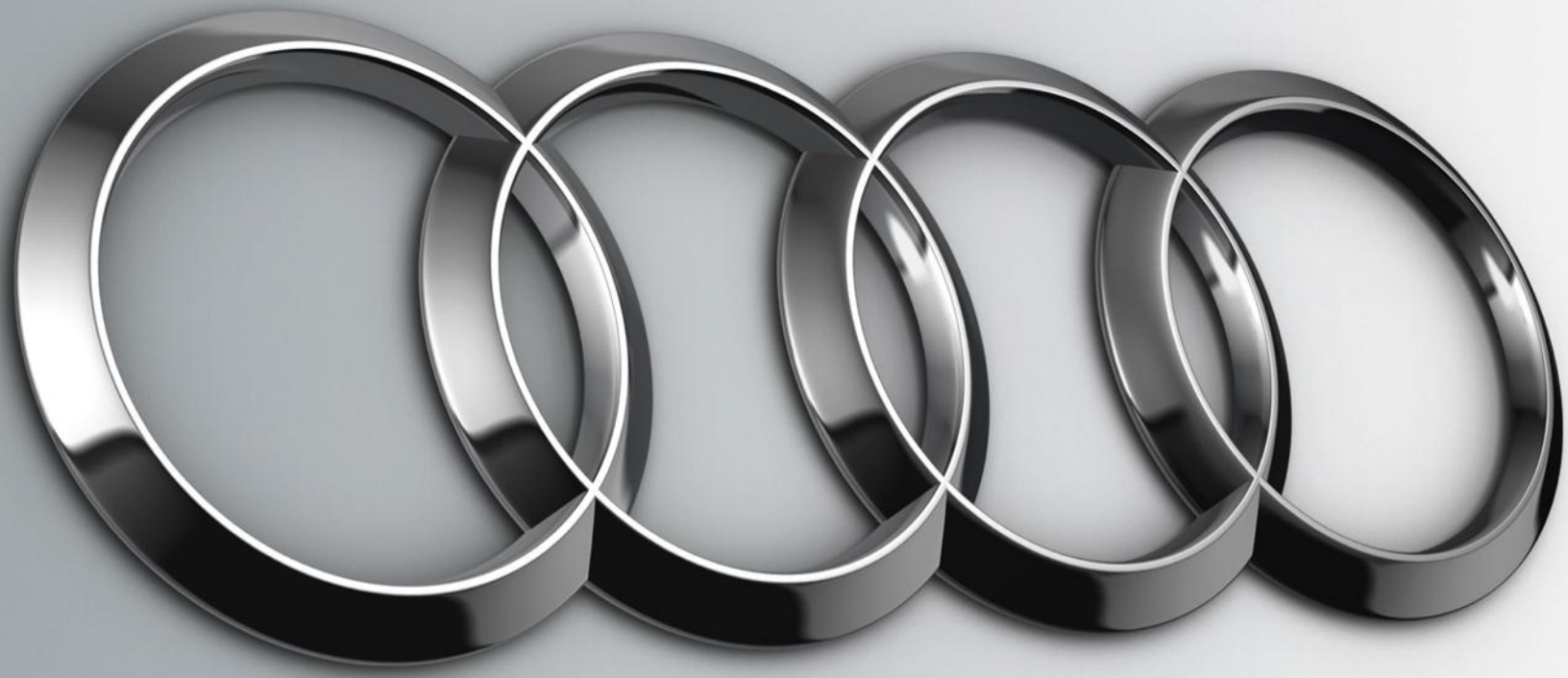
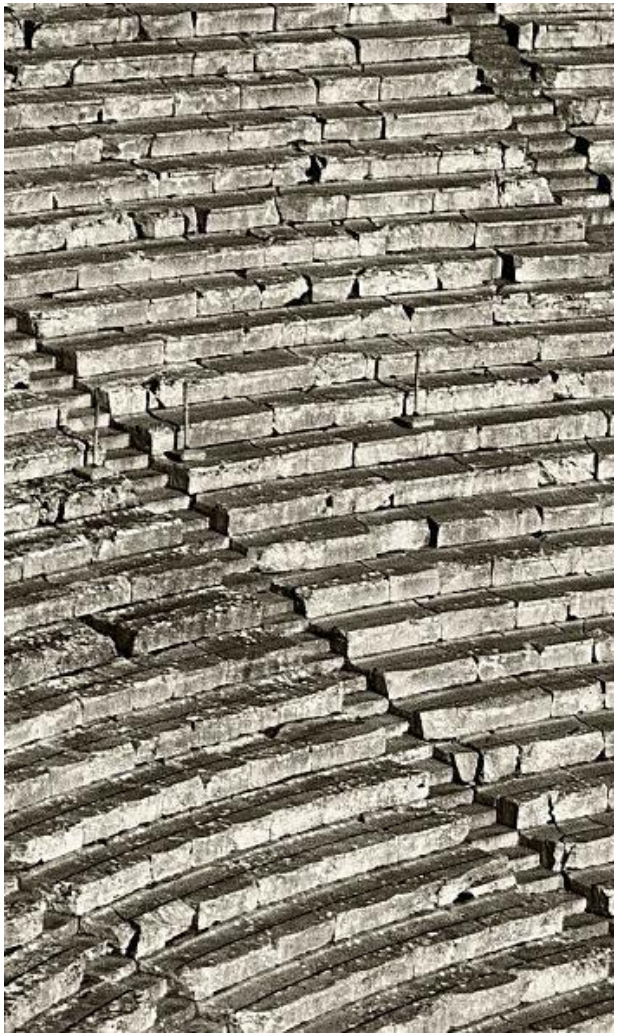
Audi
Vorsprung durch Technik



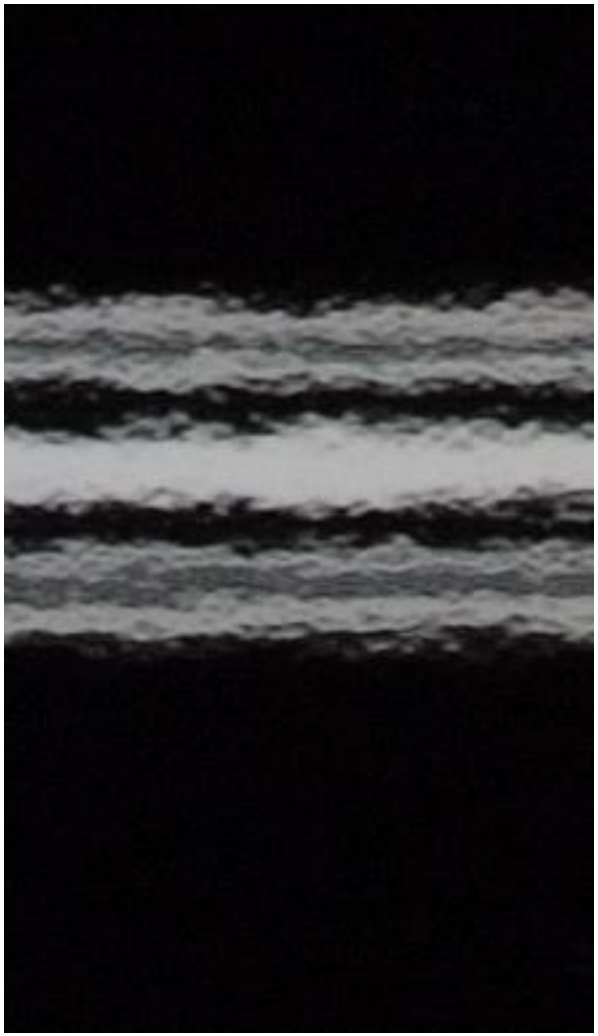
Paint Appearance - Perception, - Acceptance and Preference

What‘s common?



Source : TC-Allround.de, Greek Amphitheater

Source : NASA, South polar region of Epimetheus Saturn moon photographed on 12. 03.2007 by Cassini

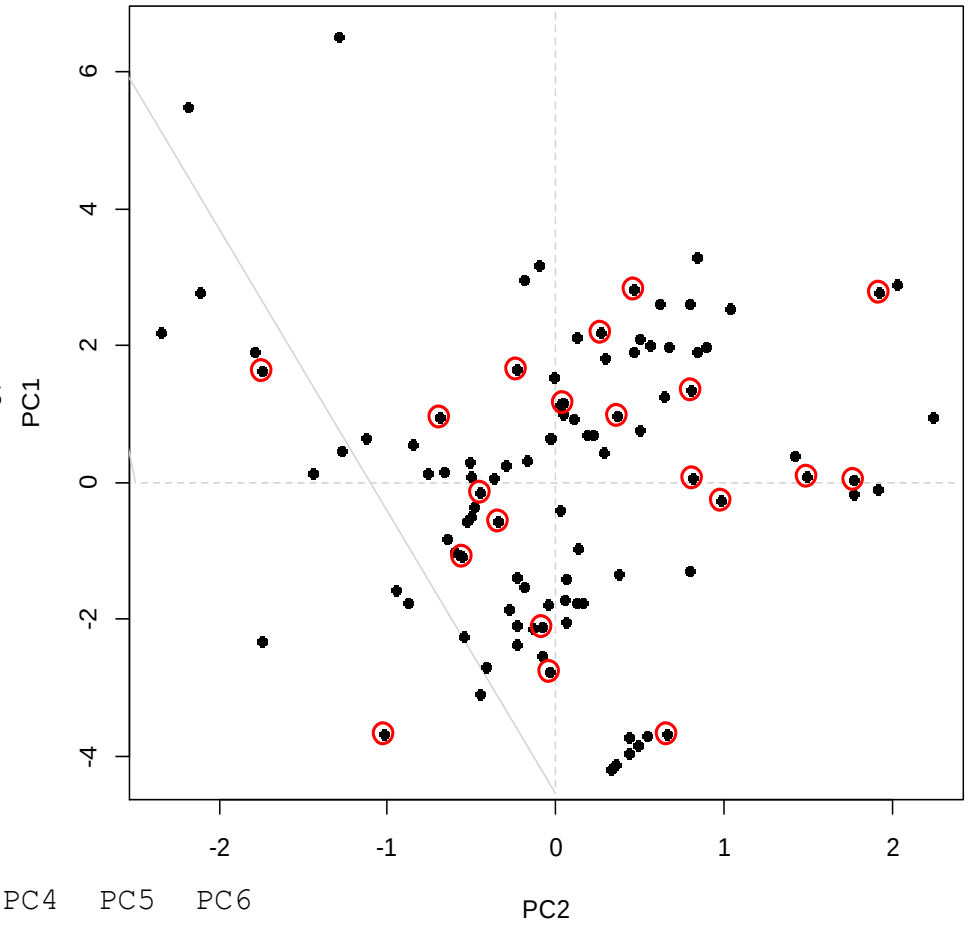


Objective of the experiment

- Development of a perception based structure space.
- Fitting the coordinates by Wave-Scan values.
- Estimation of limits for structure harmony.
- Analyzing the preference behavior.

Sample Selection

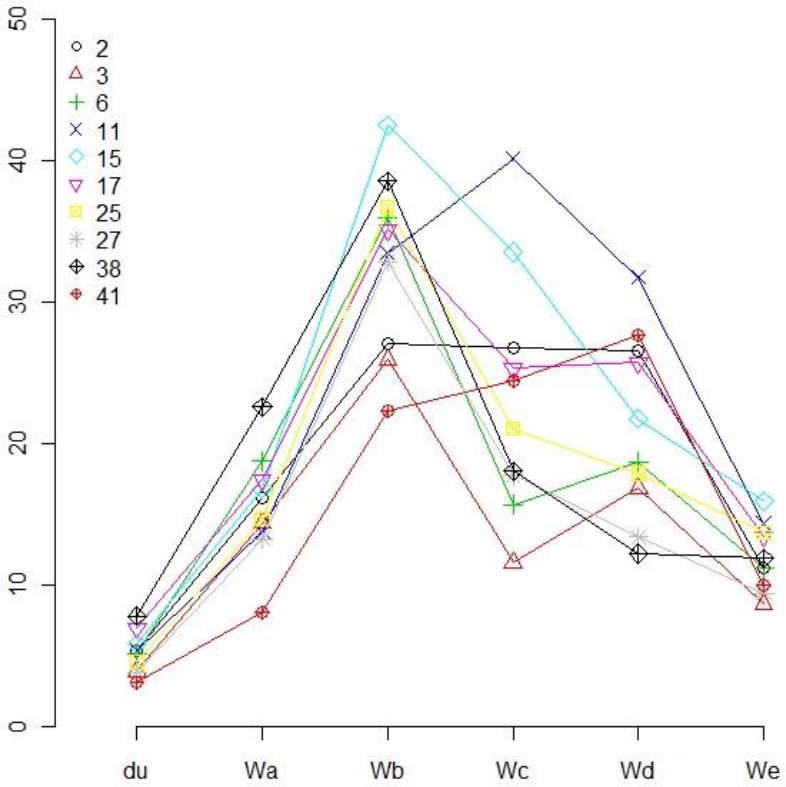
- Complete pair test.
- Reasonable number of assessable pairs is 190.
- How to select 20 representative panels out of 101 different structure panels?
- We used Principle Component Analysis to select representative panels.

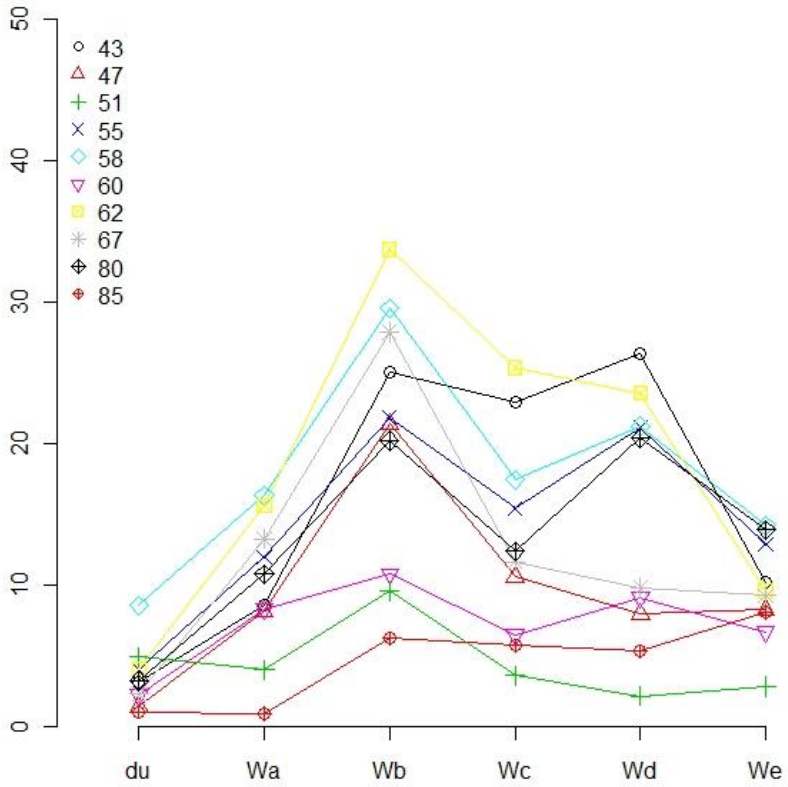



```
Importance of components:
                          PC1   PC2   PC3   PC4   PC5   PC6
Standard deviation     15.24 7.00 2.94 2.31 1.73 1.10
Proportion of Variance  0.78 0.16 0.03 0.02 0.01 0.00
Cumulative Proportion   0.78 0.94 0.97 0.99 1.00 1.00
```

Structure Spektra of selected Samples

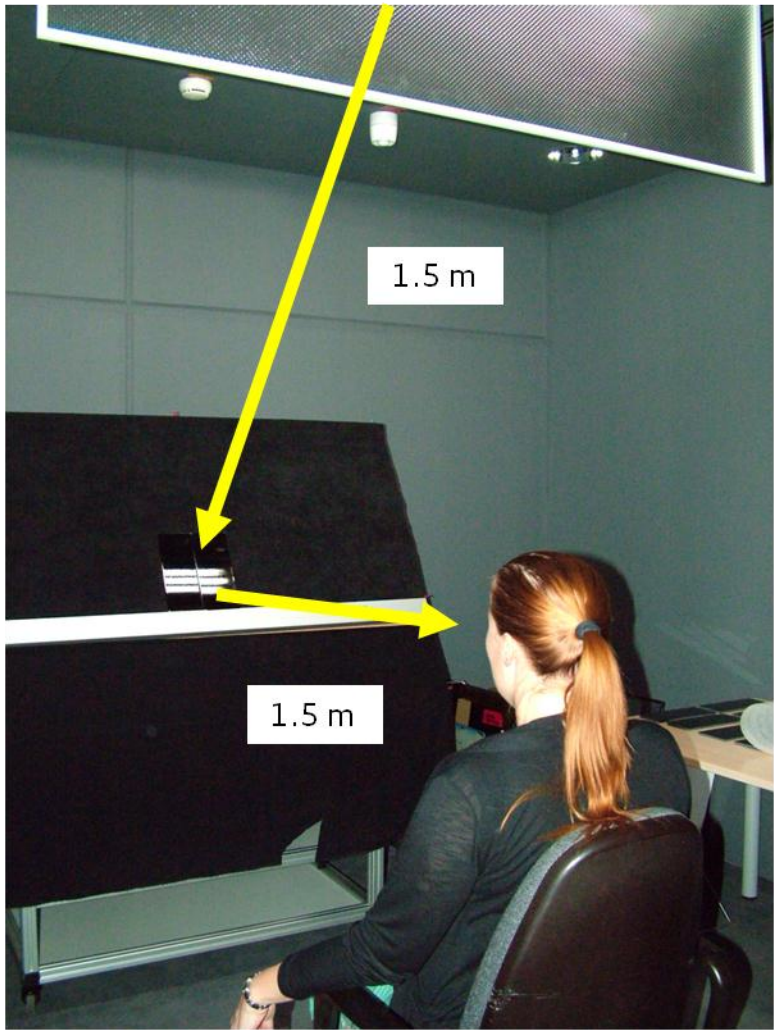
du	< 0.1mm	SW	0.3 – 1.2mm
Wa	0.1 – 0.3 mm	LW	1.2 – 12mm
Wb	0.3 – 1.0mm		
Wc	1.0 – 3.0mm		
Wd	3.0– 10mm		
We	10 – 30mm		





Viewing Conditions

- Single fluorescent lamp.
- Triple reflection due to reflector.
- Viewing distance approximately control distance of cars.
- 43 test persons in total.

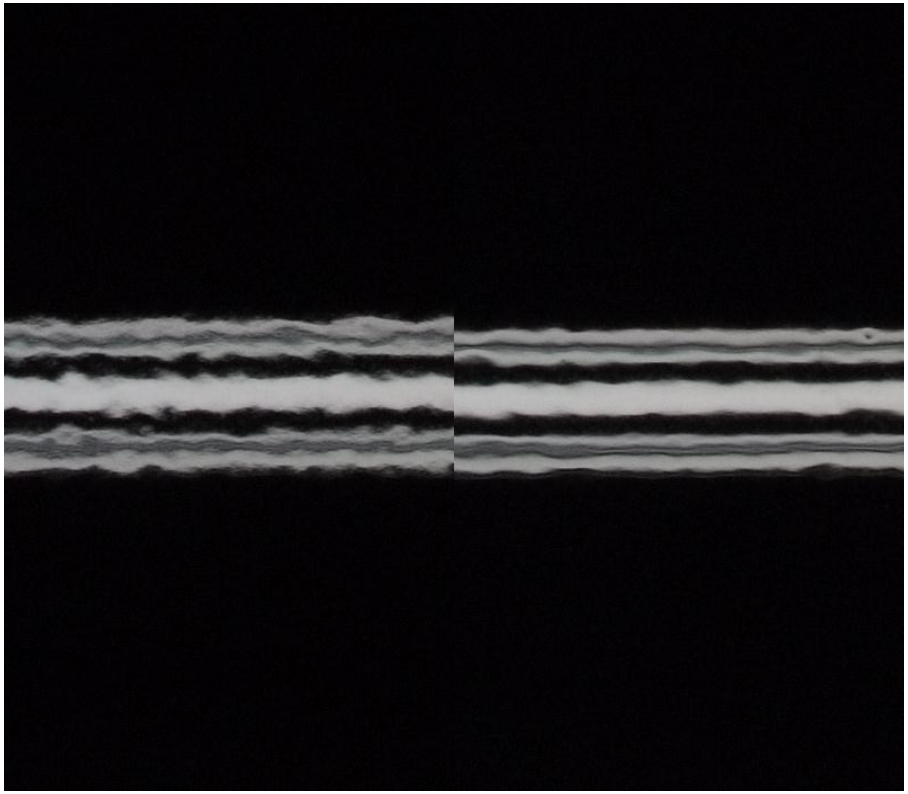


Assessment Tasks

- Rate the resemblance of the two structure on a scale of 0 to 10.
  0 = no difference,
  10 = no resemblance.

- Would you accept the presented difference between two adjacent car parts?

- Which structure do you prefer?

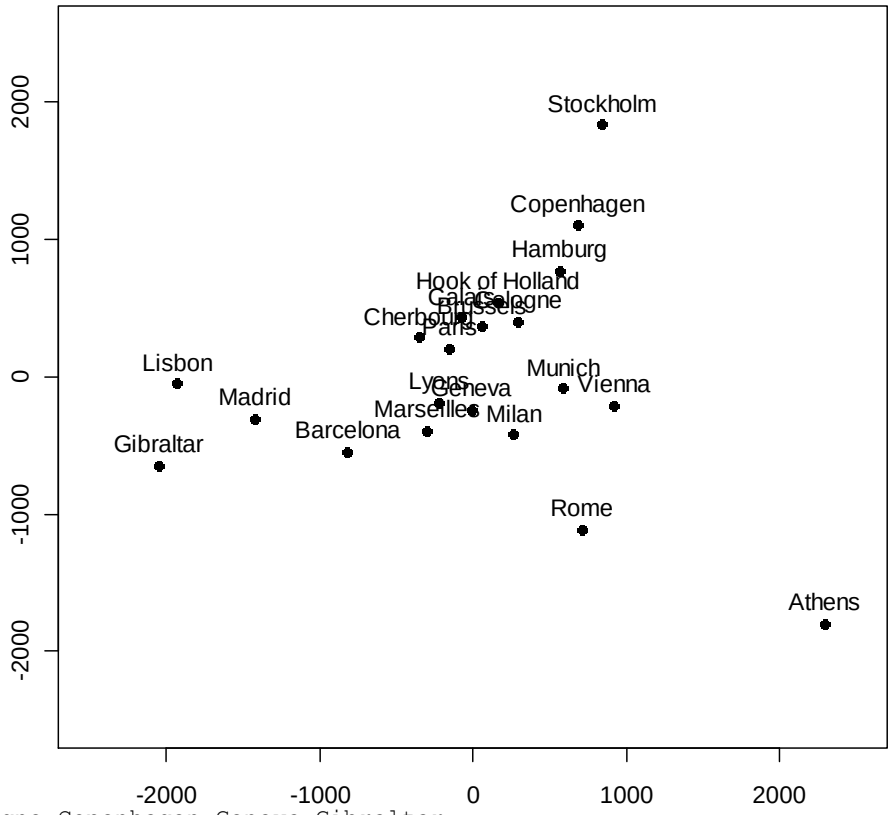


Multidimensional Scaling

We used MDS to unfold the perception space from the estimated distances of the 190 pairs. Doing this an equidistant space is to be obtained.

To link the perception space to physical parameters, we used linear regression to combine the perception coordinates with the Wave-Scan values.

If MDS is applied on city distances the coordinates of the cites can be reconstructed. .

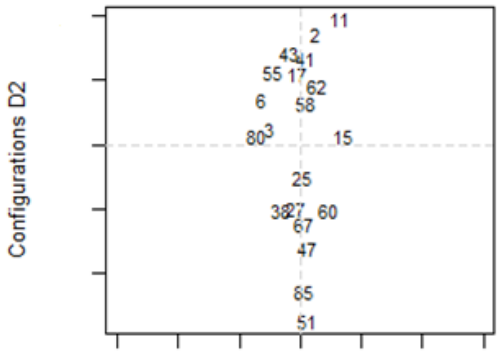


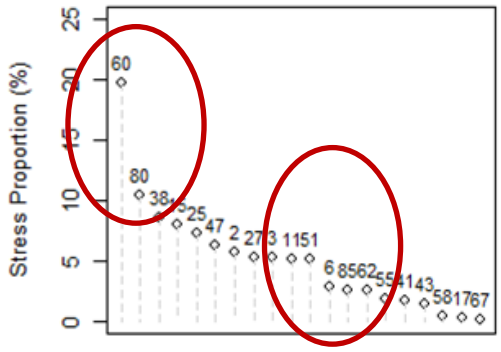
	Athens	Barcelona	Brussels	Calais	Cherbourg	Cologne	Copenhagen	Geneva	Gibraltar
Barcelona	3313								
Brussels	2963	1318							
Calais	3175	1326	204						
Cherbourg	3339	1294	583	460					
Cologne	2762	1498	206	409	785				
Copenhagen	3276	2218	966	1136	1545	760			
Geneva	2610	803	677	747	853	1662	1418		
Gibraltar	4485	1172	2256	2224	2047	2436	3196	1975	
Hamburg	2977	2018	597	714	1115	460	460	1118	2897

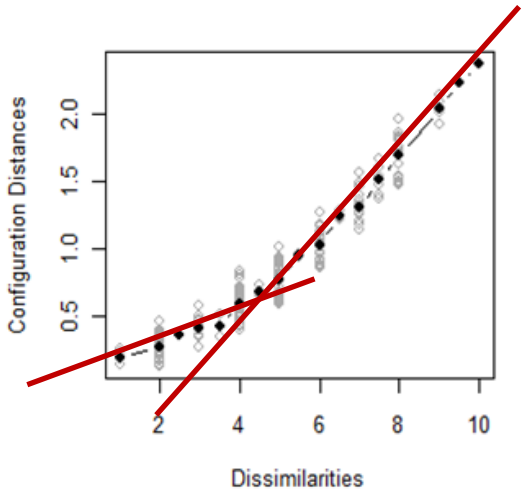
Results

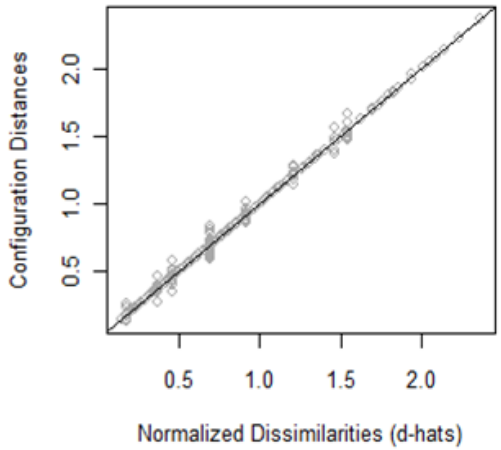
Perceptional Structure Space

Structure Space of the Average Test Person









Very good fit of dimension 2.
R^2= 0.97

Poor fit of dimension 1.
R^2 = 0.66

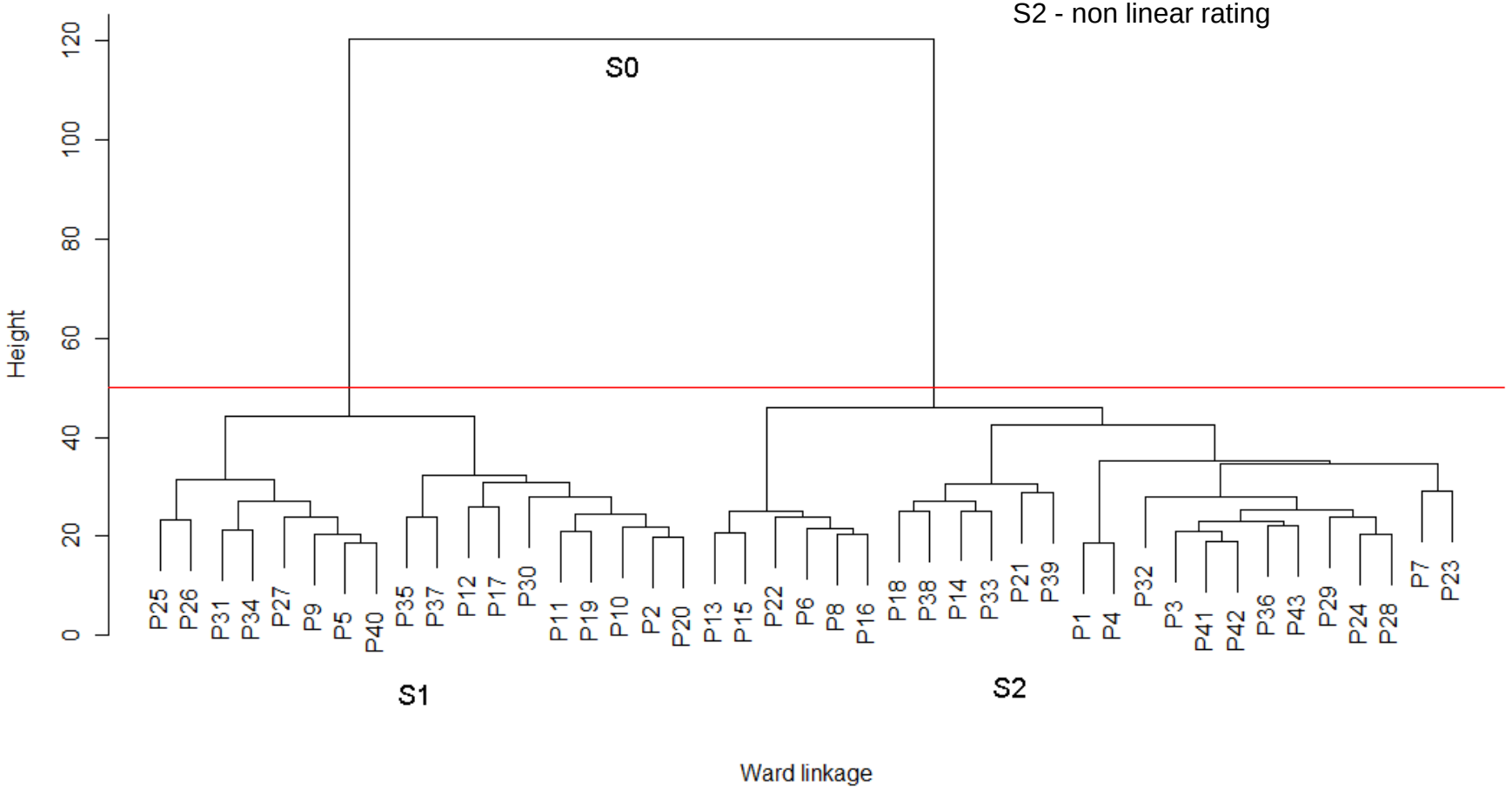
Diagnostic graphs show curiosities.

- Non linear scoring . Small differences . More severe for small differences and generous for big differences in structure.
- No homogeneous reconstruction for all panels. #60 and #51 unusual.

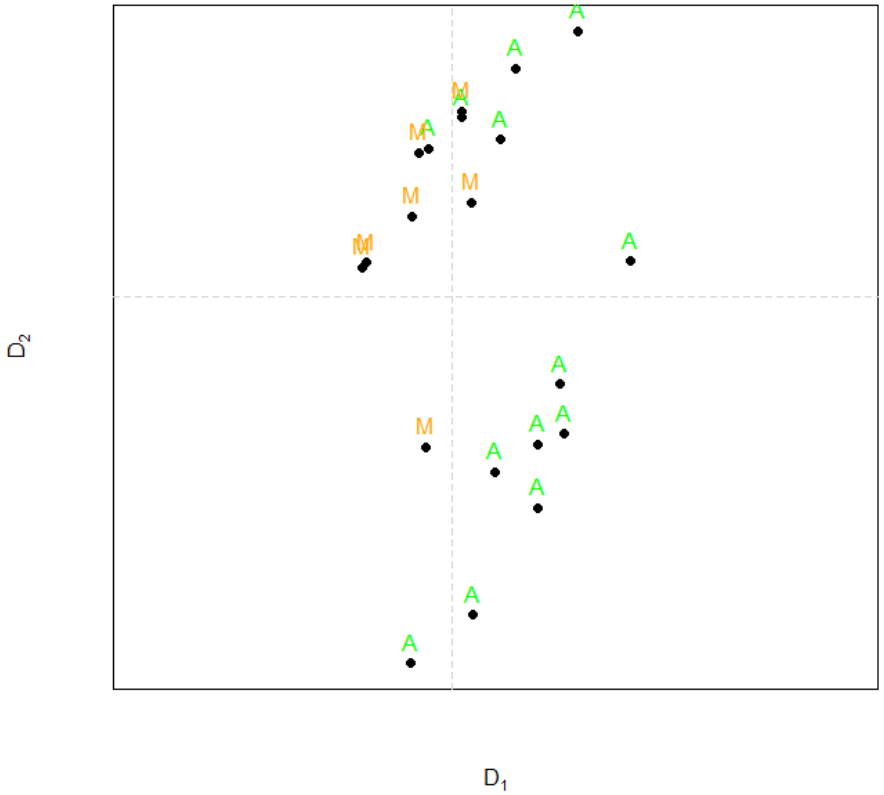
Looking for Group Effects

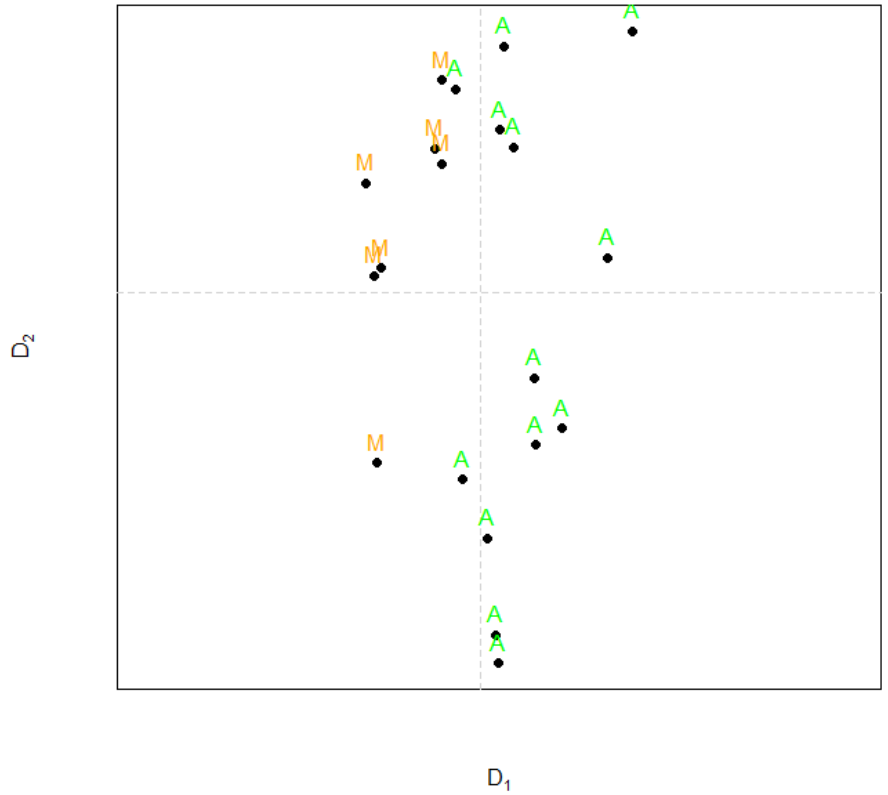
Applying a cluster analysis on the scoring of the test persons yields two groups.

S1 - linear rating
S2 - non linear rating

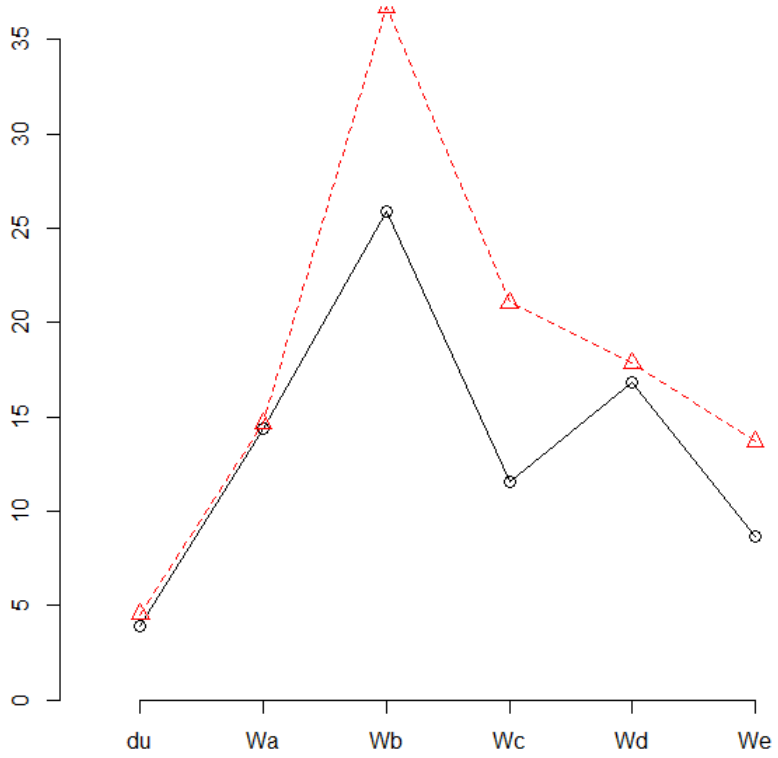


Perception Spaces of Group S_1 and S_2

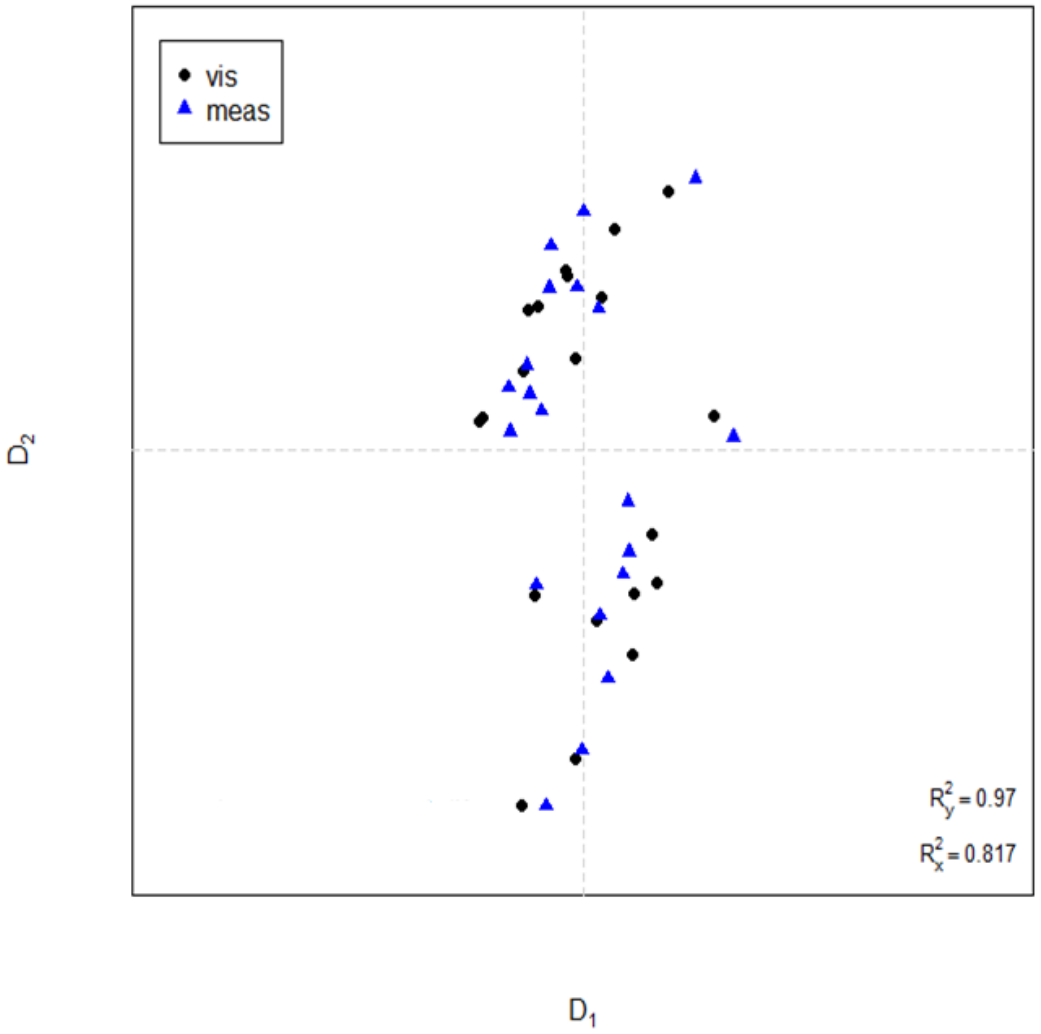




Structure Characteristic M-Type And A-Type



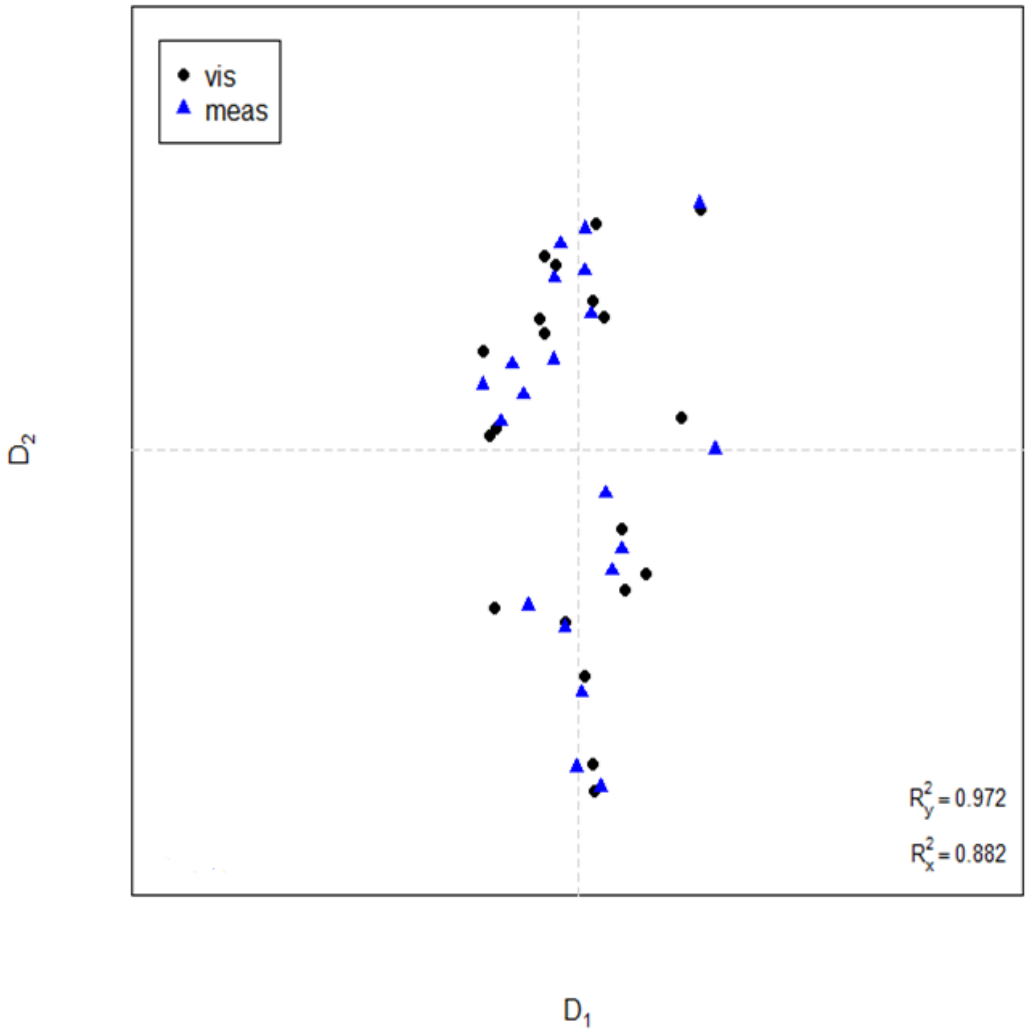
Perception Space S_1 and Property Fitting



$D_2 = a_2\,Wa + a_5 Wd - a_1 du - a_6\,We + a_0$

$D_1 = b_4\,Wc + b_6 We - b_1 du - b_5 Wd + b_0$

Perception Space S_2 and Property Fitting



$$D_2 = a_2\,Wa + a_5 Wd - a_3 Wb - a_6\,We + a_0$$

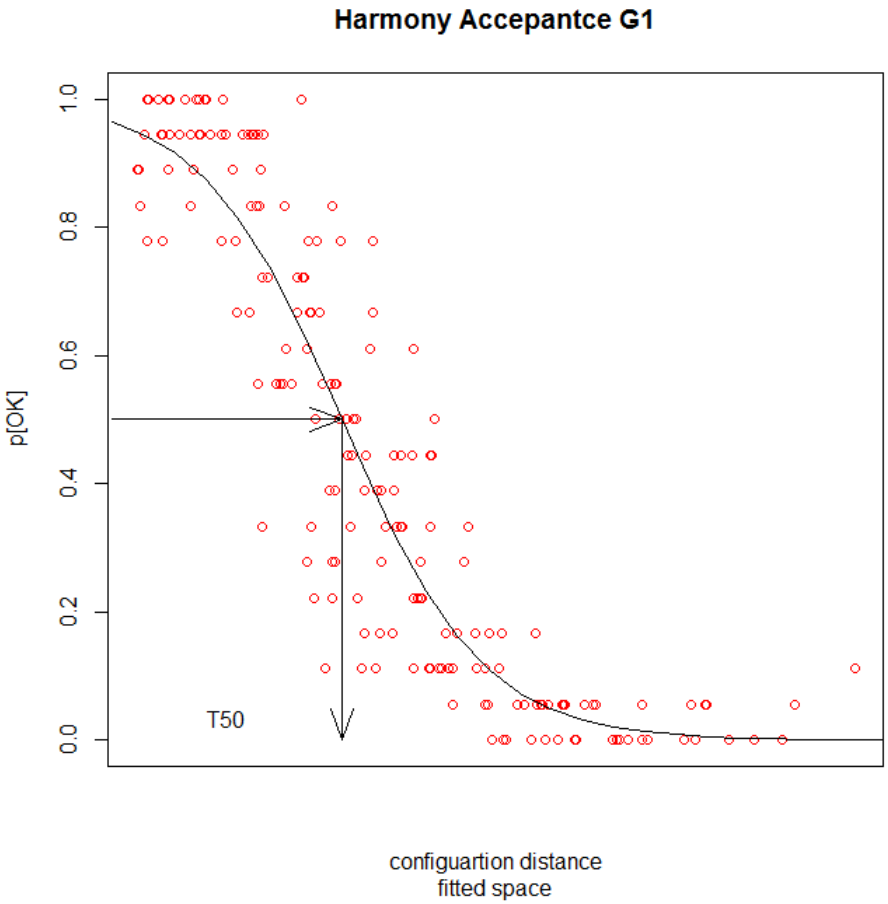
$$D_1 = b_1\,du + b_4 Wc - b_2 Wa - b_5 Wd + b_0$$

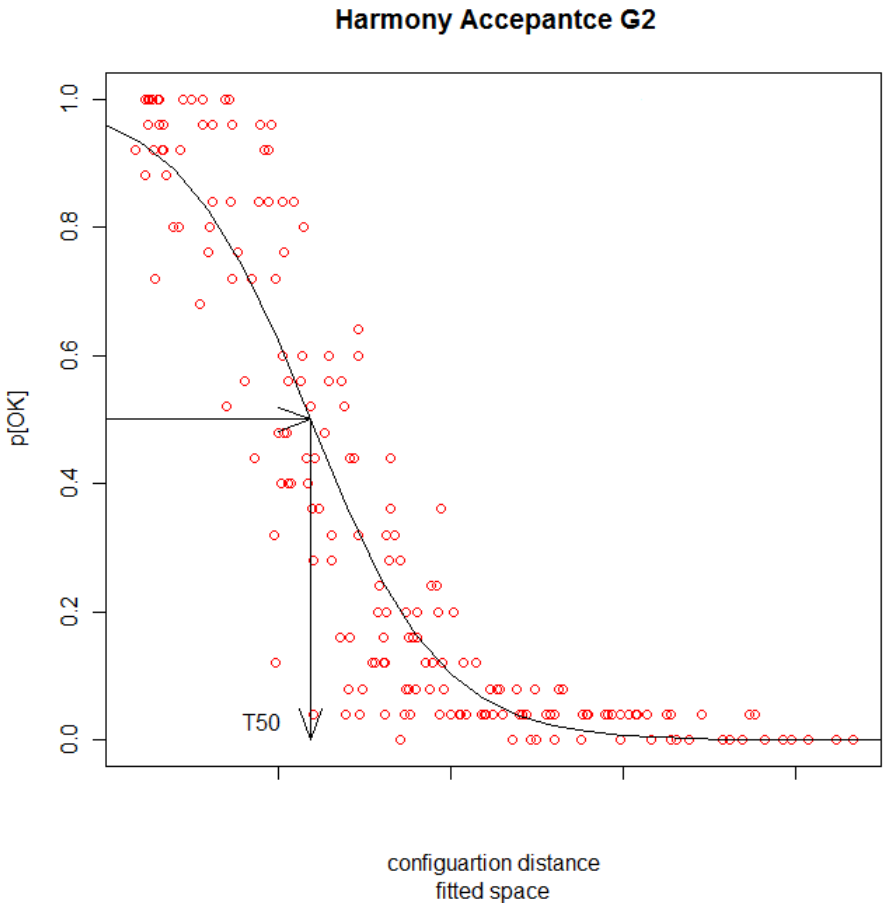
Summary Perception Space

- The structure perception is different to all known transformations.
  - The dimensions are:
    - Total waviness
    - Structure characteristic
- The new structure space can be described by Wave-Scan values du, Wa…We.
- A description by balance and waviness was not significant!
- Even distance rating is highly subjective!
  - Part of the test persons score small differences more severe than bigger ones.
  - Another part of the test persons score homogeneous.

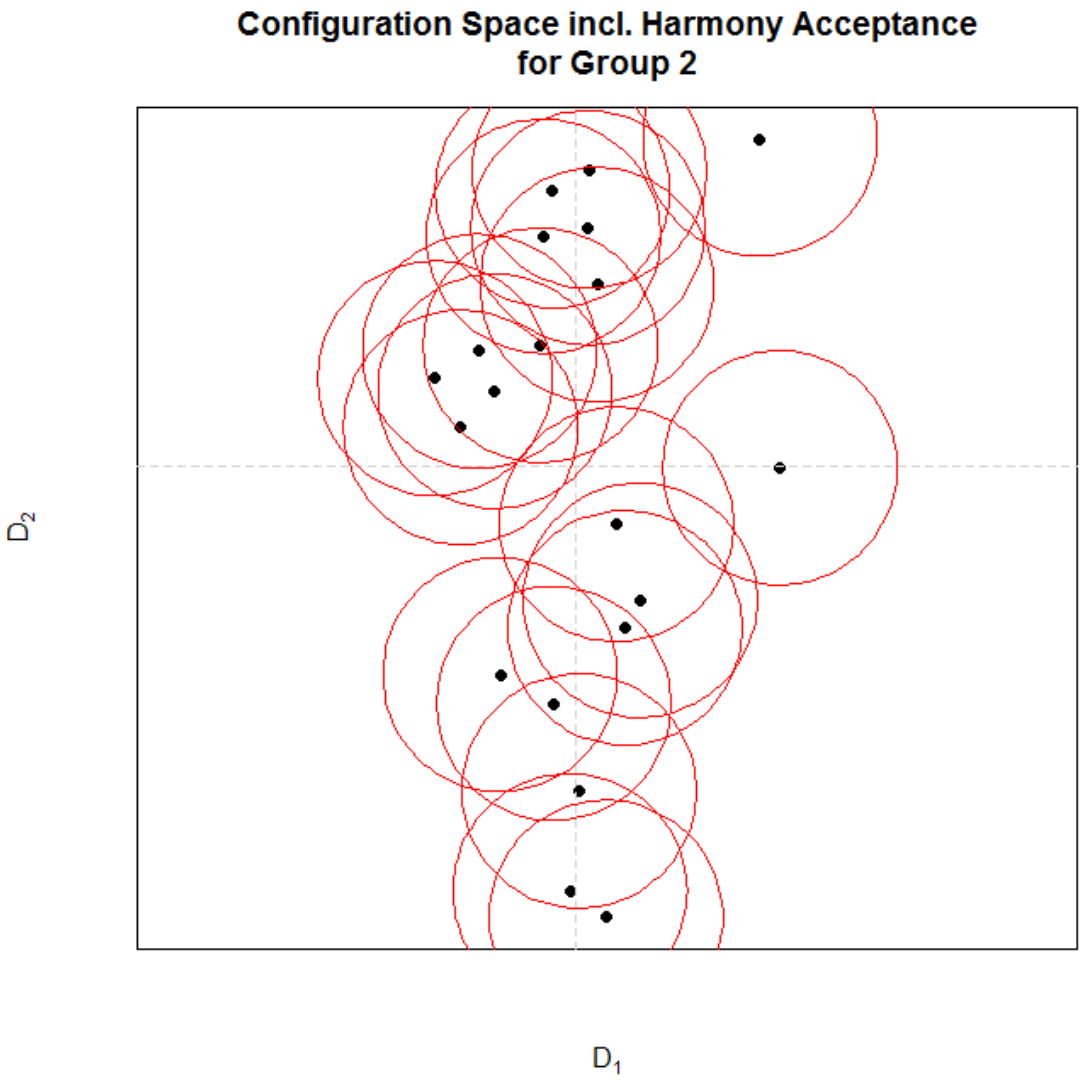
Structure Harmony Acceptance

Structure Harmony Tolerance





Example: Harmony Tolerances for Independent Processes



Example: Structure Space S_2

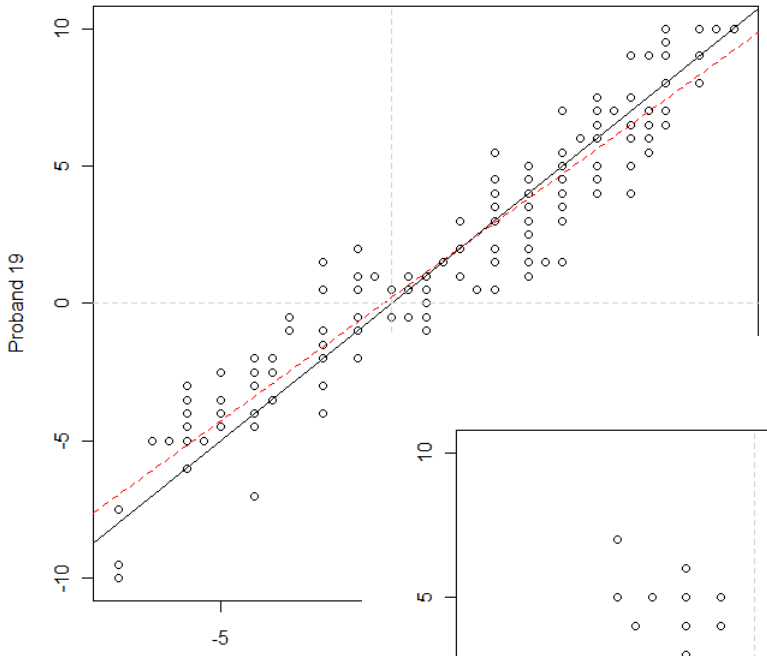
Only structure differences within a circle would be accepted between adjoining parts.

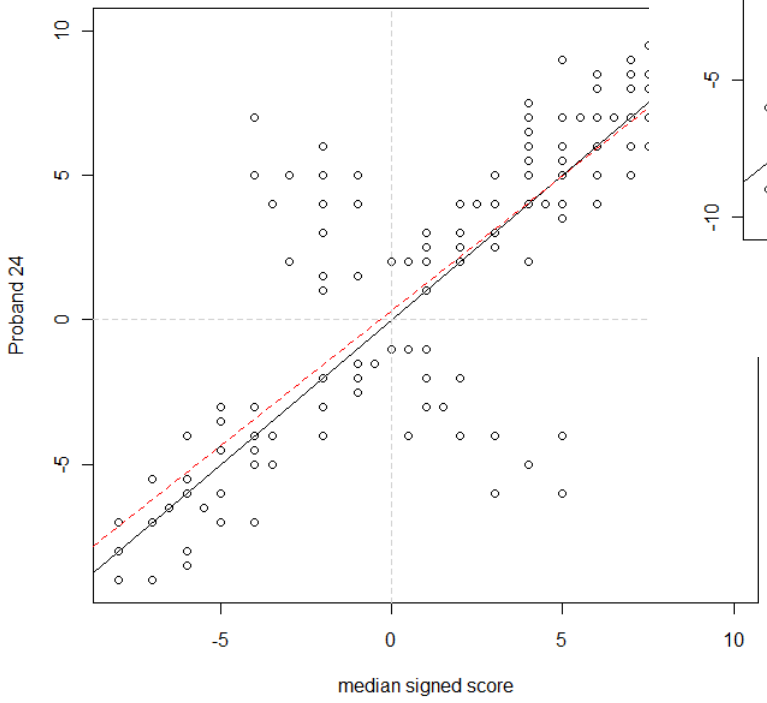
Summary

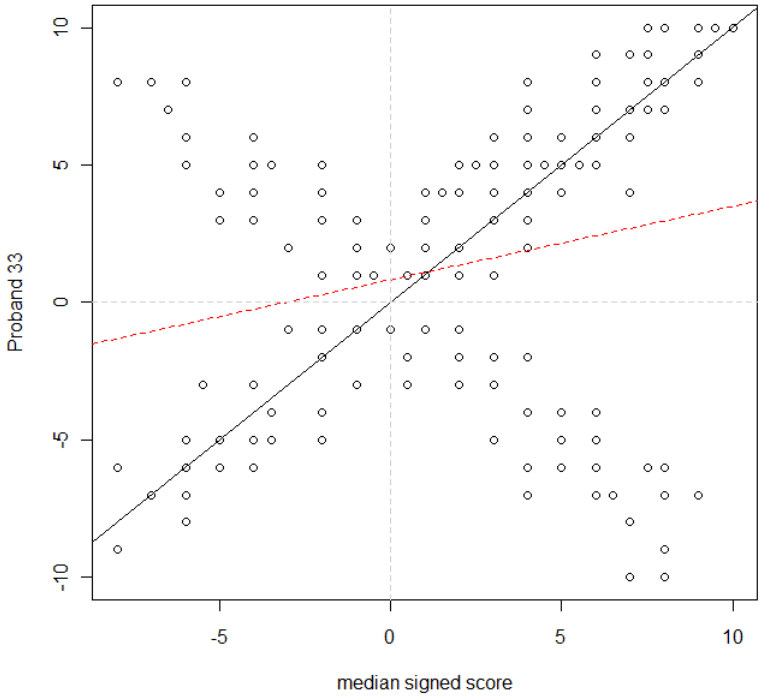
- Based on the new structure space it is easy to specify tolerances for adjacent car parts.
- The assessment showed that the tolerances are much smaller than tolerances established at the moment.
- This would imply the necessity of specifying a reference structures similar to color references.

Structure Preference

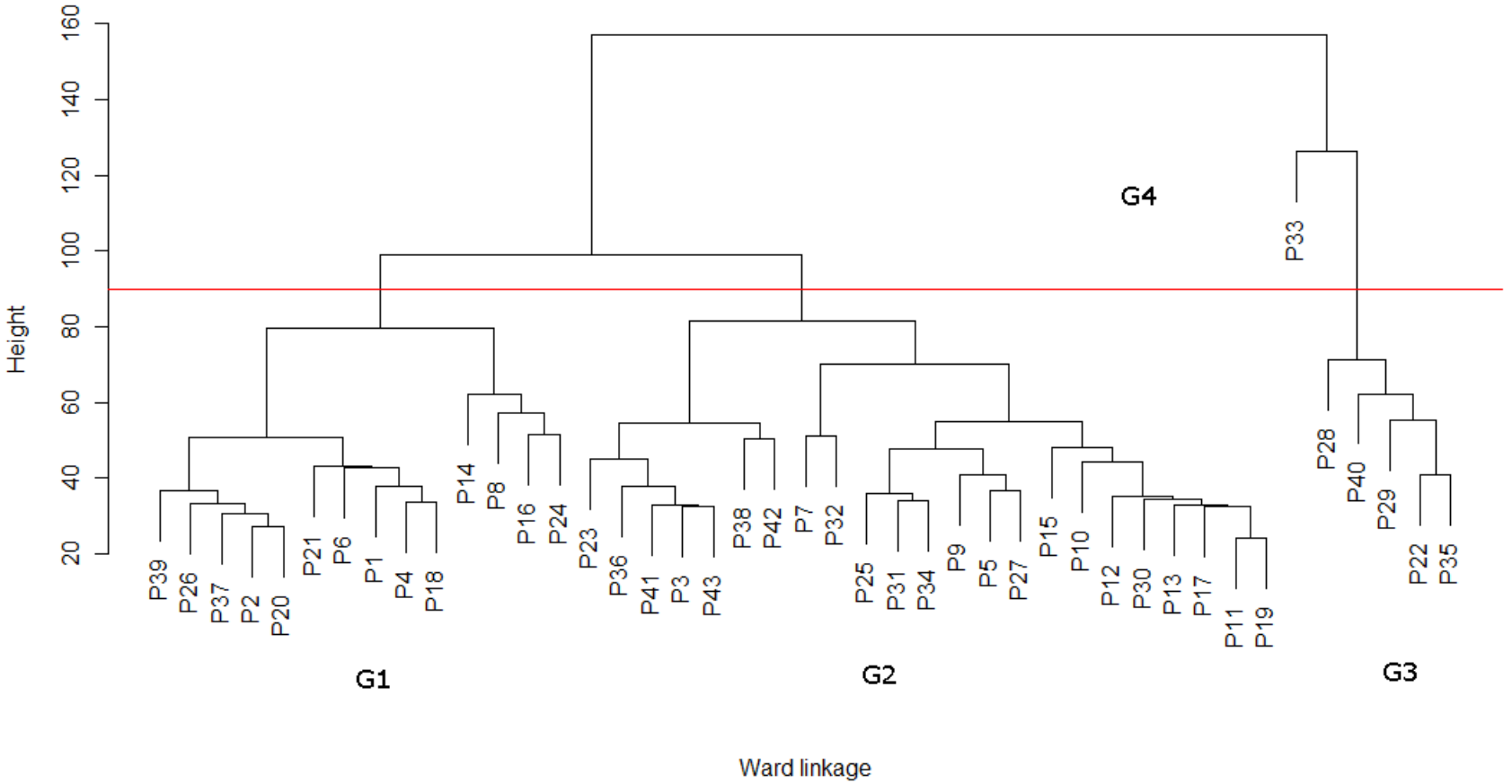
Example: Different Preference of Test Persons







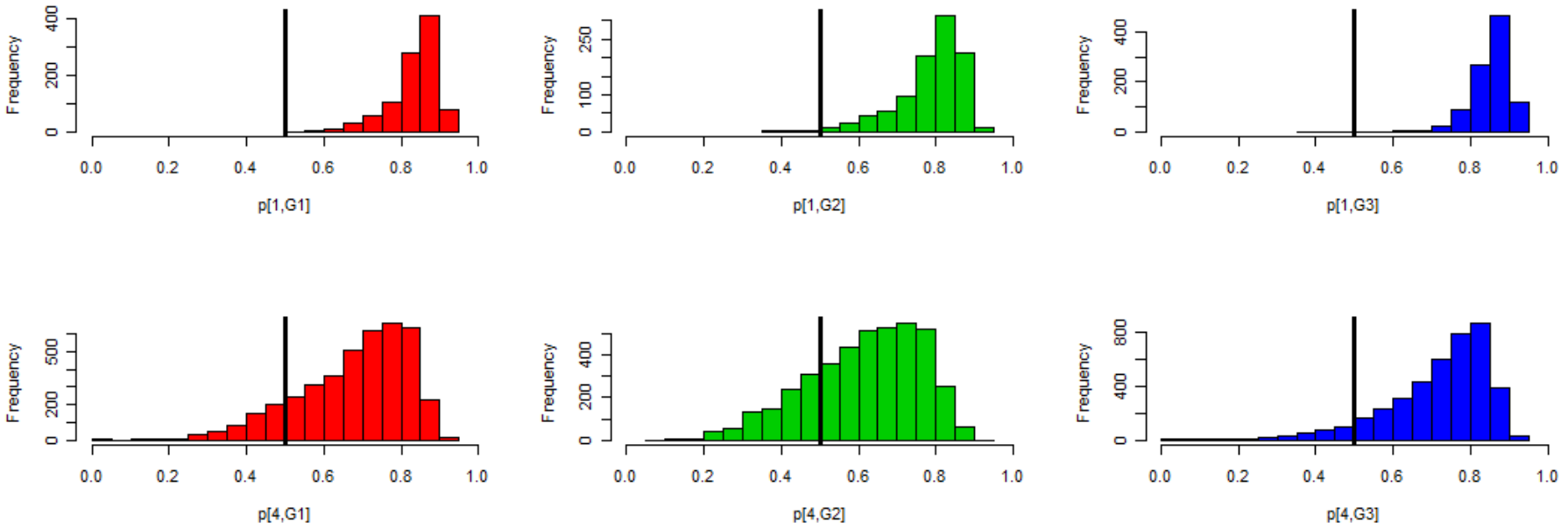
Preference Groups



Preference

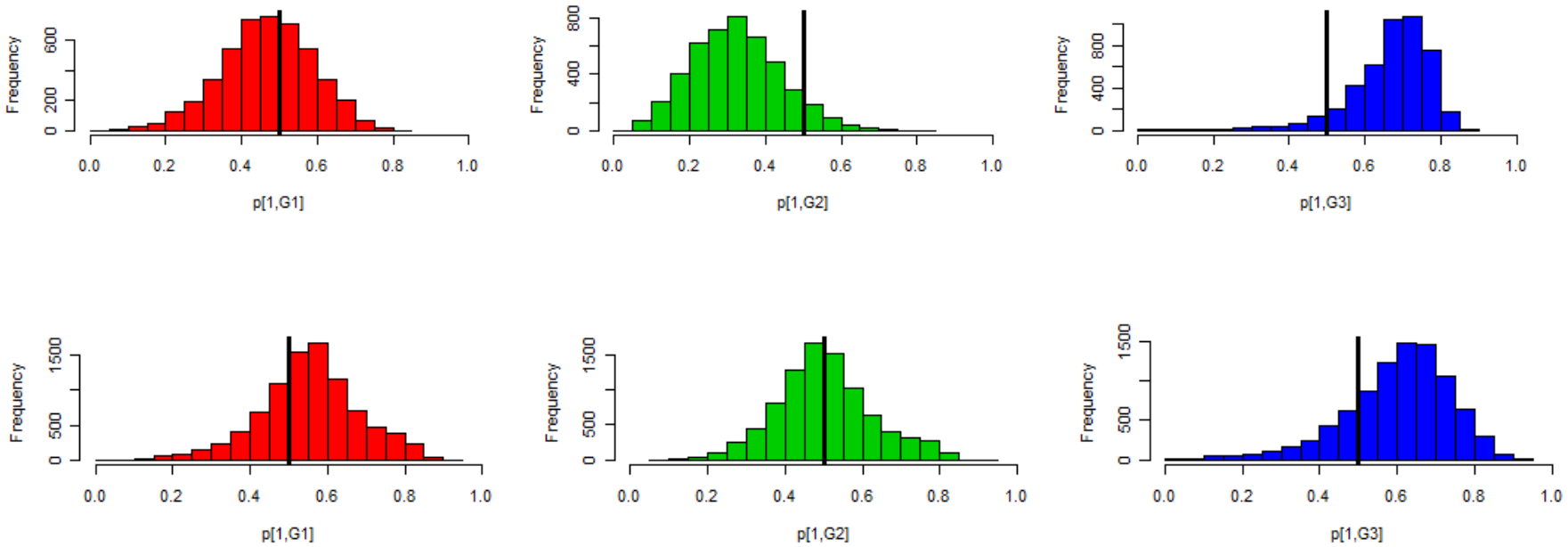
- Persons of group 3 prefer smooth surfaces with a high DOI and therefore with low shortwaviness.
- Persons of group 2 are the counterpart of group 3. They detest visible longwaviness and accept high amounts of shore waviness. Even a certain dullness is accepted as.
- Group 1 is somewhere in between the two groups. The test persons prefer harmonic structures without much dominance of either longwave or shortwave. Up to a certain degree they accept some shortwaviness and are therefore closer related to group 2 than to group 1.
- All groups have one thing in common: the smoother the surface the higher the preference.
- The preference only shows up if the total waviness is approximately the same.
- The preference probability for every group can be calculated with high accuracy using the Wave-Scan values du, Wa…We.

Preference and Production Monitoring
Example: 2 different paint lines – horizontal parts



The figure show the preference probability for the 3 group of every measured horizontal part

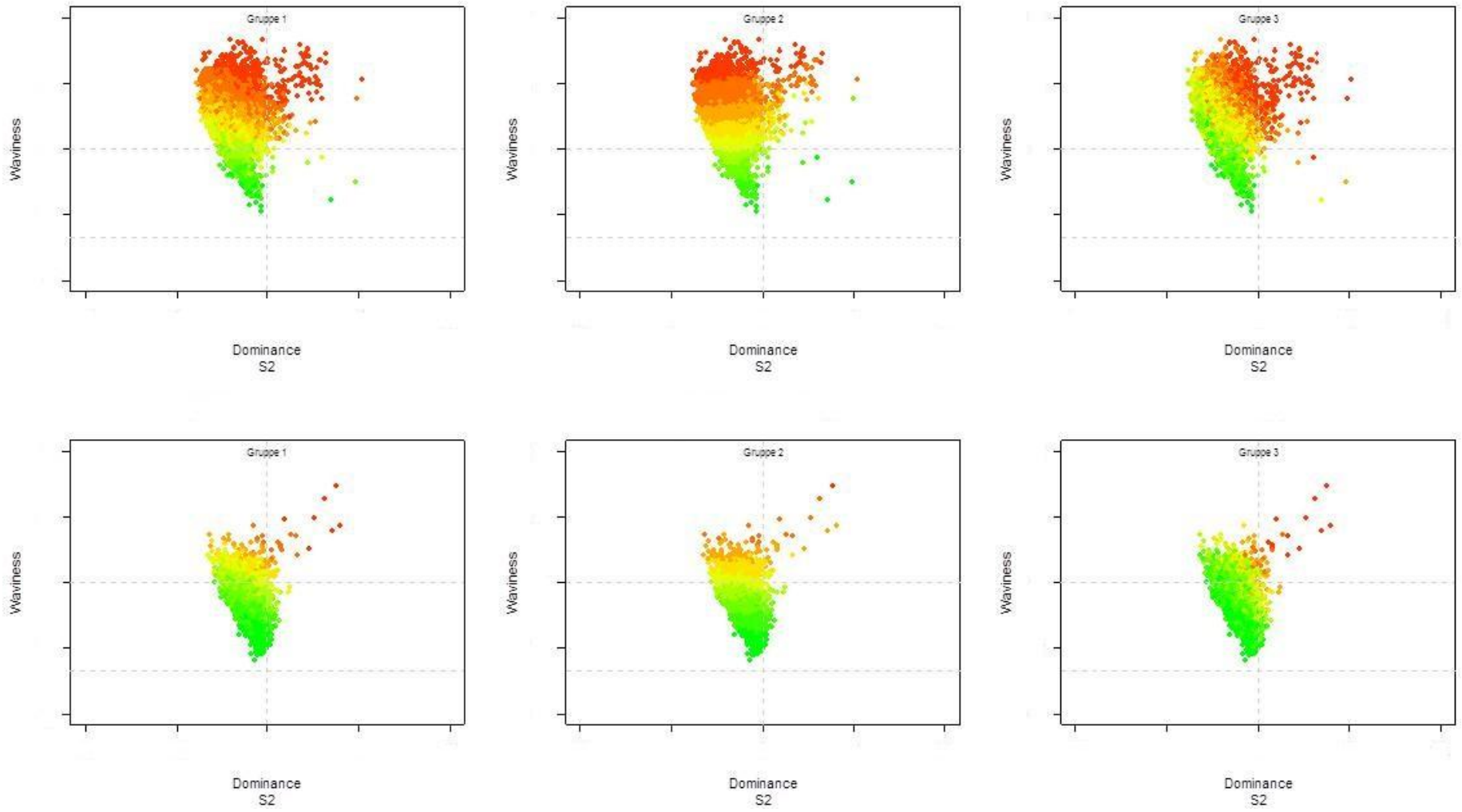
Preference and Production Monitoring
Example: 2 different paint lines – vertical parts



The figure show the preference probability for the 3 group of every measured vertical part

Preference Probability and Perception Space

Group 1 | Group 2 | Group 3



Summary

- 3 different structure preference types:
  - Smooth structures with high DOI (G_3) (~10%).
  - Visually smooth, but high shortwaviness (G_2) (~50%).
  - Harmonic structures- not too dull yet no obvious longwaviness (G_1) (~40%).
- For parts of the test persons the claim Wb helps to hide longwaviness is proven.
- All preference type can be described by Wave-Scan values
- All types have one in common: he less the waviness the better the structure is rated! In case of similar waviness the preference decides.

Audi
Vorsprung durch Technik

Thank you.