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)

Product effect

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

$$a_i \sim N(0, \sigma^2_{assessor})$$

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

$$\varepsilon_{ijl} \sim N(0, \sigma^2_{error})$$

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

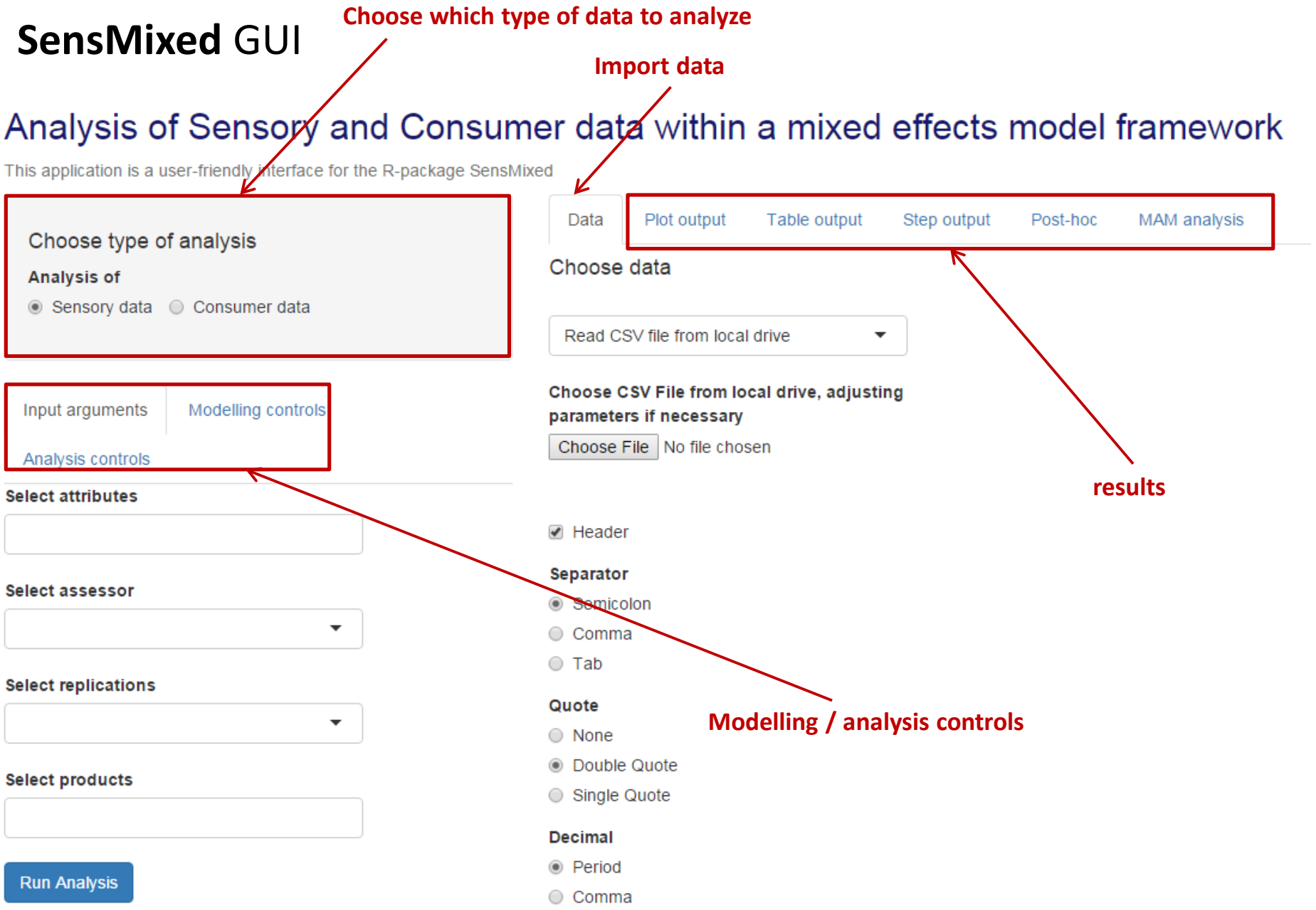
SensMixed R- package with GUI

- 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



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

Choose sensory data

Choose TVbo data

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 Elasticeffect

Select assessor

Assessor

Select replications

Repeat

Select products

TVset Picture

Run Analysis

Multi-way product structure

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

Choose data

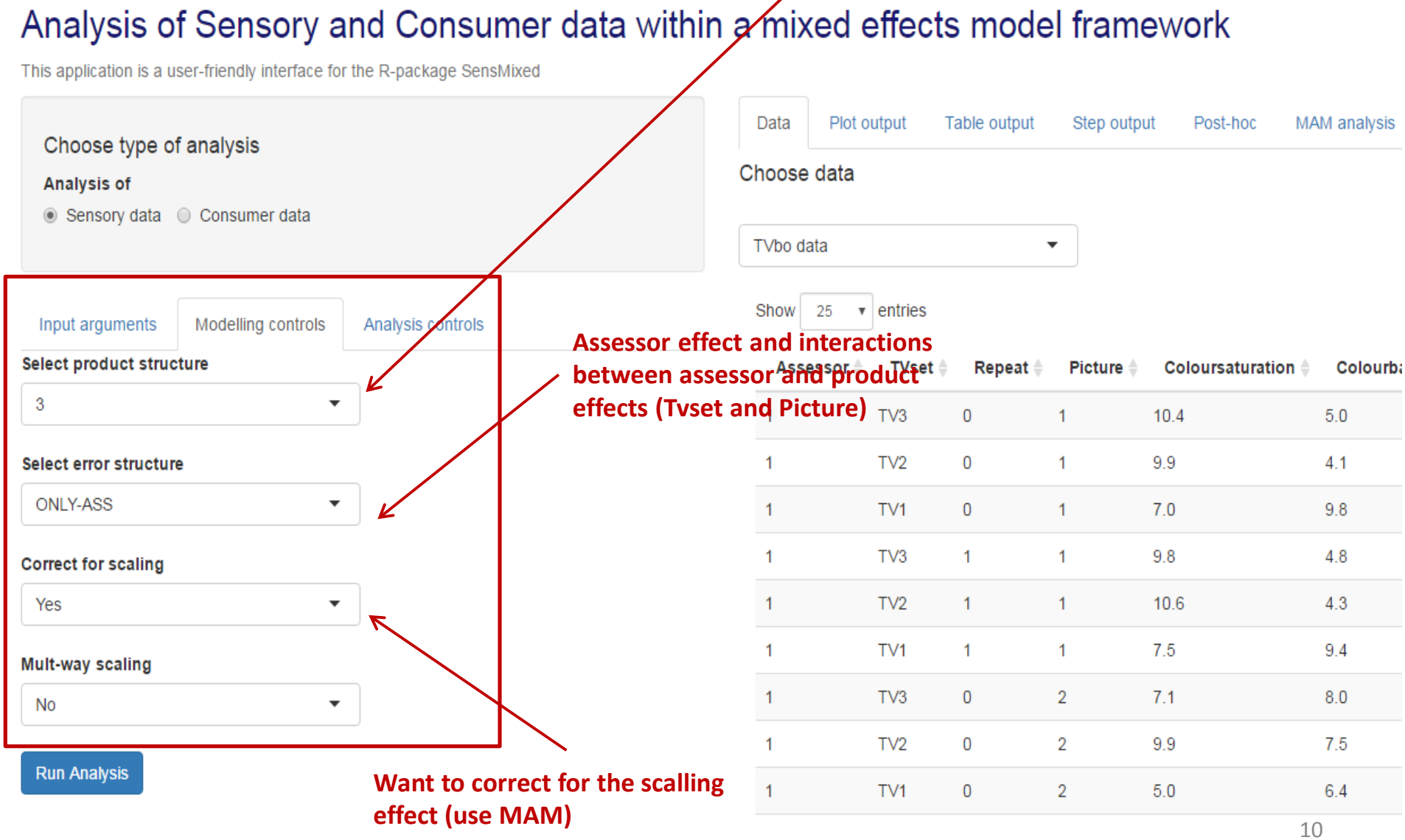
TVbo data

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

Step 2: Select modelling controls

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

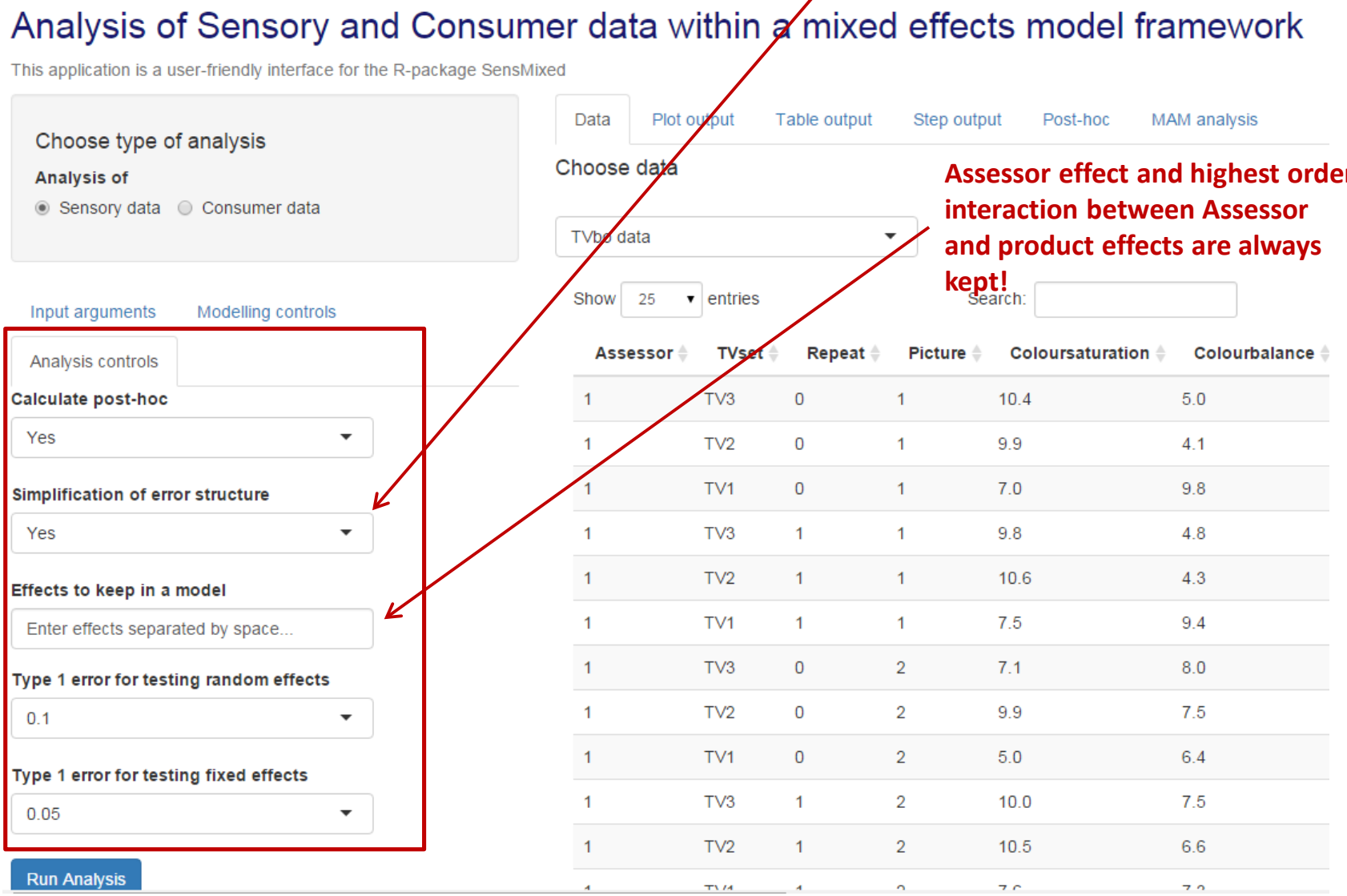


Assessor effect and interactions between assessor and product effects (Tvset and Picture)

Want to correct for the scalling effect (use MAM)

Step 3: Select analysis controls

Step-wise selection process



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

What is actually done?..

Individual scaling slopes

Centered product averages inserted a covariate

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

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

error structure = ONLY-ASS
(no replicate effect)

Scaling effect

2. 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)

3. 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

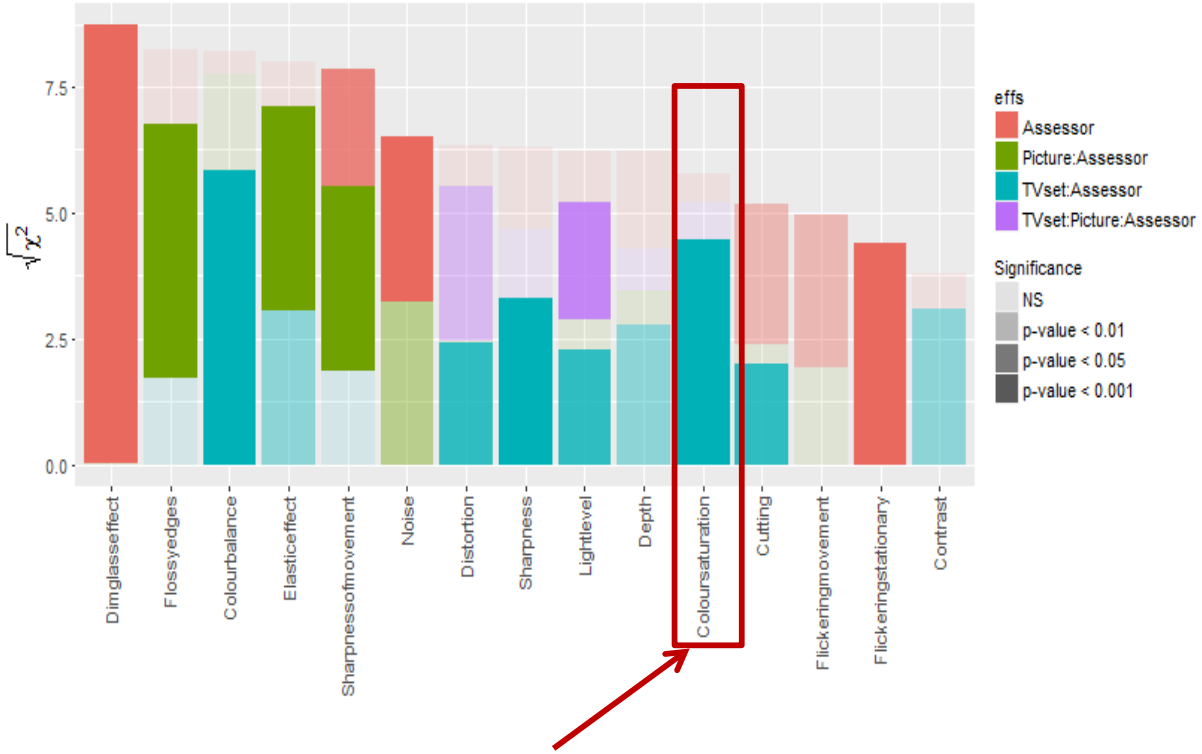
Layout

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

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Plot effects

scaling

Plot type

d-prime

☑ stacked

Layout

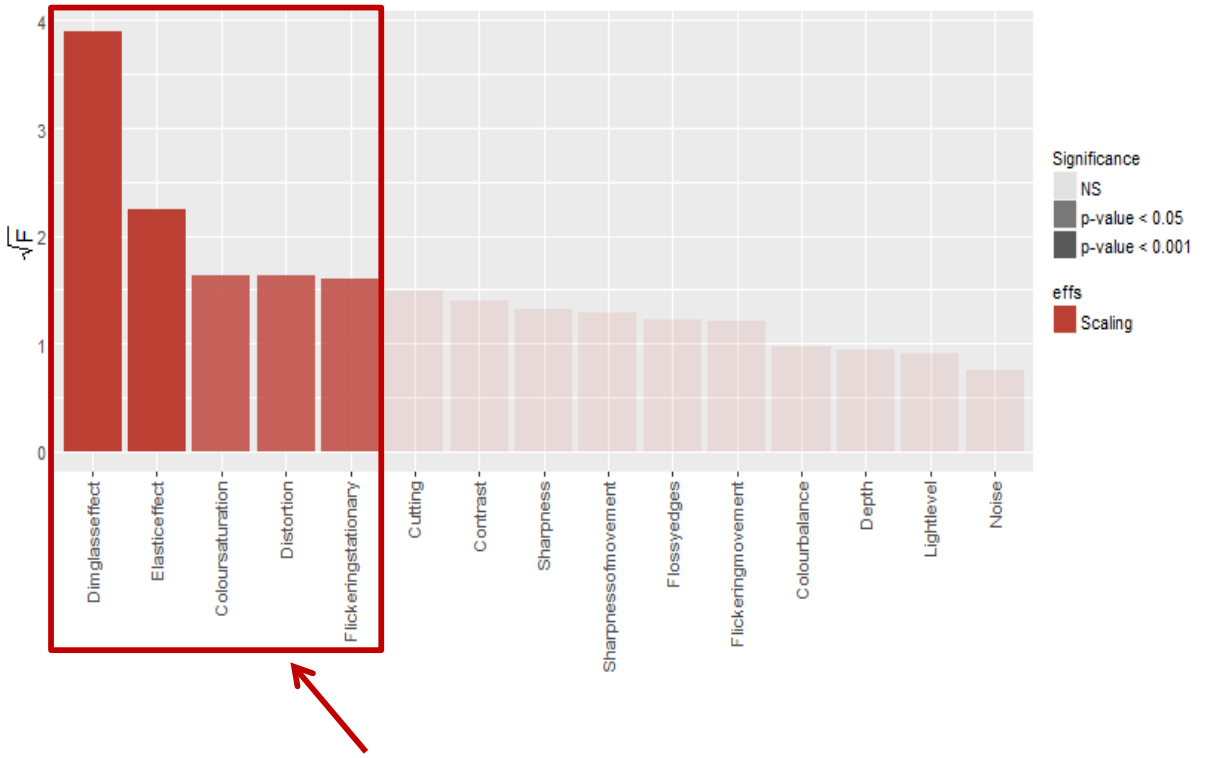
single

Scale plot

1

Download Plot

The F test for the scaling effect



For the attributes Dimglasseffect, Elasticeeffect, 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

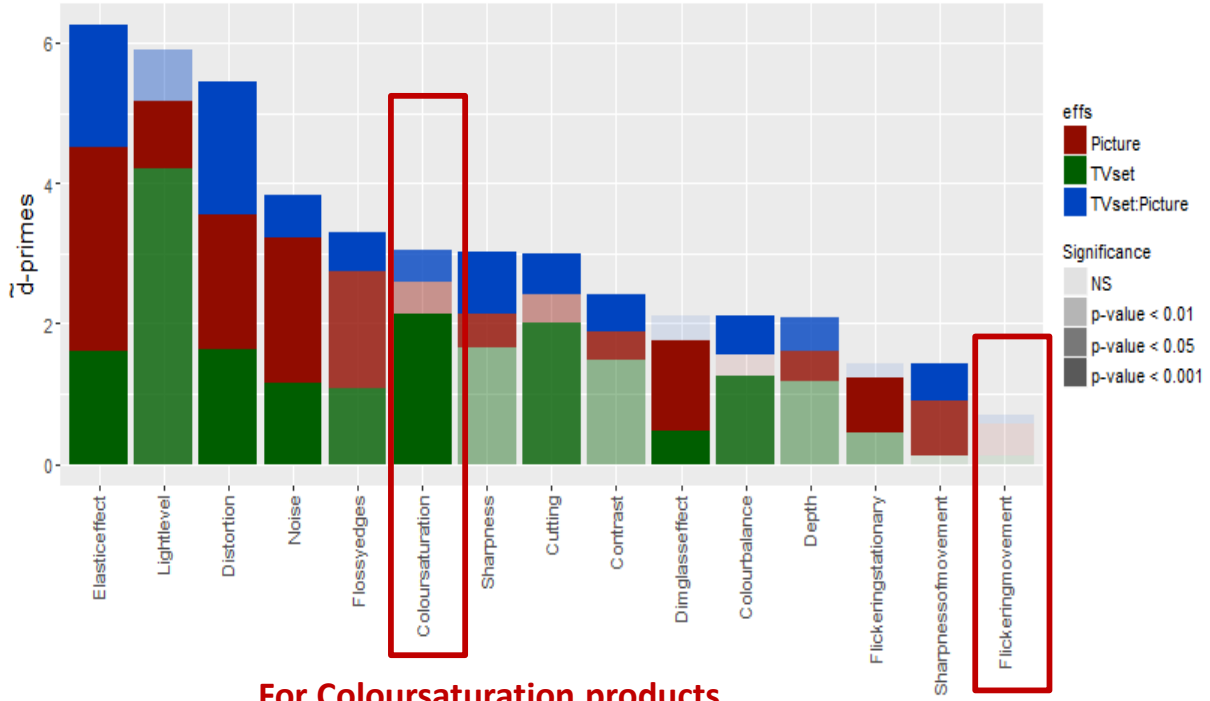
Plot type
d-prime

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. $y = \mathbf{TV} + \mathbf{Pic} + \mathbf{TV}\mathbf{:}\,\mathbf{Pic} + \boldsymbol{Scaling} + Ass + Ass\mathbf{:}\,TV + Ass\mathbf{:}\,Pic + Ass\mathbf{:}\,TV\mathbf{:}\,Pic + \varepsilon$

Keep the assessor effect

Keep the highest order interaction between Assessor and product effects

2. $y = \mathbf{TV} + \mathbf{Pic} + \mathbf{TV}\mathbf{:}\,\mathbf{Pic} + \boldsymbol{Scaling} + Ass + Ass\mathbf{:}\,Pic + Ass\mathbf{:}\,TV\mathbf{:}\,Pic + \varepsilon$

Test fixed effects using the F test

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

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

Select attribute

Coloursaturation

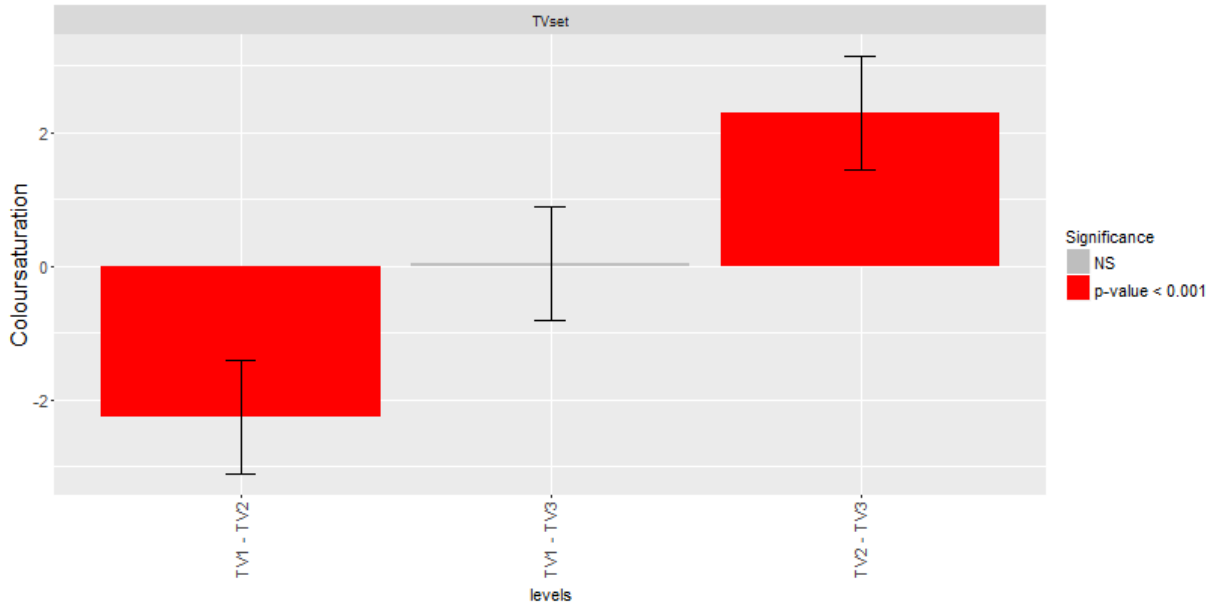
Type of Plot

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")
```

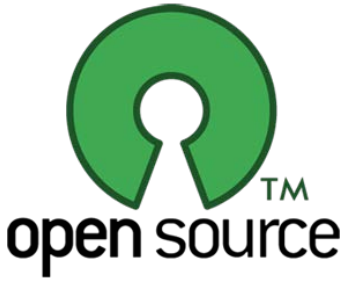
Attach the package by typing:

```
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)

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

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

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

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

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:

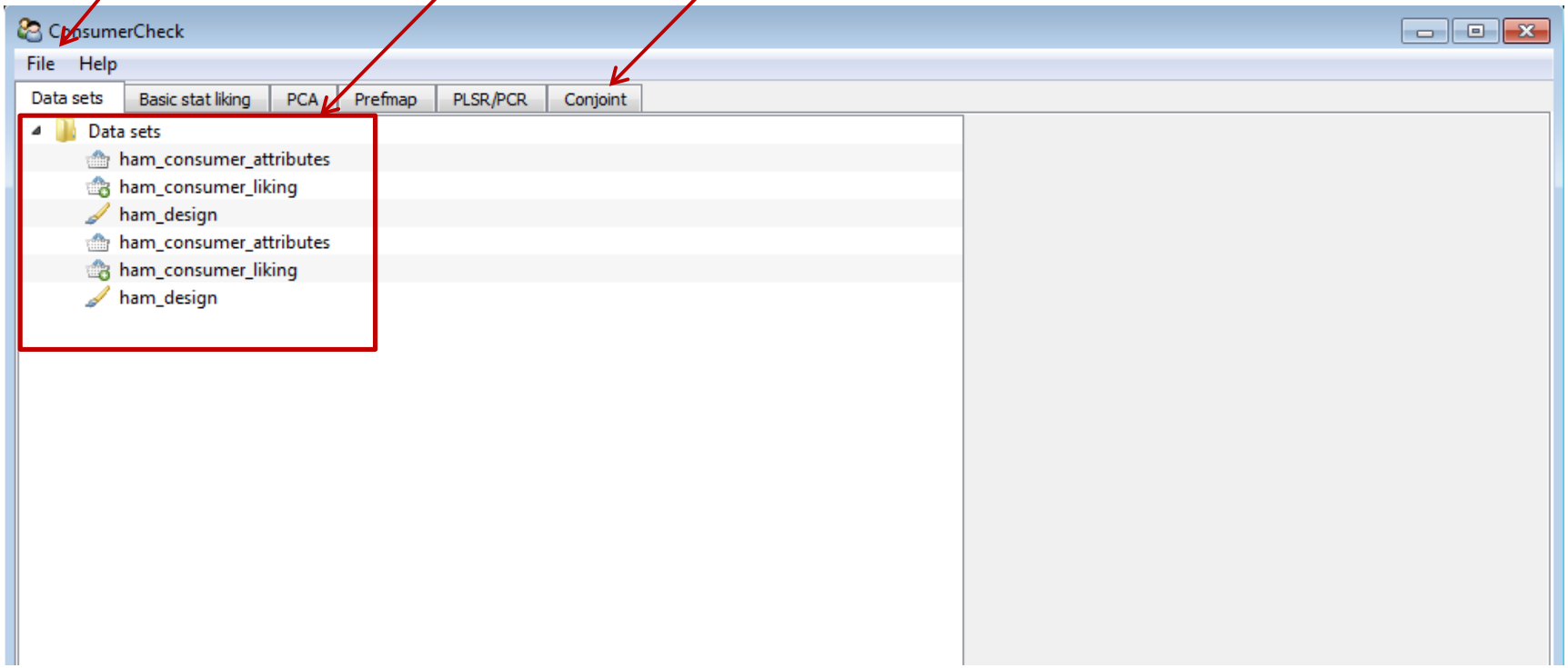
- Handling these more complex situations
- Advanced mixed effects model tools
- Specifically designed for analysis of such data
- Flexible, user friendly

ConsumerCheck GUI

Import data from the local disc

Or use ham data

Perform Conjoint analysis

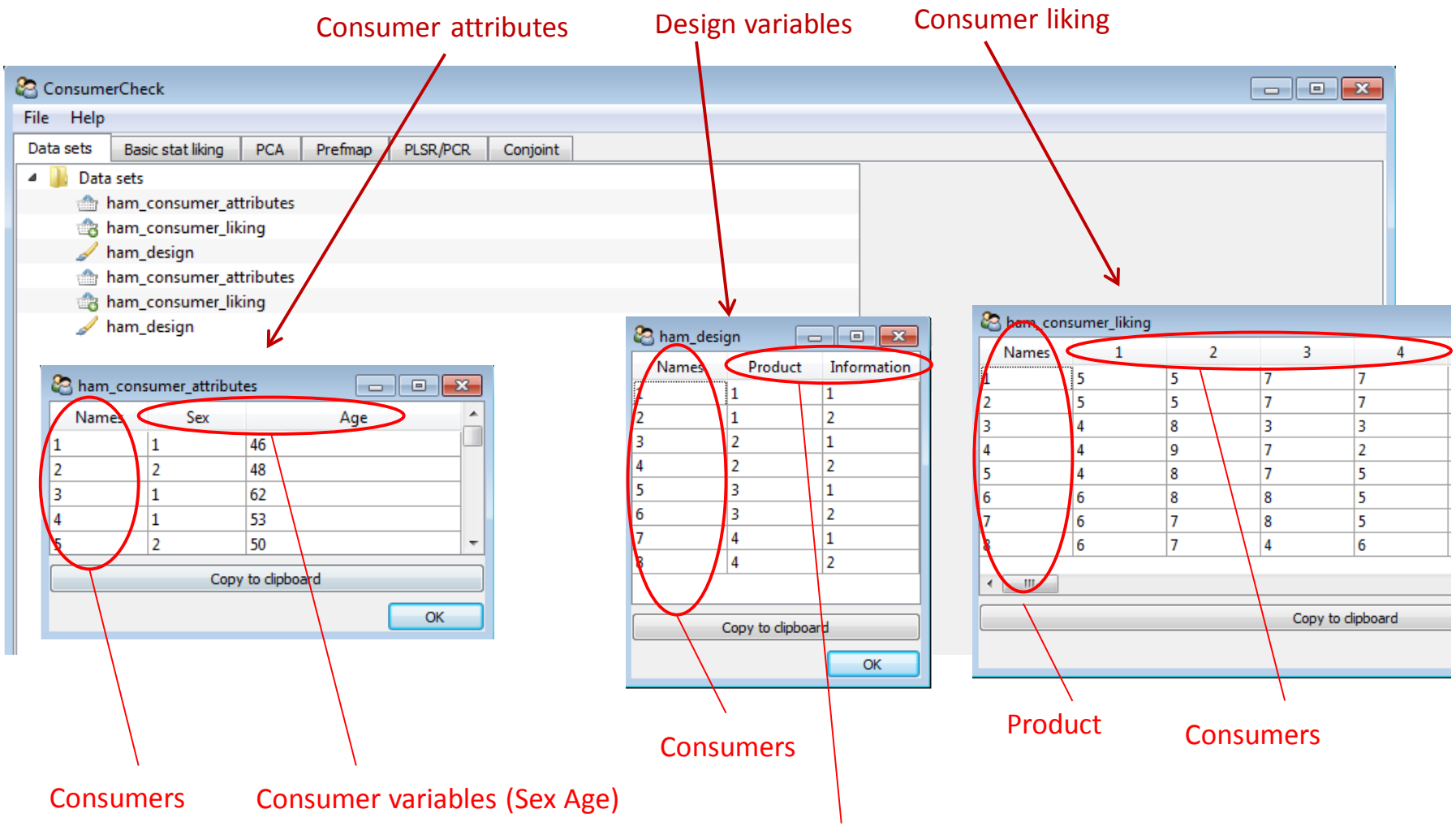


Example: ham data:

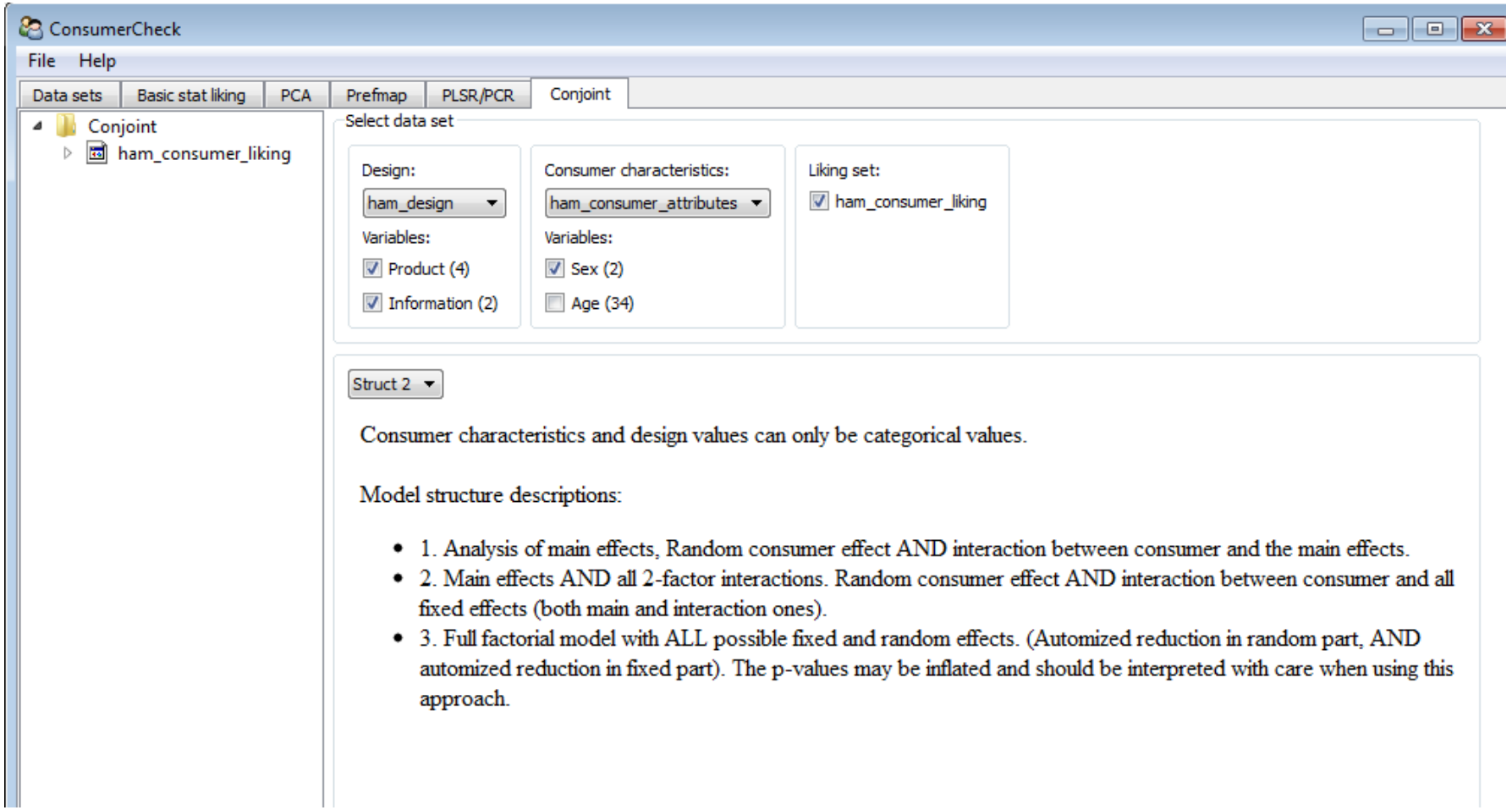
- 8 “products”
  - 4 ham products
  - 2 levels of information
- 81 consumers
- Gender, Age (quantitative)

Example: ham data

Conjoint uses three data sets



Example: ham data



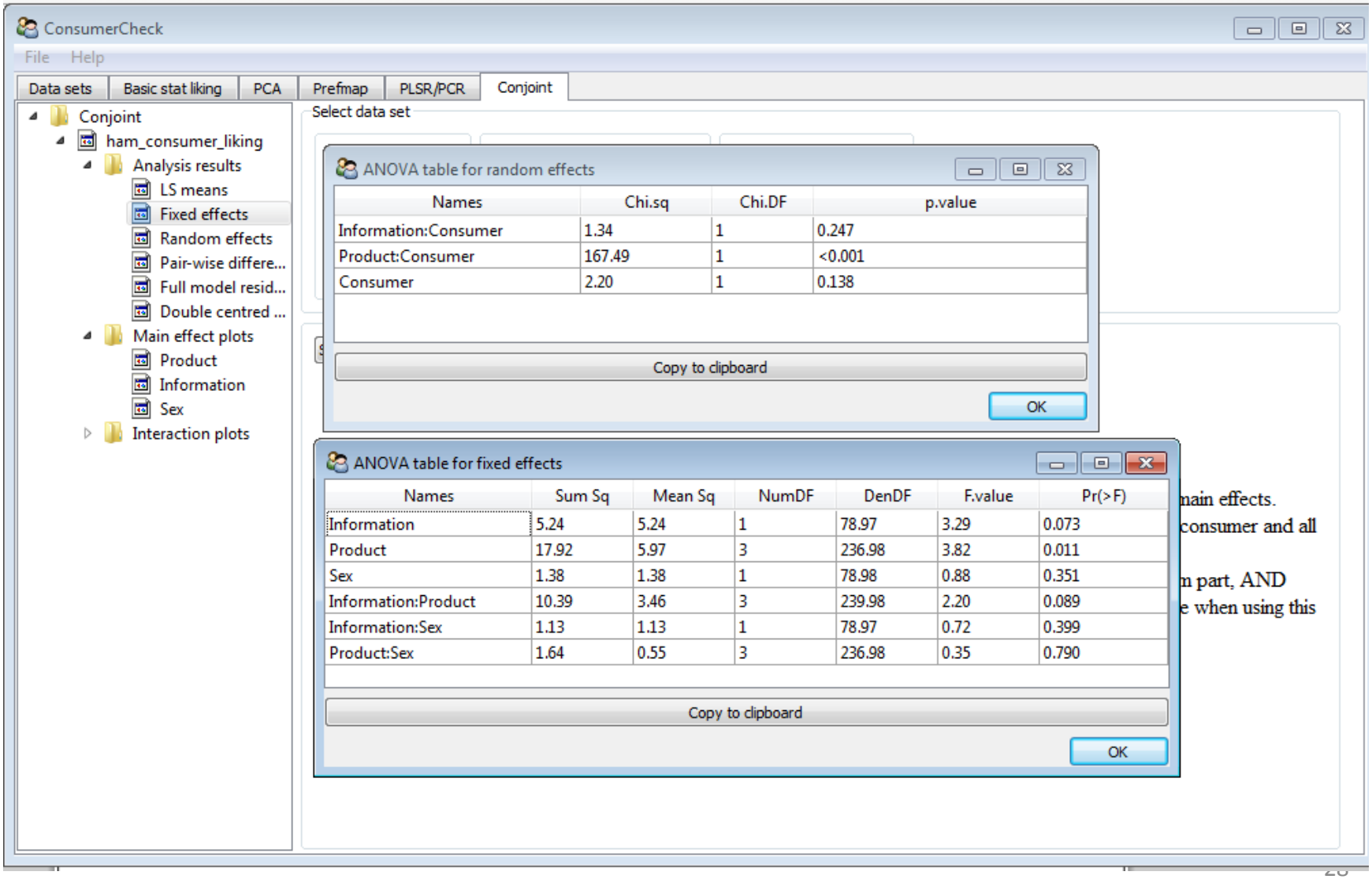
Model structures in conjoint

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

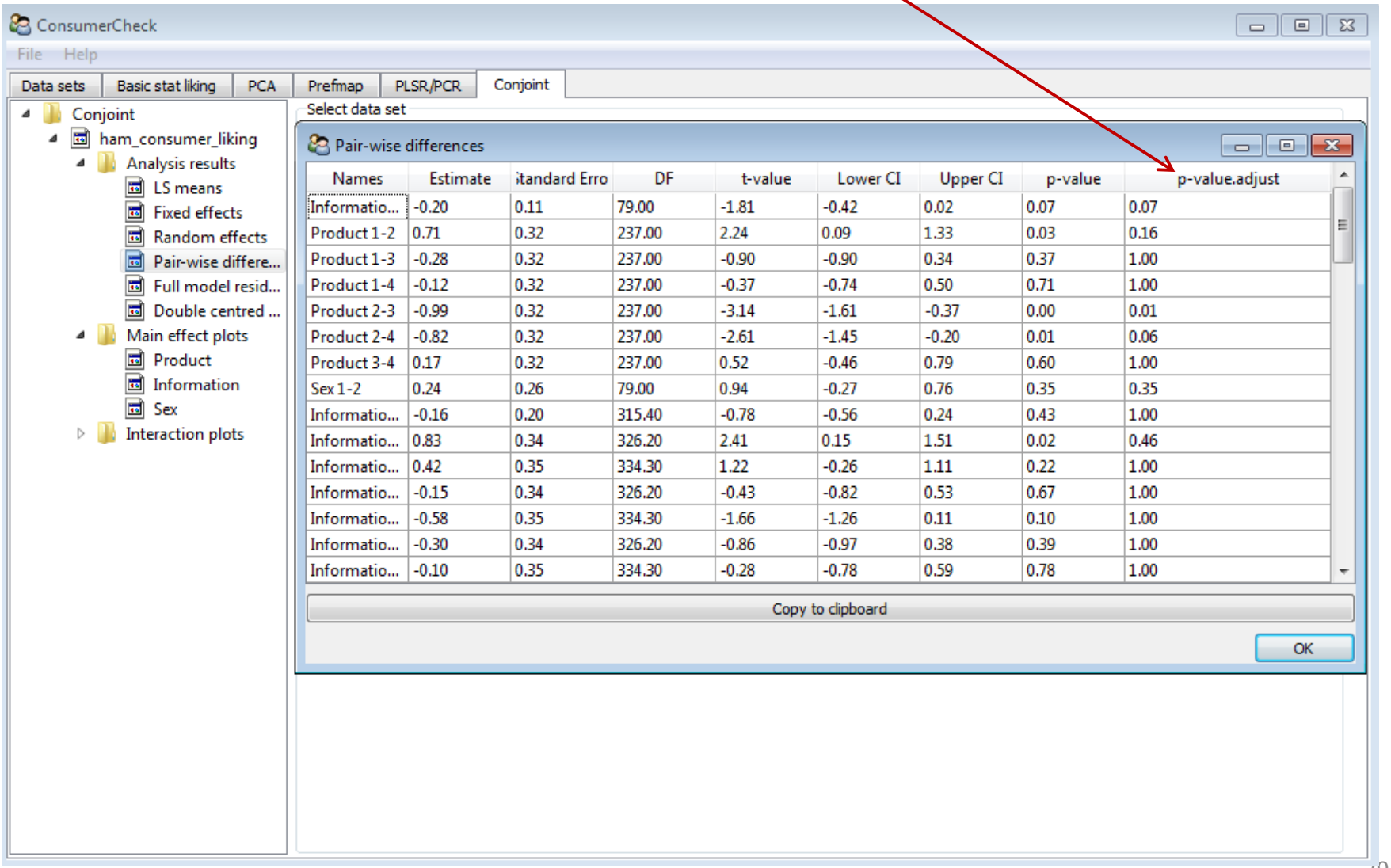
Struct 3 Full factorial model with all possible fixed and random effects. Automated reduction in random part following by automated reduction in fixed part. The automated reduction in fixed part uses the principle of marginality, that is the highest order interactions are tested first: if they are significant,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

Example: ham data

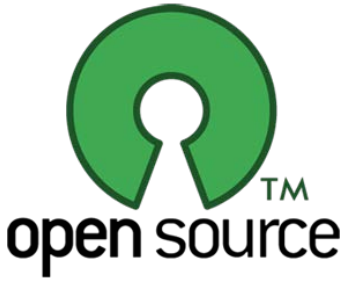


Example: ham data

Bonferroni corrected



Names	Estimate	tandard Erro	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