Human sensitivity to light zones in virtual scenes

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Abstract

We investigated perception of light properties in scenes containing volumes with dramatically different light properties (direction, intensity, diffuseness). Each scene had two light zones, defined as distinct spatial groupings of lighting variables significant to the space- and form-giving characteristics of light [Mad07]. The results show that human observers are more sensitive to differences in illumination between two parts of a scene when the differences occur in the picture plane than in depth of the scene. We discuss implications for and possible applications of our results in computer graphics.

CCS Concepts
•***Human-centered computing*** → *Empirical studies in HCI;*

1. Introduction

Computer graphics currently allows complex lighting with multiple sources [FDF*95]. This causes intricate optical interactions between the primary sources and (currently also optically complex) materials in the scene, such as scattering, shad(ow)ing, vignetting, refractions, (inter-) reflections and so forth. Altogether this results in a spatial light distribution or luminous environment that varies as a function of direction and position (we ignore spectral and temporal variations to keep the problem tractable). Yet, there are limited studies on the sensitivity of human observers to spatial variations of illumination. The aim of our study is to understand human sensitivity for such variations, in order to be able to create perceptually intelligent lighting designs.

In our previous study [KRP*15], we found that observers' light inferences were rather consistent in paintings with uniform or diverging light, but showing striking individual differences in paintings containing spaces with different illuminations across the depth of scenes (inside and outside of a window, or with a second room visible in the back through a door opening). The most plausible explanation seemed to be that observers varied in interpretations between the borders of illumination volumes. In this study we investigate the perception of light in such volumes named light zones [Mad07] depending on their orientation with respect to an observer.

2. Visual light zones

In the first experiment of the study we tested whether observers could distinguish the differences in illumination between light zones. We created a natural-looking scene with two light zones, contrasting mainly in light direction. In one condition light zones were on the left and right of the scene (LR), in another condition in the front and back parts of the scene (FB). The light inferences were measured over a grid of points using probes (white matte spheres). The observers were asked to set the light on the probe (one per trial) as if the sphere belonged to the scene [KPD*07]. For condition LR the settings were highly consistent over observers. On the other hand, for condition FB the results showed high inter-observer variability, suggesting that the participants varied in their estimations of relative sizes of the zones.

Next, we focused on the question whether the orientation of the light zones (in the picture plane versus in depth) influences the light inferences. For the second experiment, we created three configurations of light sources and occluders in a rotationally symmetric scene. Each configuration created adjacent light zones that were viewed from two perpendicular directions (see Figure 1, top row). The symmetry of the scene allowed very systematic testing, changing the arrangement of light zones relative to a viewer, but keeping the observed geometry of the scene the same. The probing method was the same as for the first experiment, with five white spheres, positioned such that two were in one light zone, two in another, and one in the middle (see Figure 1, top row middle image).

Results showed higher deviations and variations between and within observers for back zones of FB conditions than for corresponding zones of LR conditions. It appeared that the participants often made the settings in the back light zone of the FB conditions in accordance to the illumination in the front light zone of those conditions (see Figure 1, bottom row).

3. Conclusion

Our findings show that human observers are less sensitive to light properties variation in depth of the scene than in the picture plane.

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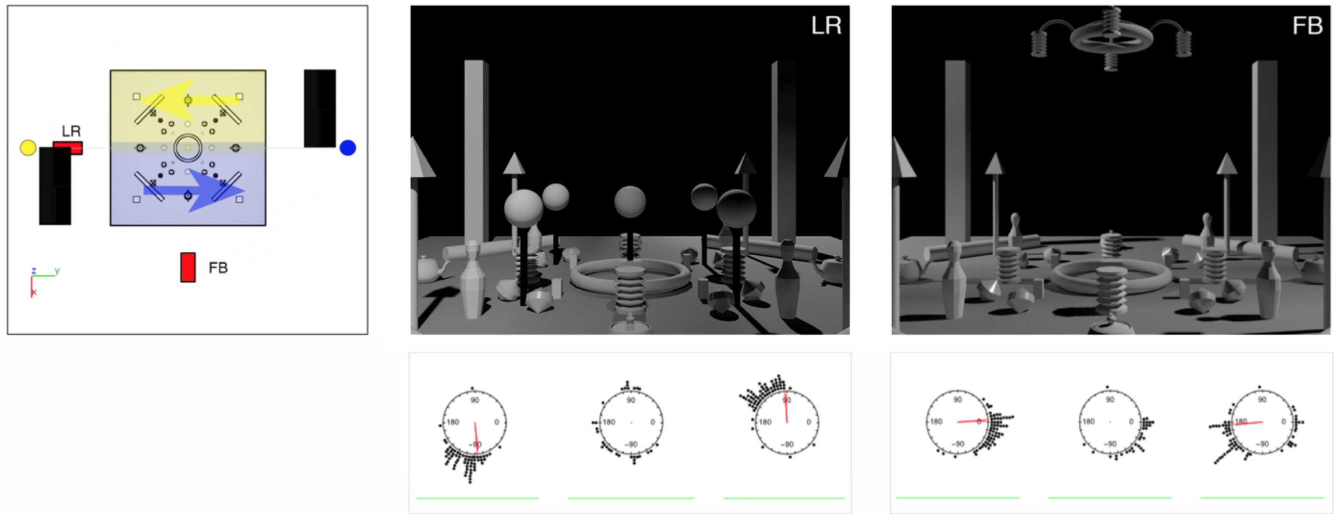

Figure 1: *One of the tested conditions. Top left is a schematic representation of the scene (top view): red rectangles are the cameras, labeled according to the resulting scene image; yellow and blue circles are the light sources; black rectangles are the shades occluding illumination from a half of the scene; the yellow and blue arrows show the approximate light orientations (as a vector, pointing towards the source) in the zones color-coded corresponding to the light sources illuminating them. Top middle and right are the resulting test images, with the middle image containing white spheres rendered at the probe positions.*
The bottom figures are circular histograms of the direction settings (top view, the green line represents the picture plane). Results are grouped in triplets such that the left histogram shows the settings made on the two probes in the left or front light zone (for LR or FB respectively), the middle histogram shows the settings on the middle sphere, and the right histogram shows the settings made in the right or back light zone (for LR or FB respectively). The red lines inside the circles show the veridical light directions (red dots instead of lines mean that the veridical light vector points straight up or straight down). The rightmost histogram shows that in the back of the FB condition many settings were opposite to the veridical direction.

This has implications for lighting design [SPN*16], namely that scenes with lighting variations will be much better "readable" if those occur in the picture plane than in depth. Earlier we have shown that human observers neglect subtle variations in the light direction [KSR*16], suggesting grouping into uniform, diverging and converging structures. Additionally, the light zones concept can be used for segmenting scenes, for example for precomputed lighting and as a lighting design tool.

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