**Exercise 02 Report:** *Color Maps Applications and Color Deficiency Correction*

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**Summary:** This report applies different colormaps to the original color schema choice in our visualization in Exercise #1 to avoid color deficiency. Our visualization in Exercise #1 consists of a bar chart and a choropleth map to track the medal-winning countries in the Olympics. The color is used to encode the country so that users can pick out the values of specific countries. What's more, by moving the cursor over the bar chart and choropleth map, the country name and medal number will display and be highlighted. The original choice of colors turns out to be problematic for several types of color-blindness, particularly for green-blindness, red-blindness, and blue-blindness. The effect is that all areas become light brown and indistinguishable from one another. The effectiveness of the visualization of our color schemes is analyzed in the following sections.

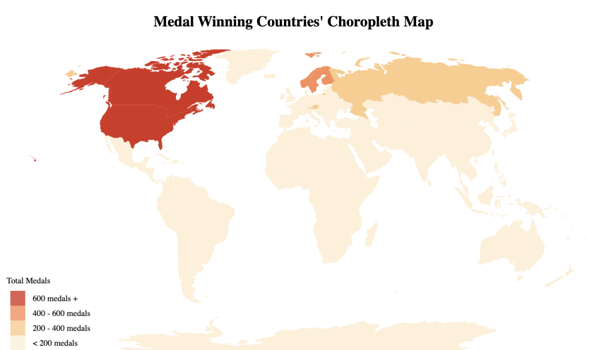


*Figure 1: Original Choropleth Map*

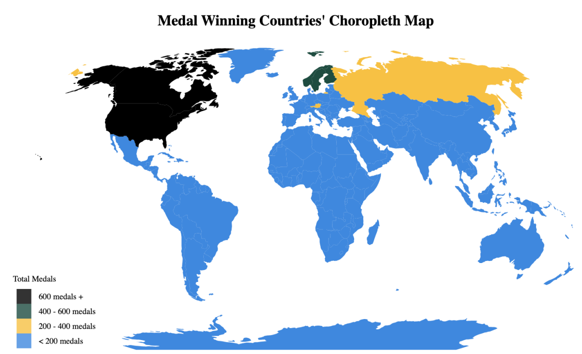


*Figure 2: New Choropleth Map*

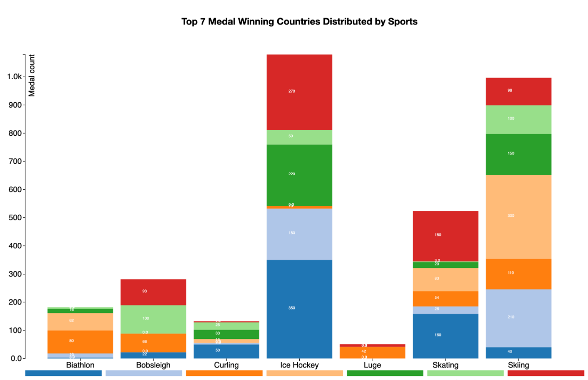


*Figure 3: Original Barchart*

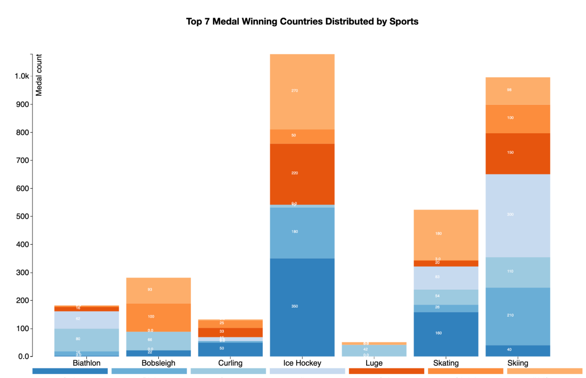


*Figure 4: New Barchart*

**Original and New Color Schemes:** Different colormaps from colorbrewer2.org have been applied for the original visualizations for Exercise #1. Figure 1 shows the original Choropleth Map, which consumes color range d3.schemeOrRd[]. And Figure 3 shows the original Barchart, which consumes color range d3.category20(). The original color scheme doesn't hold up well under various kinds of color blindness as several of the colors become hard to distinguish. Figure 2 and Figure 4 are new visualizations that apply different colormaps. Figure 2 consumes a new color palette that are colorblind-friendly, with color code as "#1E88E5", "#FFC107", "#004D40", and "#000000", while Figure 4 consumes color range d3.category20c().

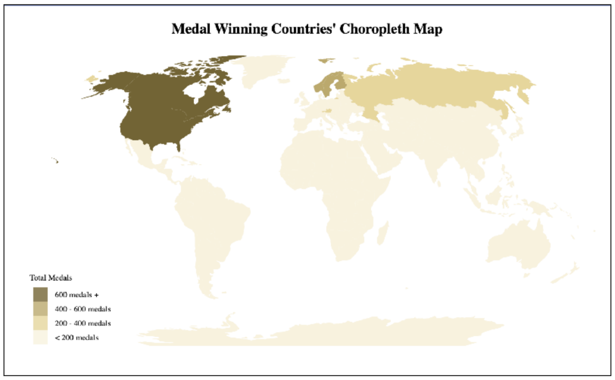


*Figure 5: Deuteranope*

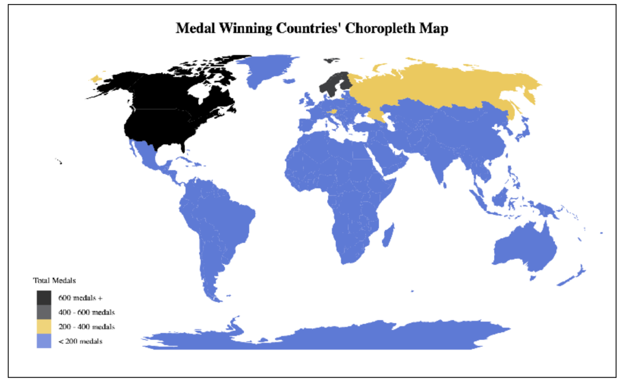


*Figure 6: Correction of Deuteranope*

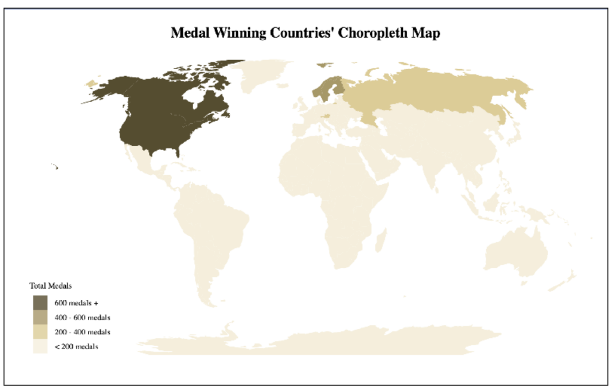


*Figure 7: Protanope*

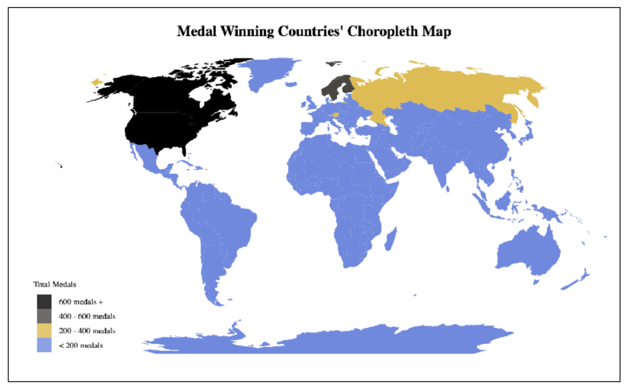


*Figure 8: Correction of Protanope*

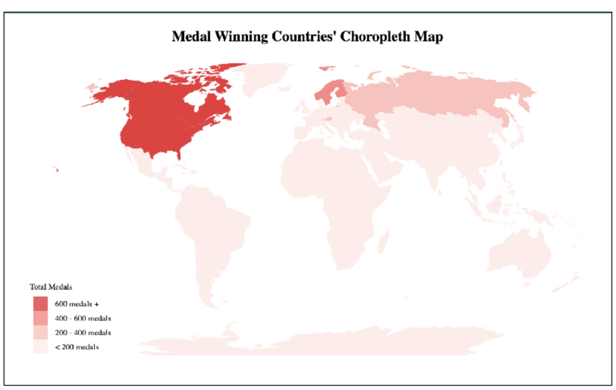


*Figure 9: Tritanope*

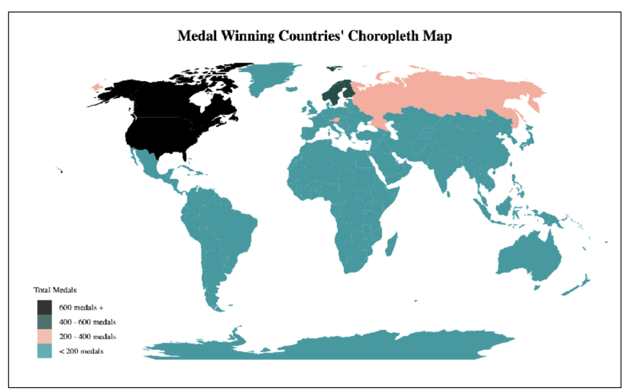


*Figure 10: Correction of Tritanope*

**Color Deficiency and Correction:** Three common color deficiencies have been tested by using the website here. By comparing the deficiency of the Figures of our original visualization and corrected visualization, it can better reflect the problems encountered by changing the colormap.

For Choropleth Map, it shows in Figure 5 (red-green color blindness) that the mutated green pigmentation yields reduced sensitivity of the green area of the spectrum, which is the most common color vision deficiency. In Figure 7, it shows that the mutated red pigment yields a darkening of red colors such that red colors can appear nearly black, which causes less ability to discriminate colors. It is another color vision deficiency that is less common than deuteranomaly in Figure 5. Another color deficiency is tritanomaly, shown in Figure 9. It is also known as "blue-yellow color blindness" but is relatively rare. The mutated blue pigment makes it difficult to distinguish between blueish and greenish hues, as well as between yellowish and reddish hues. Similarly, for Barchart, it encounters the same color deficiency issues mentioned above. Please refer to Figure 11, Figure 12, and Figure 13.

In order to avoid these color deficiency issues, new colormaps have been applied to help colorblindness better distinguish as many colors as possible. For Choropleth Map, in Figure 6 and Figure 8, after correction of Deuteranope and protanope, users can better distinguish red. And in Figure 10, after correction of Tritanope, users can better distinguish blue and yellow. For Barchart, since there are so many colors in each bar and the color deficiency issues cannot be avoided by purely changing to different colors, color range d3.category20c() has been chosen to better distinguish each color for color blindness. For example, in Figure 11, it will be really hard for red-green color blindness to distinguish between Norway and Switzerland as they are both light brown. After color correction, In Figure 14, it is easier for them to differentiate Norway and Switzerland as they are totally different colors(light purple and light brown), and so are the others.

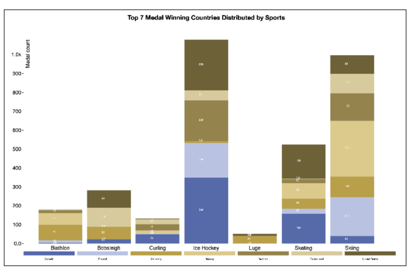


*Figure 11: Deuteranope*

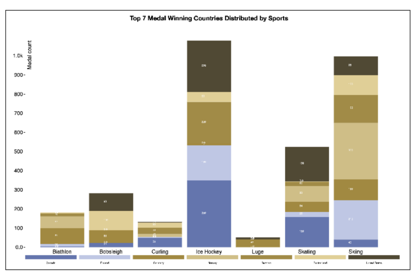


*Figure 12: Protanope*

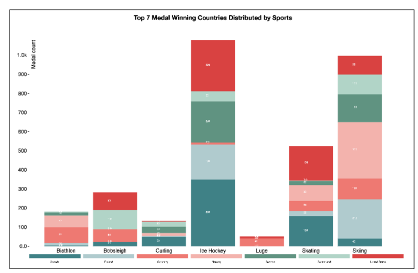


*Figure 13: Tritanope*

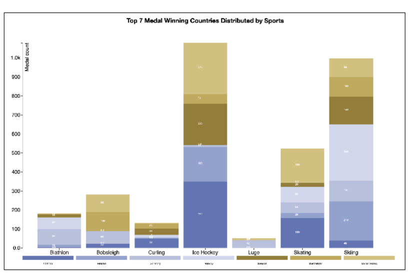


*Figure 14: Corr. of Fig.11*

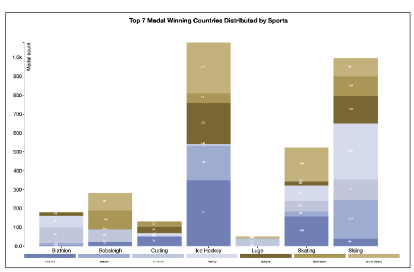


*Figure 15: Corr. of Fig.12*

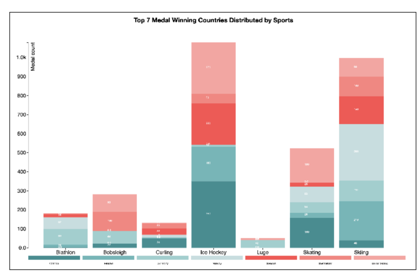


*Figure 16: Corr. of Fig.13*

**Conclusions:** Millions of people suffer from color blindness. The new colormap changes the effectiveness of visualization as it significantly improves the visualization experience for them.