FORUM

Comment on "Color Schemes for Improved Data Graphics," by A. Light and P. J. Bartlein

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As a color-blind climatologist, I very much appreciated the important color-awareness issues raised by A. Light and P. J. Bartlein in their recent *Eos* article titled "The End of the Rainbow? Color Schemes for Improved Data Graphics," (*85*(40), 5 October 2004, p. 385).

Meteorological and climate information is frequently communicated in the form of highly colored spatial maps (e.g., daily weather forecasts). The use of color is so endemic in climate research that it would be unthinkable to present scientific work at a climate conference without using color! The color schemes generally chosen to create such maps follow no universal convention and often consist of colors that cause confusion to both color-impaired and non-color-impaired people.

Light and Bartlein raised several pertinent points and made some good recommendations. However, a number of points require some more clarification.

First, Light and Bartlein's example in Figure 1 showed simulations of how images might appear to people with protanopic vision, which they claimed to be "one of the most common types of color-vision deficiency in which the retina lacks red-sensitive cones." However, of the 8% of Caucasian males and 0.4% of Caucasian females with color-impaired vision, only 2% of all males and 0.01% of all females have this form of color-impairment.

By far the more common forms of color-impaired vision are deuteranopia/deuteranomaly (green-weakness), with 6% and 0.25% overall prevalence in Caucasian males and females, respectively. People with these conditions have cones that are less sensitive to medium wavelengths (greens) and so have reduced ability to discriminate the green (rather than the red) component in colors.

Deuteranopia and deuteranomaly are also known as Daltonism after the well-known scientist, John Dalton, in recognition of his groundbreaking scientific study on color vision [*Dalton,* 1798]. Dalton's diagnosis was confirmed as deuteranopia in 1995, some 150 years after his death, by DNA analysis of his preserved eyeball. Interestingly, Dalton was also a keen meteorological observer and so perhaps would be very sympathetic to the color issues now being raised here in *Eos*.

Since deuteranopia is much more prevalent than protanopia, it makes sense to focus attention on color schemes that work for deuteranopia, and it would have been more relevant if Light and Bartlein had presented a deuteranopic simulation (green-deficient) rather than a protanopic (red-deficient) simulation in their Figure 1.

This perhaps explains why as someone with deuteranomalous vision, I find the color schemes in Light and Bartlein's Figure 2 rather difficult to identify. For example, I would have referred to their purple colors as blue, and this can easily cause much embarrassment in, say, a scientific talk. Their categorical color key in Figure 2e is particularly difficult—a color-blind colleague and I could each only successfully name nine out of the 12 colors.

Light and Bartlein presented three suggestions to improve color schemes: Avoid spectral schemes, use yellow with care and avoid yellow-green colors, and use color intensity to reinforce hue. Suggestions 1 and 3 make good sense to me, but I disagree with suggestion 2—yellow is one of the colors I can distinguish the most easily, and so I favor this as a middle color in color schemes (and in my PowerPoint talks).

A few other recommendations to help improve color plots are:

1. Avoid using red and green together in a color scheme (remember the old adage: "Red and green should never be seen …"!). It is best to avoid using green completely if possible. Distinguishing between green and brown is especially difficult, and so these two colors should be avoided.

2. Use a limited number of high-contrast primary colors (e.g., white, black, blue, yellow, red) rather than a large number of pastel shades. Bright colors such as those commonly used for water sport equipment are good, whereas pastel shades such as Monet's water lily colors are a nightmare!

3. Check your figures (and Web pages) using the excellent and simple-to-use image checking tools that are now available on the Internet (e.g., http://www.vischeck.com).

More information on color vision and how to design for it is given by *Viénot et al.* [1995] and on Christine Rigden's informative Web pages (http://more.btexact.com/people/rigdence/colors).

References

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