A BIBLIOMETRIC STUDY OF GRAPHIC VARIABLES USED ON TACTILE MAPS

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ABSTRACT:

Tactile maps are accessible for visually impaired people. Therefore, studies on the use of graphic variables in tactile cartography are necessary. A search for papers related to the keyword "tactile map" was conducted in the Scopus database and in the annals of the International Cartographic Conference, between the years 2009 and 2019, with the objective of identifying in the international literature the topics concerning to graphic variables, especially those related to color code systems. Among the full manuscripts found in the Scopus and International Cartographic Association databases, the countries with the largest number of publications in the tactile cartography field were Brazil, United States, Greece, Spain and Germany. The main topics related to tactile maps in the last 10 years were: visual impairment, navigation and wayfinding, perception, universal design, among others. Some of the papers suggest the representation of colors for colorblind people, but there is a gap regarding the use of color codes as graphic variables on tactile maps.

1. INTRODUCTION

A map is a graphic representation of the space, used broadly to include all aspects of the cultural and physical environment (Robinson, Petchenik apud Dent et al., 2009). However, this definition also includes mental abstractions that are not physically present in the geographical landscape. Therefore, a map can describe similar realities for some people and different realities for others, because maps are "models of reality" (Dent et al., 2009). A map is called tactile when it is in a format that allows it to be understood by touch, through a tactile graphic language with embossed signs (Almeida, 2011).

The International Cartographic Association defines a thematic map as "a map designed to demonstrate particular features or concepts" (Meynen apud Dent et al., 2009). A qualitative thematic map presents the spatial distribution or location of a single theme of nominal data, whereas a quantitative thematic map presents spatial aspects of numerical data, which are in most instances a single variable, such as income data or population (Dent et al., 2009).

Thematic mapping techniques (Choropleth maps, Dot maps, Proportional symbol maps, Isarithmic maps, Value-by Area maps and Flow maps) use symbols to display spatial phenomena. The visual variables size, value, texture, color, orientation, and shape can be manifested in a graphic system formed by points, lines or areas in order to locate spatial objects on maps (Dent et al., 2009). These variables were proposed by Jacques Bertin between 1967-1977 and most of them were adapted to a tactile language, by Vasconcellos in 1993, to make maps accessible to visually impaired people, except for the variable "color" (Almeida, 2011). Then, Nogueira [Loch] (2008) proposed the minimum dimension for line, maximum diameter and minimum diameter for points in the tactile graphic variables (Figure 1):

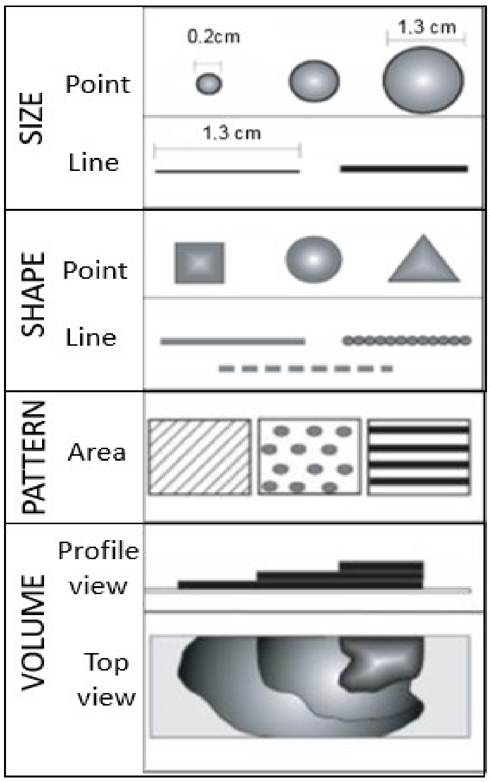

Figure 1. Tactile Graphic Variables. Source: Adapted from Nogueira [Loch], 2008.

The International Statistical Classification of Diseases and Health-Related Problems defines visual impairment as blindness

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when the vision, or corrected visual acuity, is inferior to 20/400. It is defined as low vision when the value of corrected visual acuity in the best eye is lower than 0.3 or equal to 0.05, or if the visual amplitude is lower than 20º in the best eye with the best optical correction (CBO, 2015).

The efficiency of spatial analysis is related to the cartographic language and communication established in the cartographic design (Sluter, 2008). During the development of a project the graphic variables to be used on the map are selected with the purpose of meeting the needs of a particular set of users, as making maps to meet the needs of all users would be a complex task. However, tactile maps, which are more commonly used by blind people, should be an alternative for most visually impaired users (Nogueira [Loch], 2008).

People who lost their vision before the age of five are characterized as congenitally blind. Those who lost their vision after that age are called adventitiously blind (Nunes, Lomônaco, 2008). For congenitally blind individuals who have no visual experience, colors are abstractions. However, adventitiously blind people can keep visual memories of images, lights and colors, depending on the age at which they became blind (Oliveira, 1998).

A study conducted by Bianchi et al. (2016) on the meaning of colors for congenitally blind individuals and people with normal color vision showed that colors are similarly interpreted by both groups. In the Arts, for example, embossed color codes are applied to identify the colors of pens or pots of paints, on hangers to identify the color of the clothes when their labels do not have this feature, and even to communicate the color of makeup products, among other uses (Marchi, 2019).

In a recent study, Ribeiro (2019) evaluated the performance of blind individuals when reading an image adapted from the work of art Abaporu (Figure 2), which was originally created in 1928 by the Brazilian artist Tarsila do Amaral in the period called Modernism. The adapted image includes visual colors and an embossed color code system called See Color (presented in the following topic) where the codes associated with the shapes of the embossed elements allowed the blind individuals to correctly interpret the elements: sun, sky and cactus. However, the meaning of the entire work was understood by only 2 out of 10 individuals.

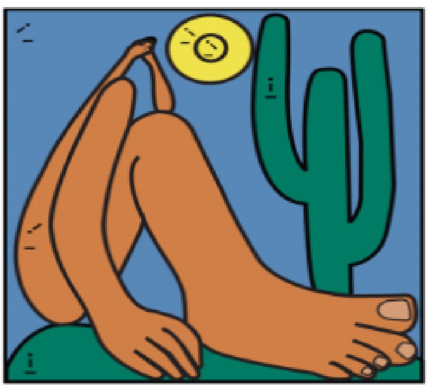

Figure 2. Abaporu adapted as a tactile picture using the See Color code. Source: Ribeiro, 2019.

The Abaporu depicts a man sitting on the grass, in the caatinga biome, a typical region in the northeast of Brazil. Behind him there is a green cactus and a yellow sun combined with a blue sky. Noticeably, the artist applied exaggerations in the size of the man's feet, head, nose and arms. According to Ribeiro (2019), the disproportionality of the human form caused confusion in some of the blind individuals participating in the experiment, who perceived it as a mountain. Besides being used in works of art, color codes may also be used on maps, in addition to tactile graphic variables.

The process of transforming geographic data into maps and diagrams needs to be adapted to a specific product using a tactile language, preferably combined with the visual language (Almeida apud Almeida, 2011). The variables proposed by Jacques Bertin are fundamental units for the development of other variables (MacEachren, 1994). An alternative to exploring blind people's cognitive ability to identify colors on thematic maps could be the use of an embossed color code in system models, including a combination of other variables such as shape (Figure 3, Figure 4, Figure 5, Figure 6), pattern (Figure 3), orientation and arrangement (Figure 5 and Figure 7).

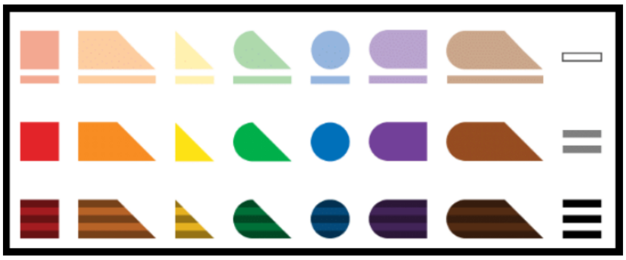

Figure 3. Feelipa color code. Source: https://www.feelipa.com/for-visually-impaired/ (2020)

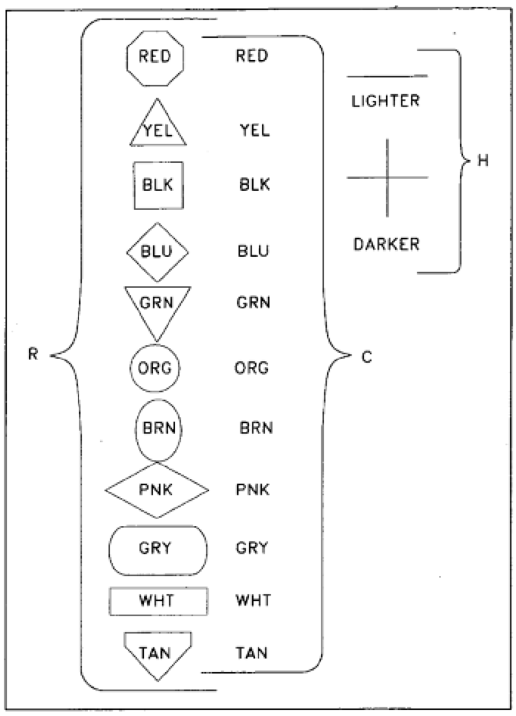

Figure 4. Gagne Todd system. Source: Todd, 2006.

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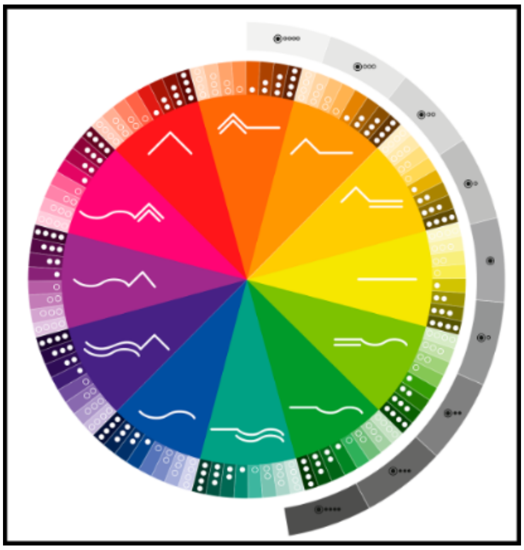


Figure 5. Constanz system. Source: http://www.sistemaconstanz.com/sistema-constanz/(2020)

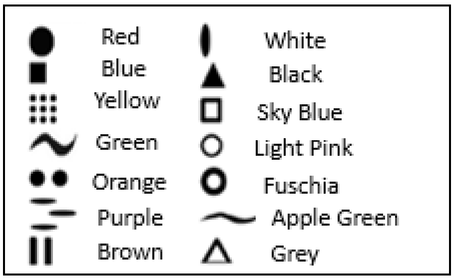


Figure 6. Ramsamy-Iranah system. Source: Ramsamy-Iranah, 2016.

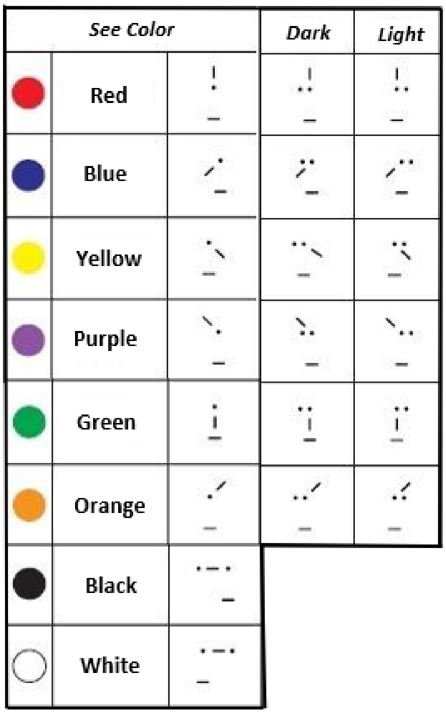


Figure 7. See Color code. Source: Adapted from Marchi, 2019

Figure 8. ColorADD color identification system. Source: http://www.coloradd.net/code.asp (2020)

There are also color code systems for colorblind people - those with disabilities in the color-sensing cones in their eyes - such as the ColorADD (Figure 8), created by Miguel Neiva. It has no embossed elements and combines different variables, such as shape and orientation.

Given the above, studies on the use of these codes in cartography are necessary. So, a search for papers related to the keyword "tactile map" was conducted in the Scopus database and in the annals of the International Cartographic Conference, between the years 2009 and 2019, with the objective of identifying in the international literature those topics concerning to graphic variables on tactile maps. This paper presents an analysis of a bibliometric study on the current subject in academic research related to tactile cartography and the main discussions about tactile graphic variables in the last ten years.

1.1 Production of tactile maps and use of graphic variables

According to Koch (2012), in addition to the usual tactile maps, new cartographic products accessible to the visually impaired now include multisensory features such as audio-tactile dialogue, virtual screens including or not the support to the Global Positioning System (GPS), Geographic Information Systems (GIS), internet, touch screens, among others. In this context, the most common production techniques in the area of tactile cartography are: thermoform, supported by the principle of shaping maps by applying vacuum pressure under plastic material; thermal printing on special paper, supported by the principle of shaping the map from the expansion of microcapsules of alcohol, using a heat fusing machine; as well as embossing, manual techniques, 3D printing, and also modern trends in the use of computer interfaces or other accessible devices for people with visual impairments.

Therefore, the development of this field can be characterized according to the type of media, symbols, map design and production methods.

Tactile maps for orientation and mobility are preferably made with punctual and linear symbols to provide information and help people with visual impairments to make decisions in indoor or outdoor environments. Thematic maps regarding physical or human phenomena such as those commonly employed in the teaching of geography, or general maps, such as those providing political data, are cartographic products that use embossed graphic variables usually implemented within an area (Nogueira [Loch], 2008). The aforementioned author suggests a complementary alternative in cartographic communication, parallel to tactile variables, by using letters or numbers in braille to inform themes within areas (Figure 9).

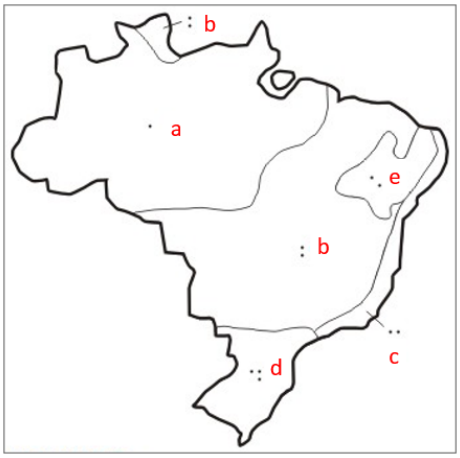


Figure 10. Tactile map layout of Brazilian Climates with Braille letters. Source: Adapted from Nogueira [Loch], 2008.

Studies coordinated by Nogueira [Loch] (2008) show that visually impaired individuals can discriminate classes or attributes in areas more easily through numbers or letters than by textures. Also, the smaller the scale of the map, the more complex is the tactile discrimination of graphic variables implemented in each area. Unlike sighted people, who are able to differentiate textures easily due to their vision, the visually impaired have more difficulty discriminating textures than letters and numbers in Braille. Figure 10 depicts examples of both representations on two tactile maps concerning to Brazilian climates. In any case, the study recommends that the amount of letters or numbers used in zonal representations should be inferior or equal to seven.

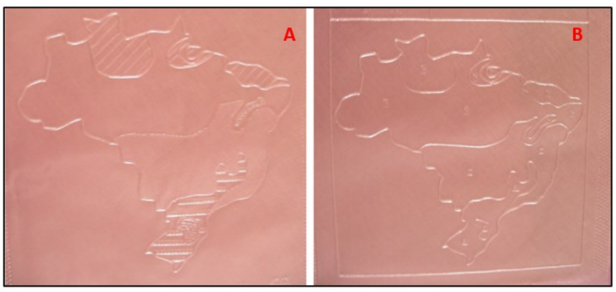


Figure 10. Tactile maps of Brazilian Climates produced by thermoform. Map A with textures and Map B with letters. Source: Nogueira [Loch], 2008.

A group of researchers (Araújo et al., 2020) realized that, similarly to the use of letters or numbers in tactile cartography, it might be possible to represent zonal phenomena on thematic maps through the use of the tactile language of the See Color code (seecolor.com.br). These researchers consider that tactile cartography can advance in studies on the use of color codes on tactile maps, as it may improve the ability of abstraction of the congenitally blind on the meaning of colors, visually rescue colors in the mind of the adventitiously blind, and allow people with low vision to distinguish non-contrasting colors.

In that sense, the authors have sought to evaluate the potential of using the See Color code on tactile maps to represent zonal phenomena, which is compatible with the degree of importance of the graphic variable "texture", with the advantage of this system being less complex for tactile cognition, as it is based on Braille writing, widely recognized throughout the world. Thus, choropleth maps, for example, could be more universal for both sighted and visually impaired individuals if, in addition to visual colors and tactile elevation, they also included an embossed color code.

2. MAIN BODY

2.1 Materials and Method

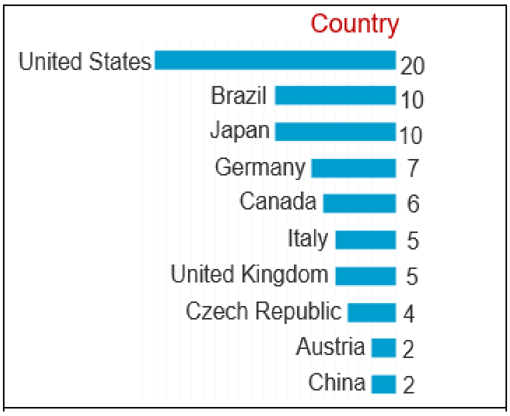
Bibliometric and bibliographic studies were performed on international papers related to graphic variables used on tactile maps, in journals available in the Scopus database and in the annals of the International Cartographic Association (ICA). A qualitative research was performed, based on a content analysis technique called thematic categorical analysis (Bardin, 2011). The categories were organized into a group of elements with common characteristics, based on keywords.

A search filter was applied in databases with the keyword "tactile map" between the years 2009 and 2019, in order to obtain results within the research areas: Arts and Humanities, Earth and Planetary Sciences, Engineering, and Social Sciences. The categorical analysis was developed in three stages: first, the selection of articles, then, the reading of the material, and finally, the evaluation of contents of the articles to verify which countries, affiliations and areas have more publications related to the theme and the research gaps on the tactile graphic variables.
These procedures are important when gathering the main scientific works. They guide the researcher to find alternatives on tactile cartography, and indicate possible alternatives that may contribute to the progress in the area. However, there are many scientific ramifications to explore regarding the subject, as it involves technological, educational, psychological, and ergonomic aspects, among others. So, a filter was used in the Scopus platform in order to find the main authors who publish about the subject, regardless of period. Then, all documents, except for the abstracts, were added in a spreadsheet and organized as follows: year, country, title, author, keywords, abstract, journal or conference.

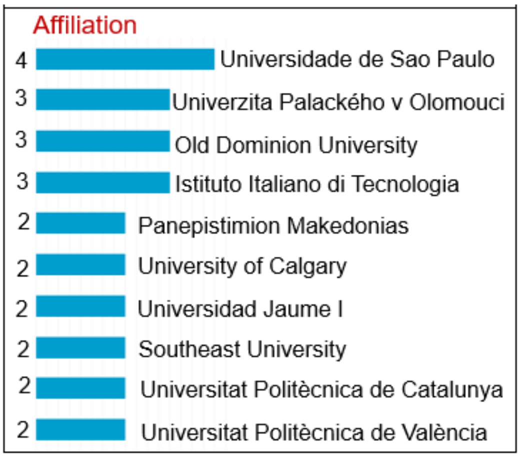
The analysis was conducted to identify the most common keywords in the papers and characterize the profile of publications, the most discussed topics and probable gaps. Keywords were grouped in 14 categories considering common aspects. For example, words related to tactile maps, tactile information, and haptic maps may belong to the same group. However, words such as "orientation" or "mobility" may belong to a different group. Finally, keyword frequency was investigated to find the main topics studied in recent years.

3. RESULTS

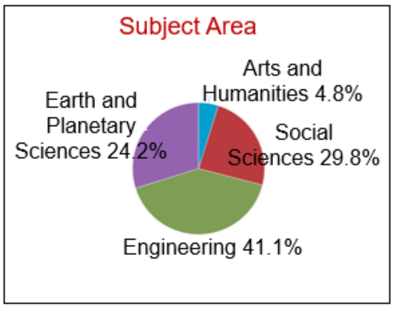
The Scopus database results provided 91 documents including the keyword "tactile map", published between the years 2009 and 2019, in four areas (Figure 3): Arts and Humanities (6), Earth and Planetary Sciences (30), Engineering (51), Social Sciences (37). The research also showed the main countries and affiliations which published the most on tactile maps in the studied period (Graph 1, Graph 2 and Graph 3).



Graph 1. Documents related to the keyword "tactile map", by country, 2009-2019. Source: Scopus, 2019. Organized by the authors.



Graph 2. Documents related to the keyword "tactile map", by affiliation, 2009-2019. Source: Scopus, 2019. Organized by the authors.



Graph 3. Documents by subject area related to the keyword "tactile map", 2009-2019. Source: Scopus, 2019. Organized by the authors.

In this study 124 articles were found, but as some of them may belong to more than one area, there were repetitions. Of these articles, 65 were available for download and were published within the last 10 years. In the filter used to find the main authors who write on the subject, the following were identified: Anke Brock from the Ecole Nationale de l'Aviation Civile (ENAC) in France, Ann Gardiner from the University of Manchester in the United Kingdom, Daniel Jacobson from the University of Calgary in Canada, Don McCallum from the Anglia Ruskin University in the United Kingdom, Emma Pike from Sheffield University in the United Kingdom, Jaume Gual from Jaume I University in Spain, Papadopoulos Konstantinos from the University of Macedonia in Greece, Regina Almeida [Vasconcellos] from the University of São Paulo (USP) in Brazil, Sandra Jehoel from Surrey University in the United Kingdom, and Simon Ungar from Surrey University in the United Kingdom. Most of the researchers with articles published internationally on the subject are from Europe, North America, and South America. It was possible to download 36 articles written by these authors. Although the United States is the country that publishes the most, the University of São Paulo (USP) has the largest number of publications in the area of tactile cartography.

In South America the first university to study tactile maps was the Universidad Tecnológica Metropolitana (UTME) – in Chile, 1987, where methodological procedures for the development of a tactile graphic language were studied.
In Brazil there is a partnership among researchers from USP and the Universidade Estadual Paulista Júlio de Mesquita Filho (UNESP) who share theoretical and practical experiences on the production and evaluation of maps for people with visual impairment (Freitas, Ventorini, 2011).

In relation to the publications within the last 10 years in the annals of the International Conference promoted by the International Cartographic Association (ICA), 21 papers were found regarding the keyword "tactile map", of which 10 were produced in Brazilian institutions. These conferences happened in Chile in 2009, France in 2011, Germany in 2013, Brazil in 2015, United States in 2017, and recently in Japan in 2019. In summary, Graph 1 shows the countries that published the most regarding the subject in the last 10 years, considering the two databases with 86 documents in total: 65 from Scopus and 21 from the annals of the International Cartographic Association. The 303 keywords that appeared most frequently in the articles show that the main topics discussed within tactile cartography in the last 10 years are related to tactile maps, visual impairment, navigation and wayfinding, perception, universal design, three-dimensional printing, assistive technology, cognition, audio, graphic variables, symbols, orientation, mobility and generalization (Table 1).

Keywords	Number
Mapa Tátil, maps for blind, Tactile Guide Map, Tactile map, Tactile maps, handdrawn map, mapping tactile, tactile production methods, Haptic search, Haptics, haptic maps, tactile graphics, Tactile information, Tactile interaction, non-visual communication.	45
Blind, blind navigation, blindness, Blind people, blindness, Pessoas com Deficiência Visual, disability, Low vision, Reduced visibility, visually impaired.	41
Wayfinding, Tactile navigation displays, Tactile guidance, Navigation, Open Street Map, tactile display, Mobile applications.	22
Perception, percepção, Discriminability, Edge Clarity, Natural world.	13
Universal Design, Inclusive cartography, inclusive design, map design, usability, Ergonomics, map use, Search time.	13
3D print, 3D printing, Prototipagem Rápida, 3D map, 3D cartography, tactile printer, technology.	12
Assistive technology, Accessibility, Assistive, social impact, social inclusion.	10
Spatial Cognition, cognitive maps, Spatial coding, Mental representations, Spatial information, pattern recognition, spatial knowledge, Spatial relations, Spatial coding.	09
Audio, Multisensory maps, Spatialized audio, Verbal instructions, 3D audio, geo-multimedia.	07
Size, elevation, Striped Pattern, texture and reliefs and chromatic contrast, standard, color.	06
Cartographic symbol, symbolization, tactile symbol.	05
Orientation, orientação, mobility, mobility maps.	04
Generalization, map automation.	02
Other words	114
Total	303

Table 1. Groups of keywords related to a similar context. Organized by the authors.

Among the full articles found, there were few topics related to the variables “color” and “usability”, which are still little explored in tactile cartography. In a paper regarding colors, the authors analyzed the color scheme of the standard openstreetmap.org map style in what concerns to users with color vision impairments. In that study, the users were not completely blind, but had disabilities in the color-sensing cones in their eyes (Krögere et al., 2013).

Of the other five publications on graphic variables, one was developed in Japan with the purpose of investigating the influence of edge clarity on embossed symbols on tactile maps (Doi et al., 2011). In the same country, after the creation of the new Barrier−free Law, some authors investigated the use of dot pattern and texture and also striped pattern pinions on maps (Wada et al., 2009). A study in the Czech Republic showed results of “a three-dimensional model with discrete hypsometric layers, with Braille writings and with contrasting colors that distinguish it for people with visual impairment” (Voženílek et al., 2012). In Brazil, researchers developed different tactile textures through 3D printing to help blind people interpret tactile maps (Oliveira et al., 2016). In Indonesia, researchers adopted and modified the designs of tactile symbols organized by specialized entities considering the tactile variables proposed by Vasconcellos, adapted from Bertin, to develop the tactile maps of the city of Yogyakarta (Rahardjo et al., 2019).

The bibliometric research of the last 10 years showed that there is a gap about alternatives to represent colors on tactile maps for blind users. The full papers regarding graphic variables had more content about textures, elevation, and symbol size.

In the first half of 2020 there was the publication of an article regarding the use of color codes on tactile maps using the See Color code. The patent for this code (BR 10 2017 018174 0) was issued in 2017 and map experiments using this system started in 2019 by Araújo et al. (2020). Then, a partnership was established between researchers in the area of Cartography linked to the Postgraduate Program in Geodetic Sciences at the Federal University of Paraná (BR) and Dr. Sandra Marchi, artist and creator of the See Color code, who was associated that year to the Postgraduate Program in Mechanical Engineering at the same university, in the area of Ergonomics and Usability.

The study used the See Color code on maps following the theme “Temperature” (Figures 11 and 12). It was found that this color code system was effective to inform the colors on the maps to both congenitally blind individuals (03) and adventitiously blind individuals (03). However, its association with thermal sensation (hot or cold regions) was effective only for the adventitiously blind.

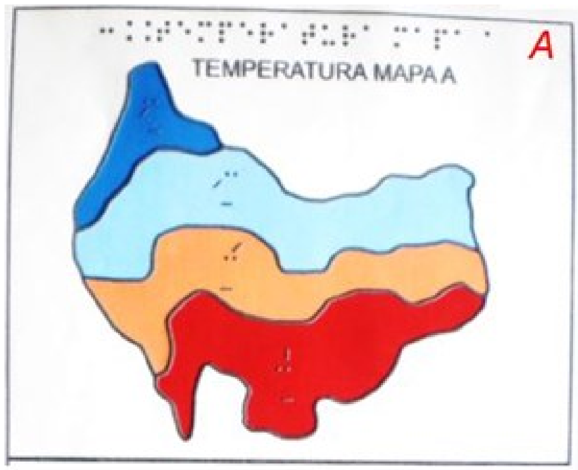


Figure 11. Map A, theme: Temperature, printed on special paper with divergent colors along with the tactile language of the See Color code.
Source: Araújo et al., 2020.

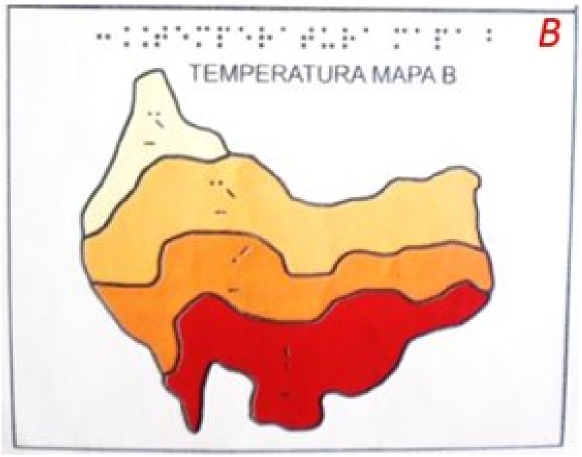


Figure 12. Map B, theme: Temperature, printed on special paper with sequential colors along with the tactile language of the See Color code.
Source: Araújo et al., 2020.

The study showed that the light and dark colors of the See Color code require more attention of the user, who may be uninterested in learning tertiary colors to use this more detailed color code system. Therefore, the authors suggest a further study that considers a big group of visually impaired users and tests usability with different tactile materials, method of implementation, and user experience with maps.

4. CONCLUSIONS

Among the full papers found in the Scopus and International Cartography Association databases, the most productive countries in terms of number of publications in the Tactile Cartography field were Brazil, United States, Greece, Spain and Germany. This study showed that the main topics related to tactile maps in the last 10 years were: visual impairment, navigation and wayfinding, perception, universal design, three-dimensional printing, assistive technology, cognition, audio, graphic variables, symbols, orientation, mobility and generalization. Some papers suggest the representation of colors for colorblind people, but there is a gap regarding the keyword “color code” in the topic of graphic variables on tactile maps.

In the literature there are several other publications related to graphic variables on tactile maps, but their download is either restrict or the research may have been published only as an abstract or indexed in other databases. However, this study provided a relevant sample of the main papers published internationally on the subject.

Assistive technologies and scientific discoveries associated with interdisciplinary studies between Arts, Design and Cartography provide new approaches and the revision of paradigms consolidated in the academic area. In the Arts and in the field of product design, for example, color codes have been applied to various objects for the personal or professional use of blind individuals. Thus, considering that choropleth thematic maps are common in the universe of people with normal color vision, it would be inclusive to develop tactile maps to help blind people to perceive colors.

In this context, in-depth studies on the usability of color codes are recommended in order to analyze which systems could integrate the existing tactile graphic variables, and also whether it would be possible to explore themes such as color saturation or luminosity, so that cartographic communication is effective and efficient for visually impaired users.

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