International Cartographic Association
Association Cartographique Internationale

The Influence of Intuitive Associations on our Reading Comprehension of Temperature Maps

Markus Hamann [a,*], Jochen Schiewe[a], Dušan Petrovič [b]

[a] *HafenCity Universität Hamburg, markus.hamann@hcu-hamburg.de , jochen.schiewe@hcu-hamburg.de*
[b] *University of Ljubljana, dusan.petrovic@fgg.uni-lj.si*

* *corresponding author*

Keywords: effectiveness, user experience, color schemes, color vision deficiencies, temperature maps

Abstract:

Weather forecast maps are one of the most common types of maps presented to the public. The communication of weather and climate phenomena plays an important role in everyday life as well as in current debates about weather and climate phenomena - be it for explaining them to the public or for exploring and analyzing very large amounts of data.

The focus of this article is on the representation of absolute temperatures as the most important weather parameter alongside precipitation. There is no uniform, generally accepted and standardized color scheme for this; there are even a number of practical examples that violate basic cartographic rules. There is also a lack of empirical studies that examine the intuitive recognition of the specific variable temperature in more detail (Schiewe 2023).

We conducted a quantitative survey to compare the effectiveness of five different color schemes in relation to each other. These schemes were ABC (abc.net, Australia), Tagesschau (German TV), NOAA (National Oceanic and Atmospheric Administration), SAWS (South Africa Weather Service), as well as "12Tempera" (an own development; Schiewe 2023). 448 participants responded to that survey, 68 of whom reported suffering from an unspecified type of color vision deficiency that was either protanopia/protanomaly, deuteranopia/deuteranomaly, tritanopia/tritanomaly or monochromatic vision (Kolb et al. 1995). Among other questions, they were asked to identify global temperature maxima and minima from a given selection and to count local temperature maxima and minima on a given map, as well as to estimate temperature differences between two given points and, at the end, to rank the five color schemes according to their reading comfort.

The results firstly revealed a significantly reduced reading comprehension for the temperature maps that do not visualize maximum values with shades of red and minimum values with shades of blue. This effect showed to be reinforced among participants with color vision deficiencies.

Another takeaway from the survey results is a reduced effectiveness of temperature spot comprehension among participants with color vision deficiencies who read temperature maps that follow a strictly spectral "rainbow" color scheme, as it was the case for the ABC and NOAA color schemes (Figure 1). The SAWS and "12Tempera" color schemes, which almost entirely omitted shades of green and therefore follow a color path that resembles divergent color schemes more, produced more accurate counts that come closer to the true value of 11, marked by the red line in figure 1.

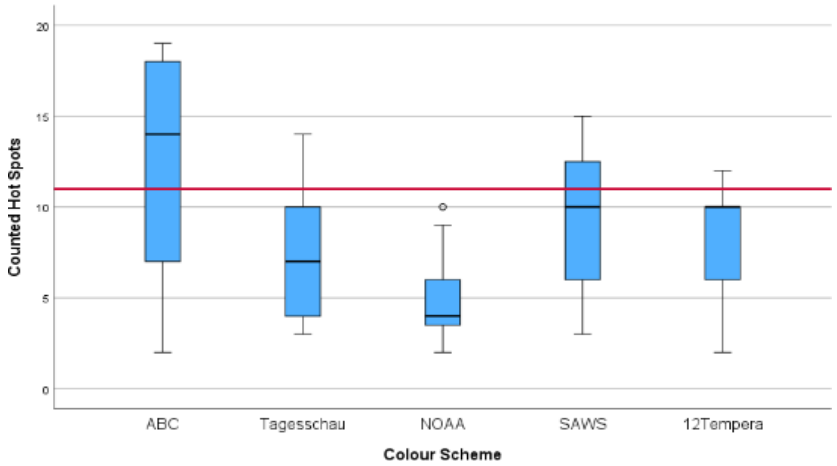

Figure 1. Distribution of counted temperature maxima among participants with color vision deficiencies (red line indicates correct value)

Abstracts of the International Cartographic Association, 10, 97, 2025
32nd International Cartographic Conference (ICC 2025), 17–22 August 2025, Vancouver, Canada.
https://doi.org/10.5194/ica-abs-10-97-2025

The reduced effectiveness of strictly spectral color schemes stands in contrast to their very good subjective impression ranking among all participants. For the NOAA scheme in particular, participants reported the highest reading comfort. The user experience ranking revealed therefore a contradiction between the effectiveness and subjective impression. This finding is not new, it has already been discovered by Brewer et al. (1997).

Concerning temperature difference estimation, users without and with color vision deficiencies were compared. For this purpose, the app *ColorOracle* (Jenny & Kelso 2007) was used to simulate color perception deficiency. Based on these simulated "colors", the CIEDE2000 algorithm was applied to calculate color differences $\Delta E00$. According to Brychtová & Çöltekin (2017) for a value of $DE_{00} > 10$ two colors can be safely differentiated. Figure 2 presents that, to our surprise, the participants with color vision deficiencies estimated the temperature differences between the two points (with $DE_{00} < 10$) in a deuteranopia simulation temperature map almost as accurately as all participants (for color differences $DE_{00} > 10$) did. The participants with color vision deficiencies seem to have somehow recognized that these two seemingly similar points show a larger temperature difference than their color displayed.

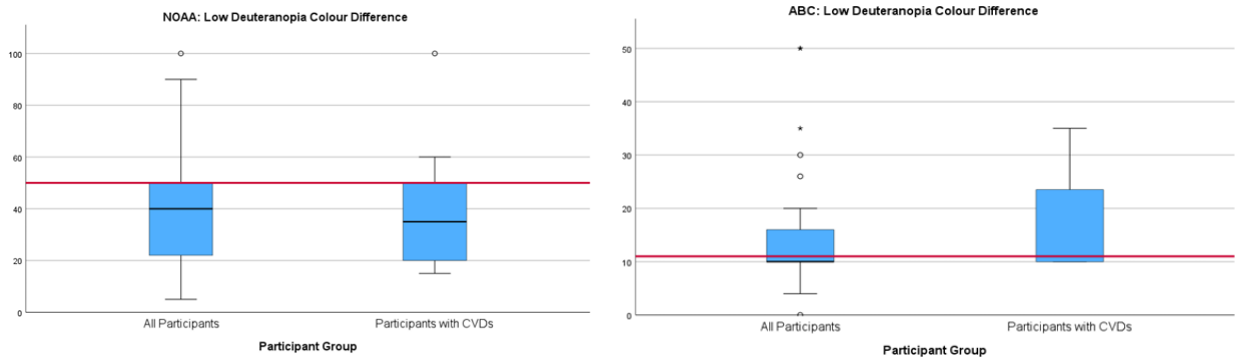

Figure 2. Distribution of estimated temperature differences in °C among respective participant groups for two schemes (CVDs = color vision deficiencies; red lines indicate correct values)

All in all, our study revealed important design requirements for temperature maps – in particular, the demand for applying the red and blue metaphor for very high and low temperatures together with the concept of a diverging scheme. Despite of rather small color differences, participants with color deficiencies performed surprisingly well, which – beyond the application of temperature maps – raises the interdisciplinary research question of which coping mechanisms the participants with color vision deficits were able to activate so that they were able to recognize the differences almost as well as all the other participants.

References

Brewer CA, MacEachren AM, Pickle LW, Herrmann D (1997) Mapping Mortality: Evaluating Color Schemes for Choropleth Maps. Annals of the American Association of Geographers, 87(3) 411-428. DOI: https://doi.org/10.1111/1467-8306.00061

Brychtová A, Çötekin A. (2017) Calculating Colour Distance on Choropleth Maps with Sequential Colours — A Case Study with ColorBrewer 2.0. *j. Cartogr. Geogr. inf.* 67: 53–60 (2017). DOI: https://doi.org/10.1007/BF03545377

Jenny, B, Keslo NV (2007) Color Oracle - Design for the Color Impaired. Cartographic Perspectives, 58: 61-67. DOI: https://doi.org/10.14714/CP58.270

Kolb H, Kalloniatis M, Luu C (1995) Webvision: The Organization of the Retina and Visual System. University of Utah Health Sciences Center, Salt Lake City (UT)

Schiewe J (2023) Farbschemata für Temperaturkarten – Was liegt zwischen Blau und Rot? KN - Journal of Cartography and Geographic Information, 3: A13-A19. https://static-content.springer.com/esm/art%3A10.1007%2Fs42489-023-00147-5/MediaObjects/42489_2023_147_MOESM1_ESM.pdf