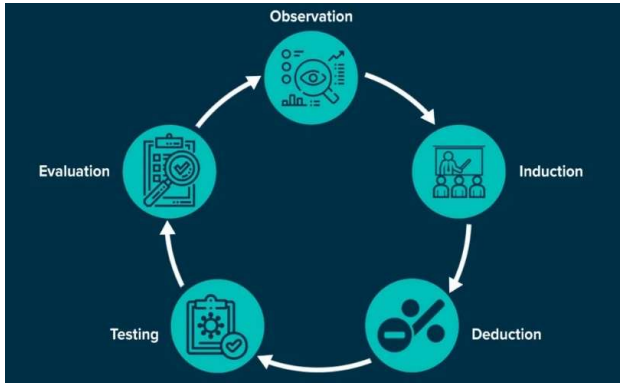
Empirical research in management and economics

Conjoint analysis



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Evaluation is now open

Please take part in the evaluation of the module!

Your feedback is highly appreciated.

Evaluation period: 10–23 January

Recap from last lecture

- What is the goal of cluster analysis, and how does it differ from factor analysis?
- Give two ways to measure similarity and describe how they differ from each other
- What‘s the purpose of linkage methods, and how do single linkage, complete linkage, and Ward‘s method differ from each other?
- Give a measure to quantify the model fit of a cluster solution
- Give two measures of model performance of a cluster solution that trade off model fit against model complexity
- What do high and low values on the Silhouette score mean?

Agenda for the semester

Session	Date	Topic
1	13 October	Introduction
2	20 October	Descriptive data analysis
3	27 October	Hypothesis development and measurement
4	3 November	Inferential data analysis I
5	10 November	Inferential data analysis II
6	17 November	Simple regression
7	24 November	Multiple regression
8	1 December	Logistic regression
9	8 December	Factor analysis
10	15 December	Cluster analysis
11	**12 January**	**Conjoint analysis**
12	19 January	The replication crisis and open science
13	26 January	Summary and questions
	11 February	Exam

Statistical software

- For the exercise, please download & install R and RStudio

  https://www.rstudio.com/products/rstudio/download/#download

- If you don't know R yet you can make yourself familiar with it

→ Free tutorials and help files

- http://www.r-tutor.com/r-introduction
- https://cran.r-project.org/doc/contrib/Torfs+Brauer-Short-R-Intro.pdf
- You can take the free DataCamp online tutorial! (https://www.datacamp.com/courses/free-introduction-to-r)

Goals for this week

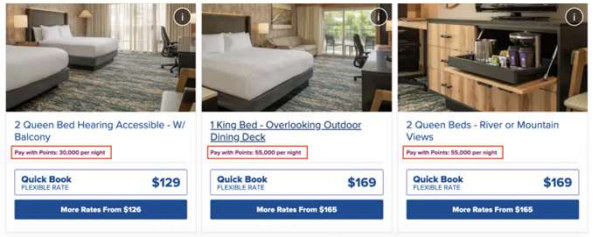
- You know the goals and principles of conjoint analysis
- You know how to design attribute profiles for collecting preference data for a conjoint analysis
- You are familiar with different methods for collecting preference data
- You know the general structure of a conjoint analysis model
- You understand what partworth utilities and attribute importances are and how they are calculated
- You understand how to use the results of a conjoint analysis to predict the utility of new attribute profiles

Decomposing people‘s preferences

- Marketing

  What features of hotel rooms do guests care about?

  → Attributes: size of bed, size of room, type of view, balcony



- Education

  What are the key aspects driving students‘ course preferences?

  → Attributes: applied content, quality of lecturer, credit requirements

- Medicine

  What are key aspects for women‘s preferences between treatment options after a miscarriage?

  → Attributes: time in hospital, risk of complication, duration of recovery

Conjoint analysis

- Developed by Paul E. Green (e.g., Green & Rao, 1971; Green & Srinivasan, 1978)
- Basic assumption: Preference is based on a combination of all attributes (they are “CONsidered JOINTly“)
- Goal

  Determine how important different attributes and attribute levels are for people‘s preferences

  → It is a *decompositional* method
- Principle

  Create options that represent combinations of different attribute levels and measure people‘s preferences for the different options; then infer the impact of the different attributes and attribute levels on the preferences

Steps of a conjoint analysis

Selection of attributes and attribute levels

Automatic dosing mode	Price	Capacity	Power consumption
yes	600€	6kg	170 kWH/year
no	700€	8kg	140 kWH/year
	800€	10kg	110 kWH/year

Design of the options and collection of preferences

Washing machine B

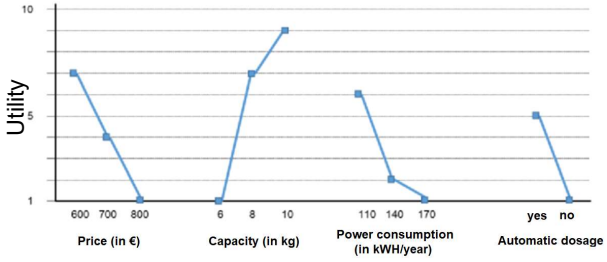
- No automatic do
- Price: 600€
- Capacity: 8kg
- Power consumpt

Washing machine A

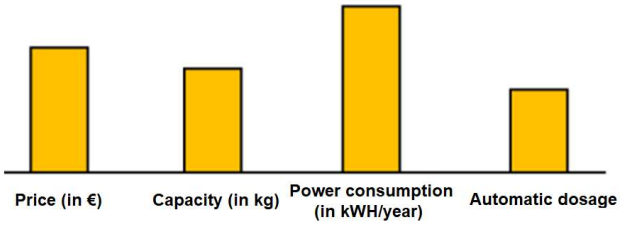
- Automatic dosing
- Price: 700€
- Capacity: 8kg
- Power consumption: 140 kWH/year

etc

Partworth utilities



Importance of the individual attributes



Criteria for selecting attributes and attribute levels

- *Relevance*: The attributes must be relevant for people's preferences
- *Actionable attributes*: The attributes should be modifiable
- *Realistic and feasible*: The attribute levels and their combinations have to be plausible
- *Manageable number of attributes and attribute levels*: The number of attributes and attribute levels should not be too high
- *Compensatoriness*: The attributes should be able to compensate for each other (e.g., an increase in price can be compensated by an improvement in taste). The attribute levels should not be exclusion criteria (e.g., a very high amount of calories cannot be compensated by a fancy packaging).
- *Independence*: The utility of an attribute level should not depend on the value of another attribute

A working example

Attributes

Attribute levels

Flavor	Price	Container	Topping
Chocolate	1.50€	Cone	Yes
Vanilla	2.00€	Cup	No
Strawberry	2.50€		

$L_{Flavor} = 3$ $L_{Price} = 3$ $L_{Container} = 2$ $L_{Topping} = 2$

Ice cream!

Designing the options

Construction of the attribute profiles: Full factorial design

Attributes

Attribute levels

Flavor	Price	Container	Topping
Chocolate	1.50€	Cone	Yes
Vanilla	2.00€	Cup	No
Strawberry	2.50€		
$L_{Flavor} = 3$	$L_{Price} = 3$	$L_{Container} = 2$	$L_{Topping} = 2$

→ 3 × 3 × 2 × 2 = 36 profiles

→ In a full factorial design, the attributes are orthogonal (i.e., uncorrelated)

Profile	*Flavor*	*Price*	*Container*	*Topping*	*Profile*	*Flavor*	*Price*	*Container*	*Topping*
1	Chocolate	1.50 EUR	Cone	Yes	**19**	Vanilla	2.00 EUR	Cup	Yes
2	Chocolate	1.50 EUR	Cone	No	**20**	Vanilla	2.00 EUR	Cup	No
3	Chocolate	1.50 EUR	Cup	Yes	**21**	Vanilla	2.50 EUR	Cone	Yes
4	Chocolate	1.50 EUR	Cup	No	**22**	Vanilla	2.50 EUR	Cone	No
5	Chocolate	2.00 EUR	Cone	Yes	**23**	Vanilla	2.50 EUR	Cup	Yes
6	Chocolate	2.00 EUR	Cone	No	**24**	Vanilla	2.50 EUR	Cup	No
7	Chocolate	2.00 EUR	Cup	Yes	**25**	Strawberry	1.50 EUR	Cone	Yes
8	Chocolate	2.00 EUR	Cup	No	**26**	Strawberry	1.50 EUR	Cone	No
9	Chocolate	2.50 EUR	Cone	Yes	**27**	Strawberry	1.50 EUR	Cup	Yes
10	Chocolate	2.50 EUR	Cone	No	**28**	Strawberry	1.50 EUR	Cup	No
11	Chocolate	2.50 EUR	Cup	Yes	**29**	Strawberry	2.00 EUR	Cone	Yes
12	Chocolate	2.50 EUR	Cup	No	**30**	Strawberry	2.00 EUR	Cone	No
13	Vanilla	1.50 EUR	Cone	Yes	**31**	Strawberry	2.00 EUR	Cup	Yes
14	Vanilla	1.50 EUR	Cone	No	**32**	Strawberry	2.00 EUR	Cup	No
15	Vanilla	1.50 EUR	Cup	Yes	**33**	Strawberry	2.50 EUR	Cone	Yes
16	Vanilla	1.50 EUR	Cup	No	**34**	Strawberry	2.50 EUR	Cone	No
17	Vanilla	2.00 EUR	Cone	Yes	**35**	Strawberry	2.50 EUR	Cup	Yes
18	Vanilla	2.00 EUR	Cone	No	**36**	Strawberry	2.50 EUR	Cup	No

Designing the options

Construction of the attribute profiles: Fractional orthogonal designs

Goal: Get a smaller set of stimuli where attributes are still uncorrelated

→ Based on simulation methods

Full factorial design

Profile	*Flavor*	*Price*	*Container*	*Topping*
1	Chocolate	1.50 EUR	Cone	Yes
2	Chocolate	1.50 EUR	Cone	No
3	Chocolate	1.50 EUR	Cup	Yes
4	Chocolate	1.50 EUR	Cup	No
5	Chocolate	2.00 EUR	Cone	Yes
6	Chocolate	2.00 EUR	Cone	No
7	Chocolate	2.00 EUR	Cup	Yes
8	Chocolate	2.00 EUR	Cup	No
9	Chocolate	2.50 EUR	Cone	Yes
10	Chocolate	2.50 EUR	Cone	No
11	Chocolate	2.50 EUR	Cup	Yes
12	Chocolate	2.50 EUR	Cup	No
13	Vanilla	1.50 EUR	Cone	Yes
14	Vanilla	1.50 EUR	Cone	No
15	Vanilla	1.50 EUR	Cup	Yes
16	Vanilla	1.50 EUR	Cup	No
17	Vanilla	2.00 EUR	Cone	Yes
18	Vanilla	2.00 EUR	Cone	No
19	Vanilla	2.00 EUR	Cup	Yes
20	Vanilla	2.00 EUR	Cup	No
21	Vanilla	2.50 EUR	Cone	Yes
22	Vanilla	2.50 EUR	Cone	No
23	Vanilla	2.50 EUR	Cup	Yes
24	Vanilla	2.50 EUR	Cup	No
25	Strawberry	1.50 EUR	Cone	Yes
26	Strawberry	1.50 EUR	Cone	No
27	Strawberry	1.50 EUR	Cup	Yes
28	Strawberry	1.50 EUR	Cup	No
29	Strawberry	2.00 EUR	Cone	Yes
30	Strawberry	2.00 EUR	Cone	No
31	Strawberry	2.00 EUR	Cup	Yes
32	Strawberry	2.00 EUR	Cup	No
33	Strawberry	2.50 EUR	Cone	Yes
34	Strawberry	2.50 EUR	Cone	No
35	Strawberry	2.50 EUR	Cup	Yes
36	Strawberry	2.50 EUR	Cup	No

Fractional orthogonal design

Profile	*Flavor*	*Price*	*Container*	*Topping*
1	Vanilla	1.50 EUR	Cone	Yes
2	Strawberry	2.00 EUR	Cone	Yes
3	Chocolate	2.50 EUR	Cup	Yes
4	Chocolate	1.50 EUR	Cone	No
5	Chocolate	2.00 EUR	Cone	No
6	Vanilla	2.50 EUR	Cone	No
7	Strawberry	2.50 EUR	Cone	No
8	Strawberry	1.50 EUR	Cup	No
9	Vanilla	2.00 EUR	Cup	No

Correlation matrix

	Flavor	**Price**	**Container**	**Topping**
Flavor	1			
Price	0	1		
Container	0	0	1	
Topping	0	0	0.00000000000000000014	1

Collecting preference data

Collecting preference data

Ordinal methods

- Ranking

  → “Please rank the 9 options according to how attractive you find them, that is, from most preferred (rank 1) to least preferred (rank 9).“

- Pair comparisons

  →“Please indicate which option you find more attractive.“

  Option A vs. Option B
  Option A vs. Option C
  Option A vs. Option D
  Option B vs. Option C
  Option B vs. Option D
  …

Collecting preference data

Metric methods

- Rating scale
  → "Please indicate how attractive you find Option A on a scale from 1 (= not attractive at all) to 10 (= very attractive)."
- Dollar metric
  → "How much would you pay for Option A?"
  → "How much more would you pay for Option A relative to Option B?"
- Constant-sum method
  → "Distribute 100 points across the options such that a more strongly preferred option receives proportionally more points."

	Flavor	*Price*	*Container*	*Topping*	***Rank***
Option 1	Vanilla	1.50 EUR	Cone	Yes	**3**
Option 2	Strawberry	2.00 EUR	Cone	Yes	**4**
Option 3	Chocolate	2.50 EUR	Cup	Yes	**9**
Option 4	Chocolate	1.50 EUR	Cone	No	**8**
Option 5	Chocolate	2.00 EUR	Cone	No	**1**
Option 6	Vanilla	2.50 EUR	Cone	No	**5**
Option 7	Strawberry	2.50 EUR	Cone	No	**7**
Option 8	Strawberry	1.50 EUR	Cup	No	**6**
Option 9	Vanilla	2.00 EUR	Cup	No	**2**

Ranking task

"Please rank the 9 options according to how attractive you find them—that is, from most preferred (rank 1) to least preferred (rank 9)."

Structure of a conjoint analysis model

Overall utility of object *k*

Coding matrix (representing the value of attribute *j*)

$$u_k = b_0 + \sum_{j=1}^{J} X_{jk} \times B_j$$

Intercept (base utility)

Regression coefficient matrix for attribute *j*

"Effect coding" of attribute values

For *L* = 2 attribute levels

	x_j
$Level_{1,j}$	1
$Level_{2,j}$	-1

$\times [b_j]$

For *L* = 3 attribute levels

	$x_{j,1}$	$x_{j,2}$
$Level_{1,j}$	1	0
$Level_{2,j}$	0	1
$Level_{3,j}$	-1	-1

$\times \begin{bmatrix} b_{j,1} \\ b_{j,2} \end{bmatrix}$

For *L* = 4 attribute levels

	$x_{j,1}$	$x_{j,2}$	$x_{j,3}$
$Level_{1,j}$	1	0	0
$Level_{2,j}$	0	1	0
$Level_{3,j}$	0	0	1
$Level_{4,j}$	-1	-1	-1

$\times \begin{bmatrix} b_{j,1} \\ b_{j,2} \\ b_{j,3} \end{bmatrix}$

etc

Structure of a conjoint analysis model

Flavor	$x_{Flavor,1}$	$x_{Flavor,2}$
Chocolate	1	0
Vanilla	0	1
Strawberry	-1	-1

Price	$x_{Price,1}$	$x_{Price,2}$
1.50€	1	0
2.00€	0	1
2.50€	-1	-1

Container	$x_{Container}$
Cone	1
Cup	-1

Topping	$x_{Topping}$
Yes	1
No	-1

$$u_k = b_0 + X_{Flavor,1} \times b_{Flavor,1} + X_{Flavor,2} \times b_{Flavor,2} + X_{Price,1} \times b_{Price,1} + X_{Price,2} \times b_{Price,2} + X_{Container} \times b_{Container} + X_{Topping} \times b_{Topping}$$

Structure of a conjoint analysis model

Flavor	$x_{Flavor,1}$	$x_{Flavor,2}$
Chocolate	1	0
Vanilla	0	1
Strawberry	-1	-1

Price	$x_{Price,1}$	$x_{Price,2}$
1.50€	1	0
2.00€	0	1
2.50€	-1	-1

Container	$x_{Container}$
Cone	1
Cup	-1

Topping	$x_{Topping}$
Yes	1
No	-1

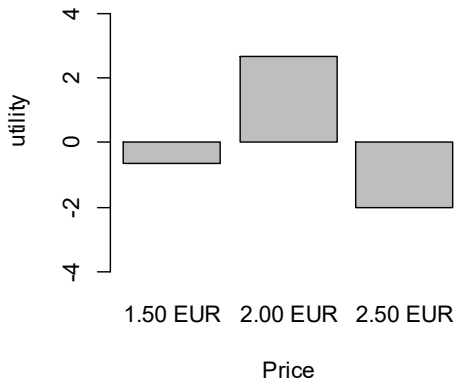
$$u_k = 4.75 + X_{Flavor,1} \times -1 + X_{Flav\ \ ,2} \times 1.667 + X_{Price,1} \times -0.667 + X_{Price,2} \times 2.667 + X_{Container} \times 0.5 + X_{Topping} \times -0.25$$

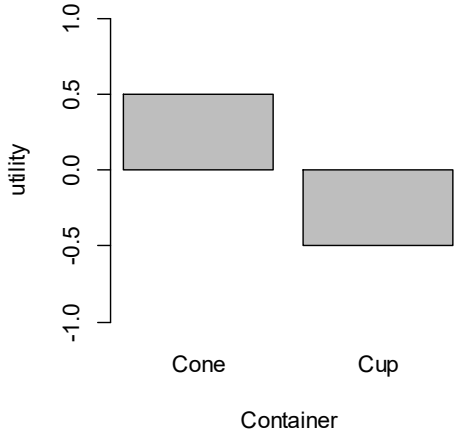
R^2 = .83

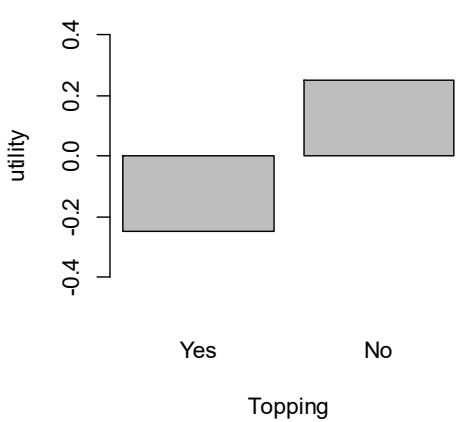
Partworth utilities

	Attribute	Attribute levels	$x_{1,j}$	$x_{2,j}$	Regression weights (b) $b_{j,1}$	$b_{j,2}$	Partworth utilities	
	Flavor	*Chocolate*	1	0			-1.000	$b_{Flavor,1} \times 1 + b_{Flavor,2} \times 0$
		Vanilla	0	1	-1.000	1.667	1.667	$b_{Flavor,1} \times 0 + b_{Flavo\ ,2} \times 1$
		Strawberry	-1	-1			-0.667	$b_{Flavor,1} \times -1 + b_{Flavo\ ,2} \times -1$
	Price	*1.50€*	1	0			-0.667	$b_{Price,1} \times 1 + b_{Price,2} \times 0$
		2.00€	0	1	-0.667	2.667	2.667	$b_{Price,1} \times 0 + b_{Pri\ \ ,2} \times 1$
		2.50€	-1	-1			-2.000	$b_{Price,1} \times -1 + b_{Price,2} \times -1$
	Container	*Cone*	1		0.500		0.500	$b_{Container} \times 1$
		Cup	-1				-0.500	$b_{Container} \times -1$
	Topping	*Yes*	1		-0.250		-0.250	$b_{Topping} \times 1$
		No	-1				0.250	$b_{Topping} \times -1$

Partworth utilities







Attribute importance

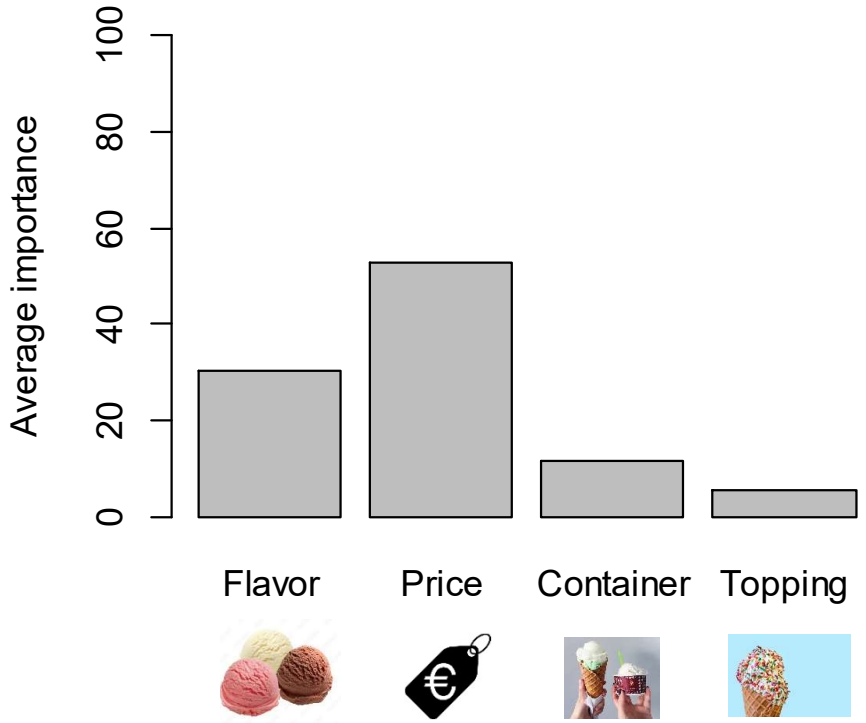
Range of partworth utilities across attribute levels (l) for attribute j

$$w_j = \frac{\overbrace{\max_l\{p_{jl}\} - \min_l\{p_{jl}\}}}{\sum_{j=1}^{J}\left(\max_l\{p_{jl}\} - \min_l\{p_{jl}\}\right)}$$

Attribute	Attribute levels	Partworth utilities (p)	Range	Importance (w)
Flavor	*Chocolate*	-1.000	1.667- (-1.000) = 2.667	2.667/8.834 = 0.301
	Vanilla	1.667		
	Strawberry	-0.667		
Price	*1.50€*	-0.667	2.667- (-2.000) = 4.667	4.667/8.834 = 0.529
	2.00€	2.667		
	2.50€	-2.000		
Container	*Cone*	0.500	0.500-(-0.500) = 1.000	1.000/8.834 = 0.113
	Cup	-0.500		
Topping	*Yes*	-0.250	0.250-(-0.250) = 0.500	0.500/8.834 = 0.057
	No	0.250		
			Σ = 8.834	

Attribute importance

$$w_j = \frac{\max_l\{p_{jl}\} - \min_l\{p_{jl}\}}{\sum_{j=1}^{J}\left(\max_l\{p_{jl}\} - \min_l\{p_{jl}\}\right)}$$



Estimating the utility of the options

	Flavor	Price	Container	Topping
Option 1	Vanilla	1.50 EUR	Cone	Yes
Option 2	Strawberry	2.00 EUR	Cone	Yes
Option 3	Chocolate	2.50 EUR	Cup	Yes
Option 4	Chocolate	1.50 EUR	Cone	No
Option 5	Chocolate	2.00 EUR	Cone	No
Option 6	Vanilla	2.50 EUR	Cone	No
Option 7	Strawberry	2.50 EUR	Cone	No
Option 8	Strawberry	1.50 EUR	Cup	No
Option 9	Vanilla	2.00 EUR	Cup	No

Option 1

Flavor	*Price*	*Container*	*Topping*
Vanilla	1.50 EUR	Cone	Yes

Attribute	Attribute levels	$x_{1,j}$	$x_{2,j}$	b_0 = 4.75 Regression weights (b) $b_{j,1}$	$b_{j,2}$	Partworth utilities
Flavor	*Chocolate*	1	0	-1.000	1.667	-1.000
	Vanilla	0	1			1.667
	Strawberry	-1	-1			-0.667
Price	*1.50€*	1	0	-0.667	2.667	-0.667
	2.00€	0	1			2.667
	2.50€	-1	-1			-2.000
Container	*Cone*	1		0.500		0.500
	Cup	-1				-0.500
Topping	*Yes*	1		-0.250		-0.250
	No	-1				0.250

$$u_k = b_0 + \sum_{j=1}^{J} X_{jk} \times B_j$$

$$u_{Option\ 1} = 4.75 + \underbrace{0 \times -1 + 1 \times 1.667}_{Vanilla} + \underbrace{1 \times -0.667 + 0 \times 2.667}_{1.50\ EUR} + \underbrace{1 \times .5}_{Cone} + \underbrace{1 \times -.25}_{Topping}$$

Partworth utility for:

$$u_{Option\ 1} = 6$$

	Flavor	*Price*	*Container*	*Topping*	***Rank***	***u***
Option 1	Vanilla	1.50 EUR	Cone	Yes	**3**	**6**
Option 2	Strawberry	2.00 EUR	Cone	Yes	**4**	**7**
Option 3	Chocolate	2.50 EUR	Cup	Yes	**9**	**1**
Option 4	Chocolate	1.50 EUR	Cone	No	**8**	**3.833**
Option 5	Chocolate	2.00 EUR	Cone	No	**1**	**7.167**
Option 6	Vanilla	2.50 EUR	Cone	No	**5**	**5.167**
Option 7	Strawberry	2.50 EUR	Cone	No	**7**	**2.833**
Option 8	Strawberry	1.50 EUR	Cup	No	**6**	**3.167**
Option 9	Vanilla	2.00 EUR	Cup	No	**2**	**8.833**

Ranking task

"Please rank the 9 options according to how attractive you find them—that is, from most preferred (rank 1) to least preferred (rank 9)."

$R^2 = .83$

Using the results of a conjoint analysis

- Revising an existing product portfolio
  - Which products (and attribute levels) could be eliminated from the product portfolio?
  - How sensitive would customers be to changes in an attribute (e.g., an increase in price)?
- Simulating customer preferences for new products
  - Which new combination of attribute levels should be introduced?

Predicting the utility of a new profile

Flavor	*Price*	*Container*	*Topping*
Strawberry	2.00 EUR	Cone	No

Attribute	Attribute levels	$x_{1,j}$	$x_{2,j}$	b_0 = 4.75 Regression weights (b) $b_{j,1}$	$b_{j,2}$	Partworth utilities
Flavor	*Chocolate*	1	0	-1.000	1.667	-1.000
	Vanilla	0	1			1.667
	Strawberry	-1	-1			-0.667
Price	*1.50€*	1	0			-0.667
	2.00€	0	1	-0.667	2.667	2.667
	2.50€	-1	-1			-2.000
Container	*Cone*	1		0.500		0.500
	Cup	-1				-0.500
Topping	*Yes*	1		-0.250		-0.250
	No	-1				0.250

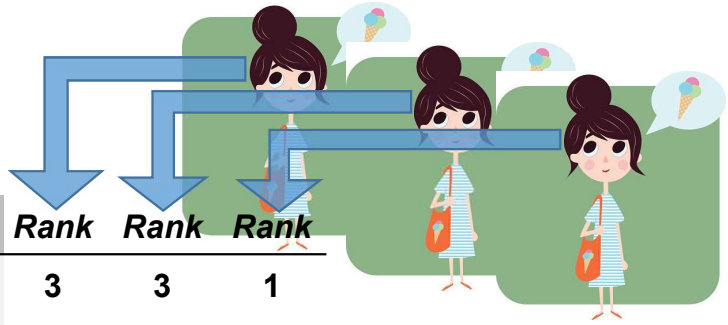
$$u_k = b_0 + \sum_{j=1}^{J} X_{jk} \times B_j$$

$$u_{new} = 4.75 \underbrace{-1 \times -1 + -1 \times 1.667}_{\text{Strawberry}} + \underbrace{0 \times -0.667 + 1 \times 2.667}_{\text{2.00 EUR}} + \underbrace{1 \times .5}_{\text{Cone}} + \underbrace{-1 \times -.25}_{\text{No topping}}$$

Partworth utility for:

$$\Rightarrow \quad u_{new} = 7.5$$

Ranking task



	Flavor	*Price*	*Container*	*Topping*	***Rank***	***Rank***	***Rank***
Option 1	Vanilla	1.50 EUR	Cone	Yes	**3**	**3**	**1**
Option 2	Strawberry	2.00 EUR	Cone	Yes	**4**	**5**	**4**
Option 3	Chocolate	2.50 EUR	Cup	Yes	**9**	**1**	**2**
Option 4	Chocolate	1.50 EUR	Cone	No	**8**	**6**	**8**
Option 5	Chocolate	2.00 EUR	Cone	No	**1**	**8**	**9**
Option 6	Vanilla	2.50 EUR	Cone	No	**5**	**9**	**5**
Option 7	Strawberry	2.50 EUR	Cone	No	**7**	**2**	**7**
Option 8	Strawberry	1.50 EUR	Cup	No	**6**	**7**	**6**
Option 9	Vanilla	2.00 EUR	Cup	No	**2**	**4**	**3**

…

…

"Please rank the 9 options according to how attractive you find them, that is from most preferred (rank 1) to least preferred (rank 9)."

Self-quiz questions

- What is the goal of conjoint analysis?
- What are important criteria when designing attribute profiles for a conjoint analysis?
- How does a fractional orthogonal design differ from a full factorial design? What does it mean if a fractional design is orthogonal?
- Give different approaches to collect preference data
- What is the structure of a conjoint analysis model?
- How does effect coding differ from dummy coding?
- Describe the calculation of partworth utilities
- Describe the calculation of attribute importances

Background reading for next week

Pennington, C. R. (2023). A student's guide to open science. In: C. R. Pennington, *A student's guide to open science. Using the replication crisis to reform psychology* (p. 56–75). McGraw Hill, Open University Press.

Andraszewicz, S., Scheibehenne, B., Rieskamp, J., Grasman, R., Verhagen, J., & Wagenmakers, E. J. (2015). An introduction to Bayesian hypothesis testing for management research. *Journal of Management*, *41*(2), 521–543.

Homework for Exercise next week

Watch this brief tutorial (< 9 min) on preparing a preregistration on AsPredicted

https://www.youtube.com/watch?v=7ic_Bgpmakl