

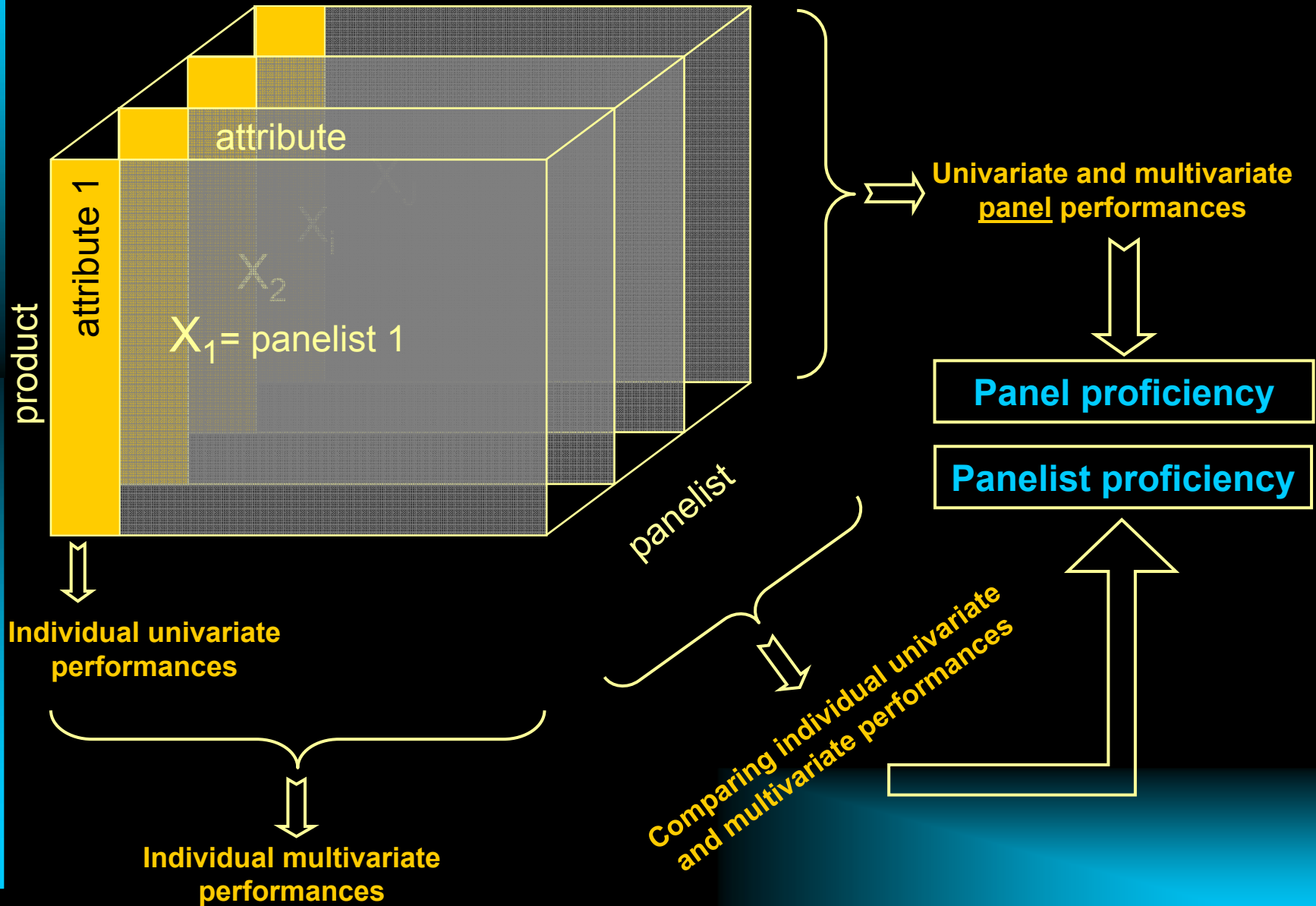
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- Hey Mostapha: what have you done with our replicates ?
- Consider the univariate ANOVA framework
- Make it clean \Rightarrow CAP table and map
- Extend it to MANOVA \Rightarrow Enjoy CVA
- Use 3 different RV coefficients to evaluate multivariate panel homogeneity
- Feed our sensory database with your data
Get in return the outputs of our analysis run on your data

Sensory profiling data



4 cases to fill in

	Univariate	Multivariate
Panelist	Monitoring the panel Panel leader everyday job	
Panel	Validating the panel Panel leader objective	

3 basic performances



- Reliability - Repeatability
 - to give the same scores to the same products
 - replicates required
- Validity - Accuracy
 - for an individual: to be in agreement with the panel
 - In agreement with a “mean” of the panel
 - for the panel: not to include too many individuals who disagree
 - Concept of “panel homogeneity”
- Discrimination
 - to give scores different “enough” to different products
 - “Enough” means relatively to repeatability at individual level
 - “Enough” means relatively to panel homogeneity at panel level

No individual reliability \Rightarrow No panel validity \Rightarrow No product discrimination

ANOVA for the 2 univariate cases

Panelist

Univariate

Multivariate

ANOVA model: Prod

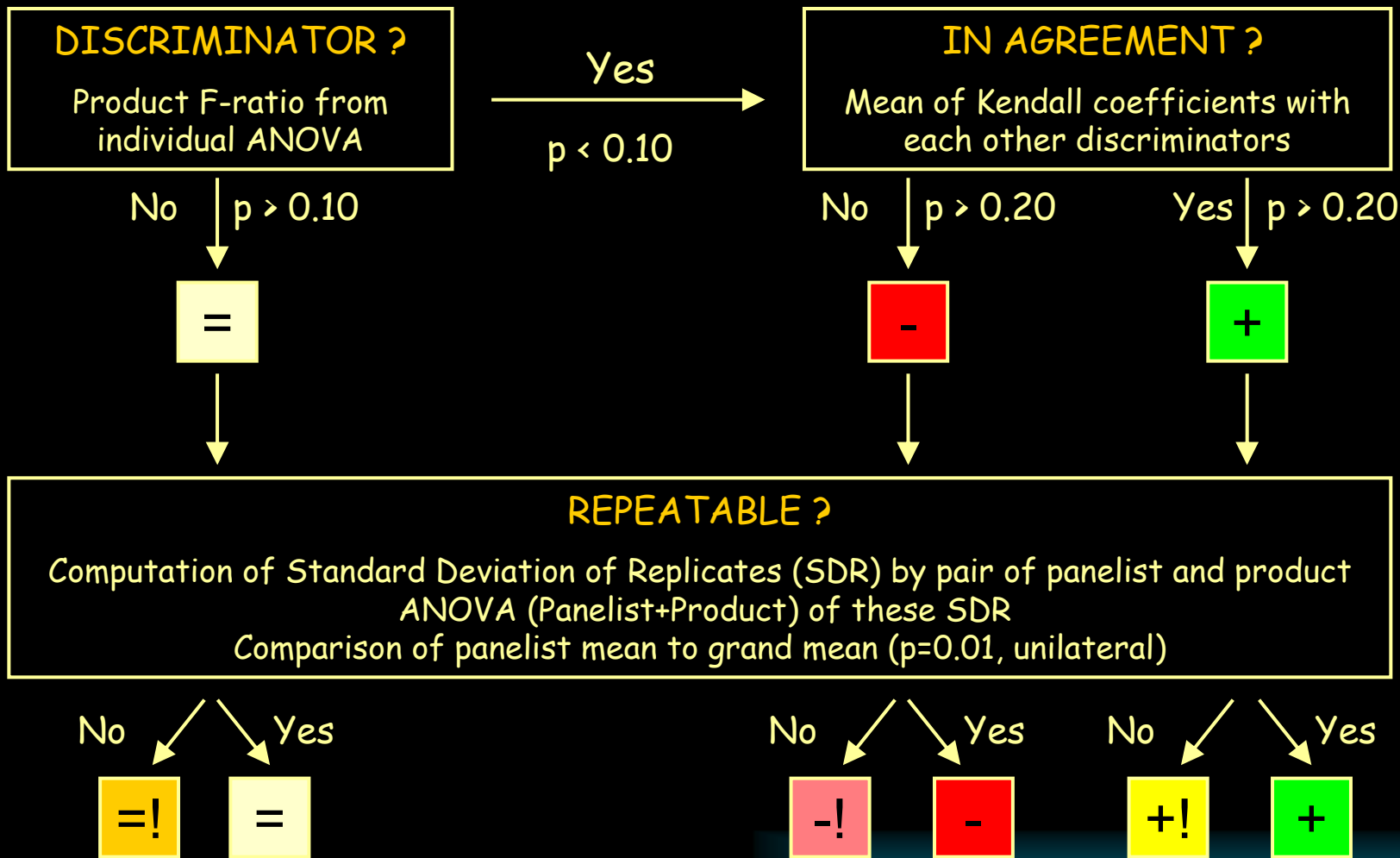
- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: correlation with panel mean
- Discrimination: $F = MS_{Prod} / MS_E$

Panel

ANOVA model: Prod + Pan + Prod*Pan

- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: $F = MS_{Prod*Pan} / MS_E$
- Discrimination: $F = MS_{Prod} / MS_{Prod*Pan}$

CAP: Control of Panelist Performances



6 different diagnostics possible for each pair of panelist and attribute

(Schlich, 1997)

The CAP table

16 steamed potatoes profiled in duplicate - 10 texture attributes - 14 panelists

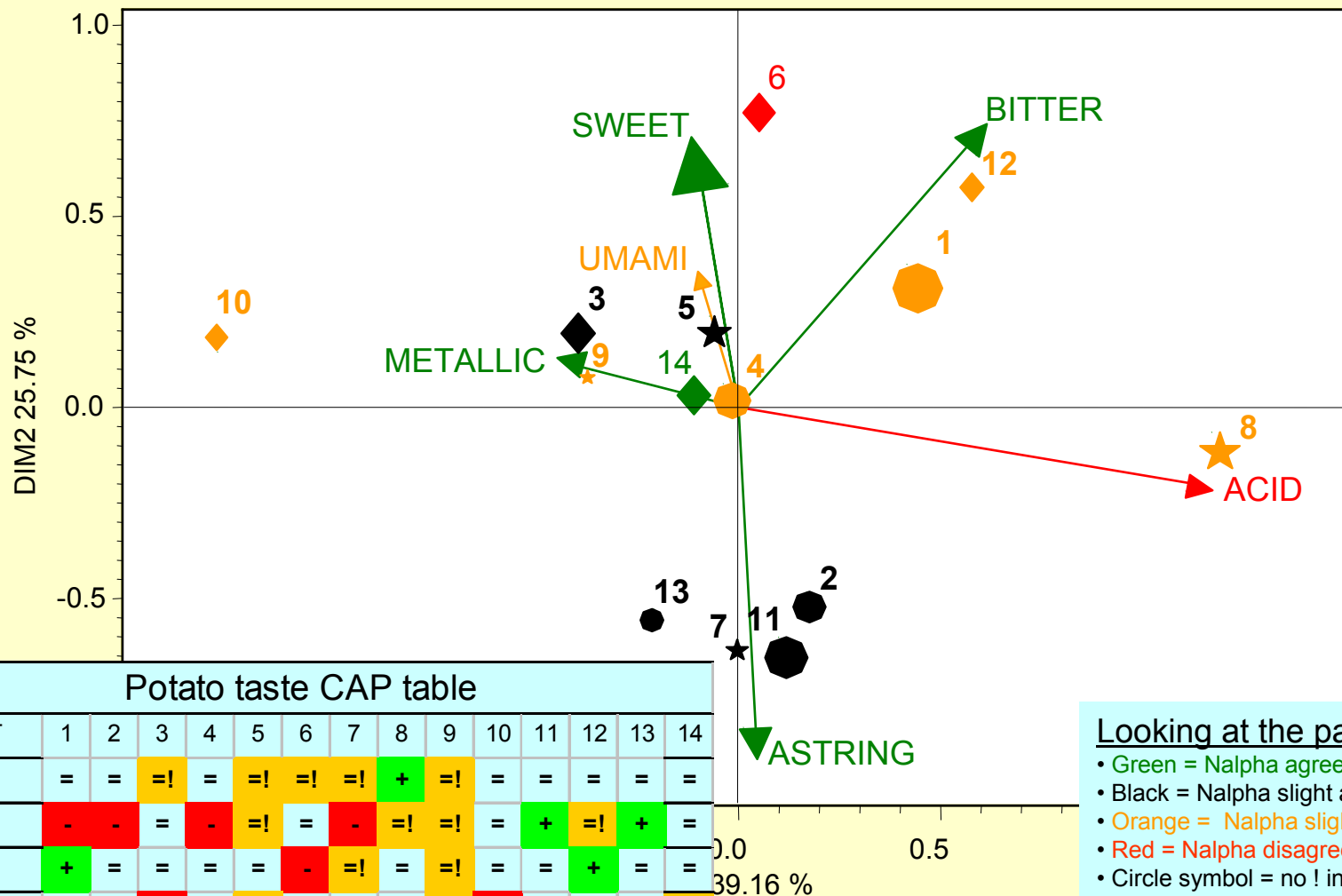


	MEAN	RMSE	FPROD	FINTER	PANELIST														+ / - / !	
					7	5	4	10	11	9	3	8	1	14	12	2	13	6		
RANKF					3.73	5.09	5.36	6.00	6.73	7.27	7.45	7.64	8.45	8.64	8.82	8.91	9.64	11.27		
FIRM	37.50	18.80	17.17	1.51	+	+	+	+	=	+	+	+	+	+	+	+	+	=	=!	11/0/1
MASHABLE	40.20	25.50	13.92		+	=	=	=	+	+	+	=!	=	+	=	+	=	=	=	6/0/1
MOIST	46.90	21.10	11.65		+	+	+	+	+	+	+	+	=	=!	=	=	=	=	+	9/0/1
GRAINY	26.90	20.60	11.58		+	+	+	=	=	+	+	=	=!	+	+	=	=	=	=!	7/0/2
MEALY	42.30	25.20	11.45		+	=	+	=	=	=	=	=	=!	=	=	+	=	=	=	3/0/1
COMPACT	48.60	18.60	8.58	1.77	+	+	+	+	-	=	=!	+	=	+	=!	+	+	+	=!	8/1/3
HOMOGEN	59.00	22.40	7.41		+	+	+	=	+	+	+	+	=	=!	=	=	=	+	=	8/0/2
GREASY	15.30	15.70	5.27	1.47	+	+	+	+	=	=!	=!	=!	=	=	=	=	=	=	=	4/0/4
PASTY	34.70	22.80	3.68	1.32	+	=!	+	-	+	=!	+	=	+	=!	=!	=	=	=	=!	5/1/5
STICKY	27.60	22.50	2.95	1.31	=	+	+	-	=	=	=	+	=	=!	=	=	=	=	=	3/1/1
ASTRING	29.30	21.90	2.58		-	=!	-	=	+	=!	=	=!	-	=	=!	-	+	=	=	2/4/4
+ / - / !					9/1/1	7/0/3	9/1/0	4/2/0	5/1/0	5/0/3	6/0/2	5/0/3	2/1/2	4/0/4	2/0/3	4/1/0	3/0/0	1/0/4		

- MEAN is the mean scores over products and panelists.
- RMSE is the root mean square of errors in the 2-way mixed model: PROD+PAN+PROD*PAN
- FPROD and FINTER are PRODUCT and PROD*PAN F-ratio in that model, printed when significant (p=0.05)
- RANKF is the mean of individual FPROD ranks over the attributes.
- Attributes and subjects are sorted from the most to the least discriminative power
- + / - / ! = number of + / number of - / number of !

The CAP map to summarize panelist performances Potato taste

Panelist-Attribute Biplot based on square root of individual F-Product



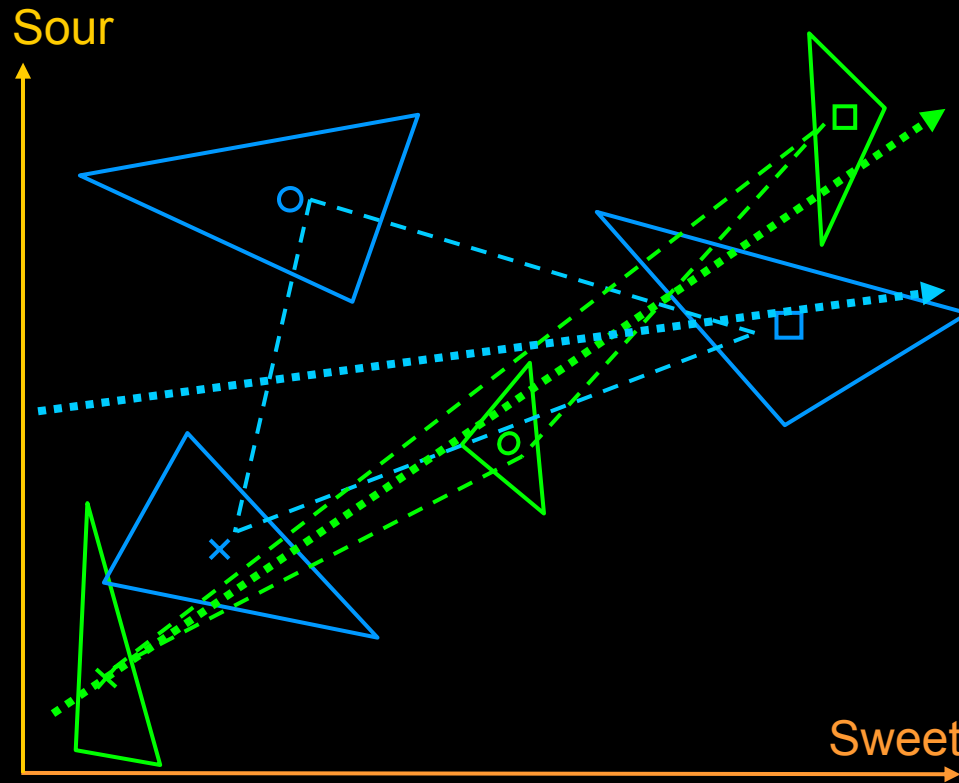
Potato taste CAP table

SUBJECT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
ACID	=	=	=!	=	=!	=!	=!	+	=!	=	=	=	=	=
ASTRING	-	-	=	-	=!	=	-	=!	=!	=	+	=!	+	=
BITTER	+	=	=	=	=	-	=!	=	=!	=	=	+	=	=
METALLIC	=	=	-	=	=!	=	=	=	=!	-	=	=	=	=!
SWEET	=	=	+	+	=	+	=	=!	=	=!	=	=	=	+
UMAMI	-	=	-	=	=!	=	=!	=!	=!	=	=	=	=	=

Looking at the panelists:

- Green = Nalpha agreement
- Black = Nalpha slight agreement
- Orange = Nalpha slight disagreement
- Red = Nalpha disagreement
- Circle symbol = no ! in CAP
- Diamond symbol = at least one ! in CAP
- Star symbol = at least one third of ! in CAP
- Symbol size proportional to F-Prod in MANOVA of the 6 attributes

From univariate to multivariate



UNIVARIATE

- Blue is less repeatable on both attributes
- Green is less repeatable on sour compared to sweet
- Agreement on sweet is quite good
- Disagreement occurs on sour
- Blue is less discriminative than Green on both attributes, because of his lower repeatability
- Green is less discriminative on sour compared to sweet

MULTIVARIATE

- Product configurations are different
- Blue is bidimensional (blue dotted line triangle), whereas Green is monodimensional (flat green triangle)
- Higher product distances and higher repeatability make Green more discriminative
- Correlation between sweet and sour is higher in Green compared to Blue

Panelist 1 in blue

Panelist 2 in green

3 Products: □ ○ ×

3 Rep per product



Non repeatability is triangle surface

Agreement is overlapping of triangles with a same symbol

Discrimination is separation of triangles with different symbols

From ANOVA to MANOVA

One attribute analysed at a time

p attributes analysed simultaneously

Comparing product means

Comparing product locations in the sensory space

Product Mean Square MS_{prod}

Between product covariance matrix B_{pxp}

Product by subject interaction Mean Square
 $MS_{\text{prod*subj}}$

Within product by subject covariance matrix W_{pxp}

$$F = MS_{\text{prod}} / MS_{\text{prod*subj}}$$

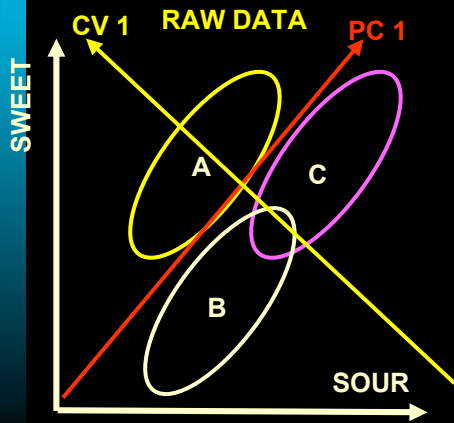
The eigenvalues of BW^{-1} which measure strength of product discrimination

Thus, any ANOVA model...

has its multivariate model counterpart

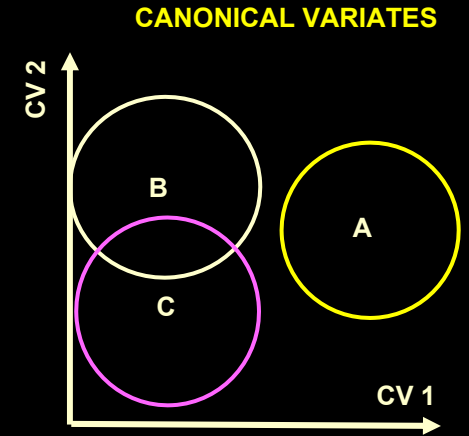
The eigenvectors of BW^{-1} (called the canonical variates) are the most important directions of discrimination. Finding them is doing a Canonical Variate Analysis (CVA)

Geometry of Canonical Variate Analysis

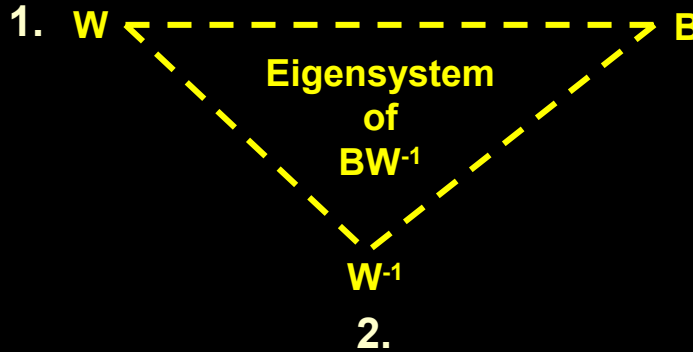


1. Within-product PCA of W
2. Equalize within-product variation along axes
3. Between-product PCA of B

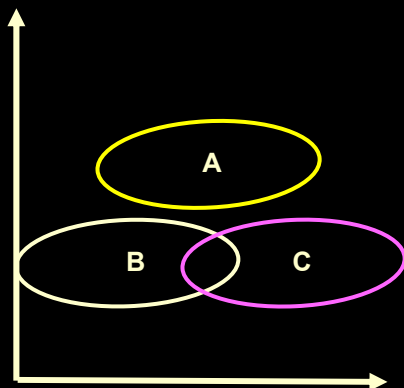
⇒ **CVA is a PCA of product mean scores with Mahalanobis metric W^{-1}**



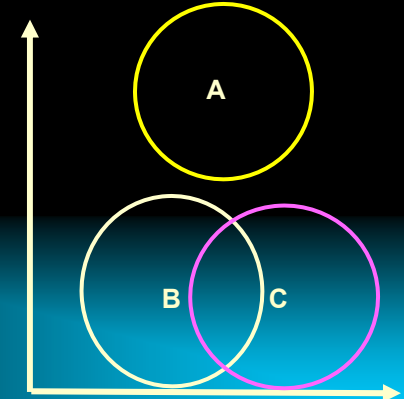
ROTATE TO MAXIMIZE WITHIN-PRODUCT VARIATION



3. ROTATE TO MAXIMIZE BETWEEN-PRODUCT VARIATION



2. RESCALE TO STANDARDIZE WITHIN-PRODUCT VARIATION



Statistical tests and multivariate indicators

$\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_k$ eigenvalues of BW^{-1}

MANOVA tests:

"Is $\sum \lambda_i$ large enough?"

or

"Are the product profiles different?"

Dimensionality test:

"How many λ_i are enough?"

or

"On how many sensory dimensions the product differ?"

Comparing panels, panelists, types of attributes ... on:

strength of
product discrimination

complexity of
product discrimination

Multivariate panelist performances based on MANOVA and CVA



Panelist

Univariate

ANOVA model: Prod

- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: correlation with panel mean
- Discrimination: $F = MS_{Prod} / MS_E$

Multivariate

MANOVA model: Prod

- Discrimination: MANOVA test of Prod

Canonical Variate Analysis (CVA)

- Dimensionality of product configuration
- Stepwise selection of attributes
- Saliency of product differences

Panel

ANOVA model: Prod + Pan + Prod*Pan

- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: $F = MS_{Prod*Pan} / MS_E$
- Discrimination: $F = MS_{Prod} / MS_{Prod*Pan}$

Discrimination and dimensionality of individual potato configurations



Subject	From 14 flavor attributes			From 6 taste attributes			From 10 texture attributes		
	NSEL	MANOVA F	NCAN	NSEL	MANOVA F	NCAN	NSEL	MANOVA F	NCAN
1	5	5.77	3	2	3.04	1	2	2.77	1
2	0	.	0	1	2.60	1	2	2.59	2
3	3	6.48	2	2	2.70	2	3	2.48	2
4	0	.	0	2	2.38	1	2	3.82	2
5	3	2.63	2	4	1.92	1	3	6.24	3
6	6	3.96	3	2	3.60	2	2	2.18	1
7	6	2.13	4	1	2.88	1	3	3.50	3
8	3	3.84	2	1	6.10	1	3	2.68	2
9	1	2.60	1	0	.	0	3	2.86	2
10	2	3.29	2	1	2.54	1	4	7.87	4
11	5	2.72	4	1	2.75	1	2	3.16	2
12	4	3.24	2	1	2.82	1	2	6.41	2
13	1	3.98	1	1	1.97	1	2	3.18	2
14	1	10.67	1	2	2.57	1	4	4.96	3

NSEL: number of selected attributes by Proc STEPDISC (SLE=0.15 SLS=0.15) - No selection done at panel level

NCAN: number of significant ($p=0.10$) canonical axes

MANOVA F: **green if $p<0.05$** , no color if $0.05<p<0.15$ and **in red when non significant**

Multivariate panel performances based on MANOVA and CVA



Panelist

Univariate

ANOVA model: Prod

- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: correlation with panel mean
- Discrimination: $F = MS_{Prod} / MS_E$

Multivariate

MANOVA model: Prod

- Discrimination: MANOVA test of Prod

Canonical Variate Analysis (CVA)

- Dimensionality of product configuration
- Stepwise selection of attributes
- Saliency of product differences

Panel

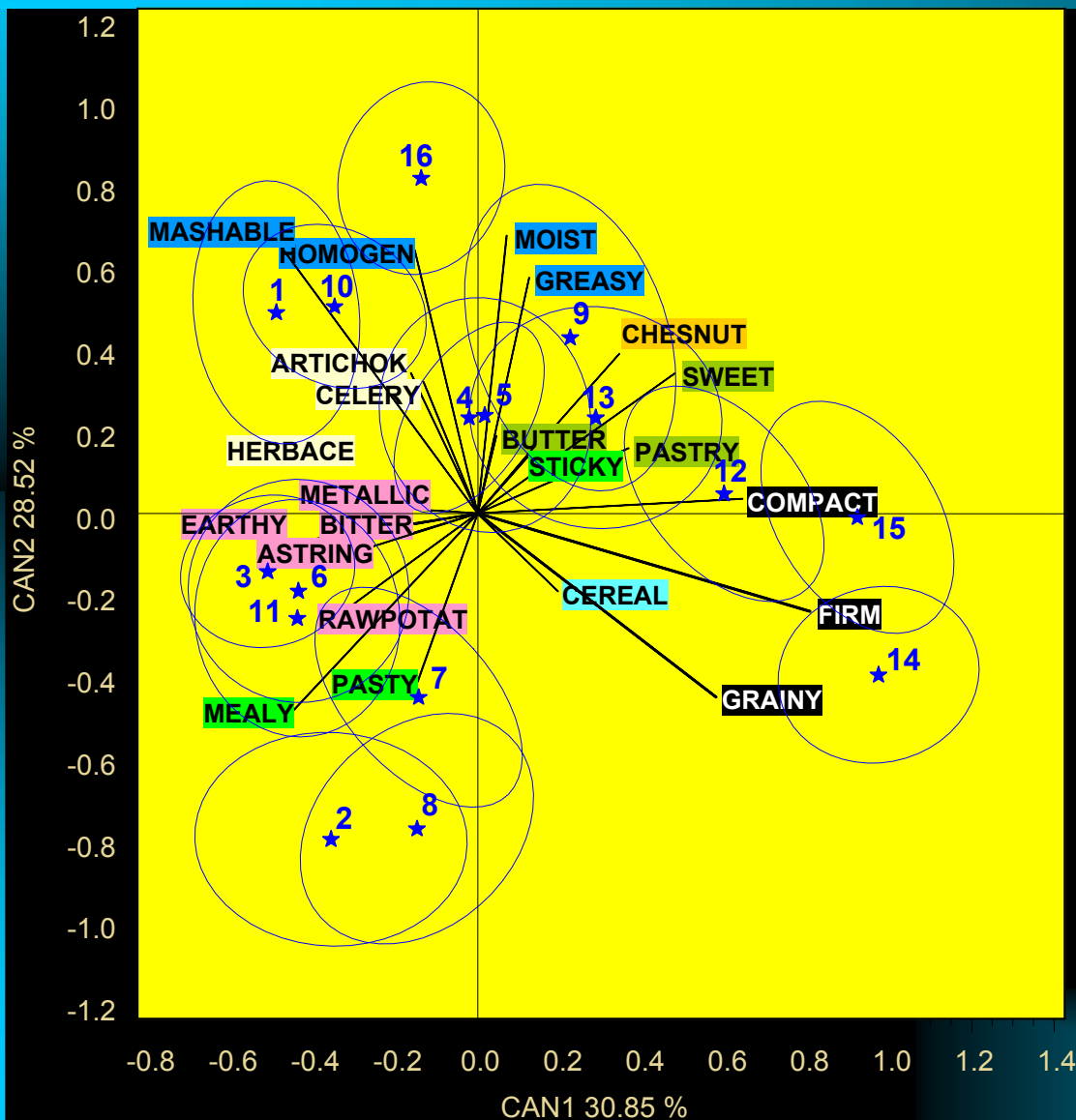
ANOVA model: Prod + Pan + Prod*Pan

- Repeatability: $\sqrt{MS_E}$ (Root mean square of error)
- Validity: $F = MS_{Prod*Pan} / MS_E$
- Discrimination: $F = MS_{Prod} / MS_{Prod*Pan}$

MANOVA model: Prod + Pan + Prod*Pan

- Homogeneity: MANOVA test of Prod*Pan
- Discrimination: MANOVA test of Prod
- Canonical Variate Analysis (CVA)
- Dimensionality of product configuration
- Product confidence ellipses on CVA map to contrast homogeneity and discrimination

CVA of 16 steamed potatoes



The colors on the attribute names refer to 8 attribute clusters obtained by VARCLUS in SAS

Attributes are located on the canonical map thanks to their correlations with canonical components

The confidence ellipses suggest that product 14 and 15 are not really different, whereas product 12 is less firmer than 14 but not than 15

MANOVA F = 3.57 NDIMSIG = 5 - 90 % Confidence Ellipses of Means

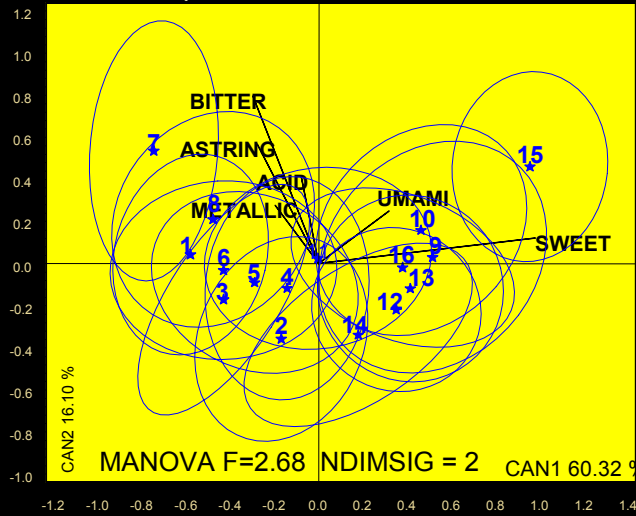
Comparing group to individual discrimination and dimensionality

Subject	From 14 flavor attributes			From 6 taste attributes			From 10 texture attributes			
	NSEL	MANOVA F	NCAN	NSEL	MANOVA F	NCAN	NSEL	MANOVA F	NCAN	
1	5	5.77	3	2	3.04	1	2	2.77	1	
2	0	.	0	1	2.60	1	2	2.59	2	
3	3	6.48	2	2	2.70	2	3	2.48	2	
4	0	.	0	2	2.38	1	2	3.82	2	
5	3	2.63	2	4	1.92	1	3	6.24	3	
6	6	Table of discrimination and dimensionality at individual level seen earlier...							18	1
7	6	Table of discrimination and dimensionality at individual level seen earlier...							50	3
8	3	3.04	2	1	6.10	1	3	2.68	2	
9	1	2.60	1	0	.	0	3	2.86	2	
10	2	3.29	2	1	2.54	1	4	7.87	4	
11	5	2.72	4	1	2.75	1	2	3.16	2	
12	4	3.24	2	1	2.82	1	2	6.41	2	
13	1	3.98	1	1	1.97	1	2	3.18	2	
14	1	10.67	1	2	2.57	1	4	4.96	3	
Panel	14	1.98	3	6	2.68	2	10	5.68	3	

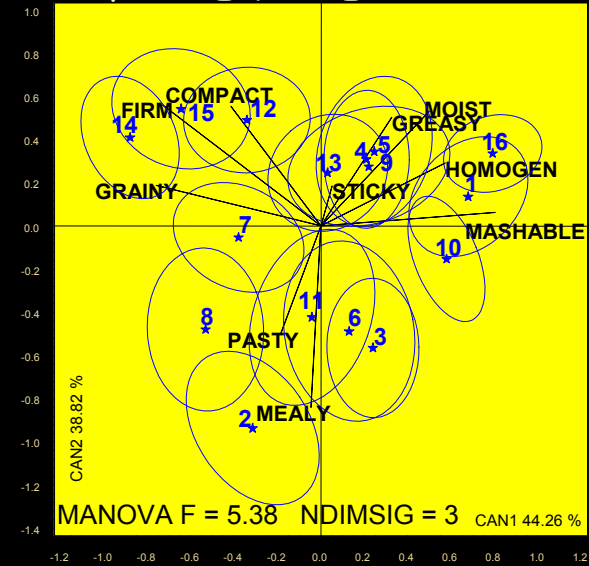
Remember that product discrimination is the ratio of product differences to either unrepeatability at individual level or panelist disagreement at group level

Comparing flavor, taste and texture discrimination and dimensionality

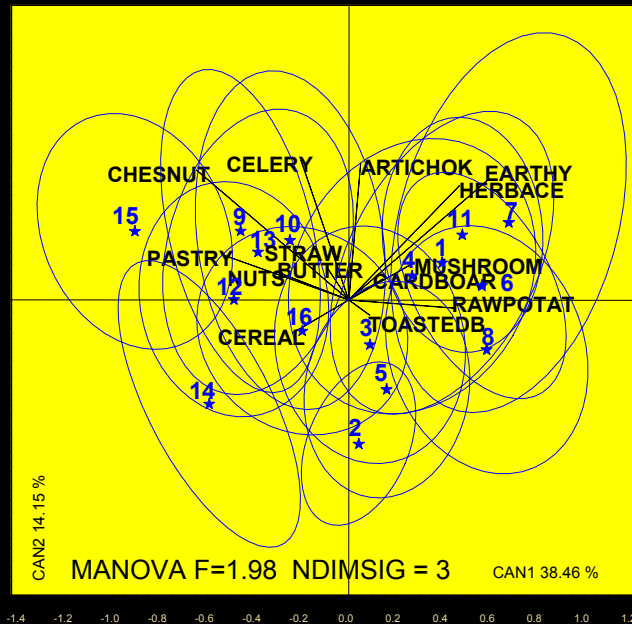
CVA of 6 TASTE attributes



CVA of 10 TEXTURE attributes

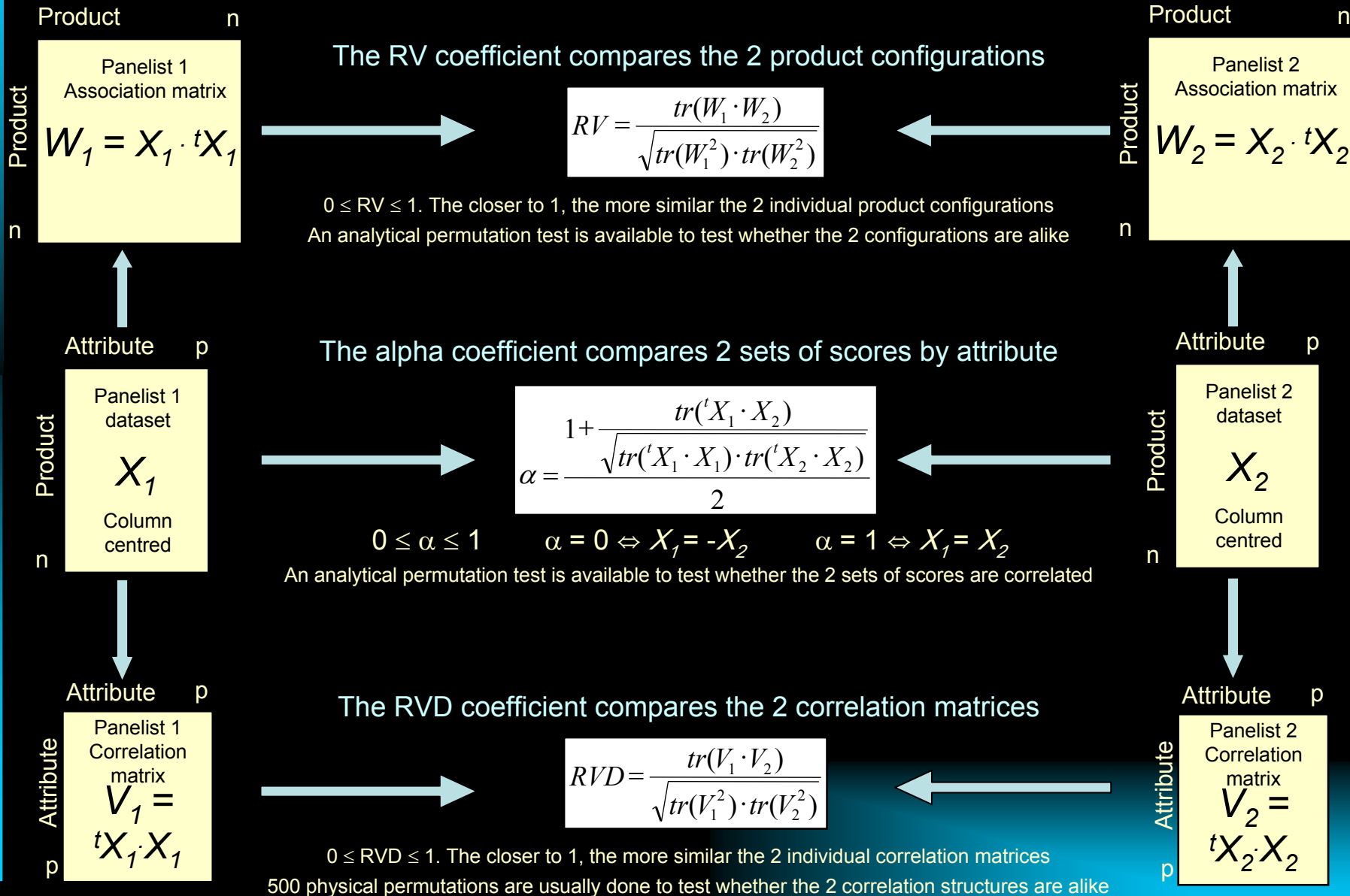


CVA of 14 FLAVOR attributes



- MANOVA F and ellipse sizes show that texture is more discriminative than taste and flavor
- Taste space is less complex than texture and flavor spaces

The Conf-Scor-Corr RV framework to further investigate panel homogeneity



Conf-Scor-Corr agreement on potato flavor

14 panelists - 16 products - 14 Flavor attributes

Panelist	RV	α	RVD	NRV	N α	NRVD
1	0.29	0.56	0.53	0.40	1.25	2.46
2	0.38	0.59	0.54	1.32	2.04	2.51
3	0.37	0.59	0.53	1.91	1.74	3.53
4	0.35	0.56	0.51	1.07	1.20	3.12
5	0.37	0.58	0.60	1.35	1.62	3.39
6	0.28	0.51	0.52	-0.02	0.18	2.98
7	0.37	0.61	0.52	1.20	2.46	3.12
8	0.29	0.53	0.41	0.21	0.80	2.45
9	0.33	0.57	0.54	1.17	1.39	2.95
10	0.40	0.61	0.54	2.15	2.27	3.14
11	0.27	0.57	0.52	0.61	1.39	2.56
12	0.32	0.55	0.45	0.75	1.29	2.67
13	0.27	0.54	0.50	0.40	0.72	3.22
14	0.36	0.57	0.44	0.72	1.66	2.14
Mean	0.33	0.57	0.51	0.94	1.43	2.88

- RV, alpha and RVD are indices of agreement in [0,1] in terms of product configuration, product scores and attribute correlations
- NRV, Nalpha and NRVD are standardized deviation of these indices to their distribution under permutation
- NRV and Nalpha are obtained by formulas whereas 500 permutations were drawn for NRVD

Green = Agreement – **White = Slight Agreement**
Orange = Slight Disagreement - **Red = Disagreement**

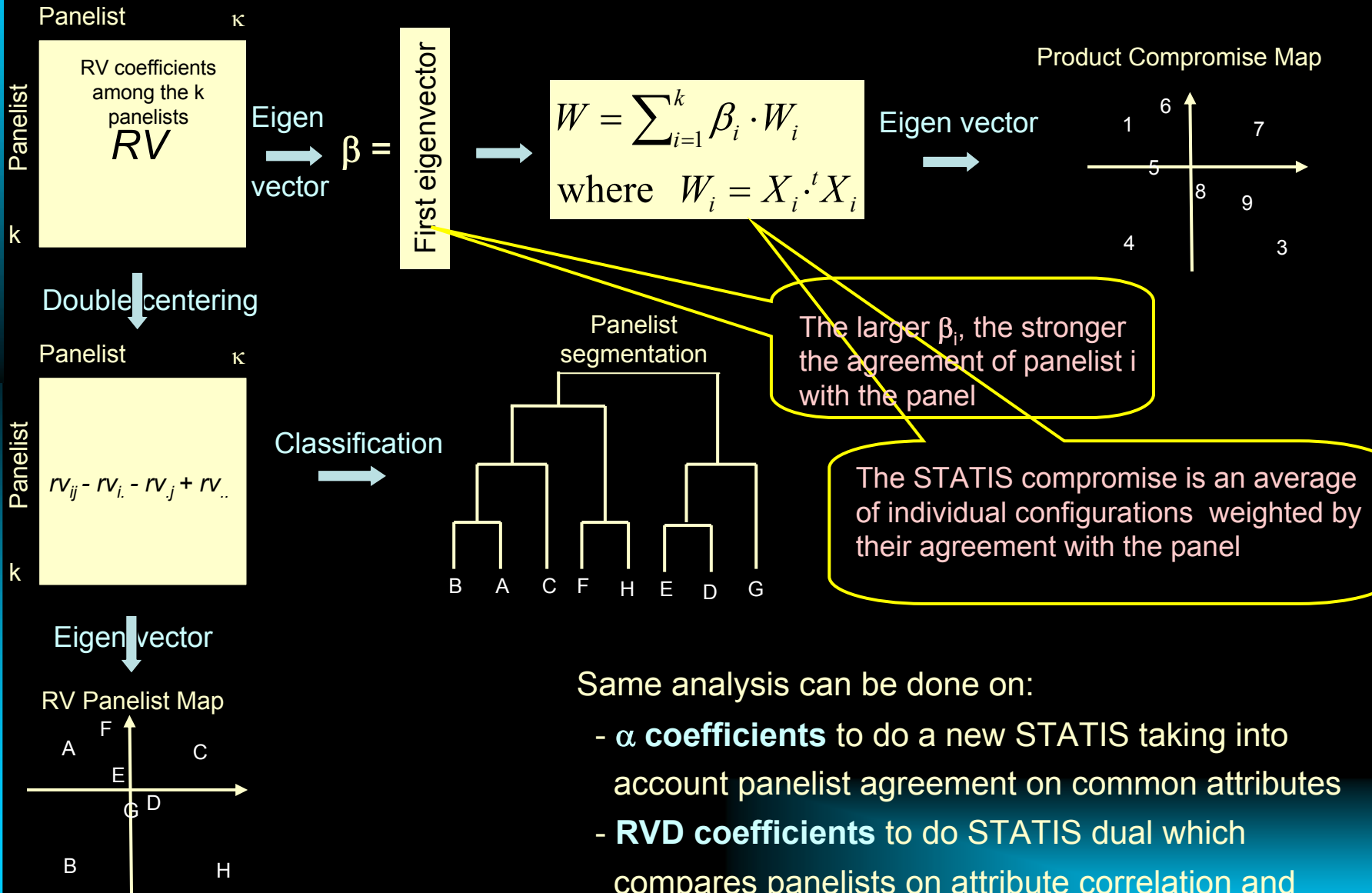
Agreement on potato flavor, taste and texture



	14 Flavor attributes			6 Taste attributes			10 Texture attributes		
Panelist	NRV	N α	NRVD	NRV	N α	NRVD	NRV	N α	NRVD
1	0.40	1.25	3.24	0.56	1.10	1.00	3.71	3.07	2.68
2	1.32	2.04	3.03	1.07	1.58	1.21	4.50	3.91	4.13
3	1.91	1.74	3.85	1.01	1.55	0.42	3.65	3.49	4.04
4	1.07	1.20	3.11	0.01	1.09	1.62	3.53	3.56	2.66
5	1.35	1.62	4.23	1.16	1.63	1.54	4.27	3.63	3.69
6	-0.02	0.18	2.94	-0.19	0.66	1.30	2.69	2.88	3.68
7	1.20	2.46	2.94	1.75	1.55	0.59	4.20	3.68	3.22
8	0.21	0.80	1.82	0.98	1.19	0.87	3.39	3.44	3.31
9	1.17	1.39	3.57	0.66	1.09	0.40	2.44	2.92	3.35
10	2.15	2.27	3.50	1.50	1.37	0.35	2.83	3.29	3.20
11	0.61	1.39	3.57	0.73	1.63	0.50	2.64	2.75	2.79
12	0.75	1.29	2.48	0.73	1.23	1.42	3.31	3.08	2.95
13	0.40	0.72	3.46	1.53	1.61	1.60	2.08	2.67	3.47
14	0.72	1.66	1.42	1.21	1.86	1.68	3.98	3.56	2.60
Mean	0.94	1.43	3.08	0.91	1.37	1.04	3.37	3.28	3.27

Green = Agreement – **White = Slight Agreement**
Orange = Slight Disagreement - **Red = Disagreement**

Defining the STATIS compromise

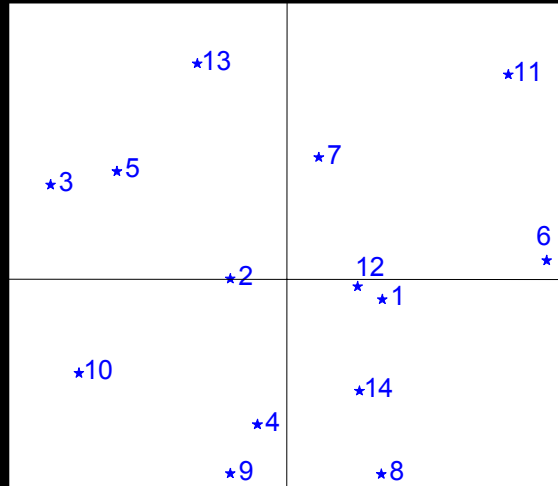


Same analysis can be done on:

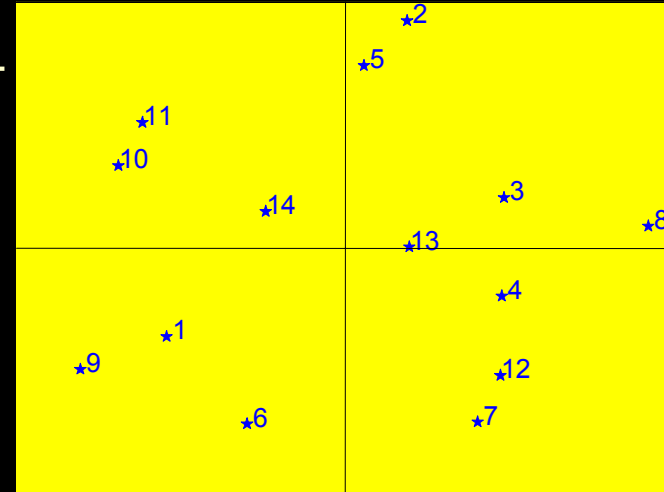
- α coefficients to do a new STATIS taking into account panelist agreement on common attributes
- RVD coefficients to do STATIS dual which compares panelists on attribute correlation and produces an attribute compromise map

Flavor panelist maps based on RV, α and RVD

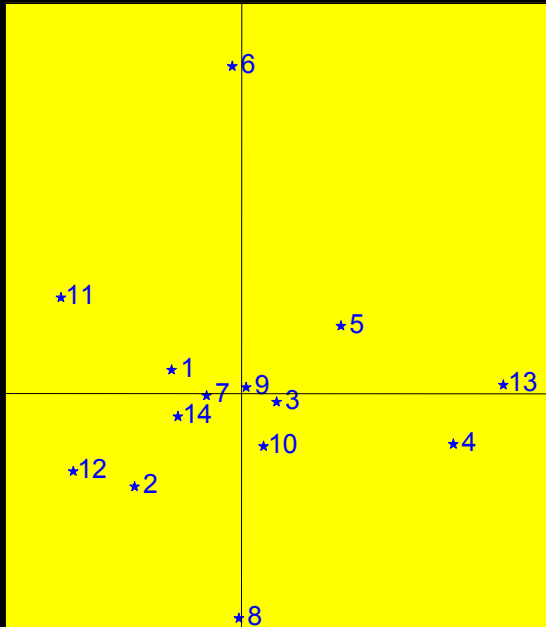
RV Panelist Map



RVD Panelist Map

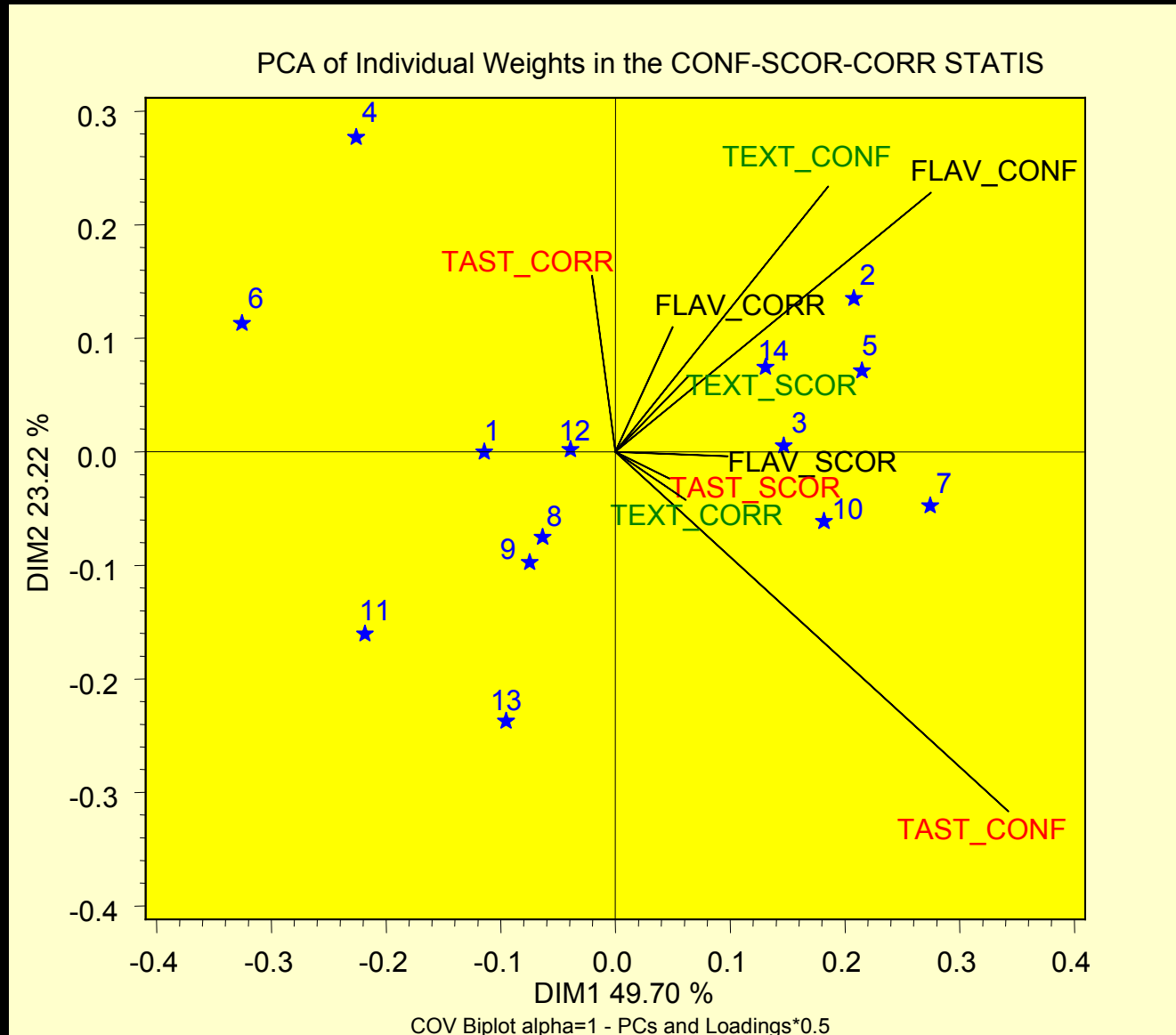


α Panelist Map



- Maps are clearly different
- Panelists 6, 8 and 13, who were the 3 reds on $N\alpha$, are apart on α -map
- RVD map useless since everybody agree
- RV map can be used to segment people with similar product configuration

Comparing individual weights from the 3 STATIS CONF-SCOR-CORR on the 3 sensory aspects



- CONF-SCORE-CORR different weights
- CONF weights more heterogeneous
- 2 groups of panelists along the first bisector
- Panelists 4 and 6 are special

Individual weights in Taste STATIS			
Panelist	CONF	SCOR	CORR
4	0.66	0.98	1.05
6	0.70	0.93	1.06
1	0.94	0.97	0.99
11	0.94	1.02	0.94
9	0.97	0.96	0.89
12	1.00	0.99	1.09
8	1.02	0.98	1.00
2	1.05	1.02	1.07
3	1.06	1.02	0.93
14	1.07	1.06	1.06
13	1.11	1.04	1.01
10	1.13	0.98	0.87
5	1.13	1.03	1.08
7	1.23	1.01	0.95

Panelists sorted by CONF weight

Finally, let's define
a unique and definitive method
for the analysis of sensory profiling data

Hahaha...
just kidding !

An e-barter deal as a conclusion



- We run these analysis for free on any dataset sent to us in a defined format
- We return quickly tables & plots seen in this presentation
- In exchange, we add the data to a sensory database currently in construction at CESG
- When large enough, this sensory database will be data mined for:
 - Documenting practices in descriptive analysis
 - Understanding panelist and panel proficiency
 - Benchmarking sensometric techniques

Interested to send data ?

just give me your card

or drop me a mail at schlich@cesg.cnrs.fr

The sensory database team:

Sylvie Cordelle
The database
architect

Nicolas Pineau
The dataminer

Delphine Brajon
The computer
brain

Pascal Schlich
The old-timer

