

**SensMixed:** R-Package for analysis of sensory and consumer data within a mixed effects model framework

**ConsumerCheck:** stand-alone tool for analysis of consumer data

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## Overview

- **SensMixed** package
  - Simple mixed effects models in sensory studies
  - Motivation for extensions
  - Overview of the **SensMixed**
  - Example (B & O data)
  - Obtaining **SensMixed**
- **ConsumerCheck** software
  - Overview
  - Simple mixed effects models in consumer studies
  - Motivation
  - **ConsumerCheck** GUI
  - Example (ham data)

## Simple LMM is sensory studies

- I assessors
- J products
- R replicates
- K attributes

2-way randomized replicate (T. Lawless, H. Heymann 2010)

$$y_{ijl}^k = \mu + a_i + \overbrace{\beta_j + d_{ij}}^{\text{Product effect}} + \varepsilon_{ijl}$$

$$a_i \sim N(0, \sigma_{\text{assessor}}^2)$$

$$d_{ij} \sim N(0, \sigma_{\text{assessor} \times \text{product}}^2)$$

$$\varepsilon_{ijl} \sim N(0, \sigma_{\text{error}}^2)$$

## Simple LMM is sensory studies

F tests for product effects in balanced situations

- 2-way randomized block analysis

$$F_{product} = \frac{MS_{product}}{MS_{error}}$$

- 2-way randomized replicates analysis

$$F_{product} = \frac{MS_{product}}{MS_{assessor \times product}}$$

- 3-way sessioned/batched analysis

$$F_{product} = \frac{MS_{product}}{MS_{assessor \times product} + MS_{session \times product} - MS_{error}}$$



## Simple not always enough!

- Unbalanced data (e.g. missings)
- Multi-way product structure (products are formed as combination of features)
- Complex blocking, product replication, product batch structures
- Mixed assessor models (correction for the scaling effect)

## Aim of the new tool:

- Handling these more complex situations
- Advanced mixed effects model tools
- Specifically designed for sensory practitioners
- Visualization of the analysis

## SensMixed R- package with GUI

- Automated mixed effects modeling for sensory and consumer data
- $d - \tilde{}$  multi-attribute plots (Per B. Brockhoff et. al.)
- Scaling correction via MAM (Mixed Assessor Models)  
general + complex mixed models + unbalanced
- MAM confidence intervals and performance indices (only balanced data)  
(Per B. Brockhoff, P. Schlich and I. Skovgaard 2015)
- Plots, post-hoc analysis
- Ready to publication output (.doc, .tex, .html)
- GUI
- Valuable for sensory practitioner!

# SensMixed GUI

Choose which type of data to analyze

Import data

## Analysis of Sensory and Consumer data within a mixed effects model framework

This application is a user-friendly interface for the R-package SensMixed

**Choose type of analysis**

Analysis of

Sensory data  Consumer data

Input arguments | Modelling controls

[Analysis controls](#)

Select attributes

Select assessor

Select replications

Select products

Run Analysis

Data | Plot output | Table output | Step output | Post-hoc | MAM analysis

Choose data

Read CSV file from local drive

Choose CSV File from local drive, adjusting parameters if necessary

Choose File No file chosen

Header

Separator

- Semicolon
- Comma
- Tab

Quote

- None
- Double Quote
- Single Quote

Decimal

- Period
- Comma

results

Modelling / analysis controls

## Example: TVbo data:

- 12 products
  - 3 TV sets
  - 4 Pictures
- 2 replicates
- 8 assessors
- 15 sensory attributes



Assessor	TVset	Repeat	Picture	Coloursaturation	Colourbalance	Noise	Depth	Sharpness	Lightlevel
1	TV3	0	1	10.4	5.0	13.1	3.1	8.3	9.5
1	TV2	0	1	9.9	4.1	10.9	7.4	5.3	9.9
1	TV1	0	1	7.0	9.8	13.1	6.0	7.9	6.9
1	TV3	1	1	9.8	4.8	13.2	5.7	9.3	9.8
1	TV2	1	1	10.6	4.3	13.3	6.7	4.7	10.3
1	TV1	1	1	7.5	9.4	13.3	5.8	6.6	6.7
1	TV3	0	2	7.1	8.0	12.0	8.2	10.7	10.3
1	TV2	0	2	9.9	7.5	8.7	6.3	7.5	9.5



## Step 1: Choose type of analysis and choose data

### Choose type of analysis

#### Analysis of

Sensory data  Consumer data

Input arguments

Modelling controls

Analysis controls

#### Select attributes

Coloursaturation Colourbalance Noise  
Depth Sharpness Lightlevel Contrast  
Sharpnessofmovement  
Flickeringstationary Flickeringmovement  
Distortion Dimglasseffect Cutting  
Flossyedges Elasticffect

#### Select assessor

Assessor

#### Select replications

Repeat

#### Select products

TVset Picture

Run Analysis

Choose sensory data

Choose TVbo data

Data Plot output Table output Step output Post-hoc MAM analysis

### Choose data

TVbo data

Show 25 entries

Search:

Assessor	TVset	Repeat	Picture	Coloursaturation	Colourbalance
1	TV3	0	1	10.4	5.0
1	TV2	0	1	9.9	4.1
1	TV1	0	1	7.0	9.8
1	TV3	1	1	9.8	4.8
1	TV2	1	1	10.6	4.3
1	TV1	1	1	7.5	9.4
1	TV3	0	2	7.1	8.0
1	TV2	0	2	9.9	7.5
1	TV1	0	2	5.0	6.4
1	TV3	1	2	10.0	7.5
1	TV2	1	2	10.5	6.6
1	TV1	1	2	7.6	7.3
1	TV3	0	3	9.1	6.7

Multi-way product structure

## Step 2: Select modelling controls

# Analysis of Sensory and Consumer data within a mixed effects model framework

This application is a user-friendly interface for the R-package SensMixed

Choose type of analysis

Analysis of

Sensory data  Consumer data

Data | Plot output | Table output | Step output | Post-hoc | MAM analysis

Choose data

TVbo data

Show 25 entries

	Assessor	TVset	Repeat	Picture	Coloursaturation	Colourb
1	TV3	0	1	10.4	5.0	
1	TV2	0	1	9.9	4.1	
1	TV1	0	1	7.0	9.8	
1	TV3	1	1	9.8	4.8	
1	TV2	1	1	10.6	4.3	
1	TV1	1	1	7.5	9.4	
1	TV3	0	2	7.1	8.0	
1	TV2	0	2	9.9	7.5	
1	TV1	0	2	5.0	6.4	

Main effects and all possible interactions (accounting for the multi-way product structure)

Assessor effect and interactions between assessor and product effects (Tvset and Picture)

Want to correct for the scaling effect (use MAM)

Input arguments | Modelling controls | Analysis controls

Select product structure

3

Select error structure

ONLY-ASS

Correct for scaling

Yes

Mult-way scaling

No

Run Analysis

### Step 3: Select analysis controls

## Analysis of Sensory and Consumer data within a mixed effects model framework

This application is a user-friendly interface for the R-package SensMixed

Choose type of analysis

Analysis of

Sensory data  Consumer data

Choose data

TVbo data

Show 25 entries

Search:

Assessor TVset Repeat Picture Coloursaturation Colourbalance

Assessor	TVset	Repeat	Picture	Coloursaturation	Colourbalance
1	TV3	0	1	10.4	5.0
1	TV2	0	1	9.9	4.1
1	TV1	0	1	7.0	9.8
1	TV3	1	1	9.8	4.8
1	TV2	1	1	10.6	4.3
1	TV1	1	1	7.5	9.4
1	TV3	0	2	7.1	8.0
1	TV2	0	2	9.9	7.5
1	TV1	0	2	5.0	6.4
1	TV3	1	2	10.0	7.5
1	TV2	1	2	10.5	6.6

Analysis controls

Calculate post-hoc

Yes

Simplification of error structure

Yes

Effects to keep in a model

Enter effects separated by space...

Type 1 error for testing random effects

0.1

Type 1 error for testing fixed effects

0.05

Run Analysis

**Step-wise selection process**

**Assessor effect and highest order interaction between Assessor and product effects are always kept!**

## What is actually done?..

- $$y = \underbrace{\text{TV} + \text{Pic} + \text{TV: Pic}}_{\text{product structure} = 3} + \underbrace{\text{Ass} + \text{Ass: TV} + \text{Ass: Pic} + \text{Ass: TV: Pic}}_{\text{error structure} = \text{ONLY-ASS}} + \underbrace{\beta: x}_{\text{Scaling effect}} + \varepsilon$$

**product structure = 3**  
 (main effects: TVset and Picture and interaction between them)

**error structure = ONLY-ASS**  
 (no replicate effect)

**Scaling effect**

Individual scaling slopes  
 Centered product averages inserted a covariate
- Error structure is reduced using the step-wise selection method by Applying the likelihood ratio test– details in **Step output**  
 ( A. Kuznetsova, C. Bavay, R. H. Christensen, P. B. Brockhoff, 2015)
- Fixed effects are tested based on the reduced error structure by using the F-test

### Step 3: Look at the results. Multi-attribute plot for the random effects

**Sequential Chi-squared values  
(from the stepwise selection  
process) – details in Step output**

Data Plot output Table output Step output Post-hoc MAM analysis

Note: This output is only dedicated for analysis of sensory data

**Plot effects**  
random

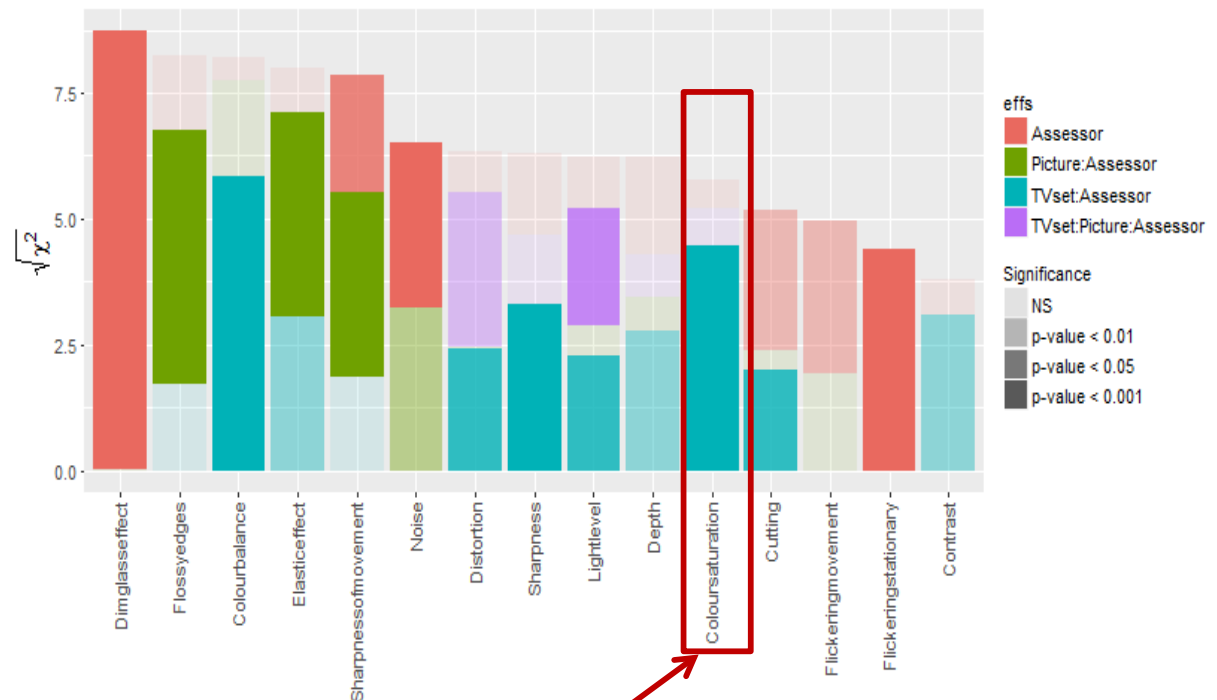
**Plot type**  
d-prime

stacked

**Layout**  
single

**Scale plot**  
1

[Download Plot](#)



**Assessors disagree in scoring between products for Coloursaturation, but mainly due to TVset**

### Step 3: Look at the results. Multi-attribute plot for the scaling effect

Data Plot output Table output Step output Post-hoc MAM analysis

#### The F test for the scaling effect

Note: This output is only dedicated for analysis of sensory data

**Plot effects**  
scaling

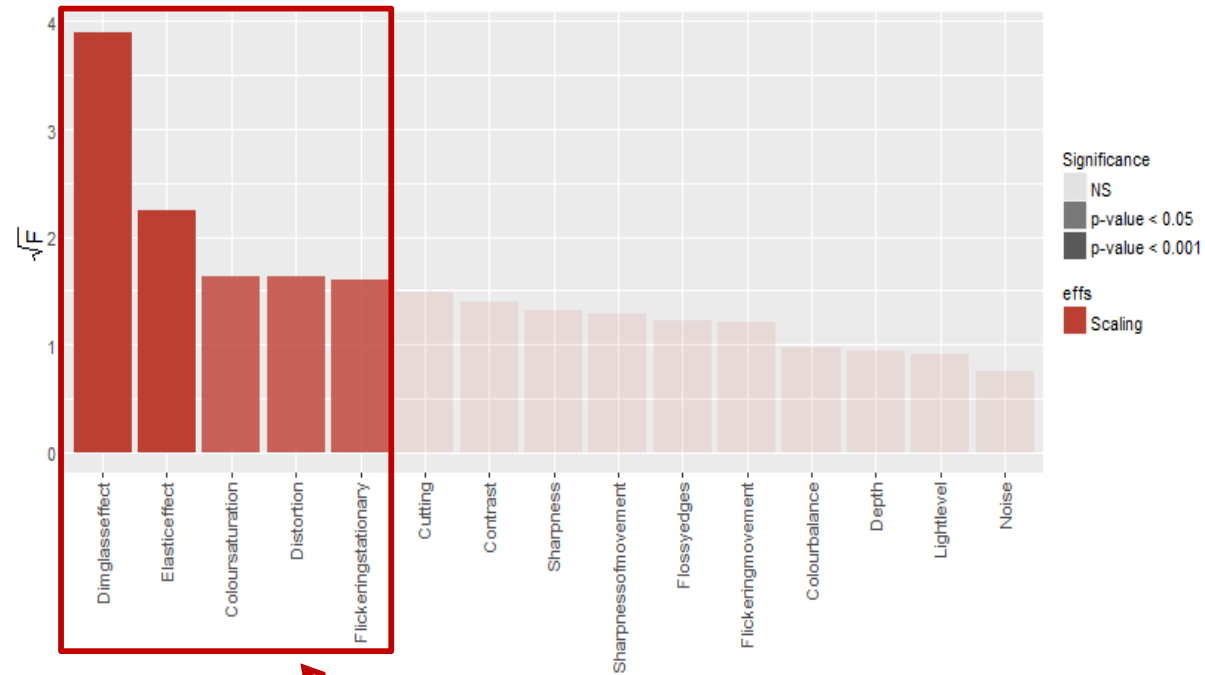
**Plot type**  
d-prime

stacked

**Layout**  
single

**Scale plot**  
1

[Download Plot](#)



For the attributes Dimglasseffect, Elasticeffect, Coloursaturation, Distortion and Flickeringstationary the scaling effect is significant according to the 0.05 level

### Step 3: Look at the results. Multi-attribute plot for the fixed effects

The sizes of the bars correspond to the sizes of the product effects.

Data Plot output Table output Step output Post-hoc MAM analysis

Note: This output is only dedicated for analysis of sensory data

**Plot effects**  
fixed

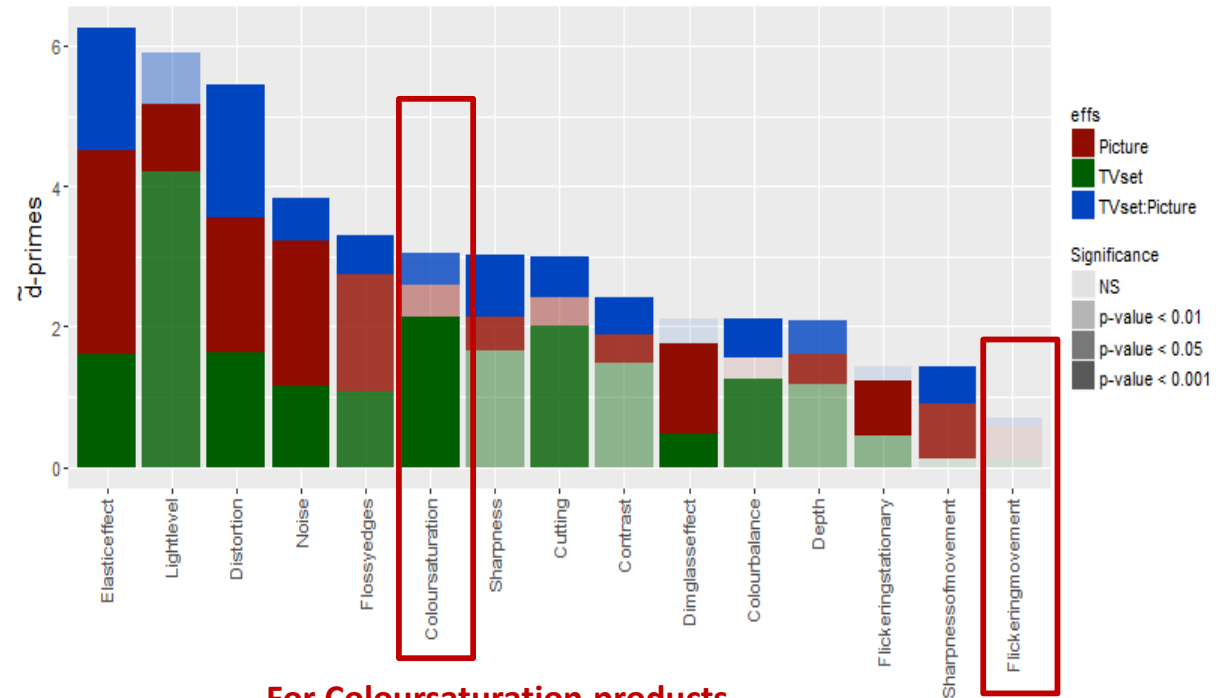
**Plot type**  
d-prime

stacked

**Layout**  
single

**Scale plot**  
1

[Download Plot](#)



For Coloursaturation products differ mainly due to the Tvset feature

Assessors cannot discriminate the products for the Flickeringmovement attribute

### Step 3: Look at the results. The Step output

Data Plot output Table output **Step output** Post-hoc MAM analysis

**Select attribute**

Coloursaturation ▼

**Type**

html ▼

[Download Table](#)

Likelihood ratio tests for the random-effects and their order of elimination representing Step 1 of the automated analysis for the attribute Coloursaturation

	Chi.sq	Chi.DF	elim.num	p-value
TVset:Assessor	19.81	1	0	<0.001
TVset:Picture:Assessor	0.55	1	0	0.457
Assessor	0.33	1	0	0.565

F-tests for the fixed-effects for the attribute Coloursaturation

	Sum Sq	Mean Sq	NumDF	DenDF	F-value	d-prime	Pr(>F)
TVset	31.62	15.81	2	10.64	20.96	2.14	<0.001
Picture	9.45	3.15	3	60.98	4.18	0.45	0.009
TVset:Picture	11.63	1.94	6	60.98	2.57	0.46	0.028
Scaling	14.19	2.03	7	26.96	2.69	1.00	0.030

$$1. y = \mathbf{TV + Pic + TV: Pic + Scaling} + \underbrace{Ass}_{\text{Keep the assessor effect}} + Ass:TV + Ass:Pic + \underbrace{Ass:TV:Pic}_{\text{Keep the highest order interaction between Assessor and product effects}} + \varepsilon$$

$$2. y = \underbrace{\mathbf{TV + Pic + TV: Pic + Scaling}}_{\text{Test fixed effects using the F test}} + Ass + Ass:Pic + Ass:TV:Pic + \varepsilon$$



### Step 3: Look at the results. The post-hoc output

Data Plot output Table output Step output

Post-hoc MAM analysis

Select attribute

Coloursaturation

Type of Plot

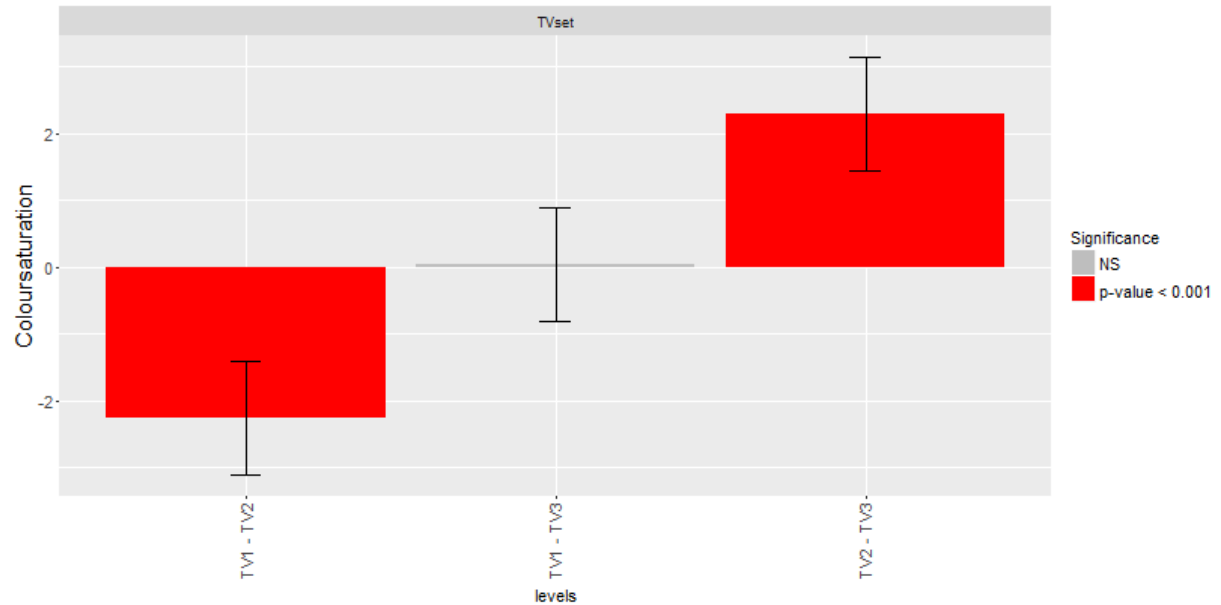
DIFF of LSMEANS

Effects

TVset

Download Table

Download Plot



Multiple comparison tests for attribute Coloursaturation

	Estimate	Standard Error	DF	t-value	Lower CI	Upper CI	p-val
TVset TV1 - TV2	-2.25	0.41	18.20	-5.54	-3.11	-1.40	<0
TVset TV1 - TV3	0.05	0.41	18.20	0.12	-0.80	0.90	0.
TVset TV2 - TV3	2.30	0.41	18.20	5.67	1.45	3.16	<0

**Pairwise comparisons tests for the TVset feature for the Coloursaturation attribute**

## Obtaining **SensMixed**

**SensMixed** is on CRAN. In order to install it either install it through Rstudio *Install* button, or write in the **R** console:

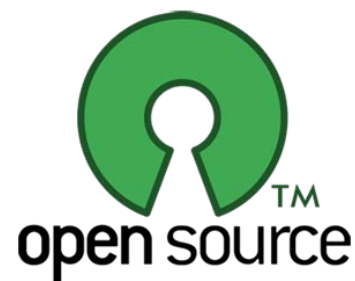
```
install.packages("SensMixed")
```

Attach the package by typing:

```
require("SensMixed")
```

The following command runs the application:

```
SensMixedUI()
```



## Summary **SensMixed**

- Easy-to-use application for non-statisticians
- Handles complex linear mixed effects models
- Different options making the analysis more flexible
  - + Specification of the mixed effects models
  - + Simplification of the mixed effects models
  - + Type 1 error rates for random and fixed effects
  - + keep block effects
  - ...
- New multi attribute plots (delta-plots)
- Handling Mixed Assessor Model
- Analysing consumer data within a mixed effects model framework

# ConsumerCheck



- Standalone software dedicated for analysis of consumer data
- **PanelCheck**-like software
  - easy-to-use
  - Flexible
  - dedicated for sensory practitioners
- Visualize and analyze your data fast and efficient!
- Classical and advanced statistical methods:
  - Basic statistics (plots/tables)
  - PCA
  - Preference mapping (PLSR, PCR)
  - **Conjoint analysis (mixed effects models)**



## Simple mixed effects models in consumer studies

**Conjoint analysis** (Green and Rao 1971; Green and Srinivasan 1978) is a method for analyzing the effects of product factors and consumer characteristics on consumer likings

N consumers

J products

K background information on consumers (e.g. gender)

$$y_{jkn} = \beta_j + \gamma_k + (Cons \times \beta)_{jn} + (Cons \times \gamma)_{kn} + \varepsilon_{jkn}$$

$$(Cons \times \beta)_{jn} \sim N(0, \sigma_{consumer \times product}^2)$$

$$(Cons \times \gamma)_{jn} \sim N(0, \sigma_{consumer (gender)}^2)$$

$$\varepsilon_{jkn} \sim N(0, \sigma_{error}^2)$$

## Simple not always enough!

- Multi-way product structure (products are formed as combination of features)
- Multiple consumer variables (qualitative / quantitative)

### Aim of the new tool:

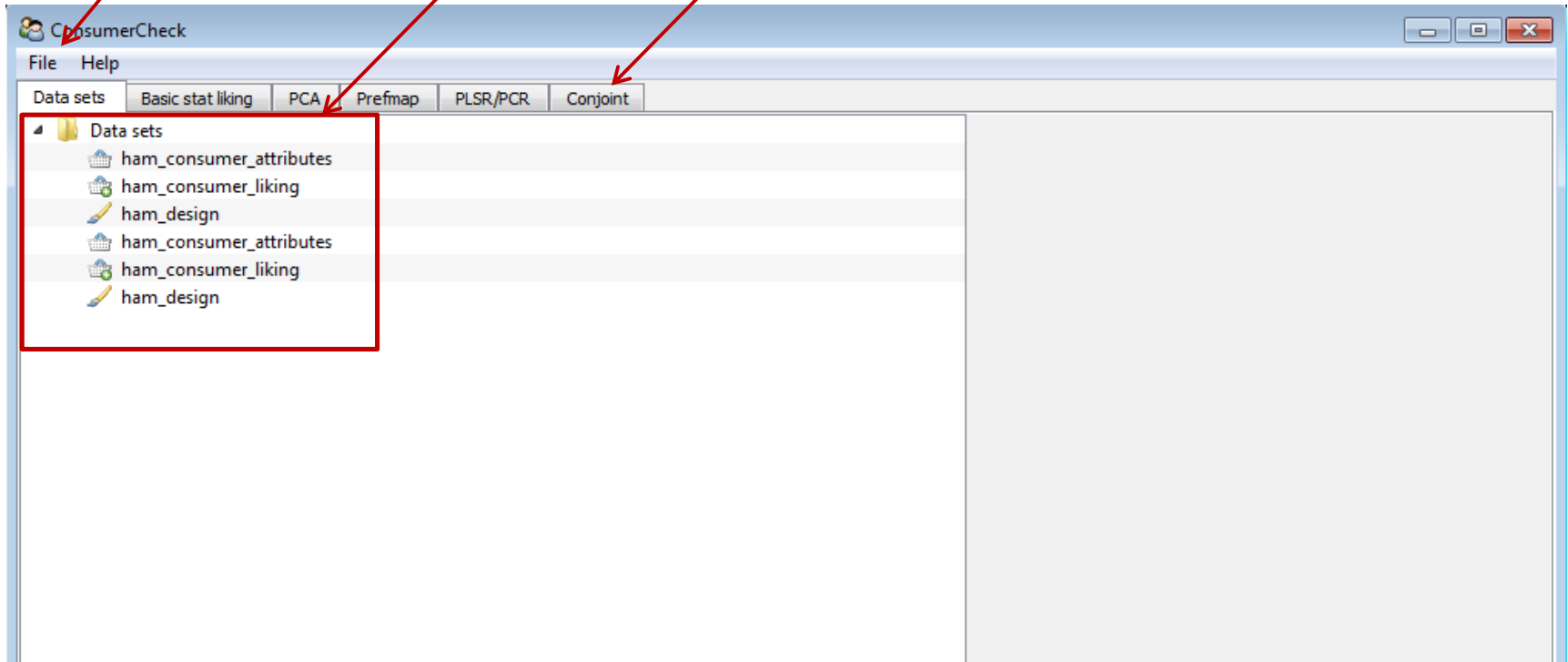
- Handling these more complex situations
- Advanced mixed effects model tools
- Specifically designed for analysis of such data
- Flexible, user friendly

# ConsumerCheck GUI

Import data from the local disc

Or use ham data

Perform Conjoint analysis



## Example: ham data:

- 8 “products”
  - 4 ham products
  - 2 levels of information
- 81 consumers
- Gender, Age (quantitative)





# Example: ham data

Conjoint uses three data sets

Consumer attributes

Design variables

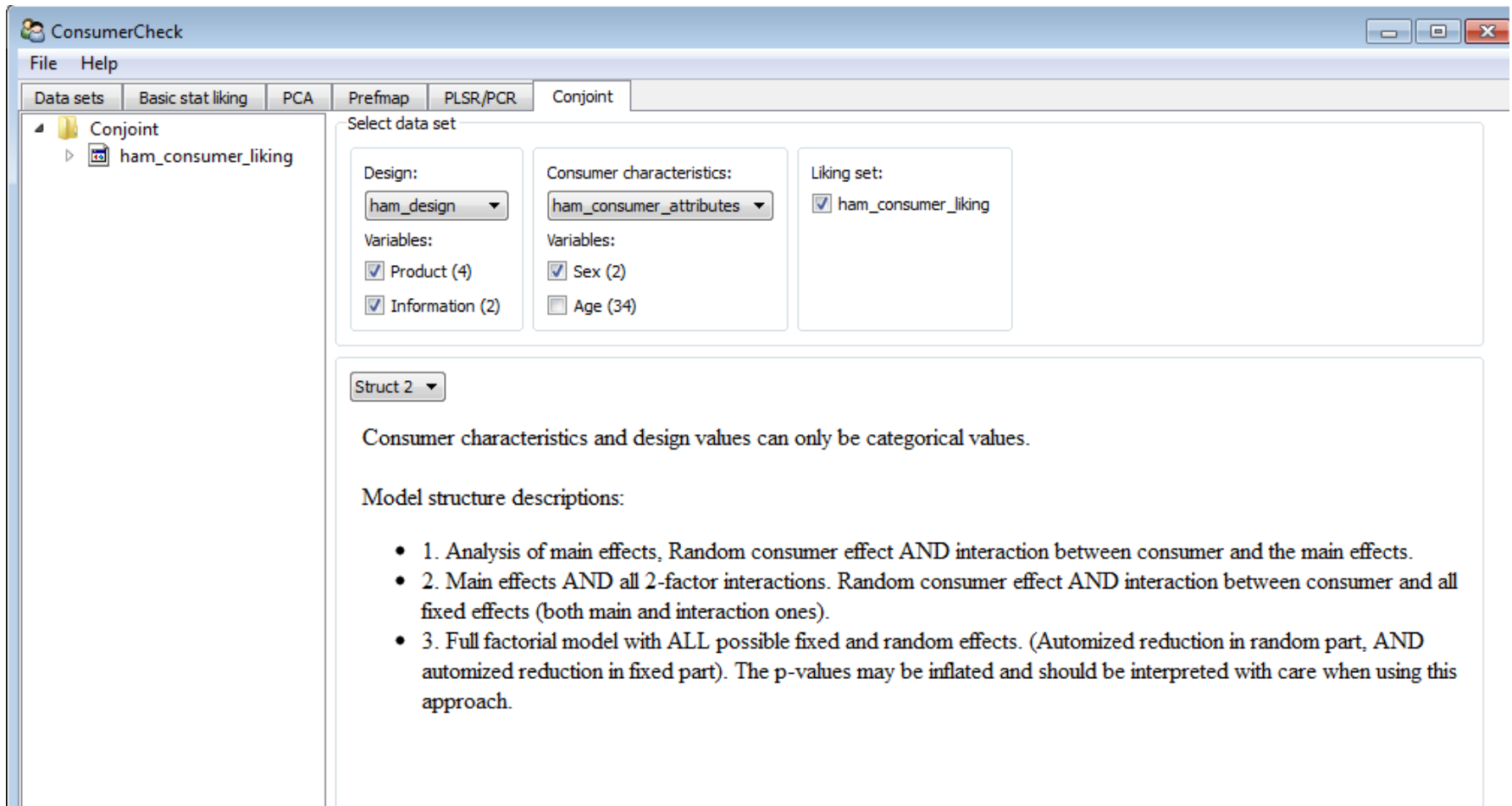
Consumer liking

The screenshot shows the ConsumerCheck software interface with three data set windows open:

- ham\_consumer\_attributes:** A table with columns 'Names', 'Sex', and 'Age'. Red circles highlight the 'Names' column (labeled 'Consumers') and the 'Sex' and 'Age' columns (labeled 'Consumer variables (Sex Age)').
- ham\_design:** A table with columns 'Names', 'Product', and 'Information'. Red circles highlight the 'Names' column (labeled 'Consumers') and the 'Product' and 'Information' columns (labeled 'Design variables (Product Information)').
- ham\_consumer\_liking:** A table with columns 'Names' and four unlabeled columns (1, 2, 3, 4). Red circles highlight the 'Names' column (labeled 'Consumers') and the four unlabeled columns (labeled 'Product').

Design variables (Product Information)

## Example: ham data



The screenshot shows the ConsumerCheck software interface. The window title is "ConsumerCheck". The menu bar includes "File" and "Help". The main menu is "Conjoint", with other options like "Data sets", "Basic stat liking", "PCA", "Prefmap", and "PLSR/PCR" visible. The left sidebar shows a tree view with "Conjoint" expanded to show "ham\_consumer\_liking".

The main area is titled "Select data set" and contains three panels:

- Design:** A dropdown menu showing "ham\_design". Below it, "Variables:" includes checked boxes for "Product (4)" and "Information (2)".
- Consumer characteristics:** A dropdown menu showing "ham\_consumer\_attributes". Below it, "Variables:" includes checked boxes for "Sex (2)" and "Age (34)".
- Liking set:** A checked box for "ham\_consumer\_liking".

Below these panels is a dropdown menu for "Struct 2".

Consumer characteristics and design values can only be categorical values.

Model structure descriptions:

- 1. Analysis of main effects, Random consumer effect AND interaction between consumer and the main effects.
- 2. Main effects AND all 2-factor interactions. Random consumer effect AND interaction between consumer and all fixed effects (both main and interaction ones).
- 3. Full factorial model with ALL possible fixed and random effects. (Automized reduction in random part, AND automized reduction in fixed part). The p-values may be inflated and should be interpreted with care when using this approach.



## Model structures in conjoint

**Struct 1** Analysis of main effects. Random Consumer effect AND interaction between Consumer and the main effects

**Struct 2** main effects AND all all 2-way factor interactions. Random Consumer effects and all interactions between Consumer and fixed effects

**Struct 3** Full factorial model with all possible fixed and random effects. Automated reduction in random part following by automated reduction in fixed part. The automated reduction in fixed part uses the principle of marginality, that is the highest order interactions are tested first: if they are significant, the lower order effects are not eliminated even if being non-significant.

# Example: ham data

The screenshot shows the ConsumerCheck software interface. The left sidebar displays a tree view under 'Conjoint' with 'ham\_consumer\_liking' selected. The main window shows 'ANOVA table for random effects' and 'ANOVA table for fixed effects' dialog boxes.

**ANOVA table for random effects**

Names	Chi.sq	Chi.DF	p.value
Information:Consumer	1.34	1	0.247
Product:Consumer	167.49	1	<0.001
Consumer	2.20	1	0.138

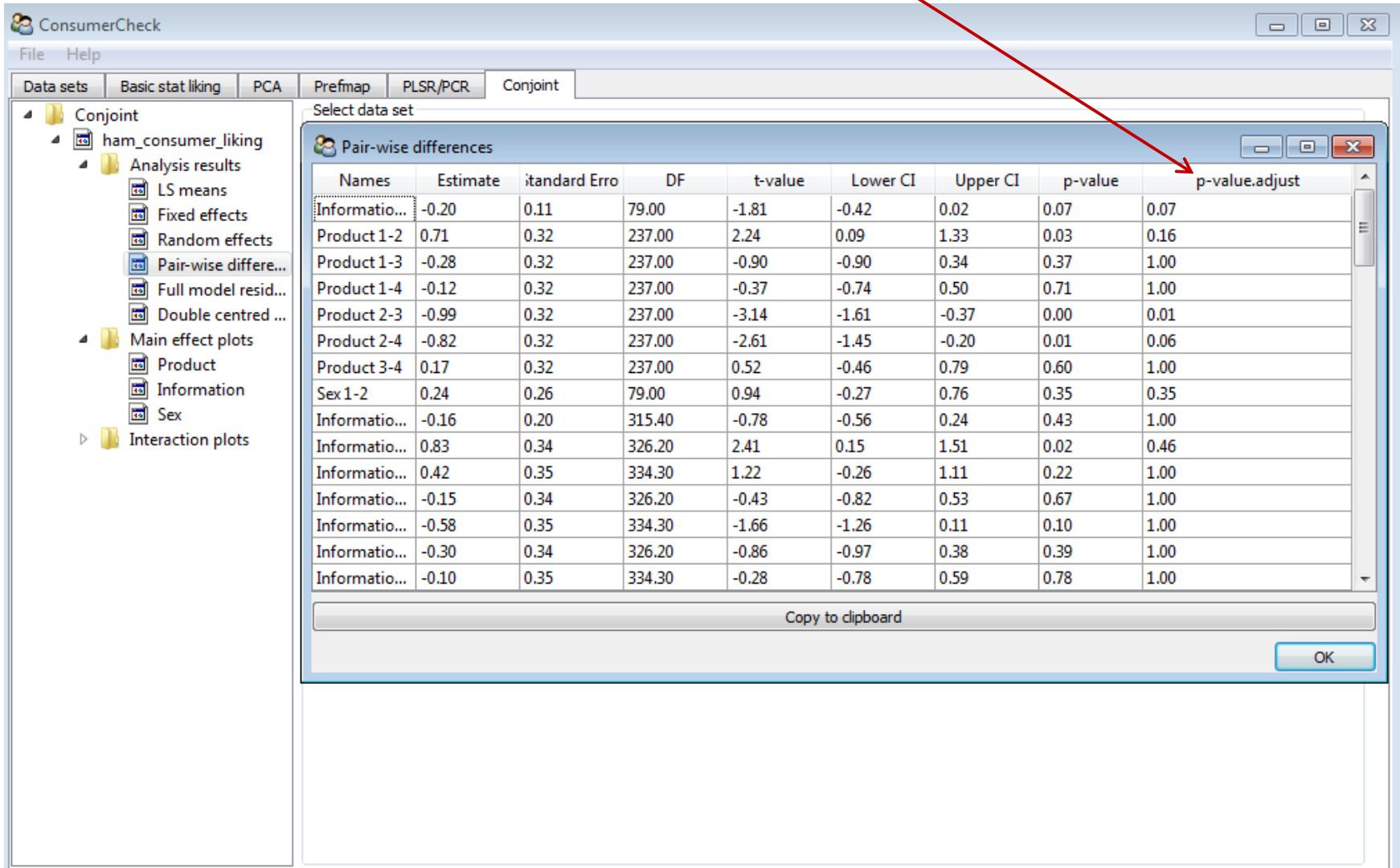
**ANOVA table for fixed effects**

Names	Sum Sq	Mean Sq	NumDF	DenDF	F.value	Pr(>F)
Information	5.24	5.24	1	78.97	3.29	0.073
Product	17.92	5.97	3	236.98	3.82	0.011
Sex	1.38	1.38	1	78.98	0.88	0.351
Information:Product	10.39	3.46	3	239.98	2.20	0.089
Information:Sex	1.13	1.13	1	78.97	0.72	0.399
Product:Sex	1.64	0.55	3	236.98	0.35	0.790

main effects.  
consumer and all  
in part, AND  
e when using this

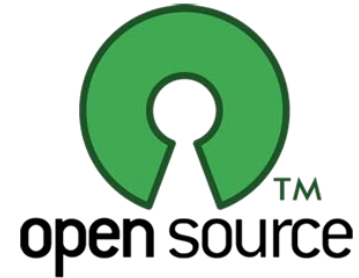
# Example: ham data

Bonferroni corrected



The screenshot shows the ConsumerCheck software interface. The 'Conjoint' tab is active, and the 'Pair-wise differences' window is open. The table displays statistical results for various product and sex comparisons. The 'p-value.adjust' column shows the Bonferroni corrected p-values. A red arrow points from the text 'Bonferroni corrected' to the 'p-value.adjust' column header.

Names	Estimate	Standard Error	DF	t-value	Lower CI	Upper CI	p-value	p-value.adjust
Informatio...	-0.20	0.11	79.00	-1.81	-0.42	0.02	0.07	0.07
Product 1-2	0.71	0.32	237.00	2.24	0.09	1.33	0.03	0.16
Product 1-3	-0.28	0.32	237.00	-0.90	-0.90	0.34	0.37	1.00
Product 1-4	-0.12	0.32	237.00	-0.37	-0.74	0.50	0.71	1.00
Product 2-3	-0.99	0.32	237.00	-3.14	-1.61	-0.37	0.00	0.01
Product 2-4	-0.82	0.32	237.00	-2.61	-1.45	-0.20	0.01	0.06
Product 3-4	0.17	0.32	237.00	0.52	-0.46	0.79	0.60	1.00
Sex 1-2	0.24	0.26	79.00	0.94	-0.27	0.76	0.35	0.35
Informatio...	-0.16	0.20	315.40	-0.78	-0.56	0.24	0.43	1.00
Informatio...	0.83	0.34	326.20	2.41	0.15	1.51	0.02	0.46
Informatio...	0.42	0.35	334.30	1.22	-0.26	1.11	0.22	1.00
Informatio...	-0.15	0.34	326.20	-0.43	-0.82	0.53	0.67	1.00
Informatio...	-0.58	0.35	334.30	-1.66	-1.26	0.11	0.10	1.00
Informatio...	-0.30	0.34	326.20	-0.86	-0.97	0.38	0.39	1.00
Informatio...	-0.10	0.35	334.30	-0.28	-0.78	0.59	0.78	1.00



## Summary **ConsumerCheck**

- Easy-to-use software for non-statisticians
- Proposes advanced tools for analysis of consumer data
- Different options making the analysis more flexible
  - + Specification of the mixed effects models
  - + Simplification of the mixed effects models