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Universal color code as alternative for visual disabilities

Código universal de cores como alternativa para deficientes visuais

Codificación de colores universal como alternativa para personas con discapacidad visual

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ABSTRACT

This paper presents the research results of Color Universal Code (UCC), held in 2018, through a partnership between the National Institute of Technology (NIT) and the Benjamin Constant Institute (BCI). The exploratory research was carried out based on the guidelines of Tullis and Albert (2008) and aimed to evaluate the UCC, as an alternative code for reading and representing colors, by people with visual impairments. During the tests, different techniques and instruments were used, including focus group and usability test. The data were analyzed using the content analysis method of Glaser and Strauss (1967) and demonstrated positive results, regarding the possibilities of using UCC for educational purposes.

Keywords: Universal Color Code. UCC. Braille. Visual Impairment. Inclusion.

RESUMO

O presente artigo apresenta os resultados de pesquisa do Código Universal de Cores (CUDC), realizada em 2018, por meio de uma parceria entre o Instituto Nacional de Tecnologia (INT) e o Instituto Benjamin Constant (IBC). A pesquisa exploratória foi realizada com base nas

orientações de Tullis e Albert (2008) e teve como objetivo a avaliação do CUDC, como um código alternativo para a leitura e representação de cores, por pessoas com deficiência visual. Durante os testes foram utilizadas diferentes técnicas e instrumentos de coleta, incluindo grupo focal e teste de usabilidade. Os dados foram analisados a partir do método de análise de conteúdo de Glaser e Strauss (1967) e demonstraram resultados positivos, no que tange às possibilidades de uso do CUDC para fins educacionais.

Palavras-chave: *Código Universal de Cores. CUDC. Braille. Deficiência Visual. Inclusão.*

RESUMEN

Este artículo presenta los resultados de una encuesta del Código de Color Universal (CUDC), realizada en 2018, a través de una asociación entre el Instituto Nacional de Tecnología (INT) y el Instituto Benjamin Constant (IBC). La investigación exploratoria se llevó a cabo en base a las pautas de Tullis y Albert (2008) y tuvo como objetivo evaluar el CUDC como un código alternativo para la lectura y representación del color por personas con discapacidad visual. Durante las pruebas se utilizaron diferentes técnicas e instrumentos de recolección, incluidos grupos focales y pruebas de usabilidad. Los datos se analizaron mediante el método de análisis de contenido de Glaser y Strauss (1967) y arrojaron resultados positivos en cuanto a las posibilidades de utilizar el CUDC con fines educativos.

Palabras clave: *Código de color universal. CUDC. Braille. Discapacidad visual. Inclusión.*

Introduction

According to data from the World Health Organization (WHO), people with visual impairment (PVI) - a group that includes not only the blind, but also color blind and people with low vision - total approximately 246 million people worldwide, of which 39 million are totally blind (WHO, 2018). In Brazil alone, this number reaches 6.5 million people, with 582 thousand totally blind (IBGE, 2017). This is an expressive portion of the population, which are imposed daily challenges for their autonomy and inclusion, taking into account that much of the information that circulates in the most varied contexts of daily life, is presented in a visual way.

In order to minimize these challenges, several systems proposals for coding visual information have been developed and tested. A milestone in this development, was the creation of the Braille alphabet in 1824, by the Frenchman Louis Braille, a tactile coding system, based on a cell with six points distributed in three lines and two columns, allowing up to 63 combinations, presented in the figure below:

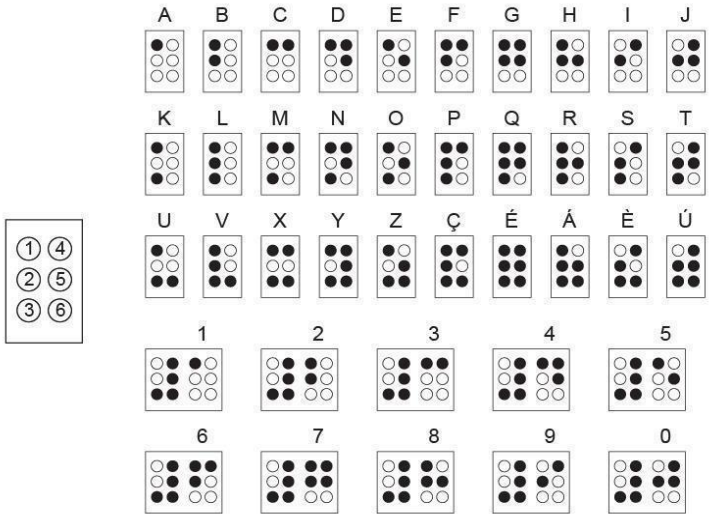


Figure 1 – Braille System
Source: Authors' elaboration.

Initially developed as a form of coding, to represent letters and signs of the alphabet, the Braille System began to incorporate new possibilities of representation, including numbers, mathematical symbols, Greek and Cyrillic alphabets, musical notes, as well as rules for representing chemical elements. Despite the expansion of its possibilities in terms of representation, the Braille System does not yet have a way to represent colors that is accepted and standardized.

In order to create alternatives for the tactile color coding, some initiatives have been observed, such as the "Feelipa Color Code" (Pires, 2011, 2017). The proposal uses a system with four geometric figures in relief (circle, triangle, square and rectangle), whose combinations, among these elements, represent primary and secondary colors and different tones.

In a third codification proposal, on which this research is centered, is the Universal Color Code (UCC), proposed by Pereira and Ferronato (2019). Unlike the previous systems, the UCC does not use geometric figures, but the system of points of the Braille cell, as a form of representation. The cell lines are used to represent the primary colors (red, blue and yellow), while the columns represent the intensity variations of the colors (0%, 33%, 66% and 100%) and their mixtures, allowing the representation of up to 64 colors. A comparative summary with the 3 proposals mentioned is shown below:

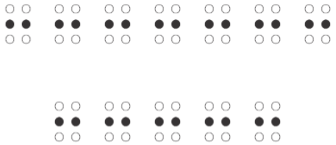
Codings accessible to visually impaired people (VIP)				
Colors	**UCC**	**Feelipa**	**Colorad d**	**textual braille**
Red				
Blue				
Green				
Purple				
Light yellow				
Gray				

Table 1 – Comparing color codes
Source: Authors' elaboration.

Observing the need for a tactile color representation system that could be used by Braille literate people, the the Secretariat for Social Inclusion of the Ministry of Science, Technology and Innovations of Brazil, requested a survey that could evaluate a color code to be used by visually impaired people (VIP). The study sought to evaluate with the VIP, three main points: *(1) Is the system understandable for the VIP?; (2) Does the system meet the needs of the VIP for apprehension and color communication?; (3) In what contexts and in what form should the system be applied?*

The code chosen for evaluation was the Universal Color Code (UCC), because it is the only one based on an already standardized system, Braille (Brazilian association of Technical Standards [ABNT], 2015) and because it demands tactile reading skills that are already developed by VI people in teaching the blind in schools. In addition, because it is based on Braille, the code allows the use of different existing resources, such as Braille

printers and writing instruments (slate and stylus), facilitating the adoption of its use by students and teachers. The UCC is presented below:

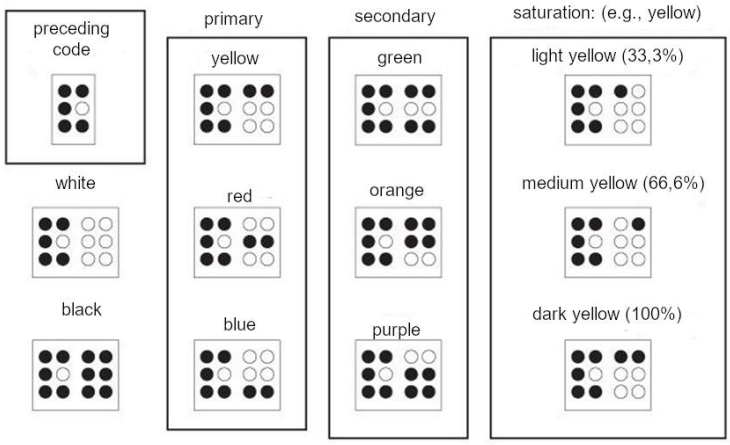


Figure 2 – The UniversalColor Code (UCC)
Source: Authors' elaboration.

Although this research works with the standard model of the code (with two columns) - because it is the version already standardized and UCC the similarity with the standard Braille cell, familiar to the participants of the research - the UCC provides the possibility of adding a third column to the matrix. This way it is possible, varying the standard Braille cell, to increase its capacity of representation from four to eight saturation levels (0%, 14.3%, 28.6%, 42.9%, 57.1%, 71.4%, 85.7% and 100%), and from 64 to 512 representable colors. Regardless of the variation in the number of columns, the UCC always foresees the use of three lines, representing three primary colors, already defined in the initial code proposal (Pereira & Ferronato, 2019).

The primary colors are those that, through their mixture in different proportions, allow to obtain the other colors, based on the spectrum of colors that are visible to the human eye. In this sense, there are different color systems, which assign three or more different colors as primary, two of which are the most used, the additive system and the subtractive (Pedrosa, 2010).

The additive system, also known as RGB (Red, Green and Blue), uses red, green and blue as primary colors. The sum of these three colors at maximum levels of saturation generates white, while their absence results in black. It is a system, employed in devices that have light as color support, such as computers, projectors and television sets.

As far as the subtractive system is concerned, unlike the additive, the sum of its three primary colors at maximum saturation generates black and its absence generates white. The primary colors used in the system are also different, making use of cyan, magenta and yellow in their compositions. It is a system used in devices that use ink as color support, also known as CMY (Cyan, Magenta and Yellow), commonly used in the printing industry and in home printers[1].

Although these two systems are the most precise to obtain all the other colors, there are other models more used in certain segments. This is the example of RYB (Red, Yellow and Blue), used in plastic arts and education. This system employs red, yellow and blue as primary colors, generating orange, green and purple as secondary colors. Despite being more used, it is an imprecise model, whose mixture of its primary colors does not allow obtaining all the others from the visible spectrum. The black color, for example, is not obtained in the sum of colors, but a dark color that only approaches this one. The spread of this model has occurred among painters throughout history, due to the difficulty of obtaining natural pigments of cyan and magenta colors (Pedrosa, 2010).

Of the systems previously presented, the UCC uses the RYB system, as it is the most adopted by schools (Pedrosa, 2010). It is understood in this sense that the adoption of a different model from that used by students would represent a greater level of difficulty for its use and could even mask the results of the tests carried out regarding its ease and suitability for use. In addition, the other color representation codes discussed above also adopt RYB as primary colors and assume that its mixture originates black, which allows for other possible comparative studies.

This article presents the result of the research conducted, related to the evaluation of the UCC. So far, we have sought to present the different existing proposals, which arise as alternative resources for the representation of colors by VIP. In Scenario and Justification, we will present the theoretical reference adopted, as well as discuss the role of colors in teaching and inclusion of POS. In the next step, we will

[1] Although from the physical point of view the mixture of the three colors generates black, in the printers this color normally comes separated, already with the ready mixture, as a fourth color. In this way the waste of ink is avoided, besides the risk of deformation of the paper by the excess of ink, coming from the overlapped layers. In this case, the acronym that designates the system is CMYK (Cyan, Magenta, Yellow and black).

present the method used in the survey, the research protocols and the sample profile of the participants. The fourth section of this article discusses the results of the analysis, including the conclusions about the tested code, its possibilities of use evidenced with the participants, as well as possible developments and considerations on the need for identification of colors by VIP.

2. Scenario and Justification

Colors carry meanings and information, playing an important role in almost every element present in our lives and in society. Books, clothing, cosmetics, medicines, food, means of transportation, packaging, toys, signage, among others, are just some examples of the importance of colors in daily life.

In the field of education, textbooks often present part of their information through visual supports, such as graphics, maps and drawings. The existing lines in these images can be reproduced in relief, as an alternative way to approach these contents for POS. However, based on Vygotsky's (1997) studies on blindness, Camargo (2012, pp. 47-48) points out the existence of inseparable meanings of visual representations, which "can only be registered and internally represented through codes and visual representations [...], inaccessible to the blind people of birth". In this sense, the author understands the existence of limitations for VIP, especially for congenital blind people, for whom the understanding of elements such as: "light, dark, colors, etc." presents an even greater challenge.

In personal routines, social interactions and self-care activities, colors are also present, and can have a strong impact on subjects' self-esteem and sense of belonging. Personal presentation, regardless of individual limitations, is a characteristic of the human being, such as the social being it is. In this way, it represents a fundamental aspect for the self-esteem and feeling of social inclusion. At the time of make-up, for example - although there are already courses on make-up for blind people - the identification of the colors of the case, as well as the palettes used, only becomes possible with the help of others. The impossibility of apprehending colors can also have a potential impact on personal security at the VIP. It is observed in this sense that colors are often used as a way of signaling situations involving danger, alerting about the need for attention.

Another challenge imposed to the VIP regarding the use of colors is related to the fact that there is not yet a standardized tactile coding system that can serve as an alternative for the representation and incorporation of colors in their daily lives.

An example that illustrates the attribution of meanings through the colors, can be observed on the research made by Silva (2017), which sought to identify possible representations brought by the colors, used on the perfume industry, on the conception of its products. His initial hypothesis would be that, because there would be multi-sensorial correspondences of the perception on the meaning attribution, the colors would bring with them, extra information, which could be incorporated by the industries, contributing on the strengthening and on the attribution of new meanings to their products.

From the results obtained, it was identified that the use of colors by the perfume industry was compatible with the perceptions and sensorial associations demonstrated in research. It was observed in this sense, the use of multi-sensorial elements by the industry, involving different associated stimuli, including fragrances, packaging format and colors. In this way, an attempt is observed, from the multi-sensorial aspects present in the perception of the subjects, of amplification and attribution of meanings. A world projected to which, people with visual impairment seem not to have been invited.

For Bianchi et al. (2016, p. 147), teaching color to blind people has been a challenge for educators, especially physics teachers, representing an "insurmountable" barrier, especially for the blind inborn. The authors observe, however, that such a barrier is not justified, given that the learning process is multi-sensory, and the formation of meanings is sociolinguistic. In this sense, the imagery contents formed, as well as the concept of colors, would not depend exclusively on the stimuli received by the receptors of our senses, involving other associations.

It is known that blindness can originate from different ages and can present itself from the formation of the individual still in his uterine life, as in different stages throughout life, for different causes and diseases in degenerative processes. Due to these differences, there are vast definitions in the academic literature - in an attempt to characterize what should be understood as congenital and acquired blindness - and in this sense there is no uniformity of these definitions. For this work, we adopted the socio-educational perspective defended by Amiralian (1997), who considers as congenital blindness, that which occurs until the age of five, a phase in which, according to Lowenfeld's studies, visual image retention would not occur.

For Amiralian (1997), the impossibility of forming visual memories has a direct impact on the way VIP structure their other senses for their understanding of the world. In addition, this perspective also meets Piaget's studies on human development, which considers that until the age of five - the phase he called preoperative - the child does not yet have enough images to represent or anticipate unknown processes, which would only occur in the operative phase, after 5 years of age. Phase in which there could be some significant impact on learning, due to the existence of visual memories. Thus, due to the possible impacts discussed by the authors in the process of VIP teaching-learning and depending on the nature of the proposed research, we opted for a characterization of the sample based on Amiralian's (1997) socio-educational perspective.

The attribution of meanings, influenced by the relationships and experiences experienced by the different subjects, had already been observed by Vygotsky (2001, 2007), who considers that everything that exists in our consciousness depends on the constitution of meanings. These, formed from the intrinsic relationship we establish with the world and the associations we build through our received relationships and stimuli. In the author's understanding, "The formation of concepts is the result of a complex activity in which all the fundamental intellectual functions participate [...] cannot be reduced to association, tendency, imagery, inference or determining tendencies" (Vygotsky, 2001, p. 61). Thus, the very communication between the subjects only becomes possible in the existence of shared meanings, allowing for their understanding.

In agreement with Vygotsky (2001, 2007) and in order to find ways to study colors by VIP, Bianchi et al. (2016) carried out a research to identify with the blind people at birth, the references that they had when it came to colors. The qualitative approach research by word association, counted with the participation of 81 students, being nine blind people from birth and 72 sighted, all the participants in the age group between 16 and 21 years.

The study demonstrated the presence of subjective and multi-sensorial issues during color association, with similarity of both groups of students. It was observed in this sense that the references used by blind students, despite their limitations in the sense of sight, were the same as those of sighted. Another previous study, by Bustos et al. (2004), aiming to analyze the perception of blind people in the association between colors and textures, had also pointed out this relationship, demonstrating that there is little

difference in the association of colors between people with congenital and acquired blindness, by associating colors to the textures of objects.

From the results observed by Bustos et al. (2004), there was similarity in the responses among the acquired blind participants, with those at birth, for whom visual references of color and light would not exist. For the authors, the results are in line with what is already known about human perception, whose influences are not limited to sensory stimuli received from the environment, but also to the characteristic questions of the environment and culture, in the interactions we carry out in the spaces with those we interact with. In this context, the rough and pointed textures were associated to the dark colors, such as black, brown "[...] triggering a sensation of darkness and pain", while the light colors, such as "yellow, white and green" were associated to "smooth, polished, bright and soft surfaces with pleasant sensations" (p. 08). From the tonal preferences pointed out by the interviewees, they stood out:

> [...] Yellow, for associating with smooth surfaces, sun and light; blue, for associating with satin surfaces, sky and water; green, for associating with nature; pink, for associating directly with soft surfaces and flowers; white, for associating with soft surfaces such as fabrics and cotton, and orange, for associating directly with fruit. The colors they didn't like are black and brown, for being associated to pointed surfaces, to pain, to darkness. (Bustos et al., 2004, p. 08)

It is also worth mentioning two other points observed by the authors during the research. The first related to the way people look for different ways to perceive the world around them, through different stimuli, a question observed, when they verified that one of the participants eventually resorted to smell before answering about the colors they related to the textures. The second, related to the descriptions of colors in relation to elements of nature and daily life, probably formed from the interaction with the people of their lives. In this sense, the descriptions obtained - added to the other stimuli received from the environment - such as smell, would collaborate in the viewpoint of the authors, to give concreteness in the perception of objects, since, for blind people, "[...] colors are understood as an abstraction [...]", depending on other relationships that collaborate in the attribution of meanings, allowing them to form a significant world view (Bustos et al., 2004, p. 09).

As we discussed earlier, studies conducted in the field of design have shown the importance of colors also in the assignment of meanings. In a world designed for sighted,

the attribution of information by means of colors can represent different forms of exclusion for the visually impaired, especially for people blind at birth, imposing limitations on their effective participation in society. In this sense, it goes against the legal guarantees provided by the Constitution (Brazil, 1988), the inclusion law (Brazil, 2015), and the principles provided by the Universal Declaration of Human Rights (UN, 1948).

Despite the barriers imposed in the teaching of colors for VIP, the researches point to ways that go beyond the limitations attributed to them by visual impairment. In this sense, the UCC color code may represent a viable alternative for us to think of new forms of expression and social participation, in view of the use of colors in society, in the expansion and representation of meanings.

3. Methodology

The research aimed at conducting a preliminary evaluation of the Universal Code of Colors, by people with visual impairment literate in Braille. In this sense, we tried to evaluate with the participants their impressions about the proposed code, verifying eventual difficulties and resistances, as well as the possible adaptations observed by them for its use. The study was divided into six stages, including: preliminary investigations, development of the methodology, selection of participants, preparation of participants, usability test and evaluation of the code.

In the preliminary research stage, a study on the Braille System was carried out, aiming at a greater understanding of its codes used, as well as of references that would address the issue of perception and color teaching for people with visual impairment. In addition, for a greater knowledge of the field and of the participants - the teachers of the Benjamin Constant Institute - were conducted exploratory interviews, with the purpose of investigating the practices adopted by the institute, in Braille literacy, in addition to the curricular contents related to colors. These interviews collaborated in the development of the methodology and course for presentation of the UCC to the participants.

Course participants were recruited and selected through the Benjamin Constant Institute (BCI), a national reference center in the area of visual impairment. The testing and evaluation of the code with the participants was done qualitatively, using different techniques and instruments for data collection, including focus group, individual interviews and usability testing. The procedures were performed over two consecutive days, as we will detail in the survey.

The usability test was conducted in a qualitative way, as a formative type test, based on the guidelines of Tullis and Albert (2008) - because it is the most suitable method for research with small groups, allowing greater depth about issues that may not yet be clear to the researcher.

3.1. Profile of participants

Adult individuals working in the Braille Press Division (DIB) of the Benjamin Constant Institute were recruited to conduct the research. The selection of candidates was defined based on criteria of Braille mastery, interest and availability. The option for a group, with high ability in Braille reading, was intended to reduce possible bias in the interpretation of the code due to reading errors. The sample profile is detailed in the following table:

Participant	Age	Sex	Occupation	* Based on Amiralian (1997)		
				Impairment type*	Visual Memory*	Color Perception *
P1	38	M	Reviewer	Acquired Blindness	Yes	Yes
P2	25	F	Reviewer	Acquired Blindness	No	No
P3	35	M	Reviewer	Acquired Blindness	Yes	Yes
P4	21	F	Reviewer	Acquired Blindness	No	No
P5	27	F	Reviewer	Acquired Blindness	Yes	Yes
P6	34	F	Reviewer	Acquired Blindness	No	No
P7	35	F	Reviewer	Acquired Blindness	Yes	Yes
P8	32	F	Reviewer	Acquired Blindness	Yes	Yes
P9	32	M	bookbinder	Acquired	No	No

				Blindness		
P10*	-	-	Reviewer	-	-	-

Table 2 – Sample profile
Source: Authors' elaboration.

One of the selected participants (P10), appeared only from the second day of application of the research. For this reason, the data obtained from this participant in the usability test were discarded from the analysis, as we understand that his absence, even if partial, could affect the results. It was chosen in this sense, only the maintenance of qualitative data from this candidate, obtained during the test and the focus group, because we believe that these could contribute to the understanding of the needs of VIP in terms of color representation, without representing risks to the credibility of the data.

3.2 Preparation of participants

The preparation for the usability test took place on the first day of the research application. It was carried out in a group and consisted of two stages: the first with a brief initial dynamic, lasting approximately ten minutes, and the second through the course for presentation of the Universal Code of Colors. The initial dynamic was thought of as a strategy of relaxation and as a way to stimulate the feeling of autonomy of the participants, minimizing risks of tension, embarrassment or negative issues that could influence self-esteem, potentially provoked "by the evocation of memories or by reinforcements in the awareness of a restrictive physical or psychological condition" (CEPSH-UFSC, 2015).

During the dynamics, making use of the method of word association, the participants were asked to say out loud what came to their mind, as they heard the name of certain words pronounced by the researchers. This stage also aimed to bring out the participants' mental representations related to colors, in order to point out ways that could facilitate the learning of the code - through the associations of meanings attributed by the participants themselves. The result obtained can be seen in the table below:

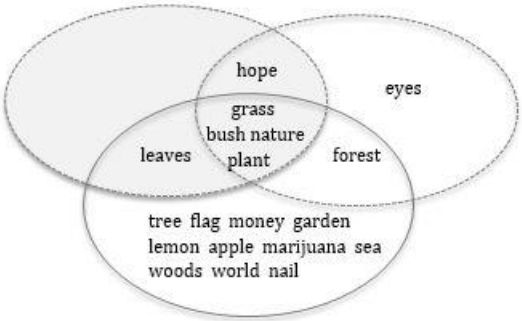
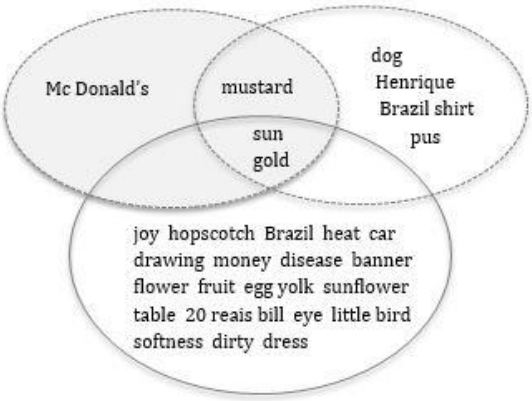
COLORS	"Ah, the world, right? The world is all made of colors" (P5)			
	"State of mind" (P8)	"The sky, the dark" (P9)	"Art" (P2)	"Sea, sun, clothes" (P1)

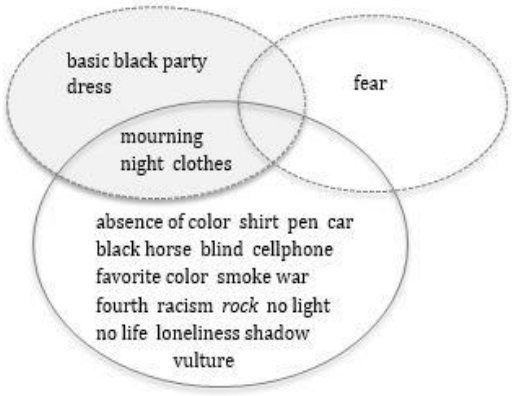
	"Rainbow" (P7)	"Pink" (P6)	"Nature" (P3)	“Intense, but fragile" (P4)
Blue	"Sky" (unanimous, everyone laughs)		"Sea”	“Pool”
Yellow	“Sun, gold”		“McDonald´s”	
Red	"Heart, blood" (P5)	"Passion" (P5)	"It's my favorite color" (P5)	
Gray	"Cloudy"	"There is a lot of black, gray, white pigeon" (P8)		
	"Pigeon" (P5)	"there is gray dog, gray clothes"		
Black	“Grief”	“Basic black outfit for parties”		“Clothes”
White	“Peace!”		“Healing”	
Verde	“Leaf”	“Hope”	“Nature”	“Plant”
	“Grass”		“Bush”	
Orange	“Fruit””	“That uniform of the street cleaners”	"Comlurb" – Garbage collection company of Rio de Janeiro	“Street cleaner” (The street cleaners from “Comlurb” wear orange uniforms.
	“"Orange people say it’s joy, don’t they?"!?” (P6)			
Purple	"October 31st! It's Halloween" (P7)		"Grape” (P6)	
Magenta	"Magenta will vary, it's complicated, right?" (P5)		"Magenta is red!"	
Lilac	"It's from P7*!" (P2)		"Flowers, right?" (P1)	
Light	"A Sunny Day" (P5)	“Peace” (P1)	“Lights on"	
Dark	“Rock and roll”		"The night” (P5)	
	"Dark disappears, [short pause] blackout" (P9)		"That's what headbangers like, right?" (P5)	

Table 3 – Free association of words
Source: Authors' elaboration.

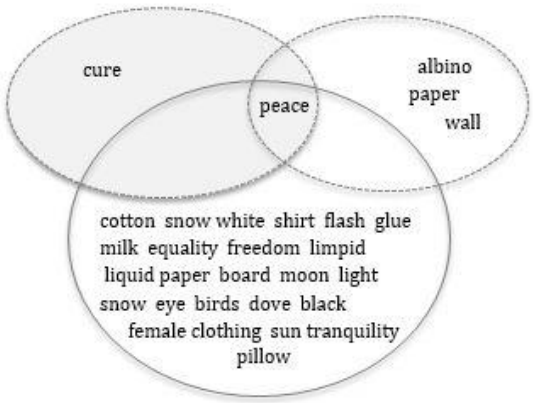
Because it was a group dynamic in which several people spoke at the same time, it was not possible to identify all the authors in their respective lines. In this sense, it was chosen not to interfere during the process, so that it could flow in a natural way, avoiding any discomfort that could inhibit the participants, even if this would result in the loss of identification of authors.

The result of the associations of meanings related to colors, along the dynamics, was similar to those found in the researches of Bianchi et al. (2016) and Bustos et al. (2004) - whose findings, as observed by the authors, were in line with Vygotsky's studies on the attribution of meanings (2001, 2007). Thus, this research once again corroborates the understanding that the formation of color-related meanings is influenced by cultural and social aspects, connected to people's life experiences. These are meanings that, due to interactions, tend to be shared in common sense. The relationship between the different studies and their results is shown below.

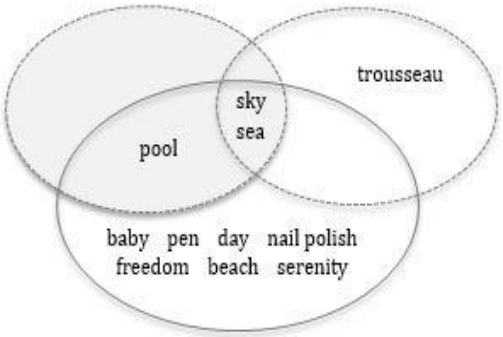
Green	**Yellow**
	
Black	**White**



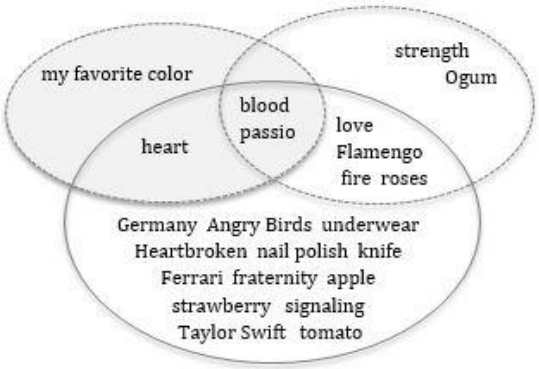
Blue



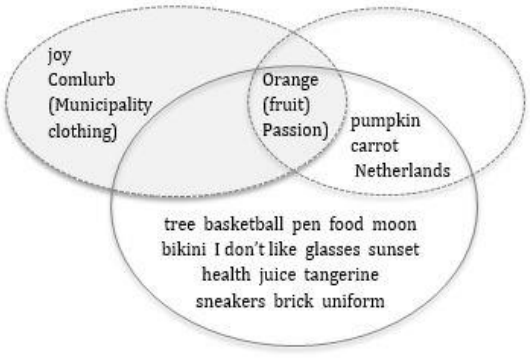
Red

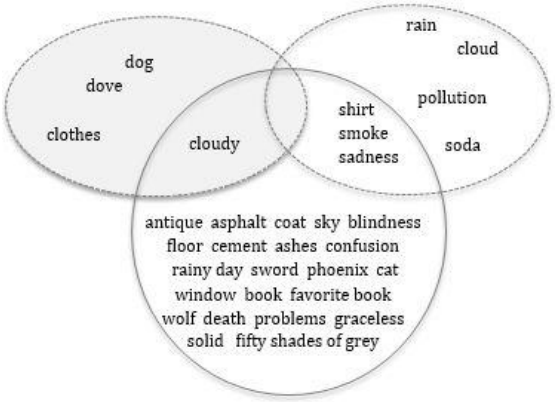


Orange



Gray





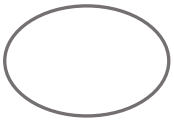
		
Blind UCDC Test	**Blind** Biachi, Ramos and Barbosa-Lima (2016)	**Sighter** Biachi, Ramos and Barbosa-Lima (2016)

Table 4 - Comparative free association of words related to colors

Source: Authors' elaboration based on research data (Bianchi et al., 2016; CUDC).

The UCC course, which lasted approximately thirty minutes, was then taught. The approach adopted throughout the course was based on the teaching of color formation from mixtures, working on primary, secondary and tertiary color concepts - concepts considered fundamental for the understanding of the code. As a way to help and guide the participants, a handout in Braille was distributed, containing fixation exercises and the content of the systematized course.

3.3 The evaluation of the code

The evaluation of the code followed a two-step sequence. The first, through the individual usability tests and the second, through the focus group. In the initial stage two instruments were used, the UCC code test and the System Usability Scale (SUS), developed by John Brooke (1986, apud Tullis & Albert, 2008). Before the application of the instruments, containing ten questions each, a brief group review was performed, approximately ten minutes in length. The result of the UCC evaluation was measured considering the time, accuracy and satisfaction of the participants during the activity.

For the code test, three different levels of hit were considered: total hit, partial hit and error. It was considered a total hit when both the name of the color and its intensity (clear, medium or strong) were said correctly by the participants. In the case of mixtures, as occurs in secondary or tertiary colors, the name of the primary colors that gave them origin, with their respective intensities, was also considered the correct answer. For example, the strong green color as the resulting color could also be identified as the sum of "strong yellow with strong blue". In this same logic, the identification of a color when, only its intensity, was incorrect was considered as a partial answer.

During the tests, besides the verbal instructions, each participant received in Braille the material with the statement and the sequence of questions. Throughout the process, participants were asked to read aloud, question by question, providing in the sequence of each one their respective answers. At the end of the test, the usability scale was applied, whereby participants provided their answers from a predefined numerical scale, or using the semantic expressions related to them. Possible answers included: (1) I totally disagree, (2) I partially disagree, (3) I neither agree nor disagree, (4) I partially agree, (5) I totally agree.

At the end of the tests, the participants were gathered for the focal group, the second stage of evaluation of the code, which lasted about 18 minutes. The dynamic was guided by a set of questions previously prepared by the researchers, in which the participants freely provided their impressions about the code. The data were obtained and recorded with the aid of audiovisual resources, and later transcribed for joint analysis. The method for content analysis used was based on the theoretical codification proposed by Glaser and Strauss (1967 apud Flick, 2009), whose transcriptions are analyzed in an open and selective manner. As a result, it was possible to identify possible applications and limitations of the proposed code.

4. Results and discussion

The tests were performed with an average time of 93 seconds, and no difficulties were evidenced in relation to the reading of the code, following which the 10 questions were presented. Despite the time explained, it is observed that it tends to be even shorter than that recorded, given the eventual delays in the answers - resulting from conversations and comments by the participants themselves.

The questions were presented in an interspersed way, in different degrees of difficulty, containing only two repetitions - inserted intentionally in different places. The purpose of this measure was to verify possible errors caused by participants' nervousness, which could result in errors, during the interpretation of the data.

The average hit rate was 8.7 points, represented mainly by issues involving primary colors, to which they do not have mixtures, or in issues that presented simpler mixtures, with the same intensity variation as those that make up the mixture. In this sense, a possible easiness of the participants stands out, not only because of the simplified

mixture, but also because of the correlation of these colors with their daily lives, whose meaning tends to be influenced by people of their coexistence (Vygotsky, 2007).

Regarding the satisfaction with the use of the code, the participants considered it easy to learn, highlighting the possibility of eventual difficulties by people who did not have "Braille mastery" (P3), so that some "visually impaired [could not] be reached by it" (P6). In this sense, it is important to emphasize that, although this is a valid concern, it is not related to the UCC itself, considering that the mastery of Braille is a pre-requisite of its proposal, aligned with the public for which it is intended.

Another question posed by the interviewees was the time of learning, due to concepts that tend to seem strange to VIP. It was a point that was mainly observed throughout the tests, when the participants dealt with colors coming from different mixtures and intensities, as in the secondary and tertiary ones, which tend to seem "at the beginning [...] a little [difficult] you have to study a little more" (P01), for considering "the part of the mixture [...] a little more complicated [...] question of really studying, of understanding! (P9). This need for a better understanding of the concepts of color was put by the participants in relation to a possible deficit in school education, a neglected content, which tends to collaborate so that the "visually impaired [...] from birth, we do not [have] this information" (P6). This same question was also highlighted in the speech of another participant:

> [...] we studied in a school specializing in visual impairment, so I don't know, at least not me, when in early childhood education, in the first years of training, we didn't have it here [...] it's like this, from school to school, from teaching to teaching, and I don't think it has anything to do with code. I think it has more to do with the education that this child will have. [...] I know some people who studied in regular schools, even blind people by birth, who studied in regular schools, where the teacher had that thing. But that was the teacher's, that was the school that sat and explained about primary, secondary, tertiary colors, about warm colors, cold colors. It's not the code... it's previous knowledge [...]. (P2)

In the view of the interviewees, this is a content that is not normally worked by schools when it comes to VIP, which would not allow them "this notion of primary colors, secondary colors, so that you can arrive and form a color" (P3). In this sense, we emphasize that this point aligns the motivation in which this research was justified - to offer an alternative for the reading and representation of colors by VIP, due to the absence of standardized representative color systems.

Another concern presented by the interviewees was related to the potential of UCC to represent different colors and variations in daily life, enabling its practical use. As mentioned by the participants, some colors tend to be popularized "with very specific names such as pumpkin color [...]" (P2), and may also be related to "trends, and you follow the trends is very complicated" (P5), or yet, because they may present different nuances, as in "printed" (P7), or "checkered" (P2).

In this sense, we noticed a certain anxiety, generated by the expectation of a code of representation, which could provide greater autonomy in the life of VIP, which was projected in the UCC. An alternative that could reduce a constant need to always turn to another "human being [to] ask what you want to know" (P02). Despite the possible limitations observed, due to the different color nomenclatures, it is worth mentioning that these present themselves as a challenge even for the sighted, because of the different color palettes used, which tend to adopt different nomenclatures for specific colors. Another issue that deserves to be highlighted is the potential of the UCC, which is still unknown by the participants and by the researchers themselves, considering that only its standard version with two columns was used during the tests performed.

5. Final considerations

Preliminary tests have indicated UCC as a viable alternative for the representation of colors by VIP, literate in Braille. The high average rate of hits, obtained from a short period of training, highlighted the low complexity of the code and ease in learning. Another issue highlighted by the participants in this sense, refers to the possible difficulties that may arise as a result of the way the concepts related to colors have been worked by schools. A content that, if neglected, can cause eventual difficulties in understanding color related concepts and with that, in the use of color representation systems. In this sense, eventual contributions of the UCC to these contents, which are worked on in class - among other possibilities of use - according to the needs presented by the participants throughout the research. However, it is important to point out that some of the possibilities of representation of the code, desired by the participants, require new tests of the code - due to the need for representative amplification of the colors - which could be supplied from the amplification of the standard model tested in this research, with only two columns.

As future possibilities, we recommend the extension of the tests performed in this research to different VIP profiles, in different segments of school life. The possibility of more complex tests, through the inclusion of a third representative column of colors in the UCC - as already foreseen in its proposal - may contribute to a greater dimension of its representative potential, in relation to the expectations of use pointed out by the participants. In addition, a survey on the different forms, as the concepts related to colors have been worked on throughout the formation of these subjects - in the various disciplines that tend to address the theme - may contribute to point out ways to collaborate with representative systems more adjusted to the needs of VIP.

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References

ABNT (2015). Brazilian association of Techincal Standards. *NBR 9050 Accessibility to buildings, furniture, urban spaces and equipment* (Acessibilidade a edificações, mobiliário, espaços e equipamentos urbanos).

Alisson, E. (2013). *New instrument reduces learning time in Braille* (Novo instrumento reduz tempo de aprendizado de braille). Fapesp Agency Fapesp. Available at http://agencia.fapesp.br/novo-instrumento-reduz-tempo-de-aprendizado-de-braille/17250/.

Amiralian, M. (1997). *Understanding the blind: a psychoanalytic view of blindness through story-drawings* (Compreendendo o cego: uma visão psicanalítica da cegueira por meio de desenhos-estórias). São Paulo: Casa do Psicólogo.

Benjamin Constant Institute - Ministry of Education (2019). *High School Technical Vocational Education* (Educação Profissional Técnica de Nível Médio). Available at http://www.ibc.gov.br/educacao-basica/ensino-medio-tecnico.

Bianchi, C. et al. (2016). Knowing the colours without ever having seen them. (Conhecer as cores sem nunca tê-las visto) *Revista Ensaio Pesquisa em Educação em Ciências*. Belo Horizonte, 2016, vol.18, n.1, pp.147-164. ISSN 1415-2150. Available at https://www.scielo.br/pdf/epec/v18n1/1983-2117-epec-18-01-00147.pdf.

BRAZIL (1988). *Federal Constitution (1988)*. Constitution of the Federative Republic of Brazil. Brasília, DF: Senate. Available at: http://www.planalto.gov.br/ccivil_03/constituicao/constituicao.htm.

BRAZIL (2015). *Law nº 13.146*. Brazilian Law on Inclusion of Disabled People (Statute of the Person with Disabilities). Brasília. Available at http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2015/lei/l13146.htm.

Bustos, C. et al. (2004). Perception of visual deficientes: colours X textures (Percepção dos deficientes visuais: cores X texturas). *Proceedings of the 1st Latin American Conference on Sustainable Construction and the 10th National Meeting on Built Environment Technology*, São Paulo.

Camargo, E. P. (2012). *Teacher knowledge for the inclusion of visually impaired students in physics classes* (Saberes docentes para a inclusão do aluno com deficiência visual em aulas de física). São Paulo: UNESP.

CEPSH-UFSC. Guidelines to prevent your project from being on hold (Orientações para evitar que seu projeto fique em pendência). Florianópolis. Available at https://cep.ufsc.br/orientacoes-para-evitar-que-seu-projeto-fique-em-pendencia-3/. Acesso em: 13 jul. 2020.

Flick, U. (2009). *Introduction to qualitative research* (Introdução à pesquisa qualitative). Porto Alegre: Artmed.

Glaser, B. G. & Strauss, A. L (1967). The discovery of grounded theory: strategies for qualitative research. London: Aldine Transaction.

IBGE (2012). Brazilian institude of geography and statistics. *Demographic Census 2010*: General results of the sample. Rio de Janeiro. Available at https://biblioteca.ibge.gov.br/visualizacao/periodicos/99/cd_2010_resultados_gerais_amostra.pdf.

Neiva, M. (2017). *Colloradd*. Available at http://www.coloradd.net/.

Pereira, G. S. & Ferronato, R. (2019). *Tactile colour identification code for visually impaired people* (Código tátil de identificação de cores para pessoas com deficiência visual). Applicants: Géssica dos Santos Pereira e Rubens Ferronato.

Pedrosa, I. (2010). From the color, to the nonexistent color (Da cor a cor inexistente). São Paulo: Senac.

Pires, F. N. (2017). *Feelipa color code*. Available at http://www.feelipa.com/pt/.

Silva, C. A. P. (2017). *The colours and shapes of smells*: the correspondence between the senses of smell and sight in perfume bottles (As cores e as formas dos cheiros: as correspondências entre os sentidos do olfato e da visão em frascos de perfumes). PhD in Design and Architecture, University of São Paulo, São Paulo. Available at http://www.teses.usp.br/teses/disponiveis/16/16134/tde-21122017-095951/.

Tullis, T. & Albert, W. (2008). *Measuring the User Experience*: Collecting, Analyzing, and Presenting Usability Metrics. Burlington: Morgan Kaufmann.

Vygotsky, L. (2001). *Thought and Language*. Electronic edition: Ridendo Castigat Meres. Available at http://www.ebooksbrasil.org/eLibris/vigo.html.

Vygotsky, L. (2007). *Mind in Society: Development of Higher Psychological Processes* (A formação social da mente) (7. ed). São Paulo: Martins Fontes. Available at http://www.egov.ufsc.br/portal/sites/default/files/vygotsky-a-formac3a7c3a3o-social-da-mente.pdf.

WHO (2018). *WHO says there are 39 million blind people in the world*. Available at https://nacoesunidas.org/oms-afirma-que-existem-39-milhoes-de-cegos-no-mundo/.

UN (1948). Universal Declaration of Human Rights. Available at http://www.onu-brasil.org.br/documentos_direitoshumanos.php.

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