

Three-way Principal Component Analysis applied to Noodles Sensory Data Analysis *(plus something else)*

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THE SOURCE OF THE DATA

ANALYZING AND CORRELATING INSTRUMENTAL AND SENSORY DATA: A MULTIVARIATE STUDY OF PHYSICAL PROPERTIES OF COOKED WHEAT NOODLES¹

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THE DATA SET (I)

Eight different formulations

Sample	Formulation	Protein (% w.b.)
1	60% SWF ^a + 40% WS ^b	5.20
2	100% SWF	8.52
3	100% DWF	12.30
4	97% SWF + 3% WG ^d	11.10
5	94% SWF + 6% WG	13.61
6	98.6% SWF + 1.4% GMS ^e	8.38
7	97.2% SWF ^c + 2.8% GMS	8.26
8	91.2% SWF + 6% WG + 2.8% GMS	13.50

^a SWF: soft wheat flour, ^b WS: wheat starch, ^c DWF: durum wheat flour, ^d WG: wheat gluten, ^e GMS: glyceryl monostearate

Sample 1 (40% WS): low protein reference

Sample 3 (100% DWF): high protein reference

Previous knowledge:

- A high gluten content is beneficial for pasta eating quality.
- A study on high temperature-short time extruded precooked pasta indicated that sensory textural attributes including firmness, springiness and chewiness were not affected by gluten but reduced by GMS.

THE DATA SET (II)

The extrusion of these noodles followed a randomized complete block design (RCBD) with **four replications**.

All eight noodle samples were manufactured in succession, in one day, as one batch (one sample replication).

Four batches of samples were produced in **four different days**. The order of noodle formula extrusion was randomized across replications.

The sensory profiling was performed by a **trained descriptive panel** consisting of **twelve** students and staff (6 males and 6 females) from the Food Science and Engineering Unit at University of Missouri-Columbia.

The panelists were selected based on their previous sensory evaluation experience.

Each of the four batches of samples was tested **twice** by each judge. These eight evaluation sessions were completed within **four consecutive days**. All eight samples were presented at a time to each judge in each session. **The order of sample presentation was completely randomized across sessions and judges.**

THE DATA SET (III)

Eight descriptors, four appearance-related and four texture-related, were selected:

Appearance: evaluate under the incandescent light by **visual observation**

- 1) Yellow color: the intensity of the yellow color of noodle surfaces
- 2) Translucency: the extent to which the light glows through the noodle.
- 3) Shininess: the extent to which the light reflects on the noodle surface.
- 4) Surface smoothness: the size of the pinholes on noodle surfaces

Texture: evaluate under the red light by manipulating samples **in the mouth**

- 5) Firmness: the force required to cut through the noodle using front teeth.
- 6) Chewiness: the length of time required to masticate the noodle to a state for swallowing.

Texture: evaluate under the red light by manipulating samples **using hands**

- 7) Surface stickiness: the extent to which *two* pieces of noodles stick together when separated.
- 8) Elasticity: the extent to which one piece of noodle returns to its original length when stretched.

THE DATA SET (IV)

Unstructured, unipolar 15 cm line scales were used with the left anchor representing low intensity in a particular attribute and the right anchor representing high intensity.

Summarizing:

- 8 formulations
- 4 replicates
- 2 sessions
- 8 variables
- 12 assessors

formul.	judge	replication	session	color	translucent	shiny	smooth	firm	chewy	sticky	elasticity
1	1	1	1	3.5	11.9	13	2.3	10	10.5	10	9.6
1	1	1	2	5.2	10.3	13.2	1.8	12.1	12.1	10.7	10.9
1	1	2	1	2.1	6	13.2	0.6	9.6	10.1	8.7	9.9
1	1	2	2	1.5	10.5	14.2	0.4	11.6	10.1	10.5	10.5
1	1	3	1	4	11.8	14	0.8	8	8.3	9.4	6.6
1	1	3	2	3	11.1	12.5	1	8.6	8.9	9.7	7.3
1	1	4	1	3.6	8.5	13.3	1.2	8.3	8.6	9.7	5.3
1	1	4	2	1.4	8.1	12.8	1.3	9.8	10.1	9.8	9.8
2	1	1	1	7.8	3.9	12.9	2	8.1	7.7	9	6.4

Matrix with 768 rows (8 x 4 x 2 x 12) and 8 columns

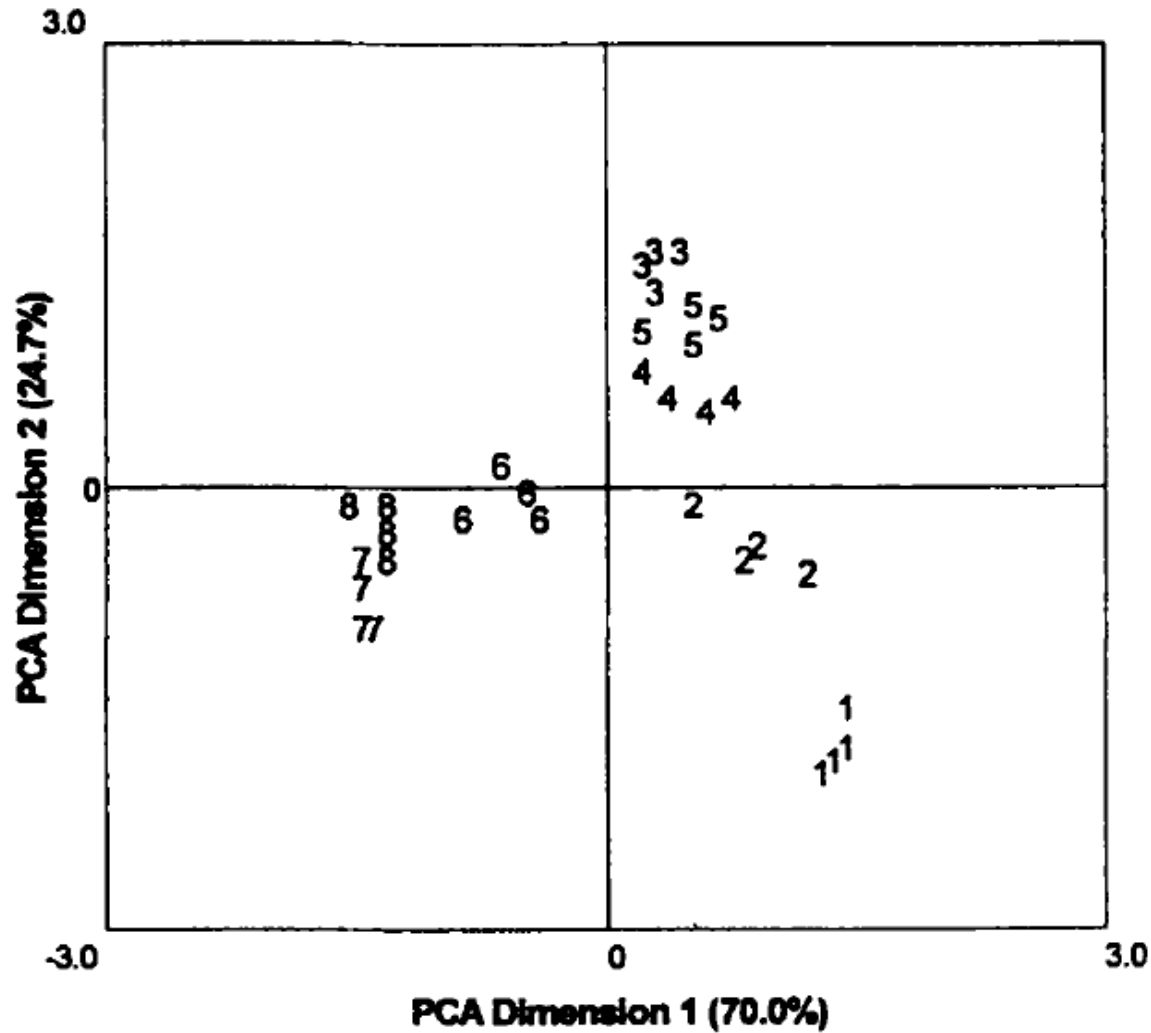
IN THE ORIGINAL PAPER...

MANOVA suggested that the **eight noodles were significantly different in their overall sensory characteristics** (Wilks' lambda value for treatment effect was 0.008, $p < 0.001$).

Further **three-way ANOVA** for samples, judges and replications as main effects and all two-way interactions were conducted for each individual sensory attribute.

- All eight **sensory attributes significantly discriminated among the eight samples** ($p < 0.001$).
- **The judge effect was significant**, indicating that the panelists used different parts of the scale during evaluation which is normal in sensory evaluation.
- For most of the attributes, **the interaction between sample and replication was significant** ($p < 0.05$) which suggested sample variation across the replications.
- **The sample and judge interaction was also significant for all attributes** which revealed that not all the judges evaluated all the samples in the same fashion.

IN THE ORIGINAL PAPER...



PCA on the data averaged across the 2 sessions and the 12 assessors

THINKING N-WAY...

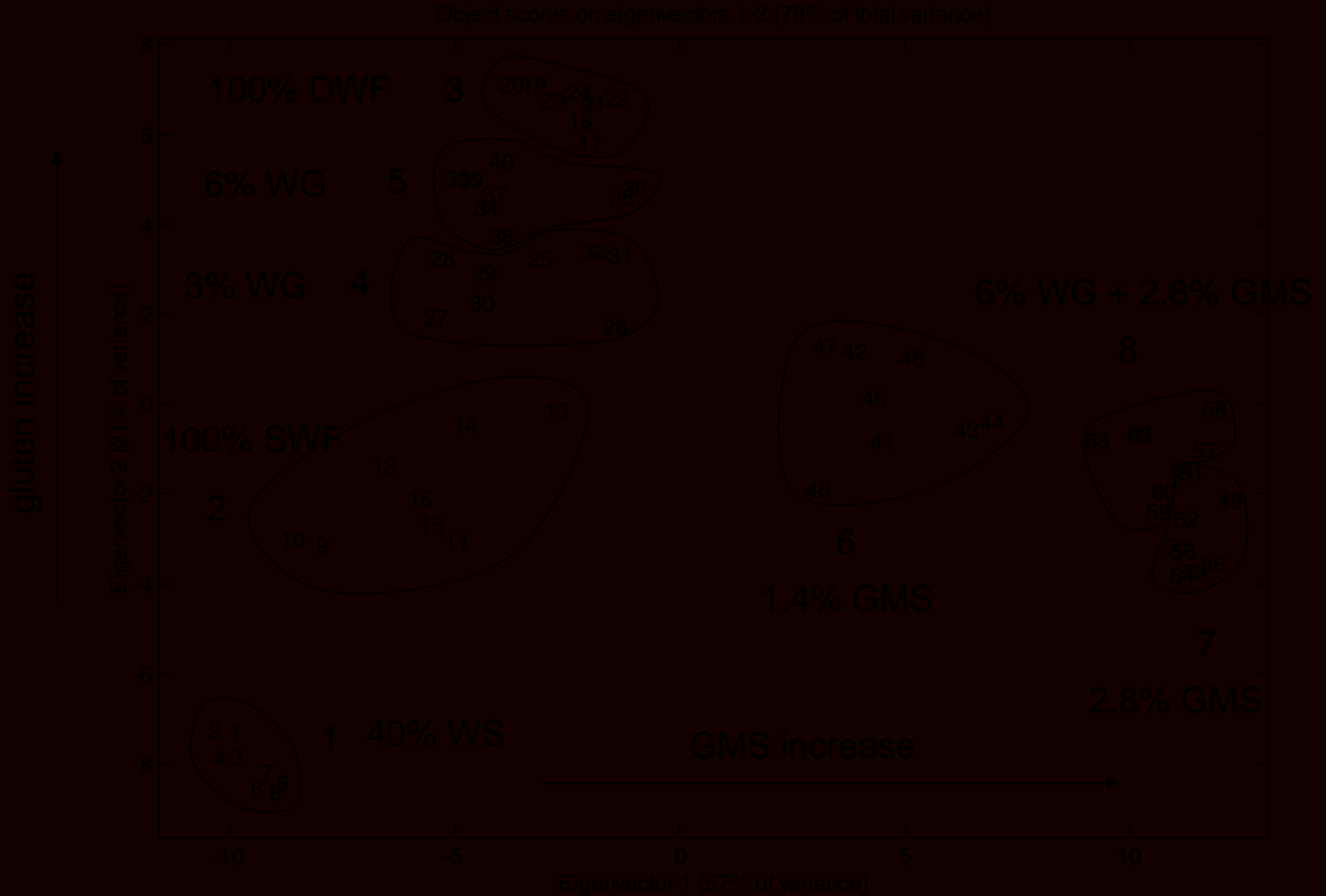
3 modes:

- mode 1: 64 samples (8 formulations x 4 batches x 2 replicates)
- mode 2: 8 variables
- mode 3: 12 assessors

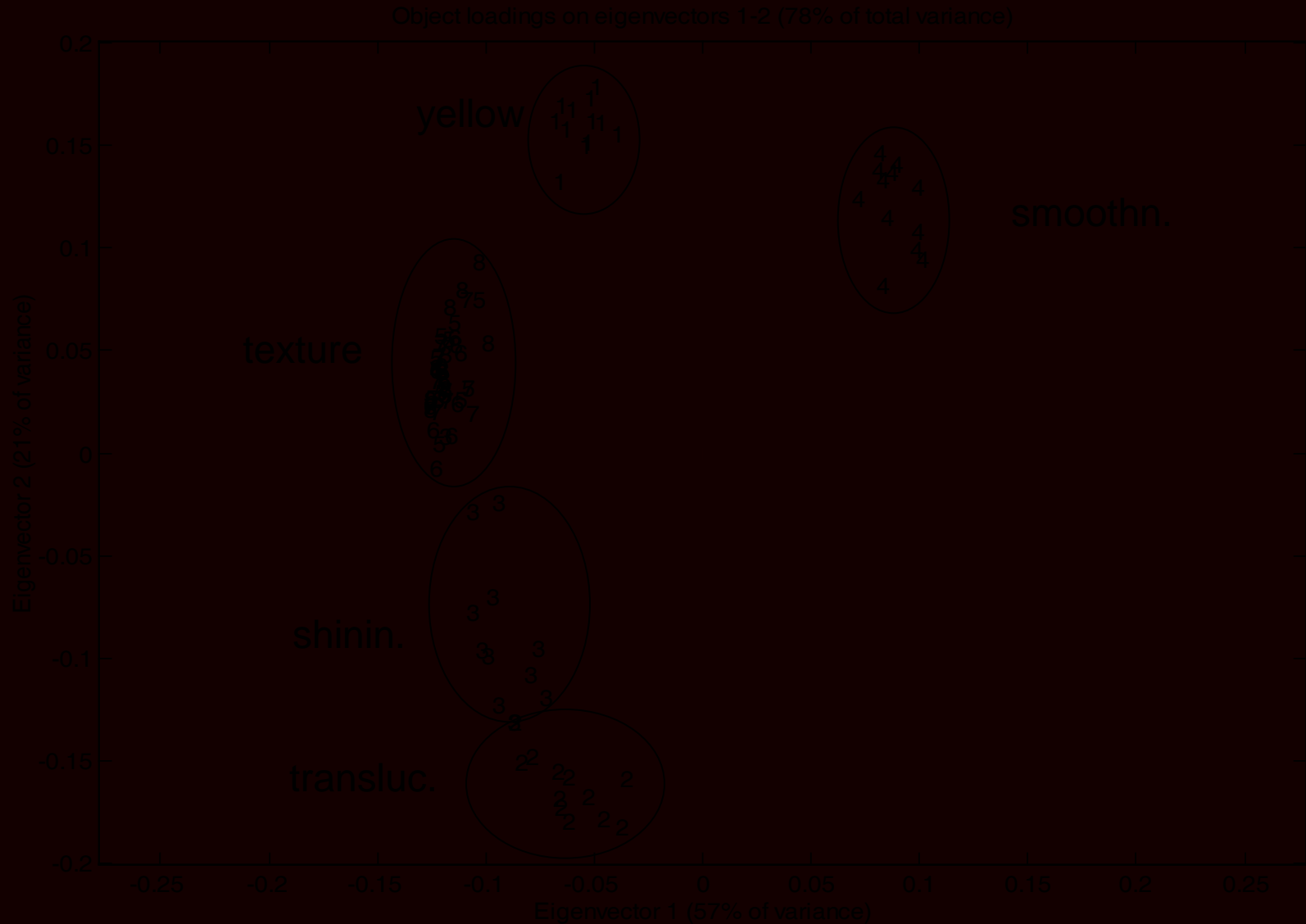
Coding in mode 1:

- samples 1-8, 9-16, ... come from the same formulation
- samples 1-2, 3-4, ... are the two replicates of the same batch

TUCKER 1



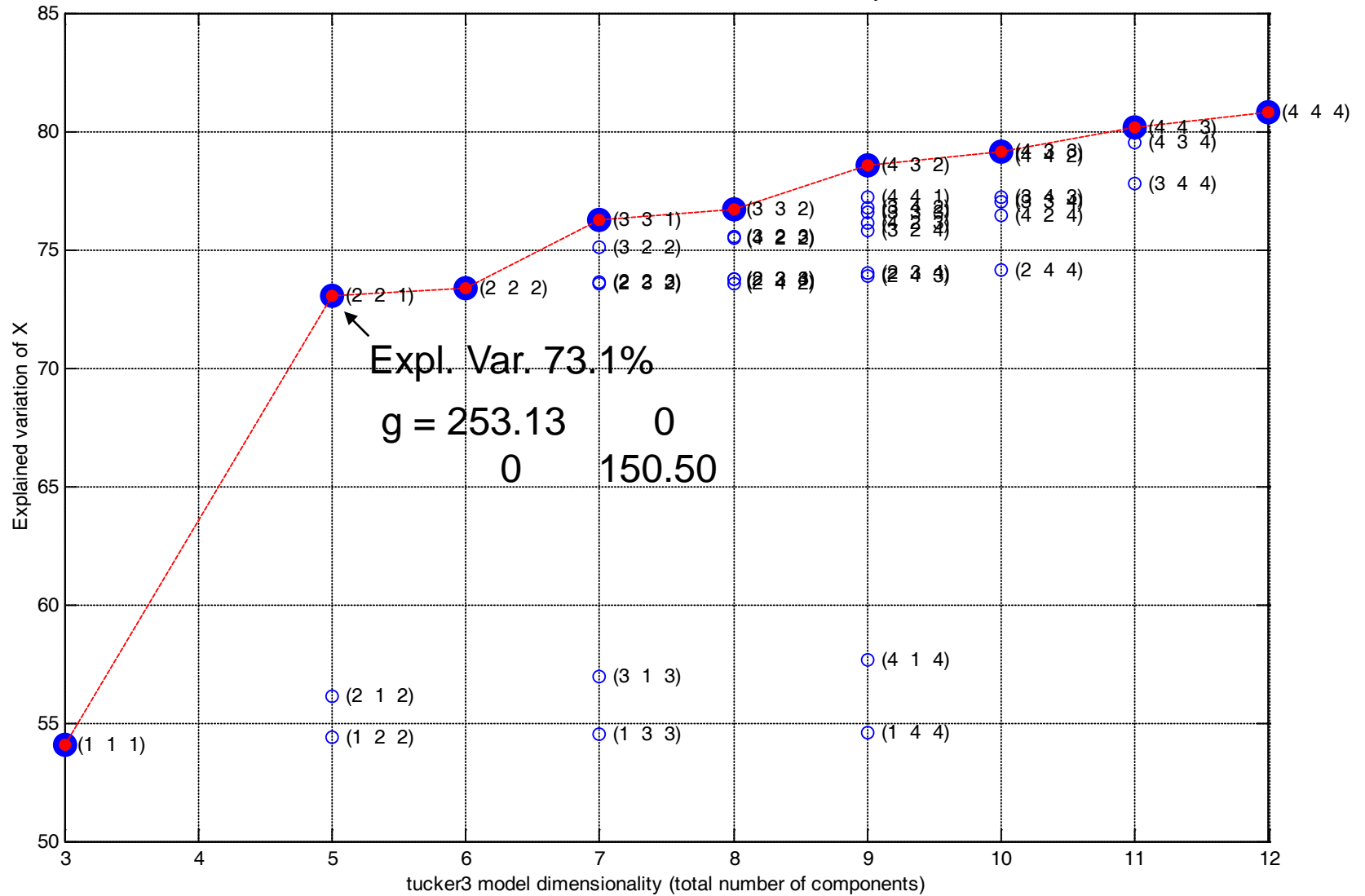
TUCKER 1



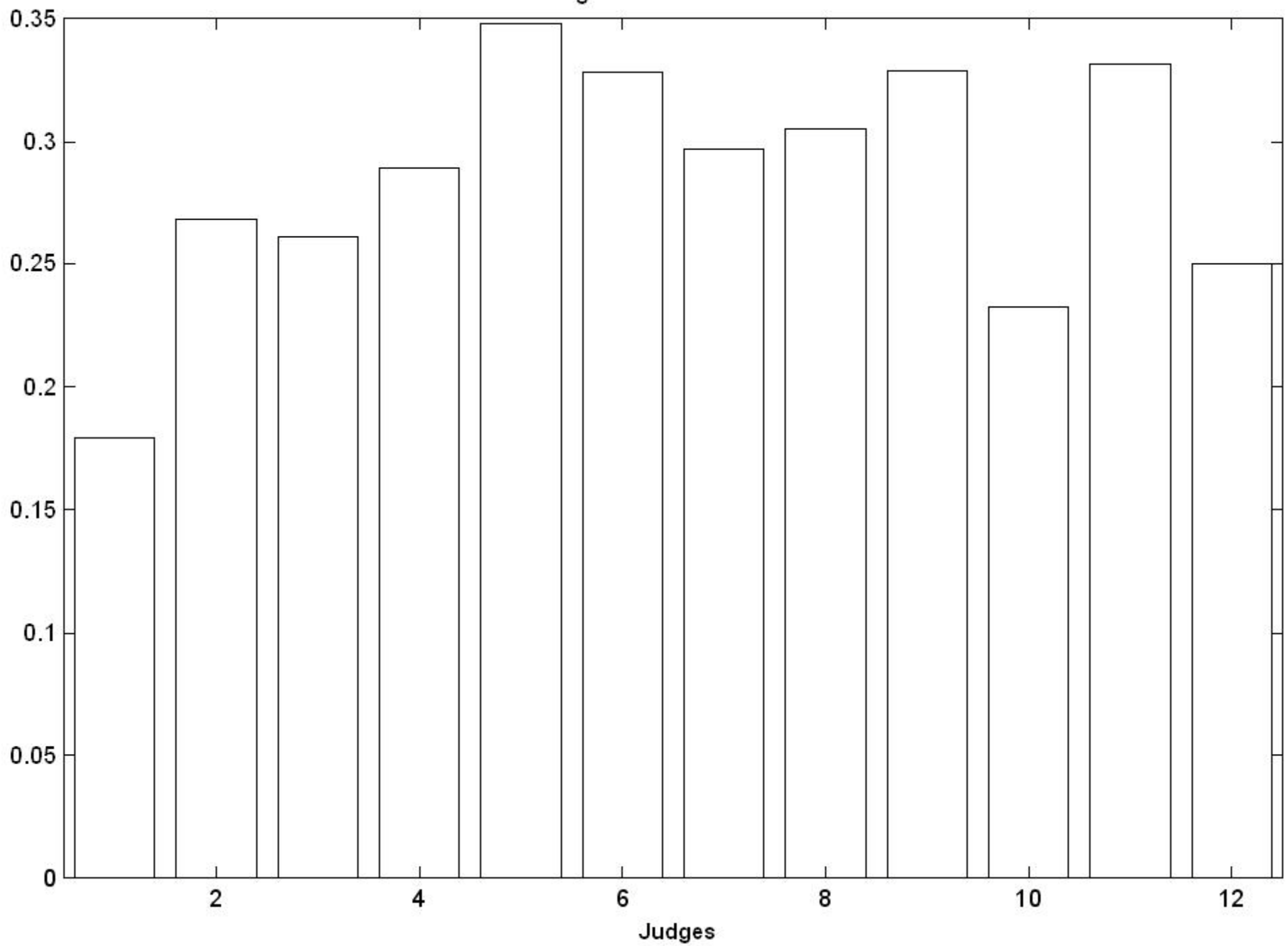
TUCKER 3

(after column centering)

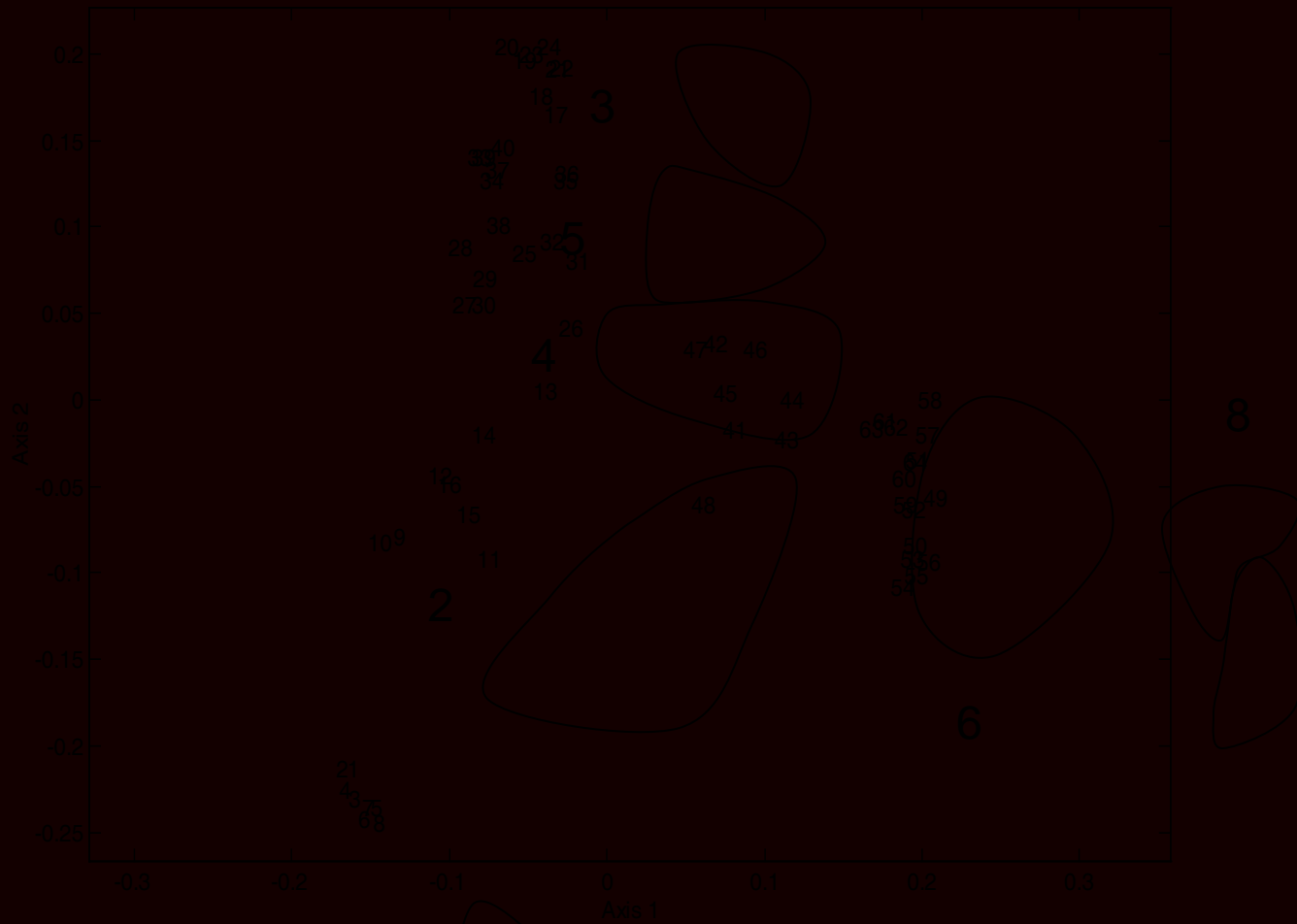
SSE_x as function of tucker3 model dimensionality



Loadings of conditions on axis 1



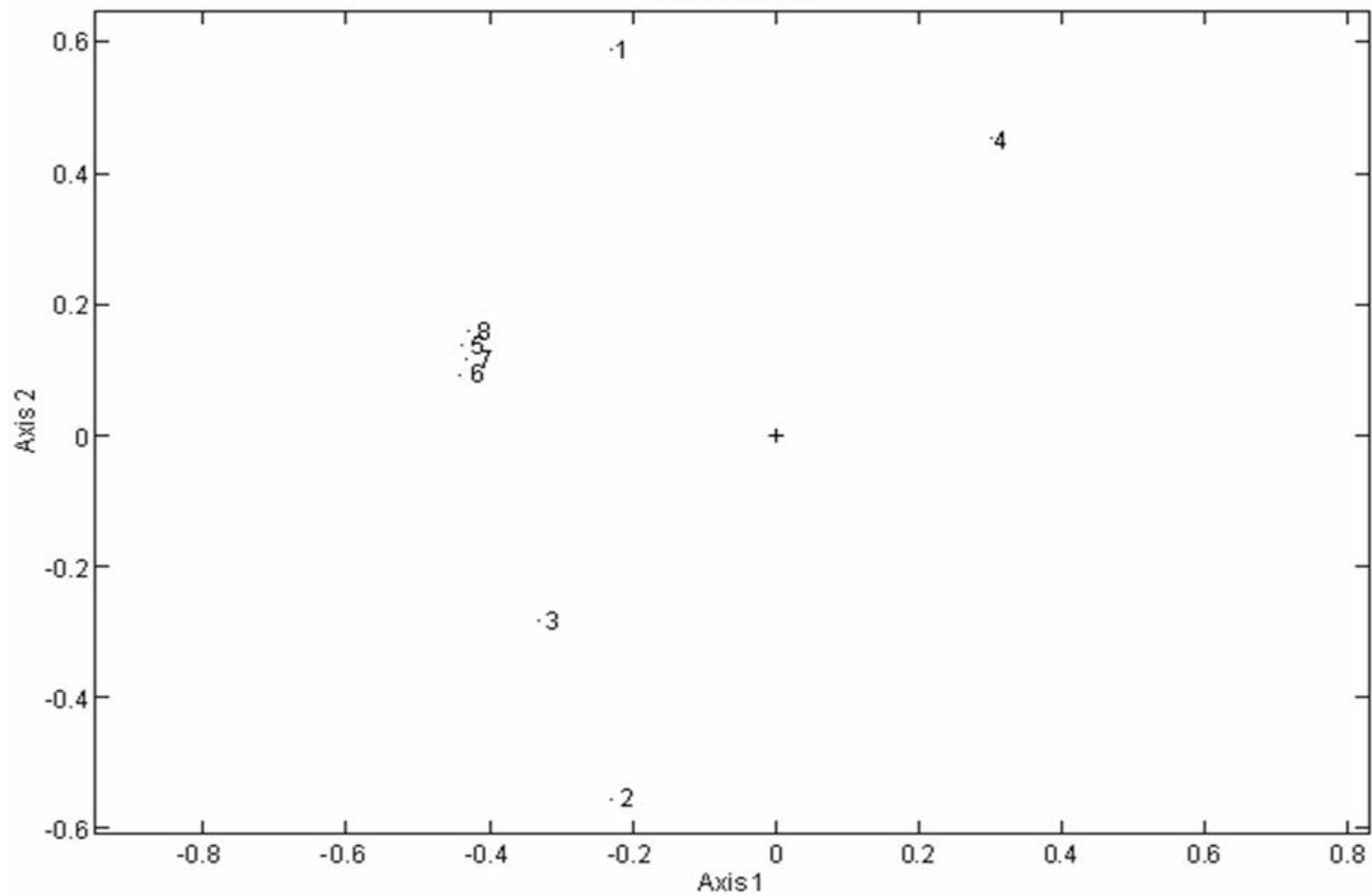
Plot of objects



1

7

Plot of variables



FEED-BACK OF A COURSE IN EXPERIMENTAL DESIGN

topic		prev. knowl.	presentation	information	timing
1	introduction				
2	full factorial				
3	screening				
4	practical application				
5	fractional factorial				
6	CCD				
7	Doehlert				
8	D-optimal				
9	qualitative variables				
10	mixtures				
11	composite design				
12	global				

- Previous knowledge: how much of the material was already known
- Presentation: clarity of presentation
- Information: the amount of new information obtained
- Timing: if the teacher was going too slow (low score) or too fast (high score)

Scores in the range 0-4 (2 being the “neutral” value)

10 participants

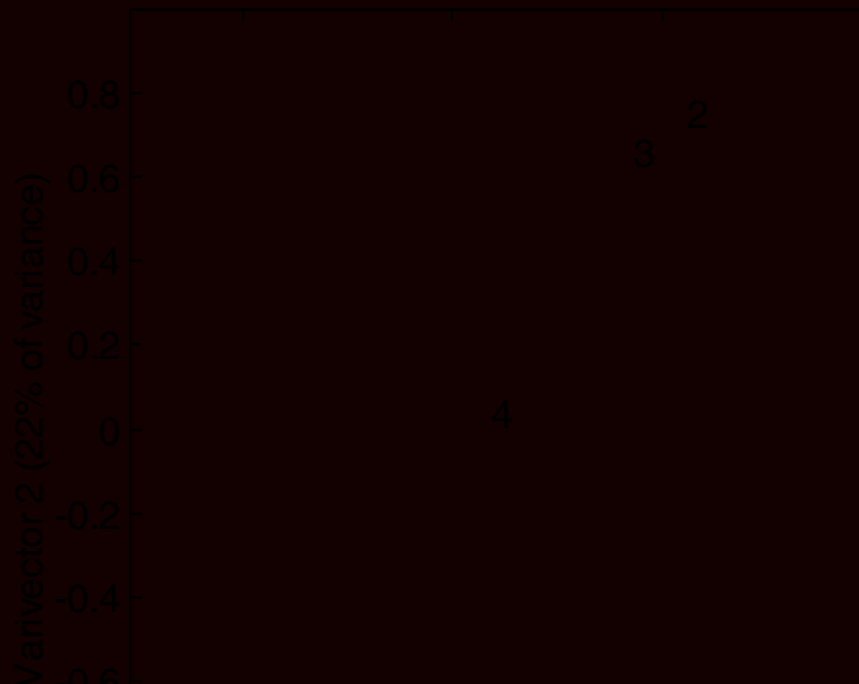
AVERAGES COMPUTED THROUGH THE PARTECIPANTS

	prev. knowl.	presentation	information	timing
introduction	2.4	3.6	3.0	1.7
full factorial	1.7	3.5	3.6	2.2
screening	1.1	3.4	3.5	2.4
practical application	1.5	3.4	3.5	2.5
fractional factorial	1.4	3.5	3.4	2.8
CCD	1.0	3.3	3.3	2.6
Doehlert	0.1	3.1	3.2	2.7
D-optimal	0.8	3.1	3.0	2.9
qualitative variables	0.8	2.7	2.7	2.9
mixtures	0.6	3.4	3.4	2.2
composite design	0.3	2.9	3.0	2.6
global	0.9	3.6	3.4	2.6

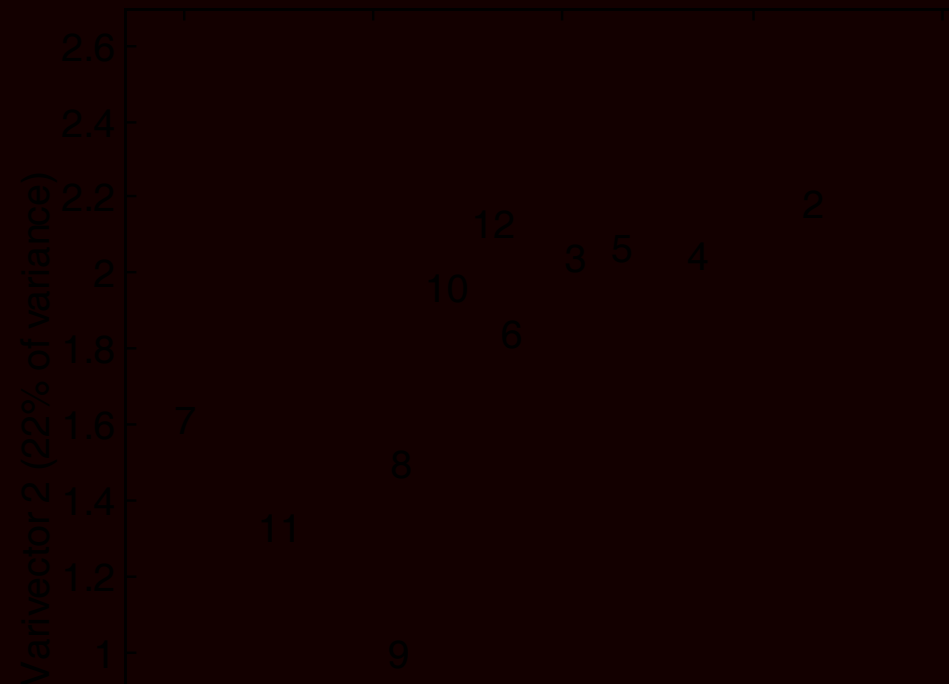
PCA ON THE AVERAGES

Pretreatment: To all the elements of the data table the value 2 (the “neutral” one) has been subtracted

Variable loadings on varivectors 1-2 (99%)



Object scores on varivectors 1-2 (99% of total variance)



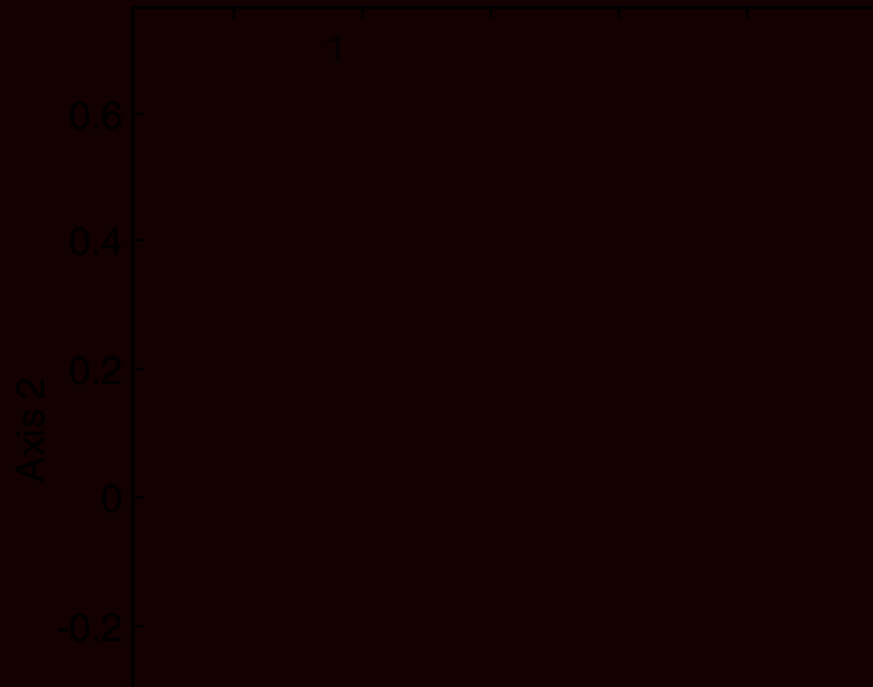
TUCKER 3

The (2,2,2) model explains 79.3% of the total variance.

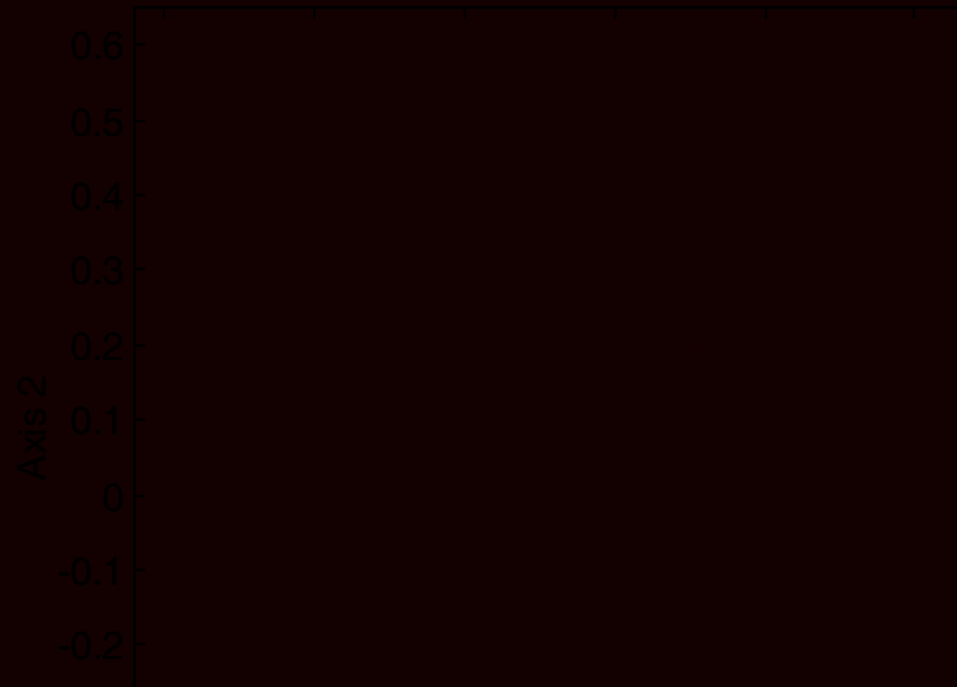
After having maximized the superdiagonality of the core matrix, the following core matrix has been obtained:

24.94	0.07	-1.45	4.08
-0.92	5.03	-0.21	6.32

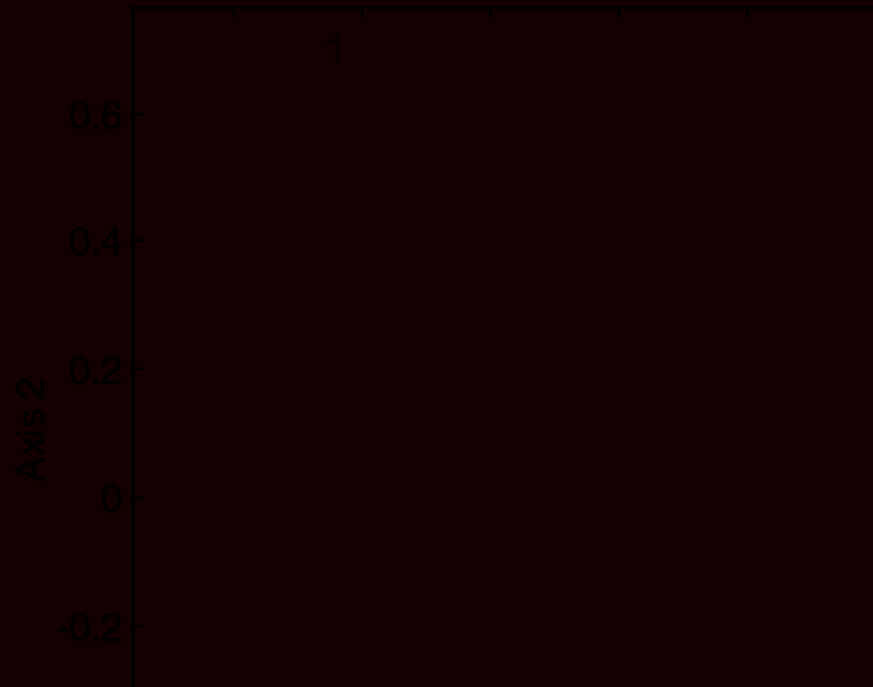
Plot of variables



Plot of objects



Plot of variables



Plot of conditions

