Sensory Methods and Interpretation of Sensory Results

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Topics for the day

• Sensory Evaluation-Taste, Experience and Chemistry
  • Perception and Latent Phenomena

• A brief introduction to DoE and Multivariate analysis

• Examples justifying the use of Statistical methods in Sensory data used in R&D and market research
  • Reference Products
  • Perception of creaminess
  • Preference mapping for product optimization
  • Conjoint Analysis
What is Sensory Evaluation?

A scientific discipline used to evoke, measure, analyze and interpret those responses to products that are perceived by the senses of sight, smell, touch, taste and hearing.
Taste, Experience, and Chemistry

Description of a wine:

- great potential, masculine, strong body, good balance between fruity aromas and acids, long aftertaste *etc.*

- wine can be astringent, have strong aromas from black currant, plum, asparagus, and a hint of burnt match, kerosene, vanilla, and hazelnut.

- wine can also be characterized by its absorption spectrum or a gas chromatography profile.
Taste, Experience, and Chemistry

Wine contains over 800 aroma components!!

Together these compose a complex structure, Experienced when wine is consumed.

The experience consists of chemical components in interaction with our senses,

and

the interpretation of the perceived entity by the INDIVIDUAL.
Taste, Experience, and Chemistry

How does one define taste of wine?

Human perception vs. Chemical analyses?

Can we model human perception?

Are the compounds in greatest abundance the ones that are the most influential or is there a complex interaction between?

Example: In work with off-flavours, it is the components present in very small concentrations that give rise to strong affective reactions.
Role of perception

In sensory experiments, both the chemical signal (the given signal) and the human response, have potential interest for the experimenter.

These are difficult to distinguish and depend on large part on the design of experiment, and also in the interpretation of results.
How do we perceive *juiciness* of an apple
Role of perception

Task: Buy *juicy* apples from a supermarket shelf.

In order to say *it looks juicy* (a latent phenomena) it is necessary with previous experience of juiciness in apples.

The task will require a previous experience of juiciness in apples.

Even more difficult is to explain why an apple looks juicy.

This requires an understanding of how experience is related to visual keys, for there has at this point not been any experience of the juiciness of this apple. The only part of experience available has come through eyes.
Role of perception

In order to buy the right apple one needs to know what an apple is.

The data available in the experience, the apple data, aggregate in the apple related phenomena, or latent apple structures in order to simplify the search for the *right* apple.

Rather than scanning through previous experience an apple was seen, eaten or talked about, the *latent* structures or concepts are talked about in an upcoming ”apple” situation.

This makes the search simpler and faster.
Humans organize experience into simplified structures (latent structures) used for consultation when some decisions are to be made.

The more experience accumulated, the more conceptual structures are formed.

The situation, where “apple” concepts are being formed is very similar to analysis of data from a sensory profiling exercise.

First, the experience database is generated as profiles (data are provided by the panel). Then the database is used to describe ”apple variation”. Finally, the data are used (a statistical model) in order to calculate central tendencies in data structures, which can later be used for predictions.
Sensory Panel

A sensory panel may be described as a group of testers who have exceptional sensory faculties and can describe products on the basis of taste, smell or feel.

The sensory panelists are trained to describe their sensory experiences using words they generate in previous training sessions. These words are more detailed than those used by consumers, and more useful for R&D departments.

The parameters they can measure:

- **Smell**: Perfumes and Aromas etc.
- **Taste**: Flavor, Texture etc
- **Touch**: Viscosity for cosmetics, roughness/smoothness for a leather steering wheels, for instance
- **Other sensations** like vibration of a drill, smoothness of a car ride etc.
When to use Sensory Panels

Sensory Panels may be used as part of market understanding to:

- **Describe** current products in the market (mapping a market)
- **Tracking** competitive product changes over time

They can be used as part of **product development program** to:

- Develop a new product from gaps in existing market maps
- Determine if it is possible for consumers to notice changes
- Understand the magnitude of changes that will get a particular consumer reaction
- Determine which products and concepts in a range of new ones are the most promising
- Substantiate advertising propositions and label claims

Sensory panels can also be utilized in the **Quality management** process for:

- Determining product changes over time for shelf life evaluation
- Determining the effect of in-house ingredients and process changes (Quality Improvement and Cost Reduction)
- Understanding tolerances for a QA program
Advantages of Sensory Panels

• Sensory panels help manufacturers, scientists, food technologists etc. gain a clear **perception** of what ordinary consumers may experience.

• Sensory panel testing can be much **more rapid** than most non-sensory methods (would require multiple instruments to replace: sensory-nose, GC-nose,

• Sensory panelists use more than one sense, making them more **flexible** instruments.

• Sensory panelists can be very **sensitive** and good at detecting minute differences in product characteristics.

• Sensory panels are **acceptable** for writing into specifications for quality.

• Laboratory facilities are not required to conduct the descriptive analysis of a product. This makes sensory panels a **feasible** proposition to study products.
Disadvantages of Sensory Panels

• Sensory panelists can become **fatigued** with the entire process of testing and assessing descriptive data

• Assessors may be subject to **biases** e.g. from loss of interest or from distractions

• To ensure precision in the analysis and interpretation of the descriptive data, several assessors may be required, making it an **expensive** proposition

• The entire process of recruiting and training sensory panelists can be a **time-consuming** and costly process

• It may **not be easy** to replace assessors quickly, as the incoming assessor will have to be given intensive training to develop requisite expertise of the job

• The sensory panel method can be more expensive than some non-sensory methods

• The panelists may **not be good at quantifying** perceptions

• Interpretation of results may get problematic and be **open to dispute**
Sensory vs. Instrumental Analysis

Texture, Sweetness, Juicy, Acidity, Firmness, Ripeness, Colour...

FTIR - Spectra

Make predictive models relating sensory parameters to instrumental variables.
Is there a need for experimental design and multivariate data analysis in the food industry

- Food is characterized using many different attributes: taste, appearance, texture, presentation etc.

- Relationships between the different raw-materials and process variables can be studied in an optimal way using design of experiment (DOE) and by analyzing the information collected using multivariate methods.

- DOE combined with MVA represents a sequential and a systematic approach to achieving results, and can have a beneficial effect on time and economic factors related to product development.
What is required of a well planned experiment

• Well defined goal

• Sequential progress (screening, optimization)

• Partitioning of the different variance component (Blocking and Randomization)

• Simplest possible choice of the experimental design
Experimental Designs

Factorial Designs

Fractional Factorial Designs

Response Surface (CCD)

Mixture Designs
Principal Component Analysis (PCA)

- **Exploratory data analysis**
- **Extract information/Remove noise**
- **Reduce dimensionality**
- **Variable reduction**
- **Classification**
- **Compression**

\[
\text{Data} = \text{Structure} + \text{Noise}
\]
The Principles of Projection

Each object is a point in the variable space
Each variable defines an axis
The Principles of Projection

Data table = Swarm of points in the variable space
The Principles of Projection

Variable 1
Variable 2
Variable 3

Average

Variable 1
Variable 2
Variable 3
The Principles of Projection
Score Plot - Map of Samples
Example: Beverage Preferences in Europe
Case Study

An Application of Multivariate Analysis in Product Development in the Food Industry
Product Brief:

To emulate a an existing product in the market (a reference product).

Assumption: You have a similar product line to manufacture that product.
  • Initial phase: try-and-error
  • Screeing phase
  • Optimizsation phase

Sahni et al. (1999), An application of multivariate analysis in product development in the food industry, Quality Engg., (11)4, 579-586.
Attributes Studied

Sensory Evaluation

The sensory analysis was performed according to a descriptive sensory strategy. The sensory panel consisted of seven trained panelists. The properties evaluated were (1) integrity of shape (IOS), (2) glossiness, (3) smoothness, (4) toughness, (5) whipping test, and (6) stability. The panelists were calibrated for the sensory characteristics of the product before each session. A continuous scale, from 1 to 9, was used for evaluation of the first four attributes, whereas a binary scale (0–1) was used for attributes 5 and 6.

Instrumental variables

pH, Stevens (Texture analysis)
List of Variables Investigated

<table>
<thead>
<tr>
<th>Step 1 No.</th>
<th>Variable name</th>
<th>Step 2 No.</th>
<th>Variable name</th>
<th>Step 3 No.</th>
<th>Variable name</th>
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<tr>
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<td>Starch 1</td>
<td>B</td>
<td>Starch 2</td>
<td>B</td>
<td>Stabilizer 5</td>
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<tr>
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<td>C</td>
<td>Stabilizer 2</td>
<td>C</td>
<td>Stabilizer 6</td>
</tr>
<tr>
<td>D</td>
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<td>D</td>
<td>New stabilizer</td>
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<tr>
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<td>E</td>
<td>Preservative</td>
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<tr>
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<td>F</td>
<td>Emulsifier</td>
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<tr>
<td>G</td>
<td>Stabilizer 4</td>
<td>G</td>
<td>Oil</td>
<td></td>
<td></td>
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<tr>
<td>H</td>
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<td></td>
<td>H</td>
<td>Color</td>
</tr>
<tr>
<td>I</td>
<td>Emulsifier</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>J</td>
<td>Oil</td>
<td></td>
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<tr>
<td>K</td>
<td>Color</td>
<td></td>
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</tr>
<tr>
<td>L</td>
<td>Salt</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Multivariate Analysis in Food Industry

$2^8-4$ design (design for optimization)
### Analysis of Variance for the Screening \( (2^{8-4}) \) design

**Table 4.** ANOVA for the \( 2^{8-4} \) Design

<table>
<thead>
<tr>
<th>Variable</th>
<th>IOS</th>
<th>Glossiness</th>
<th>Smoothness</th>
<th>Toughness</th>
<th>Whipping</th>
<th>Stability</th>
<th>pH</th>
<th>Stevens</th>
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</thead>
<tbody>
<tr>
<td>A. Water</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.035↓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. Starch 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.021↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C. Stabilizer 2</td>
<td>0.013↓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. New stabilizer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. Preservative</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.039↓</td>
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<td></td>
</tr>
<tr>
<td>F. Emulsifier</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G. Oil</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H. Color</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>Significant interactions(^a)</td>
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<td></td>
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<tr>
<td>i(3)</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>i(4)</td>
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<td>0.019</td>
<td>0.012</td>
<td></td>
<td></td>
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<tr>
<td>i(5)</td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>i(7)</td>
<td></td>
<td></td>
<td></td>
<td>0.035↓</td>
<td>0.019</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* The numbers in the table are the \( p \) values for the significant \( X \) variables (\( p < 0.05 \)). The arrows represent the positive (↑) or the negative (↓) regression coefficients of the respective \( X \) variables [Eq. (1)].
Multivariate Analysis in Food Industry

$4^{-2}$ design (design for optimization)
Multivariate Analysis in Food Industry

Initial full scale experiments

$2^{8-4}$ experiment

$4^{4-2}$ experiment
Case Study

Perception of Creaminess
A Case Study: Perception of Creaminess

• It is well known that perception of creaminess in foods is very complex.

• Textural creaminess is not a primary sensory attribute and may include thickness/viscosity, smoothness and fatty mouthfeel characteristics.

• The case study presented here is exploratory and compares the actual in-mouth creaminess with expected creaminess based on product concepts communicated by package labels.

• Both creamy and non-creamy products were evaluated.
A Case Study: Perception of Creaminess

- 24 Panelists evaluated 20 products for a very specific but a complex attribute- *creaminess*.

- For ”in-mouth” evaluations, samples were served as 30 ml servings, completed in two-sessions.

- For concept evaluations, the panlists were shown the actual product label pasted onto individual cards and asked to sort them based on the creaminess similarity of the products described on the label.
Case study: Food products and labels used in creaminess evaluation

Apple Sauce (Schnucks)
Chocolate Pudding (Del Monte)
Chocolate Syrup (Hershey)
Chocolate/hazelnut spread (Nutella, Ferrero)
Chocolate Milk (Schnucks)
Cream Soda (A & W)
Creamy Peanut Butter (Schnucks)
Evaporated Light Skimmed Milk (PET)
Half and Half (Schnucks)
Marshmallow Creme (Schnucks)
Non-dairy Creamer (CoffeeMate, Carnation)
Non-fat Sour Cream (Land-O-Lakes)
Part-skim Ricotta Cheese (Schnucks)
Ranch Creamy Dressing (Hidden Valley Ranch)
Skim Milk (Schnucks)
Soft Philadelphia Cream Cheese (Kraft)
Sour Cream (Schnucks)
Sweetened Condensed Milk (Meadow Gold)
Water (Culligan)
Whole Milk (Schnucks)
Perception of Creaminess

Two dimensional MDS map of the “in-mouth” creaminess sorting
Perception of Creaminess

Two dimensional MDS map of the label creaminess sorting
Prefernc e Mapping for Product Optimization

PREFMAP is used to interpret preference patterns and help determine why products are positioned where they are.

PREFMAP displays rating scale data in the same plot as an MDS or MDPREF plot.

PREFMAP shows both products and product attributes in one plot.
• Data are collected by asking respondents to rate their preference for a set of objects.

• Typically in marketing research, the objects are products—the client’s products and the competitors’.

• Questions that can be addressed with MDPREF analyses include:

• Who are my customers? Who else should be my customers? Who are my competitors’ customers? Where is my product positioned relative to my competitors’ products? What new products should I create? What audience should I target for my new products?
Preference Mapping as a Method

There are two parts to Preference Mapping

(1) Internal Preference Mapping

This includes a simple (PCA) plot based on the product acceptability information provided by each consumer. A segmentation is then possible by visually examining the plot of each consumer preference directions.

This method only uses the consumer data, and thus no information about why the samples are liked or disliked are given.
Preference Mapping as a Method

There are two parts to Preference Mapping

(1) External Preference Mapping

The basic idea here is to map the acceptability data for each consumer onto an existing perceptual map of the products, usually obtained from profiling.

In effect, the profile space is external to the acceptability data.
Preference Mapping as a Method

There are two (three) kinds of models that can be fit. These include:

(1) The Vector Model
This is a linear model which pertains to "the more, the better" type acceptance behaviour.

(2) The Ideal Point Model
Here we deal with "some amount is ideal" acceptance behaviour. Basically, this means that there are samples in the space which are perceived as having excessive or insufficient amount of the sensory attribute.

Underlying assumption is that there is some combination of attributes which make the ideal product.
Advantages and Disadvantages of External Preference Mapping

**Advantages**

- Offers a relatively straightforward procedure for relating sensory and consumer information.

- Helps identify new markets

- Provides direction for future product development

- Provides information on market segmentation, with respect to sensory preferences.

- Can identify the need to make alternative types of product for different market segments.

- Using market samples, the technique can be a first step in looking at products currently available to the consumer, before developing specific formulations for a more detailed study.
Advantages and Disadvantages of External Preference Mapping

Disadvantages
- A fairly large number of samples are required to ensure that preference mapping can be undertaken successfully.

- Every consumer must evaluate all samples.

- Preference data is not always directly related to the sensory profile map because the way trained panels perceive products is different from consumers.

- Is best suited to be used for understanding and direction, not prediction.

- Not all consumers well represented by the models.
Case Study: Preference Mapping
Content

• Background
  • Objectives
  • Methodology
  • Samples

• Descriptive Statistics

• Texture Preference Mapping
  • In-house Expert Panel
  • consumer Data

• Results and Suggestions for Further Studies
Objectives

• A pilot study to gain insight into the texture likeability aspects of different products within a given population

• Look at different ways to relate expert in-house panel to the consumer data – *preference mapping*

• Give recommendations for designing a more elaborate study along the same lines.
Data Description

Three data sets were generated and analyzed in this project.

• Expert in-house panel tasting 10 different attributes on 12 different products on a hedonic 1-9 scale.

• External consumers (# 57 consumers) each asked to score texture likeability for each of the 12 products on a 1-9 scale.

• Frequency counts table generated on the basis on the attributes (# 19 attributes) chosen by each consumer for each of the 12 products.
Descriptive Statistics
Distribution of the 12 products (averaged over all panellists) included in the study (in-house Panel)
Sensory Profiles of the Samples

- First bite
- Hardness (Subsequent eat)
- Crispiness
- Easy to Swallow
- Melt in Mouth
- Sticks to teeth
- Oily

Overall Flavour

Flavour/taste attributes

Texture attributes

- Saltiness
- Spiciness
- 156
- 293
- 314
- 591
- 602
- 649
- 738
- 178
- 213
- 262
- 535
- 639
Distribution of the texture likeability averaged over all products as judged by external consumers
Texture likeability as judged by each individual consumer
Texture Preference Mapping
Bi-plot obtained using PCA of the in-house sensory panel.
PCA plot of texture likeability scores judged by the external consumers

Scores plot

Loadings plot

F1 (30.01 %)
Correspondence analysis based on frequency table obtained from consumer choice of 19 attributes for each product.
Mapping texture likeability data of each consumer to the expert Panel space

RV-coefficient = 0.64
p-value = 0.012
Mapping texture likeability data of each consumer to the consumer questionnaire space (19 attributes)

RV-coefficient = 0.62
p-value = 0.005
Consumer preference map taking into account 3 different consumer groups (segmented using k-means). This is a between-consumer segment analysis, which aims to discriminate the consumers, given the texture likeability data.

Segmentation of consumers in 3 clusters,
Results and Suggestions for further studies

• Initial results indicate that there is a consensus on the products perceived to be similar by both the external consumers and the expert panel.

• The results presented have focused on method development and to gain some initial insight into what can be obtained from similar studies.

• Based on the results it is recommended that the study be carried out on a larger scale
  • involving a trained expert panel in order to better elucidate the drivers for the observed behaviour
  • looking at a larger consumer segment
  • include free choice profiling to map the individual consumers preferences
  • consider including conjoint analysis to study the factors that influence consumers’ purchasing decisions.
Conjoint Analysis
Conjoint Analysis

Conjoint analysis is a popular marketing research method used to determine what features a new product should have and how it should be priced.

It is also used for:

- finding consumers’ product preferences and simulate consumer choice.
- factors that influence consumers’ purchasing decisions.
When approaching a business problem with conjoint analysis, we accept the premise that buyers value products or services based on the sum of their parts.

**Credit Card:**

Brand + Interest Rate + Annual Fee + Credit Limit

**On-Line Brokerage:**

Brand + Fee + Speed of Transaction + Reliability of Transaction + Research/Charting Options

If we learn how buyers value the separate components of an offering, we are in a better position to design those that improve profitability.
How Does Conjoint Analysis Work?

- We vary the product features (independent or predictor variables) to build many (usually 12 or more) product concepts.
- We ask respondents to rate/rank those product concepts (dependent variable).
- Based on the respondents’ evaluations of the product concepts, we figure out how much unique value (utility) each of the features added.
  - (Regress dependent variable on independent variables; betas equal part-worth utilities.)
A conjoint analysis study includes the following key steps:

**Attribute List Formulation.** A business problem is defined and an attribute (features) list is developed to study the problem.

**Data Collection.** Respondents are asked to express the trade-offs they are willing to make among product features by rating, sorting or choosing among hypothetical product concepts.

**Utility Calculation.** A set of preference values or part worth "utilities" is derived from the interview data; they reflect the trade-offs each respondent made.

**Market Simulation.** The utility values are used to predict how buyers will choose among competing products and how their choices are expected to change as product features and/or price are varied.

*The value of conjoint analysis is in its ability to estimate choice behavior for a wide range of market scenarios.*
How Conjoint Analysis Is Used in Industry

• Pricing Research
• Brand Equity Research
• Market Segmentation
• Product Positioning/Line Extensions
• Employee Research (benefits, retention, etc.)
• New Product Introduction

• Other interesting uses: Litigation (assessment of damages), environmental impact studies, capital budgeting, patient/physician communications, job search/hiring.

Conjoint analysis may be considered most anytime to study situations in which people face tradeoffs!
Conjoint Analysis

Examples include:

• Developing health services in which three attributes are considered to be important: hospital (A or B), cost($x or $y), and doctor (consultant or non-consultant).

• Preference for a combination of chocolate candies

• Exploring product preferences

Method of ratings include rank score (1 to 8), or to rate on a preference Scale of 1 to 10 (10 being the most preferred) for each combination.
Conjoint Analysis

Important terms in Conjoint Analysis

**Utility score** is derived from the responses of each individual which measures the unique subjective judgement of preference. This includes both the tangible and intangible features of that product or service.

**Part-worth utility scores** are used to determine the importance of each attribute for that product or service.
Chocolate Candy example

One subject was asked to rate his preference for eight chocolate candies. The covering was either dark or milk chocolate, the center was either chewy or soft, and the candy did or did not contain nuts.

The candies were rated on a 1 to 9 scale where 1 means low preference and 9 means high preference.
<table>
<thead>
<tr>
<th>Chocolate, type of center, and nuts</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Chewy Nuts</td>
<td>7</td>
</tr>
<tr>
<td>Dark Chewy No Nuts</td>
<td>6</td>
</tr>
<tr>
<td>Dark Soft Nuts</td>
<td>6</td>
</tr>
<tr>
<td>Dark Soft No Nuts</td>
<td>4</td>
</tr>
<tr>
<td>Milk Chewy Nuts</td>
<td>9</td>
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<td>8</td>
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<tr>
<td>Milk Soft Nuts</td>
<td>9</td>
</tr>
<tr>
<td>Milk Soft No Nuts</td>
<td>7</td>
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## Part-Worth Utilities

<table>
<thead>
<tr>
<th>Label</th>
<th>Utility</th>
<th>Error</th>
<th>Importance</th>
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<tbody>
<tr>
<td>Intercept</td>
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<tr>
<td>Chocolate, Dark</td>
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<td>50.00 (rank 1)</td>
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<tr>
<td>Chocolate, Milk</td>
<td>1.2500</td>
<td>0.17678*</td>
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<tr>
<td>Center, Chewy</td>
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<td>Nuts, No Nuts</td>
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<tr>
<td>Nuts, Nuts</td>
<td>0.7500</td>
<td>0.17678*</td>
<td></td>
</tr>
</tbody>
</table>
A Few Recommendations

• Sensory panels help manufacturers, scientists, food technologists etc. gain a clear perception of what ordinary consumers may experience.

• Sensory panel testing can be much more rapid than most non-sensory methods (would require multiple instruments to replace: sensory-nose, GC-nose,)

• Sensory panelists use more than one sense, making them more flexible instruments.

• Sensory panelists can be very sensitive and good at detecting minute differences in product characteristics.

• Sensory panels are acceptable for writing into specifications for quality.

• Laboratory facilities are not required to conduct the descriptive analysis of a product. This makes sensory panels a feasible proposition to study products.