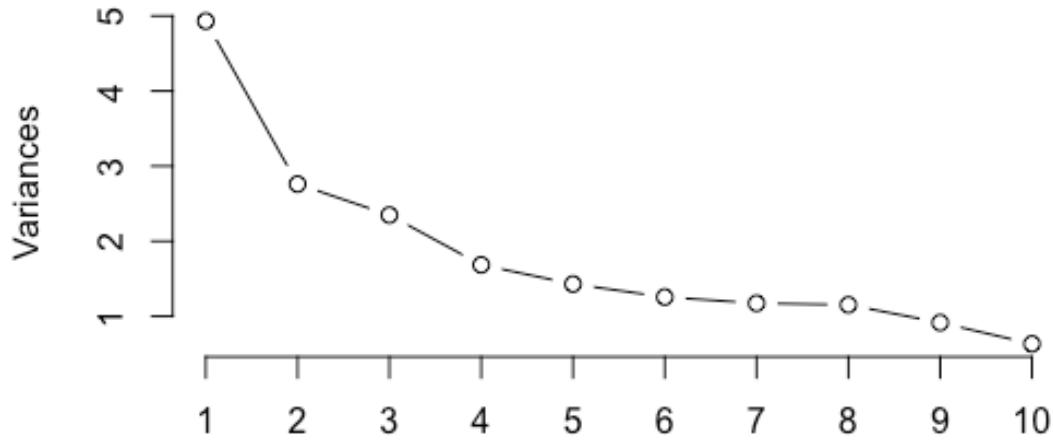
sense_of_humour	-0.430	0.113			-0.145				
mark_easily	0.270	-0.168			-0.198	0.277			
moves_around	-0.234	0.208	-0.102	-0.241	0.205	0.152			
offers_lecture_notes			-0.372	0.420	-0.202	0.289			
clear_objective	-0.377			0.420	-0.218	-0.233			
solicit_questions			-0.606			-0.367			
text_book			0.255		0.359				
primary_research		-0.130			0.257	-0.123			
own_research			0.197		-0.248	0.206			
teach_in_team		-0.247			0.198				
understand_principles	0.176			0.130	0.133	0.183			
use_a_pointer	0.434	0.352	0.114	0.198	0.346	-0.121			
well_respected		0.231			-0.370				
	Comp.1	Comp.2	Comp.3	Comp.4	Comp.5	Comp.6	Comp.7	Comp.8	Comp.9
SS loadings	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Proportion Var	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048
Cumulative Var	0.048	0.095	0.143	0.190	0.238	0.286	0.333	0.381	0.429
	Comp.10	Comp.11	Comp.12	Comp.13	Comp.14	Comp.15	Comp.16	Comp.17	
SS loadings	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	
Proportion Var	0.048	0.048	0.048	0.048	0.048	0.048	0.048	0.048	
Cumulative Var	0.476	0.524	0.571	0.619	0.667	0.714	0.762	0.810	
	Comp.18	Comp.19	Comp.20	Comp.21					
SS loadings	1.000	1.000	1.000	1.000					
Proportion Var	0.048	0.048	0.048	0.048					
Cumulative Var	0.857	0.905	0.952	1.000					

Screeplot

To do a screeplot, follow the commands below. Note this is the standard deviations, which are just square root of the variances or eigenvalues.

```
CODE
screeplot(pca1, type = "lines")
```

pca1



Principal Component Scores

To get your principal components scores for plotting and analysis, do the following:

```
CODE  
pca1$x
```

OUTPUT

	PC1	PC2	PC3	PC4	PC5	PC6
[1,]	0.834364400	-0.44633674	-0.7389322	0.6505980	0.67162071	-0.059426515
[2,]	-0.057591233	2.43259604	0.3643921	0.1044273	-1.35364156	-1.513379283
[3,]	-1.414356172	-0.85486631	0.2591048	-0.7950895	0.39445964	-0.362282532
[4,]	-3.007651543	-1.54426710	1.8013306	-1.4495208	-0.06900951	-0.378437639
[5,]	-0.913357854	0.15572053	1.9852660	0.26474465	0.05455313	-0.190589811
[6,]	2.715375811	-0.61458292	1.2581973	0.6291478	1.66664928	0.980101358
[7,]	-3.260274779	-1.46022078	-1.3182136	-1.5445289	2.59801832	1.373084699
[8,]	1.690020920	4.10059174	-0.8286511	-2.7204201	-0.89839668	0.477869956
[9,]	-2.017591018	-0.19055562	1.2282190	-0.1591693	-1.81724286	-0.504760633
[10,]	2.684027310	-0.28238921	-2.7053968	-0.6373616	1.24913045	0.114945320
[11,]	1.602080176	1.73848677	-0.7560946	-0.1669273	1.46214681	-1.241067456
[12,]	3.864282071	0.91902758	-3.0506154	-0.3116270	0.14774890	-1.707816527
[13,]	-1.537400621	0.79553155	0.2734490	2.2991348	-1.33509038	1.020459263
[14,]	-3.180580364	-1.55370059	-1.1043790	0.3994455	-0.21820422	-0.416321249
[15,]	0.251424671	-0.87357501	0.8416185	1.3248859	1.62509470	-1.332946815
[16,]	2.892895033	-0.54107588	-0.4987349	0.5314171	-0.40738282	-0.008629769
[17,]	2.025139659	0.87994104	2.1794942	1.4021183	-1.10315491	-1.185333328
[18,]	-4.509205462	2.93089784	-2.9570995	3.4152682	0.56608967	1.421754123
[19,]	-0.363910804	0.59536235	1.0533136	-0.1849003	-0.12823425	-0.808435775
[20,]	0.513833400	1.34820539	1.7227901	-1.3132714	-1.04480943	0.987729132

[21,]	0.671318696	-1.57314535	0.3233421	-0.3775963	1.07805278	0.122220926
[22,]	-1.199789658	-0.75223096	0.2125650	-1.9753352	-0.38988416	2.577574944
[23,]	2.699925571	-4.05301101	-2.2580650	0.1089181	-2.08232998	0.035139868
[24,]	3.671607537	-2.76308860	2.3108314	1.9763565	-0.12222446	1.145347105
[25,]	1.708338444	1.14870366	0.1941423	-0.8978228	0.53891069	1.218476886
[26,]	0.697044049	-0.09475043	-0.9235260	0.5556583	1.51777743	-0.726583470
[27,]	-3.637428809	-1.19350763	-0.2178772	-1.3363292	-0.26449368	-3.193959083
[28,]	0.919217152	1.59671229	1.9213986	0.1968770	0.58065284	0.264448784
[29,]	-0.012679393	2.32518659	0.2155462	0.3501560	-0.47396645	0.658332807
[30,]	-2.075112687	-0.04538414	0.2156446	-1.0632633	0.42197992	0.038464825
[31,]	-2.320188992	-0.57228262	-0.1349819	2.0161446	-0.36632609	-0.152398000
[32,]	0.005054503	-1.40748778	-2.5517407	-0.5548639	-3.02867573	0.937512584
[33,]	0.061169986	-0.15050467	1.6836625	-0.7372732	0.53018221	0.408905305
	PC7	PC8	PC9	PC10	PC11	PC12
[1,]	0.94163613	1.01611660	0.65086100	0.7049538165	-0.12679861	1.07464589
[2,]	2.49608290	-1.03057653	0.99789650	-0.6955702786	0.62054036	0.43728658
[3,]	-1.14833452	-0.13690605	1.56172193	-1.0103974039	-0.22663448	-0.62688596
[4,]	1.55864777	-2.37956477	-1.88594310	0.1842266066	0.56734997	-0.37865892
[5,]	-0.90420171	-1.46124279	-0.41077774	0.7877696717	0.87274235	-0.40364293
[6,]	-0.48508037	-0.39417790	-0.13586330	-0.5943650505	-0.20101933	0.39114013
[7,]	0.92263413	0.27756052	0.64943390	0.6951735358	0.85851959	-0.18227075
[8,]	1.01619589	1.42931518	-0.35783368	-0.0705759673	0.38608546	-0.45604663
[9,]	-3.06056251	0.01542140	0.97910235	-0.3689951357	-0.81042854	0.29905809
[10,]	-1.15019858	-2.22756355	1.92108719	1.1858684843	0.03051034	-0.44295070
[11,]	-1.38076963	0.10114808	-1.28404266	0.4344189806	0.24591922	-0.18193776
[12,]	0.63745807	-0.33245072	-0.46272040	-0.4907654143	-0.49725530	0.06959804
[13,]	0.50021492	1.64298989	-0.02204408	-0.0008218307	-0.32919047	-1.47757160
[14,]	0.96910614	-0.33466161	1.43687692	-0.8126002209	-1.05968338	-0.42468108
[15,]	0.80890447	-0.52662610	-0.88626822	0.4773237243	-0.83842767	0.73180898
[16,]	0.99711436	1.01401737	-0.40202982	0.1817443327	-0.53794142	-0.60055239
[17,]	0.20967322	-0.58311856	0.70515256	-0.0396632716	0.45009864	0.68839301
[18,]	-0.81537520	-0.85666393	-0.94273181	0.0414522567	0.07186325	0.63521158
[19,]	-0.39788697	0.90638787	-0.41749861	0.8035047424	-0.32339287	-0.65225431
[20,]	-1.71530837	-0.05810388	-0.44792612	0.6080155185	0.04950397	0.22979058
[21,]	-0.17473258	-0.49430919	-0.74983375	-2.3172182635	-0.86711224	-0.89907281
[22,]	0.963355825	0.59588805	-0.69173585	0.7875438802	-1.58060139	0.69952356
[23,]	-0.79226369	0.31761740	-1.80001880	-0.5911334313	0.33709088	0.50027519
[24,]	0.66242150	0.79456398	1.28229789	1.1369072252	0.36494912	0.29993320
[25,]	0.11491096	-0.67752131	1.55591224	-0.9531517638	-0.43306504	0.96727700
[26,]	-0.97171844	2.00236186	0.03915553	0.0979107090	1.01294064	-0.86467646
[27,]	-0.10713776	1.13254478	0.06800519	1.3104870153	-0.78844151	0.38194366
[28,]	-0.11368363	-1.13303668	-0.44515516	-0.0309968966	-0.05286304	-0.17959227
[29,]	0.03995439	-0.06103477	-0.17348145	0.3417751499	-1.22149166	-0.09463653
[30,]	-0.61338026	1.72693492	-0.07276041	-1.2660686396	1.38200547	1.95263797
[31,]	0.79663725	0.35281020	0.08109498	-0.5131215937	0.67712222	-0.13873520
[32,]	-0.05972762	-1.30023954	0.11504776	0.5298008516	1.06058730	-0.29503060
[33,]	0.25541147	0.66221148	0.44501905	-0.5534313394	0.90651818	-1.05932657
	PC13	PC14	PC15	PC16	PC17	
[1,]	1.04550104	0.30220825	-0.26493487	0.990718773	-0.161522621	
[2,]	-0.51140324	0.23962723	0.04514841	-0.864576510	0.021378514	
[3,]	-0.45367844	0.47042709	0.44536737	0.117387548	1.132044168	
[4,]	0.76623701	0.33414241	-0.06674780	0.005890288	-0.317090528	
[5,]	-0.22473438	1.02668595	-1.11036905	0.253771120	0.573823233	
[6,]	-0.21758119	0.35417045	0.55539524	0.380784887	0.577014348	
[7,]	-1.13189958	-0.40654870	0.30620976	0.183130027	-0.149934970	
[8,]	0.48772693	-0.20754494	0.30040817	0.432882057	-0.190155729	
[9,]	0.47865039	0.06044313	0.29758301	0.065987000	-0.412015158	
[10,]	-0.03562393	0.19804842	0.33881205	-0.396898429	-0.531313384	
[11,]	-0.90180692	-0.34546312	-0.75620771	0.625598888	-0.544476288	
[12,]	0.30509441	0.08813338	-0.58059025	-0.035026694	0.625823661	
[13,]	-0.73594105	0.53970030	-0.79585891	0.555871566	-0.252855797	
[14,]	-0.21555707	-0.91839176	-1.10063830	-0.346724418	-0.207470713	
[15,]	0.72072562	-0.64024769	-0.07151878	-0.333963902	0.392495606	
[16,]	0.13959352	0.68049473	0.84486635	-0.265106061	-0.372669045	
[17,]	-1.02024905	-0.87052303	0.58413566	0.839988817	0.250265142	

	PC18	PC19	PC20	PC21
[1,]	0.512534055	0.403637255	-0.2288274019	-0.180597545
[2,]	0.929440714	0.048122004	0.2051146098	-0.271152883
[3,]	0.403516656	-0.074179505	-0.2401958070	-0.046316428
[4,]	-0.380413260	-0.016801083	0.0236080284	0.075154120
[5,]	-0.121436088	0.216713273	-0.2532722027	0.163180806
[6,]	0.016193332	-0.176022291	0.8096079044	-0.052570563
[7,]	-0.041349452	0.491356049	0.1502223084	-0.205615503
[8,]	-0.169826040	-0.182268894	-0.0271317045	0.331935144
[9,]	-0.170416032	0.311027931	0.4390800414	-0.032482679
[10,]	-0.228929235	-0.629795038	-0.1373141246	0.072909759
[11,]	0.223418908	-0.399313078	0.1457129024	-0.346000339
[12,]	-0.361282411	0.136577651	0.1213875759	0.000801914
[13,]	0.048394699	-0.297878346	0.0857017322	-0.076965204
[14,]	-0.556266739	0.183329956	0.1575056075	0.005626377
[15,]	0.003248088	-0.275646771	-0.0488034493	-0.010278083
[16,]	-0.569143575	0.610124017	0.0001699299	-0.165370989
[17,]	-0.876273716	0.145493206	-0.3407035497	-0.133229363
[18,]	0.139800530	0.266416571	-0.0612808299	0.138282533
[19,]	-0.288699113	-0.005113258	0.1267147465	-0.263464768
[20,]	0.261595957	0.070258777	-0.3355360658	-0.432480871
[21,]	0.478432361	-0.146679334	-0.3985086902	-0.071646635
[22,]	-0.090751620	-0.213675088	-0.1815364089	-0.142428632
[23,]	0.266768773	0.195774478	-0.1770461524	0.191720088
[24,]	0.354865033	-0.239914062	0.0937794098	0.244839284
[25,]	-0.161337294	0.208473109	-0.0508044281	0.105092550
[26,]	-0.040945263	0.377943641	-0.1672829144	0.091569499
[27,]	0.419873948	-0.083337959	0.0482601803	0.312179849
[28,]	0.322418197	0.609269862	-0.0166547989	0.337744117
[29,]	0.091695107	-0.301130070	-0.0161094691	0.322694249
[30,]	-0.412731002	-0.414631089	0.0294813311	0.084790553
[31,]	-0.298987891	-0.721677547	-0.2130771535	-0.111634161
[32,]	0.187128445	-0.059177362	0.2716590271	-0.102730154
[33,]	0.109463929	-0.037277006	0.1860798156	0.166443959

So to combine them with the original variables, do this:

```
CODE
lecturerpcscores ← cbind(lecturers, pca1$x)
```

Biplot

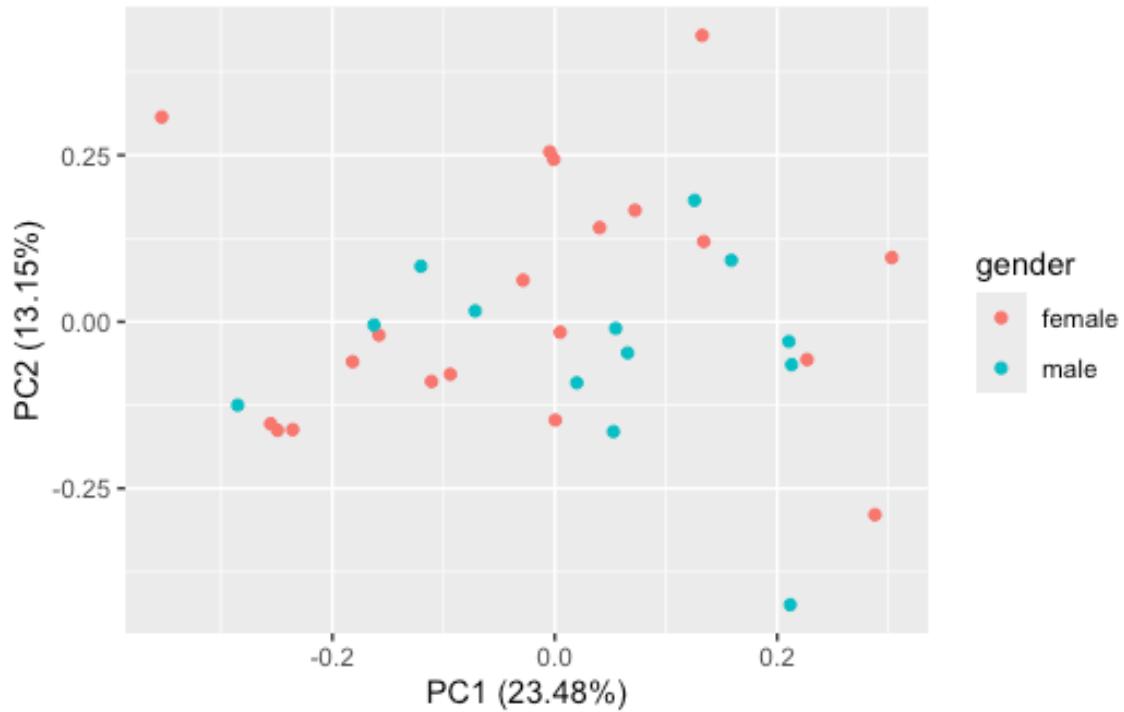
We can produce a biplot in ggplot2, using the factor gender as the colour:

```

CODE
autoplot(pca1, data = lecturerpcscores, colour = 'gender')

OUTPUT
Warning: `aes_string()` was deprecated in ggplot2 3.0.0.
i Please use tidy evaluation idioms with `aes()``.
i See also `vignette("ggplot2-in-packages")` for more information.
i The deprecated feature was likely used in the ggrepel package.
  Please report the issue at <https://github.com/sinhrks/ggrepel/issues>.

```



We could add the loadings, but they are a bit messy, best to look at loadings or rotations tables.

You can make the plot using different symbols, change background etc through reading the ggplot2 documentation.

ANOVA on PC scores

You can use this file to do the ANOVAs, you will have to do yourself. For example for differences in PC scores for gender:

```

CODE
AOV1 ← aov(lecturerpcscores$PC1 ~ gender, data = lecturerpcscores)
summary(AOV1)

```

OUTPUT

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
gender	1	4.6	4.596	0.93	0.342
Residuals	31	153.2	4.942		

You can do something similar for your projects and regression, using your PC scores as the predictors.

Boxplot

To do a boxplot of variables use ggplot2:

```
CODE
ggplot(lecturerpcscores, aes(x = gender, y = PC1)) +
  geom_boxplot()
```



Factor Analysis with Varimax Rotation

To do a Varimax rotation on your principal components, follow these commands. Do a factor analysis with the rotation being Varimax:

```
CODE
fa1 ← factanal(lecturers[, 8:28], 10, rotation = "varimax")
fa1
```

OUTPUT

```

Call:
factanal(x = lecturers[, 8:28], factors = 10, rotation = "varimax")

Uniquenesses:
      accessible        attractive       wide_range
accessible           0.381          0.005          0.005
teaching_based_research
      0.005          0.283          0.332
      gives_example    gives_out_note   sense_of_humour
      0.005          0.448          0.473
      mark_easily      moves_around    offers_lecture_notes
      0.005          0.294          0.141
      clear_objective  solicit_questions text_book
      0.244          0.005          0.310
      primary_research own_research    teach_in_team
      0.310          0.237          0.548
      understand_principles use_a_pointer well_respected
      0.584          0.067          0.005

Loadings:
      Factor1 Factor2 Factor3 Factor4 Factor5 Factor6 Factor7
accessible           -0.583  -0.426   0.222  -0.110          -0.130
attractive            0.961   0.106
wide_range           -0.177
teaching_based_research
      0.356   0.374  -0.114
Dress_nicely          0.829   0.100
      focus_on_complex_issues  0.116
      gives_example         0.122   0.112
      gives_out_note        0.362   0.290   0.216  -0.196   0.305   0.125   0.261
      sense_of_humour       0.127   0.229   0.599   0.125
      mark_easily            0.150   0.298   0.143
      moves_around           0.326   0.244   0.186  -0.102  -0.155
      offers_lecture_notes   0.362   0.240   0.333
      clear_objective        0.768   0.109   0.343
      solicit_questions       0.880  -0.139   0.130   0.109  -0.156
      text_book              0.611
      primary_research       0.100
      own_research            0.154
      teach_in_team           0.608
      understand_principles 0.164   0.146   0.902  -0.142   0.165
      use_a_pointer           0.133
      well_respected          0.121
      Factor8 Factor9 Factor10
accessible
attractive
wide_range
teaching_based_research
      Dress_nicely
      focus_on_complex_issues
      gives_example
      gives_out_note
      sense_of_humour
      mark_easily
      moves_around
      offers_lecture_notes
      clear_objective
      solicit_questions
      text_book
      primary_research
      own_research
      teach_in_team
      understand_principles
      use_a_pointer

```

well_respected	-0.100
	Factor1 Factor2 Factor3 Factor4 Factor5 Factor6 Factor7 Factor8
SS loadings	2.654 2.398 1.996 1.705 1.667 1.423 1.325 1.137
Proportion Var	0.126 0.114 0.095 0.081 0.079 0.068 0.063 0.054
Cumulative Var	0.126 0.241 0.336 0.417 0.496 0.564 0.627 0.681
	Factor9 Factor10
SS loadings	1.039 0.970
Proportion Var	0.049 0.046
Cumulative Var	0.731 0.777

Test of the hypothesis that 10 factors are sufficient.
The chi square statistic is 28.56 on 45 degrees of freedom.
The p-value is 0.973