# Comprehensive Perceptual Analysis and Rating of Material Properties from Video Data

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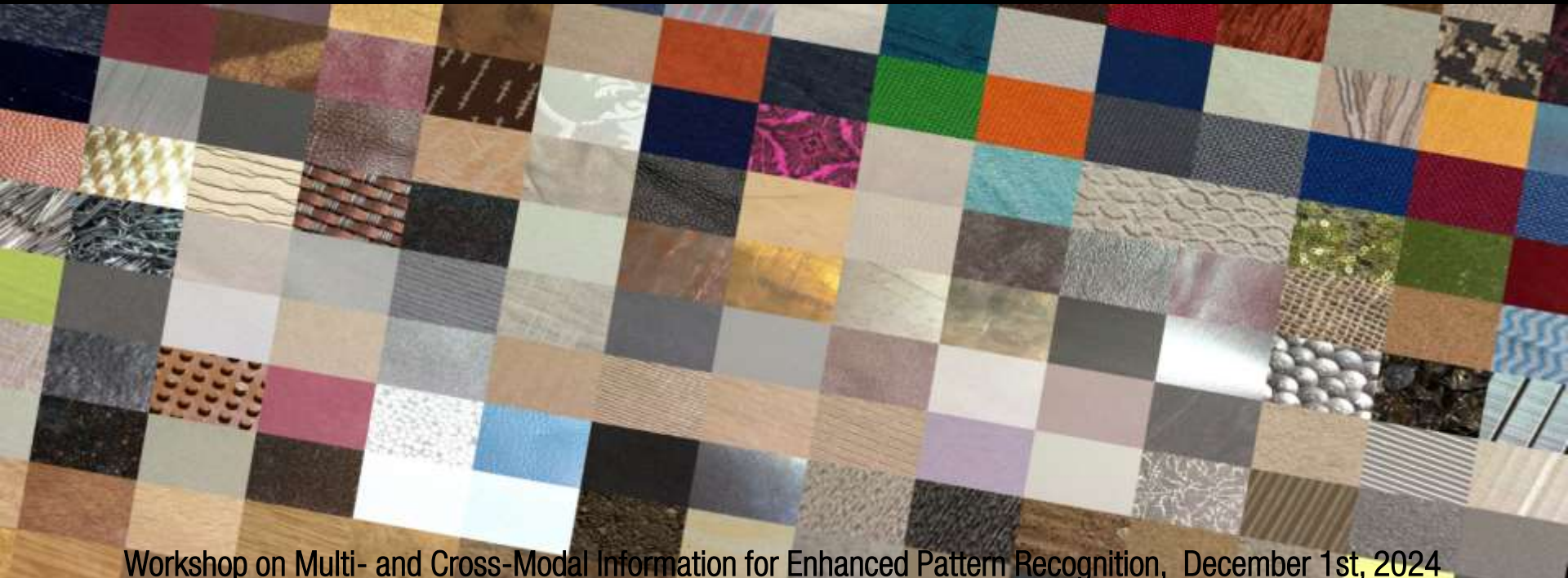


Workshop on Multi- and Cross-Modal Information for Enhanced Pattern Recognition, December 1st, 2024


• How do we distinguish materials?
• What visual features are defining individual categories?
• What are the most important visual properties of materials?

# Prior work

**[Tamura78]** a computational form of six basic texture properties and evaluated their performance on [Brodatz66] textures – **coarseness, contrast, directionality, line-likeness, regularity, roughness**

**[RaoLohse96]** perceptual texture space also by grouping [Brodatz66] textures. The grouping data were analyzed using hierarchical cluster analysis, MDS, PCA… three-dimensional space – **repetitiveness, contrast/directionality, and coarseness/complexity**

**[HeapsHandel99]** grouping experiment obtained as main attributes: **complexity, connectedness, depth, hardness, linearity, naturalness, orientation, repetitiveness, roughness, shape, shape, size, structure**

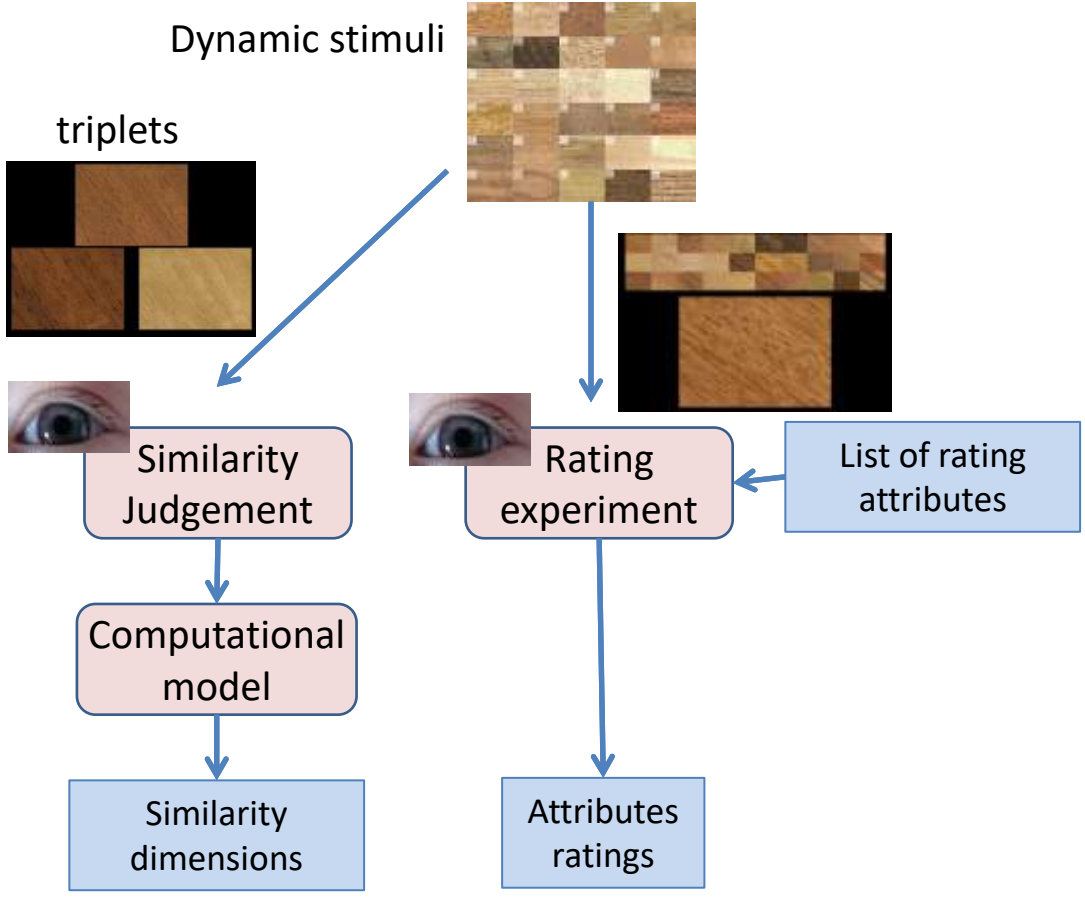
**[Mojsilovic00]** ran experiments to obtain a pattern vocabulary governed by grammar rules accounting for: **overall color, directionality and orientation, regularity and placement, color purity, complexity and heaviness**.

**[Fleming13], [Tanaka15]** studied perceptual qualities of thirteen exemplars of 10 material classes: **glossiness, transparency, colorfulness, roughness, hardness, coldness, fragility, naturalness, prettiness**

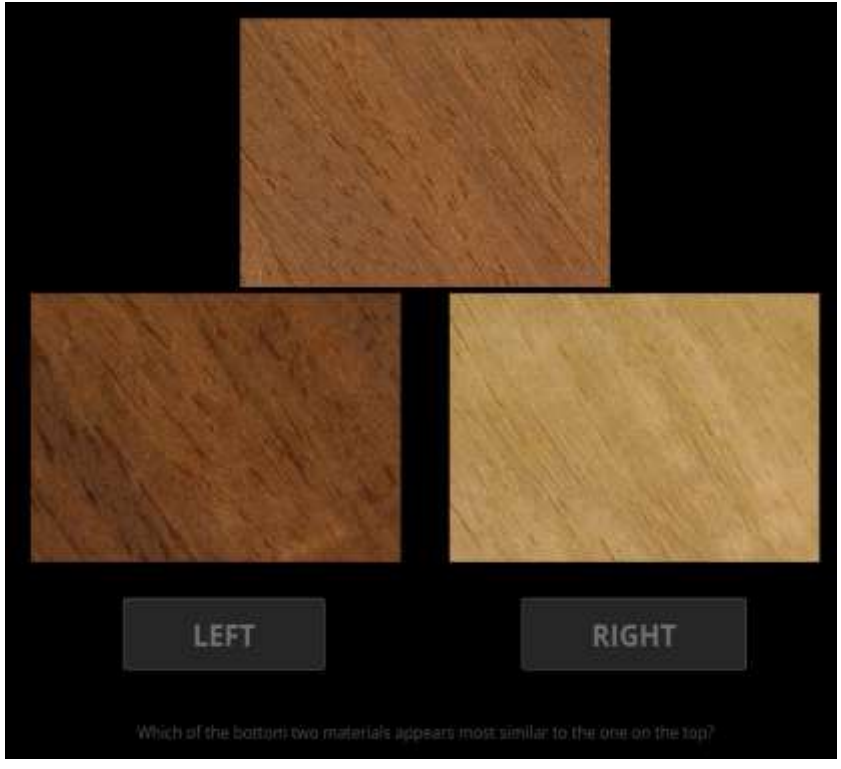
# Motivation

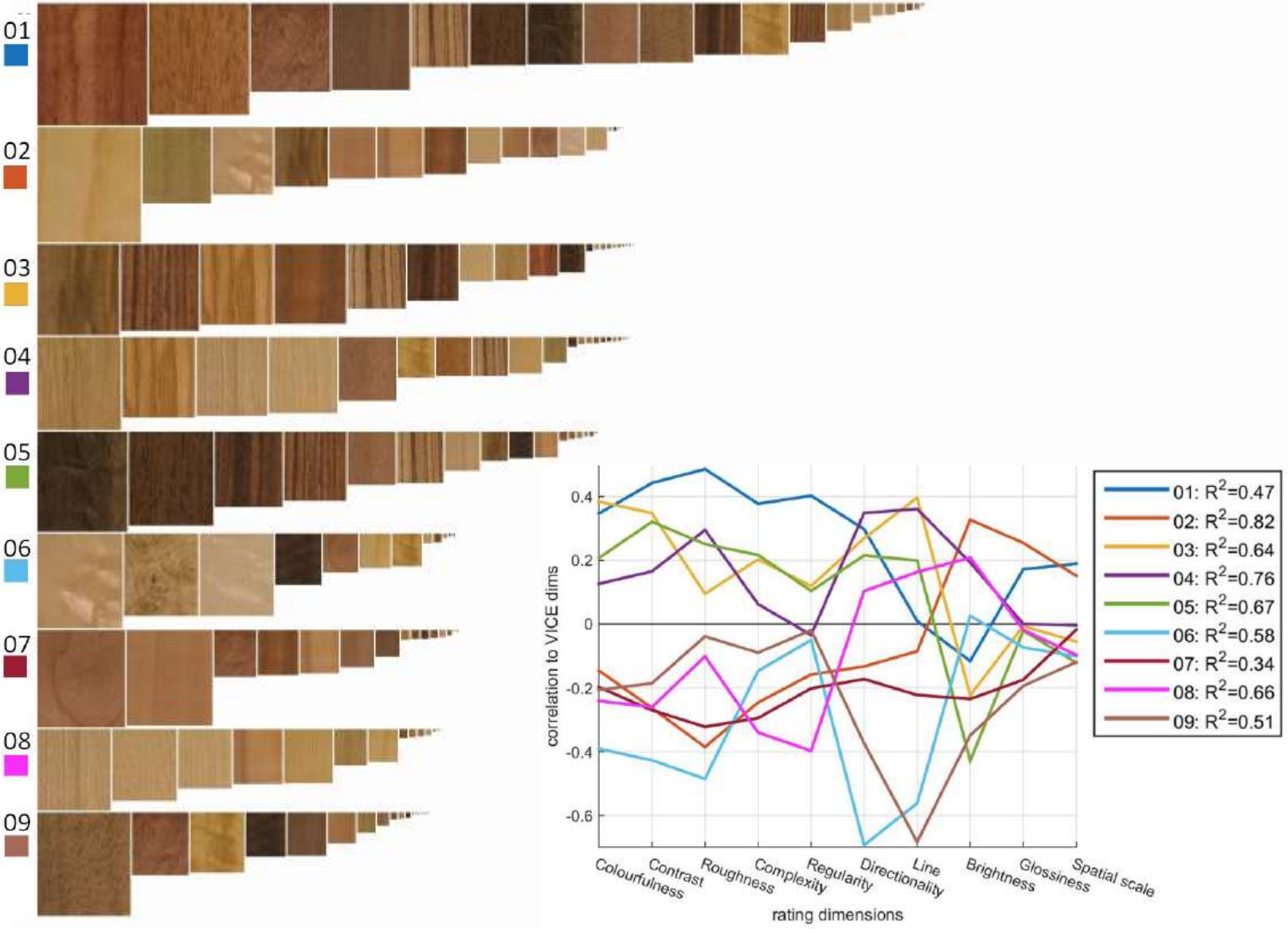
- First step ⇨ analysis of material category having less variability ⇨ wood
- 30 samples

# Research overview



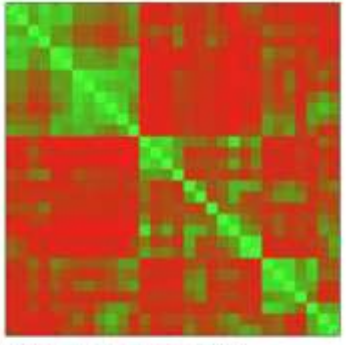
# Similarity judgements





01
02
03
04
05
06
07
08
09
0.4
0.2
0
-0.2
-0.4
-0.6
correlation to ViCE dims
Colourfulness
Contrast
Roughness
Complexity
Regularity
Directionality
Line
Brightness
Glossiness
Spatial scale
rating dimensions
01: R2=0.47
02: R2=0.82
03: R2=0.64
04: R2=0.76
05: R2=0.67
06: R2=0.58
07: R2=0.34
08: R2=0.66
09: R2=0.51

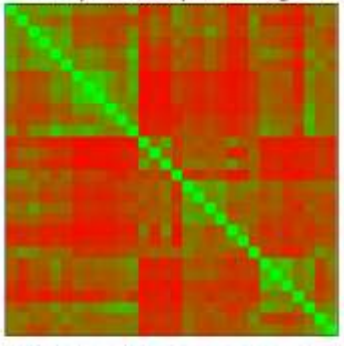
# Similarity dimensions vs. rating attributes

Similarity judgements



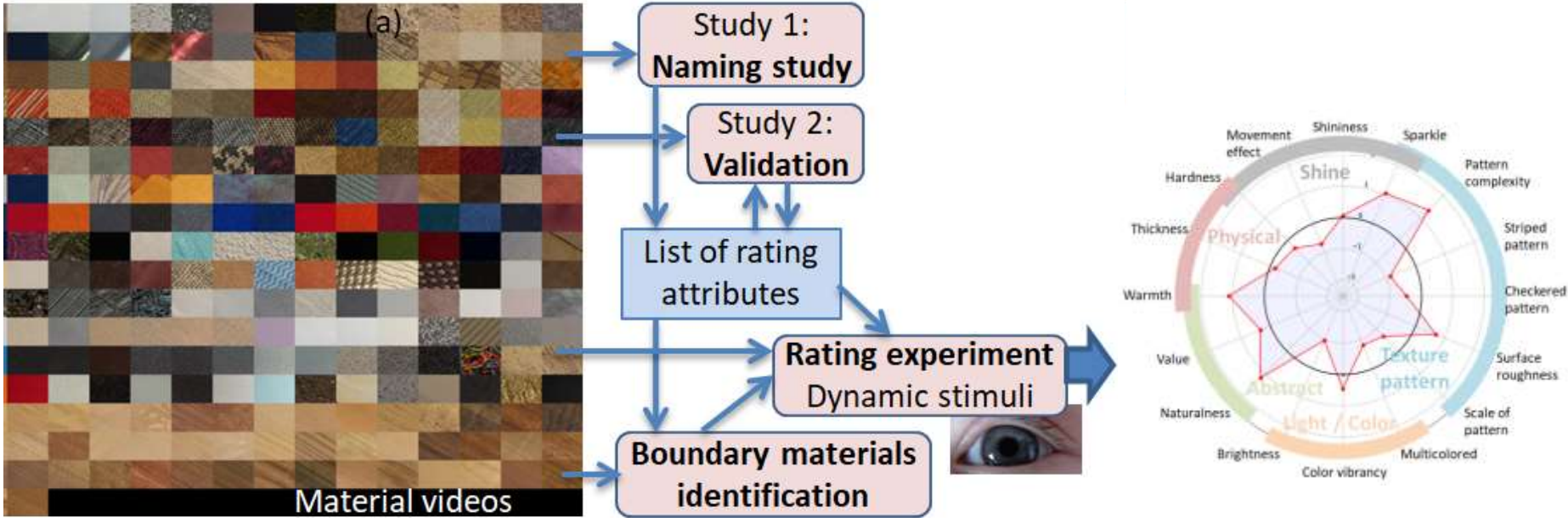
Attributes rating

similarity matrix by linear regression



# Perceptual dimensions of general materials

- 347 materials including: fabric, leather, wood, plastic, metal, paper



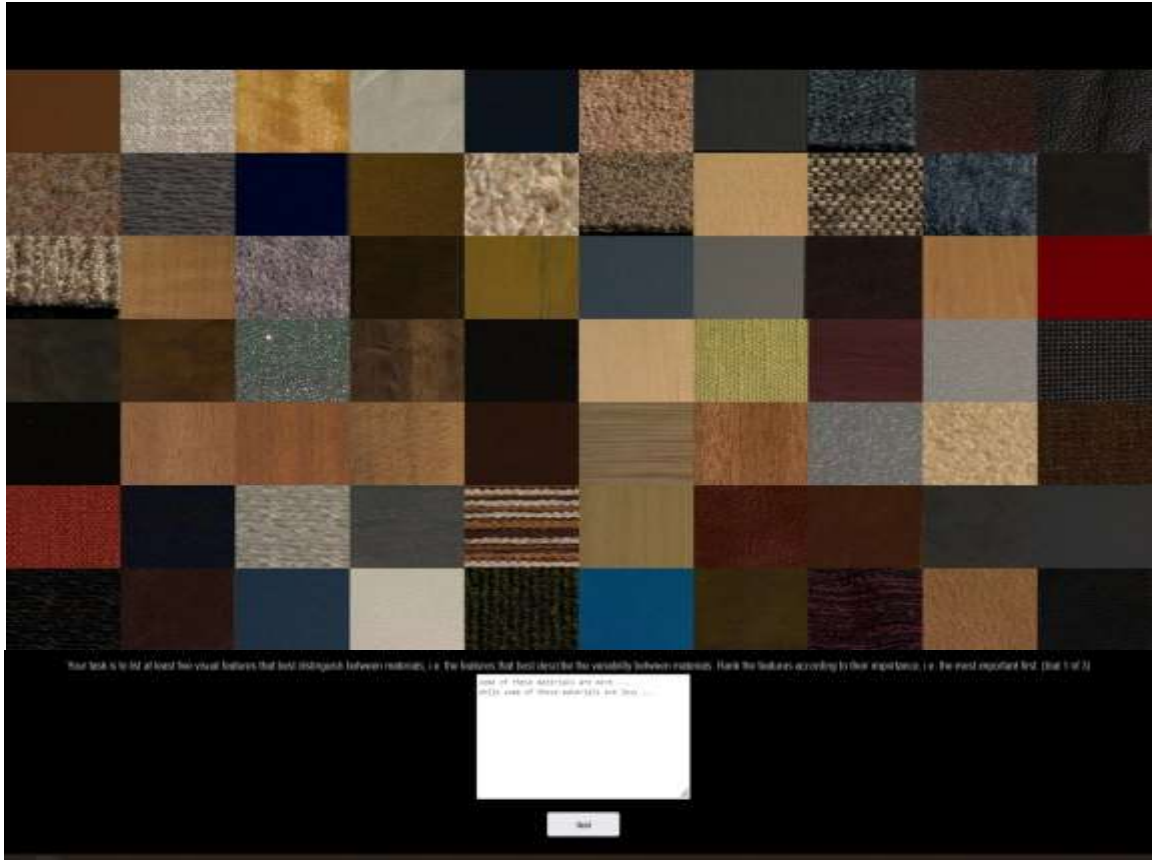
# Study 1 – Attributes identification

Task: *Identify and rank at least five most visually distinguishing features that set apart the materials within each video – the features that make materials different*

- 7 categories – fabric, carpet, wood, leather, metal, plastic, coating
- 32 observers
- 451 responses
- mean stimuli duration 2.8 minutes

Example answer:

*Some of these materials **shimmer** or **glitter** in the **light***
*Some of these materials **barely catch the light** at all.*
*Some of these materials only look **textured** in specific **lighting**.*
*Some of these materials are more **fibrous** than the others.*
*Some of these materials look **harder** than the others.*
*Some of these materials look **cheaper** than the others.*

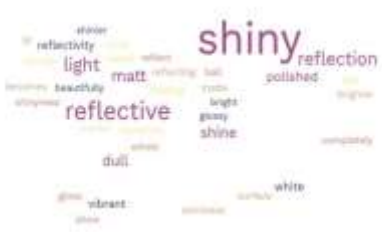


# Study 1 – Attributes identification

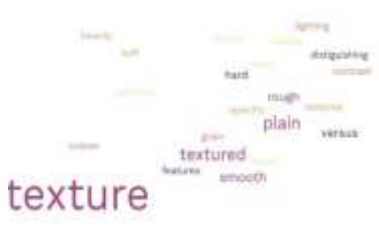
## 1. Color saturation


## 2. Roughness


## 3. Shininess




## 4. Texture




## 5. Brightness


## 6. Pattern


## 7. Soft/Hard


## 8. Category


## 9. Movement effect

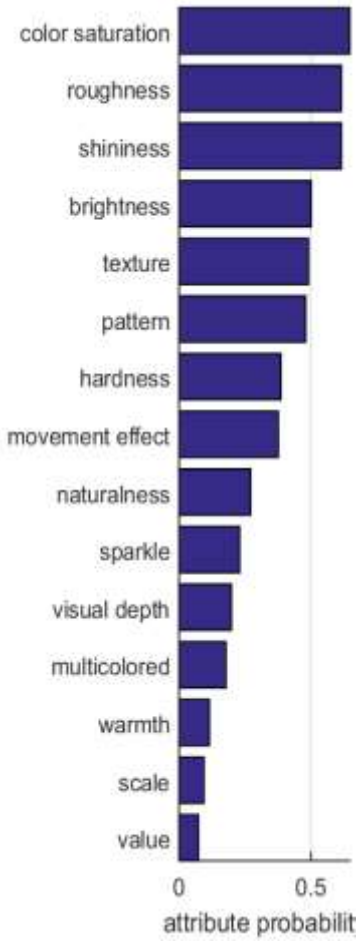

## 10. Sparkle

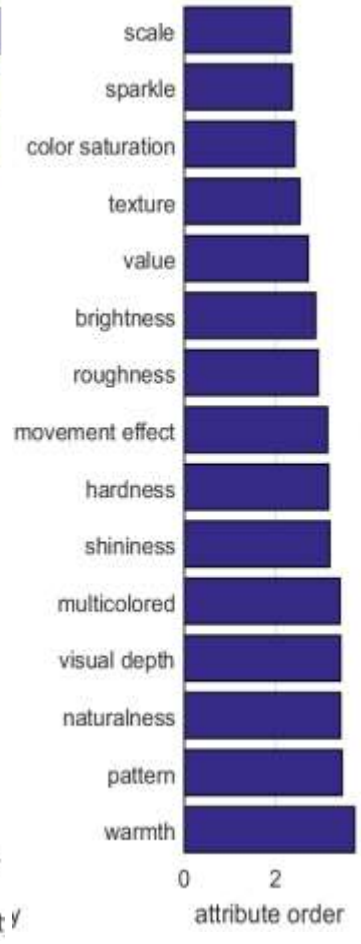

## 11. Naturalness

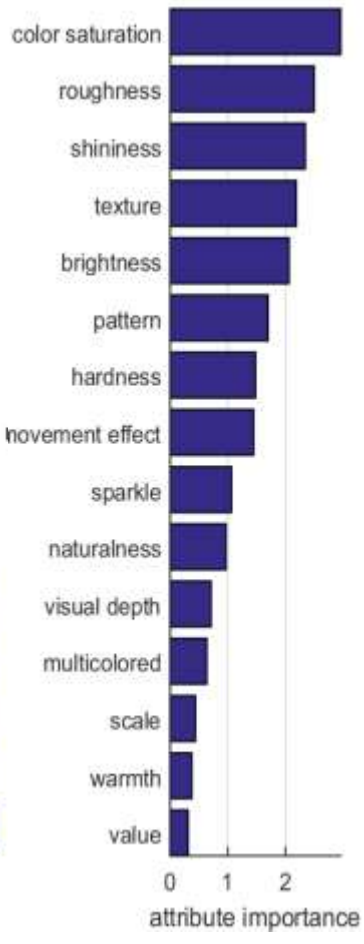

## 12. Thickness

# Study 1 – Attributes identification

- 451 valid text responses from 32 participants
- manual semantic clustering - keywords occurrence
- 15 most frequently mentioned attributes



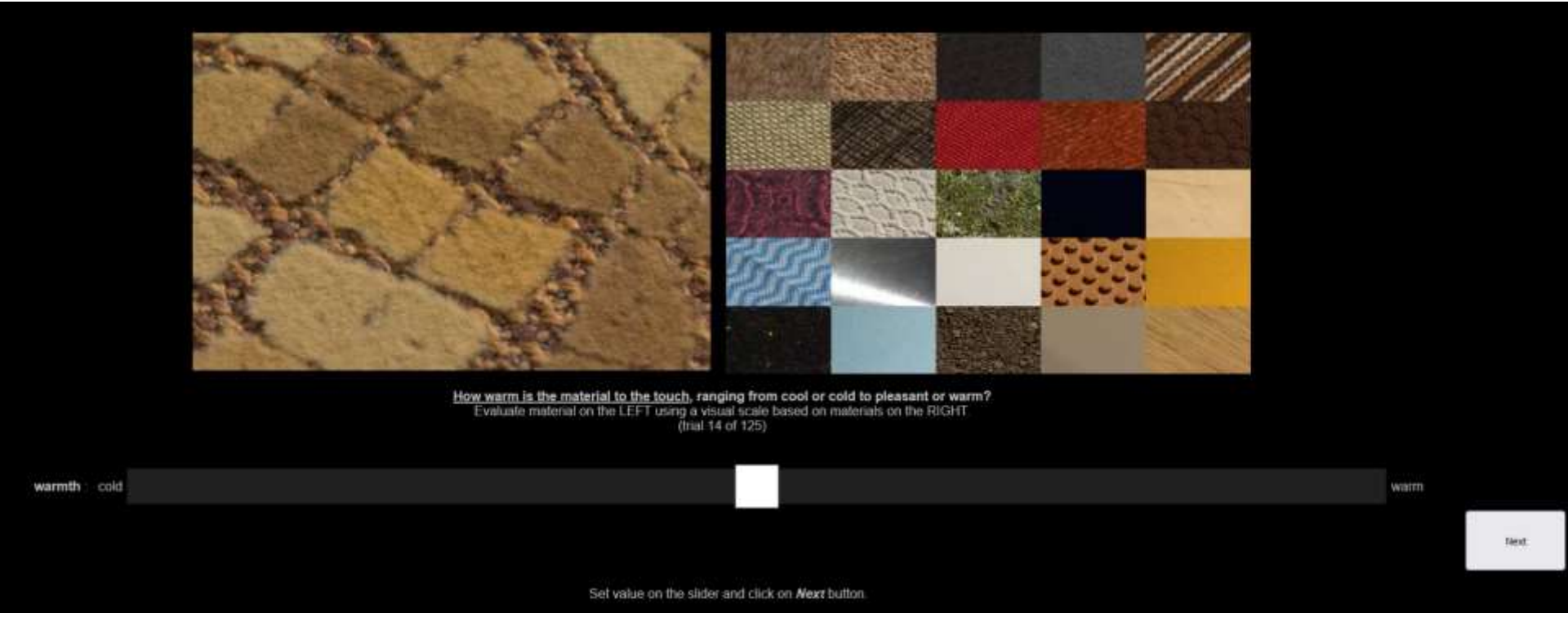



| | Suggested attributes | Extreme values | Description |
|---|---|---|---|
| 1 | **color vibrancy** | dull, vibrant | *Monochromatic or neutral-colored material, vibrantly colored material* |
| 2. | **surface roughness** | smooth, rough | *Fine and smooth texture, Coarse and grainy texture* |
| 3. | **pattern complexity** | plain, complex | *Evaluate complexity of the surface pattern from simple to intricate.* |
| 4. | **striped pattern** | no stripes, pronounced stripes | *To what extent does the material exhibit stripy patterns?* |
| 5. | **checkered pattern** | no checks, pronounced checks | *To what extent does the material exhibit checkered patterns?* |
| 6. | **brightness** | black, white | *Dim or subdued material, Bright and luminous material* |
| 7. | **shininess** | matt, mirror | *Dull and non-reflective material, Highly reflective, shiny material* |
| 8. | **sparkle** | none, sparkling | *Non-sparkling material, Sparkling and glittery material* |
| 9. | **hardness** | soft, hard | *Firm or rigid material, Soft and plush material* |
| 10. | **movement effect** | none, extreme | *Appearance change due to observer movement* |
| 11. | **scale** | fine, large | *Smooth and fine-grained surface, prominent large patterns* |
| 12. | **naturalness** | natural, manmade | *Natural origin of material* |
| 13. | **visual depth** | flat, thick | *Visually flat or shallow material, Material with pronounced visual depth* |
| 14. | **multicolored** | single, many | *Number of dominant color tones* |
| 15. | **value** | cheap, luxurious | *Simple and modest material, Luxurious and extravagant material* |
| 16. | **warmth** | cold, warm | *Cool-toned material, Warm-toned material* |

# Study 3 – Boundary material identification

# Study 4 – Rating study

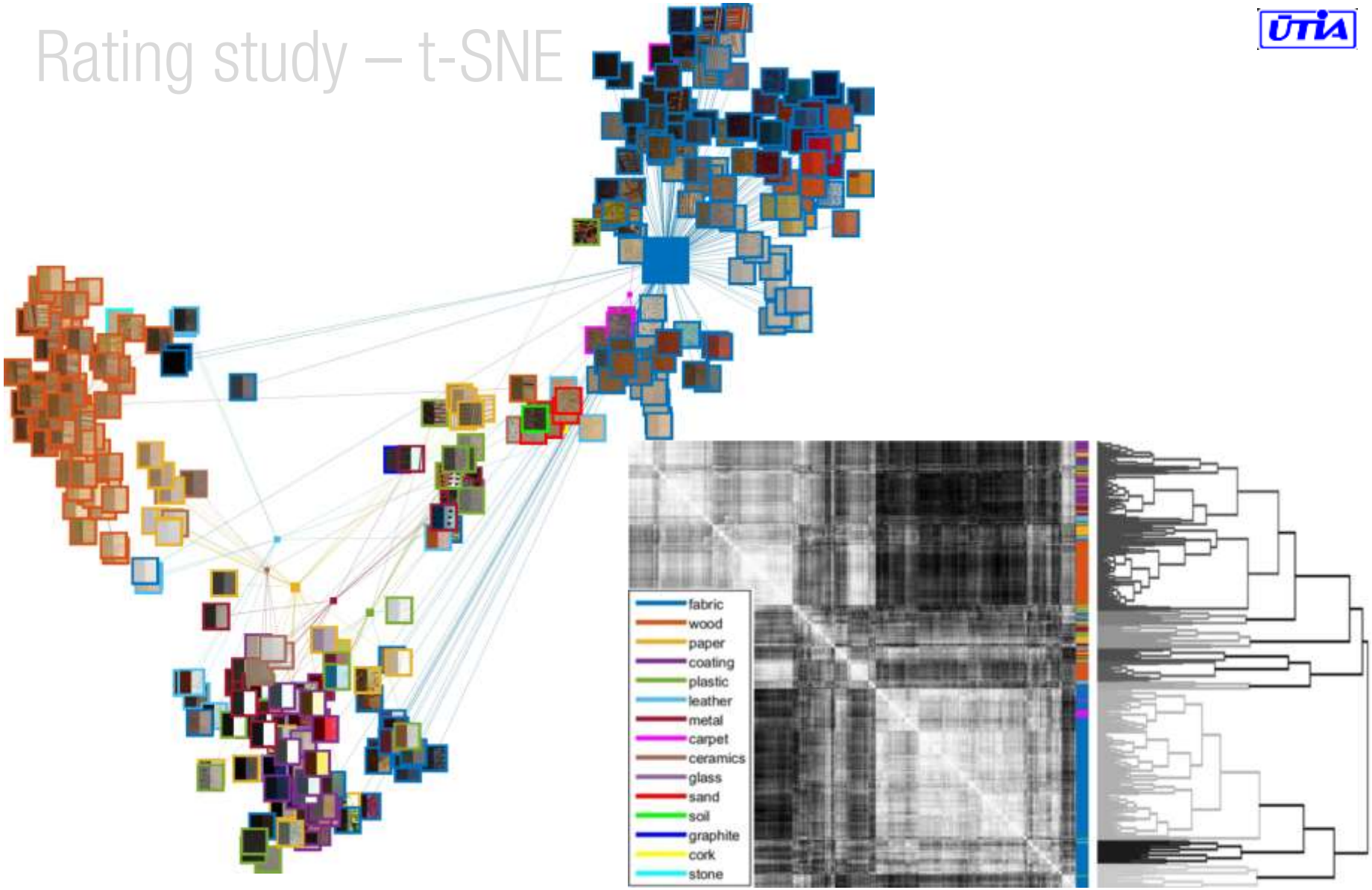



- 16 attributes – 16 independent experiments
- 20 participants rated all materials
- Prolific online platform – a total of 111 040 ratings

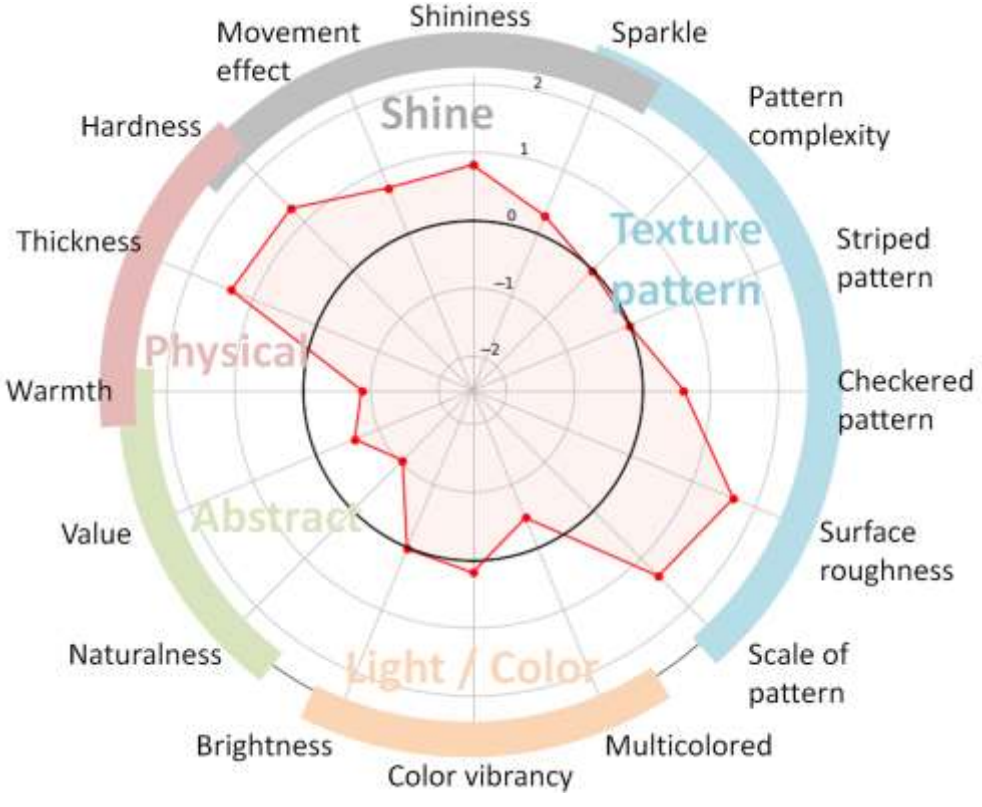
# Rating study

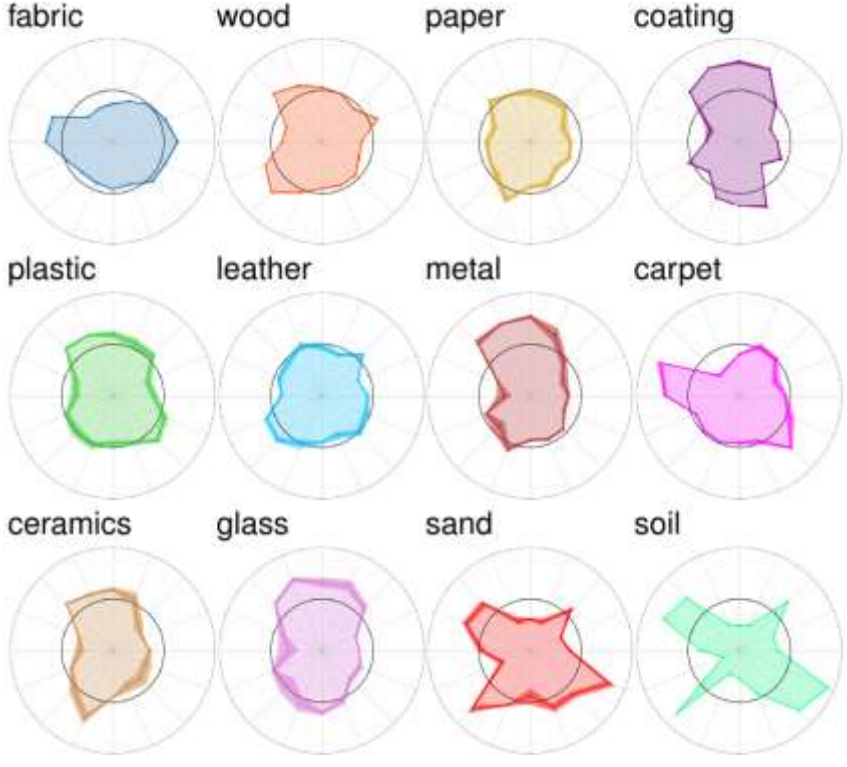
Materials rank ordering along each attribute

# Rating study – t-SNE



# Material fingerprint



# Similar material retrieval

# Similar material retrieval

# Conclusions

- Psychophysical studies involving 347 material samples across various categories ⇨ identified a set of 16 material attributes
- Obtained >100,000 observer ratings ⇨ defining a visual fingerprint for each sample
- Step towards simplifying the sharing and understanding of material properties in diverse digital environments ⇨ material identification and retrieval
- Current work is linking these dimensions to image data to allow automatic assessment of material appearance

Filip J., Dechterenko F., Schmidt F.,Lukavsky J., Vilimovska V., Kotera J., Fleming, R. W.: **Material Fingerprinting: Identifying and Predicting Perceptual Attributes of Material Appearance** , arXiv 2410.13615, October 2024

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