Mixed Models, Sensometrics and Challenges

Rune H B Christensen

DTU Compute
Section for Statistics
Technical University of Denmark
rhbc@imm.dtu.dk

August 12th 2013

DTU Compute
Department of Applied Mathematics and Computer Science

DTU

Outline

Background on Rune H. B. Christensen

Current position:
Since July 2012: Post. Doc working with statistics and sensometrics at DTU.

Previous:
Nov. '08 — Jun. '12: Ph.D in "Sensometrics: Thurstonian and Statistical Models" at DTU

Education:
Engineer from DTU in 2008 — Statistics and Data Analysis

DTU and Statistics

- DTU: 18 Departments
- DTU Compute: ∼450 people: adm., sci., Ph.D.,
- 11 sections: Algorithms, Cognitive Systems, Cryptology, Dynamical Systems, Embedded sys. eng., Image Analysis, Language-based Tech., Math., Sci. Computing, Software Eng., Statistics and Data Analysis.

Statistics and Data Analysis (∼30 people):

- DTU Data Analysis: Public sector consulting
- DTU Statistics: Research and teaching
- but in practice we all do both

Research interests

Statistics

- Ordinal models (Cumulative Link Models)
- Mixed Models
- Likelihood applications
- Categorical data analysis
- GLMs and GLMMs
- Computational statistics and **R**

Sensometrics

- Discrimination testing
- Binomial statistics (e.g. sample size estimation)
- Analysis of sensory and consumer data

R-packages I am involved with (1)

ordinal

- Regression models for ordinal data via cumulative link (mixed) models
- Author: Rune H.B Christensen
- On CRAN since March 2010
- 3 vignettes

lmerTest

- p-values for t-tests and ANOVA F-tests using Satterthwaite's approximation for denom. df (or Kenward-Roger df + F-tests via the pbkrtest package).
- In addition: Automized "step" model selection, Type III ANOVA tables, post-hoc tests, plotting methods.
- Authors: Alexandra Kuznetsova, Per B. Brockhoff, Rune H. B. Christensen
- On CRAN since Jan. 2013 (though currently down)
- The future LME engine of ConsumerCheck

R-packages I am involved with (2)

sensR

- Estimation and Inference in Thurstonian Models for Sensory Discrimination
- Authors: Rune H.B Christensen and Per B. Brockhoff
- On CRAN since 2008

binomTools

- Methods for diagnostics on binomial regression models
- Authors: Rune H. B. Christensen and Merete K. Hansen
- On CRAN since August 2011

Recent work (ordinal related)

- Researching GHQ/AGQ-methods for correlated and nested RE structures.
- Vector-valued and correlated random effects in `ordinal::clmm`
- Adding `ranef` and `VarCorr` methods
- Better computation of Var-Cov matrix in `clm` and `clmm`
- Adding `nominal_test` and `scale_test` for automatic (`add1`-like) testing of nominal and scale effects in CLMs
- Allowing zero-weights in `clm`

Outline

What is *Sensometrics*?

Sensometrics: is the scientific area that applies mathematical and statistical methods to problems from sensory and consumer science.

Discrimination testing: Sensory differences between products or *stimuli* are detected and quantified by the use of human senses.

Industrial use of discrimination testing:

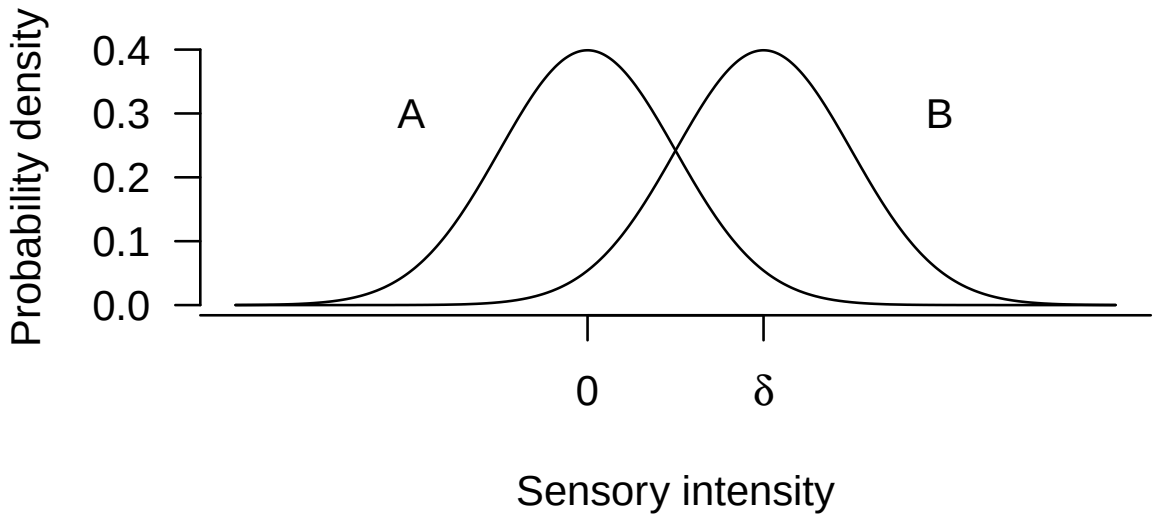
- Product development
- Ingredient substitution
- Health initiatives
- Process control

Academic interests:

- Psycho-physical understanding — how do humans discriminate?

What is a Thurstonian Model?

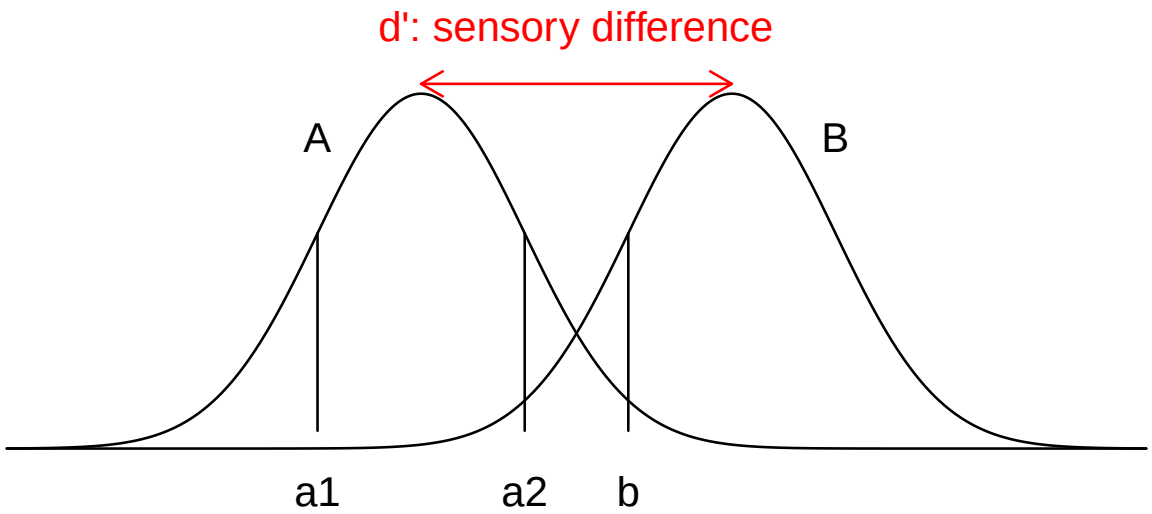
1. A common scale for quantification of "Sensory Difference" $\rightarrow d'$ (or δ)
2. A psycho-physical model for the cognitive process
3. A stochastic model for the data-generating mechanism



(Thurstone, 1927)

Example: The Triangle discrimination test

Given two samples of one kind (A) and one sample of an other kind (B)
Question: Which sample is *most different*?



Assumptions in Thurstonian model:

- Perceptions are random and normally distributed
- Decision rule: Pick the sample the furthest from the others

Thurstonian and statistical models

Thurstonian models for some common protocols can be identified as well-known statistical models.

Protocol	Statistical model	Source
Triangle, m-AFC, ...	GLM with special links	(Brockhoff and Christensen, 2010)
A-not A	GLM with probit link	(Brockhoff and Christensen, 2010)
A-not A w. sureness	CLM	(Christensen et al., 2011)
Paired pref.	GLM with probit link	
Paired pref. (no-pref.)	CLM	(Christensen et al., 2012)

GLM: Generalized linear model (McCullagh and Nelder, 1989)
CLM: Cumulative link model (McCullagh, 1980; Agresti, 2002)

Software for GLM: **R**-package **sensR** (Christensen and Brockhoff, 2012)
Software for CLM: **R**-package **ordinal** (Christensen, 2012)

Outline

Mixed Models in sensory and consumer science — Overview

Non-Gaussian responses:

- Binomial GLMMs for discrimination and paired-preference data
- CLMMs for discrimination and rating data, e.g. from questionnaires

Gaussian response:

- Sensory profile data: Assessor by products in an (in)complete randomized block design. Ususally with missing values and sometimes with replications.
- Consumer data from line-scale or ordinal-scale data. Often nested or sparse-block designs with some missing values.
- External Preference mapping: Combining profile data (often 1-3 PCs) with consumer liking data.

Mixed Models in sensory and consumer science — Challenges (1)

Non-Gaussian responses:

- Accurate ML estimation and LR-tests — people don't buy 'approximate' here.
- Reasonably fast and reliable estimation.
- "REML"-like tests.

Gaussian response (`lmer`):

- Automatic detection of (approximate) denominator df in (approximate) F-tests for fixed effect (terms).
- . . . and for random effect terms.
- Non-standard, e.g. rank-deficient design matrices.
- Population-average predictions ("lsmeans" type).
- Type I, II and III Wald F-tests.
- Post-hoc comparisons, e.g. all pairwise comparisons.

Mixed Models in sensory and consumer science — Challenges (2)

General challenges:

- Detection of boundary fits.
- Reliable convergence checking.
- (Profile CI for r.e. cov-var parameters.)

Agresti, A. (2002). *Categorical Data Analysis* (Second ed.). Wiley.

Brockhoff, P. B. and R. H. B. Christensen (2010). Thurstonian models for sensory discrimination tests as generalized linear models. *Food Quality and Preference 21*, 330–338.

Christensen, R. H. B. (2012). ordinal—regression models for ordinal data. R package version 2012.09-12 http://www.cran.r-project.org/package=ordinal/.

Christensen, R. H. B. and P. B. Brockhoff (2012). sensR: An R-package for Thurstonian modelling of discrete sensory data. R package version 1.2.13 http://www.cran.r-project.org/package=sensR/.

Christensen, R. H. B., G. Cleaver, and P. B. Brockhoff (2011). Statistical and Thurstonian models for the A-not A protocol with and without sureness. *Food Quality and Preference 22*, 542–549.

Christensen, R. H. B., H.-S. Lee, and P. B. Brockhoff (2012). Estimation of the Thurstonian model for the 2-AC protocol. *Food Quality and Preference 4*, 119–128.

McCullagh, P. (1980). Regression models for ordinal data. *Journal of the Royal Statistical Society, Series B 42*, 109–142.

McCullagh, P. and J. Nelder (1989). *Generalized Linear Models* (Second ed.). Chapman & Hall/CRC.

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review 34*, 273–286.