Color Research Applications in Mapping and Visualization

Cynthia A. Brewer
Pennsylvania State University
University Park, Pennsylvania, USA

Abstract

Color science has provided a wealth of research that is useful in mapping and visualization. Cartographers use work on perceptual color systems, color vision deficiencies, surround induction, color naming, printing and display, and conversion between color systems. From this grounding, we structure our symbols to represent real-world phenomena so they can be discovered and understood by map readers. Color offers a three-dimensional structure which can be used to organize symbols for multivariate mapping. Mapmakers do not always have the color specification skills for this type of analytical design work, but color schemes offered on the Web at ColorBrewer.org provide starting sets that are structured to match the basic organizations of map data: sequential, diverging, and qualitative schemes.

Introduction

Maps are simultaneously works of art, scientific documents, and news. The whorl of a hurricane spinning through a rainbow of colors attracts our eye because it is colorful and because it menaces the coast. The swelling mesh of red lines on a city traffic map needs to contrast with its background and use color to clearly identify where traffic is crawling. The gutter of orange tints down the middle of a U.S. census map tells us where we are losing population <www.census.gov/population/cen2000/atlas/censr01-103.pdf>. And red and blue states have become a shorthand for the election battle this year.

Cartographers use color as one of the symbols for representing data. Early maps relied on spot color. For example, topographic maps used green ink for the green symbols for wooded areas. A statistical map may have used light-to-dark screens of one ink to show low-to-high population densities. Early computer maps limited to 4-bit color made the best of the limited set of six hues that could be created (we still see the echo of this early limitation in the spectral schemes that pervade scientific graphics).[1] In all of these examples, the sophistication of perceptual color spaces, color difference measures, or adaptation to illumination were all trumped by the challenge of simply managing to get any map out with a bit of color on it. Increasingly sophisticated presentation media—color monitors, web publishing, color printers, color in newspapers, and color projectors—not only make it possible to present geographic information in full color, they demand it.

In this short paper I will sketch the ways color science has been applied in cartography and visualization with reference to the research I have initiated or been involved in since the late 1980s.

Applying Color Research

Maps today are computer graphics and cartographers are able to take advantage of the numerous advances made in color science that are driven by more lucrative markets. Mapmakers seek to understand what is happening on the ground and make it visible to people living there or making decisions about those patterns. Our graphics are built using color symbols or false-color image processsing—they are rarely photographs of visible surfaces. We are analytical about measuring, categorizing, and generalizing the features we map. And we are analytical about how we organize the symbols we use to represent them.

More complete use of the three dimensions of perceptual color space is one way cartographers have improved the detail with which we are able to symbolize what we map.[2-4] For example, different hues for different vegetation types that are desaturated as reliability of the classification diminishes and overlaid on undulating lightness for terrain representation provides a more complete understanding of the environment than a simple patchwork map of hues for the vegetation alone. Likewise, a systematic understanding the terrain can be sought by coding slope direction by hue, shape by lightness, and steepness by saturation.[5]

Many statistical maps use color to fill enumeration areas—counties, census tracts, watersheds—to let us see patterns in physical and human phenomena. The band of high death rates from heart disease that runs through the Appalachian region down into Mississippi (Figure 1) spurs epidemiologists to investigate behavior and health care in these areas. A diverging scheme that highlights lows and highs with different hues, as well as marking median rates with a light color, is effective in revealing patterns in mortality rates.[6] Texture overlays that warn of sparse populations and unreliable rates[7] invite multivariate map reading. Mapmakers make better maps if their choices of hue

combinations are informed by color science. For example, design of diverging schemes is improved by considering research on color naming, color vision deficiencies, and induction to steer clear of hue pairs that may be confused.[1,8]

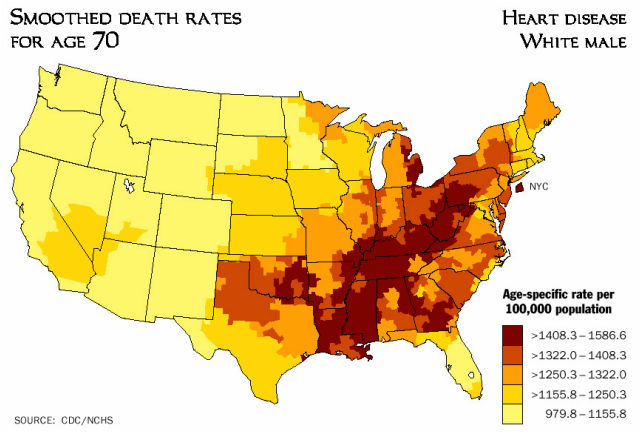

Figure 1. Example mortality map for heart disease in white males <www.cdc.gov/nchs/data/gis/atmaphd.pdf>

Pulling results from the controlled realms of vision science and psychophysics into the applied realm of making maps has been a challenge of balancing goals. Maps are read in uncontrolled viewing environments and by a wide ranging audience. We have been able to predict confusions between color symbols that will be made by people with red-green color vision deficiencies[9] and induced from surrounding colors.[10-12] It is also challenging to use the inspiration of perceptual color spaces to guide the design of logical color symbol sequences produced by people working with no color measurement and weakly controlled color printing and display.[13,14]

ColorBrewer.org

Most cartographers are amateurs when it comes to color specification and production, but we have sharp eyes and are ready to make use of the color technologies that are within our grasp. One way I have tried to make color specification for data symbolization less mysterious (or at least less relentlessly spectral) is through ColorBrewer.org (Fig. 2).[15-17] This is a simple Web site I designed, in collaboration with Mark Harrower, that offers series of good quality color schemes and RGB, CMYK, hexidecimal, CIE Lab, and HSV-based color specifications for each color in the schemes. These color schemes are useful for mapmaking with geographic information systems (such as ESRI ArcGIS), graphic design software (such as Adobe Illustrator), and web design tools (such as Macromedia Flash).

ColorBrewer schemes are organized into three groups: sequential, diverging, and qualitative—to teach users the basics of deciding how their data are structured and which of the three basic organizations of the perceptual dimensions of color will best represent their data.

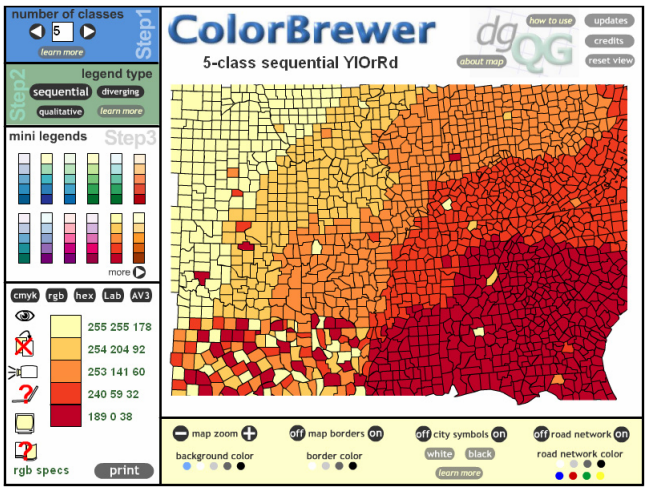

Figure 2. Example screen capture from ColorBrewer.org, an online map design tool.

The map display, on which users can test drive color schemes before using them in the mapmaking environment, is structured to test the colors in the complete range of surround conditions that would appear on the map. All colors are seen as isolated patches against all other colors in the schemes. The lightest colors are surrounded by the darkest colors in the scheme, for example, on the right side of the test map. The user decides if the light colors will remain distinguishable on the map. Some basic guidance on whether, for example, a color scheme will be useful to readers with color vision deficiencies, will hold up when printed in black and white, or retain its full variation when projected are indicated by a series of icons along the left lower corner of the ColorBrewer display.

In Summary

Over the past 15 years, I have sought to link color science and cartography, with the goal of improving communication of geographic data. Along the way, I have learned a lot about color and the community of scholars and industry people who share my passion for the analytical and aesthetic challenges it offers. I see my role as transferring the science of color, vision, and materials to an applied realm of people hoping to make beautiful and revealing maps. I get some enthusiastic fan email from ColorBrewer users, pleased for the help and more confident about their graphics. These mapmakers are trying to run their county or plan their bus routes. They won't be able to delve into the theoretical groundings of the color work they use but they sure appreciate it.

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Biography

Cynthia Brewer received her PhD from Michigan State University in 1991. She taught at San Diego State University and is now an Associate Professor of Geography at the Pennsylvania State University. She teaches cartography, and her research emphases are map design and color theory applications in cartography. She consults with the U.S. Census Bureau, National Cancer Institute, National Center for Health Statistics, and National Park Service on statistical atlas design. Cindy is a member of the Inter-Society Color Council.