

# The Influence of Colour on the Perception of Cartographic Visualizations

Zbyněk ŠTĚRBA,<sup>1</sup> Jan D. BLÁHA<sup>2</sup>

<sup>1</sup> Department of Geography, Masaryk University in Brno, Czech Republic

<sup>2</sup> Department of Geography, J. E. Purkyně University in Ústí nad Labem, Czech Republic

## ABSTRACT

The contribution provides an overview of the ways colour is used in cartographic visualizations and how it affects perception of these visualizations. Colour is generally considered as the most important graphic variable for expressing spatial information in cartographic visualizations. Through appropriate use of colours, the content of a map can be significantly accentuated, which enhances its legibility and comprehensibility profoundly. Appropriate use of colours is a very important factor in many cartographic applications, such as emergency management tools, in which cartographic visualization helps to transfer the required information effectively. A well-chosen colour scheme with appropriate contrasts is the best way to depict the overall character of an area or a phenomenon. The present paper describes the most significant approaches to colour use in cartography, which can be of immense help when communicating information to map users.

## 1. INTRODUCTION

When creating cartographic products, the form of depiction of the map's content is one of the primary outcomes of a cartographer's work. At the same time, the way various map symbols are depicted is a factor which is most likely to influence users' interpretations of the map. Different means of cartographic information transmission evolved gradually, but the greatest boom came with the development of thematic cartography, whose methods provided extra space for invention in the design of cartographic symbology.

The classic text in the field of cartographic symbology is Jacques Bertin's *Semiology of Graphics* (*Sémiologie Graphique*). The book, published in 1967, was the first to define basic cartographic means of expression, also referred to as graphic variables. Apart from the feature's position on the map, which represents the spatial location itself, external characteristics of a symbol can be described through various variables communicating different types of information. These variables, co-indicators of a symbol's content, include size, intensity, shape, orientation, structure and colour (among others).

Out of these, colour is generally considered as the most important graphic variable for expressing spatial information in cartographic visualizations. Colour can be used to display a relatively large amount of information in a single map without reducing the map's legibility and comprehensibility. Colour can also be easily combined with other variables, increasing their communication potential. Finally, in both thematic and topographic maps, colour is one of the principal enhancers of aesthetic quality, making the map much more visually attractive.

## 2. METHOD

Cartographic products are generally very powerful tools for communicating visual and spatial information. Through appropriate use of colours, the content of each map can be significantly accentuated, increasing the map's legibility and comprehensibility rapidly. Conversely, use of inappropriate colours and colour combinations can significantly undermine users' perception of the visualized information. Colour is used as a communication means in most elements and symbols within a map. Therefore, it both helps to communicate cartographic information and increases the legibility of the map and its aesthetic quality (Bláha, 2011). Hence, colours and colour contrasts influence the aesthetics of a map and the user's emotional response, as well as the map's usability.

Colour perception is definitely influenced by physiological, psychological, and other subjective factors. It is therefore always necessary to consider specific contexts in which the map will be used, such as light conditions (outdoor v. indoor use, etc.), type of cartographic product (analogue v. interactive map), map size (or display size of the display device), typical situations in which the map will be used, as well as potential cultural specifics (Bláha, 2013). Chesneau et al. (2005) argue that colours are able to elicit emotional responses that might significantly influence decision-making in map users. This effect is stronger in colour than in any other graphic variable. Drápela (1983) also views colour as a specific means of expression occupying a special position among cartographic variables and points out different aspects which should be considered when using colour effects in map design. Krygier & Wood (2005) describe several examples of inappropriate colour use in maps and emphasize the counterproductive impact of inappropriate colours on map legibility, which may manifest especially as erroneous or slow map interpretation. Inappropriate colour use also involves employment of inadequate colour ranges for displaying qualitative and quantitative data. On the other hand, use of appropriate colours and colour combinations can increase overall comprehensibility and legibility of the map substantially.

### 2.1 Colour contrast

An important thing to consider when designing map products is the contrast between different colours. This is because the effect of colours in maps – just like in any other graphic visualization – always depends on their combinations with other colours. Colour contrast can greatly enhance effective representation of the target information. A well-applied palette of contrasting colours is a perfect means of depicting the overall character of an area or a phenomenon, as the perceiver can immediately see the spatial distribution as well as the quantity and quality of different features on the map. Appropriately selected contrasts intensify the perception of the figure and the ground through dividing the map field into “layers” representing base and extension information (see Stachoň et al., 2013). As Krygier & Wood (2005) point out, contrast must be taken into consideration in any map design. It is therefore necessary to choose colours carefully to make them suitable for a particular background. Colours that are chosen arbitrarily and carelessly may produce uneven contrasts, which, in turn, may result in ambiguous perception of some of the features on the map, which become semantically indiscernible and unclassifiable.

In general, contrast refers to a situation when a clear difference can be observed between two juxtaposed objects or phenomena (Itten, 1987). Hence, contrast can result from differences in size, temperature or – in this case – colour. These observed differences are

always relative because they arise through comparisons between two or more objects. Perception of colour and colour contrasts is a largely subjective process, which makes it hard to quantify or describe in detail. In the past (especially since the early 19<sup>th</sup> century), a relatively large number of authors commented on the issue of colour contrast (for overview, see Chesneau et al., 2005). However, it was not until Johannes Itten<sup>1</sup> that colour laws were finally formulated with sufficient objectivity, and principles of colour perception postulated which are often used in cartography to this day. Itten's principles systematically and explicitly define and describe seven basic types of contrasts observable in colour perception: contrast of hue, light-dark contrast, cold-warm contrast, complementary contrast, simultaneous contrast, contrast of saturation, and contrast of extension (for more detail and examples, see Bláha & Štěřba, 2014).

It has to be noted that, in reality (and all the more on the map), the above contrast types complement and mingle with each other and therefore cannot be treated as completely separate variables. For example, simultaneous contrast especially affects areas which also show the contrast of extension. Extension (relative area size), in turn, tends to influence colour saturation and colour lightness. On the other hand, the perception of colours as cool or warm, particularly with regard to their function as depth cues, is mostly independent of relative area size. All of this indicates that there might be certain hierarchy among different contrast types. Map design, just like visual arts, uses the law of cool and warm colours. When reading a map, similarly coloured (cool or warm) areas create an impression of similar depth, independent of area size. This effect is even more marked in cartography than in visual arts, where contrasts were originally studied. An impression of depth can also be achieved through the contrasts of saturation and light and dark, which is why figure elements on the map should always be depicted in deep and dark colours. When applied appropriately, the effects of individual contrasts will be multiplied.

Design of cartographic symbology should follow certain rules which are implicitly contained in the above principles. There are also other methods of increasing contrast that can be used to enhance the distinctness of particular features on the map. For example, Kennely & Steward (2010) design choropleth maps with additional shading within the individual categorized polygons to create an illusion of a (pseudo)three-dimensional visualization. This effect enables further differentiation of individual elements within the same interval, adding new information represented – thanks to the impression of plasticity – by the polygon's "height". To a certain extent, this impression is also enhanced by appropriate choice of colour contrast – i.e. if features representing greater values are depicted in intensive and more saturated colours, there will be a stronger perception of ground features (polygons representing low values) and figure features (polygons representing high values). Obviously, a similar method could be used to visualize qualitative phenomena, namely to accentuate the contrast between warm and cool colours. Adequate choice of colour combinations and contrasts should, naturally, be also directed by the purpose for which the map is designed.

---

<sup>1</sup> Johannes Itten (1888 – 1967) was a Swiss designer, expressionist painter and theoretician closely associated with the arts and architecture group *Bauhaus*. He was especially interested in colour theory and studied the impact of colour on visual perception.

## 2.2 Effect of colour on the perception of a map

Colour perception, in general, is a very complex process. Apart from the properties discussed above, this is also caused by the fact that individual colours create different impressions in different people. Moreover, colour perception is strongly influenced by the context, i.e. colour properties of the surrounding objects as well as other external factors (Kryger & Wood, 2005).

MacEarchen (2004) notes that cartographers harnessed the knowledge of individual differences and variation in colour perception, and of the way people interpret cartographic information differently depending on the employed colour combinations, relatively early in the past. The best illustration is the cartographic visualization of elevation layers by means of hypsometric tints. This convention, established by Karl Peucker<sup>2</sup> in the late 19<sup>th</sup> century, is used in various analogous forms in atlas designs to this day (Thrower, 2008). The principle of this method consists in the fact that perception of distance (or depth) varies with changing colour tints or hues. This creates an impression of depth perspective and facilitates the process of information transmission. For example, hues of long wavelengths (orange and red) are perceived as closer on the map than hues of short wavelengths (blue and green). This phenomenon is often employed in spectral ranges (or, more often, their parts) used in cartographic visualizations. As specified by Imhof (2007), this stereoscopic effect does not result directly from physiological processes, but arises from a psychological illusion that is formed in people's minds. It is also advisable that similar colour ranges additionally involve the cold-warm contrast, which amplifies the overall impression of distance. Hence, colour ranges that include cool colours as well as warm colours (e.g. red – orange – light blue – dark blue) show particularly good properties in cartographic products.

Drápela (1983) describes the effect of colour, especially colour excitability, on the expression of positive and negative qualities of a phenomenon. “Calm” colours include shades and tints of yellow, blue and green. These colours create the most placid impression in people. “Excitable” colours, on the other hand, are represented by the other pole of the spectrum, namely by the red colour. The colour which is considered most excitable is non-spectral purple, which is physically composed of light with the shortest and longest wavelength (red and blue). This effect is probably caused by an increased struggle of the visual system to form a sharp image of purple-coloured objects on the retina. These properties are partly used – in analogy with traffic conventions – also in emergency maps to display potential hazards (see Konečný et al., 2011).

Cartographers who design maps are sometimes limited by various rules, standards and other conventions whose meaning is largely historical. Adherence to these rules is usually implicitly required by the user, and any deviations might lead to incorrect interpretations of the cartographic material. Such general conventions are summarized, for example, by Robinson et al. (1995), who find it natural that green colour represents areas covered by vegetation, brown colour indicates mountain ranges and yellow colour is used to depict areas with poor moisture supply (dry land, areas without vegetation cover, etc.). Besides mere conventionality, however, these expectations are fuelled by the connotations evoked by different colours, i.e. associations they tend to produce in most people (e.g. blue suggests moisture and cold, brown is associated with soil, etc.). Apparently, conventions

---

<sup>2</sup> Karl Peucker (1859 – 1940) was an Austrian theoretical cartographer.

such as these should be observed especially in maps designed for the general user. The more specialized a map is, the more its design should adhere to the rules and standards typical for that particular domain. As another example, Vasilev (2006) discusses how habitual practices of colour use in maps may vary due to regional or national differences. Apart from several, mostly topographical features (*blue* for bodies of water, *green* for forests and *brown* for mountains), individual colours may imply different meaning in different geographical areas. This could be caused not only by differences in culture and cultural traditions, which may produce different emotional impacts of a particular colour on the individuals, but also by differences in actual colour perception characteristic of the context or environment in which the cultural community lives. Finally, colours can also be perceived differently due to variations in individual dispositions.

### 3. CONCLUSIONS

In cartography, appropriate use of colours plays a crucial role in effective communication of the target information. A well-chosen colour scheme with suitable contrasts provides the best way of depicting the overall character of an area or a phenomenon. For these reasons, appropriate use of colours is especially important in domains such as emergency management where cartographic visualisations are extremely helpful in obtaining all of the needed information. Colour can be a very effective tool for displaying emergency situations. It can be used to depict possible hazards, ongoing events, or the current state of restoration processes in the afflicted areas. However, it must be noted that the domain of emergency management cartography tends to be particularly affected by conventions in colour use, which might be very limiting for cartographers designing these types of products.

In general, cartographic products for emergency management are employed by users who need to obtain the target information as quickly as possible, with a substantial level of accuracy. Decisions based on unclear cartographic visualisations could lead to misunderstandings that may finally turn into weighty losses. Through the employment of adequate colour contrasts, one can achieve optimum differentiation between the figure (most important) and the background (less relevant) information. This effect helps to significantly increase the efficiency and effectiveness of perception of the target information, which has a strong impact on the overall usability of a map.

### ACKNOWLEDGEMENTS

This work was supported by the project „Employment of Best Young Scientists for International Cooperation Empowerment“ (CZ.1.07/2.3.00/30.0037) co-financed from European Social Fund and the state budget of the Czech Republic.

### REFERENCES

- Bláha, J. D. (2011). Aesthetic Aspects of Early Maps. In Ruas, A. (ed) *Advances in Cartography and GIScience. Vol. 1, Selection from ICC 2011 Paris*, 53–71.
- Bláha, J. D. (2013). Cultural Aspects of Cartographic Creation: Use of Mental Maps in Cross-cultural Research. In *Proceeding of 26th ICC Dresden*, 1–15.

- Bláha, J. D., Štěrba, Z. (2014). Colour Contrast in Cartographic Works Using the Principles of Johannes Itten. In *Cartographic Journal*: 51(3), 203-213.
- Chesneau, E., Ruas, A., Bonin, O. (2005). Colour Contrasts Analysis for a better Legibility of Graphic Signs on Risk Maps. In *22nd International Cartographic Conference 9-16 July* [online], A Coruna, 2005, 10 s,
- Drápela, M. V. (1983). *Vybrané kapitoly z kartografie*, 1. vyd., SPN Praha, Brno, 1983, 128 s.
- Imhof, E. (2007). *Cartographic Relief Presentation*, 1. vyd., 2007, ESRI Press Redlands, 416 s., ISBN 978-1-58948-026-1.
- Itten, J. (1987). *Kunst der Farbe: subjektives Erleben und objektives Erkennen als Wege zur Kunst*, Maier, Ravensburg.
- Konečný, M. et al. (2011). Dynamická geovizualizace v krizovém managementu. Brno: Masarykova univerzita, 379 p. ISBN 978-80-210-5858-3.
- Krygier, J., Wood, D. (2005). *Making Maps: a Visual Guide to Map Design for GIS*, 1. vyd., New York: Guilford Press, 2005, 303 s., ISBN 1593852002.
- MacEachren, A. M. (2004). *How Maps Work: Representation, Visualisation and Design*. New York: The Guilford Press, 2004, 513 s., ISBN 0-89862-589-0.
- Robinson, A. H., Morisson, J. L., Muehcke, P. C., Kimerling, A. J., Guptill, S. C. (1995). *Elements of Cartography*, 6. vyd., Wisley&Sons, 1995, 664 s., ISBN 0-471-55579-7.
- Stachoň, Z., Šašinka, Č., Štěrba, Z., Zbořil, J., Březinová, Š. and Švancara, J. (2013). 'Influence of Graphic Design of Cartographic Symbols on Perception Structure', *Kartographische Nachrichten*, 63(4), pp. 9.
- Thrower, N. J. W. (2008). *Maps & Civilization: Cartography in Culture and Society*, 3. vyd., The University of Chicago Press, 2008, 352 s., ISBN 978-0-226-79974-2.
- Vasilev, S. (2006). Cartographical Symbolic. In *International Conference on Cartography and GIS* [online], Borovetz, 2006. Gage, J. 2008. *Signs of Disharmony: Newton's Opticks and the Artists*, *Perspectives on Science* 16(4) 360-377.

*Address: Zbyněk Štěrba, Ph.D., Department of Geography, Faculty of Natural Sciences,  
Masaryk University, Kotlářská 2, Brno, 611 37, Czech Republic  
E-mails: zbynek.ste@gmail.com, jdg@seznam.cz*