Google on down

The highly popular Google Earth, which provides a vast array of images of details of the planet's surface for users, has been extended this month to include ocean images that will allow exploration of many dramatic underwater features. Google Ocean will also include videos of marine life and watch unseen footage of historic ocean expeditions. "Biodiversity loss in our oceans in the next 20–30 years will be roughly equivalent to losing an entire Amazon rainforest, but it goes unnoticed because we can't see it," says Google chief executive, Eric Schmidt. The new Google Ocean "gives an opportunity to change everyone's prospective."

Since Google Earth launched in 2006, millions of people have used it as a virtual globe to 'travel' around the planet, even climbing a digital version of Mount Everest. It is estimated 400 million people have accessed the current site, which includes, along with Mount Everest, three-dimensional representations of many large cities, including images from the street level and aerial photography covering large tracts of the planet's land surface.

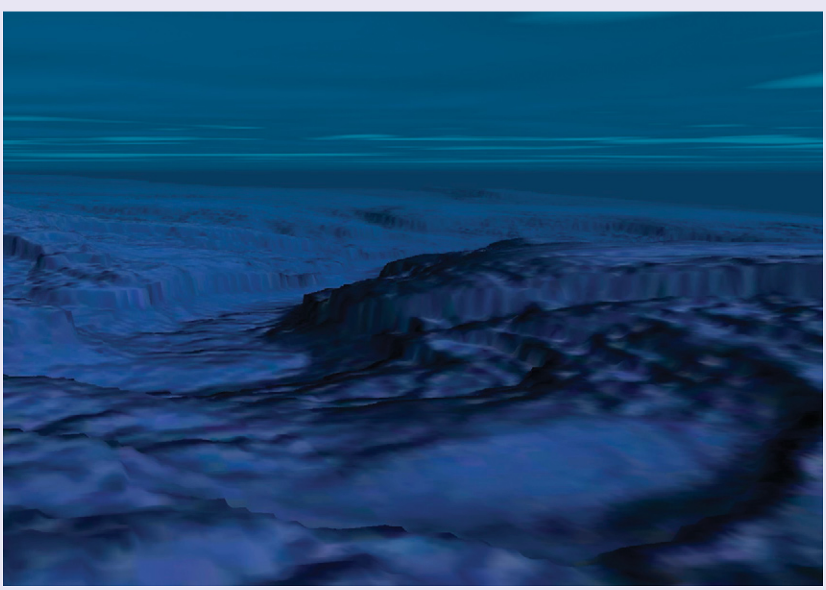
The new launch now extends this reach to the oceans. Although only about 10 per cent of the seabed has been at a useful scale for scientific studies, bathymetry experts say that the public's ability to access such information about the oceans will allow them to gain a better understanding and will impact on their perceptions of this major part of our planet.

Along with subterranean maps, the new site will also include environmental data that will help users gather more data about climate change

Along with subterranean maps, the new site will also include environmental data that will help users gather more data on climate change. "In discussions about climate change, the world's oceans are often overlooked despite being an integral part of the issue. About one third of the carbon dioxide that we emit into the atmosphere ends up in the oceans," says Schmidt.

It was no coincidence that Al Gore, former vice president and environmental campaigner, was present at the launch in San Francisco.

Nigel Williams



Sloping off: A bathymetric image of the seabed off Monterey, California. (Photo: Copyright Google.)

Quick guide

Calibrating color vision

Michael A. Webster

Why do some colors look special? Color vision is our ability to distinguish the spectral characteristics of light. Wavelength varies continuously, yet we perceive spectra in terms of a small number of dimensions anchored by salient landmarks. These dimensions define a color space, within which colors appear to vary in hue (direction) or saturation (distance) relative to a neutral gray (Figure 1). Coding relative to a norm may reflect a general strategy in perception. For example, individual faces may be judged by how they differ from a neutral or average face. Any hue can be decomposed into a mixture of the perceptually pure hues red, green, blue or yellow (for example, orange looks like a combination of red and yellow). However, no light looks both red and green, or both blue and yellow, suggesting that these hues reflect opposite poles of two opponent dimensions, in the same way that light and dark are opposing aspects of brightness.

Conventional models of color vision assume that perceptual opponency is mirrored by neural opponency, and that the primary hues look unique because they represent unique states in the neural code. For example, a 'red *versus* green' cell might be inhibited by one type of cone receptor while excited by another (Figure 1), and we might see pure blue or yellow at the wavelengths that precisely balance or null the antagonistic inputs to the red–green mechanisms. Color opponency in single cells is well established. Yet the tuning characteristics of these cells do not match the red–green and blue–yellow dimensions of color appearance. This has raised the possibility that the reason some colors look special is not because of how we are built, but because of how the world is built. For example, blue and yellow may look prominent because they describe how daylight varies and not because they isolate a special neural mechanism. A central focus of modern color science is to explore these different possible explanations for the experience of color, from physiological to environmental to cultural.

How could the environment influence color? Perhaps a better question is how could it not. Sensory systems are highly adaptable, and thus constantly adjusting their sensitivity to track the current stimulation. On a short time scale, the world can undergo enormous variation (for example, in average light level) that would swamp a visual system with static properties. Yet even for a static world, adaptation may be necessary for establishing the initial match between visual coding and the visual world. For instance, the spectral sensitivity of the eye depends on many pigments and processes that vary widely across individuals and even within the individual. Adapting color responses so that they are normalized for the spectral environment helps to compensate perception for these physiological idiosyncrasies and leaves visual coding better positioned to represent information about the environment.

What aspects of the world can color vision adapt to? The simplest example is the perception of white. If you stare at a colored disk, the sensitivity of the photoreceptors decreases roughly in proportion to their stimulation. Thus for a red disk, long-wave sensitive cones become less sensitive while short-wave cones become more sensitive. The signs of this adaptation are clearly seen in the color afterimage that is experienced if you now switch your gaze to a blank field. This adjustment renormalizes sensitivity so that over time a balanced or white response would correspond to the average spectrum you have been looking at. Thus what looks white to us may merely be the average spectrum of the environment. Yet even this case is complex, for we do not yet know how our perception of white depends on how scenes are sampled or over what timescales.

As noted, norms are not unique to color vision, and adaptation may similarly set the neutral point for many perceptual dimensions. As one example, the perception of faces is also highly adaptable and also adjusts so that the face that looks average is the average of the facial characteristics that we are exposed to. Color vision also normalizes for the range or gamut of colors. In a scene that predominantly varies from blue to yellow, we lose sensitivity to blues and yellows so that over time the range of colors appears more balanced. Still more complex adaptations may adjust for changes in hue with saturation. As the bandwidth of a spectrum increases its effective shape becomes distorted by the filtering effects of the eye. Recent evidence suggests that color appearance is compensated for this distortion so that the hues experienced correspond more closely to constant properties of the stimulus than to constant responses in color channels.

What happens to color perception when the environment changes? The color characteristics of the environment are not fixed and instead vary widely across different locations and across different times as the lighting or seasons change. In some cases adaptation removes this variation from perception. If the illumination changes, then resetting white for the new average discounts the lighting, so that the color of illuminated surfaces remains constant. In the natural world, however, much of the variation between environments may be tied to the surfaces themselves and in particular to types and states of vegetation. These reflectance differences are large enough so that individuals living in different natural settings may be held under different states of adaptation that would lead them to experience color differently. Consistent with this, studies in which observers are exposed to biased color environments have found changes in color perception at both short and long time scales.

What happens to color perception when the observer changes? The same processes that adjust to changing environments will also recalibrate perception when observers themselves change. As we age, the lens of the eye becomes more yellow, blocking more of the short wavelength light reaching the receptors. If we did not compensate for this change, then a stimulus that appeared white in our youth would look yellow when we are older, yet judgments of white instead remain constant across age. Similarly, this page appears the same white whether you look directly at it or off to the side, even though the receptors at the center of gaze are screened by macular pigment that again blocks shorter wavelengths. These physiological differences may again be discounted by adapting color perception to the average color of the world. A further revealing example of these adjustments is the change in color perception following cataract surgery. After the cataract is replaced by a clearer implant, patients report that the world appears to be too blue, yet over a period of weeks their judgments of white drift back to near their pre-surgery settings.

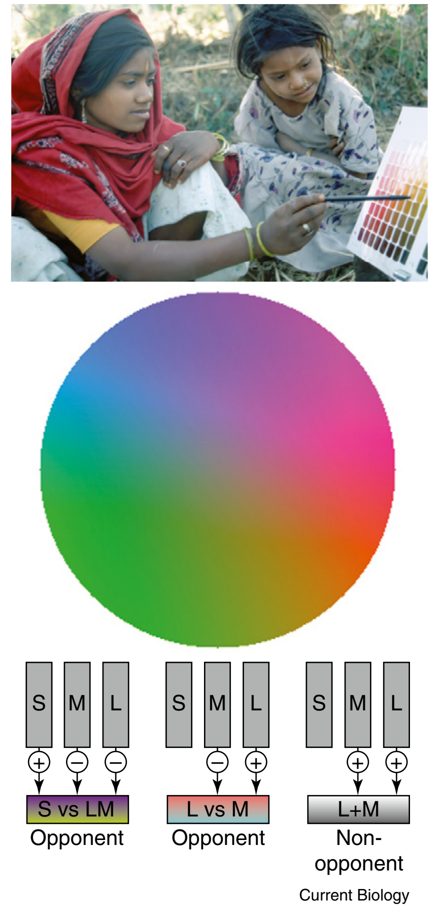


Figure 1. Many factors shape the perceptual experience of color, from the visual and cultural environment to the neural organization of the visual system.

Figure 2. Adaptation to different color environments.

The top pair of images shows a scene from western India during wet (left) or dry (right) seasons. The lower pair depicts how color might be experienced by an observer adapted to each season. The images were transformed by normalizing the responses of the receptors and post-receptoral channels to the color distributions characterizing each season, so that for each channel the average response to the image ensemble in the dry season equaled the response in the wet season or vice versa. Note that adaptation tones down the prevailing colors while increasing the salience of novel colors within each environment.

Does culture play a role? A long standing debate is the extent to which color categories might be shaped not by physiology or the physical environment, but by the social environment and language. In work starting in the 1960s, Berlin and Kay compared color naming across languages and found that the basic color terms within different languages tended to point to very similar places in color space. Thus most languages in the world have a term that corresponds to "red" in English. This work demonstrated that there are strong common trends in how colors are parsed, rather than arbitrary divisions set by language. Such results naturally fit with the notion that color categories reflect the neural coding of color, though they could also reflect the structure of color in the environment. Yet this does not mean that culture plays no role. Languages differ dramatically in the number of basic color terms, with some using as few as two terms (roughly 'light' and 'dark') to describe all colors (English has eleven basic terms). A number of recent studies suggest that the categories defined by a specific language can influence perceptual performance.

Disentangling different contributions is not easy because they are often closely intertwined. Cultures may determine which colors are most widely used or prominent and thus which colors we are exposed to, while environments can impact on physiology (most notably in damage from UV light exposure, which may significantly vary for different populations). Moreover, each account faces the problem that there are pronounced individual differences in color perception, even among normal observers sharing a common language and presumably a common environment. The basis for these individual differences remains a mystery.

Can we visualize how colors might look to others? The conscious experience of color is completely private, for there is currently no way to objectively measure that experience or probe it in others. Nevertheless, many studies have attempted to simulate how the world might appear to different individuals, for example to try to mimic a color deficiency or an infant's eye. Typically these simulations filter the images for the altered spectral and spatial sensitivity of the observer — removing the information they cannot see. However, these individuals will also adapt in ways that will partly compensate their perception for these sensitivity losses. As noted, the world does not appear yellow to someone with a yellower lens, nor may it feel blurred to someone with low acuity. To the extent that we understand these adaptations, incorporating them into simulations may better illustrate the perceptual consequences of development or disease or how perception changes as the environment changes (Figure 2). As a fanciful example, when we begin to colonize Mars the 'red' planet may not look very red to the inhabitants, who may instead find that the greens of nature on Earth appear as saturated and unnatural as a Nevada casino.

Where can I find out more?

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