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UNESP – UNIVERSIDADE ESTADUAL PAULISTA

"JÚLIO DE MESQUITA FILHO"

CÂMPUS DE PRESIDENTE PRUDENTE

Programa de Pós-graduação em Ciências Cartográficas

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COLOR PREFERENCE OF CARTOGRAPHIC SYMBOL DESIGN RELATED TO THE URBAN LANDSCAPE CHARACTERISTICS OF SÃO PAULO WESTERN REGION FOR 1:10,000 TOPOGRAPHIC MAPS

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Master Science dissertation presented to the Programa de Pós-graduação em Ciências Cartográficas, Faculdade de Ciências e Tecnologia de Presidente Prudente/SP – UNESP.

Supervisor: Prof. Dr. Edmur Azevedo Pugliesi

Presidente Prudente – SP

2021

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Câmpus de Presidente Prudente

ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DE GUSTAVO GRASSI, DISCENTE DO PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS CARTOGRÁFICAS, DA FACULDADE DE CIÊNCIAS E TECNOLOGIA.

Aos 13 dias do mês de setembro do ano de 2021, às 14:00 horas, por meio de Videoconferência, realizou-se a defesa de DISSERTAÇÃO DE MESTRADO de GUSTAVO GRASSI, intitulada **COLOR PREFERENCE OF CARTOGRAPHIC SYMBOL DESIGN RELATED TO THE URBAN LANDSCAPE CHARACTERISTICS OF SAO PAULO WESTERN REGION FOR 1:10,000 TOPOGRAPHIC MAPS.** A Comissão Examinadora foi constituida pelos seguintes membros: Prof. Dr. EDMUR AZEVEDO PUGLIESI (Orientador(a) - Participação Virtual) do(a) Departamento de Cartografia / Faculdade de Ciencias e Tecnologia de Presidente Prudente, Profa. Dra. CLAUDIA ROBBI SLUTER (Participação Virtual) do(a) Instituto de Geociências / Universidade Federal do Rio Grande do Sul, Prof. Dr. JOÃO VITOR MEZA BRAVO (Participação Virtual) do(a) Instituto de Geografia / Universidade Federal de Uberlândia. Após a exposição pelo mestrando e arguição pelos membros da Comissão Examinadora que participaram do ato, de forma presencial e/ou virtual, o discente recebeu o conceito final: APROVADO . Nada mais havendo, foi lavrada a presente ata, que após lida e aprovada, foi assinada pelo(a) Presidente(a) da Comissão Examinadora.

Prof. Dr. EDMUR AZEVEDO PUGLIESI

To my beloved parents, Zilda and Orlando, to my sister, Júlia, to my cats (Sami, Ninim, especially Ziva), to my dogs (Kate and Mulanguim), in memoriam of Lilica.

To my sensei, dr. Daisaku Ikeda.

To my great friends, Bruno, Mari, Vito, and colleagues with whom I shared this brief journey.

ACKNOWLEDGEMENTS

"Buddhism is a teaching of unsurpassed reason. Therefore, the strength of your faith must manifest itself in the form of studying, exercising your ingenuity, and making twice as much effort as anyone else. Earnest daimoku is the wellspring for the energy to challenge these things."

Daisaku Ikeda

Abstract

This research aims to evaluate the preference for buildings cartographic symbol designs for topographic maps at 1:10,000 scale, to define symbols that may represent part of the western urban landscape located in the state of São Paulo. Three proposals were designed to represent urban buildings in the context of topographic maps: Pink visually coherent with the national cartographic conventions; Orange visually coherent with the urban landscape of the western portion of the São Paulo state; Gray visually coherent with the digital navigational maps used frequently. The map evaluation considered the preference for the symbol designs by using two groups of participants, one named architects, and the other named non-architects. Participants gave their opinions about the designs, scored, and ordered them as well. The Orange design, understood as visually coherent with the urban landscape of the western portion of the São Paulo state, was the most preferred in all aspects, in terms of opinion, score, and order of preference. Despite that, the differences in score and order of preference between Orange and Pink designs were not statistically significant. On the other hand, the differences in score and order of preference between Gray and the two other designs were statistically significant, indicating that the Gray as the least preferred. The participants' opinions indicated that the preference for the Orange is related to the better contrast between the buildings and the other cartographic symbols on the map. Also, the preference was influenced by the visual comfort provided by the composition, for being more colorful and more attractive, when compared with Pink and Gray. Furthermore, from the statistical analysis considered, map users with background knowledge in architecture and those with other backgrounds could be considered part of the same population.

Keywords: Topographic map; Cartographic design; Cartographic symbol design; Landscape; Color preference.

Resumo

O objetivo desta pesquisa é avaliar a preferência de símbolos cartográficos de edificações em mapas topográficos na escala 1: 10.000, para definir símbolos que podem representar parte da paisagem urbana localizada no oeste do estado de São Paulo. Foram elaboradas três propostas de mapas topográficos para representação de edifícios urbanos: Rosa visualmente coerente com as convenções cartográficas nacionais; Laranja visualmente coerente com a paisagem urbana do oeste paulista; Cinza visualmente coerente com os mapas de navegação digitais usados com frequência. A avaliação do mapa considerou a preferência pelos desenhos dos símbolos usando dois grupos de participantes nomeados de arquitetos e não arquitetos. Os participantes deram suas opiniões sobre os designs, pontuaram e também os ordenaram. O design Laranja entendido como visualmente coerente com a paisagem urbana do oeste paulista foi o mais preferido em todos os aspectos, ou seja, em termos de comentários, pontuação e ordem de preferência. Apesar disso, as diferenças em pontuação e ordem de preferência entre os designs Laranja e Rosa não foram estatisticamente significativas. Por outro lado, as diferenças na pontuação e ordem de preferência entre Cinza e os dois outros designs foram estatisticamente significativas, indicando que o Cinza foi o menos preferido. As opiniões dos participantes indicaram que a preferência pelo Laranja está relacionada com o melhor contraste entre as edificações e os demais símbolos cartográficos no mapa. Além disso, a preferência foi influenciada pelo conforto visual proporcionado, por ser mais colorido e atraente que o Rosa e o Cinza. Além disso, a partir da análise estatística utilizada nesta pesquisa, os usuários do mapa com formação em arquitetura e aqueles com outras origens podem ser considerados parte da mesma população.

Palavras-chave: Mapa topográfico; Projeto cartográfico; Projeto de símbolo cartográfico; Paisagem; Preferência por cor.

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Summary

1. Introduction

Topographic maps represent natural and anthropic geographic features of the Earth's surface (KEATES, 1973). These kinds of maps present a wide variety of landscape features, and they serve as a basis for several applications (ROBINSON et al., 1995; SSC, 2005; KENT, 2009; COLLIER, 2009). The beauty associated with topographic maps is related to how the landscape characteristics are symbolized cartographically (KENT, 2005). Each country has its symbology style, which is applied to the national topographic maps (ROBINSON et al., 1995) and the style may characterize a national identity (KENT, 20009; KENT; VUJAKOVIC, 2009).

Studies regarding the representation of topographic maps that have been conducted worldwide are limited (SLUTER et al., 2018). Some of the research in Europe focused on understanding the characteristics and peculiarities of the topographic map's styles used by the national mapping agencies in European countries (KENT, 2009; KENT; VUJAKOVIC, 2009, 2011; ORY et al., 2015). The style of a topographic map could be identified by symbology and texts, which is employed to describe landscape (KENT, 2005). Those works considered topographic maps at 1:50,000 scale to identify stylistic similarities between national symbology.

In the United States, Raposo and Brewer (2014) studied the preference of different cartographic designs by using orthoimages as background for U.S. topographic maps at 1:24,000 scale. They tested different designs for the whole U.S. considering several different landscapes. Their results identified that the preference for the topographic map design was influenced by the landscape portrayed.

In Brazil, efforts have been engaged on studying large-scale topographic maps mainly with cartographic generalization (COMÉ; SLUTER, 2015; CASTRO; SLUTER, 2019; GRASSI; PUGLIESI, 2020b), cartographic representation at multiple scales (MENDONÇA;

AMORIM; PUGLIESI, 2017), and cartographic symbol design (NATINGUE, 2014; SLUTER et al., 2018; LEMES NETO, 2020). Brazilian researchers have, recently, concentrated on studying large-scale topographic maps representations due to the absence of cartographic conventions[1] (SLUTER et al., 2018).

Paraná state established its large-scale cartographic conventions visually coherent with the national cartographic conventions (SLUTER et al., 2018). In São Paulo, cartographic conventions are established by *Instituto Geográfico e Cartográfico do Estado de São Paulo -* IGCSP (Geographic and Cartographic Institute of the São Paulo State), a state mapping agency. Among the products made and supplied by IGCSP, one of them is the topographic maps at 1:10,000 scale, which are resulting from photogrammetric restitution by using Computer-Aided Design (CAD) tools. Observing the urban landscape of the western region of the São Paulo state through a true color composition of satellite images or orthoimages at 1:10.000 scale, some features are noticeable: buildings in a mix of orange, red, and brown shades; paved roads in dark gray; and vegetation in medium-dark green shades. Those features seem to be representative of the urban space at 1:10.000 scale.

Both state agencies mentioned previously employ different ways of representing the urban landscape. It seems that both of them seek to follow visual coherence with the conventions established by the national topographic mapping[2] agency instead of coherence with certain features of the urban landscape, such as those buildings symbols in shades of red. According to Sluter et al. (2018), in Parana state the *Câmara Técnica de Cartografia e Geoprocessamento* – CTCG (Technical Chamber of Cartography and Geoprocessing) agency requested from their research group a study about large-scale topographic map conventions. They declared have followed principles of legibility for topographic maps which were

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[1] The definition of cartographic conventions on topographic maps follows Kent and Vujakovic (2009), "e.g. surronding the use of color, such as blue for water, brown for contours, green for vegetation, and black for 'cultural' features".

[2] In Brazil, the expressions "national systematic mapping" or "systematic mapping" are used for topographic mapping.

presented by Keates (1973). The result presented by the authors is similar to the national cartographic conventions.

On the other hand, to represent the portion west of the São Paulo state on large-scale maps, designing cartographic symbols and evaluating the communication quality of those symbols are necessary to recommend to the IGCSP agency appropriate ways of characterizing the landscape. Since this study is purely scientific, were sought options and non-orthodoxy possibilities for conceiving a large-scale topographic map representation, which is the first Brazilian study to explore this unknown area.

The landscape representation through topographic map symbols could be established based on different aspects of visual coherence, such as the conventions established for the national topographic mapping, the experience or habit of using online maps for navigation, the similarity of the symbol with the regional landscape. The national cartographic conventions that represent the official topographic maps, for scales between 1:25,000 and 1:250,000, are available in the technical manual T34-700, are established by the *Diretoria de Serviço Geográfico do Exército* (Brazilian Army) (BRASIL, 2000). In the absence of cartographic conventions for large-scale topographic maps, the municipalities or the states could have available a standard symbology to produce a homogeneous mapping for all municipalities that respect the regional and local landscape characteristics.

The frequent experience or the habit of using online navigational maps (such as Google Maps, Bing Maps, ArcGIS Online, or Waze) may influence the preferences when choosing the symbolized landscape through a topographic map. Experience or habit is a Gestalt law in searching for visual patterns (ELLIS, 1955; MACEACHREN, 1995). According to Dearden (1984), familiarity and habit with particular places, such as forests, farms, or cities in recreational activities and travels, influenced the landscape preference. Additionally, Hammitt, Knauf, and Noe (1989) found that recreational activity preference is strongly related to experience in that activity, not their expertise.

The beauty and aesthetic of a place can be translated into cartographic conventions and applied to topographic maps (KENT 2005). Associating the cartographic symbol with the landscape could define identities that vary through the space on a topographic map. Thus, the cartographic convention could be thought of and developed to portray a local or a regional landscape.

The landscape perception is strongly related to the scale and to the observer's cultural background, and "it could be defined as the domain of the visible, that which the view encompasses" (SANTOS, 1988). Considering individual differences, people with different characteristics or levels of knowledge, such as a professional trained in architecture, an artist, or an ordinary person, could perceive the landscape differently (SANTOS, 1988).

The process of perceiving the local landscape that is portrayed on a topographic map may be entirely dissimilar among readers with different levels of knowledge. In addition, as the topographic map symbols would be consistent with the local landscape, the readers' preference for the landscape may influence his preference for different map designs.

In research carried out by Dearden (1984), the landscape preference of a group of participants was strongly influenced by the current living environment (last five years) and past landscape experiences. Also, the recreational activities and travel, otherwise, professional expertise and socio-economic variables did not influence them. In the matter of topographic map design preference, Raposo and Brewer (2014) found out that the landscape characteristics had direct influences on the map readers' preference.

Consequently, the landscape of the living environment seems to affect the individuals' preference for the landscape. It appears that the preference for different topographic map designs is closely related to the landscape characteristics. Although the national conventions are related to the landscape, the generic character of the landscape for the whole country may not be the most appropriate at the local and regional levels.

Hence, two questions are presented by considering the visual coherence between the propositions created in this research and the concepts that they represent, intending to supply the absence of large-scale topographic map conventions for the São Paulo state. First, which kind of design best represents the landscape of the western region of the state of São Paulo: national conventions, online maps for navigation, or urban landscape? Second, could professional training influence the preference for choosing different designs?

It is hypothesized that people who live in the west of the São Paulo state will prefer topographic maps at 1:10,000 scale more visually related to the landscape characteristics that are present in the region where they live due to previous experience with that landscape rather than a design visually coherent with the national cartographic conventions, or visually coherent with the online navigation maps.

1.1. Aim

This research aims to evaluate the preference for cartographic symbol designs that represent buildings on topographic maps at 1:10,000 scale, to define symbols that may represent part of the western landscape of the state of São Paulo. The specific objectives for this study are summarized in:

- Design three proposals of buildings cartographic symbol for topographic maps considering three types of visual coherence: national conventions, online maps for navigation, and urban landscape.
- Analyze the subject's opinions about each proposed design.
- Analyze the subject's preference for the designs in terms of score and order of preference.

1.2. Justification

The topographic maps at 1:10,000 scale, produced by the *Instituto Geográfico e Cartográfico do Estado de São Paulo* – IGCSP (Geographic and Cartographic Institute of the São Paulo State), are available in CAD (Computer-Aided Design) and paper formats. However, those types of material have their representations limited for database purposes and for viewing in digital media. In contrast, some countries offer online platforms for topographic maps, such as the United States of America (United States Geological Survey – USGS), Germany (*Geodateninfrastruktur Deutschland* – GDI), the United Kingdom (Ordnance Survey – OS), and the Netherlands (*Publieke Dienstverlening Op de Kaar* – PDOK), also due to the digital technology advances and a stable economy.

In Brazil, an initial effort has been conducted (https://bdgex.eb.mil.br/bdgexapp/mobile/), but it seems that official national topographic maps are far away to be constructed and used effectively online in the following years. Since there are no national cartographic conventions for maps at 1:10,000 scale, topographic maps produced by IGCSP should have their conventions.

Kent (2009) points out the importance of representing topographic maps as a means of revealing a "socially constructed landscape," which could be understood as "achievement of political independence". In addition to portraying the landscape, the cartographic symbols could reveal its beauty (KENT, 2005). A beautiful, pleasant, and attractive map tends to be used more often. In the digital environment, especially on the internet, the beauty and quality of the map are vital elements to attract the user to read, return and continue visiting your content (DEEB et al., 2015).

Topographic maps can be used to implement several applications that are part of people's daily lives. It is possible to think that the availability of topographic maps on the internet that reveal the landscape features can be reached by many users. In this sense, the

construction of a symbology based on theories of cartographic communication and psychology of perception can contribute to achieving map communication and encourage the use of topographic maps.

When considering the state of São Paulo, the most populous in Brazil, the development of user-oriented symbology can positively impact many users in different areas, such as education, urbanism, business, and engineering. This work aims to take a step towards those paths and seek an initial comprehension about the topographic maps preference with a group of people who live in the west of the São Paulo state and serve as a source of inspiration and reference for further studies research on this subject.

1.3. Dissertation overview

This dissertation was structured in the following five chapters. Chapter 2 "Literature review" serves as the theoretical basis for elaborating and evaluating the cartographic designs: topographic maps, landscape, light and receptors, perceptual organization, principles of color for mapping, and map evaluation. Chapter 3 "Cartographic design for the topographic maps" considers the processes of planning the map, obtaining and preparing the cartographic database, designing the cartographic symbols. Chapter 4 "Assessment of the user's preference" presents the steps employed to prepare questionnaires, and commitment documents that are required for the interviews, the recruitment of subjects, the experimental design, and the details of the procedure that involves the map evaluation. Chapter 5 "Results" describes the process of analyzing qualitative and ordinal data obtained from the interviews with the subjects, taking into account the statistical distribution of the data, and the type of statistical analysis that fit with the data. Chapter 6 "Conclusion and recommendations" presents the analysis of the results and bring out ideas for further research.

6. Conclusions and recommendations

Each design conceived in this research was related to a specific concept: Orange consistent with the western landscape of the state of São Paulo, Pink consistent with national cartographic conventions, and Gray consistent with frequently used navigation maps. For each one of them, it was sought to employ the basic principle of readability to achieve effective cartographic communication in terms of satisfaction. Then, it is possible to affirm that this goal was completed for the design expected to be the most appropriate concerning the visual coherence with the local landscape since the average of the scores given by the architects and non-architects was high. They were more significant than nine for the group of the architects, on a scale ranging from zero to 10.

The Orange was the most preferred by both groups in terms of scores and order of preference. It was reported as the one with the highest visual contrast between the cartographic symbols. Compared to Orange, Pink was the second most preferred by both groups, mainly because of its slightly reduced visual contrast between the map symbols. However, the difference in preference (score and order) between Orange and Pink was not statistically significant. Gray was the least preferred by architects and non-architects, mainly due to the lack of contrast between the cartographic symbols. The difference in the preference between Gray and the colored designs was statistically significant, indicating it as the least preferred for using on a topographic map.

The hypothesis was partially confirmed. The design with more remarkable similarity to the local landscape was the most preferred by the participants. However, the motivation for this preference does not have happened by the supposed visual coherence with the local landscape. The determining factor reported by the participants for that preference was related to the orange color used to represent buildings that were visually contrasting with the other cartographic symbols present on the map. From the opinions, the terms 'pleasurable,'

'comfortable,' 'readable,' and 'beautiful' stood out from other adjectives they used. Thus, from the analysis of the results, the Orange design is the most appropriate for a topographic map representing the buildings from the western portion of the state of São Paulo at 1:10,000 scale, among the three proposed designs at this study.

This approach of translating the local landscape for the topographic map aesthetic could be applied to any region, not just in urban areas, implying a non-standardized representation when regarding the "big picture" of different symbologies that will be used in different regions in a state and between them. Still, this approach allows people from other places to see the local identity cartographically. Furthermore, thinking in the long term, the cartographic convention will follow the landscape changes, which will allow knowing the landscape cartographically through the ages.

Important to highlight the hostile critics concerning the outline of the buildings in the types of designs, especially the Pink and Gray ones. The reason may be associated with displaying maps on the used website, around 10% smaller than the originals. Furthermore, the light gray color used to fill the blocks may have slightly impacted the reading since the density of information within the block was high, considering the representation of buildings at 1:10,000 scale. Additionally, a representation with blocks filled with white could be tested, intending to improve the legibility at 1:10,000 scale. Also, reading the buildings' outline may have been impacted by different displays that were not controlled in this research. The participants' displays vary in material (LCD or LED) associated with different resolutions, sizes, contrasts, brightness, and ambient lighting.

Future works can enhance the proposed designs and apply an experiment with a rigorous laboratory control that considers the characteristics of the display and lighting conditions or follow without laboratory control in an approach in line with a real case of use. Since topographic maps can be accessed almost everywhere through different media, the experiment could be adapted for seeing maps on smartphone or tablet devices.

Future topographic map evaluations could also consider aesthetic parameters by using adjectives such as 'beautiful,' 'pleasant,' 'attractive,' 'colorful,' 'not loaded' and so far, like those found out by Lavie, Oron-Gilad, and Meyer (2011). Also, further studies could use usability items like 'easy to find information,' 'information is clear,' 'easy to read,' and others, as recommended by Nielsen (1994). That kind of assessment could bring a more comprehensive understanding of the user's satisfaction and involve the user-oriented design methodology.

Another possibility of research could be performing a study that evaluates the impact of the urban morphology at the topographic map reading, comparing the subjective reactions, emotions, and perceptions among different areas (e.g., urban streets: the regular pattern versus the irregular pattern; urban buildings density: low, medium, and high).

Future investigations could also add feature classes, especially the hypsometric features (e.g., contour line and spot height), and verify if a more detailed map would critically impact map reading, resulting in different findings. Similarly, map elements could be added and assessed (e.g., legend, graphic scale, north, etc.). Important to emphasize is that the implications of presenting a complex map representation are unclear.

Another approach could connect several mapping scales in a multiscale topographic map in the Brazilian context, generating the possibility of seeing together: large-scale convention (municipalities and states), medium-scale convention (DSG), and small-scale convention (IBGE). This challenging line could bring light to the impact to the map readers of adopting a symbology visually coherent with the local landscape integrated into the national convention or even observing different symbologies originated by the local landscapes (e.g., the urban: capital city, countryside city, village; the rural: forest, swamp, farm).

In that sense, more investigations at larger scale topographic maps could bring light if there will be explicit visual coherence between the cartographic representations and the local landscape by working with larger scales and a more detailed building database. Additionally, orthoimages of the cities could be taken through aerial surveys with Remotely Piloted Aircraft

System – RPAS, since this kind of technology facilitates the way data is collected at large scales (e.g.: 1:5,000 or larger). Also, the images provided by RPAS would make it possible to symbolize the roofs of the buildings with greater levels of detail, which could better demonstrate the visual coherence between the map aesthetic and the local landscape of cities located in the west of the state of São Paulo.

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