Creative design in early stage product development of emerging technologies

Geir Birkedal, Tobias Dahl, Tormod Næs

July, 2010

About

- Elliptic labs: Touchless human-computer interfaces
- University of Oslo
- Nofima food

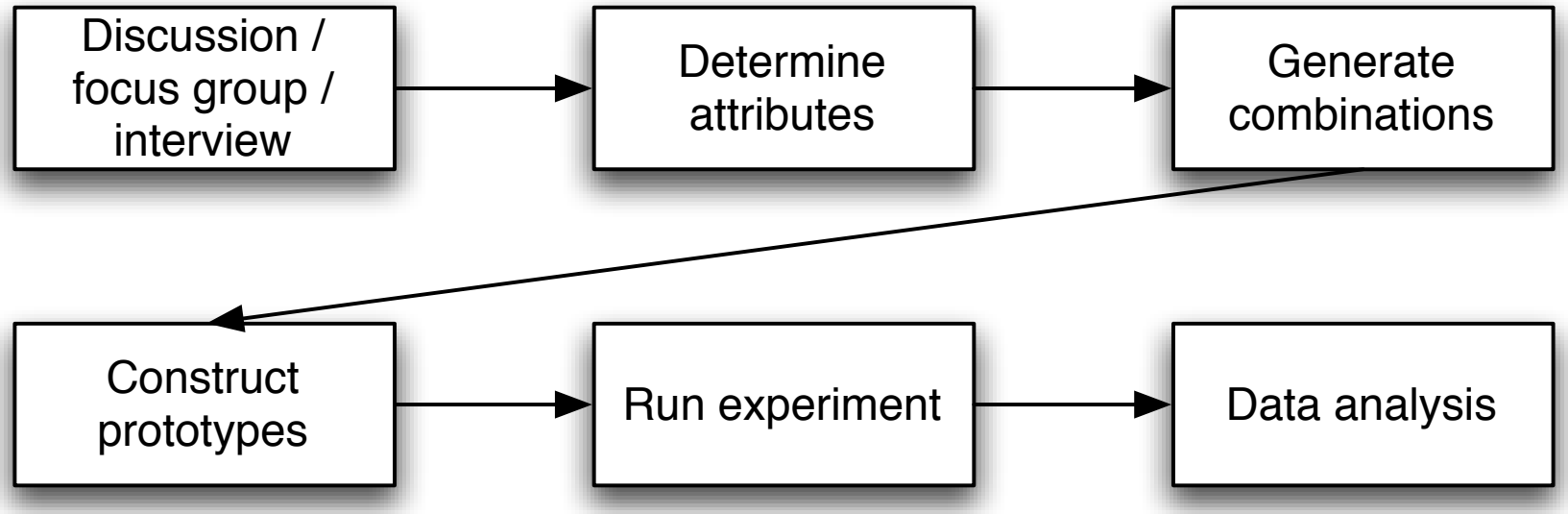
Product: Touchless mouse replacement

- Control mouse cursor by moving the hand on the table
- Small portable laptop computers
- Based on ultrasound

Objectives

- Get user feedback on a few important aspects
  - Needed early in the development process
- Explore the possibilities in multivariate analysis for consumer data in this field

Creative design [1]



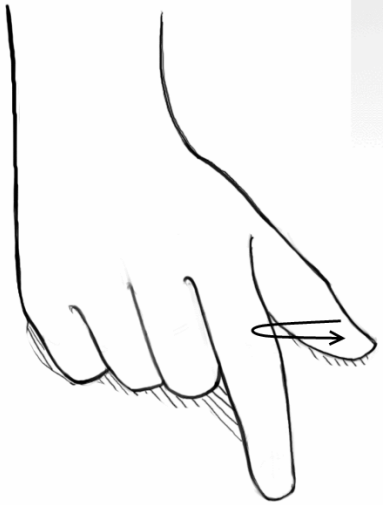
[1] T. Næs, T. E. Nyvold, *Creative design–an efficient tool for product development.* Food Quality and Preference, 2004

Attributes

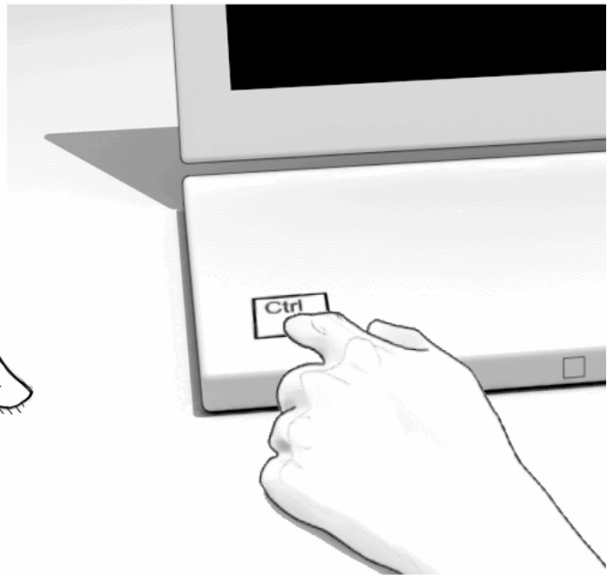
1. Clicking
2. Operating zone
3. Positioning mode
4. Delay

1. Clicking

Tap

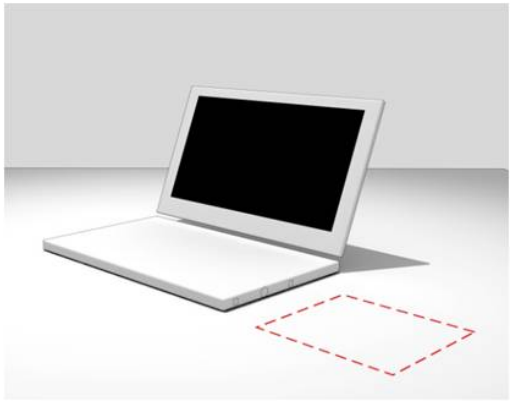


Thumb

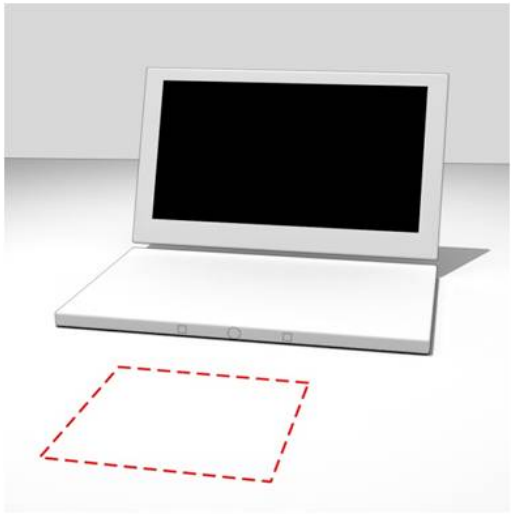


Ctrl key

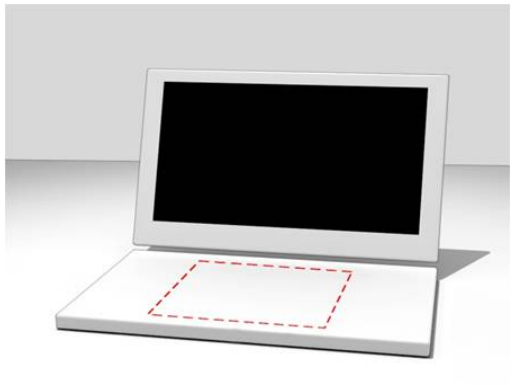
2. Operating zone



Side

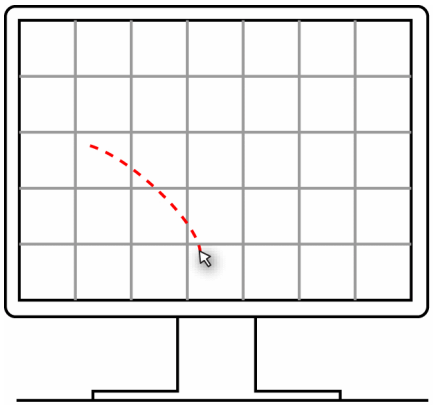


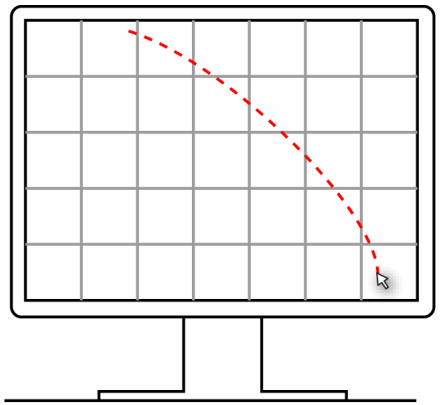
Front

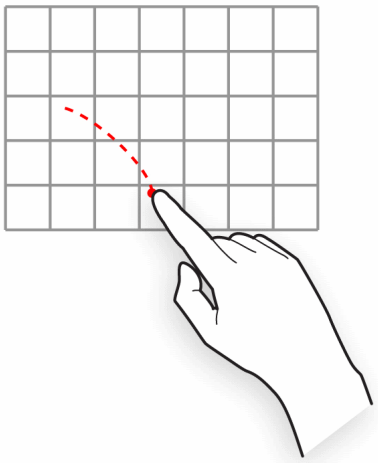


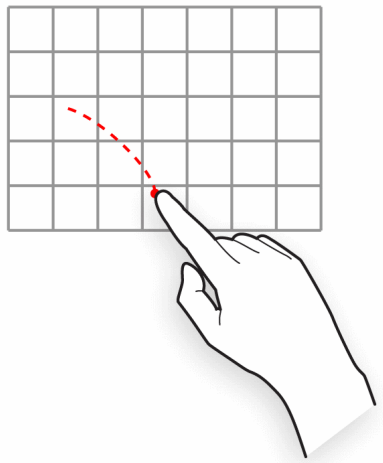
Over keyboard

3. Positioning mode









Absolute

Relative

4. Delay

- Delay between hand motion and cursor motion
- Obviously unwanted, but how much is ok?
- Tradeoff between delay and smoothness

Experimental design

- First 8 objects: fractional factorial design
- Two levels
- Resolution IV (2_{IV}^{4-1})

Number	Click type	Interaction zone	Positioning mode	Delay
P1	Tap	Front	Absolute	Off
P2	Tap	Side	Absolute	On
P3	Key	Front	Absolute	On
P4	Key	Side	Absolute	Off
P5	Tap	Front	Relative	On
P6	Tap	Side	Relative	Off
P7	Key	Front	Relative	Off
P8	Key	Side	Relative	On

Experimental design

- First 8 objects: fractional factorial design
- Two levels
- Resolution IV (2_{IV}^{4-1})
- 3 additional objects

Number	Click type	Interaction zone	Positioning mode	Delay
P1	Tap	Front	Absolute	Off
P2	Tap	Side	Absolute	On
P3	Key	Front	Absolute	On
P4	Key	Side	Absolute	Off
P5	Tap	Front	Relative	On
P6	Tap	Side	Relative	Off
P7	Key	Front	Relative	Off
P8	Key	Side	Relative	On
P9	Tap	Side	Absolute	Off
P10	Thumb	Side	Absolute	Off
P11	Key	Top	Absolute	Off

Experimental design

- First 8 objects: fractional factorial design
- Two levels
- Resolution IV (2_{IV}^{4-1})
- 3 additional objects
- Third level

Number	Click type	Interaction zone	Positioning mode	Delay
P1	Tap	Front	Absolute	Off
P2	Tap	Side	Absolute	On
P3	Key	Front	Absolute	On
P4	Key	Side	Absolute	Off
P5	Tap	Front	Relative	On
P6	Tap	Side	Relative	Off
P7	Key	Front	Relative	Off
P8	Key	Side	Relative	On
P9	Tap	Side	Absolute	Off
P10	**Thumb**	Side	Absolute	Off
P11	Key	**Top**	Absolute	Off

Experimental design

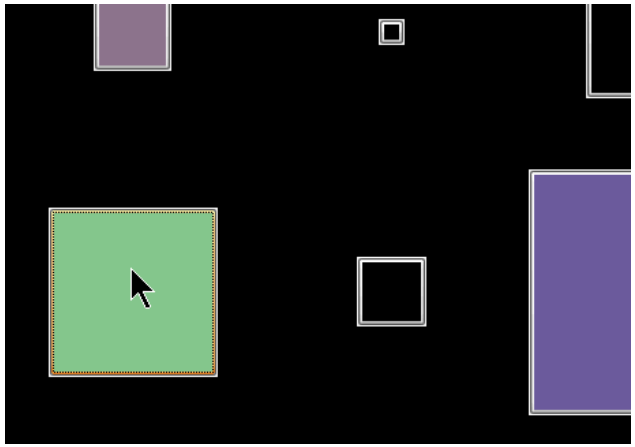
- First 8 objects: fractional factorial design
- Two levels
- Resolution IV (2^{4-1}_{IV})
- 3 additional objects
- Third level
- Randomized order

Number	Click type	Interaction zone	Positioning mode	Delay
P1	Tap	Front	Absolute	Off
P2	Tap	Side	Absolute	On
P3	Key	Front	Absolute	On
P4	Key	Side	Absolute	Off
P5	Tap	Front	Relative	On
P6	Tap	Side	Relative	Off
P7	Key	Front	Relative	Off
P8	Key	Side	Relative	On
P9	Tap	Side	Absolute	Off
P10	Thumb	Side	Absolute	Off
P11	Key	Top	Absolute	Off

Experiment

26 users, mostly students.

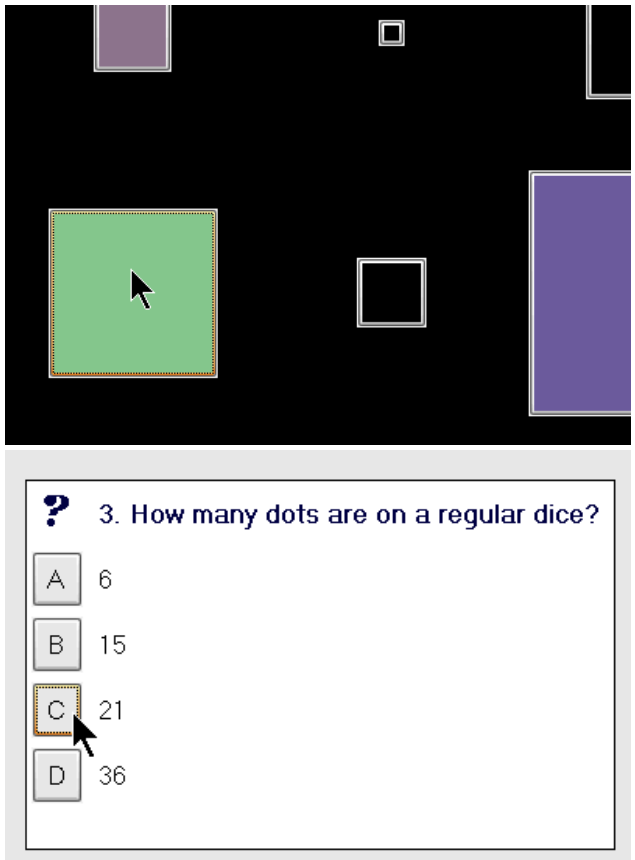
- Introduction
- One minute training



Experiment

26 users, mostly students.

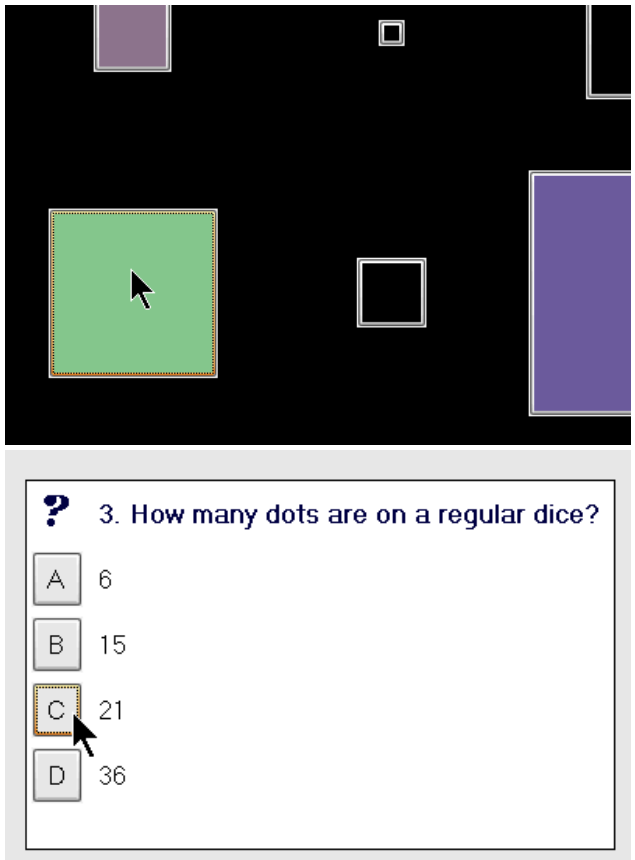
- Introduction
- One minute training
- For each prototype:
  - Simple task
  - Feedback (next slide)



Experiment

26 users, mostly students.

- Introduction
- One minute training
- For each prototype:
  - Simple task
  - Feedback (next slide)
- General info



Questions for each prototype

Four questions:

1. As expected?
2. Easy?

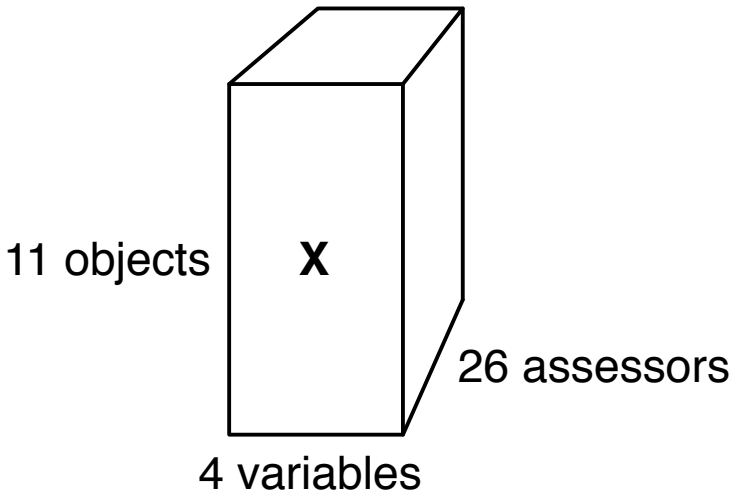
Working for 30 minutes:

3. Efficient?
4. Tired or strained?

Worst | | | | | | | | | Best

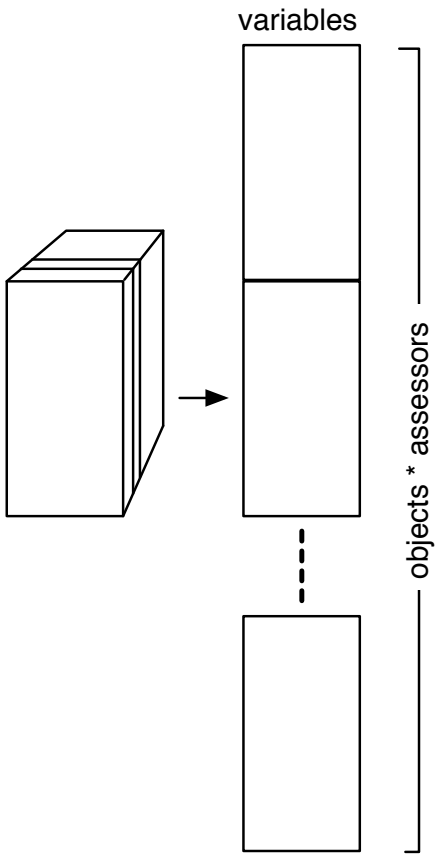
Data analysis

Data matrix



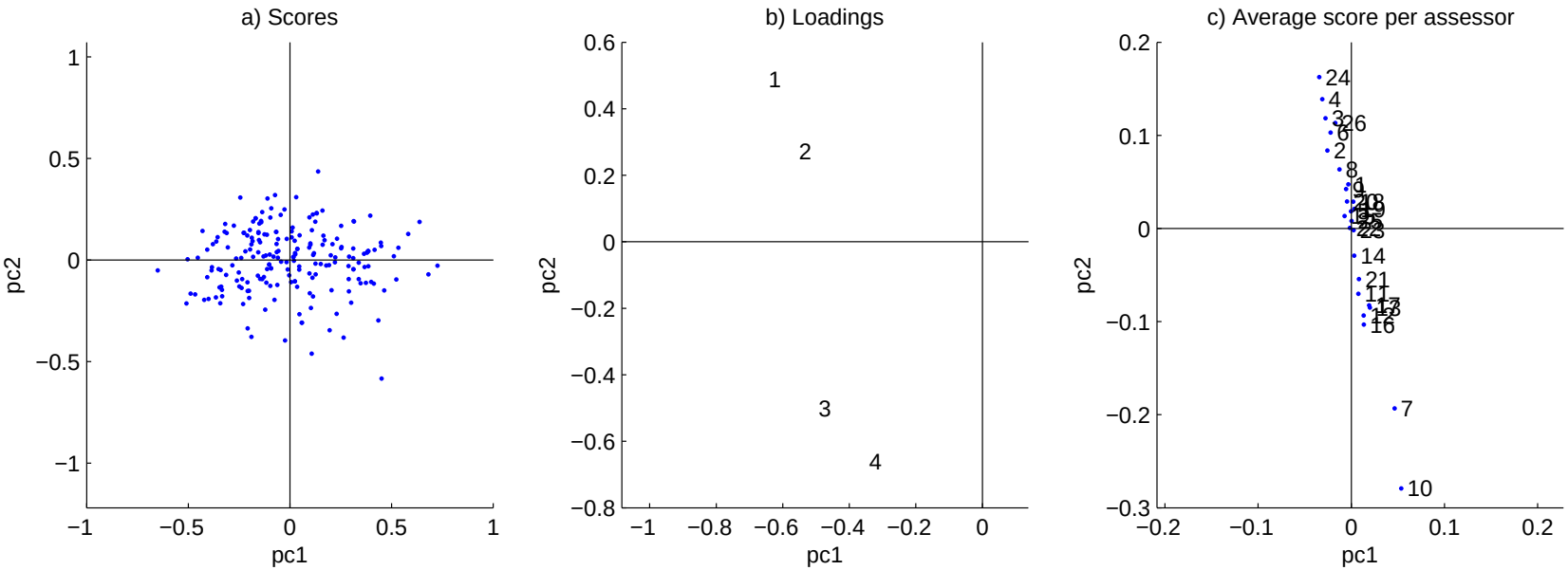
- Three-way data structure
- PCA of the unfolded data matrix
- Two ways (at least) to unfold: Vertically and horizontally

Vertically unfolded PCA



- Maintains variation between assessors
- Average difference between variables is lost, but variable variation among assessors is maintained.

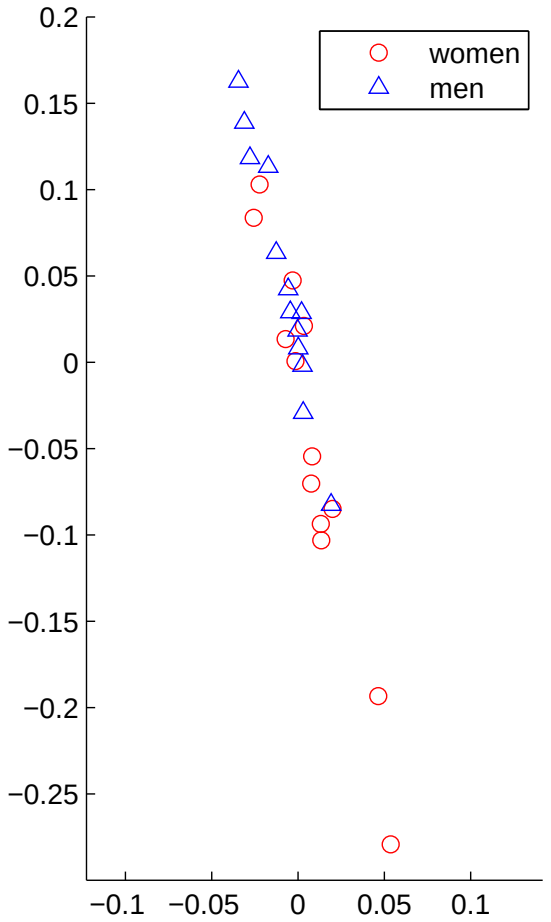
Vertically unfolded PCA



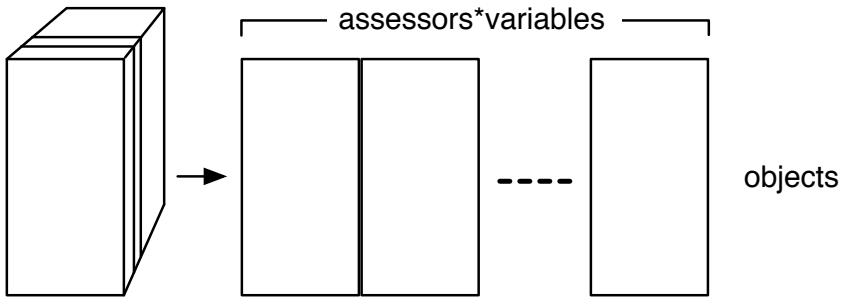
- Clear difference between variables 1-2 and 3-4
- This difference is reflected in the distribution of assessors

Gender difference

- Apparent difference between men and women
- Women score variables 3-4 relatively higher than men (p=0.036)
- Questions 3 and 4 relate to longer term usage

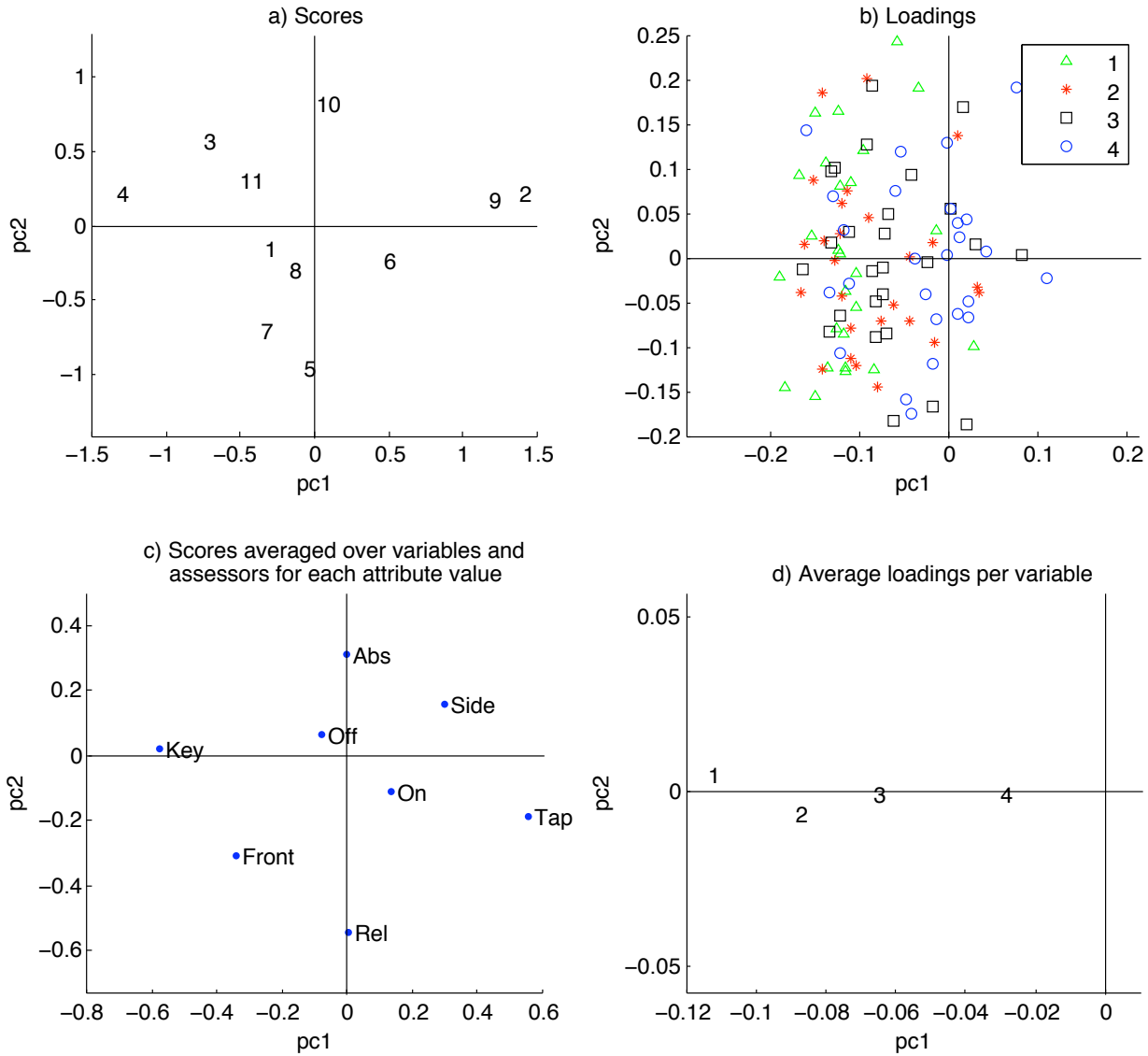


Horizontally unfolded PCA



- Discards average difference between assessor-variables
- Maintains sample variability
- Scores constitute a consensus response
- Extension of preference mapping

Horizontally unfolded PCA

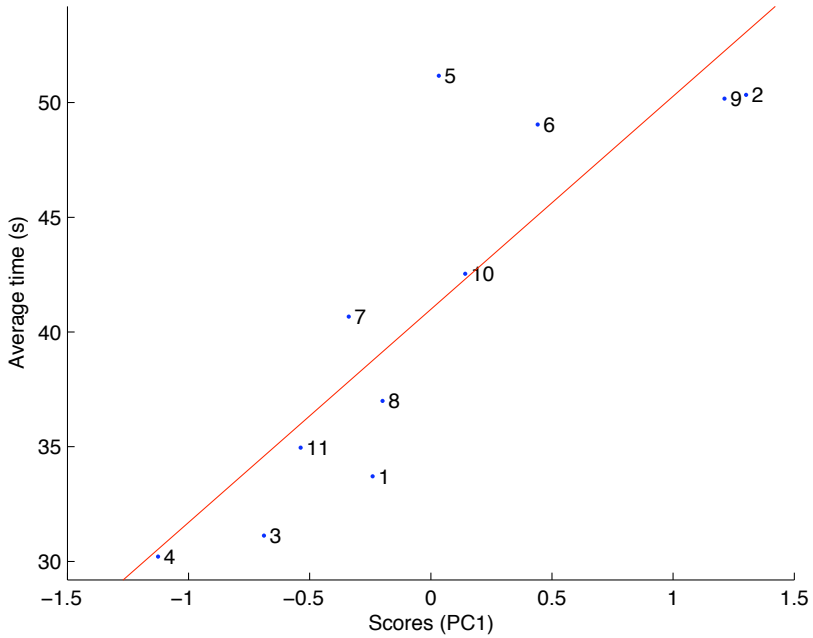


ANOVA

- Analysis of variance
- Both for each variable separately and for the PCA scores.
- Found that clicking is the most important factor

Time

- The tasks were timed
- Objective measurement
- Correlated with PC1. $R^2 = .73$



Visual interpretation

Responses and design matrix

- How are the responses related to the design matrix?
- How can we visualize this relation?

Orthogonal Procrustes

- Do the reponses span the same space as the design?
- Score matrix $\mathbf{T}$: Consensus of responses, orthogonal columns

Orthogonal Procrustes

- Do the reponses span the same space as the design?
- Score matrix $\mathbf{T}$: Consensus of responses, orthogonal columns
- Rotate $\mathbf{T}$ to fit the design matrix $\mathbf{D}$:

$$\text{Minimize} \|\mathbf{TQ} - \mathbf{D}\|, \quad \mathbf{Q}^T\mathbf{Q} = \mathbf{I}$$

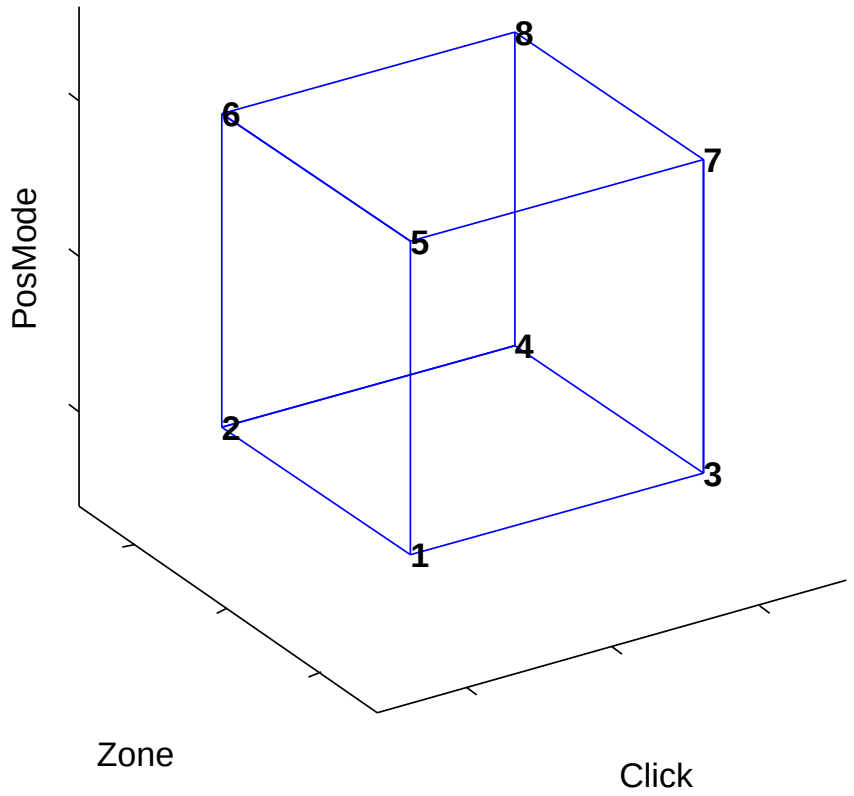
Orthogonal Procrustes

- Do the reponses span the same space as the design?
- Score matrix $\mathbf{T}$: Consensus of responses, orthogonal columns
- Rotate $\mathbf{T}$ to fit the design matrix $\mathbf{D}$:

$$\text{Minimize} \|\mathbf{TQ} - \mathbf{D}\|, \quad \mathbf{Q}^T\mathbf{Q} = \mathbf{I}$$

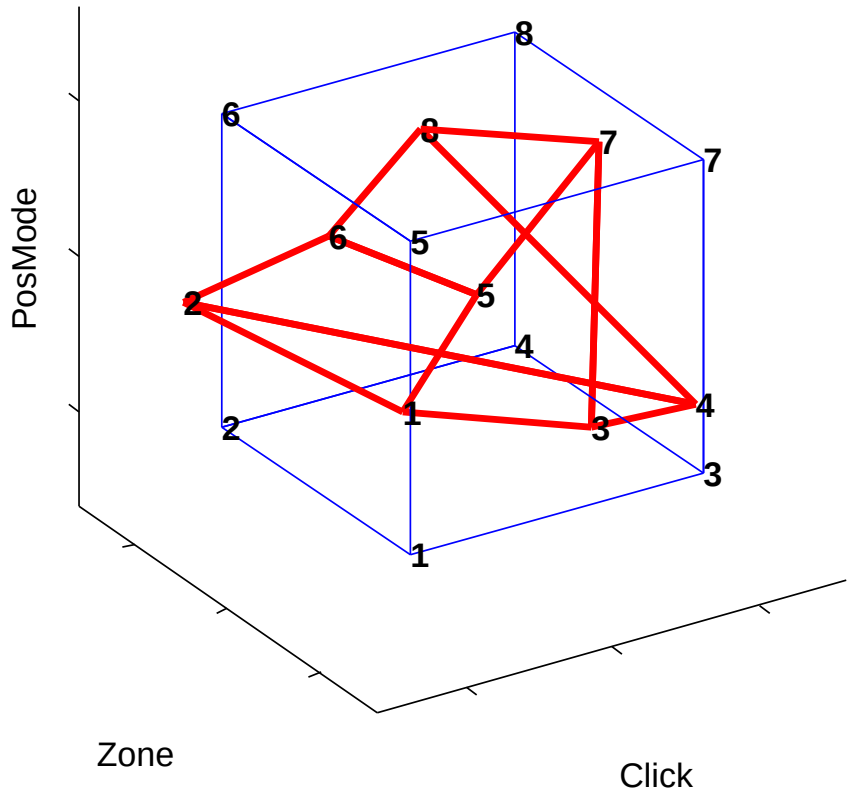
- Solution found by SVD: $\mathbf{USV}^T = \mathbf{T}^T\mathbf{D}$, $\mathbf{Q} = \mathbf{UV}^T$

Visualization of fit



$$\mathbf{D} = \begin{pmatrix} -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$

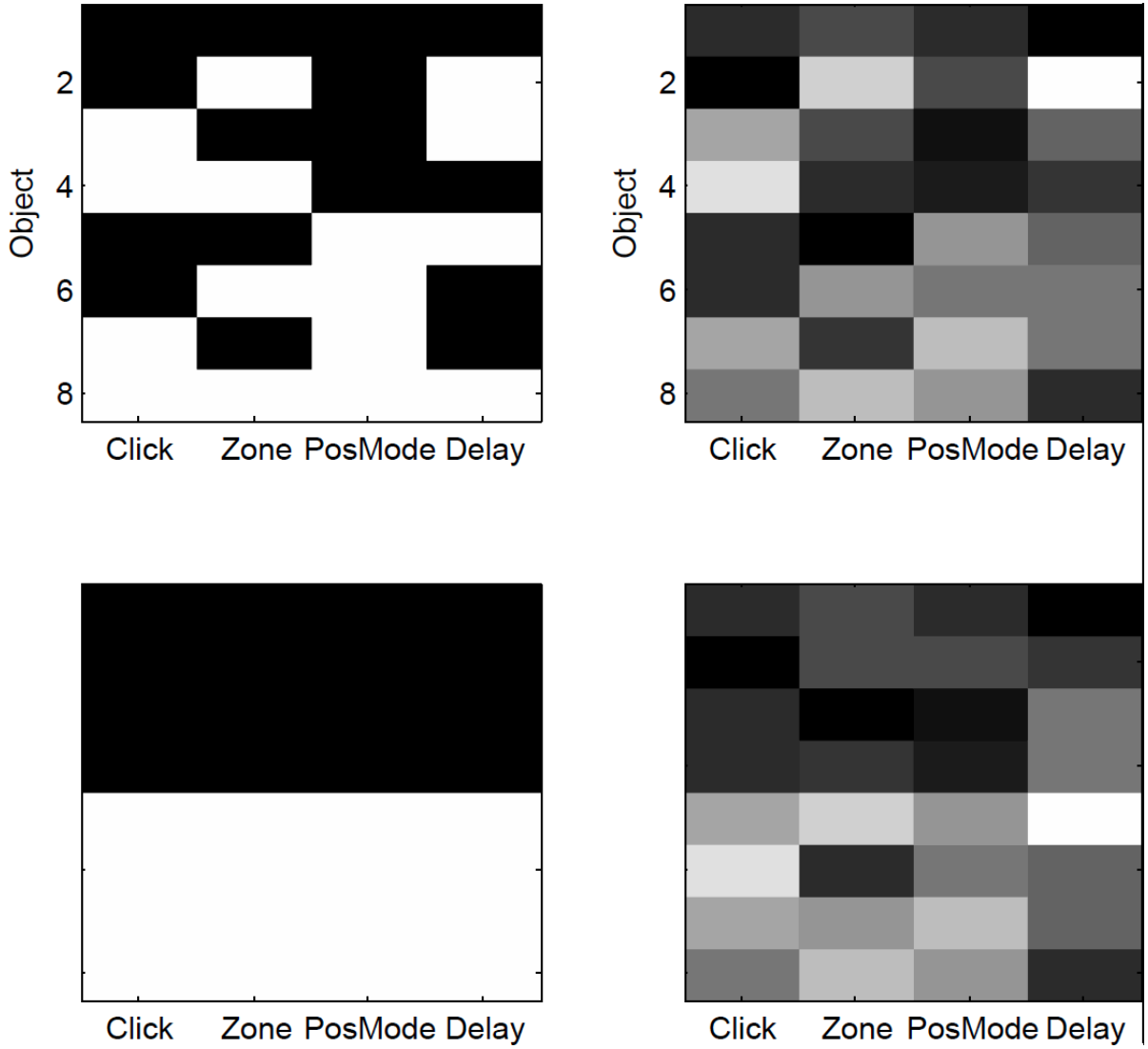
Visualization of fit



$$\mathbf{D} = \begin{pmatrix} -1 & -1 & -1 & -1 \\ -1 & 1 & -1 & 1 \\ 1 & -1 & -1 & 1 \\ 1 & 1 & -1 & -1 \\ -1 & -1 & 1 & 1 \\ -1 & 1 & 1 & -1 \\ 1 & -1 & 1 & -1 \\ 1 & 1 & 1 & 1 \end{pmatrix}$$

$$\mathbf{TQ} = \begin{pmatrix} -0.27 & -0.11 & -0.26 & -0.54 \\ -0.60 & 0.55 & -0.10 & 0.75 \\ 0.37 & -0.10 & -0.48 & 0.00 \\ 0.61 & -0.29 & -0.39 & -0.24 \\ -0.32 & -0.58 & 0.31 & 0.07 \\ -0.29 & 0.25 & 0.16 & 0.10 \\ 0.34 & -0.20 & 0.48 & 0.12 \\ 0.16 & 0.48 & 0.29 & -0.27 \end{pmatrix}$$

Another visualization of fit



Discussion

Why Procrustes?

- Geometric interpretation
- Linear combinations of columns in **D** and **T** with optimal covariance

Cons

- Needs suitable dimensionality
- Risk of finding patterns that are not there

Present and future work

- Assess the statistical validity
  - Simulations
  - Bigger data sets
- Procrustes for comparing assessors

Thank you!