

# Conjoint Analysis: past, present and issues

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# Outline

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- b. An individual compensatory utility model
- c. Choice and market share simulation

## 2. Data collection and analysis

- a. From full profiles to adaptive choice-based conjoint
- b. Models: OLS, monotone regression, multinomial logit
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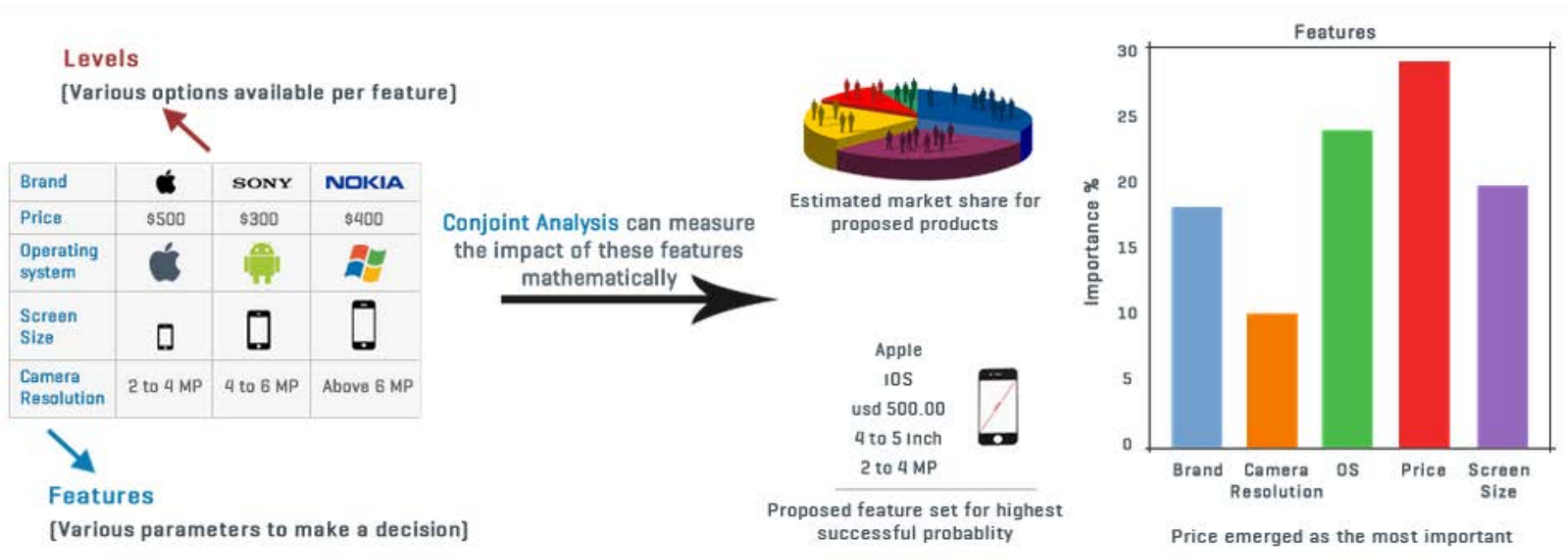
## 3. Issues

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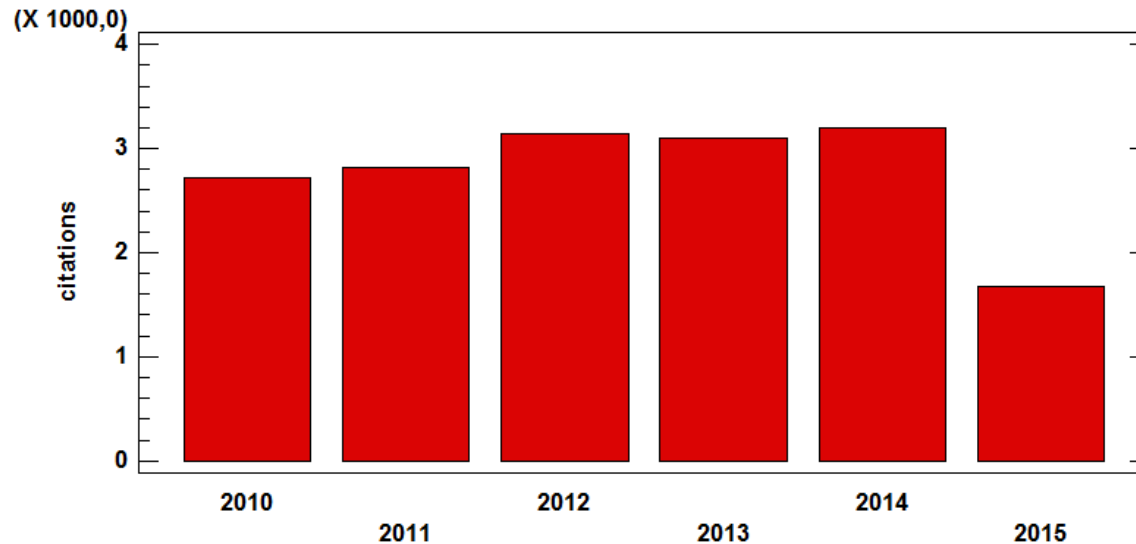
# 1. Conjoint Analysis basics

- One of the **most successful** statistical techniques in **market research**
- Aims at quantifying **how people make choices between products or services**
- A complete **survey methodology** including data collection based on **experimental designs**, a data analysis phase with parameter **estimation**, a **simulation** phase



<http://www.surveyanalytics.com/conjoint-analysis-example.html>

- About 3000 papers per year (Google scholar)



- Not only marketing: health, education etc.

# 1.a Historical background

PAUL E. GREEN and VITHALA R. RAO\*

Conjoint measurement is a new development in mathematical psychology that can be used to measure the joint effects of a set of independent variables on the ordering of a dependent variable. In this (primarily expository) article, the techniques are applied to illustrative problems in marketing. In addition, a number of possible areas of application to marketing research are discussed, as well as some of the methodology's limitations.

## Conjoint Measurement for Quantifying Judgmental Data

*Journal of Marketing Research* Vol. 8, No. 3 (Aug., 1971), pp. 355-363

- A monotonous regression applied to rank order data described by a full design

Media-planner's rankings of 40 ad.vehicle combinations

356

JOURNAL OF MARKETING RESEARCH, AUGUST 1971

Table 1  
RANK ORDER INPUT DATA FOR PROBLEM 1

Ads	Vehicles				
	1	2	3	4	5
1	1*	3	8.5	16.5	19.5
2	2	5	11	21	24.5
3	4	7	13	24.5	26
4	6	10	15	28	30
5	8.5	12	19.5	31.5	33
6	14	18	28	35	36
7	16.5	22.5	31.5	37	38
8	22.5	28	34	39	40

\* Rank 1 indicates least effective ad-vehicle combination.

Table 2  
"ORIGINAL" SCALE VALUES FOR PROBLEM 1

Ad impact values	Vehicle appropriateness values				
	$b_1 = 2$	$b_2 = 6$	$b_3 = 13$	$b_4 = 22$	$b_5 = 24$
$a_1 = 1$	3	7	14	23	25
$a_2 = 4$	6	10	17	26	28
$a_3 = 6$	8	12	19	28	30
$a_4 = 9$	11	15	22	31	33
$a_5 = 12$	14	18	25	34	36
$a_6 = 18$	20	24	31	40	42
$a_7 = 21$	23	27	34	43	45
$a_8 = 25$	27	31	38	47	49

Kruskal's monanova algorithm

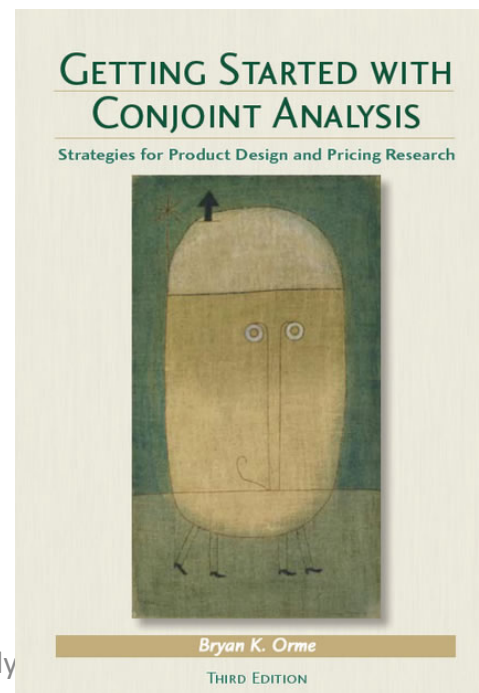
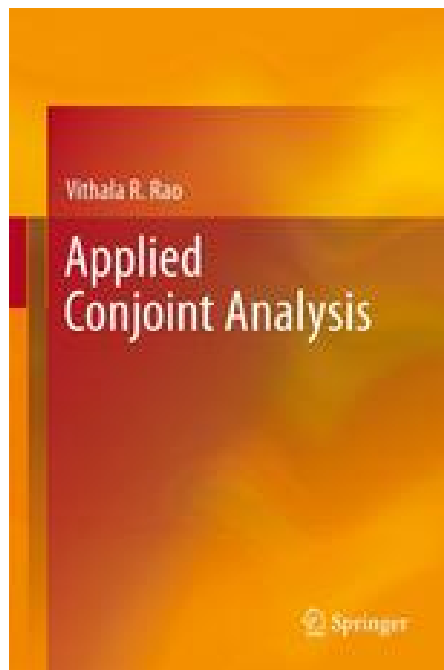
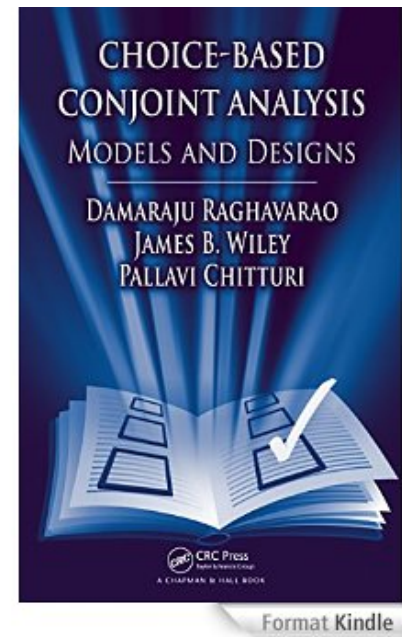
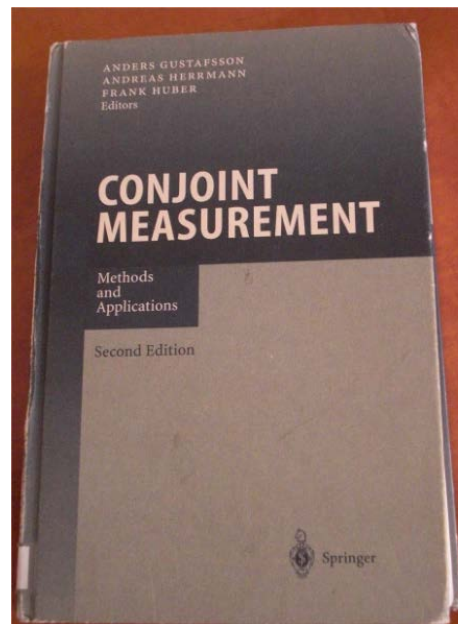
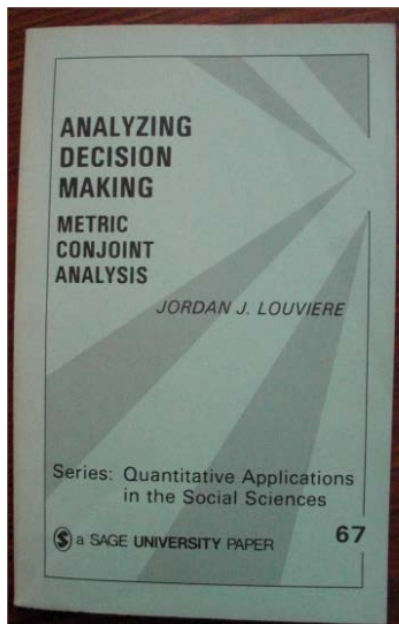
# Genealogy of conjoint measurement:

- Luce & Tukey 1964 , Debreu 1959, Von Neumann & Morgenstern 1947
- **Conjoint measurement**, as practised by mathematical psychologists, has primarily been concerned with the conditions under which there exist measurement scales for both the dependent and independent variables, given the order of the joint effects of the independent variables and a prespecified composition rule.
- The term *conjoint analysis* means decomposition into part-worth utilities or values of a set of individual evaluations of, or discrete choices from, a designed set of multi-attribute alternatives (Louviere 1988)

Jarmo Heinonen

[http://www.metodix.com/en/sisallys/01\\_menetelmat/02\\_metodiart\\_ikkelit/heinonen\\_conjoint\\_methods/kooste](http://www.metodix.com/en/sisallys/01_menetelmat/02_metodiart_ikkelit/heinonen_conjoint_methods/kooste)





## 1.b An individual compensatory model

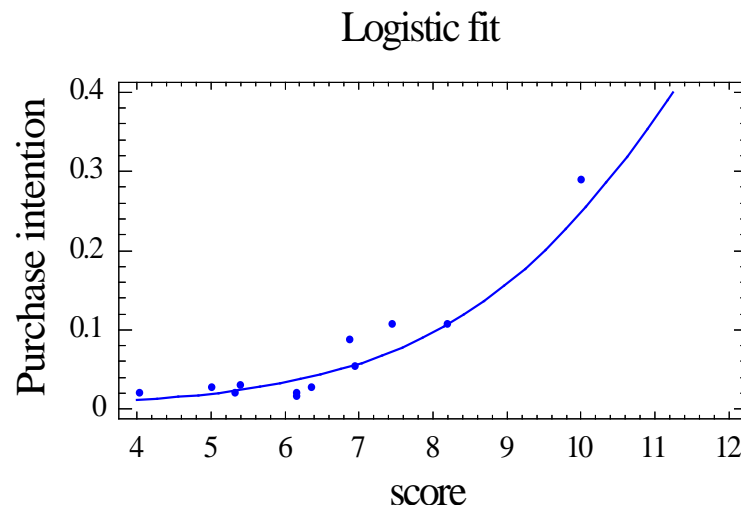
- A product is defined by a **combination** of  $p$  attributes
- The **perfect** product is generally **unrealistic** like a car with high speed, comfort, security **and** low price
- A **compensatory** model: the consumer makes a “Trade off” between attributes by putting into balance advantages and inconveniences.
- Conjoint analysis decomposes preferences according to an **additive utility** model, **specific** to each interviewee

- A product defined by a combination of levels (i,j,k,l, ..) of p attributes will have a global utility equal to  $a_i + b_j + c_k + \dots$
- Coefficients or **part-worth** utilities are different for each respondent
- N **additive** models **without interaction** are fitted: no global model
- If all combinations are feasible:  $\prod_{j=1}^p m_j$  products and  $\sum_{i=1}^p m_i - p$  independent coefficients

# 1.c Choice and market share simulation

- Let 3 **competing** products
- For each respondent  $i$  :  $U_i^1 ; U_i^2 ; U_i^3$
- Several models for respondent choice:
  - **Maximal utility** (deterministic)
  - Probabilities proportional to  $U_i^j$  (**Bradley-Terry-Luce** )
  - Probabilities proportional to  $\exp (U_i^j)$  (**« logit »**)

- A minimal utility level may be necessary. Some « poor » products will never be chosen.
- Solutions:
  - Ask a « **will buy** » question for each submitted product, hence the purchase intention, plotted against the mean utility, averaged over all respondents



- Use a **choice based conjoint** design with a «**none** » alternative

© Ipsos Market Quest

If you were shopping for kitchen cleaners and multi-purpose cleaner products today and these products and prices were available, which **one** product, if any, would you buy? If none of the product options appeal to you, select "I would not purchase any of these."



Mr. Muscle 5 in 1  
Kitchen  
500 ml  
£2.19



Flash Clean & Shine All  
Purpose Cleaner  
700 ml Mega Size  
£2.80



TESCO Value Cream  
Cleaner  
500 ml  
£0.32



TESCO Cream Cleaner  
500 ml  
£0.78



NONE:  
I would not  
purchase  
any of  
these.



## 2. Data collection and analysis

- First implementations were done with the **full profiles** method
- Since  $\prod_{j=1}^p m_j$  is generally too large, one or several **subsets** of K products are submitted to a sample of consumers

## 2.a From full profiles to ACBC

- Example « Frozen entrees » (Kuhfeld, 2009)

Factor	Levels		
Main Ingredient	Chicken	Beef	Turkey
Fat Claim Per Serving	8 Grams	5 Grams	2 Grams
Price	\$2.59	\$2.29	\$1.99
Calories	350	250	

- $p=4$  features  $\prod_{j=1}^p m_j = 54$



Obs	Ingredient	Fat	Price	Calories	Rank
1	Turkey	5 Grams	\$1.99	350	10
2	Turkey	8 Grams	\$2.29	350	12
3	Chicken	8 Grams	\$1.99	350	17
4	Turkey	2 Grams	\$2.59	250	7
5	Beef	8 Grams	\$2.59	350	6
6	Beef	2 Grams	\$1.99	350	2
7	Beef	5 Grams	\$2.29	350	4
8	Beef	5 Grams	\$2.29	250	3
9	Chicken	2 Grams	\$2.29	350	13
10	Beef	8 Grams	\$2.59	250	5
11	Turkey	8 Grams	\$2.29	250	11
12	Chicken	5 Grams	\$2.59	350	15
13	Chicken	5 Grams	\$2.59	250	16
14	Chicken	2 Grams	\$2.29	250	14
15	Turkey	5 Grams	\$1.99	250	9
16	Turkey	2 Grams	\$2.59	350	8
17	Beef	2 Grams	\$1.99	250	1
18	Chicken	8 Grams	\$1.99	250	18

Label	Utility	Standard Error	Importance (% Utility Range)
Intercept	9.5000	0.00002	
Ingredient, Beef	6.0281	0.00002	74.999
Ingredient, Chicken	-6.0281	0.00002	
Ingredient, Turkey	-0.0000	0.00002	
Fat, 2 Grams	2.0094	0.00002	25.000
Fat, 5 Grams	0.0000	0.00002	
Fat, 8 Grams	-2.0094	0.00002	
Price, \$1.99	0.0000	0.00002	0.000
Price, \$2.29	0.0000	0.00002	
Price, \$2.59	-0.0000	0.00002	
Calories, 250	0.0001	0.00002	0.001
Calories, 350	-0.0001	0.00002	

- Attribute importance
  - If **all** products are **feasible** , the **total range** (utility of the best – utility of the worst) is equal to the **sum of part-worth utilities**
  - Importance defined as the **% of utility range**

- **Ranking or ratings?**

- Each of the 18 products is presented on a card and consumers are asked to **sort** them (preference order). A rather difficult task. So why not **rate** the products?
- Rating expresses intensity of preferences, but: no comparison between products, problems with comparability of scales across respondents, risk of ties
- **Ranking** usually preferred
- Often processed as a **continuous** variable! See later

- About the design
  - Frozen entrees: one third of the complete design
  - **Orthogonal** design: all effects may be estimated without confounding
  - All **pairs** of attributes have **balanced** levels
  - **Non orthogonal** designs may be used to decrease the number of products
    - 8 products is the minimal set in frozen entrees example, since there are 7 part-worth utilities to be estimated:  $(3-1) + (3-1) + (3-1) + (2-1)$

- A few useful designs for 2 levels attributes
  - **Factorial fractional designs**
  - **Plackett & Burman**
- **Latin and graeco-latin** squares for attributes with the same number of levels
- **D-optimal** designs otherwise

# $L_8 2^7$ (Taguchi) or $2^{7-4}$ (Box-Hunter)

	A	B	C	D	E	F	G
-----							
1	1	1	1	2	2	2	1
2	2	1	1	1	1	2	2
3	1	2	1	1	2	1	2
4	2	2	1	2	1	1	1
5	1	1	2	2	1	1	2
6	2	1	2	1	2	1	1
7	1	2	2	1	1	2	1
8	2	2	2	2	2	2	2

## Plackett- Burman design $L_{12} 2^{11}$

A	B	C	D	E	F	G	H	I	J	K
1	2	1	2	2	2	1	1	1	2	1
1	1	2	1	2	2	2	1	1	1	2
2	1	1	2	1	2	2	2	1	1	1
1	2	1	1	2	1	2	2	2	1	1
1	1	2	1	1	2	1	2	2	2	1
1	1	1	2	1	1	2	1	2	2	2
2	1	1	1	2	1	1	2	1	2	2
2	2	1	1	1	2	1	1	2	1	2
2	2	2	1	1	1	2	1	1	2	1
1	2	2	2	1	1	1	2	1	1	2
2	1	2	2	2	1	1	1	2	1	1
2	2	2	2	2	2	2	2	2	2	2



- Ranking a large number of products is a **burden!**
- **Empirical bound** for the number of comparisons :  **$K \leq 16$**  profiles
- **Paired comparisons**, *choice based* and (or) **adaptive** designs are often preferred to full profile designs

# ACA

- Developed by Sawtooth Software, ACA stands for **adaptive conjoint analysis**
- Success linked to the development of CAPI and CAWI
- Core of the method: a **set of binary questions** involving an **increasing number of attributes**, depending on the previous answers, until parameters (part-worth utilities) are estimated with enough precision, in a **bayesian style**

↘ If everything else about these two computers were the same, which would you prefer?



☐  
Strongly  
Prefer  
Left



☐  
Somewhat  
Prefer  
Left



☐  
Somewhat  
Prefer  
Right



☐  
Strongly  
Prefer  
Right

- Prior **importance** and categories **ordering** are estimated through introductory questions like:

↘ If two computers were the same in all other ways, how important would this difference be to you?

Not at All  
Important

Somewhat  
Important

Very  
Important

Extremely  
Important



# Discrete Choice Models

- Instead of rating or ranking product concepts, respondents are shown several sets of products on the screen and asked to indicate **which one** they would choose.
- Also known as **Choice Base conjoint** or **CBC**

**Which of the following  
alternatives would you prefer, in  
any?**



- \$ 225
- Parent controls
- Standard remote
- Medium height

**PHILIPS**

- \$ 275
- No parental controls
- Standard remote
- Medium height

**SONY**

- \$ 300
- Parental controls
- Universal remote
- Large



**I don't like any of  
these alternatives**

- Choice tasks are **simpler than full profiles** rankings, **closer to real situations**
- The set of choice questions is obtained by design of experiments techniques
- **Adaptive** versions of **CBC** have been proposed
- However some authors consider that CBC is not conjoint analysis; see Louviere et al. , 2010

Discrete Choice Experiments Are Not Conjoint Analysis, *Journal of Choice Modelling*, 3, 3

## 2.b Estimation

- **OLS**

**y** vector of ranks

$$\min \| \mathbf{y} - \mathbf{X}\mathbf{b} \|^2$$

$$\mathbf{y} = \mathbf{X}\mathbf{b} + \mathbf{e}$$

$$\begin{pmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ y_{12} \end{pmatrix} = \begin{pmatrix} 01|01|01|.....|100 \\ 01|01|10|.....|010 \\ \cdot \\ \cdot \\ \cdot \\ 10|10|10|.....|100 \end{pmatrix} \begin{pmatrix} \alpha_1 \\ \alpha_2 \\ \cdot \\ \cdot \\ \cdot \\ \xi_3 \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ \cdot \\ \cdot \\ e_{12} \end{pmatrix}$$

- Specificities
  - Model not of full rank: constraints on utility coefficients. The most popular constraint:
 
$$\alpha_1 + \alpha_2 + \alpha_3 = 0$$
  - Only differences  $\alpha_1 - \alpha_2$  are estimable
  - Criticism to OLS : **ranks are not quantitative variables**
- **Monotonous regression**
  - fit  $T(\mathbf{y})$  instead of  $\mathbf{y}$  where  $T$  is a **monotonous** transformation of ranks:
  - minimize  $|| T(\mathbf{y}) - \mathbf{Xb} ||^2$  over  $T$  and  $b$



### Frozen Diet Entrees

Obs	Ingredient	Fat	Price	Calories	Rank	Reflected Rank	Utilities
1	Beef	2 Grams	\$1.99	250	1	17.5375	17.5375
2	Beef	2 Grams	\$1.99	350	2	17.5373	17.5373
3	Beef	5 Grams	\$2.29	250	3	15.5282	15.5281
4	Beef	5 Grams	\$2.29	350	4	15.5279	15.5280
5	Beef	8 Grams	\$2.59	250	5	13.5188	13.5188
6	Beef	8 Grams	\$2.59	350	6	13.5186	13.5186
7	Turkey	2 Grams	\$2.59	250	7	11.5095	11.5094
8	Turkey	2 Grams	\$2.59	350	8	11.5092	11.5093
9	Turkey	5 Grams	\$1.99	250	9	9.5001	9.5001
10	Turkey	5 Grams	\$1.99	350	10	9.4999	9.4999
11	Turkey	8 Grams	\$2.29	250	11	7.4908	7.4907
12	Turkey	8 Grams	\$2.29	350	12	7.4905	7.4906
13	Chicken	2 Grams	\$2.29	250	14	5.4813	5.4814
14	Chicken	2 Grams	\$2.29	350	13	5.4813	5.4812
15	Chicken	5 Grams	\$2.59	250	16	3.4719	3.4720
16	Chicken	5 Grams	\$2.59	350	15	3.4719	3.4719
17	Chicken	8 Grams	\$1.99	250	18	1.4626	1.4627
18	Chicken	8 Grams	\$1.99	350	17	1.4626	1.4625

- However:
  - High **overfitting** risk

Frozen Diet Entrees			
The TRANSREG Procedure			
The TRANSREG Procedure Hypothesis Tests for Monotone(Rank)			
Root MSE	0.00007166	R-Square	1.0000
Dependent Mean	9.50000	Adj R-Sq	1.0000
Coeff Var	0.00075429		

- **OLS** more **robust**

- Goodness of fit
  - Measure the agreement between initial ordering and the estimated one:
    - $R^2$  or **Kendall's  $\tau$**
    - Minimum value : a common practice discards respondents with low  $R^2$ , but:

Incoherence or ill-posed (no trade-off) problem?

eg: -mobile phone, whatever the price  
- garbage bags, whatever colour,  
texture, closing system

- Multinomial logit model for choice based experiments

The **multinomial logit** model assumes that the probability that an individual will choose one of the  $m$  alternatives,  $c_i$ , from choice set  $C$  is

$$P(c_i / C) = \frac{\exp(U(c_i))}{\sum_{j=1}^m \exp(U(c_j))} = \frac{\exp(\mathbf{x}_i \boldsymbol{\beta})}{\sum_{j=1}^m \exp(\mathbf{x}_j \boldsymbol{\beta})}$$

where  $\mathbf{x}_i$  is a vector of coded attributes and  $\boldsymbol{\beta}$  is a vector of unknown attribute parameters (**part-worth utilities**) .  $U(c_i) = \mathbf{x}_i \boldsymbol{\beta}$  is the utility for alternative  $c_i$ , which is a linear function of the attributes.

- Case study: launch of a public transportation pass for young people (12-26) of Paris region
- 1200 respondents
- 5 attributes:
  - Duration (2), price (4), zone-options (4), bonus card (2), communication (2)



- A specific model for binary choice
  - Choice between **pairs** of products
  - Example : 5 attributes
    - Product A  $x'(A)=10\ 1000\ 0001\ 10\ 10$
    - Product B  $x'(B)=10\ 0100\ 0100\ 01\ 01$
- $b=(b_1, b_2, \dots, b_{14})$  : utilities vector
- Scores  $s(A)=x'(A)b$   $s(B)=x'(B)b$ 
  - A is preferred to B if  $s(A)-s(B)>0$ 

$$(x'(A)-x'(B))b>0$$

- If  $n$  is the number of binary choices (« duels »)

$Xb$

$y$

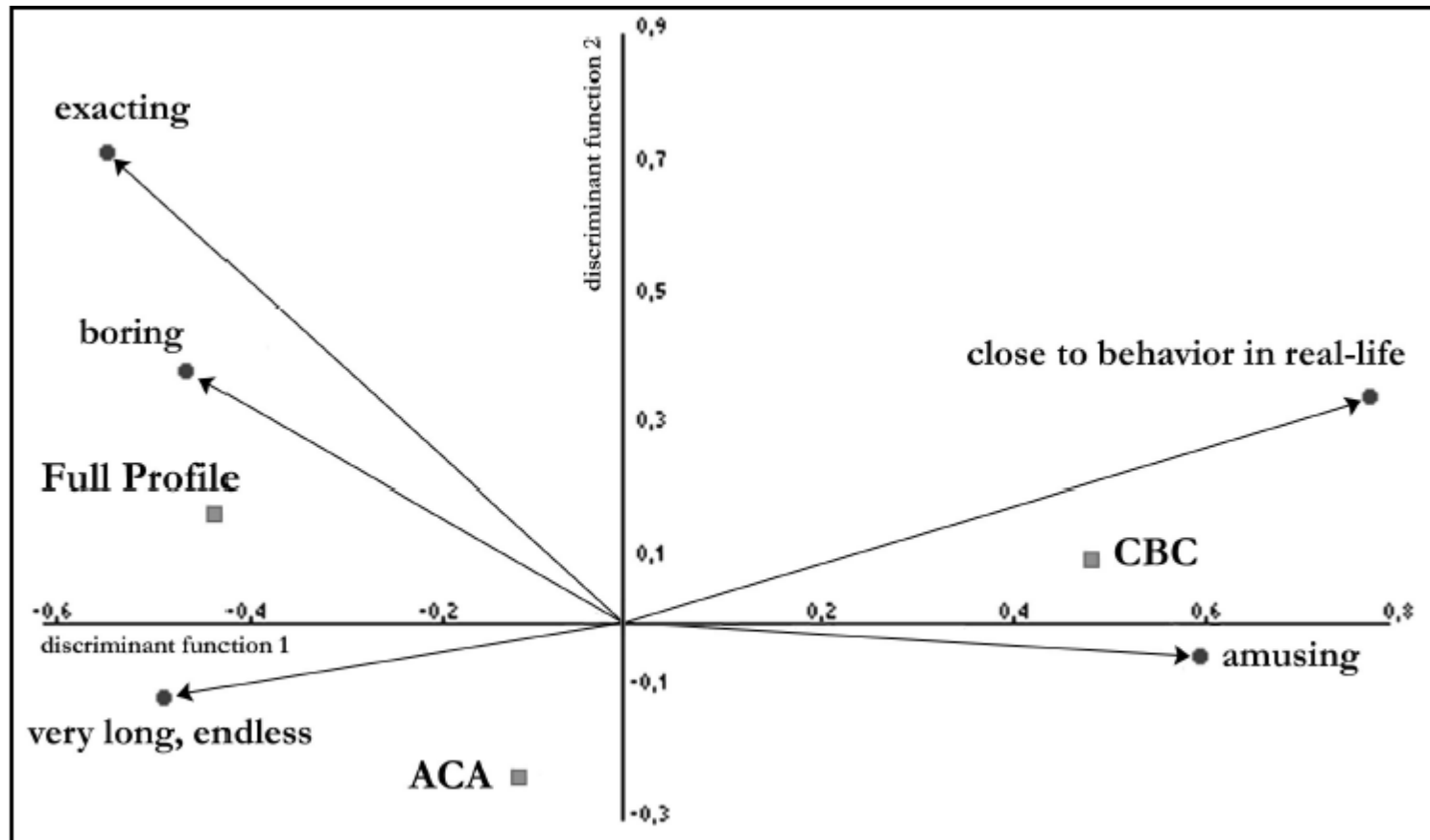
$$\begin{bmatrix} 00 & 1-100 & 0-101 & 1-1 & 1-1 \\ \vdots \end{bmatrix} \begin{bmatrix} b_1 \\ \vdots \\ b_q \end{bmatrix} = \begin{bmatrix} + \\ - \\ + \\ \vdots \\ - \end{bmatrix}$$

- X may be obtained through D-optimal design
- Estimation of b
  - **Logit model** (logistic regression) and **maximum likelihood estimates** seems appropriate but many degeneracies: **perfect separation** when consumers are rational!
  - **Fisher's linear discriminant** function (or **OLS** regression) works in all cases



## 2.c Which conjoint method?

- Subjective criteria



- Objective criteria
  - Number of attributes, number of levels
  - Survey mode , material to be presented

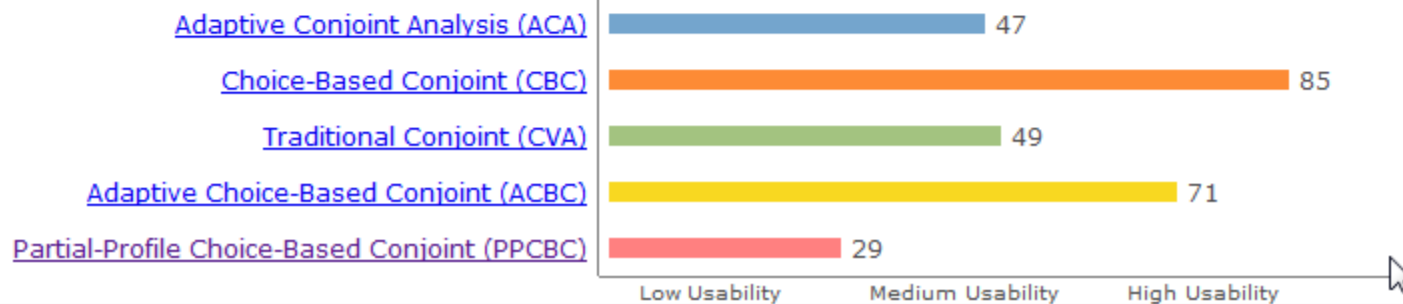
## Which Preference Modeling Method Should You Use?

What type of preference modeling problem do you need to research?

- ☐ A list of items (typically 8 or more), where the goal is to estimate the relative importance or preference for the items. Being able to estimate how multiple items taken together affect overall preference is NOT a research goal.
- ☒ Attributes each involve multiple levels (such as multiple brands, prices, speeds, or styles). The goal is to estimate how levels from different attributes combine to affect overall preference for a product.

Interviewing Mode:	Computer	Sample Size:	251+
Attributes:	5-7	Is Price an Attribute?:	No
Max number of levels in largest attribute:	15 or fewer	Show Advanced Options	

Based on your input we recommend...



**Relative Conjoint Method Usage**  
*(Sawtooth Software 2014 Customer Survey)*

CBC (Choice-Based Conjoint)	79%
ACBC (Adaptive Choice-Based Conjoint)	13%
MBC (Menu-Based Choice)	3%
CVA (Traditional Ratings-Based Conjoint)	3%
ACA (Adaptive Conjoint Analysis)	2%

## Relative Use of Different Sawtooth Software Conjoint Methods

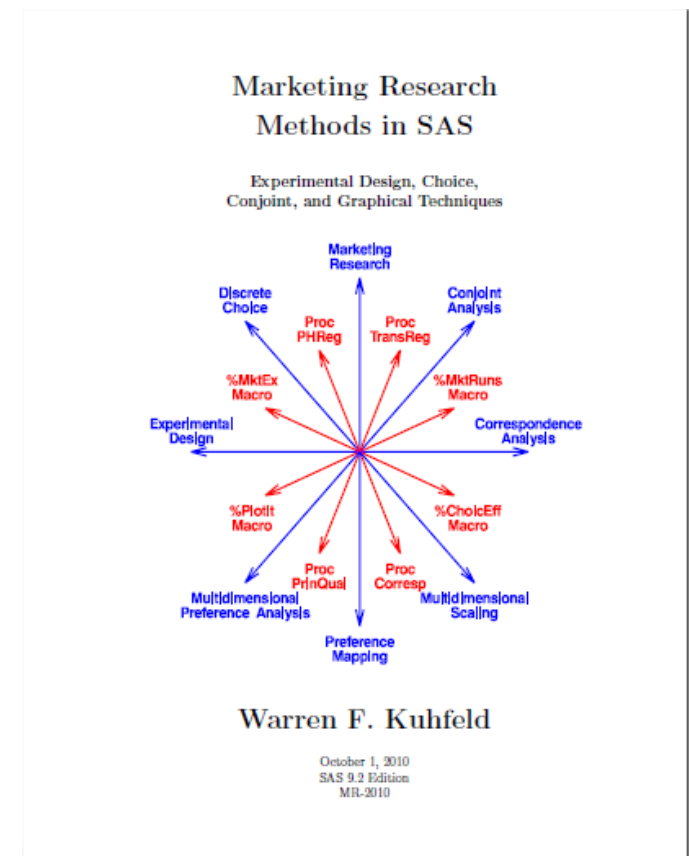


- Could be biased : CBC is the flagship product of Sawtooth Software...

## 2.d Software implementations

- General purpose softwares

### IBM SPSS Conjoint



- Specialized softwares



- Free R package

## Package ‘conjoint’

February 19, 2015

**Title** Conjoint analysis package

**Description** Conjoint is a simple package that implements a conjoint analysis method to measure the preferences.

**Version** 1.39

**Date** 2012-08-08

**Imports** AlgDesign, clusterSim

**Author** Andrzej Bak <andrzej.bak@ue.wroc.pl>, Tomasz Bartlomowicz  
<tomasz.bartlomowicz@ue.wroc.pl>

**Maintainer** Tomasz Bartlomowicz <tomasz.bartlomowicz@ue.wroc.pl>

**License** GPL (>= 2)

**URL** [www.r-project.org](http://www.r-project.org), <http://keii.ue.wroc.pl/conjoint>

**Repository** CRAN

**Date/Publication** 2013-08-15 07:02:02

**NeedsCompilation** no



# 3. A few issues

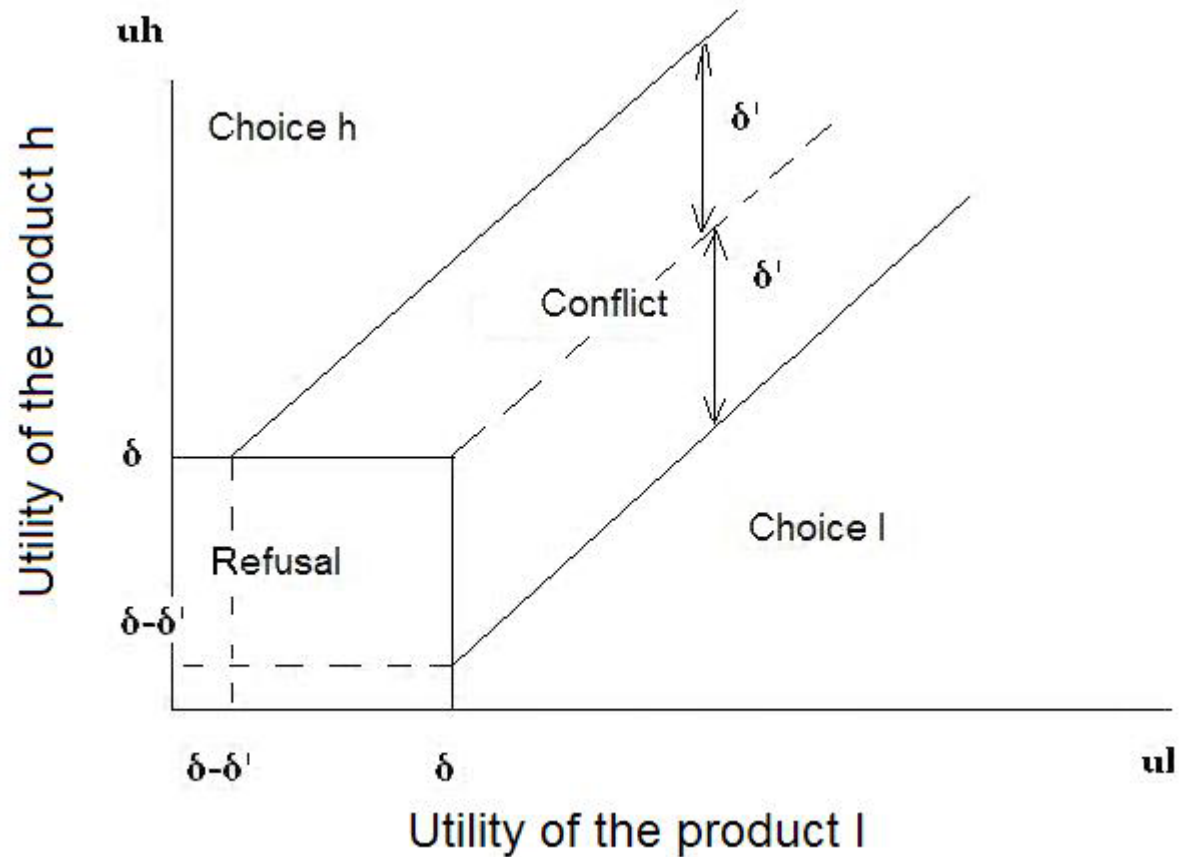
- Standard issues:
  - Influence of level choice on attribute importance like price
  - Main effects only
  - Beware of means! Perform segmentations on utilities to identify homogenous groups of respondents

## 3.a The « no choice » issue

- Elrod, Louviere and Krishnakumar (1992) specify the no choice as **another alternative** with the **attributes equal to zero** and determine the choice between the products and the option "zero" by comparing their utilities.
- Highly arguable!

- Ohannessian & Saporta, 2008 proposed a solution inspired by the censored regression models (**tobit** models) that suppose a change of the dependent variable from a certain threshold. A comparison between the utilities remains, but it only takes place **between the products utilities**, because the "zero" option is not described by an utility.
- Another explanation of the « no choice » was also proposed: **conflict**

- Refusal or **conflict** when utilities are too close



## 3.b Incomplete rankings

- In classical full-profiles interviews, respondents may **rank** only their **top choices** , or are only **reliable** for them.
- Simulation studies tends to prove that ranking **half of the scenarios** is enough to estimate utilities. (Benammou & al, 2003)

## 3.c Internal expertise or third parties?

- At least in the french market, **Sawtooth** Software's products have a **dominant** position especially in market research companies (eg BVA, IPSOS, TNS Sofres)
- **Loss of expertise** by the end users and by consultants
  - Easier to use CBC than writing code lines in SAS or R!

# Conclusion

- CA is a **versatile technique**, very useful to quantify consumer's decisions
- **Common features** of various methods
  - a trade-off hypothesis
  - Computation of individual part-worth utilities
  - Market share simulation
- **Neglected:** Hierarchical Bayes, MaxDiff , or Best/Worst and a few others

- Beyond market research studies: applications to **new fields** of human decision (medicine)
- **Academic** production still **high**
- Only **few tools** used in **companies**



**Grazie per l'attenzione!**

# References

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