

SensoMineR

A package for sensory data analysis with R

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Sensory analysis

- *Sensory Analysis (or Sensory Evaluation) is a scientific discipline that applies principals of experimental design and statistical analysis to the use of human senses (sight, smell, taste, touch, hearing) for the purposes of evaluating consumer products.*

A typical sensory data table

6 Chocolates (Lindt)
14 variables (descriptors)

29 panelists
2 sessions

| Session | Panelist | Rank | Product | CocoaA | MilkA | CocoaF | MilkF | Caramel | Vanilla |
|---------|----------|------|---------|--------|-------|--------|-------|---------|---------|
| 1 | 1 | 1 | choc6 | 7 | 6 | 6 | 5 | 5 | 3 |
| 1 | 1 | 2 | choc4 | 8 | 5 | 4 | 4 | 4 | 4 |
| 1 | 1 | 3 | choc2 | 8 | 6 | 5 | 4 | 7 | 4 |
| 1 | 1 | 4 | choc5 | 7 | 5 | 3 | 5 | 6 | 2 |
| 1 | 1 | 5 | choc1 | 7 | 8 | 8 | 3 | 3 | 2 |
| 1 | 1 | 6 | choc3 | 6 | 7 | 2 | 7 | 8 | 4 |
| 1 | 2 | 1 | choc4 | 6 | 1 | 8 | 1 | 0 | 0 |
| 1 | 2 | 2 | choc5 | 4 | 1 | 7 | 1 | 0 | 0 |
| 1 | 2 | 3 | choc6 | 5 | 1 | 8 | 1 | 0 | 0 |
| 1 | 2 | 4 | choc3 | 4 | 2 | 3 | 4 | 0 | 0 |
| 1 | 2 | 5 | choc2 | 5 | 2 | 8 | 1 | 0 | 0 |
| 1 | 2 | 6 | choc1 | 6 | 1 | 8 | 0 | 0 | 0 |
| 1 | 3 | 1 | choc2 | 8 | 1 | 6 | 2 | 6 | 1 |
| 1 | 3 | 2 | choc6 | 5 | 6 | 5 | 3 | 3 | 2 |
| 1 | 3 | 3 | choc1 | 8 | 2 | 8 | 1 | 3 | 1 |
| 1 | 3 | 4 | choc4 | 6 | 1 | 5 | 0 | 5 | 2 |
| 1 | 3 | 5 | choc3 | 5 | 3 | 2 | 9 | 6 | 7 |
| 1 | 3 | 6 | choc5 | 7 | 2 | 7 | 3 | 6 | 3 |
| 1 | 4 | 1 | choc1 | 9 | 2 | 9 | 1 | 6 | 0 |

SensoMineR

- SensoMineR tackles the following problems:
 - assessing panel performances
 - characterizing products
 - relating sensory data and instrumental data
 - mapping consumers' preferences
 - categorizing products

Analysis of variance model

$$\forall (i, j, k) \quad Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \varepsilon_{ijk}$$

$$L(\varepsilon_{ijk}) = N(0, \sigma) \quad \text{and} \quad \text{cov}(\varepsilon_{ijk}, \varepsilon_{i'j'k'}) = 0 \quad \forall (i, j, k) \neq (i', j', k')$$

where:

- μ the general mean
- α_i the product effect
- β_j the judge effect
- γ_k the session effect
- $\alpha\beta_{ij}$ the product:judge interaction effect
- $\alpha\gamma_{ik}$ the product:session interaction effect
- $\beta\gamma_{jk}$ the judge:session interaction effect

Characterization of products

Anova with the following model (for CocoaA variable):

$$\text{Score} = \text{Product} + \text{Panelist} + \text{Session} + \text{Prod:Sess} + \text{Prod:Pan} + \text{Pan:Sess}$$

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|-----------|-----|--------|---------|---------|-----------|
| Product | 5 | 207.54 | 41.51 | 11.8830 | 7.752e-13 |
| Panelist | 28 | 390.43 | 13.94 | 3.9919 | 2.552e-08 |
| Session | 1 | 3.72 | 3.72 | 1.0662 | 0.3036 |
| Prod:Pan | 140 | 322.29 | 2.30 | 0.6590 | 0.9929 |
| Prod:Sess | 5 | 8.14 | 1.63 | 0.4659 | 0.8011 |
| Pan:Sess | 28 | 72.11 | 2.58 | 0.7373 | 0.8256 |
| Residuals | 140 | 489.03 | 3.49 | | |

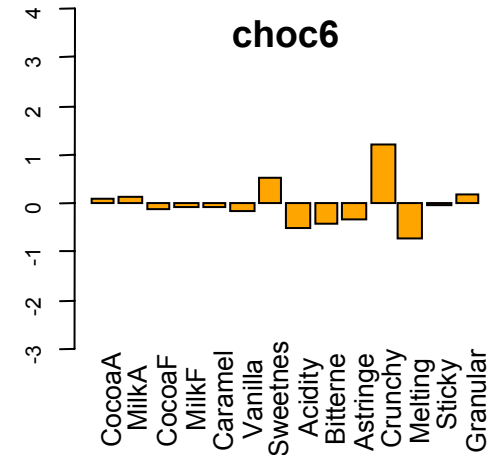
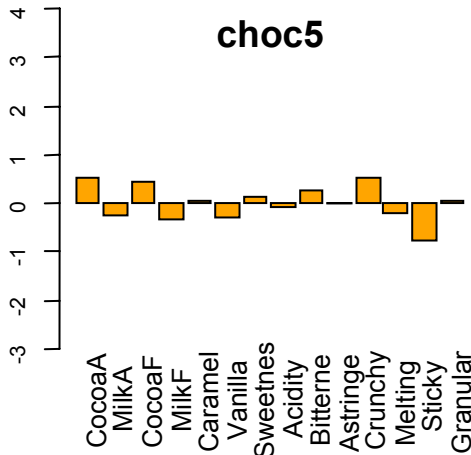
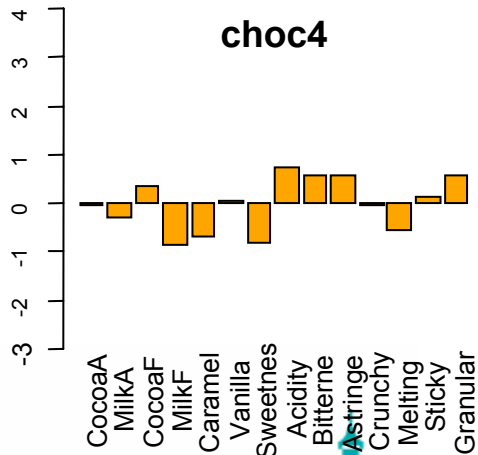
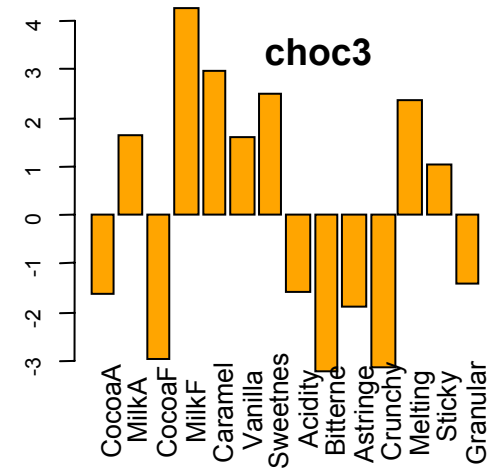
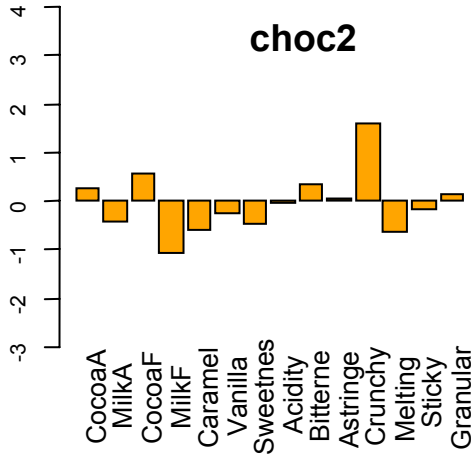
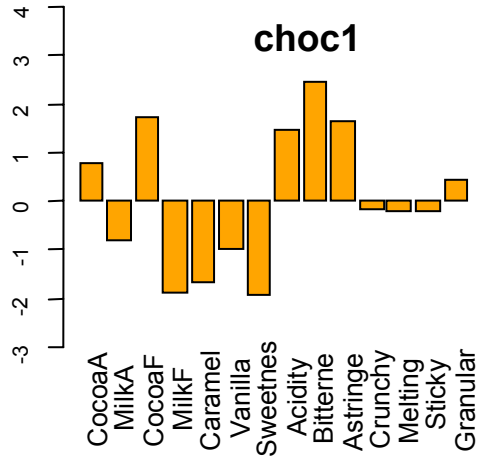
| Coefficients: | Estimate | Std. Error | t value | Pr(> t) |
|---------------|-----------|------------|---------|----------|
| (Intercept) | 6.287356 | 0.100188 | 62.756 | < 2e-16 |
| Product1 | 0.798851 | 0.224026 | 3.566 | 0.000497 |
| Product2 | 0.264368 | 0.224026 | 1.180 | 0.239971 |
| Product3 | -1.614943 | 0.224026 | -7.209 | 3.22e-11 |
| Product4 | -0.028736 | 0.224026 | -0.128 | 0.898120 |
| Product5 | 0.505747 | 0.224026 | 2.258 | 0.025522 |

Characterization of products

| | P-value |
|-------------|-----------|
| MilkF | 9.664e-61 |
| CocoaF | 1.015e-41 |
| Bitterness | 6.529e-41 |
| Crunchy | 4.817e-37 |
| Caramel | 4.568e-31 |
| Sweetness | 1.305e-30 |
| Astringency | 1.643e-19 |
| Melting | 1.967e-17 |
| Acidity | 5.669e-15 |
| Vanilla | 1.262e-13 |
| CocoaA | 7.752e-13 |
| MilkA | 1.551e-09 |
| Granular | 6.186e-06 |
| Sticky | 0.000183 |

| | Df | Sum Sq | Mean Sq | F value | Pr(>F) |
|-----------|-----|--------|---------|---------|-----------|
| Product | 5 | 207.54 | 41.51 | 11.8830 | 7.752e-13 |
| Panelist | 28 | 390.43 | 13.94 | 3.9919 | 2.552e-08 |
| Session | 1 | 3.72 | 3.72 | 1.0662 | 0.3036 |
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| Pan:Sess | 28 | 72.11 | 2.58 | 0.7373 | 0.8256 |
| Residuals | 140 | 489.03 | 3.49 | | |

Characterization of products



Characterization of products

| | CocoaA | MilkA | CocoaF | MilkF | Caramel | Vanilla | Sweetness | Acidity | Bitterness | Astringency | Crunchy | Melting | Sticky | Granular |
|-------|--------|-------|--------|-------|---------|---------|-----------|---------|------------|-------------|---------|---------|--------|----------|
| choc1 | 7.086 | 3.586 | 8.069 | 1.569 | 1.672 | 1.103 | 3.138 | 4.655 | 7.069 | 4.759 | 5.966 | 4.741 | 3.759 | 3.448 |
| choc2 | 6.552 | 4 | 6.914 | 2.379 | 2.776 | 1.81 | 4.621 | 3.138 | 4.948 | 3.155 | 7.707 | 4.328 | 3.828 | 3.155 |
| choc3 | 4.672 | 6.052 | 3.379 | 7.707 | 6.328 | 3.672 | 7.603 | 1.569 | 1.397 | 1.207 | 2.983 | 7.31 | 5.034 | 1.603 |
| choc4 | 6.259 | 4.103 | 6.69 | 2.586 | 2.672 | 2.121 | 4.293 | 3.931 | 5.19 | 3.69 | 6.103 | 4.379 | 4.103 | 3.552 |
| choc5 | 6.793 | 4.172 | 6.793 | 3.121 | 3.414 | 1.793 | 5.224 | 3.086 | 4.879 | 3.103 | 6.638 | 4.741 | 3.224 | 3.069 |
| choc6 | 6.362 | 4.569 | 6.224 | 3.362 | 3.259 | 1.914 | 5.621 | 2.672 | 4.19 | 2.759 | 7.328 | 4.207 | 3.931 | 3.172 |

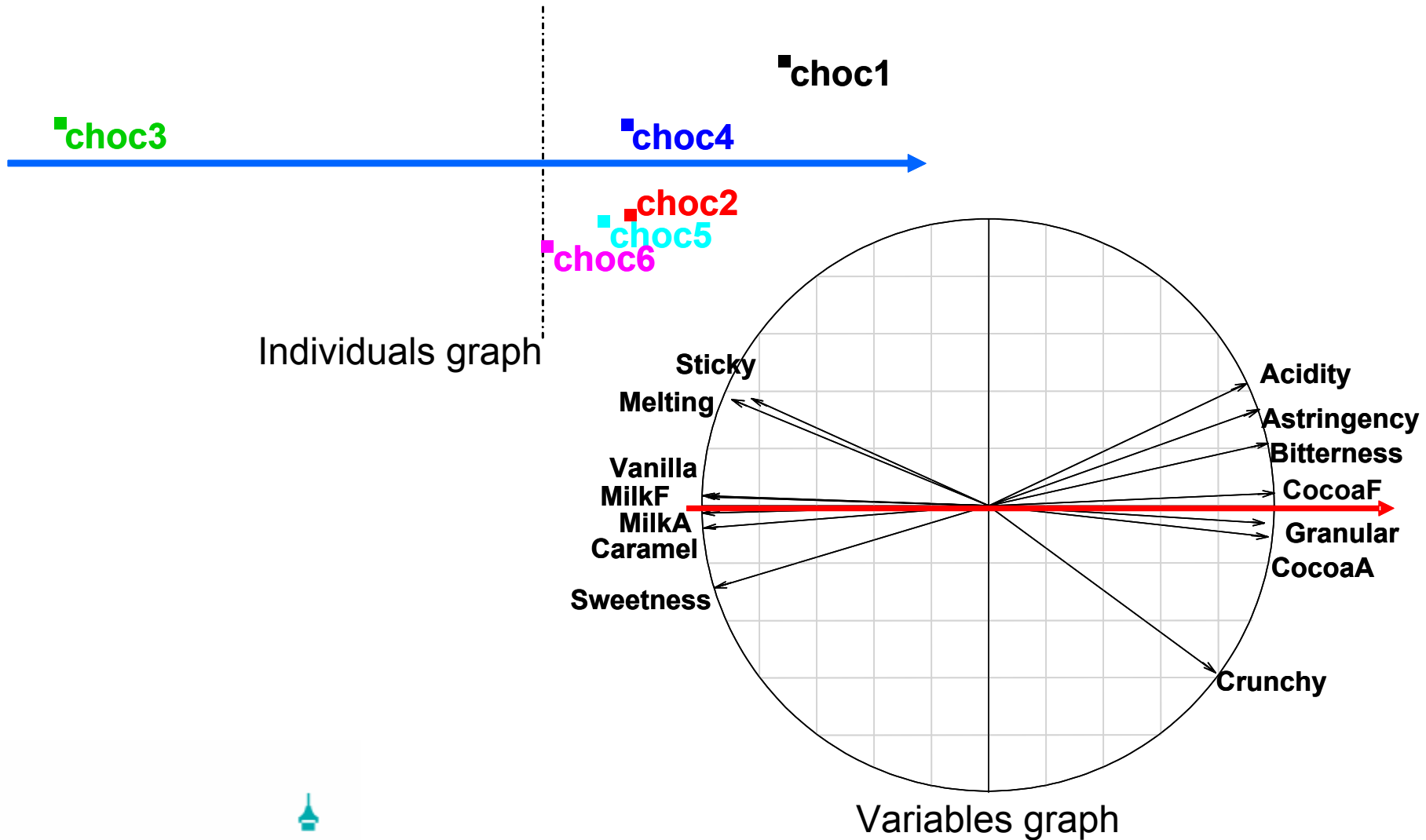
Characterization of products

| | CocoaA | MilkA | CocoaF | MilkF | Caramel | Vanilla | Sweetness | Acidity | Bitterness | Astringency | Crunchy | Melting | Sticky | Granular |
|-------|--------|-------|--------|-------|---------|---------|-----------|---------|------------|-------------|---------|---------|--------|----------|
| choc1 | 7.086 | 3.586 | 8.069 | 1.569 | 1.672 | 1.103 | 3.138 | 4.655 | 7.069 | 4.759 | 5.966 | 4.741 | 3.759 | 3.448 |
| choc2 | 6.552 | 4 | 6.914 | 2.379 | 2.776 | 1.81 | 4.621 | 3.138 | 4.948 | 3.155 | 7.707 | 4.328 | 3.828 | 3.155 |
| choc3 | 4.672 | 6.052 | 3.379 | 7.707 | 6.328 | 3.672 | 7.603 | 1.569 | 1.397 | 1.207 | 2.983 | 7.31 | 5.034 | 1.603 |
| choc4 | 6.259 | 4.103 | | | | | | | | | | | | |
| choc5 | 6.793 | 4.172 | 6 | | | | | | | | | | | |
| choc6 | 6.362 | 4.569 | 6 | | | | | | | | | | | |

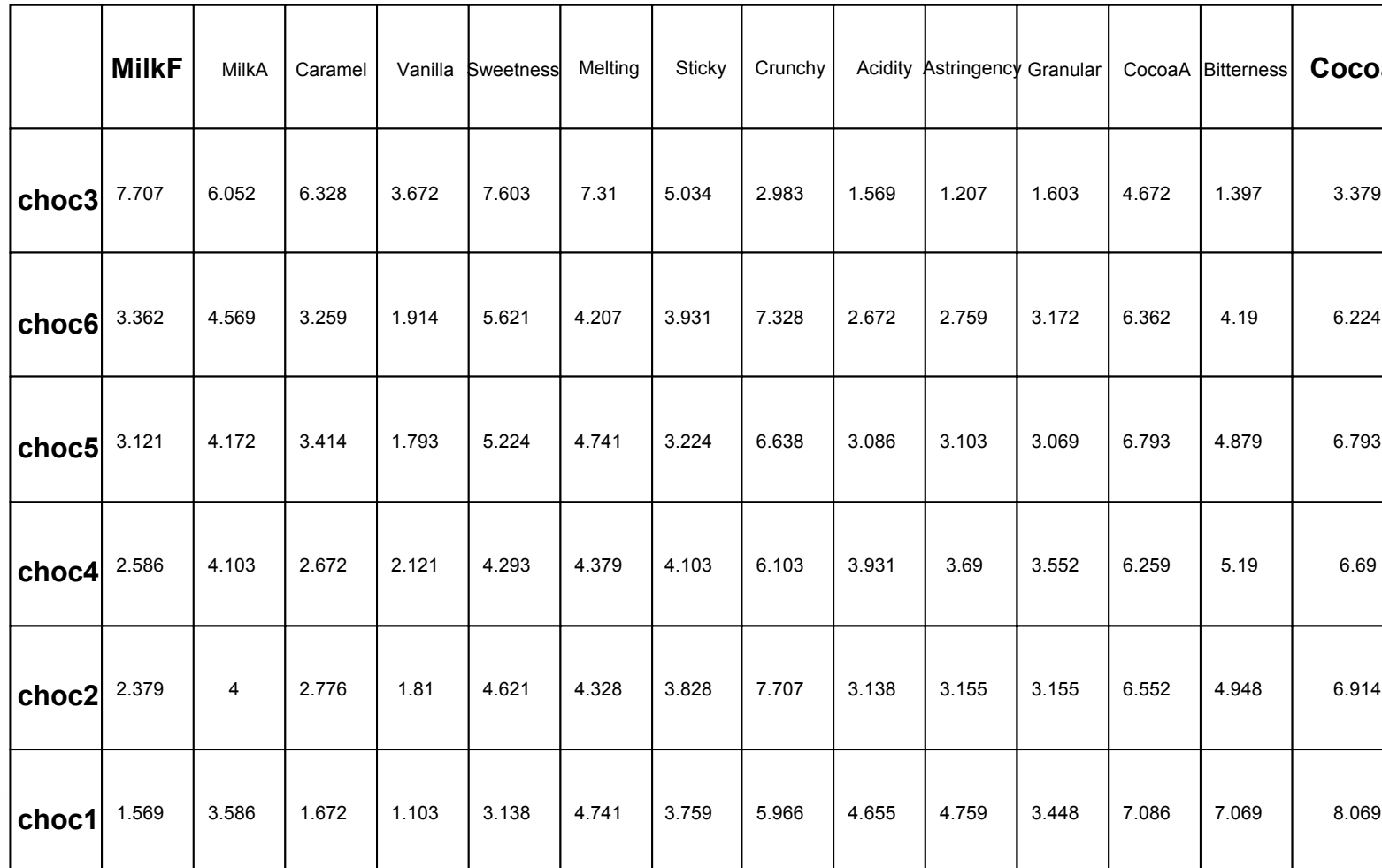
| | Estimate | Std. Error | t value | Pr(> t) |
|-----------|-----------------|------------|---------|----------|
| Intercept | 6.287356 | 0.100188 | 62.756 | < 2e-16 |
| Product1 | 0.798851 | 0.224026 | 3.566 | 0.000497 |
| Product2 | 0.264368 | 0.224026 | 1.180 | 0.239971 |
| Product3 | -1.614943 | 0.224026 | -7.209 | 3.22e-11 |
| Product4 | -0.028736 | 0.224026 | -0.128 | 0.898120 |
| Product5 | 0.505747 | 0.224026 | 2.258 | 0.025522 |

$$\hat{\mu} + \hat{\alpha}_1 = 6.287 + 0.798 = 7.086$$

Sorting from the PCA graphs



Characterization of products



| | MilkF | MilkA | Caramel | Vanilla | Sweetness | Melting | Sticky | Crunchy | Acidity | Astringency | Granular | CocoaA | Bitterness | CocoaF |
|--------------|--------------|-------|---------|---------|-----------|---------|--------|---------|---------|-------------|----------|--------|------------|---------------|
| choc3 | 7.707 | 6.052 | 6.328 | 3.672 | 7.603 | 7.31 | 5.034 | 2.983 | 1.569 | 1.207 | 1.603 | 4.672 | 1.397 | 3.379 |
| choc6 | 3.362 | 4.569 | 3.259 | 1.914 | 5.621 | 4.207 | 3.931 | 7.328 | 2.672 | 2.759 | 3.172 | 6.362 | 4.19 | 6.224 |
| choc5 | 3.121 | 4.172 | 3.414 | 1.793 | 5.224 | 4.741 | 3.224 | 6.638 | 3.086 | 3.103 | 3.069 | 6.793 | 4.879 | 6.793 |
| choc4 | 2.586 | 4.103 | 2.672 | 2.121 | 4.293 | 4.379 | 4.103 | 6.103 | 3.931 | 3.69 | 3.552 | 6.259 | 5.19 | 6.69 |
| choc2 | 2.379 | 4 | 2.776 | 1.81 | 4.621 | 4.328 | 3.828 | 7.707 | 3.138 | 3.155 | 3.155 | 6.552 | 4.948 | 6.914 |
| choc1 | 1.569 | 3.586 | 1.672 | 1.103 | 3.138 | 4.741 | 3.759 | 5.966 | 4.655 | 4.759 | 3.448 | 7.086 | 7.069 | 8.069 |

Coloring the table

| | MilkF | MilkA | Caramel | Vanilla | Sweetness | Melting | Sticky | Crunchy | Acidity | Astringency | Granular | CocoaA | Bitterness | CocoaF |
|-------|-------|-------|---------|---------|-----------|---------|--------|---------|---------|-------------|----------|--------|------------|--------|
| choc3 | 7.707 | | | | | | | | | | 1.603 | 4.672 | 1.397 | 3.379 |
| choc6 | 3.362 | | | | | | | | | | 3.172 | 6.362 | 4.19 | 6.224 |
| choc5 | 3.121 | 4.172 | 3.414 | 1.793 | 5.224 | 4.741 | 3.224 | 6.638 | 3.086 | 3.103 | 3.069 | 6.793 | 4.879 | 6.793 |
| choc4 | | | | | | | | | | | | 6.259 | 5.19 | 6.69 |
| choc2 | | | | | | | | | | | | 6.552 | 4.948 | 6.914 |
| choc1 | | | | | | | | | | | | 7.086 | 7.069 | 8.069 |

If $\hat{\alpha}_i \neq 0$ (significantly) \Rightarrow color the cell
 if $\hat{\alpha}_i < 0$ in red
 if $\hat{\alpha}_i > 0$ in blue

| | Estimate | Std. Error | t | value |
|-------------|-----------|------------|--------|----------|
| Pr(> t) | | | | |
| (Intercept) | 6.287356 | 0.100188 | 62.756 | < 2e-16 |
| Product1 | 0.798851 | 0.224026 | 3.566 | 0.000497 |
| Product2 | 0.264368 | 0.224026 | 1.180 | 0.239971 |
| Product3 | -1.614943 | 0.224026 | -7.209 | 3.22e-11 |
| Product4 | -0.028736 | 0.224026 | -0.128 | 0.898120 |
| Product5 | 0.505747 | 0.224026 | 2.258 | 0.025522 |

Characterization of products

| | MilkF | MilkA | Caramel | Vanilla | Sweetness | Melting | Sticky | Crunchy | Acidity | Astringency | Granular | CocoaA | Bitterness | CocoaF |
|-------|-------|-------|---------|---------|-----------|---------|--------|---------|---------|-------------|----------|--------|------------|--------|
| choc3 | 7.707 | 6.052 | 6.328 | 3.672 | 7.603 | 7.31 | 5.034 | 2.983 | 1.569 | 1.207 | 1.603 | 4.672 | 1.397 | 3.379 |
| choc6 | 3.362 | 4.569 | 3.259 | 1.914 | 5.621 | 4.207 | 3.931 | 7.328 | 2.672 | 2.759 | 3.172 | 6.362 | 4.19 | 6.224 |
| choc5 | 3.121 | 4.172 | 3.414 | 1.793 | 5.224 | 4.741 | 3.224 | 6.638 | 3.086 | 3.103 | 3.069 | 6.793 | 4.879 | 6.793 |
| choc4 | 2.586 | 4.103 | 2.672 | 2.121 | 4.293 | 4.379 | 4.103 | 6.103 | 3.931 | 3.69 | 3.552 | 6.259 | 5.19 | 6.69 |
| choc2 | 2.379 | 4 | 2.776 | 1.81 | 4.621 | 4.328 | 3.828 | 7.707 | 3.138 | 3.155 | 3.155 | 6.552 | 4.948 | 6.914 |
| choc1 | 1.569 | 3.586 | 1.672 | 1.103 | 3.138 | 4.741 | 3.759 | 5.966 | 4.655 | 4.759 | 3.448 | 7.086 | 7.069 | 8.069 |

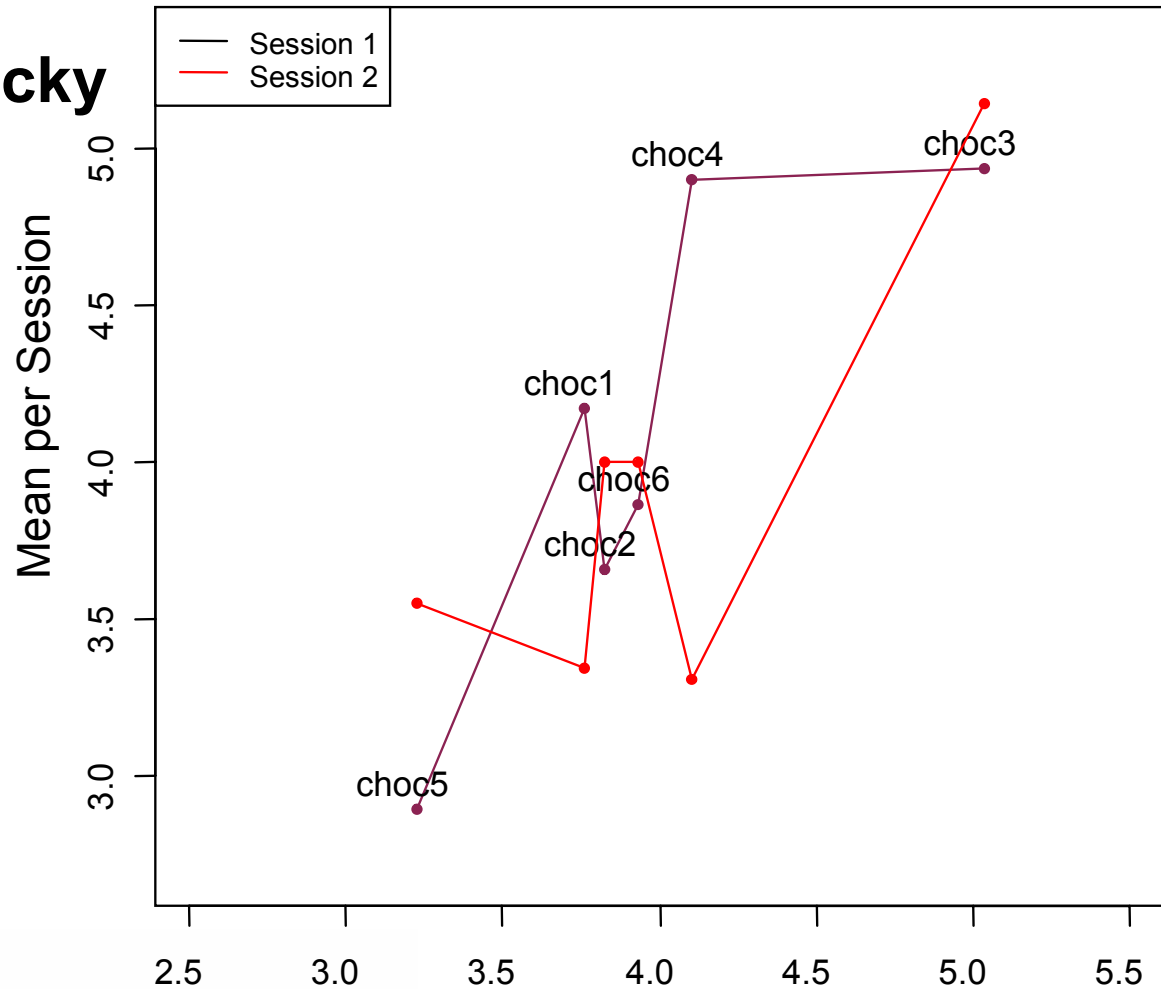
Results of anova models

Note = Product + Panelist + Session + Prod:Sess + Prod:Pan + Pan:Sess

| | Prod | Panelist | Session | Prod:Pan | Prod:Sess | Pan:Sess | Sigma(res) |
|-------------|-----------|-----------|----------|-----------|-----------|-----------|------------|
| MilkF | 3.74e-40 | 7.512e-11 | 0.02138 | 0.006824 | 0.1182 | 0.01535 | 1.474 |
| Bitterness | 1.875e-29 | 1.639e-10 | 0.001103 | 0.0258 | 0.1897 | 0.05538 | 1.689 |
| CocoaF | 1.748e-28 | 1.997e-11 | 0.04235 | 0.00665 | 0.4487 | 0.09411 | 1.413 |
| Crunchy | 2.878e-27 | 2.88e-14 | 0.005173 | 0.02381 | 0.6869 | 0.004479 | 1.623 |
| Sweetness | 1.106e-24 | 2.416e-12 | 0.005932 | 0.1177 | 0.1188 | 0.003246 | 1.669 |
| Caramel | 1.183e-22 | 2.386e-23 | 0.9217 | 0.00312 | 0.07315 | 0.0008459 | 1.634 |
| Astringency | 1.467e-15 | 1.142e-22 | 0.9249 | 0.05936 | 0.08183 | 0.05854 | 1.702 |
| CocoaA | 8.85e-14 | 2.552e-08 | 0.3036 | 0.9929 | 0.8011 | 0.8256 | 1.869 |
| Melting | 4.577e-12 | 1.202e-17 | 0.04919 | 6.88e-05 | 0.3041 | 0.06195 | 1.648 |
| Acidity | 5.263e-11 | 6.143e-25 | 0.3848 | 0.0009151 | 0.9835 | 0.008124 | 1.66 |
| Vanilla | 2.785e-10 | 9.748e-23 | 0.1191 | 0.002577 | 0.3183 | 0.03775 | 1.436 |
| MilkA | 6.442e-08 | 1.097e-13 | 0.236 | 0.09279 | 0.8287 | 0.2333 | 1.892 |
| Granular | 9.083e-05 | 2.32e-21 | 0.1148 | 0.01502 | 0.283 | 0.3101 | 1.892 |
| Sticky | 0.0005312 | 8.365e-21 | 0.3641 | 0.05412 | 0.009964 | 0.04789 | 1.825 |

Interaction product - session

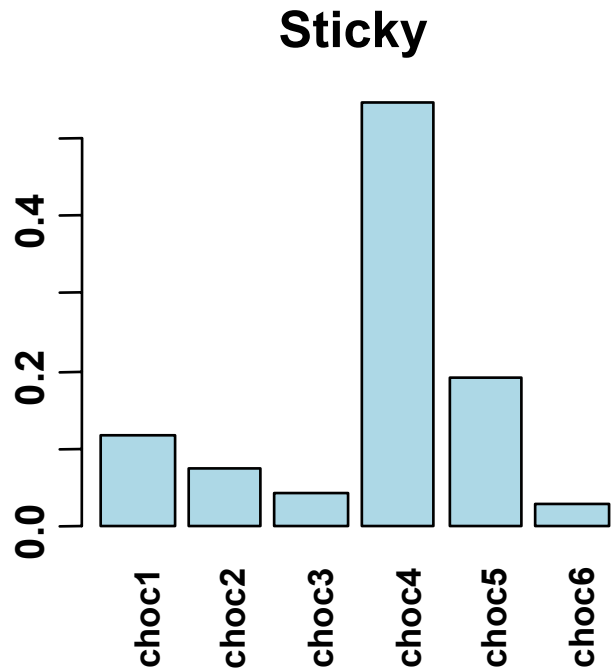
Sticky



Products are sorted by mean

One line per session

Interaction product - session



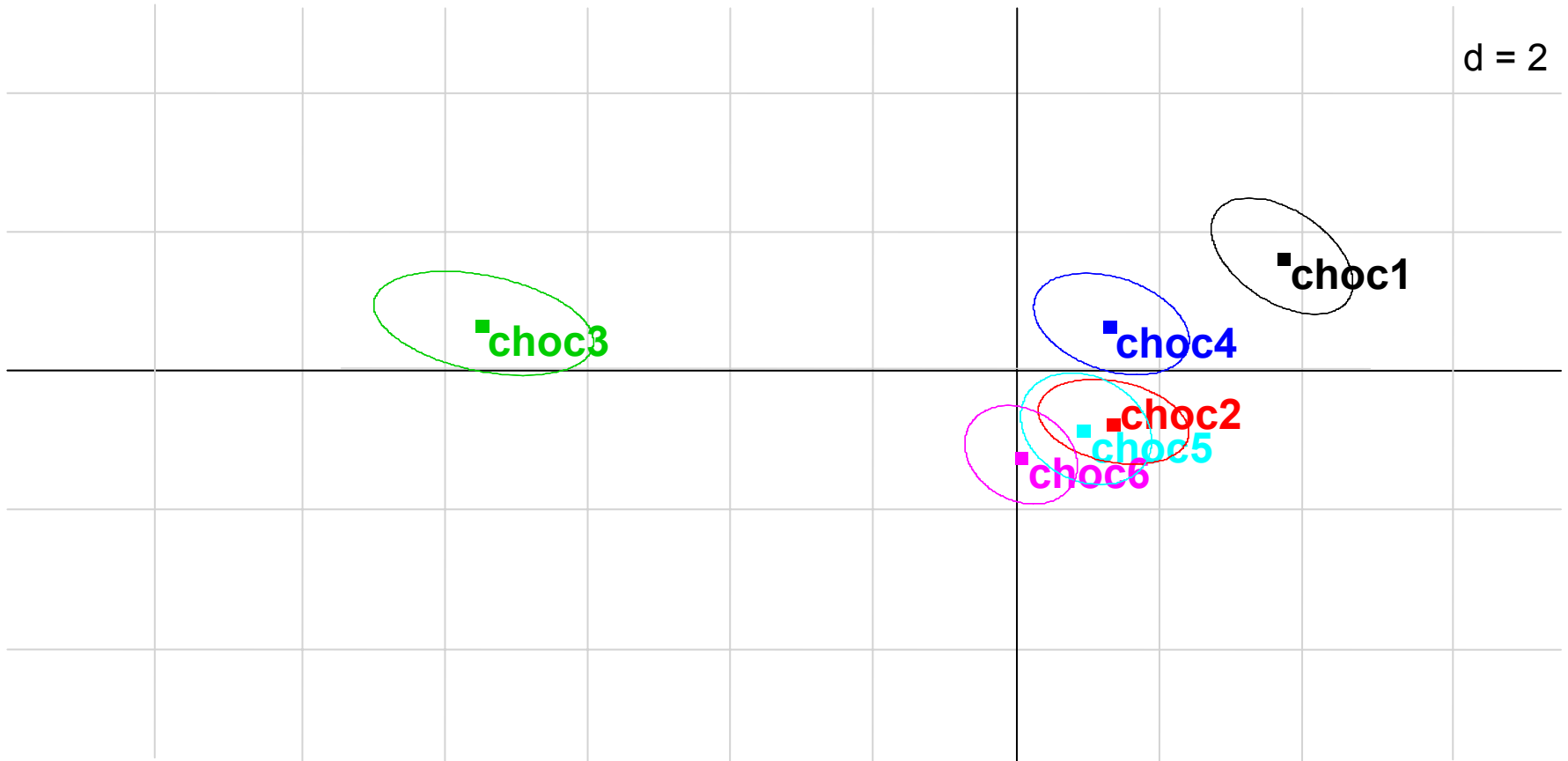
Chocolate 4 contributes more than 50% to the interaction product – session calculated in the following way:

$$Prod_i = \frac{\sum_{j=1}^J \alpha \beta_{ij}^2}{\sum_{i=1}^I \sum_{j=1}^J \alpha \beta_{ij}^2}$$

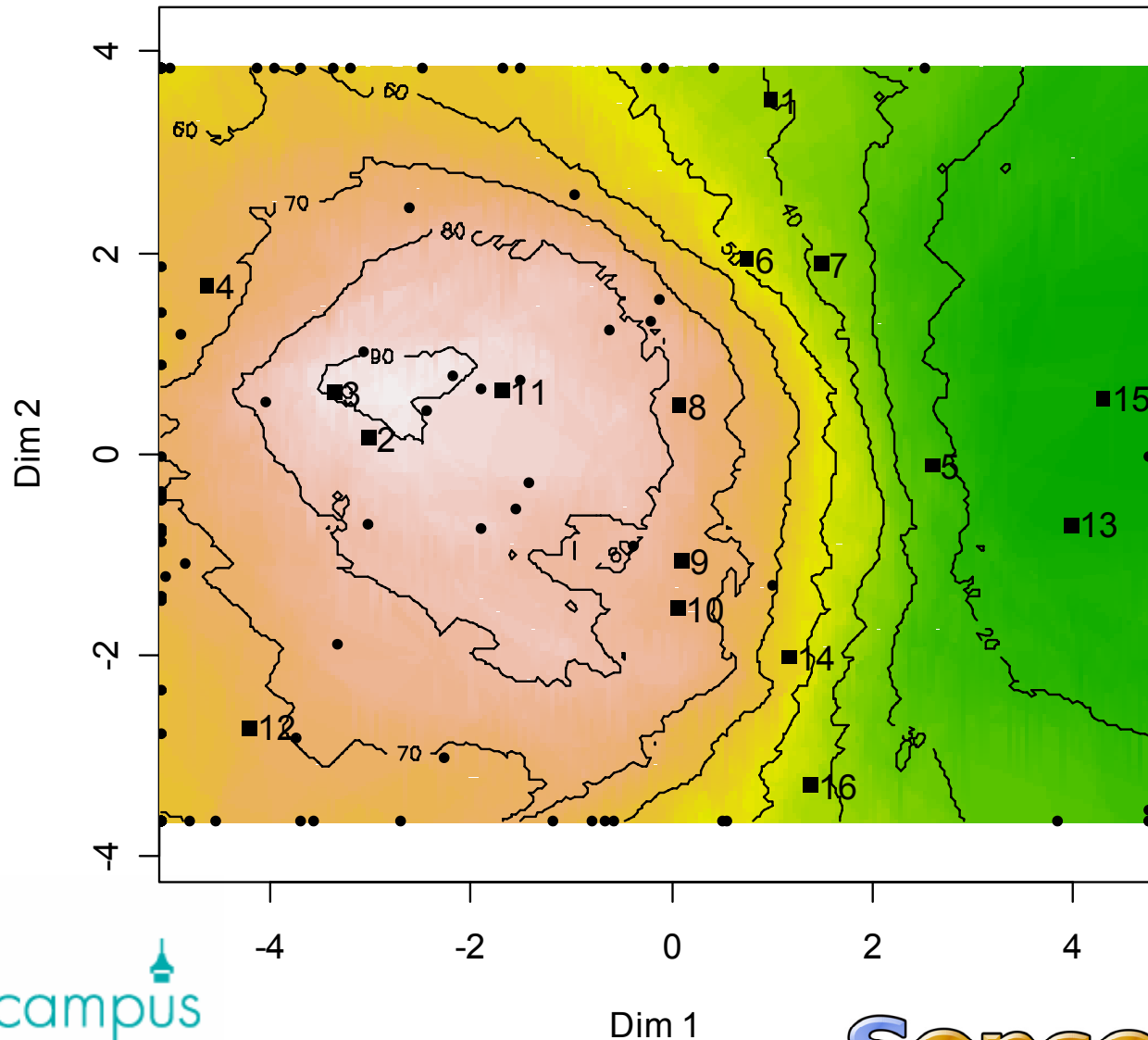
Assessing panel performances

| | MilkF | Crunchy | Bitterness | CocoaF | Sweetness | Melting | Caramel | Vanilla |
|--------|---------|---------|------------|---------|-----------|---------|---------|---------|
| 16 | 0.024 | 0.044 | 0.001 | 0.023 | 0.0078 | 0.0015 | 0.002 | 0.16 |
| 28 | 0.0015 | 0.086 | 0.0014 | 0.013 | 0.00016 | 0.04 | 0.019 | 0.18 |
| 24 | 0.078 | 0.021 | 0.06 | 0.015 | 0.024 | 0.37 | 0.022 | 0.032 |
| 9 | 0.031 | 0.064 | 0.081 | 0.0074 | 0.0025 | 0.31 | 0.022 | 0.34 |
| 17 | 0.019 | 0.011 | 0.13 | 0.052 | 0.021 | 0.0097 | 0.004 | 0.008 |
| 3 | 0.013 | 0.071 | 0.018 | 0.065 | 0.0041 | 0.79 | 0.28 | 0.54 |
| 15 | 0.065 | 0.047 | 0.016 | 8.3e-05 | 0.091 | 0.24 | 0.005 | 0.15 |
| 23 | 0.0049 | 0.065 | 0.033 | 0.0027 | 0.15 | 0.24 | 0.013 | 0.13 |
| 22 | 0.019 | 0.0049 | 0.0079 | 0.14 | 0.38 | 0.057 | 0.003 | NaN |
| 11 | 0.012 | 0.12 | 0.11 | 0.35 | 0.033 | 0.027 | 0.0064 | 0.041 |
| 10 | 9.4e-05 | 0.016 | 0.048 | 0.069 | 0.087 | 0.74 | 0.068 | 0.14 |
| 1 | 0.0065 | 0.43 | 0.071 | 0.011 | 0.031 | 0.072 | 0.13 | 0.066 |
| 14 | 0.1 | 0.097 | 0.1 | 0.061 | 0.26 | 0.11 | 0.025 | 0.83 |
| median | 0.019 | 0.068 | 0.071 | 0.08 | 0.095 | 0.11 | 0.13 | 0.18 |

Characterization of products



Mapping consumers' preferences



SensoMineR

<http://sensominer.free.fr>