Effects of Supervised and Unsupervised Categorization on Visual and Haptic Object Representations

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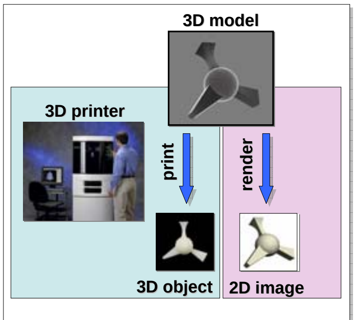
At a Glance

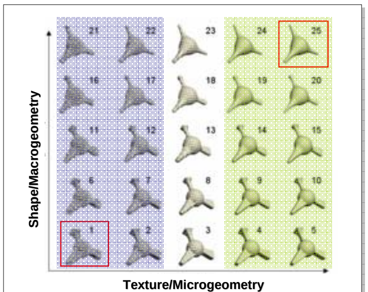
Background: Perceived **similarity** between two objects can vary according to whether they are seen or touched [1]. Similarity can also be shaped by prior **category learning**, by increasing the saliency of diagnostic dimensions, for example [2,3].

Question: Category learning effects have **mainly been shown for visual perception**. Can category learning affect similarity when **touch** is used instead? Can both **supervised and unsupervised** learning invoke changes in perceptual similarity?

Approach: Using either **vision or touch,** humans **rated similarity** between novel objects either **1) without** prior categorization experience, **2)** after an **unsupervised** categorization task, or **3)** after a **supervised** learning task. We then looked for task effects on the relative importance of object properties in similarity judgments.

Stimuli: A Family of Touchable 3D Objects





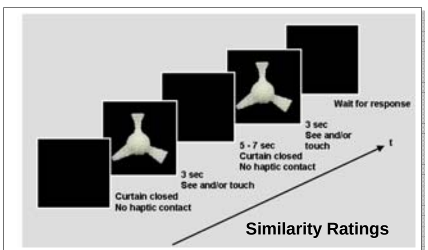
Prototypes used for unsupervised categorization task
Rough/smooth categories learned in supervised categorization task

Parametric object property manipulations

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 suggests that **shape** is especially salient for the **visual** system, while **texture** is more salient for the **haptic** system [4].

Experimental Design



General Parameters

- 10 naïve subjects per condition
- Objects were *either* seen or touched (contour-following)
- Similarity rated verbally on a 7-point scale (1 = low, 7 = high)
- Stimuli ~ 8x8 cm and placed 40cm away from subject (12°)

Condition 1: Naïve Similarity Ratings

- Subjects performed similarity ratings **without any prior experience** with objects
- Similarities gathered for 25 object pairs; 3 repeated measures

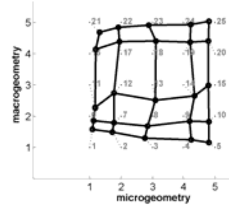
Condition 2: Unsupervised Categorization + Similarity Ratings

- Subjects performed similarity ratings **after unsupervised categorization task**
- Similarities gathered for 50 object pairs; 4 repeated measures
- Unsupervised categorization task:
  - Subjects were shown 2 object pairs (object X + object 1, object X + object 25) and asked whether the first or second pair belonged to the same category (4 repeated measures)

Condition 3: Supervised Categorization + Similarity Ratings

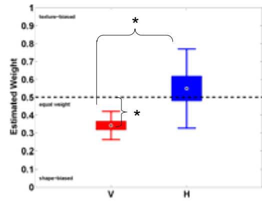
- Subjects performed similarity ratings **after a supervised categorization task**
- Similarities gathered for 50 object pairs; 4 repeated measures
- Supervised categorization task:
  - 2AFC (category A or B) with feedback
  - A = 10 objects with roughest textures; B = 10 objects with smoothest textures
  - 20 objects shown 16 times each

Naïve Similarity Judgments



Perceptual Map
Derived from Naïve Similarity Ratings

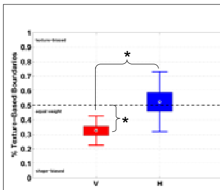
"Base" perceptual map for the object set measured in [1]: individual subject maps can be modeled as linearly scaled versions of it. In this study, a subset of interstimulus distances was measured.



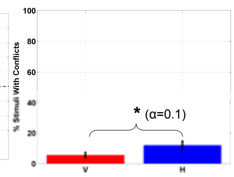
Relative Shape/Texture Weight for Naïve Similarity Ratings

Shape/texture weights estimated by finding the scaling factor, which when applied to the base map, yields the best fit to the subjects' similarity ratings.

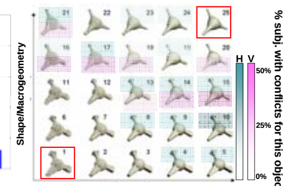
Naïve Similarity vs. Unsupervised Categorization



Relative Shape/Texture Weight for Unsupervised Categorization



Similarity/Categorization Conflicts
Stimuli Judged as Belonging to Category Defined by Less Similar Prototype

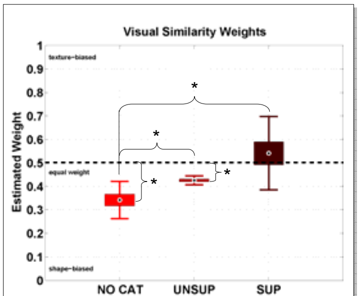


Similarity/Categorization Conflicts
Distribution of Conflicts By Object and Modality

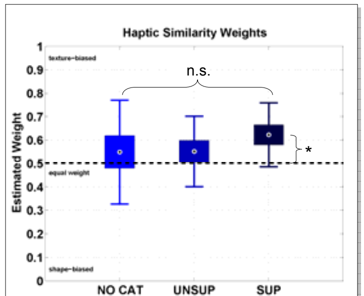
Evidence for connection between naïve similarity and unsupervised categorization:

1. **Same relative shape/texture weight** for touch and vision (defined as relative use of properties to separate stimulus space into "1s" & "25s")
2. **Few conflicts:** On average, 90% of objects deemed relatively more similar to 1 were classified as "1s", and vice-versa

Effects of Categorization Experience on Similarity



When viewing the objects, both types of category learning led subjects to place greater relative importance on texture.



When touching the objects, unsupervised learning had no effect, while supervised learning shifted weight only slightly more towards texture → **Is touch more invariant to category learning than vision?**

Conclusions

- **In unsupervised categorization,** subjects used same modality-dependent weights as they did for naïve similarity judgments → similar underlying mechanisms (2 comparative tasks)
- **Both unsupervised and supervised category learning** can change how properties are used to judge **visual** similarity, while **haptic** similarity weights seem more **insensitive to learning**
  → Effect may be hidden by initial 50/50 weighting and/or higher variability in haptic weights

References

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4. Klatzky, R., *et al.* (1993). Haptic exploration in the presence of vision. *JEP: HPP*, *19*(4), 726-743.

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