Lightness Constancy in Surface Visualization

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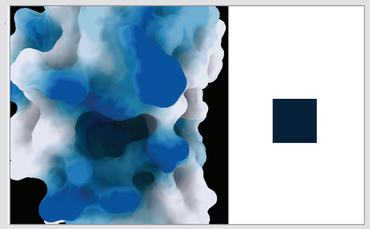
Lightness constancy allows people to accurately perceive colors in real shadows, yet its effectiveness in surface visualizations is not well understood. Through a series of initial studies, we confirm the existence of lightness constancy effects in surface visualization and evaluate how common design decisions impact viewers' abilities to accurately identify colors on molecular surfaces rendered with ambient occlusion.

Motivation

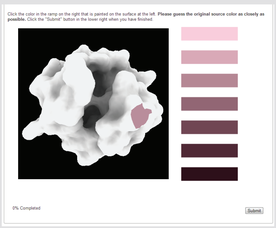


Colors in the pocket appear lighter than when on a plane

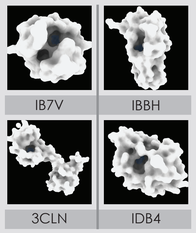
Color is commonly used to display data in surface visualization. However, shadows and shading manipulate encoded color to show depth. Ambient occlusion models lighting from all angles to simulate shadow. Approximations made by this model may hinder factors leveraged by the visual system to disentangle color and shadow.

Experimental Design

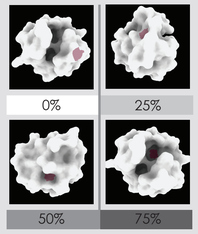
We evaluated lightness constancy by measuring how well participants matched surface colors to a color ramp over a series of mixed-design Mechanical Turk studies.



Experimental Set-Up



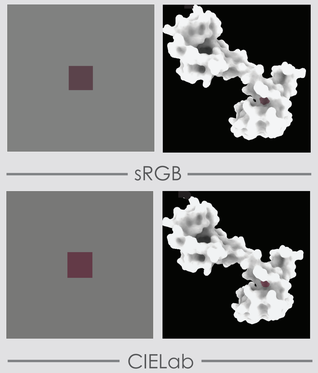
Molecular Surfaces



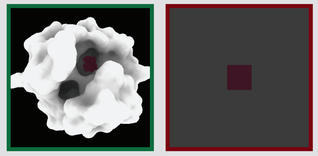
Shadow Levels

Untangling Contrast and Constancy

Do ambient occlusion surfaces support lightness constancy?



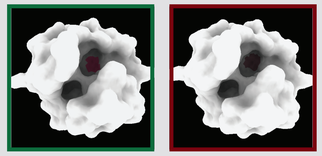
Both color contrast between a color and its surrounding shadow and lightness constancy may improve participants abilities to identify color in shadow. The color model used to compute shadow attenuation may also influence how well the visual system can account for shadow.



p = 0.002

Shadowed surface colors were more accurately identified than shadowed 2D colors, suggesting that constancy aids color legibility.

Surface color attenuated with CIELab was more accurately identified than when attenuated with sRGB. No difference was observed for 2D colors.

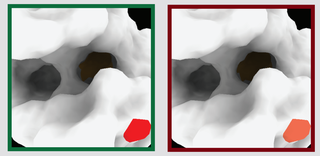


p = 0.005

Lightness Constancy and Ramp Selection

Can color ramp design support accurate perceptions of color in shadow without requiring lightness constancy?

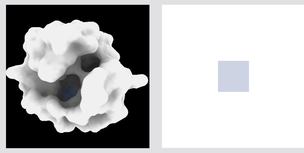
Ambient occlusion attenuates a color's luminance to model shadow. If ramps that vary strictly in hue and saturation support accurate surface color identification, than visualizations may not need to consider how to support lightness constancy.



p < 0.001

Participants better identified colors from luminance varying ramps than from isoluminant ramps.

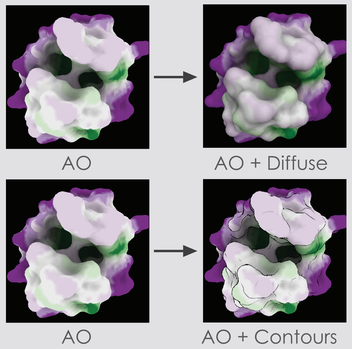
High luminance, low saturation colors proved difficult to distinguish from the shadow.



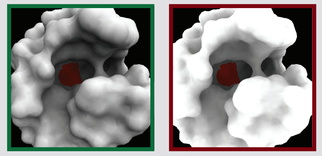
Pale blues and yellows were difficult to extract from dark shadows

Evaluating Supplemental Depth Cues

How does supplementing surface shape and structure cues influence lightness constancy mechanisms?



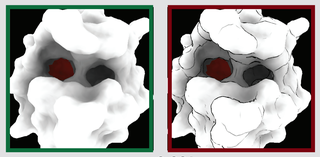
Alternative shading and lighting models can be used to supplment depth and shape perception in ambient occlusion visualizations. Diffuse lighting can enhance apparent depth and realism while stylized contours emphasize surface shape.



p = 0.05

Supplementing with diffuse lighting improved how accurately participants identified surface colors.

Supplementing with contours resulted in worse accuracy the when using ambient occlusion alone.



p < 0.001

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