DEALING WITH OBVIOUS ISSUES IN LIGHTING

Lighting does not have large effects via subtle mechanisms

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In an article last month, I listed six reasons why theory is important for lighting research and practice:

1. Theory is what engineers do. For instance, all electrical engineers must understand circuit theory.
2. It's hard to vary light source size. Theory can isolate the effects of source area. Experiments to vary size while controlling other parameters would be hard.
3. It's also hard to vary spectral power distribution.
4. Optics is not controversial. Much of the theory needed for the discussion of lighting quality is simple optics as applied to the interaction of light and objects.
5. Theory guides experiment. Theory helps in the design of experiments.
6. More speculative theories may also have a place. Theory lets you move forward from the simple to the complicated.

These six reasons for the use of theory all come down to this: Lighting is complicated, but theory can help you to understand it step by step. In this article, I want to look at one more rationale for the use of theory. In a final article, I'll talk about the payoffs that a more theoretical approach to lighting may give. I believe that better use of theory may lead to solid advances in the design of luminaires and systems, but that's for next time.

Obvious lighting features

Consider an early controlled study of lighting effects. Gray and Prevetta[2] addressed the question of "Fluorescent Light versus Daylight?" Their 50 subjects read books for 2 hrs under daylight of "20 foot-candles intensity" and for 2 hrs under fluorescent lights of the same illuminance. The daylight illuminance was regulated using venetian blinds; all peripheral background surfaces were pastel green. The same book was read under both conditions, and reading booths reduced outside distractions. At the beginning, middle, and end of each reading session, visual skills were measured using a commercial instrument. Some subjects did the fluorescent condition first; others did the daylight condition first.

The outcome was that acuity, stereopsis, and phorias did not change significantly between the two conditions. In other words, fluorescent light was just as good as daylight in the context of this experiment.

From the point of view of scientific method, this is a model experiment. Illuminance was controlled: The descriptions imply that both light sources were diffuse. Although spectral power distribution (SPD) was not controlled, the task was black and white, so color rendering effects were minimized. The task did not move much, so any stroboscopic effect due to the pulsation of the fluorescent light was minimized. In short, every obvious difference between the two lighting systems was controlled. This was a model controlled experiment, right?

There's just one problem here. In everyday situations, fluorescent lighting differs decisively from daylight in those variables that were controlled. Fluorescent lamps inevitably give diffuse light because of their low luminance and large area; the sun is small as seen from earth but high in luminance.[3–5] Daylight is among the best sources for revealing color contrasts, while fluorescent light tends to lose color contrast.[6] Fluorescent light usually flickers, while daylight never does. Thus, under normal conditions we would expect substantial differences between the two types of lighting, with regard to very obvious and measurable physical properties.

Gray and Prevetta controlled for just those features that distinguish one lighting system from another. Then they got a null result. Let us ignore the issue of whether acuity, stereopsis, and phoria are appropriate measures of visual fatigue. Certainly, attempts to measure fatigue have been a major dead-end in lighting research,[7] but let's assume that the skills measured are sensitive to lighting effects. Gray and Prevetta's experiment shows mainly that the results are null when the experimental conditions counteract some major differences between the two light sources.

The stated goal of Gray and Prevetta was bland: "to measure the effects of two hours of continuous reading under daylight as compared with two hours of continuous reading under fluorescent lights."[2] The implicit goal was to find out whether the two light sources differed in some subtle way, not obvious to the experimenter or the subject, but that would have an effect on the subject over time. Possible subtle effects might involve ultraviolet light or flicker, for instance, so such an idea is reasonable. At the same time, the goal of finding subtle effects was convenient from the point of view of scientific method, as it permitted an experiment that was almost blind. In the experiment, subjects surely knew if the light was coming from the venetian blinds or from a fluorescent fixture, but beyond that the setups were made to appear similar. A blind experiment has the familiar format of drug trials that are reported in the news. Subjects can't cheat because they don't know which condition they're under.

To put it simply, the effects of a subtle difference between two lights, if any, would be easier to experiment with than the effects of an obvious difference. Gray and Prevetta's experiment was not unique: Many lighting experiments have carried on their search for subtle effects, usually without stating the goal in that way.

The reader may see where the argument is headed. Controlled experiments and blind experiments are wonderful tools because they give uncomplicated results. Lighting is not a drug, however. You can't put a fluorescent tube and the sun into two gelatin capsules and make them look alike. The desire to do simple experiments is not consistent with the need to understand the full range of lighting effects.

An alternative approach

Gray and Prevetta's experiment got a null result in a test of a narrow hypothesis. To get a broader understanding, and perhaps to design experiments that will give positive results, requires a more methodical approach. The methodical approach can also give some negative results along the way, but at least it keeps moving along from one thing to the next.

With regard to spectral power distribution, the problem is to separate the normal variation from the abnormal, since the normal daylight spectrum varies with solar elevation, atmospheric conditions, and surrounding reflectances. Whereas Gray and Prevetta minimized spectral effects with their black-and-white reading task, the early visual clarity experiments of Aston and Bellchambers were a successful attempt to choose the lights and the objects viewed in order to get an interesting non-null result.[8] I showed by novel calculations that lights differ in their ability to reveal red-green contrasts, and that this could explain the visual clarity results.[6] I then showed experimentally a strong effect of illuminant SPD on the perceived distinctness of a red-green border between colored papers.[10]

With regard to light source area, it would be easy to show positive effects. We could, for instance, suspend a straightedge over a sheet of paper, and then ask a subject which source casts a sharper shadow: A small filament lamp or a 4-ft fluorescent tube? The problem is not to get the odd positive result, but to organize what we know. Familiar lights vary in the solid angle they subtend by a factor of 10^5 or more. This is closely related via photometry to the fact that familiar sources vary in luminance by more than 10^5. A compact source gives highlights that merit the name by being much brighter than white: A large source gives only veiling reflections. The radiance theorem implies that a luminaire can have a luminance approaching that of the light bulb within it, but not higher. Thus, lamp luminance constrains fixture luminance, which constrains fixture size, which constrains the contrasts of the lighted environment. There is more, and there are, of course, equations and verbal conclusions.[4,5]

An important line of experimental research need not involve human subjects, but would consist in quantifying the overall contrast changes when source area is varied in more-or-less complicated situations. Systematic effects are expected: Nearly all types of objects lose contrast with increasing source area. Follow-up research would relate the physical changes more closely to vision.

Conclusion

Theory helps us deal with the obvious. In the theoretician's orderly universe, it is normal to state the obvious, to work with it, and to calculate things from it.[3–5] By contrast, a desire to avoid theory in a field as complicated as lighting may lead to ignoring the obvious, as in Gray and Prevetta's experiment.

This is not to say that simple experiments such as Gray and Prevetta's are invalid or teach us nothing. However, we should learn from such experiments that lighting does not have large effects via subtle mechanisms. Forty years after Gray and Prevetta, it is past time to talk about the obvious differences between lighting systems and the obvious effects that lighting has on the contrasts available to the eye. The needed research will almost certainly have a mathematical and theoretical ring to it.

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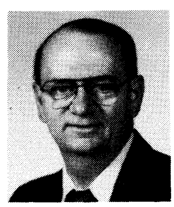

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