Pediatric RESEARCH

COMMENT

Use of color in journal figures

Mark A. Klebanoff[1,2,3]

Pediatric Research (2021) 90:22; https://doi.org/10.1038/s41390-020-01258-9

In humans, complete inability to see colors (monochromacy) is extremely rare; therefore, "colorblindness" is a misnomer. However, color vision deficiency (the preferred, technically correct term) is relatively common, affecting 1 of 12 (8%) males and 1 of 200 (0.5%) females.[1] Color is perceived by cone cells in the retina, of which there are three types, each most sensitive to red, green or blue. Defective red (long wavelength) cells result in protanopia; defective green (medium wavelength) cells result in deuteranopia.[2] Both defects are transmitted in an X-linked manner, and result in the so-called "red-green" color vision deficiency. About 2% of males are protanopes and 6% are deuteranopes. Defective blue cone cells, tritanopia, are not X-linked, and are rare.[1,2]

The relatively high prevalence of color vision deficiency, particularly among males, should be considered by anyone who prepares color figures for publication, slides for presentation, and indeed, any venue where differentiating colors matters for understanding the information being conveyed. Hints for preparing graphs, charts, and other figures, as well as websites where figures can be checked for how they will be perceived by color-vision-deficient individuals, have been published recently, and readers are referred there for specific guidance.[1,3–5]

Some advice can be given. Perhaps the most important advice is not related to color vision deficiency: a substantial number, perhaps a majority, of manuscript and grant reviewers prefer to print out the material, rather than read it online; many of them do not use a color printer. Most of the information in elegant graphs, fluorescent images, and heat maps will be completely lost to those reviewers, perhaps to the detriment of your submission. Authors are well-advised to provide brief verbal summaries of the graphics for the benefit of these reviewers. Authors can use techniques that bypass the need to discern colors: line graphs can employ different line patterns, and bar and pie graphs can employ different cross-hatching, in addition to different colors.[1,3,5] If authors must use colors that individuals with deficient color vision cannot distinguish, hue and saturation can be helpful—a light green and a medium or dark red, for example, since most affected individuals can distinguish contrast even if they cannot distinguish the specific colors. However, some affected individuals see dark red as black, so authors should exercise caution.[1,3,5] Specific color combinations should be avoided, recognizing that if they cannot, then differences in color saturation may be helpful. These combinations include red and green, green and brown, blue and purple, and several others.[5] Blue, which can be perceived normally by almost everyone, is probably the first color one should use.[1] Yellow is also well perceived, although it may be difficult to distinguish against a white background; providing a non-white border can remedy this.[1] Finally, white, gray, and black, while technically not colors, are universally perceived. Additional guidance is provided in the cited references.

The Journal has no intention of mandating specific color choices in the figures authors submit, but we do ask that authors be aware of this concern and do their best to design figures with it in mind.

ADDITIONAL INFORMATION

Competing interests: M.A.K. reports color vision deficiency but otherwise reports no conflicts of interest.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

REFERENCES

1. Roskoski, R. Jr. Guidelines for preparing color figures for everyone including the colorblind. *Pharm. Res.* **119**, 240–241 (2017).
2. Swanson, W. H. & Cohen, J. M. Color vision. *Ophthalmol. Clin. North Am.* **16**, 179–203 (2003).
3. Wong, B. Color blindness. *Nat. Methods* **8**, 441 (2011).
4. Carter, M. *Designing Science Presentations: A Visual Guide to Figures, Papers, Slides, Posters, and More [text]* (Elsevier/Academic Press, Amsterdam, 2013).
5. Cravit, R. How to use color blind friendly palettes to make your charts. https://venngage.com/blog/color-blind-friendly-palette/ (2017).

[1]Center for Perinatal Research, The Abigail Wexner Research Institute at Nationwide Children's Hospital, Columbus, OH, USA; [2]Departments of Pediatrics and Obstetrics and Gynecology, The Ohio State University College of Medicine, Columbus, OH, USA and [3]Division of Epidemiology, The Ohio State University College of Public Health, Columbus, OH, USA
Correspondence: Mark A. Klebanoff (mark.klebanoff@nationwidechildrens.org)

Received: 28 September 2020 Accepted: 13 October 2020
Published online: 10 November 2020