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Wednesday, 13 June 2012

The Inconstant Eye

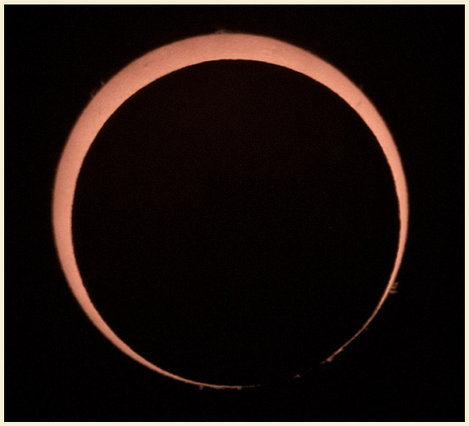
By **Ctein**

Paula and I went off to see the annular solar eclipse three weeks ago. By the time the moon was covering barely 25% of the sun, she, I, and the friends we were hanging out with all noticed that the landscape had gotten distinctly darker. That's at less than a half stop down from full sunlight.

Our eyes are usually very insensitive to gradual changes in illuminance; they have what's called "brightness constancy." We have very adaptable visual systems that allow us to see over a brightness range of greater than a billion to one. Apparently, though, we have a reference point wired into our brains for how bright normal sunlight should be. I hadn't noticed that before. Interesting! Also, it led me directly to this week's little lesson.

Visual constancy isn't perfect. Our ability to distinguish different tones diminishes under very bright or very dim light. There's a sweet spot around several hundred footcandles—the equivalent of a heavily overcast day or very bright indoor lighting—where we have a maximum ability to distinguish tones. In brighter light than that, we lose the ability to separate tones near white. In the other direction, we lose the ability to separate tones in the shadows.

The total number of tonal steps we can see a surprisingly small, about 650 for the average eye over that entire billion-to-one brightness range. Under optimal viewing conditions, in a typical photographic print, we can distinguish about 250 tones. If the light is significantly brighter or dimmer than that, we not only lose tonal discrimination but we lose it disproportionately at one end of the brightness scale or the other. That's why it's so easy to see "into the shadows" in a print when it's in direct sunlight and so hard under dim indoor light. More broadly, it's why we try to make our prints under conditions vaguely like the way we expect an audience to be viewing them. If our viewing lights are significantly brighter or dimmer than our audience's, they will perceive the prints as being too dark or too light (compared to what we intended them to see).



Third contact in the annular eclipse, as seen in H-alpha light, photographed through my Coronado PST. A few prominences are licking around the edge of the sun, even past the disk of the moon at the bottom of the photograph.

Our vision also has what's called "color constancy." You can vary the color temperature of the illumination over a considerable range, and colors appear approximately the same. We take all of this for granted; it only comes to our attention because our cameras and films aren't this adaptable. If they were, we'd hardly ever have to make an adjustment for exposure or color balance.

"Approximate," though, does not mean "exact." I'm not talking about metamerism, the apparent color shifts that some dyes undergo when viewed under different kinds of illumination. That's a different problem. I'm talking about the color interpretation by our eyes. A nice silver gelatin black-and-white print, which has a pretty flat spectral reflectance and exhibits very little metamerism, still tends to look cool-toned under skylight (10,000 kelvins) and warm-toned under a 60W incandescent bulb (2,600 kelvins). It's not a big shift in apparent hue, but fussy photographers and printers are well aware of it. Of course, this affects color prints as well, metamerism or no. It's doubly important to view your color prints under illumination similar to what your audience will be using, if you have any say or knowledge in the matter.

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There's another deviation from color constancy: below 4000 kelvins or so the total range of colors we can see, our visual gamut, starts to shrink. Even with illumination of sufficient brightness, we start to lose parts of the spectrum, especially towards the cool end. By the time you get down to normal incandescent lighting, our visual gamut is substantially diminished. This is why even a slight improvement in color temperature, as when going from 100W incandescent bulbs (2800 kelvins) to quartz-halogen bulbs (3200–3400 kelvins) makes the colors look so much more vivid in a photograph, even if the brightness level of the light isn't any greater.

There's yet another deviation from color constancy. It takes our eyes time to adapt to changes in the illumination's color temperature. It used to be thought that this happened fairly quickly, in a matter of minutes. Half an hour at the most. More careful experiments and research showed that along the yellow-blue axis, in particular, it can take several hours for the eye to fully adapt! During that time, our perception of the overall color balance of the photograph is slightly but perceptably shifting.

This is just the way our eyes work. There's nothing you can do about it except to be aware of it and pay attention to it, so that it doesn't compromise you too badly.

Ctein

Ctein's weekly column appears with approximate constancy on Wednesdays.

Featured Comment by **Yves Papillon:** "My left eye is dominant. I recently compared looking trough the viewfinder of a rangefinder camera with my left and then right eye. I noticed a clear difference in image tint. One eye showed a cooler image and the other a noticeable yellow one. My two eyes are inconstant."

Posted on Wednesday, 13 June 2012 at 01:43 AM in Ctein | Permalink

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Comments

I suspect it's not a fixed reference point, but that we have learned to expect a specific contrast between sunlight and open shadow. When that contrast drops we interpret it as the bright end (the sunlight) becoming darker.

Posted by: Janne | Wednesday, 13 June 2012 at 02:33 AM

Maybe that is why if we stare long enough, the picture start to look better and better?! :)

Posted by: Chan | Wednesday, 13 June 2012 at 04:44 AM

Dear Mr. Ctein,

The text is esoteric but accessible even to one who's uninitiated. The photograph, exquisite, ethereal! Is a TOP print sale of this in the offing? If it is not asking too much, did you shoot the transit of Venus as well?

It's been pouring with constancy at TOP for more than a week now (like the onset of the rainy season here in the Philippines).

Posted by: Sarge | Wednesday, 13 June 2012 at 05:31 AM

Thanks for this post,
Would it be possible to know your sources, from a scientific point of view? Thanks. I know bloggers are not obliged to do that. But I would like to compare, to read some sources.

I know from different lectures (physiology encyclopedia,the little chapter on "the eye" in the Feynman's lectures, etc) a lot of things on the human eye. But, it seems strange to me that we can notice the difference in color rendition at different hours of the day. Even if "everybody" is saying "the eye is used to adjust itself the color temperature", I doubt.

The human eye is a good differentiator...OK. But I think this point on color temperature is unclear. We don't have to take this for granted. A blue dress is not the same blue dress at different hours of the day, a landscape also or the legs of your girlfriend...

I hope you understand my doubt. Why not a perception of color temperature or a more physical color accuracy with the brain not adjusting "automatically" the color constancy.

I can't see why it could be a useful biological and natural evolution to keep the perception of constant colors...if it's physically changing. I need more scientific studies on this topic because I doubt.

Vision is an enthralling subject.

Nicolas
(sorry for the poor english)

Posted by: Nic | Wednesday, 13 June 2012 at 05:45 AM

Very interesting, Ctein !! Thank you. "-)

The way our eyes behave in ambient light certainly affects monitor calibration/adjustment efforts, yes? Is there any hope of attaining a "proper" colour calibration given these variables (our eyes, ambient light) - even though we use a mechanical calibration device??

Posted by: Andrea B | Wednesday, 13 June 2012 at 07:35 AM

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Whenever I am cleaning my swimming pool and staring at the pretty blue water for long periods of time my eyes become used to the blue light. Then when I look up at the world it is a wonderful shade of pink for a minute or two before my eyes adjust back. We paid good money for that sort of thing back in the '60s...

Posted by: Ed Kirkpatrick | Wednesday, 13 June 2012 at 09:32 AM

Ctein's article reminds us of how great it is to look up to the sky and be awed. We had a gorgeous solar halo in Central Florida last week. I took some snaps: http://topdogimaging.net/blog/halo

I would have been happy to post just one of the pictures here, but I don't know how to do that within the confines of WP.

Posted by: Bob Rosinsky | Wednesday, 13 June 2012 at 09:44 AM

On a recent twilight nature walk at Malpais National monument, the ranger had us stand close to each other in the gloom and focus on the others face, as you backed away (not very far) the face became blurry and indistinct because our night vision has a lot less resolution than color vision.

Posted by: KeithB | Wednesday, 13 June 2012 at 10:07 AM

...cruel orb that rules the night, removes the colors from our sight...

"Nights in White Satin"

Posted by: John Robison | Wednesday, 13 June 2012 at 11:47 AM

It is interesting to speculate that if the sensitivity of our eyes extended into either the ultra-violet or infra-red, what would the "color circle" look like --RGB-UV or RGB-IR?

Posted by: Jim | Wednesday, 13 June 2012 at 11:53 AM

Apparently, though, we have a reference point wired into our brains for how bright normal sunlight should be.

That's interesting (to me, anyway!).

Some of use are fairly good at judging exposures based on the light conditions but I have always assumed that due to the iris in our eye adapting to light levels, that we judge light by contrast rather than actual level. The reasoning being that the sunlight is a constant (usually) and it is just the clouds and other atmospheric particles which can filter it and diffuse it.
I didn't think we would be able to judge light levels (in the outside daylight range) purely by brightness but possibly we can.

Posted by: Steve Smith | Wednesday, 13 June 2012 at 12:09 PM

Once again Ctein proves why he's the smartest kid in the room...

Posted by: k4kafka | Wednesday, 13 June 2012 at 12:32 PM

"it can take several hours for the eye to fully adapt!"

That might explain why I can post-process pictures a whole evening, and the next day realize that they all have a purple tint...

Posted by: Winwalloe | Wednesday, 13 June 2012 at 12:45 PM

Dear Janne,

Heh, no. There's only one light source in the scene: the sun. The contrast ratio between shadow and sunlight remains the same. So does the color temperature. So, it's not subliminal cues at work. The characteristics and quality of the illumination are essentially the same; it's only the absolute level that is changed.

When the sun is more heavily covered, approaching 50%, you do start to see some subtle differences in the shadows because the angular size of the sun is significantly diminished and the shape is substantially altered. But at 25% coverage, those differences are invisible.

When you're up near 90% coverage, shadows get really interesting because it's a slit-like arc that is casting them instead of a round object, so there are peculiar asymmetries in the fuzziness of the shadows' edges, depending on how the edges are oriented with respect to the sliver of Sun.

~~~~~~

Dear Nicolas,

Color and brightness constancy are only approximate, and our brains are very good at interpreting subliminal cues. Many photographers taught themselves to be able to accurately estimate exposures without a light meter, for example. Some of that is being able to mentally shut down the constancy, but more of it is learning how to interpret the other clues.

The degree, though, to which we actually notice changes in color or brightness is much, much smaller than the absolute physical changes. To use your example, a blue dress looks different in daylight than it does under indoor light, but we would still say it was “blue” in both circumstances. But if you look at the actual spectral reflectance from the dress, under daylight it is reflecting predominantly blue light, but under indoor incandescent light, it's primarily reflecting yellow and red light because there is so little blue light in the illuminance. Yet, we still say it's blue, whereas an uncalibrated spectrophotometer would say otherwise. As would daylight-balanced color film exposed under those conditions without a corrective filter.

pax \ Ctein
[Please excuse any word-salad. MacSpeech in training!]
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-- Ctein's Online Gallery http://ctein.com
-- Digital Restorations http://photo-repair.com
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Posted by: ctein | Wednesday, 13 June 2012 at 02:52 PM

Dear Andrea and Winwalloe,

Pretty much-- the situation is that we're ultimately dependent upon our eyes to evaluate color, and they do not behave consistently, so there's no way to get absolutely reproducible results from day-to-day. It's important thing to learn to live with, that at some point “good enough” is actually “as good as it can get.”

In my personal situation, it's a good example of precision vs. accuracy. I can color-correct some photographs down to 0.5 CC (0.005 d.u. or about 1%). I really can see a half CC shift in the overall color, and it matters to me. For me it's an obvious difference.

So, I have very precise eyes. But here's the thing, if I go back and do a color correction on the same photograph the next day, I will likely come up with a print that is a couple of CC's different! My absolute color accuracy is far worse than my precision, for all the reasons mentioned in this article and more.

Took me quite a few years to catch on to this. Once I did, I stopped worrying about it. I still tend to “over” correct, down to half a CC and unit point shifts in curves in Photoshop, but then I let go. When I look at the print the next day, I've learned not to look too closely. Otherwise I will just make myself crazy chasing my own tail.

pax \ Ctein
[Please excuse any word-salad. MacSpeech in training!]
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-- Ctein's Online Gallery http://ctein.com
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Posted by: ctein | Wednesday, 13 June 2012 at 03:04 PM

I would notice adaptation to color temperature when standing in our bathroom (incandescent lighting) and looking out into the bedroom (with daylight filtered through a neutral colored blind). The bathroom would look normal while the bedroom looked very blue by comparison. Standing in the bedroom it would look normal with the bathroom having an obvious yellow-orange cast.

This adaptability has always fascinated me.

Posted by: Paul Glover | Wednesday, 13 June 2012 at 03:25 PM

I second Nicholas on the reference request... Ctein, do you have any good books on this topic to recommend?

Posted by: Woland | Wednesday, 13 June 2012 at 04:06 PM

Dear Nicolas and Woland,

I'm afraid I don't have any references I can point you to about color constancy. It's just stuff I've learned over the years. Regarding the brightness response of the eye, the reference paper I rely on is by HL Resnikoff, “On the Psychophysical Function”, published in the Journal of Mathematical Biology 2, 265-267 (1975). It's a really nice piece of work on how to model physical phenomena, but you'll have to have some basic understanding of set and function theory as well as calculus to make any sense out of it.

pax \ Ctein
[Please excuse any word-salad. MacSpeech in training!]
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-- Ctein's Online Gallery http://ctein.com
-- Digital Restorations http://photo-repair.com
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Posted by: ctein | Wednesday, 13 June 2012 at 06:07 PM

The redoubtable Oliver Sacks has written a lot on how the eye/brain works and the anomalies of visual perception. I'd recommend *The Man Who Mistook His Wife for a Hat* and *An Anthropologist on Mars* highly. *The Island of the Colorblind* is also interesting, if not quite as good as the first two mentioned.

Posted by: Mark Roberts | Wednesday, 13 June 2012 at 07:30 PM

Nicolas:
"I can't see why it could be a useful biological and natural evolution to keep the perception of constant colors."

Being able to see the difference between good food and unripe, poisonous or spoiled food would be one good reason.

I had a friend in college with red-green color blindness and he would often ask "Does this look good to eat?"

"That flashing traffic light, yellow or red?" was another amusing survival related query

Posted by: hugh crawford | Wednesday, 13 June 2012 at 10:14 PM

This is very interesting in light of my recent adoption of underwater photography. There we are playing with substantial changes in illumination spectrum (reds start to disappear at relatively shallow depths) but yet can make out colours quite well to fairly decent depths. Throws up all sorts of intreresting issues around illumination and colour correction in photographs.

Posted by: Martin Doonan | Wednesday, 13 June 2012 at 10:24 PM

Ctein, Re: brightness constancy - I suspect that the rate of brightness fall off as a result of the moon blocking the sun is faster than the adaptation that produces the apparent constancy we experience. Also, you were more aware of the changes - you were observing the eclipse at that time

Brad

Posted by: Brad Davis | Wednesday, 13 June 2012 at 10:50 PM

Excellent.

Could you at some point write an article on the set up and details of the equipment used?

Posted by: Steve | Thursday, 14 June 2012 at 12:31 AM

For all those interested in color perception - go and see the 1985 BBC Horizon Documentation "Colourful Notions":

(Part I-IV)
http://www.youtube.com/watch?v=4YuEhr-C-8U
http://www.youtube.com/watch?v=WA-XQiCtNMU
http://www.youtube.com/watch?v=wyiXvjuiibM
http://www.youtube.com/watch?v=fsChYbBEzzw

(also featuring Edwin Land)

Posted by: Freddy Schiller | Thursday, 14 June 2012 at 02:33 AM

Dear Brad,

Dunno, you could be right about the adaptation time for luminance constancy. It takes about a half hour to go from 0% to 25% coverage, which seems like plenty of time to adapt to a mere half-stop shift. But intuition's frequently wrong about such things. Whodathunk that color constancy took hours? Not moi.

~~~~~~

Dear Steve,

The links are there for a reason.

pax / Ctein

Posted by: ctein | Thursday, 14 June 2012 at 02:40 AM

Thanks Ctein for the ref. in the Journal of Mathematical Biology. Hope I'll find some great sources there. Do you know that the math/linear algebra used for color construction in principal component is due to Shrödinger ? It always buzzed me that this topic of human color recognition was fascinating for a lot of "well known" physicists.

Dear Hugh,
Probably evolution gave better tools to different animals to recognize good food from bad one (I like blue cheeses but I notice the difference between good and bad milk with the smell first). For the traffic lights...It made me smile this reversal between cause and effect, thanks for your answer.

On color recognition, I always think about technics for the shadows used by painters (p.ex: they paint shadows with more cold colors than the illuminated object). Painters were making some good jobs to recreate the color temperature before the spectrophotometer (and even before they found the right pigments to do it). That's why I guess, since the human brain try to concentrate on the color accuracy of a scene, it must have the ability to notice that color is not something absolute. It's possible that "auto-color temperature adjustment and brightness" is not a so obvious point. There must be a difference between the auto treatment of datas from the 3 different cones (already in the nervous connection from the eye to make it fast) and the possibility of interpretation from the RAW material by the human brain's visual area (with help from the memory).
A bit like the Jpeg accompanying the RAW !-).

I don't know, really. I will always miss something...

Anyway, thank you all it's a fascinating topic.

Nicolas

Posted by: Nicolas | Thursday, 14 June 2012 at 04:41 AM

Dear Nicolas and Woland,

The best book I know about color appearance, that also covers the basics of human vision, is "Color Appearance Models" by Mark D. Fairchild (2nd Edition, 2005, John Wiley & Sons Ltd). With respect to color constancy he writes on page 132:

Typically color constancy is defined as the apparent invariance in the color appearance of objects upon changes in illumination. This definition is somewhat misleading. The main reason for this is because color constancy does not exist in humans!
[...]
Then why does the term color constancy exist? Perhaps a quote from Evans (1943) answers that question best; '. . . in everyday life we are accustomed to thinking of most colors as not changing at all. This is due to the tendency to remember colors rather than to look at them closely.' When colors are closely examined, the lack of color constancy becomes extremely clear.
[...]
~~~~~~

Jameson and Hurvich (1989) discussed some interesting concepts in regard to color constancy, the lack thereof in humans, and the utility in not being color constant that are suitable to end this chapter. They pointed out the value of having multiple mechanisms of chromatic adaptation, thus producing imperfect color constancy and retaining information about the illumination, to provide important information about changes, such as weather, light, and time of day, and the constant physical properties of objects in the scene.

Chrigu

Posted by: Chrigu | Thursday, 14 June 2012 at 05:59 AM

Our chickens headed for the roost at about half coverage.

Posted by: J | Thursday, 14 June 2012 at 08:20 AM

Take some photos at dusk exposed to make a mid grey appear mid grey, and you will find that the shots look, well, odd. I've noticed this before, but spotted it again recently on a major French tennis match shown on TV that went on until the sun had dropped below the horizon. It sort of looked over exposed, but it wasn't, given the intention to show the match. Skin tones were right, for example.

The commentator had to explain that despite the well lit appearance that was just the cameras and it was in fact almost dark.

Posted by: Roger Bradbury | Thursday, 14 June 2012 at 08:47 AM

Oh my.I read the article twice and missed the link both times. Thanks for the response.

Posted by: Steve | Friday, 15 June 2012 at 02:53 AM

Chrigu, that's a reference I'll be glad to read. I'll try to find it in our University library. Thank you very much!

Posted by: Nicolas | Friday, 15 June 2012 at 04:39 AM

The comments to this entry are closed.