Multidimensional Scaling

Outline

- Motivation
- An Example on Haptic Texture Perception
- Summary

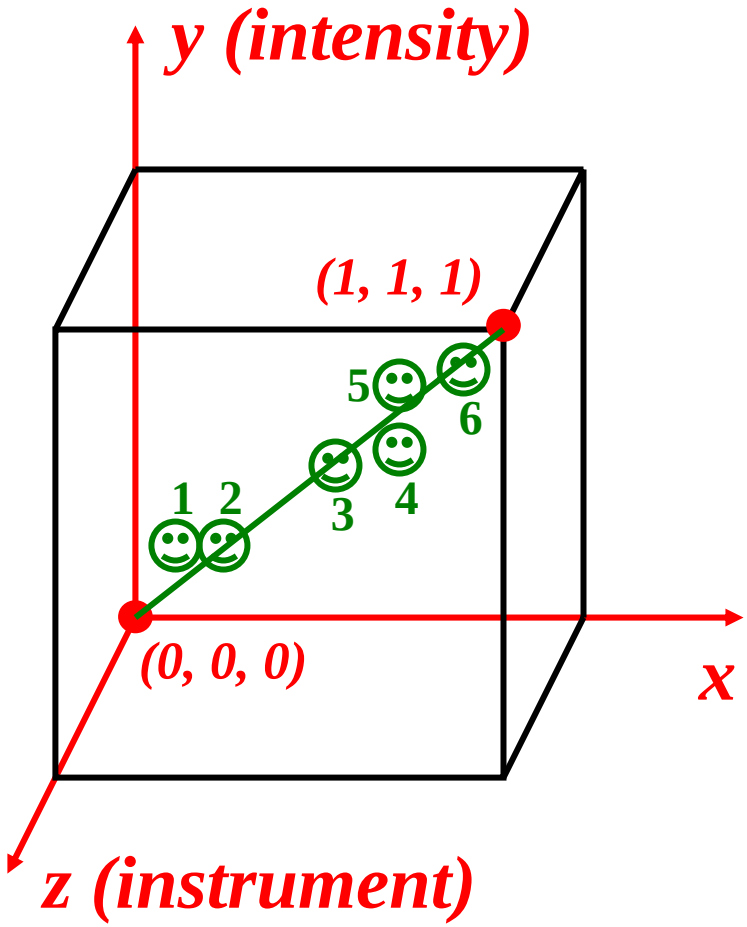
Motivation

- In general, multidimensional stimuli lead to higher *information transfer*
- *Perceptual* dimensionality is related to, but not necessarily identical to, *physical* dimensionality
- Real-world stimuli are usually complex and multidimensional. How do we determine their associated *perceptual* dimensionality?
  - Example 1. Face recognition
  - Example 2. Color perception
  - Example 3. Haptic surface texture perception

Multidimensional Scaling (MDS) — An Overview

- **MDS is a technique that lets us investigate the underlying dimensionality associated with a stimulus set.**
- **Given a set of *n* objects**
  - **Obtain "dissimilarity" measures δ_{rs} for each pair of objects (r, s)**
  - **Search for a low dimensional perceptual space, where each object is represented by a point**
  - **Ensure that the distances between the points in perceptual space, $\{d_{rs}\}$, match the original dissimilarities $\{\delta_{rs}\}$.**

MDS — The Idea

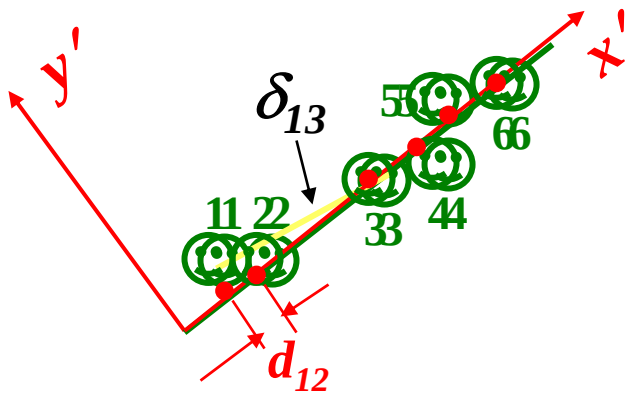


$\delta_{12}=1.0$
$\delta_{13}=5.0$
$\delta_{56}=1.5$
etc.

MDS — The Result(s)

Dissimilarity Judgments

$\delta_{12}=1.0$
$\delta_{13}=5.0$
$\delta_{56}=1.5$
etc.



Recovered Perceptual Distances

An Example: Texture Perception

- Hollins et al., *P&P*, 1993.
- Stimuli: 17 texture samples
- Procedure: passive stimulation
- Dissimilarity Scores
  - Grouping (i.e., similarity scores)
  - Co-occurrence scores (0.0 or 1.0)
  - Dissimilarity = 1 – Co-occurrence
- MDS analysis (ALSCAL, SAS)

Co-occurrence Matrix
Average over All Subjects

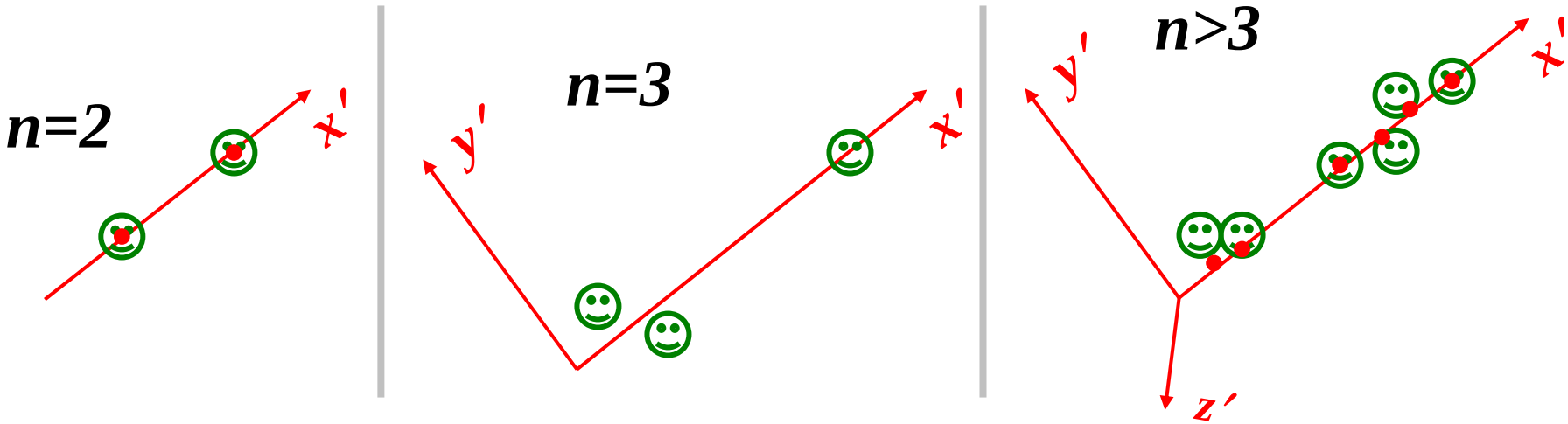
Stimulus	Felt	Straw	Wax Paper	Cork	Tile	Card-board
Felt	1.00					
Straw	.00	1.00				
Wax paper	.05	.00	1.00			
Cork	.10	.05	.30	1.00		
Tile	.05	.00	.60	.55	1.00	
Cardboard	.05	.00	.60	.60	.95	1.00

(cont.)

- **Dissimilarity = 1 – Co-occurrence**
- **MDS analysis (ALSCAL, SAS)**

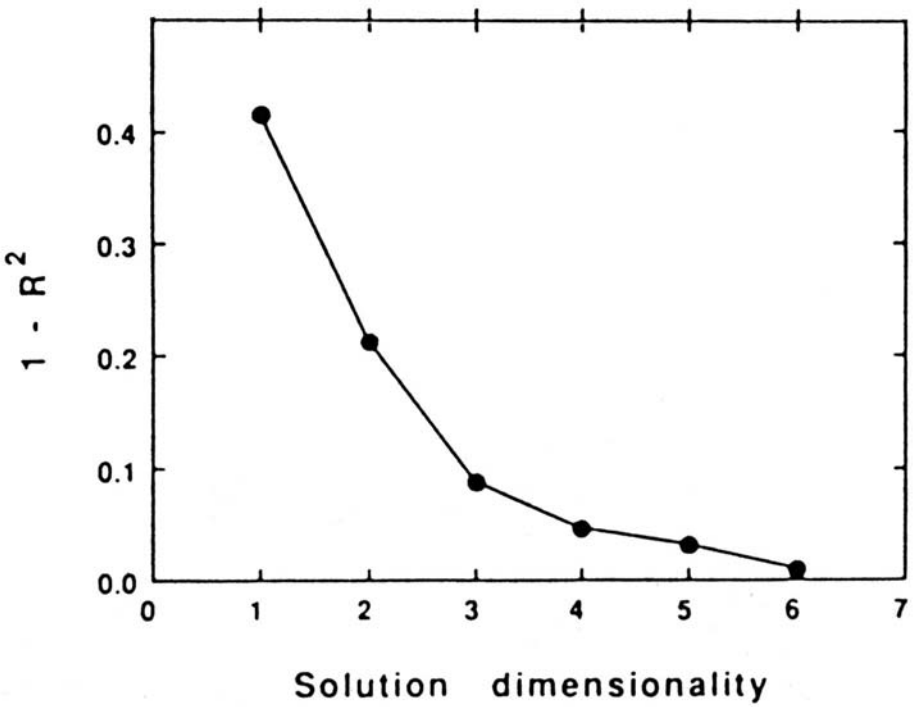
How many dimensions?

- Given *n* objects, MDS analysis recovers (*n–1*) underlying dimensions

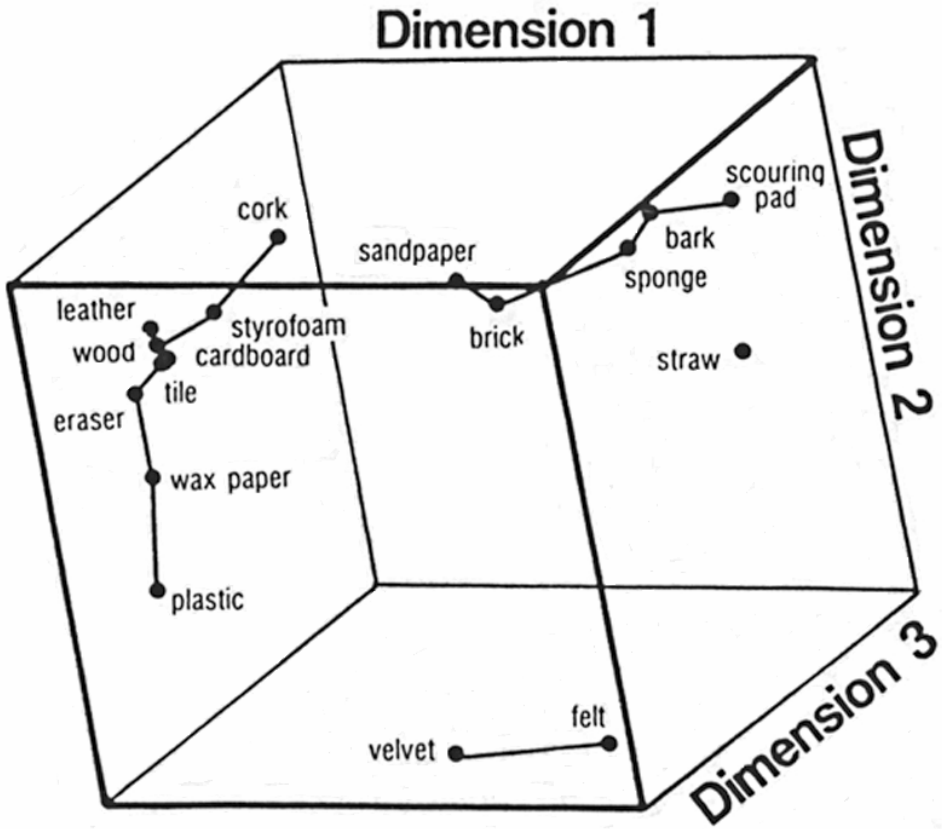


- Dimensionality is determined by examining S-Stress, Stress, and $1–R^2$, as a function of dimensions

1-R^2 Plot from Hollins *et al.*



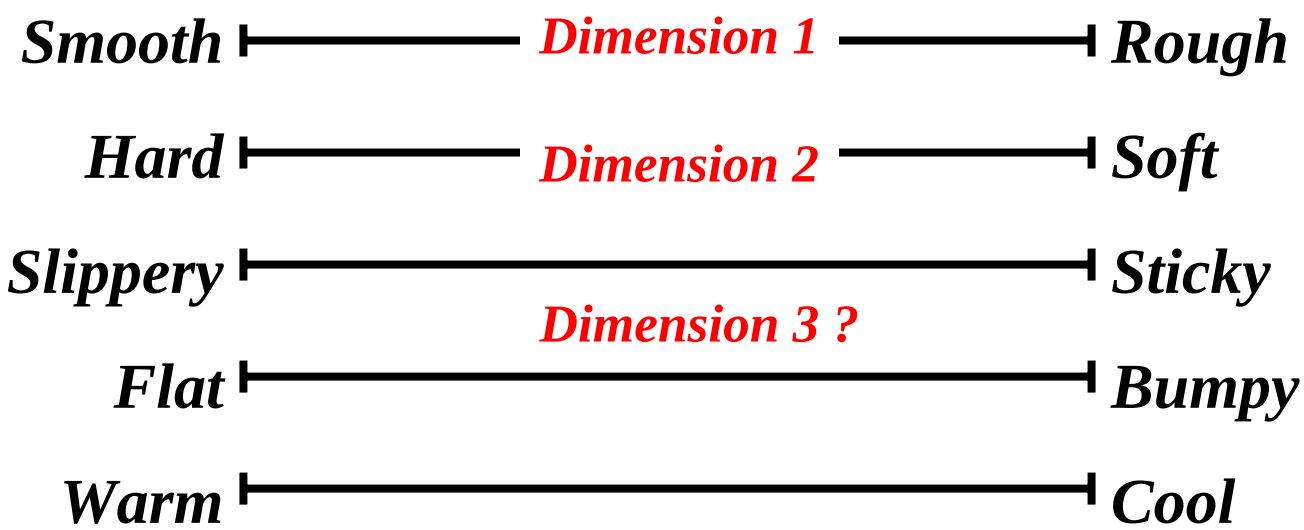
A 3-D Solution



Cube representing the 3-dimensional multidimensional scaling solution.
(From Hollins, Faldowski, Rao & Young, 1993)

Interpreting the MDS Solution

- **Adjective Rating**



Summary of MDS

- Experimental procedures
  - Key is to obtain dissimilarity scores
  - Grouping, similarity, dissimilarity
  - Ordering (non-metric)
  - etc.
- Data analysis
  - Use statistical packages such as SAS
  - For *n* objects, (*n*–*1*) dimensional solution

- **Select solution dimensionality**
  - **S-Stress, Stress, and $1 - R^2$**
- **Interpretation of MDS solutions**
  - **Adjective rating**
- **Known problems and limitations**
  - **Invariant to translation, rotation, reflection**
  - **May "discover" non-existent perceptual spaces**
- **Verification of MDS solution**
  - **Adjective rating**
  - **Matching experiments**

    Color perception: $X + rR = gG + bB$

Readings

- **T. F. Cox and M. A. A. Cox, *Multidimensional Scaling*. New York: Chapman & Hall, 1994.**
- **M. Hollins, R. Faldowski, S. Rao, and F. Young, "Perceptual dimensions of tactile surface texture: A multidimensional scaling analysis," *Perception & Psychophysics*, vol. 54, pp. 697-705, 1993.**