RAPID SENSING OF MATERIAL AFFORDANCES

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New York

Affordance Workshop, Berkeley 2014
# Affordances

<table>
<thead>
<tr>
<th>Properties</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>soft – rough</td>
<td>If you felt this material on your skin would it feel soft or rough?</td>
</tr>
<tr>
<td>flexible – stiff</td>
<td>If you folded or draped this material would it be stiff or flexible?</td>
</tr>
<tr>
<td>absorbent – repellent</td>
<td>Would you use this material to repel water or would you use it to absorb water?</td>
</tr>
<tr>
<td>warm – cool</td>
<td>Would clothes made of this material keep you warm or cool?</td>
</tr>
</tbody>
</table>

![Diagram of property comparison](image)
Consensus

Material property classification

- **Soft**
  - Images of soft materials
- **Rough**
  - Images of rough materials
- **Flexible**
  - Images of flexible materials
- **Stiff**
  - Images of stiff materials
- **W.-absorbent**
  - Images of water-absorbent materials
- **W.-repellent**
  - Images of water-repellent materials
- **Warm**
  - Images of warm materials
- **Cool**
  - Images of cool materials

Rapid Sensing of Material Affordances

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Associations

**Material property classification**

<table>
<thead>
<tr>
<th>Associations</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Soft &amp; Flexible</strong></td>
<td><img src="image1" alt="Soft &amp; Flexible images" /></td>
</tr>
<tr>
<td><strong>Rough &amp; Stiff</strong></td>
<td><img src="image2" alt="Rough &amp; Stiff images" /></td>
</tr>
<tr>
<td><strong>Water-absorbent &amp; Warm</strong></td>
<td><img src="image3" alt="Water-absorbent &amp; Warm images" /></td>
</tr>
<tr>
<td><strong>Water-repellent &amp; Rough</strong></td>
<td><img src="image4" alt="Water-repellent &amp; Rough images" /></td>
</tr>
<tr>
<td><strong>Flexible &amp; Cool</strong></td>
<td><img src="image5" alt="Flexible &amp; Cool images" /></td>
</tr>
</tbody>
</table>

**Rapid Sensing of Material Affordances**

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Frequency band analysis

Soft vs. rough

6.5 – 15.2 cpd

Spatial frequency (cpd)
Relative energy

Rough
Soft

0 2 4 6 8 10 12 14 16 18
0.01 0.02 0.03 0.04 0.05

Spatial frequency (cpd)
Frequency band analysis

Undulated vs. flat

0.5 – 2.3 cpd

Spatial frequency (cpd)
Relative energy

FLAT
UNDULATED
Thin vs. Thick

2.3 – 4.3 cpd

![Image of thin and thick material samples]

![Graph showing frequency band analysis with relative energy on the y-axis and spatial frequency (cpd) on the x-axis, comparing thin and thick materials.]

Rapid Sensing of Material Affordances
Frequency band manipulations

- Spatial frequency bands
  - 0.5 – 2.3 cpd: Undulation (flexibility) band
  - 2.3 – 4.3 cpd: Thickness band
  - 6.5 – 15.2 cpd: Roughness band

- Multiplicative scaling of frequency band

\[
\text{Multiplicative scaling} = \text{FFT}^{-1} \left( |\text{FFT} (\text{signal})| \times \text{constant} \right)
\]

- Constant total energy
Undulation (flexibility) band
0.5 – 2.3 cpd
Thick or thin
Roughness band
6.5 – 15.2 cpd
Transfer of structures

Examples

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Rapid Sensing of Material Affordances
Frequency band manipulations

Transfer of structures

& $\Phi_2$

Rapid Sensing of Material Affordances
Transfer of structures

\((\mathcal{M} + \mathcal{Q}) \& \Phi_2\)
### Stimuli

<table>
<thead>
<tr>
<th>Volume</th>
<th>Increased++</th>
<th>Increased+</th>
<th>ORIGINAL</th>
<th>Decreased-</th>
<th>Decreased--</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>Thickness</td>
<td><img src="image6.png" alt="Image" /></td>
<td><img src="image7.png" alt="Image" /></td>
<td><img src="image8.png" alt="Image" /></td>
<td><img src="image9.png" alt="Image" /></td>
<td><img src="image10.png" alt="Image" /></td>
</tr>
<tr>
<td>Roughness</td>
<td><img src="image11.png" alt="Image" /></td>
<td><img src="image12.png" alt="Image" /></td>
<td><img src="image13.png" alt="Image" /></td>
<td><img src="image14.png" alt="Image" /></td>
<td><img src="image15.png" alt="Image" /></td>
</tr>
</tbody>
</table>
After adaptation, decide which of the two images is thicker. Press key.

Which of the two images was thicker?

0.8s
60s/10s
0.25s
2s
Results

- **Image 1**
  - More volume
  - Thicker
  - Rougher

- **Image 2**
  - More volume
  - Thicker
  - Rougher

N=5
Results

Image 1

Image 2

% more volume

% thicker

% rougher

N=5

0
25
50
75
100

0
25
50
75
100

0
25
50
75
100

0
25
50
75
100

** ** *

Volume Thickness Roughness

*
Retinal versus material spatial frequency

Comparison monitor

Test monitor

Test monitor

Test monitor

132 cm

66 cm

33 cm

- EQUAL
- FAR
- NEAR

Control experiments  Distance experiment
Control experiments  Distance experiment

Retinal versus material spatial frequency

- **Test monitor**
  - 132cm

- Comparison monitor
  - 66cm

- Test monitor
  - 33cm

- **EQUAL**
- **FAR**
- **NEAR**

---

**Image 1**

- % more volume
- N=3

---

**Image 2**

- % thicker

---

**% rougher**

---

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Rapid Sensing of Material Affordances
Retinal versus material spatial frequency

- **Comparison monitor**
- **Test monitor**

<table>
<thead>
<tr>
<th>Volume</th>
<th>Thickness</th>
<th>Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>60</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>90</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

% more

- **EQUAL**
- **FAR**
- **NEAR**

Rapid Sensing of Material Affordances

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Material property ranking
Undulation (Flexibility)

Control experiments
Material property ranking

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Thickess

Control experiments

Material property ranking

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Roughness

Control experiments

Material property ranking

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Validation of frequency bands from ranking data

Spatial frequency bands (cpd)

Correlation

Undulation
Thickness
Roughness

0 5 10 15 20
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

Rapid Sensing of Material Affordances
Material rankings and affordances

- Rough
- Flexible
- Warm
- Repellent

Correlation

Material properties
- Undulation
- Thickness
- Roughness

Rapid Sensing of Material Affordances
Limitations

- Homogeneous, texture-like materials
- Fronto-parallel presentation
- Narrow range of distances
- Limitations imposed by the contrast sensitivity for spatial frequencies and cross-band masking effects
- Role of structure
Structure

SOFT

ROUGH
Spatial frequency information plays a role in the perception of material properties and material affordances.

The results demonstrate the importance of spatial structure and scale as opposed to global image statistics.

Structure at specific spatial scales might be directly related to certain material properties.

The method of frequency manipulation could be useful for fast and efficient material editing.
Thank you

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Consensus

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Associated affordances

Images rated as...

- soft
- rough
- flexible
- stiff
- w.-absorb.
- w.-repell.
- warm
- cool

... were also rated as...

- soft
- rough
- flexible
- stiff
- w.-absorb.
- w.-repell.
- warm
- cool

Percent
Manipulation of noise and synthetic texture

A

B
Joint frequency manipulations

A

B

C

D

Spectral weighting functions

Additional material
## Paper sorting data

<table>
<thead>
<tr>
<th></th>
<th>Undulation</th>
<th>Thickness</th>
<th>Roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulation</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thickness</td>
<td>0.28</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Roughness</td>
<td>-0.35</td>
<td>0.21</td>
<td>1.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>$W_t$</th>
<th>$\chi^2$</th>
<th>$df$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undulation</td>
<td>0.619</td>
<td>297</td>
<td>160</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.651</td>
<td>312</td>
<td>160</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Roughness</td>
<td>0.692</td>
<td>332</td>
<td>160</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Undulated $\sim$ Thick</th>
<th>Undulated $\sim$ Rough</th>
<th>Thick $\sim$ Rough</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. 1</td>
<td>0.162</td>
<td>-0.185</td>
<td>0.202</td>
</tr>
<tr>
<td>Obs. 2</td>
<td>0.248</td>
<td>-0.096</td>
<td>0.257</td>
</tr>
<tr>
<td>Obs. 3</td>
<td>0.132</td>
<td>-0.293</td>
<td>0.160</td>
</tr>
</tbody>
</table>
Implementations in the spatial domain


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Rapid Sensing of Material Affordances
Implementation in the spatial domain

Additional material

Spatial implementation

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