

# Automated Mixed ANOVA Modelling of sensory and consumer data



Alexandra Kuznetsova<sup>1</sup>, Rune H.B. Christensen<sup>1</sup>,  
Cécile Bavay<sup>2</sup>, Per Bruun Brockhoff<sup>1</sup>

<sup>1</sup>*DTU Informatics,  
Technical University, Denmark*

<sup>2</sup>*LUNAM Université, SFR QUASAV 4207, Groupe ESA,  
UPSP GRAPPE*

$$f(x+\Delta x) = \sum_{i=0}^{\infty} \frac{(\Delta x)^i}{i!} f^{(i)}(x) \int_a^b \varepsilon \Theta^{\sqrt{17}} + \Omega \int \delta e^{ix} = \{2.7182818284\}$$

The equation is decorated with various mathematical symbols and colors: a purple integral sign, a yellow integral sign, a blue Greek letter epsilon, a purple Greek letter theta, a red Greek letter omega, a red integral sign, a red delta, a red exponential function, a red equals sign, a red curly brace, a red infinity symbol, a red sigma symbol, a red arrow, a red exclamation mark, and a red comma.

# Take home



$$f(x+\Delta x) = \sum_{n=0}^{\infty} \frac{(\Delta x)^n}{n!} f^{(n)}(x)$$

A collection of colorful mathematical symbols including  $\Delta$ ,  $\int$ ,  $\Theta$ ,  $\infty$ ,  $\chi^2$ ,  $\Sigma$ ,  $!$ ,  $\pi$ ,  $\delta$ ,  $e$ ,  $\pi$ ,  $\sqrt{17}$ , and  $\pi$ .



- **NEW R-package: *ImerTest***
  - <https://r-forge.r-project.org/projects/Imertest/>
- **Mixed modeling in R more useful for practitioner:**
  - *F-tests of fixed effects*
  - *LSMEANS*
  - *Satterthwaithe and Kenward Rogers degrees of freedom*
- **Offers automated model selection/adaptation**
  - *In random effects*
  - *In fixed effects*
- **This is a valuable tool for Sensory and Consumer data!**

# Simple Mixed Models in *Sensory and Consumer*

- **Balanced/complete simple designed sensory profile or consumer preference data:**

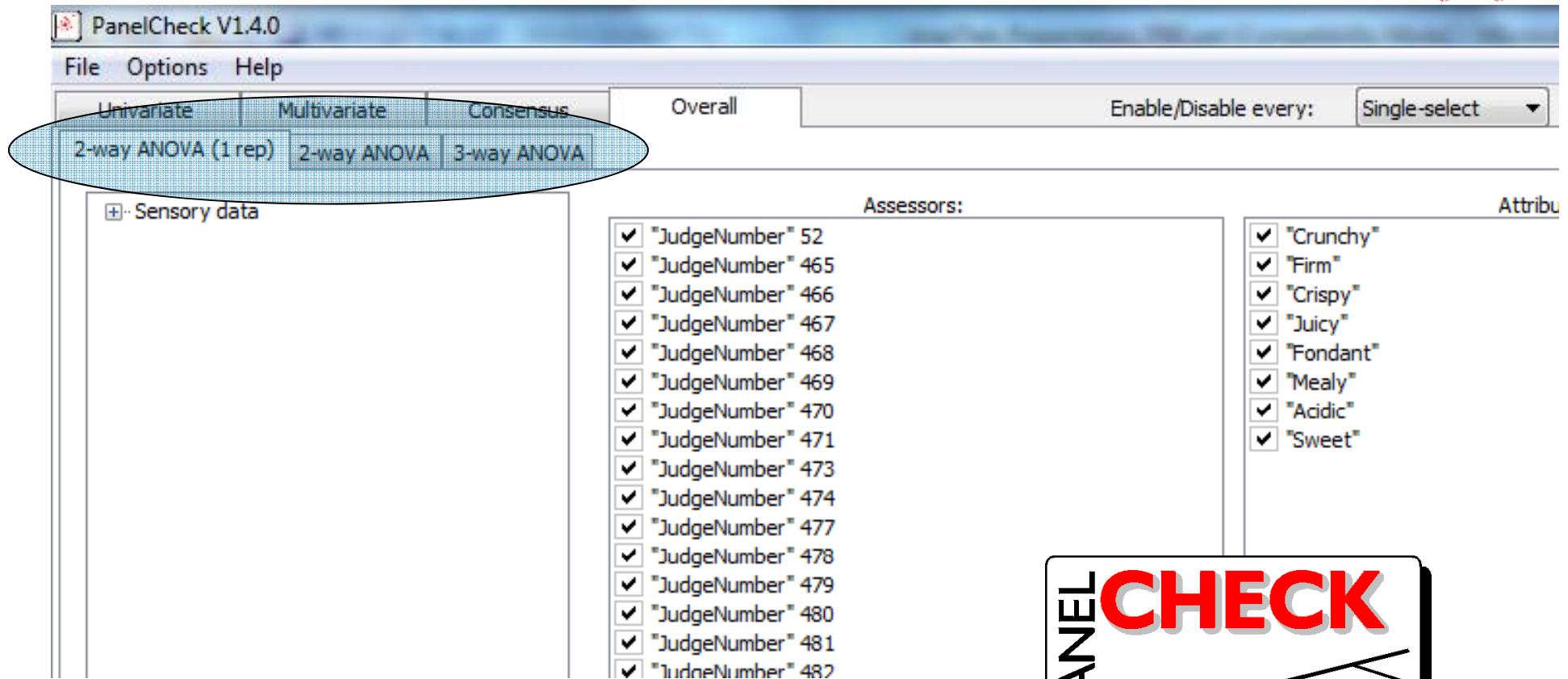
- **2-way randomized block analysis:** 
$$F = \frac{MS_{Prod}}{MS_{Error}}$$

- **2-way randomized replicates analysis:** 
$$F = \frac{MS_{Prod}}{MS_{Prod*Assessor}}$$

- **3-way sessioned/batched analysis:**

$$F = \frac{MS_{Prod}}{MS_{Prod*Assessor} + MS_{Prod*Session} - MS_{Error}}$$

# Available in PanelCheck



# Simple not always enough

## 4 Examples in paper

$$f(x+\Delta x) = \sum_{n=0}^{\infty} \frac{(\Delta x)^n}{n!} f^{(n)}(x)$$
$$\int_a^b \epsilon^{\Theta} + \int \delta e^{i\pi} = 2.7182818284$$

$\chi^2$   $\Sigma$   $!$   $\gg$   $\int$



- **HAM data** (Mæs, Brockhoff and Tomic, 2010)
  - *”Conjoint with consumer background info”*
- **TV data** (Bang&Olufsen, Sensometrics, Ås, 2006)
  - *”Sensory Profile with multi-way product structure”*
- **CARROTS data** (Brockhoff, DTU course 02429)
  - *”External Preference Mapping with consumer background”*
- **APPLES data** (Cécile Bavay, 2012)
  - *”Sensory Profile with complex product blocking/sampling”*

# Simple not always enough

## 2 Examples

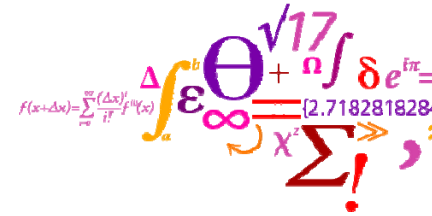
$$f(x+\Delta x) = \sum_{n=0}^{\infty} \frac{(\Delta x)^n}{n!} f^{(n)}(x)$$
$$\int_a^b \epsilon^{\Theta} + \int \delta e^{i\pi} = 2.7182818284$$

$\chi^2$   $\Sigma!$



- **HAM data** (Næs, Brockhoff and Tomic, 2010)
  - *”Conjoint with consumer background info”*
- **TV data** (Bang&Olufsen, Sensometrics, Ås, 2006)
  - *”Sensory Profile with multi-way product structure”*

# HAM data



- 4 ham products
- 2 levels of information
- 81 Consumers (liking scores for all 8 combis)
  
- Consumer background info:
  - Gender
  - Age (quantitatively)

# HAM data



```
library(lmerTest)
```

```
data(ham)
```

```
m2<-lmer(Informed.liking ~  
  Product*Information*Gender*Age+  
  (1|Consumer) +(1|Product:Consumer) +  
  (1|Information:Consumer), data=ham)
```

```
s<-step(m2)
```

**Fixed effects**

**Random effects**



# HAM data



## Random effects:

	Chi.sq	Chi.DF	elim.num	p.value
(1   Consumer)	3.09	1	0	0.08 .
(1   Product:Consumer)	174.16	1	0	<2e-16 ***
(1   Information:Consumer)	1.62	1	1	0.20

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

# HAM data



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# HAM data



## WITHOUT *ImerTest*:

```
> anova(m2)
```

Analysis of Variance Table

**No P-Values!**

	Df	SumSq	MeanSq	Fvalue
Product	3	17.3395	5.7798	3.7379
Information	1	5.1979	5.1979	3.3616
Gender	1	1.3373	1.3373	0.8649
Age	1	0.0232	0.0232	0.0150
Product:Information	3	10.3873	3.4624	2.2392
Product:Gender	3	1.5905	0.5302	0.3429
Information:Gender	1	1.1221	1.1221	0.7257
Product:Age	3	2.9273	0.9758	0.6311
Information:Age	1	0.0067	0.0067	0.0043
Gender:Age	1	1.1028	1.1028	0.7132
Product:Information:Gender	3	5.9915	1.9972	1.2916
Product:Information:Age	3	7.1015	2.3672	1.5309
Product:Gender:Age	3	0.5835	0.1945	0.1258
Information:Gender:Age	1	4.2583	4.2583	2.7539
Product:Information:Gender:Age	3	7.2065	2.4022	1.5535

(Type I ANOVA table)

# HAM data



## Fixed effects: (WITH ImerTest)

	NumDF	DenDF	F.value	elim.num	p.value
Product	3	240	3.82921	0	0.01 *
Information	1	323	3.87139	0	0.05 *
Gender	1	79	0.87892	13	0.35
Age	1	78	0.01507	11	0.90
Product:Information	3	317	2.08337	7	0.10
Product:Gender	3	234	0.18440	4	0.91
Information:Gender	1	322	0.83529	12	0.36
Product:Age	3	237	0.80899	6	0.49
Information:Age	1	321	0.00498	9	0.94
Gender:Age	1	77	0.71315	10	0.40
Product:Information:Gender	3	311	1.18630	3	0.32
Product:Information:Age	3	314	1.45313	5	0.23
Product:Gender:Age	3	231	0.12579	2	0.94
Information:Gender:Age	1	320	3.18169	8	0.08 .
Product:Information:Gender:Age	3	308	1.46065	1	0.23

---

Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Type I/III ANOVA table)

# HAM data



## Fixed effects: (WITH ImerTest)

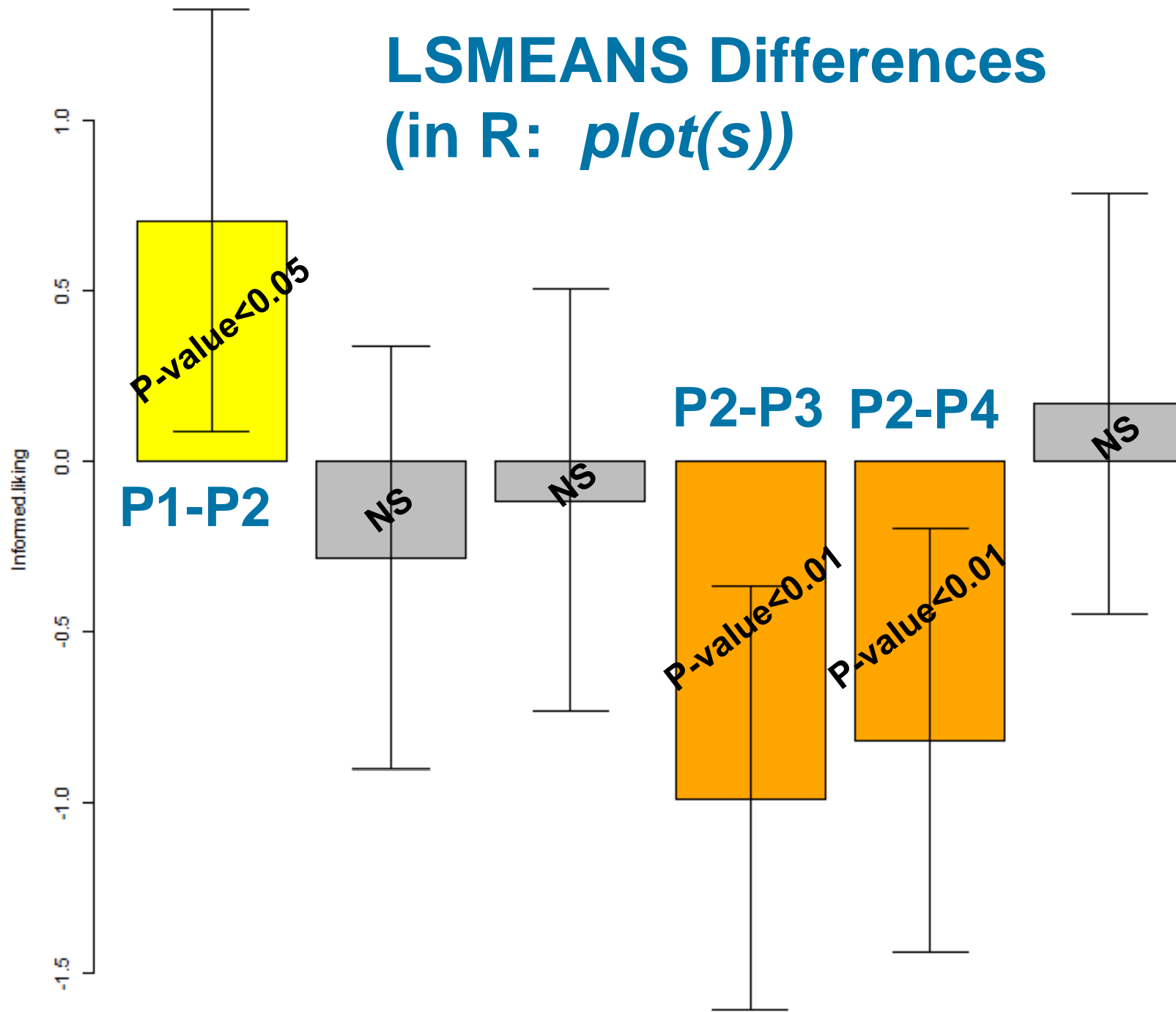
	NumDF	DenDF	F.value	elim.num	p.value
Product	3	240	3.82921	0	0.01 *
Information	1	323	3.87139	0	0.05 *
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---

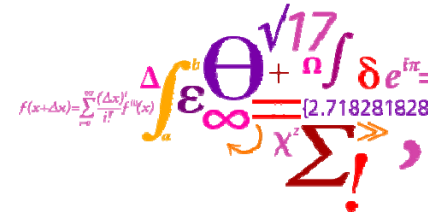
Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1

(Type I/III ANOVA table)

# LSMEANS Differences (in R: *plot(s)*)



# TV data



- **12 “Products”:**
  - 3 TV sets
  - 4 Pictures
- **2 replicates**
- **8 Assessors**
  
- **15 Sensory Attributes**



# TV data



By attribute

Fixed effects

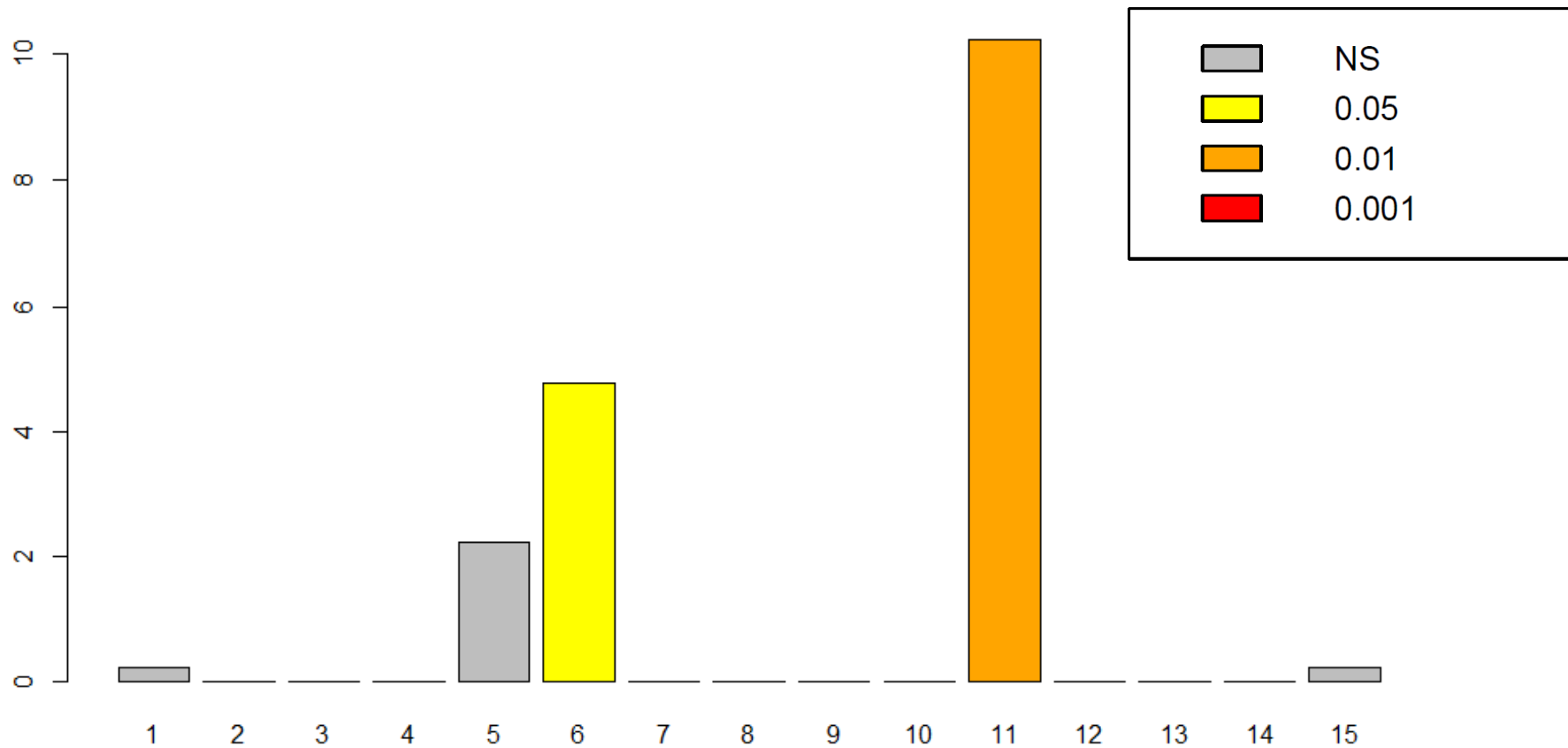
```
data(TVbo)
```

```
m<-lmer(TVbo[,i]~TVset*Picture+  
(1|Assessor)+(1|Assessor:TVset)+  
(1|Assessor:Picture)+(1|Assessor:TVset:Picture),  
data=TVbo)
```

Random effects

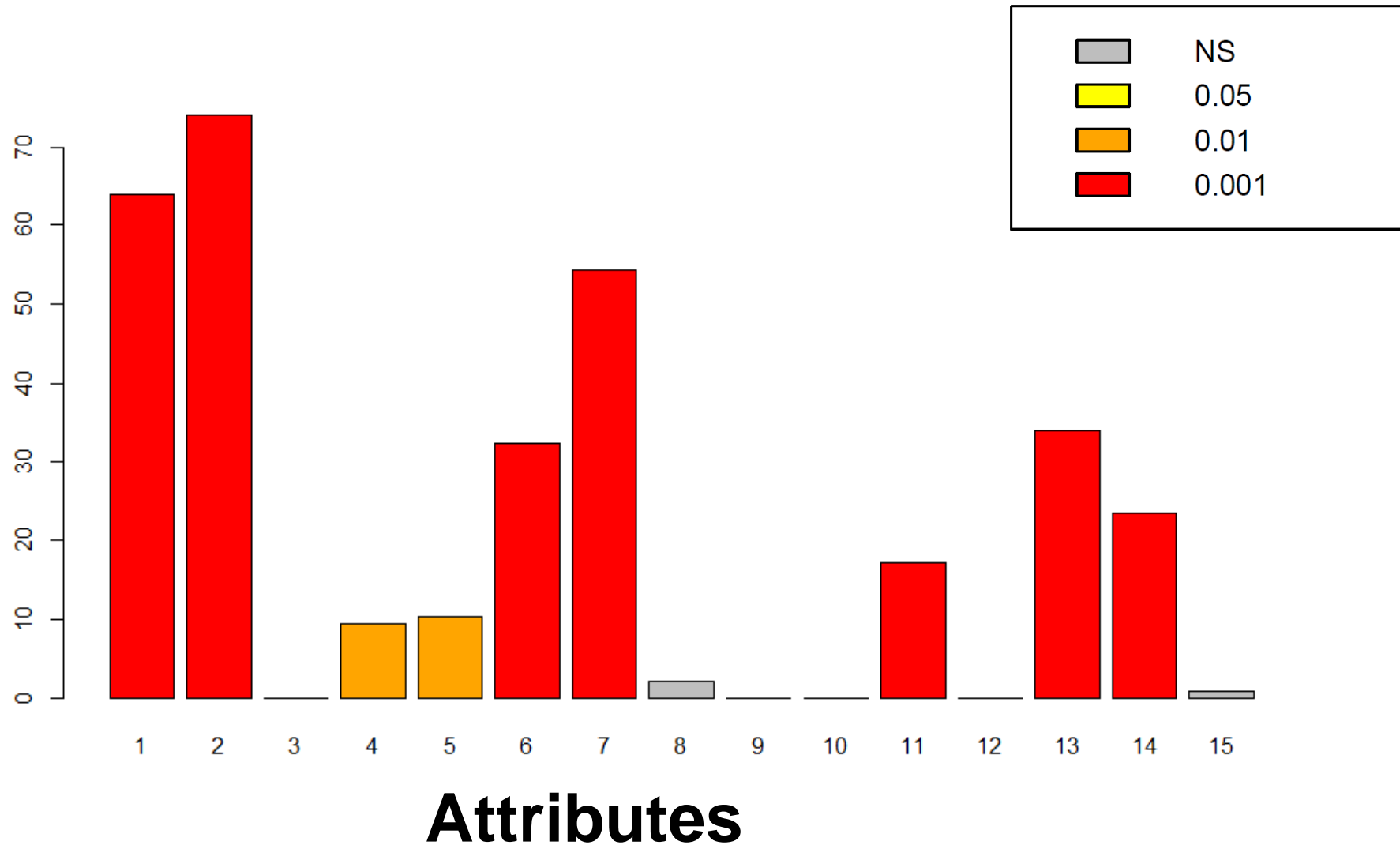


# Tests for Assessor-by-(TV:Picture)

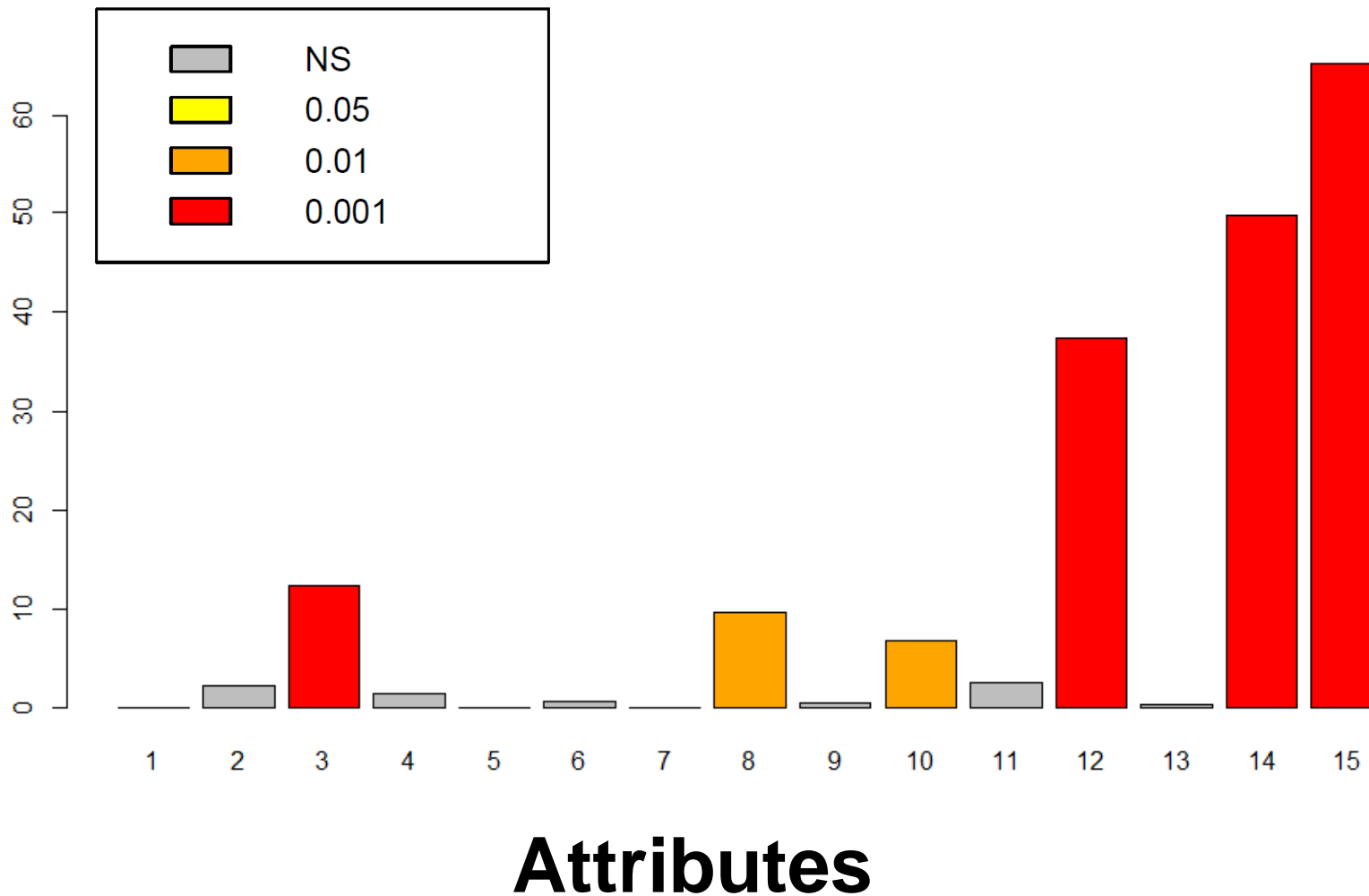


## Attributes

# Tests for Assessor-by-TVset



# Tests for Assessor-by-Picture



# TV data

## What about replicates???



Fixed effects

```
m<-lmer(TVbo[,i]~TVset*Picture+
(1|Assessor)+(1|Assessor:TVset)+
(1|Assessor:Picture)+(1|Assessor:TVset:Picture)
, data=TVbo)
```

Random effects



# TV data

## What about replicates???



Fixed effects

```
m<-lmer(TVbo[,i]~TVset*Picture+
(1|Assessor)+(1|Assessor:TVset)+
(1|Assessor:Picture)+(1|Assessor:TVset:Picture)
+(1|Repeat)+(1|Repeat:TVset)
+(1|Repeat:Picture)+(1|Repeat:TVset:Picture), data=TVbo)
```

TRY – and let the  
data speak!!

Random effects

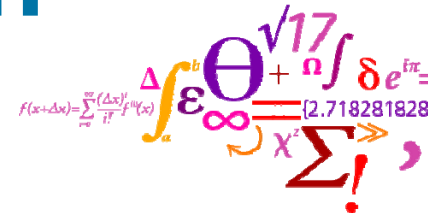


Will be removed if not important...!

# Simple not always enough!

- Unbalanced sensory profile data (e.g. missings)
- Incomplete consumer preference data
- 2- (or higher)way product structure in sensory
- 2- (or higher)way product structure in consumer (Conjoint)
- Extending Conjoint to include Consumer background/design factors/covariates
- Complex blocking, product replication, product batch structures in as well sensory as consumer
- A mixed model approach for performing external preference mapping
- Extending mixed model external preference mapping to include product and consumer background/design factors/covariates (segments)

# Summary of approach



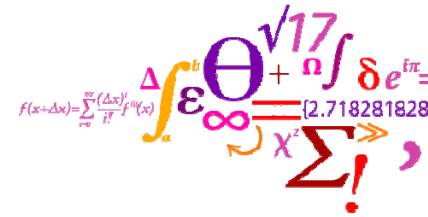
1. Identify and express the largest possible model
2. Run that in “usual” R-way (*Imer*)
3. Use NEW step-function of *ImerTest*
4. Interpret results:
  1. (Attribute-wise) Random ANOVA tables
  2. (Attribute-wise) Fixed ANOVA tables
  3. Multi-attribute plots of random and fixed effects (a la PanelCheck)
  4. (Attribute-wise) Post hoc plots of LSMEANS and differences of these



# A bit more detail on *ImerTest*

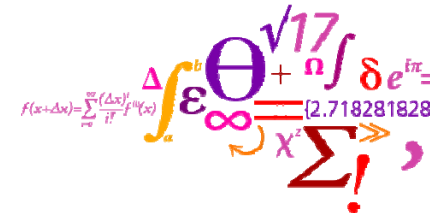
- Satterthwaithe DFs, Type III F tests and LSMEANS:
  - Involves rather technical stuff (cf. e.g. SAS documentation)
- Step-wise eliminations of random effects:
  1. Remove “zero-terms”
  2. Remove by P-value size (default alpha=0.10)
- Step-wise eliminations of fixed effects:
  1. Obeys marginality principle
  2. Remove by P-value size
  3. Provides a Type I/Type III hybrid ANOVA table

# Perspectives, future



- Making mixed modeling easy to use for most (at least more) people
- Will be the “mixed model engine” of **ConsumerCheck**
- Combining with binary/ordinal modeling (thurstonian)
- Combining with scaling correction (MAM: Mixed Assessor Model)

# Take home



- **NEW R-package: *ImerTest***
  - <https://r-forge.r-project.org/projects/Imertest/>
- **Mixed modeling in R more useful for practitioner:**
  - *F-tests of fixed effects*
  - *LSMEANS*
  - *Satterthwaithe and Kenward Rogers degrees of freedom*
- **Offers automated model selection/adaptation**
  - *In random effects!!!!!!*
  - *In fixed effects*
- **This is a valuable tool for Sensory and Consumer data!**