The effect of viewpoint on perceived surface roughness in binocularly viewed scenes

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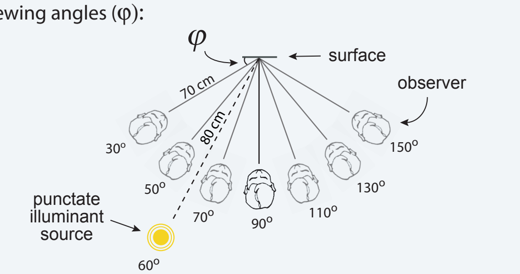
How does viewing angle affect visual judgments of surface roughness?

Viewing angles

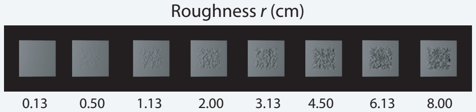
We fixed the illuminant direction to the surface and tested 7 viewing angles (φ):



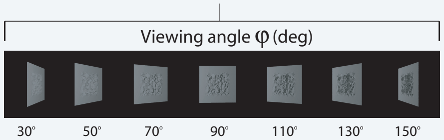
Stimuli

Side profile of surface with roughness *r* (max range of facet heights) rendered in Radiance[1] and displayed binocularly:

Roughness *r* (cm)

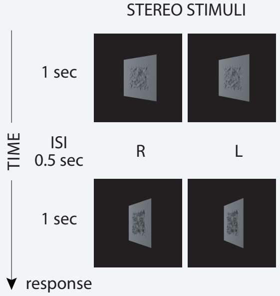


Viewing angle φ (deg)



Methods

STEREO STIMULI



2-IFC Task "Which one is rougher?"

SPECIFICATIONS

Test surface roughness $r \in [0.50, 6.13]$

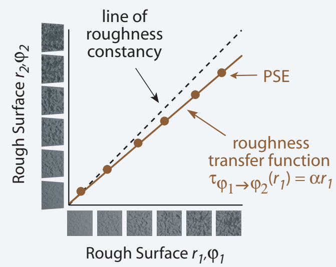
Points of subjective equality (PSEs) obtained via interleaved staircases

Two staircases (1-up,2-down & 2-up, 1-down) per test

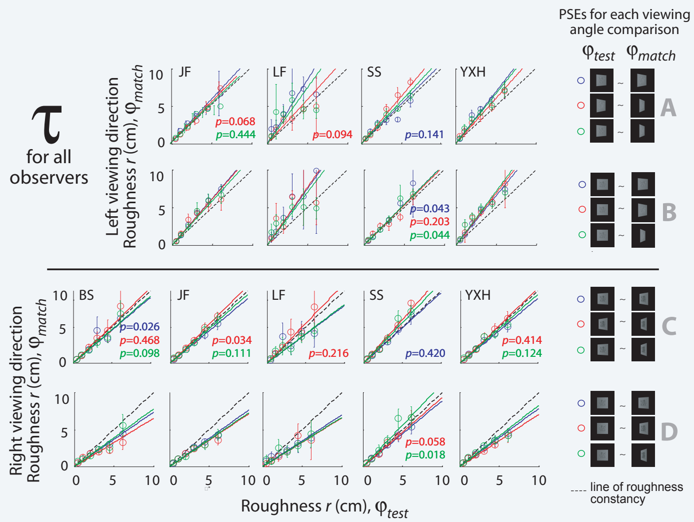
Match roughness varied

Roughness Transfer Function

The roughness transfer function $r_2 = \tau_{\varphi_1 \rightarrow \varphi_2}(r_1)$ gives the degree of roughness r_2 of a surface viewed from angle φ_2 that appears equal in roughness to surface r_1 viewed from φ_1, i.e., a PSE.



Results



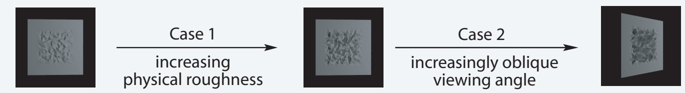
NOTE: *p*-values indicate values of α (slope) *not* significantly from 1 (line of roughness constancy) at the Bonferroni-adjusted level for number of observers.

Are observers roughness constant across viewing angles?

TEST SURFACE ORIENTATION

VIEWING DIRECTION	oblique	frontoparallel
Left	A: NO — 4 out of 12 times α ≅1	B: NO — 3 out of 12 times α ≅1
Right	C: YES — 10 out of 15 times α ≅1	D: NO — 2 out of 15 times α ≅1

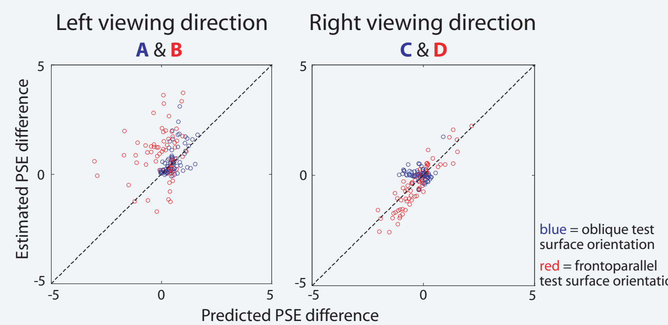
Cue Combination Model



Notice how the proportion of shadows increases in both Case 1 and 2. This is one example of a variety of cues that may confound changes in surface roughness with changes in scene properties, e.g., viewing angle. We call these cues *pseudo-cues*[2]. We use the difference between pseudo-cues calculated from two rough surfaces in a linear regression equation to predict failures of roughness constancy:

$$\Delta R_d = a_s \Delta r_s + a_m \Delta r_m + a_p \Delta r_p + a_c \Delta r_c$$

- ΔR_d: predicted failure of roughness constancy
- Δr_s: *shading* or standard deviation of non-shadowed pixels
- Δr_m: *mean* luminance of non-shadowed pixels
- Δr_p: *proportion* of shadows
- Δr_c: texture *contrast*[3]



Pseudo-cues correlate best with failures of roughness constancy for comparisons between frontoparallel and right oblique viewing angles.

Summary

Observers are not always roughness constant across viewing angle; rough surfaces tend to appear rougher when mean luminance is lower and variation in shading, proportion of shadows, and texture contrast are higher.

References

1 Ward, G.J. The RADIANCE lighting simulation and rendering system. *Computer Graphics, 28*(2), 459-472.
2 Ho, Y.-X., Landy, M.S., & Maloney, L.T. (2006). How direction of illumination affects visually perceived surface roughness. *Journal of Vision*, in press.
3 Pont, S.C., & Koenderink, J.J. (2005). Bidirectional texture contrast function. *International Journal of Computer Vision, 66*(1/2), 17-34.

Acknowledgements

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Image (top left): Cryptobiotic crust up close (Grand Escalante, Utah). Photographed by Yun-Xian Ho, 2005.