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)

\[ y_{ijkl} = \mu + a_i + \beta_j + d_{ij} + \varepsilon_{ijl} \]

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

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

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

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

Input arguments
- Modelling controls

Analysis controls

Select attributes

Select assessor

Select replications

Select products

Run Analysis

Modelling / analysis controls

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
Example: TVbo data:

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

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<th>TVset</th>
<th>Repeat</th>
<th>Picture</th>
<th>Coloursaturation</th>
<th>Colourbalance</th>
<th>Noise</th>
<th>Depth</th>
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<td>9.5</td>
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</table>
Step 1: Choose type of analysis and choose data

Choose type of analysis:
- Sensory data
- Consumer data

Choose data:
- TVbo data

Select attributes:
- Coloursaturation
- Colourbalance
- Noise
- Depth
- Sharpness
- Lightlevel
- Contrast
- Sharpnessofmovement
- Flickeringstationary
- Flickeringmovement
- Distortion
- Dimglaseffect
- Cutting
- Flossyedges
- Elasticeffect

Select assessor:
- Assessor

Select replications:
- Repeat

Select products:
- TVset
- Picture

Multi-way product structure
Step 2: Select modelling controls

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

Want to correct for the scaling effect (use MAM)

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

Step-wise selection process

Assessor effect and highest order interaction between Assessor and product effects are always kept!
What is actually done?..

1. \[ y = TV + Pic + TV: Pic + Ass + Ass: TV + Ass: Pic + Ass: TV: Pic + \beta \cdot x + \epsilon \]

   - **Product structure** = 3
     - (main effects: TVset and Picture and interaction between them)
   - **Error structure** = ONLY-ASS
     - (no replicate 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

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

The F test for the scaling effect

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

For Coloursaturation products differ mainly due to the Tvset feature.

Assessors cannot discriminate the products for the Flickeringmovement attribute.

The sizes of the bars correspond to the sizes of the product effects.
Step 3: Look at the results. The Step output

1. \( y = TV + Pic + TV:Pic + Scaling + Ass + Ass:TV + Ass:Pic + Ass:TV:Pic + \varepsilon \)
   - Keep the assessor effect
   - Keep the highest order interaction between Assessor and product effects

2. \( y = TV + Pic + TV:Pic + Scaling + Ass + Ass:Pic + Ass:TV:Pic + \varepsilon \)
   - Test fixed effects using the F test
Step 3: Look at the results. The post-hoc output

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:

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

Attach the package by typing:

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

The following command runs the application:

```r
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)

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

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

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

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

- Consumer attributes
- Design variables
- Consumer liking

Consumers
Consumer variables (Sex Age)

Design variables (Product Information)

Product
Consumers
Example: ham data

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
Example: ham data

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<th>Names</th>
<th>Estimate</th>
<th>Standard Error</th>
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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