Explore Connections Between Similarity and Categorization Using Vision and Touch

**At a Glance**

**Background:**
Perceptual similarity has often been considered under the restricted scenario of unimodal perception, usually visual (e.g., [1], [2]). Visual similarity between objects has been proposed as a mechanism capable of supporting recognition and categorization [3].

**Questions:**
Are similarity relationships between objects the same when objects are experienced using different modalities? Can the notion of similarity still provide a basis for explaining categorization in a multimodal context?

**Approach:**
Using vision, touch, or both, humans rated similarity between novel objects, which varied in shape and texture, and then freely categorized them into groups. We then examined the correlation between the structure of categories created and perceptual similarity between the objects as a function of modality [4].

**Stimuli: A Family of Touchable 3D Objects**

Object properties are varied parametrically:
1. Macrogeometric smoothing averages out sharp edges in global shape
2. Microgeometric smoothing reduces bumpiness in local texture

Although both shape and texture properties can be extracted by vision and touch, previous work has shown that shape is especially salient for the visual system, while texture is more salient for the haptic system [5].

**Experimental Design**

- Subjects explored the objects by touch alone, vision alone, or both
- 10 subjects per modality condition
- Stimuli were presented for 3s and subtended 16°
- Haptic exploratory procedure was contour-following

**Task 1: Similarity Ratings**
- Verbally on a 7-point scale (1 = low, 7 = high)
- 3 blocks of 325 pairwise ratings in random order
- Duration was 10 hrs (2 hrs/day for 5 days)
- Simplicity data analyzed using individual differences multidimensional scaling (INDSCAL MDS program in SPSS)

**Task 2: Free Sort Categorization**
- Directly followed the similarity ratings
- Subjects defined numbered categories in writing
- Objects presented sequentially using identical setup
- Subjects provided the corresponding category number
- Stimuli iterated until the same number was given twice in a row
- Duration was approx. 30 min.

**Multimodal Similarity: Results**

Map and weights obtained by performing multidimensional scaling (MDS) on similarity data. A single, multimodal MDS model (as opposed to separate, modality-specific models) with modality-weighted dimensions was able to account for similarity data.

Dimension weights estimated using the number of adjacencies in the stimulus map (along either shape or texture dimensions) crossed by each subject's category boundaries.

**Connections Between Similarity & Categorization**

- Category membership and boundary placement correlate with similarity
- Same modality effects observed on dimension weights for similarity and categorization tasks
- However, categories could not be predicted from individual similarity maps
- Free sorting task may have favoured the use of unidimensional rules instead of distance in similarity space as category formation strategy

**Conclusions & Future Work**

Are perceptual similarity and categorization affected by a change of modality?
- Yes: the relative importance of object properties varied systematically according to modality for both tasks
- Shape > texture for vision only, but texture = shape for touch and vision + touch
- Modality differences can be modeled as a modality-dependent rescaling of a single map

Can similarity explain categorization in a multimodal setting?
- Dimension weights for both tasks modulated in the same way by modality change
- Category membership and boundary placement correlate with similarity
- However, free sorting categories could not be predicted from similarity

Future work includes:
- Generalizing results to new stimulus classes
- Systematic variation of exploratory procedures and viewpoint

**References**