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ANVUR Agenzia Nazionale Valutazione sistema Universitario e Ricerca
APeJ Academic Publications eJournal
BASE Bielefeld Academic Search Engine
DBH Database for statistikk om høyere utdanning
DOAJ Directory of Open Access Journals
EZB Elektronische Zeitschriftenbibliothek Regensburg
JURN Search tool for open access content
ROAD Directory of Open Access scholarly Resources

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PEER REVIEW PROCESS
All articles submitted to the Color Culture and Science Journal are peer-reviewed according to the following procedure:

First review level
The Associate Editors evaluate each article to determine if the topic and content are of interest to the journal. Once the article passes the initial review, the Associate Editors select several reviewers from the Editorial Board based on their expertise in a particular subject area or topic.

Second review level
Two or three experts review each article with a blind peer-review process where the reviewers are kept anonymous. Reviewers are asked to evaluate the manuscript based on the following criteria:

- Originality
- Relevance to journal's aims and scope
- Technical merit and/or validity
- Soundness of methodology
- Completeness of the reported work
- Conclusions supported by the data
- Correct acknowledgment of the work of others through reference
- Effectiveness of the manuscript (organization and writing)
- Clarity of tables, graphs, and illustrations
- Importance to color researchers
- Relevance to color practices

If the article is accepted with major revisions, the author(s) are asked to improve the article according to the reviewers' suggestions. The revised article will then be submitted for further review.
After collecting the reviewers' reports, the Associate Editors recommend the acceptability of the article to the Editor-in-Chief.

TOPICS
The CCSJ accept papers on a wide range of topics on color, including and not limited to the following:

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2. Color and Digital. Reproduction, management, digital color correction, image processing, graphics, photography, film and video production, printmaking and 3D print, artificial vision, virtual reality, multispectral imaging, data visualization. Light field imaging. Multi-sensor fusion. Color localization, recognition, HDR imaging, ADAS systems.
3. Color and Lighting. Metamerism, color rendering, adaptation, color constancy, appearance, illusions, color memory and perception, color in extra-atmospheric environments, lighting design, lighting technologies, visual comfort.
4. Color and Physiology. Mechanisms of vision in their experimental and theoretical aspects, color vision and color appearance, deficiencies, abnormalities, clinical and biological aspects, synesthesia, health, well-being.
5. Color and Psychology. Phenomenology of colors, color harmonies, color & form, perceptive, emotional, aesthetic, and diagnostic aspects.
6. Color and Production. Food and beverages, agriculture, textiles, plastic materials, ceramics, paints, gemology, color in the food industry.
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8. Color and Environment. Representation and drawing, urban planning, the project of color, architecture, interior design, landscapes & horticulture, color and architectural syntax, territorial identities, biodiversity.
9. Color and Design. Furniture, CMF design, fashion, textiles, textures, cosmetics, food design, museography.
10. Color and Culture. Arts and crafts, history, philosophy, aesthetics, ethno-anthropology, graffiti, geology, sociology, lexicology, semantics, anthropology of vision, food culture and heritage, color naming.
11. Color and Education. Pedagogy, didactics of color, aesthetic education, artistic education.
12. Color and Communication/Marketing. Graphics, communication, packaging, lettering, exposure, advertising.

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Editorial

"The dog days are over
The dog days are done
Can you hear the horses?
'Cause here they come"

[Florence + the machines]

Dear readers,

After different years of contributing to Color Culture and Science Journal (CCSJ) as an author, I am proud to write this editorial as Deputy Editor together with the Editor-in-Chief. In recent years we assisted in the development, growth and resilience of the Associazione Italiana Colore and this Journal.

In 2020 they organized the first online conference of the association, and in 2021 the association was able to organize, manage and handle the AIC International 14th Congress, creating an event which connected people all over the world. In the same year, a new international conference was proposed, the "Colour Photography and Film: sharing knowledge of analysis, preservation, conservation, migration of analogue and digital materials", held online in 2021, and in person in 2022, in its second edition. After so much work online, this year it has been a pleasure to meet all the colour experts, professionals, academics and passionate again in person during the "XVII Color Conference" in September.

During the pandemic, the Associazione Italiana Colore did not stop, but found new energy to develop, improve and complete regular and extraordinary tasks. And I am so glad to become part of this organization.

This editorial is dedicated to all the volunteers supporting the Associazione Italiana Colore, from the inside and outside. I want to thank all the backbones of this group, who contributed to building a stable and robust community, able to face all the encountered difficulties, and all the volunteers managing the website, the secretary, the promotion and the online environments during the conferences. An enormous thank you to the members who are no longer with us, who set the basement to the foundation of the Associazione Italiana Colore.

Now that "The dog days are over", we are ready to restart full of energies, new ideas and projects to improve the Associazione Italiana Colore and Color Culture and Science Journal. We invite you to publish and promote our journal, which is a blind, peer-reviewed, *diamond open access*, free for readers and authors.

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Colours, light and well-being: characterization of chromatic phenomena in collective housing.

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ABSTRACT

The objective of the study presented is to demonstrate the interest of chromatic and luminous analysis of a place in the pre-design phase. This analysis protocol is in line with the designer's ethic, which is to anticipate and respond to the conscious and unconscious needs of users, thus participating in the construction of a quality approach. Based on the case study of the "Bonamour" project (Capbreton, France), we question the value and interest of promoting a protocol that favours a benevolent and differentiated design approach. This will allow us to evaluate the relevance of the devices applied. In the end, the data collected and the recommendations applied to the project will allow property developers to progressively turn towards a more inclusive and sensitive design of lighting and colours applied in the residential sector.

KEYWORDS (Light design, Color design, Visual comfort, Protocol, Accompaniment)

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1. Introduction

1.1 Health and housing threats

The recent pandemic we have suffered is the sixth to hit humanity since the Spanish flu of 1918. According to ONU report, the frequency and severity of these global epidemics could accelerate in the coming years, due to our lifestyles and the incredible adaptability of viruses (Intergovernmental Science-Policy Platform On Biodiversity And Ecosystem Services (IPBES), 2020). In this exceptional health context, we have seen that housing conditions have had a greater impact than ever on our daily lives. We therefore realised that the problems linked to the quality and sharing of collective living spaces during a pandemic will be major issues in the future and will require the full attention of real estate professionals.

All the more so for many reasons, staying at home can be accompanied by multiple and varied disabilities, thus affecting quality of life (Eideliman and Gojard, 2008), (Piccoli et al., 2020), (ONU, 2020). In France, approximately 12 million people are affected by a disability, including 1.5 million by a visual impairment and 850,000 by reduced mobility, (Mormiche, 2001). Age is also a factor to be taken into consideration, as in 2050, metropolitan France will have about 70 million inhabitants, of which more than a third will be 60 years old, (Brutel, 2002). For all these people, the positive and reassuring perception of the daily environment must become an important issue. It is therefore necessary to adapt the environment of collective housing to people with different pathologies and their potential consequences on their habits.

1.2 Chromatic effects and methods of approach.

With this study we want to provide reflections on design issues such as the design of sensitive and inclusive built spaces. To do so, we focused on what inclusion means in creating the atmosphere of a place through its influences of colour and light. To this end, we defined that an inclusive atmosphere translates into situations of sensitive interactions understood as the plural and singular experience one has of a given place at a given time, influencing our sensations and quality of life. For many years, designers and authorities have been placing people and their plurality at the heart of architectural projects, based in particular on guides such as the Well Building Standard ('WELL Building Standard (English version). However, if we confine ourselves to strict compliance with the standards, since people do not meet any average, there are still many gaps. For example, in French standards (EN 12464-1 supplemented by NF X35-103), the only indications are that the age of people must be taken into account to define the lighting levels of work surfaces. In collective housing, Article 10 of the Order of 24 December 2015 imposes minimum characteristics to ensure average horizontal illuminance values measured at the floor along a usual circulation route, taking into account transition zones. It goes without saying that strict compliance with these standards does not guarantee the success of an architectural project in the perception of these users (Mudri, 2002).

1.3 Colours and lights: factors of identity and orientation.

In the literature of cognitive science and psychology, there is little research on the role of colour in its relationship to space and in particular in the spatial orientation of people. However, we know that a visual environment adapted to the pathologies of people with disabilities has positive effects, but must respect a certain number of criteria such as a certain amount of light, contrasts and an appropriate spatial distribution (Damelincourt *et al.*, 2010). We have therefore hypothesised that colour and lighting devices in the architectural environment of collective housing could help with spatial orientation, particularly for disoriented people who are less receptive to conventional signage systems (Bay and Fayolle, 2020).

In doing so, this empirical approach will hopefully lead to a reflection on colour in collective housing environments. Inherited from hygienic and standardised norms, we note, even today, that few works integrating colour are the object of a voluntary approach. The choice of colours and materials often depends on the tastes of the project manager and the usual validation of the client, but what seems to be a secondary issue is in reality a key point in the evaluation of the success of an architectural project. The results of this study will allow the development of a creative protocol that will help the developer to design visual environments that are adapted to the needs of all inhabitants.

The main results expected from this study are:

1. To improve the analysis and interpretation protocol for defining comfortable visual environments.
2. To develop tools to simulate the lighting environment in the design phase of the programme.
3. Facilitate the integration of the results of this study by professionals.

2. Materials and methods

2.1 Color-matter, color-light

The protocol presented is based on a combination of chromatic expertise (chromatic countertype) concerning the choice of materials, textures and finishes, favouring colour for its plastic character; and lighting (light

characterization) concerning the quantity and colour character of light, with particular emphasis on different colour temperatures. This study focuses mainly on the creation of the common spaces and the interior horizontal circulations. Indeed, the visual ambience of these spaces should create a sense of welcome, visual comfort and safety for all users, of all ages, day and night. The bi-disciplinary method used will therefore serve to create coherence and harmony between the exterior landscape treatments and the interior colour and light treatments in order to create an intuitive and inclusive chain of movement. The method was divided into two stages:

2.1.1 Step 1: Captures

The surveys presented were carried out on 26 June 2019 in Capbreton (Landes, France) over a period of 8 consecutive hours on the site of the future "Bonamour" residence built by the property developer SOBRIM (SOBRIM - HARANAM).

The first phase consisted of collecting photographs of the site. The inventory of the existing site is an essential phase before any project. Equipped with a camera (Canon EOS 2000D, Adobe rvb colour space), this preliminary chromatic analysis was accompanied by a walk on the site which aimed at establishing a diagnosis of the architectural and vegetal environment surrounding the project in order to transcribe the essential elements. Photographs cannot faithfully reproduce the colours of a palette. However, they are essential graphic documents for memorising, visualising and disseminating information (Lenclos and Lenclos, 2016). Most chromatic studies employ photographic investigations to support colour surveys. In our case, photography was used in two approaches, one aimed at establishing an inventory of surrounding urban colours and forms, the other a colour and light diagnosis in order to judge the appearance of the site under cyclical conditions. This step was a way to transcribe and analyse the experience of a space. The second phase consisted of referencing the colours of the site with the help of countertypes. In our study, the colour survey consisted of observing the colours that make up the environment and the architectural elements surrounding the project in order to compare them to reference colour samples. Here we used the colours of the NCS colour chart. The Natural Color System is a universal system used for standardised colour communication, based on an intuitive coding system designed for human vision. This reference system allows us to communicate colours universally in different fields of application. This representation has also allowed us to translate these colour readings into values using the CIE XYZ L.a.b system, taking into account the logarithmic response of the eye, but also the specific characteristics of coloured surfaces with their luminance index. The third phase consisted of a series of measurements to characterise the lighting environment of the site. This pre-assessment was carried out at three different times of the day (10:00, 14:00, 17:30) to measure the light amplitude. In addition, in order to analyse the distribution of light in the space, the space was divided into several areas of the site. This series of measurements was carried out with the IRC CL-70F chromameter, allowing the collection of all light values. A video-luminance meter (CANON EOS 2000D, Fish-eye 4.5mm 1:2.8 lens + PHOTOLUX 3.1 software) was also used to identify areas that may be sensitive to glare and shadows caused by future buildings.

2.1.2 Step 2: Creation

The first phase consisted in analysing the elements collected: evolution of the existing light according to the architectural and plant masks, as well as the chromatic identity of the site (see Figure 1).

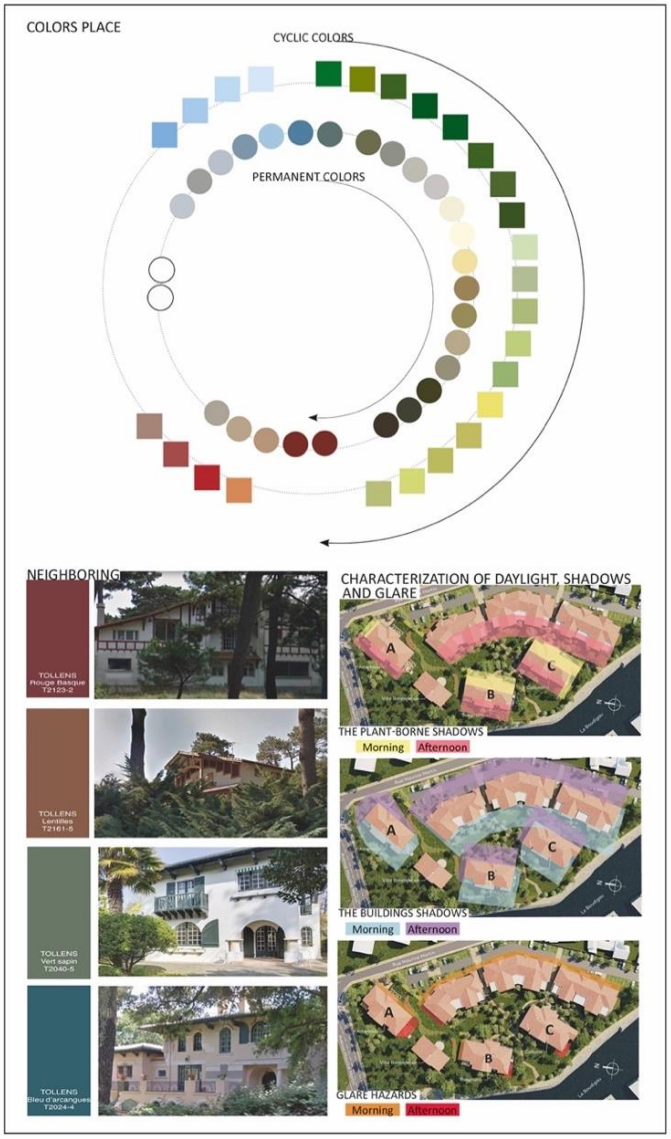

Fig. 1. Environment study, Capbreton, France.

Each environment has a unique identity, of which colour and light are part. The mission of the colour designer must necessarily include a diagnosis of the existing environment. This stage defines the way in which we will approach the existing environment and certain elements in relation to the project, but also in relation to the promoter's wishes in terms of expected aesthetic and functional ambitions. In this phase, we have taken into account the so-called "permanent" and "cyclical" colours. The "permanent" colours are the basis of any chromatic study. They constitute the stable elements of the place, having a durable character, such as the building materials. They are opposed to "cyclical" colours, which are unstable and subject to innumerable temporal, meteorological and light variations, such as the colour of patinas, plants and the sky (etc.).

The second phase consisted of recommending ambiences adapted to the site, using chromatic ranges, materials and lighting systems that favour the safety and visual comfort of all the inhabitants. This method consisted of experimentally constructing chromatic ranges by means of the view, proceeding by variation and multiplication of optical combinations until a visual impression was obtained that conformed to the aesthetic expectations of the project. To design these colour schemes, we used the NCS colours previously surveyed on site, which we then matched with the paint and plaster manufacturers' colour charts used for the project. Thus, a visual and aesthetic atmosphere was conceived around the spirit of the place, the chosen shades are sublimated by the contribution of contrast around several soft and affirmed tones inspired by nature which create a coherent harmony with the vegetation present on the site. These prescriptions led to the creation of three specific colour palettes for each building in the project (see Figure 2).

Inside, the chromatic combinations are composed of five shades, but established on a dominant trichromy , varying at each level, thus avoiding any visual disturbance caused by a discordant polychromy, and relieving the space of a certain visual monotony recurrent in this type of place. Particular attention was paid to chromatic contrast and luminance values, as contrast sensitivity generally decreases with age and can be even more disturbed when visual pathology is added. Thus, the luminance indices of each recommended colour are between 0.6 and 0.9 for light colours and between 0.2 and 0.45 for dark colours, and finally, a contrast of 70% has been respected between the various important media so that they can be perceived by a visually impaired person, whose sensitivity to contrasts is still operating. Here, light colours are used for large surfaces and dark colours for small surfaces or accessories to allow better discrimination of spatial elements. Some of the contrast values are not equal to 70%, but they have been accepted because of a negligible margin of error. The creation of these differentiated harmonies allowed us to design circulation spaces with chromatic variations for each level, favouring intuitive orientation as well as efficient and comfortable reading of the movement chain for all inhabitants.

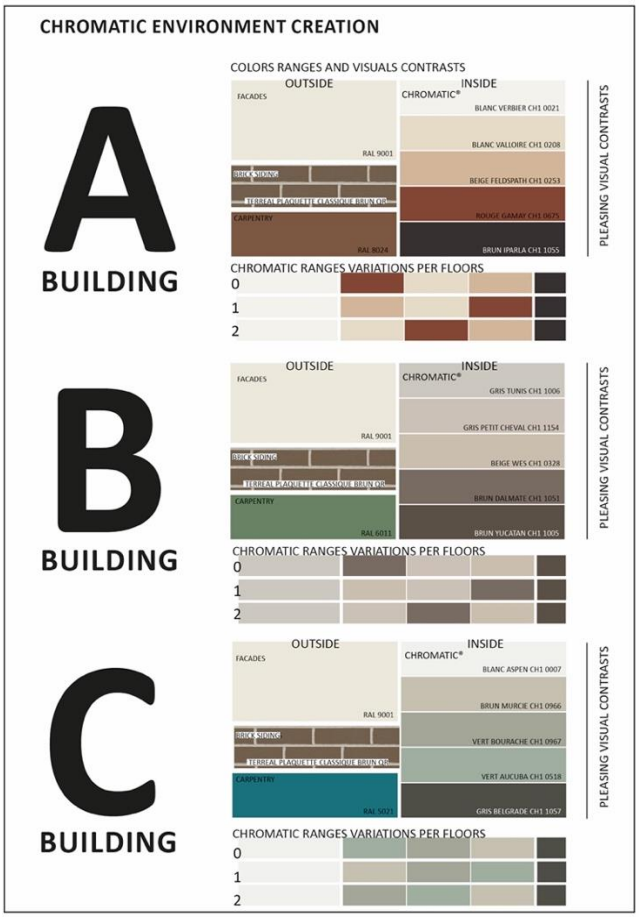

Fig. 2. Chromatic environment creation.

These harmonies were also accompanied by a lighting project. This was studied so that the quantity and quality of light would meet the needs of all inhabitants, because the visual, light and lighting needs of people over 75 are not those of a 50 year old, and even less so of a 30 year old. Due to the physiological ageing of the eye and the retina, more light is needed to perform certain daily tasks. This need is increased in the case of diseases such as glaucoma, cataract or eye damage caused by diabetes or medication. As a result, from the age of 55 onwards, the amount of light required is 300% higher than at the age of 25, and this for an equivalent level of visual performance ,(Association française de l'éclairage, 2020). For this reason, we recommended an average of 300 lux on the floor throughout the chain of movement of interior spaces (entrance halls, corridors, staircases), while taking care to accentuate certain

important areas or elements by light contrast, such as the highlighting of signage elements, access to lift doors and wall decorations serving as visual and orientation markers in long corridors. This was achieved through the use of LED general and ambient lighting systems that provide both direct and indirect light to accentuate the volumes while not producing harsh light-dark transitions. Finally, we chose to apply a colour temperature of approximately 3000 Kelvin; this choice was supported by the fact that we plotted this data on the Kruithof curve (Viénot, Durand and Mahler) in order to deduce whether the visual ambiences are considered comfortable for the majority of observers (see figure 3).

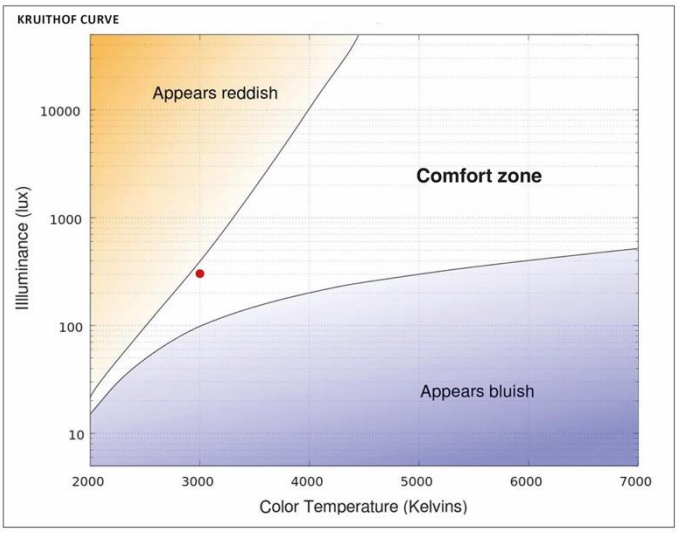

Fig. 3. Choice of illuminance and colour temperature to create a comfortable visual environment.

In addition, recent research has shown consistent effects of lighting characteristics on perceived ambience. Increasing illuminance would result in a less difficult and more vivid perception of the overall ambience as would the application of warm white light (2800K) which would be perceived as more comfortable than cold white light (6000K).(Kuijsters *et al.*, 2011).

Also, concerning the choice of materials, we studied their LRV (Light Reflectance Value) in order to recommend suitable finishes in all the circulation zones according to the natural light input and thus not to generate too much glare or darkness.

Finally, the third phase was the creation of a technical execution file for the project management. This file is based on and complements the documents provided by the project architect and includes normative descriptions as well as graphic documents such as colouring diagrams on plans, lighting system layout diagrams, cross-sections, a details and signage booklet, as well as a material library to ensure the proper implementation and monitoring of the project.

3. Result

The different phases of analysis helped to demonstrate how qualitatively and quantitatively the project could be perceived by the inhabitants ,(INSEE, 2017). Mainly thanks to the exposure of the buildings, their light contributions in relation to the different masks, and the architectural and landscape aesthetics of the overall environment.

The interpretation of these results allowed us to prescribe effective and coherent lumino-chromatic ambiances, taking into account the constraints linked to the respect of the local architectural aesthetics found around the site, the respect of visual contrasts as well as the hypothetical contribution of natural light entering each building. This design phase, of course, complies with current standards in the field of lighting design for this type of space, but it calls for an experimental construction method (Pfeiffer, 1966), taking into account several factors intrinsic to the project:

- The analysis of the colour and light characterization of the site.
- The spirit and visual coherence of the project location.
- An efficient chain of movement.
- The comfort of use and appreciation of the spaces for all inhabitants.

The outcome of this protocol was the creation of a construction file and a detail book, intended for the client in order to transcribe the information gathered into technical prescriptions, colouring principles and effective lighting of the future building (see Figure 4).

Fig. 4. Results obtained to facilitate the assimilation of space and movement.

We hypothesize that this bidisciplinary experimental expertise of chromatic and luminous characterization within its future circulation spaces will generate more visual cues and comfort of use thanks to this protocol.

4. Discussion

The issue of lighting and colour in collective housing is quite complex, as designers' preferences vary greatly according to both objective and quantifiable conditions (economy, standardization of practices, specific needs related to people with disabilities, etc.) and socio-cultural and subjective conditions (preference for a particular colour scheme, type of luminaire, type of covering, etc.).

As a result, and in the absence of standards directly related to these semi-private spaces, architects tend to use very neutral, even monotonous, colours and materials, and struggle to install lighting that is sufficiently effective, comfortable and aesthetic in common areas. With the help of this study, we are beginning to awaken designers to the challenges of colour and light. Because together, beyond their simple aesthetic contribution, they make it possible to secure and make efficient the circulations while allowing the inhabitants to plunge into singular universes where the atmosphere becomes a factor of wellbeing and cohesion.

5. Conclusion

In the next few years, we will repeat these measurements in the built collective residences and a comparative study will complete the research-creation protocol studied in this article. This comparative study will take into account the values obtained in the old residences and those that were built using this protocol. This study will be completed by a questionnaire intended for the inhabitants, where they will be asked to answer questions relating to their state of health, their general satisfaction with the care given to the (interior) environment of their residence and finally to describe in detail their long-term visual impression of the common spaces. They will then be asked to evaluate their visual comfort in specific places and times of the day using sensation grids.
This will allow us to compare this feedback with measurements taken in situ in order to correlate the metric data collected with the visual atmosphere felt. This study will enable the property developer to ensure the efficiency of its approaches and to continue to systematically and sustainably design visual environments better adapted to human physiological needs by proving the validity of qualitative approaches in terms of the design of light and colour within its property programmes.

6. Declaration of funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or non-for-profit sectors.

7. Declaration of conflict of interest

The author has declared that no competing interests exist.

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9. Biography of the authors

Lorrain Caumon is a CIFRE doctoral student in the LAPLACE and LARA-SEPPIA laboratory of the University of Toulouse (France). Since 2019, she holds a master's degree in creation, research and innovation in colour (ISCID, France) and is currently a colour designer specialising in inclusive space design within the company SOBRIM. Her research focuses on the interaction between colour design and lighting sciences, with the aim of promoting comfort and well-being in collective housing.

Estelle Guerry is a doctor of the universities of Toulouse (France). She specialises in colour design and lighting science, with the aim of promoting the comfort of the elderly.

Georges Zissis, PhD, is a full Professor and Director of “Light & Matter” research group of LAPLACE (Toulouse 3 University, France). His primary area of work is in the field of light sources science and technology.

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Christelle Infantes, DPLG architect and head of the Haranam research and development department, within the company Sobrim from 2017 to 2021.

Licensing terms

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Colours of Emotion, Trust, and Exclusivity: A Cross-Cultural Study

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ABSTRACT

Colours influence the way people feel, think, and behave. The globalising (internet) economy induces traditions and beliefs to be transferred from one society to another. Nevertheless, although people may now act more globally, they also still act locally within their cultural groups. This points to the possibility of continuous change in universal and culturally specific colour associations. Therefore, this study aims to investigate variations in colour associations across cultures. To get a better grip on the global impact on the cultural dynamics, cultural groups are distinguished through self-identified membership, instead of through country and nationality demographics. Specifically, a comparison is made with the colours for trust, emotion, and exclusivity between 1,218 individuals from four cultural (ethnic) groups: Dutch; French; Greek; and Russian. Participating in an online survey, they indicated their associations for colour variations of blue, red, yellow, and black. The results confirm general, universal colour associations. Some distinctive independent cultural specifics through varying colour brightness may possibly render the association more or less strong for the colour–attitude relationships of red for emotion and blue for trust. Pure yellow was a noticeable colour associated with emotion by the Russian group.

KEYWORDS colour, culture, emotion, trust, exclusivity

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1. Introduction

Colours are everywhere and influence people's attitudes and behaviour. The ongoing process of a globalising (internet) economy causes traditions and beliefs to be transferred from one society to another. However, although people are now acting more globally, they also still act locally within their cultural groups. This points to the possibility of (continuous) change in universal and culturally specific colour associations. Several overview studies have noted that colour meanings, as well individuals' preferences, are moderated by their cultural backgrounds (Lee and Lee, 2021; Yi and Shamey, 2015). Recently, Mohr *et al.* (2018) noted that prior colour studies have provided too heterogenous findings that were dependent on the context (such as the appropriate colour for interior spaces, logos, websites, etc.). They emphasised that empirical evidence-based investigations are needed to unravel the universal and culturally specific association patterns. In a similar vein, Witzel (2019) highlighted misconceptions about colour categories that should be considered. Subsequently, colour-specific findings would advance, more generally, the exploration of the biological, ecological, and cultural influences of human functioning. Remarkably, cross-cultural studies on colour have mostly identified groups by nationality or country. These constructs have provided a rather imprecise identification; it has been increasingly found that comparing national cultures or countries does not reflect reality. A better way of categorising cultures is through (ethnic) self-identification. This information is more indicative of the cultural identity and considers the dynamics in societies (for further references, see Broeder, 2022). The present study addresses this gap in prior cross-cultural colour investigations. Members of cultures are identified through their ethnic self-identification. Hence, this study aims to unravel colour associations across cultures. New empirical data are presented for four cultural groups in Europe.

This paper is structured as follows. First, the core dimensions of colour are clarified. Additionally, colour variations are related to their impacts on people. Specifically, some recent findings are discussed regarding the attitudes and purchase intentions of consumers online. To this end, the findings are detailed regarding the colour association for emotion, trust, and exclusivity, differentiated by the Dutch, French, Greek, and Russian cultural groups.

1.1. *Colour differentiations*

Colours vary on multiple attributes. The basic dimensions are hue, lightness, and chroma (Elliot and Maier, 2012; Fraser and Banks, 2004). Hue refers to the wavelength of a colour. Human eyes absorb light on different wavelengths, after which our brain converts it into the colours we see. Hues are the specific colour variations perceived by human beings (such as in a rainbow). The second colour dimension specified is lightness (or brightness). This is basically the white-to-black attribute of a colour, i.e., the presence of grey (tone), white (tint), or black (shade). Finally, the chroma attribute refers to colourfulness. This is basically the vividness of a colour.

Blue and red are the most investigated and compared colours, detailed overviews for which are provided by Labrecque et al. (2013), Labrecque (2020), and Roschk et al. (2017). Traditionally, and in general, some colours are perceived as more attractive than others. According to Kodžoman et al. (2022), blue is the most attractive colour, followed by red and green. The least preferred colour is yellow. Recently, cross-country investigations by Jonauskaite et al. (2016) have supported that, in general, the most preferred hue is green-blue (cyan) and the least preferred hue is yellow.

Prior studies have discovered that colour variations have different physiological, attitudinal, and behavioural influences (Elliot and Maier, 2014). Physiologically, different colours have been investigated for their influence on heart rate, respiratory rate, blood pressure, and skin-conductance response. Saturated and bright colours evoke higher arousal; specifically, red elicits higher arousal than blue (Wilms and Oberfeld, 2018) and green (Kuzinas et al., 2016).

Several extant studies have found attitudinal effects of interior surface colours, such as the wall colour of a classroom (Yildirim et al., 2016), the (paper) background colour of a restaurant menu (Magnini and Kim 2016), or a luxury hotel room (Kim et al., 2020). Generally, warm colours are more arousing, exciting, and distracting than cool colours. In particular, the warm colour red is linked to excitement, activity, strength, and stimulation. It stimulates human feelings and activates people (Al-Ayash et al., 2016; Chou et al., 2020; Gorn et al., 2004). Cool colours are more satisfying than warm ones. These colours, especially the colour blue, are generally perceived as comfortable, relaxing, peaceful, and calming. Additionally, they have the potential to decrease anxiety levels (Clarke and Costall, 2008; Song et al., 2020). Warm colours have a negative association in terms of evoking pleasure. Conversely, cool colours make one feel good, joyful, happy, or satisfied (Mazaheri et al., 2011). Specifically, in a retail context, cool colours increase (online) shopping intentions (Roschk et al., 2017; Seckler et al., 2015).

In a general sense, high value colours produce greater feelings of relaxation and greater liking for the brand or product. Specifically, for pleasure, light shades of red are recommended (Gorn et al., 1997). Across 55 countries, Jonauskaite et al. (2019) explored the influence of the physical environment on colour associations. They found that people living further away from the equator, in less sunny and more rainy countries, were more likely associate the colour yellow with the emotion of joy. For evoking trust, the most prominent colour is blue, especially compared to the distrust associated with red (Su et al., 2019). Darker shades, particularly black and purple, express exclusivity and sophistication (Labrecque and Milne, 2012).

For behavioural intentions in online shopping contexts, several studies have confirmed that colours contribute to the web store's 'motivational power' (arousal and emotion) and 'likeability' (pleasure) (Poels and De Witte, 2008). Colours have a specific impact on shopping behaviour, such as unplanned purchase, time spent on the web site, and overall satisfaction (Choi et al., 2020; Koo and Ju, 2010; Mummalaneni, 2005). Specifically, Lee and Lee (2006) found that a lighter red colour toned down the associations of aggression and active feelings, in comparison to a darker shade of red.

1.2. *Cultural differentiations*

Adams and Osgood (1973) provided a good example of a classic study on cultural colour differentiations. They investigated the affective meaning of eight distinct colour concepts (reported by male high school student groups from 20 countries representing 23 cultures). Through a semantic differential consisting of opposite adjective pairs, the culturally diverse group rated colours for the following factors: valuation (good/bad); potency (strong/weak); and activity (active/passive). This three-dimensional construct was stable across cultures. For the evaluation factor, the colour blue scored the highest (i.e., most cultures preferred this colour). The most potent colours were black and red; the most active colour was red; black was the most consistently agreed upon colour; and blue was ranked as the most familiar one. Follow-up cross-cultural studies on colour meanings have revealed that people of different cultures have a wide variety of types of meanings and attitudes. Empirical investigations support the existence of universal and culture-specific patterns for colour meanings. The overall favourite colours have been ordered as follows: blue; red or green; and then yellow (Aslam, 2006; Bakker et al., 2015; Cyr et al., 2010; Madden et al., 2000). Ou et al.'s (2018) quantitative modelling techniques based on empirical data from 12 regions worldwide presented consistent, culture-independent patterns for colour emotions (regarding warm/cool, heavy/light, active/passive). Elaborating on this, Witzel et al. (2019) noted that the perception of purer (saturated) red, yellow, green, and blue colours exhibited more cross-cultural stability than other colours.

From on (online) marketing communication perspective, Broeder and Scherp (2017) initiated a series of cross-cultural investigations on the influence of colour on online purchasing intention in a mock-up web shop. Pure yellow was the most evocative colour where persuasion was concerned. In their study, the colour made Western consumers score higher on purchase intention than the pure colours red and blue. A similar, more or less evocative impact of a specific colour could not be found for Asian consumers. Some recent investigations, following on from Broeder and Scherp (2017), have indicated that colours contribute to the web store's motivational power and likeability, consequently enhancing the possibility that the intended behaviour (purchase, booking) is actually performed. In this regard, the colour variations compared in these follow-up studies are presented in Figure 1.

	Light values	Dark values
Blue trust		
Red emotion		

Figure 1. Colour variations compared for blue trust (Broeder and Snijder, 2019) and red emotion (Broeder and Wildeman, 2020).

Broeder and Snijder (2019) found that both Dutch and Chinese consumer groups preferred the use of very dark blue [HSL (208, 50, 20)] over very soft light blue [HSL (209, 50, 70)] in online shopping environments for creating trust. Similarly, in Broeder and Wildeman's (2020) study, red as the most emotion-inducing colour was investigated among Dutch and Vietnamese groups: very light red [HSL (0, 100, 75)] was found to be more evocative for purchase intention than dark red [HSL (0, 100, 24)].

2. Method

2.1. *Objective*

The present study specifically aims to examine: (1) the associations for emotion, trust, and exclusivity for six colours; and (2) the moderation of cultural background. New empirical insights are presented by differentiating

cultural groups through individual (ethnic) self-identification.

2.2. *Participants*

Between 2017 and 2019, an online questionnaire was completed by 1,218 participants from four different cultural groups [the Netherlands (*N* = 567), France (*N* = 158), Greece (*N* = 298), and Russia (*N* = 195)]. They were selected through non-probabilistic convenience sampling and their cultural background was ascertained through self-identification ('To what ethnic group do you belong?'). This did not necessarily match their birth-country or their country-of-living. There were 539 (44%) male and 679 (56%) female participants, and the mean age was 30 years (age range, 15–65 years). The education level was predominantly middle/higher education or university.

2.3. *Questionnaire*

The respondents filled in an online questionnaire through Qualtrics. The questions were asked in English, which was not the native language of the participants. Colour associations were assessed with three questions ('The colour I associate the most with trust/emotion/exclusivity is …'). For each question, they had to select from six coloured squares: pure blue, dark blue, pure yellow, pure red, light red, and black. The RGB (red, green, blue) and HSL (hue, saturation, lightness) codes of the colours are detailed in Table 1; the name labels and codes are derived from www.colorhexa.com. Some of these colour variations have been investigated in earlier research by Broeder and Scherp (2017), Broeder and Snijder (2019), and Broeder and Wildeman (2020).

	RGB colour model	HSL colour model			
		Hue	Saturation	Lightness	
Pure blue	#0000FF	240	100	50	
Dark blue	#1A3650	208	50	20	
Pure yellow	#FFFF00	60	100	50	
Pure red	#FF0000	0	100	50	
Light red	#FF7F7F	0	100	75	
Black	#000000	170	0	0	

Table 1. Characteristics of the colours used in this study.

3. Results

3.1. *Colour and emotion*

The colour–emotion profiles for the four groups are presented in Figure 2. Red, specifically pure red, was associated the most with emotion, whereas dark blue and black were associated with it the least.

The proportion of emotion association with pure red reported by the Dutch (62%) and Greek (57%) respondents was higher compared to that of the French (46%) and Russian (39%) ones. Notably, yellow emerged as the second colour of emotion as reported by 33% of the Russian group (much higher than the other groups). Separate chi-square tests confirmed that there was a significant relationship between cultural groups and the emotion–colour profile: χ^2 (15) = 134,998, $p < 0.001$, *phi* = 0.192. The colour associations for emotion were independent of gender: χ^2 (5) = 8,20; $p = 0.145$.

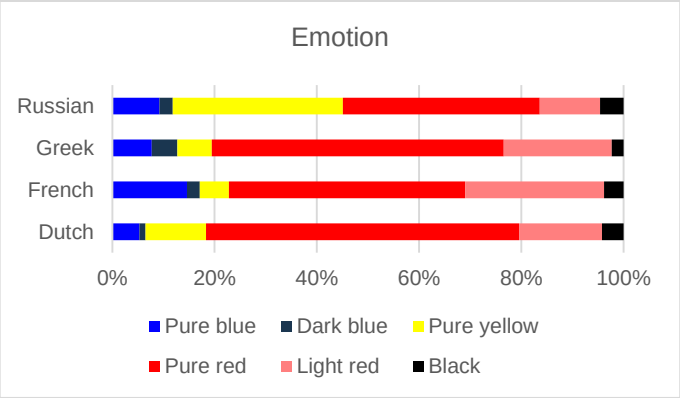

Figure 2. Colour associations for emotion.

3.2. *Colour and trust*

For all four groups, blue, specifically pure blue, was associated the most with trust. In comparison, pure red and pure yellow were associated with it the least. Figure 3 depicts the trust–colour profiles for the culturally different groups in the present study.

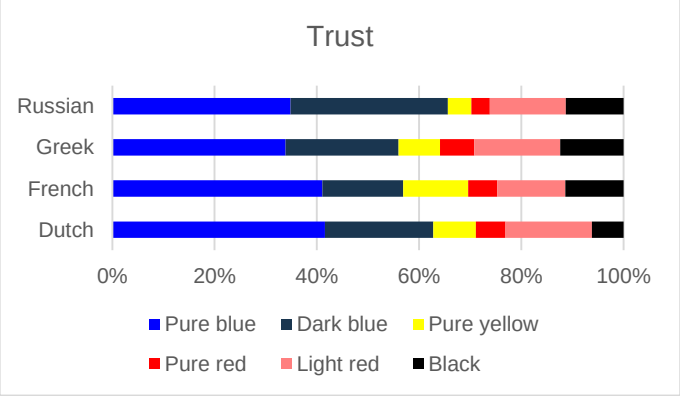

Figure 3. Colour associations for trust.

For trust, the proportion of associations with pure blue reported by the Dutch (42%) and French (41%) respondents was higher compared to the proportion of Russian (35%) and Greek (34%) ones. Dark blue emerged as the second colour for trust in all four groups.

There was a statistically significant relationship between cultural groups and the trust–colour profile: χ^2 (15) = 34,623; p = 0.003; *phi* = 0.097. A chi-square test for independence indicated a significant relationship between colour associations for trust and gender: χ^2 (5) = 21,645; p = 0.001; *phi* = 0.133. Notably, the proportion of female respondents who associated pure blue with trust (52%) was comparable to the proportion of male respondents (49%). However, a gender difference was evident for the light red associations. A higher proportion of female respondents (69%) associated trust with light red compared to the male respondents (31%).

3.3. *Colour and exclusivity*

Figure 4 displays the colour–exclusivity profiles per group. Black and dark blue were associated more with exclusivity, while pure blue and light red had the opposite association.

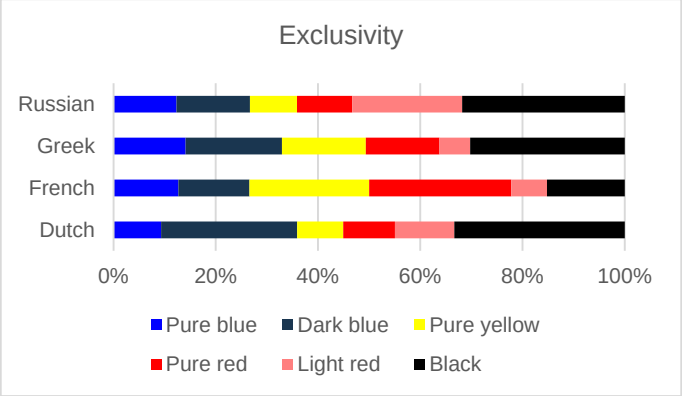

Figure 4. Colour associations and exclusivity.

The proportion of exclusivity associations with black reported by the French respondents (15%) was remarkably lower compared to the proportion in the other three cultural groups: Dutch (33%); Russian (33%); and Greek (30%). Once again, separate chi-square tests were performed. There was a statistically significant relationship between cultural groups and the exclusivity–colour profile: χ^2 (15) = 119,208; p < 0.001; *phi* = 0.181. No significant relation was found between gender and colour for exclusivity: χ^2 (5) = 3.94; p = 0.558.

4. Discussion

This study has investigated universal and culturally specific patterns of colour associations, examining their impact on emotion, trust, and exclusivity as pertaining to Dutch, French, Greek, and Russian cultures. Gender differentiations could only be pinpointed for the colour light red; women associated relatively more trust with light red compared to men. Across these four cultural groups, the following global similarities in colour associations were found:

- Red was the colour of emotion; specifically, pure red was associated more with emotion compared with a lighter variation of the colour.
- Blue was the colour related to trust, whereby pure blue was associated more with trust than a darker variation of blue.
- The most exclusive colour was black, followed by dark blue.

Some local culturally specific associations were reflected in that pure red was associated relatively more with emotion by the Dutch and Greek cultural groups (vs. French and Russian). In addition, pure blue was associated more with trust by the Dutch and French cultural groups (vs. Greek and Russian). Pure yellow was a noticeable colour associated with emotion by the Russian group. With respect to the colour yellow, a prior cross-country investigation by Jonauskaite *et al.* (2016) found that the least preferred hue is yellow. In contrast, a prior cross-cultural investigation by Broeder and Scherp (2017) found that yellow is the most persuasive colour for online use in e-commerce. Recently, Griber *et al.* (2021) provided an intergenerational linguistic analysis of the Russian colour-vocabulary, including the Russian terms for referring to the colour yellow. They noted that historic changes in the sociocultural (Soviet/Russian) reality affected the colour-vocabulary and colour-naming patterns. It can be anticipated that the colour yellow has negative emotional association for Russians. This assumption needs to be explored further.

This study has limitations that give rise to some suggestions for further research. First, the colour patches were presented in an online questionnaire with the participants asked to select one patch from the series of six coloured pictures. Factors such as the lighting of the (computer monitor) environment were not considered. This might have created a confounding variable. In this respect, Jonauskaite *et al.* (2020) found that colour–emotion associations differed between elicitations with colour terms or colour patches in their experiments. There existed high similarity patterns between the two elicitation types for a set of colours including red, blue, and yellow, but not for the (exclusive) colours black and purple. The colour term black elicited more negative associations compared with the colour patch black.

Second, and further elaborating on the previous limitation, the participants in this study reported basic unipolar colour associations, i.e., the valence aspect

(positive or negative) of each concept was not considered. Further, cross-cultural investigations might explore the bipolarity of colour associations for the three concepts focused on in the present study. For instance, the emotional valence of red is more likely negative (danger, warning) in Western cultures and positive (good fortune, prosperity) in Chinese cultures. Specifically, in contrast to Western stock exchange markets, red represents up-markets whereas green represents down-markets (Jiang *et al.*, 2021). In addition, the strength of specific colour associations might be related to other culturally specific values, such as uncertainty avoidance. For instance, based on recent empirical cross-cultural investigations by Broeder (2022), it is a reasonable conjecture that the influence of blue on trust will be stronger in higher uncertainty-avoidance cultures (such as Greece and France) compared to lower uncertainty-avoidance cultures (such as Russia and the Netherlands). In a similar vein, based on the degree of culturally specific individualism (Hofstede, 2022), it can be assumed that the exclusivity of black and dark blue will be more prominent in collectivistic cultures (such as Greece and Russia) compared to individualistic cultures (such as the Netherlands and France).

Third, it is important to keep in mind that in this study, the colours were presented isolated from context. Specifically, Martinez *et al.* (2021) noted that, in a retail environment, product and store colours cannot be considered standalone variables. For example, they observed that, in a mock-up blue retail environment, chocolate with a red package was considered more attractive and had higher purchase intentions, compared to blue and beige packaged colours. In contrast, in an orange retail environment, orange packaged chocolate was preferred. In a similar vein, Bakker *et al.* (2015) found different colour preferences among the Dutch: white was preferred in residential and office environments; however, black was mentioned as the favourite colour for clothing (more by females than males).

5. Conclusion

In general, the findings of this study suggest colour variations that are specifically associated with emotion (red), trust (blue), and exclusivity (black). In addition, some specific differentiations relate to the brightness dimension affecting the potential of a colour association. In this study pure red (vs. light red) was reported to be associated relatively more with emotion. Pure blue (vs. dark blue) was reported to be associated more with trust. These differentiations seem to be culturally independent from the colour–attitude combinations (red–emotion and blue–trust) that were explored in the current study. Further cross-cultural investigations of colours-in-context (Elliot and Maier, 2012) might reveal the underlying determinants from which colour associations and preferences originate (for references, see Gedron, 2017; MacDonald *et al*., 2018; Witzel, 2019).

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7. Declaration of conflict of interest

The author has declared that no competing interests exist.

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Licensing terms

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PIXAR's Colorscripts: Chromatic Analyses of Four Films Using Sens|Org|Int Model

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ABSTRACT

The objective of this study is to make chromatic analyses of the colorscripts of four Pixar films using Sens|Org|Int model. These analyses are intended to understand the use of color and their communicative intentions, as well as discuss communicative relationships between emotion and plot through the use of colors, identifying which aspects of chromatic perception are objective (physiological) and which aspects of chromatic perception are subjective or interpretive. The empirical research was conducted creating first an instrument of analyses for the colorscripts, based on the theoretical review. Results of the analyses indicate not only that Pixar uses color very coherently and effectively in terms of physiological visual perception, but also show which color uses and contrasts are mostly used and with which communication intentions. Also, the analyses convey a broad scope of color associations in films that could be useful for future chromatic projects.

KEYWORDS *colorscripts, emotional associations to color, animation, cinema, color communication*

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1. Introduction

The concept of colorscript (FIGURE 1) is a filming tool used in the production of some movies, mainly in animations. It allows us to see the full emotional mood that color brings to a film in a single glance, by arranging scenes side by side in a single plate. This process aims to plan and refine the visual and emotional rhythm of a film, so that it supports its story. (AMIDI, 2011)

According to Amidi (2011), the term colorscript was only recently adopted due to the great amplification, mainly by PIXAR, of its role in the film creation processes. There is some ambiguity about what constitutes a colorscript or at what stage in pre-production it should be done, there are several versions of the process, just as there are several artists to create them.

In this research, the objective was to analyze the associations of colors and emotions present in animation colorscripts, mapping objective (physiological) and subjective (interpretative) factors used for these associations.

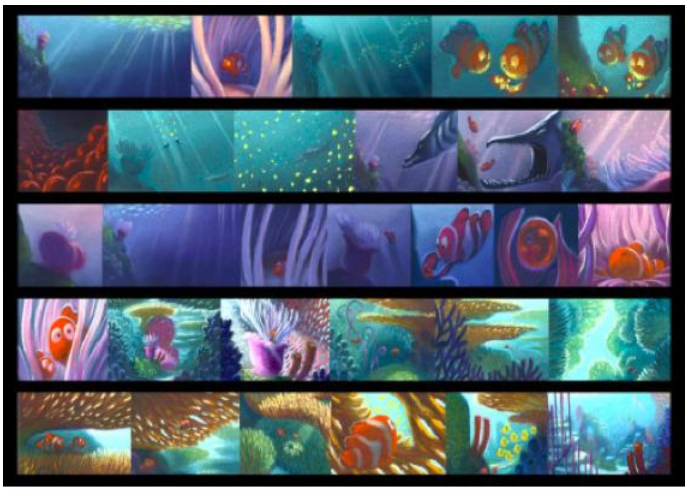

Fig. 1. Colorscript of the film "Finding Nemo" Source: The art of Pixar (2011)

2. Color in Cinema

To review the origin of color in cinema, the following authors were used: Barbosa (2007); Misek (2010); Costa (2005); Neale (1985); Reis (2016); Bordwell, Staiger, Thompson (1985); Sagen (2015); Braga (2000, 2011) and Hercules (2012), referring to the painting methods used, companies that stood out and the importance of color in narratives. The methods used include the non-photographic ones — hand painting, stencils, dyes, turnings and the Handschiegl process — and the photographic ones — Kinemacolor, Kinekrom, GaumontChronochrome, Cinecolorgraph, Kodachrome, Prizmacolor, Lumicolor, Dufaycolor, Gasparcolor and Technicolor.

2.1. *Colorscript*

This topic addresses the origin of the color-to-emotion mapping method used today by PIXAR's animated films. Its origins date back more than seventy years, and its first versions began as soon as color made its presence felt in the cinematographic world. According to Amidi (2011), in the mid-1930s, an initial colorscript process was created and employed in Hollywood live-action films by Natalie Kalmus, supervisor of Technicolor's color control department. Soon, the concept of colorscript came to Disney animated films in the 40s.

The idea of presenting the colors of an entire animated film, in a single piece of art, as they are done today, didn't fully materialize until the films made by United Productions of America, founded in the 1940s. Inspired in Disney's processes and with a team of artists who had already worked there, the UPA created "continuous color sketches" for their films in the mid-40s. (AMIDI, 2011) The modern resurgence of colorscript was brought on by Disney, more specifically, by artist Richard Vander Wende who painted scenes from the entire Aladdin movie. (AMIDI, 2011) According to Amidi (2011), the term colorscript was only recently adopted due to the great amplification, mainly by PIXAR, of its role in the film creation processes.

3. SENS|ORG|INT Model

Sens|Org|Int Model (Csillag, 2013; 2015) differentiates three processes that occur in human perception: sensory impressions, organizing processes, and interpretive processes of visual perception. The model was devised in an attempt to differentiate which principles of design tend to be common to all human beings with normal eyesight from the concepts that don't. Those that are not common therefore are learned or otherwise acquired. Therefore, this model unites the synthetic approach (Hering, 1964[1878]; Gibson, 1979), and the analytical approaches (Berkeley, 1709; Helmholtz, 1925; Bruce, Green & Georgeson, 2003), neuroscientific explanations (Chalupa & Werner, 2004; Knoblauch & Shevell, 2004; Pinna & Spillman, 2001; Shimojo, Kamitani & Nishida, 2001; Spillman & Levine, 1971; Zeki, 2000) on how the brain works, and relates them to design principles. With this framework, we are then able to tell, from the classical design "laws," which ones can truly be considered a principle that tend to be valid for all human beings from those that don't.

Sens variable (sensory impressions) is related to the sensory information received through the pupil in our visual sensory organ. This aspect of perception is a phenomenon that occurs in the eye only, still in the form of light, before it becomes neural signs in the retina.

Org variable (organizing processes) is related to organizing aspects of perception that occur starting in the retina, including what is considered the primary visual cortex, mostly in area V1 of the striate cortex. Org is related to the bottom-up approaches of visual perception in psychology. The phenomena of perception that occur as Org are what tend to be considered as principles of design.

Int variable (interpretive processes) refers to the elaboration of Org in the extrastriate visual cortex, including approximately areas V2, V3, V4 and V5 of the brain, and moving on to other areas of the brain. This variable refers to the top-down approaches to visual perception in psychology. It is in this moment of perception, that neural cascades occur, which undergo the interference of motivation, emotion, personality, culture, knowledge, etc. This aspect of perception causes variation and interpretation in design and in the proposed model, is called interpretive processes.

Figure 2 illustrates SENS|ORG|INT mode with the three variables.

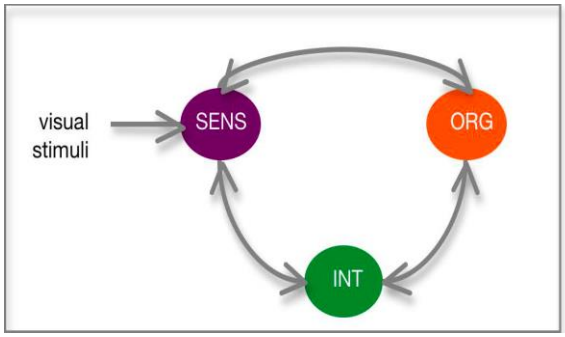

Fig. 2. Illutration of SENS|ORG|INT Model

4. Methodology and Empirical Research

The empirical research consisted primarily on the analyses of colorscripts, based on SENS|ORG|INT model. Thus, four PIXAR films were selected: *Finding Nemo, UP, Cars and Wall-e*. These were specifically selected as they represent some of the studio's early films and feature a wide variety of color usage. Following SENS|ORG|INT model, each colorscript was analyzed, in terms of objective percepts (ORG) and subjective percepts (INT). Due to space limitations, in this paper, only one example is illustrated below.

An important scene of the film "Finding Nemo", its colorscript indicates the moment when the character Marlin finds the only survivor egg after a shark attack to his nest full of eggs. The colors used in the real film feature a very important characteristic, observed using SENS|ORG|INT model. In terms of ORG variable (objective percepts), it is noted that the contrast of the egg color and its surroundings is a contrast that indicates a more saturated and thus brighter orange for the egg. And Marlin, when holding the egg on his fin, is featured with a desaturated orange (mixed with grey), indicating an orange with less brightness.

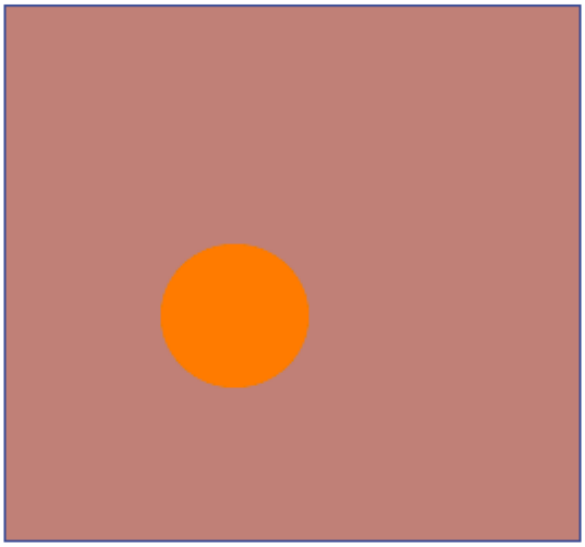

Fig. 3. Colors used in the egg scene of "Finding Nemo".

Figure 3 illustrates this use of color. Marlin's fin was featured in the film with a desaturated orange, the same color as the background of figure 3. The egg, which is the only survivor, and will become Nemo, is featured in saturated orange, as the circle in figure 3. Analyzing this scene in terms of INT variable, it is noted that the usage of a desaturated orange for the father is associated with his stressful feeling at this moment, and the saturated orange used in the egg is associated with brightness, life and hope. The real image of the film is not featured here due to copyright permissions. So, in terms of ORG, the perception of brightness of the orange is used for the egg, featuring vibrancy. This use of color only could connote several emotions, but here SENS||ORG|INT model helps understanding the use of color, thus in terms of INT, the symbolism the pure hue connotes joviality, hope, and llfe. The desaturated fin, in terms of ORG, is

perceived as less vibrant, and in terms of INT, the symbolism of the desaturated fin relates to how the father is stressed and living a terrible moment.

5. Results and Final Considerations

Through the analysis made in the colorscripts of some PIXAR films, it was possible to draw conclusions about their uses of color. First, in a general context, there is a very precise use of both objective and subjective factors in PIXAR cinematographic works. The studio knows and uses its knowledge in order to always add meaning to its productions from the initial stage (colorscript) to the film.

In the analyses, in relation to objective factors (ORG variable), it was possible to observe a greater use of communication of spatiality through hot and cold or light and dark contrast. Then comes the communication of smoothness through contrasting pastels and saturation. Both stimulation and calm communication through hot and cold contrast and high vibration communication through complementarity contrast were equally used. Next, there is the communication of vibration through contrast of pure hues, and finally there is the communication of chromatic mutation through simultaneous contrast.

The greater occurrence of objective spatiality communication factors is due to the fact that the studio prioritizes, for the most part, highlights of the character or object in relation to its background or vice versa to attract the attention of the audience. In *Finding Nemo*, it is possible to observe a constant use of communication to highlight the fish in relation to the bottom. In the other films, however, there is a rotation, some scenes prioritize the characters while others, the setting. This power of choice between what should attract the most attention shows that PIXAR knows what it's doing and explores what best contributes to the understanding of its scene.

There is also a higher occurrence of smoothness communication through saturation contrast than through pastel tones. This choice shows a preference of the studio to bring softness, but also to create focuses of attention, which occurs in the saturation contrast, since in places where pure hue was used, these focuses are created. In the analysis of the film *Wall-e*, there was a choice to predominantly use the saturation contrast, while in the other productions the two cases happened - saturation contrast and pastel tones -, again showing that the studio has the knowledge to recognize which case is ideal for each type of communication.

In the communication of stimulation and calmness, it is possible to observe that in the films *Nemo* and *Wall-e* the intention of calmness is very present due to the existence of cooler tones in the analyzed scenes. In the films *Cars* and *UP – Altas Aventuras* there was a greater balance, in some cases there is a communication of calmness through the contrast between cool colors and in others communication of stimulation through the contrast between warm colors. This choice is mainly in line with the intention that the studio wants to convey at a certain point in the film.

The communication of chromatic mutation occurred once, in *Cars*, and is a little more complex as it requires the artist who creates the colorscripts to have knowledge of the change in the color of an image due to the color used in the neighboring image. This factor was very well explored in the film, with sunlight interfering with the color of the truck's shadow.

High vibration communication through complementarity contrast occurs in all analyzed films, as well as vibration communication through pure hue contrast. Vibration plays an important role in animations as it attracts the eye and generates vibration and dynamism, suitable for a child audience.

As for the subjective factors, it is observed that, based on the authors analyzed, PIXAR knew how to use colors well in the context of communication, allowing interpretations that enrich its plots. Subjective communication was widely used to confirm, mainly, the feelings of the characters in the scenes, which occurs in all the investigated films, in addition to also giving evidence of personality, which was again used in all productions. The subjective factors of colors were also used to accompany decision-making, as analyzed in the scenes of *UP – High Adventures* and *Cars*, in moments when the colorscript color is aligned with a certain decision that determines the direction of the film.

Finally, subjective communication (INT) is applied to reaffirm the role of a place or a character, as it happens in *Nemo*, *Carros* and *Wall-e*, in moments such as when there is a feeling of danger with jellyfish (*Nemo* movie), the trophy that must be overshadowed (Movie *Cars*) and the planet Earth that must represent neglect (film *Wall-e*). These and more examples show how subjective communication has been very well studied and constructed to allow a wide variety of emotions to enrich the film's plots.

The analyses carried out on the objective (ORG) and subjective (INT) factors only show how PIXAR masters the language of colors and methodically uses them to enhance its characters and stories with emotions, creating layers of interpretations and perceptions for its films.

In addition to mastering the objective factors, they also explore the subjective part of color well by contextualizing it in colorscript and film scenes in a way that enhances the communication of the story. It is hoped with this research that these studies and analyses can contribute to those interested in the area of film and animation production or even to other trainings such as design, serving as a guide for a conscious and expressive use of color.

6. Conflict of interest declaration

The authors declare that there is no conflict of interest regarding the publication of this paper.

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8. Short biography of the author(s)

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Amanda Saibão – Graduate in Design at ESPM College.

Licensing terms

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Integrating knowledge about color within the STEM/STEAM approach: some instructional procedural principles

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ABSTRACT

This article aims to help define the STEM/STEAM approach to color education. Traditional science education seems to fail in addressing the stubborn misconceptions about color vision detected by empirical research. On the contrary, a knowledge integration approach like STEM/STEAM could provide a well-suited educational perspective for dealing with interdisciplinary issues related to color teaching and learning. Nowadays more and more schools welcome this educational paradigm as it seems to meet properly the needs of our modern knowledge society. However, this approach is somewhat ambiguous to the extent that a variety of teaching activities fall under the STEM/STEAM label. Our original contribution is to attempt to improve the conceptualization of the "STEM/STEAM approach" by identifying some instructional procedural principles that may be useful in operationally defining what we mean by "integration". Methodologically, our research consisted of three phases. In the first phase, we identified some shared features of activities classified as STEM/STEAM that we defined as the "invariants" of the STEM/STEAM approach. In the second phase, the invariants were described in terms of didactic variables drawn from the literature and some STEM/STEAM teaching activities. In the third phase, some procedural principles to guide teachers' work were formulated and discussed with reference to color teaching situations.

KEYWORDS (STEM/STEAM education, Color teaching and learning, Didactic variables, Epistemic variables, Learning variables, Procedural principles, Didactic transposition of knowledge)

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1. Some remarks on STEM/STEAM education

Interdisciplinary topics such as color vision represent a fascinating but difficult challenge to deal with while planning educational curriculum. In a previous article (Martini *et al*., 2019) we tried to make explicit the ambiguity and polysemy of the concept of color, which can take on different meanings in different contexts, imputing to this semantic complexity the multiple naïve conceptions detected by empirical research (e.g., Feher, 1992; Martinez-Borreguero *et al*., 2013).

Traditional scientific teaching about color seems not to be very effective in tackling such pervasive and stubborn misconceptions because students often fail to coherently reconcile their experiences of color perception with scientific explanations based on idealized models (Giere, 2004). This is the reason why our working hypothesis is that a knowledge integration approach like STEM/STE*A*M (Science, Technology, Engineering, *Arts*, Mathematics) – at least according to a certain interpretation of the acronym – can be a well-suited educational perspective for dealing with issues related to color teaching and learning. If it is the case, it depends on how STEM/STEAM activities are designed and performed.

We begin by briefly clarifying what we mean by the STEM paradigm to understand whether and under what conditions it can provide us with some appropriate recommendations for transforming expert knowledge about color vision into knowledge to be taught (Chevallard, 1991; Martini, 2018).

The roots of the STEM movement date back to President Dwight D. Eisenhower, and the formation of NASA and NSF in 1958 (Chesky and Wolfmeyer, 2015). In the field of science education, the acronym STEM – whose first version was SMET (Sanders, 2009) – was proposed in 2001 by either Judith Ramaley (assistant director of Education and Human Resources at NSF at the time) or Peter Faletra (then director of Workforce Development for Teachers and Scientists in the Office of Science at the Department of Energy) to refer to a group of disciplines (science, technology, engineering, mathematics) identified as fundamental to meet the challenges of the future. Historically, the STEM movement developed in parallel with the curriculum reform movement whose characteristic feature was a renewed interest in the content and purposes of education even by experts and academics. This phenomenon affected especially the Sciences and resulted in the formulation of curricula that considered scientific and cultural advances and the problems that threatened the national security in the climate of the Cold War (Bruner, 1960).

Lately, the acronym STEAM has been introduced, where the addition of the letter "A" that stands for Arts addresses the need to integrate creative thinking and applied arts into real-world situations. Some scholars believe that the addition of “A” is unnecessary, and that the application of creativity and the arts is a natural premise of STEM education. Others (e.g., Liao, 2016), however, believe it is important to highlight it, because advocating for the “A” might encourage relevant actionable pathways for transdisciplinary learning, allowing for an integration of all curricular disciplines, in line with the goals of school education (Martini, 2019).

Although the instructional models and ideas put forth under the STEM label are having a profound impact on the ongoing educational practices in schools all over the world, some educational researchers (e.g., McComas and Burgin, 2020; Chesky and Wolfmeyer, 2015) have started pointing out limits and contradictions of this potentially revolutionary approach. According to them, an uncritical and politically driven acceptance of STEM is indeed occurring to the detriment of a thorough effort to empirically investigate the merits and drawbacks of this approach which appears to be neither unambiguous nor procedurally defined.

While professional meetings and science education conferences are increasingly geared toward STEM and new textbooks and websites are popping up to advise teachers on how to implement STEM practices, STEM curricula lack an awareness of what STEM is and what STEM programs should include. Specially, two main and not particularly clear definitions of STEM are at issue (McComas and Burgin, 2020). One definition of STEM recognizes some degree of epistemic similarity among any of the four subjects that makes them potentially of interest to the same group of educators, but without any expectation that these subjects must be taught together to qualify for the STEM label. In contrast, the second definition strongly recommends knowledge integration rather than a mere juxtaposition of different subject matter contents in order to achieve proper STEM/STEAM goals (National Science Teaching Association, 2020). This interdisciplinary approach is also encouraged in K-12 education, although there is no universal consensus on how many of the four subjects should be blended and what level of integration should be pursued.

In Italy, STEM/STEAM education is addressed through different approaches. Currently, the Recovery and Resilience Plan presented by Italy envisages school reform interventions that enhance STEM in response to the need both to increase students' scientific literacy and to identify approaches for teaching scientific disciplines that are more integrated and supported by digital

technologies. Great emphasis is placed on the search for connections between disciplines and between theoretical concepts and concrete reality. This perspective aims to bridge the so-called “skill gap” between the notions learned in school and university and the skills required by the world of work. For example, as reported by Orizzonte Scuola – a well-known News and Information portal that is a useful online reference for school employees – STEM must mirror real-life scenarios. Because real-world jobs are interdisciplinary, children must be encouraged to learn how subjects fit together and work together. Since education is no longer about memorizing random facts, but about learning how to think critically, evaluate information and solve problems, knowledge and skills must be taught in an applied way, that is, in a real problem context.

Although we acknowledge the potential fruitfulness of STEM/STEAM education, we advocate nonetheless that integrating knowledge in real world contexts does not ensure success in learning. On the contrary, the very focus on experience in real contexts, where complex phenomena occur, requires a high control, both epistemic and didactic, over the learning situations. As mentioned above, idealized scientific models constructed to make color vision intelligible cannot be directly inferred from real world phenomena in which many variables interact simultaneously. On the contrary, these epistemic products are the correlate of disciplinary epistemic practices (Sandoval, 2016) [2] students need to become acquainted with to make sense of the scientific discourse (Tombolato, 2020).

This implies that teachers need to clarify not only the conceptual content (e.g., the additive and subtractive color model) but also how that specific content can be related to students' perceptual experience. Otherwise, students will continue to interpret scientific models based on ontological and epistemological assumptions about existing entities and the nature of knowledge that stem from intuition, common sense, or personal experiences.

According to our perspective, which is characterized by an epistemic approach to didactic problems (Martini, 2011; Tombolato, 2020), a fruitful way to improve the conceptualization of the STEM/STEAM approach is to identify some instructional procedural principles (Stenhouse, 1977) that can be useful to operationally define different ways and levels of knowledge integration. These content-related procedural principles are meant as pragmatic patterns of behavior that can support teachers while performing didactic transposition of expert knowledge about color into school knowledge, enabling them to create specific didactic situations that allow students to develop interdisciplinary learning outcomes and a more sophisticated idea of how scientific knowledge is constructed and legitimated.

2. Towards a clarification of the STEM/STEAM approach through the definition of some invariant features

Methodologically, our research aimed at identifying such procedural principles consisted of three phases. In the first phase, we reviewed the scholarly literature-both theoretical attempts to conceptualize the educational paradigm at stake and the instructional activities labeled by the authors as STEM/STEAM activities-in order to bring out some shared features. The analysis led us to identify four main hallmarks that we defined as the "invariants" of the STEM/STEAM approach.

A first characteristic concerns the “integration between disciplines” to overcome their separation and fragmentation. However, constructing interdisciplinary teaching situations implies distinguishing different degrees of integration that concern both the types and the in-depth level of disciplinary knowledge involved.

A second characteristic relates to "the integration of theory and practice." Often, in education curriculum, the former is treated separately from the latter without considering the relationship that exists in the process of knowledge construction between content and disciplinary epistemic practices. In addition, practice is usually referred exclusively to some kind of manual manipulative skills. In contrast, commenting on laboratory activities conducted in schools, Vicentini and Cutroni (1996, p. 167) observe that "acting with the hands must be always accompanied by acting with the mind, while acting with the mind can be accompanied by acting with the hands". From an educational perspective, for this invariant to be complied with, it is therefore necessary for disciplinary content to emerge as a result of expert practices in specific contexts.

A third characteristic concerns the "integration of disciplinary knowledge into real world contexts". However, referring to real world contexts is not in itself sufficient to ensure successful students learning. The possibility for students to grasp the problem and properly act within the context depends on their prior knowledge and on their awareness of how scientific theorization refer to reality. From an educational perspective, this means controlling the repeated processes of decontextualization and recontextualization of knowledge (Chevallard, 1991; Martini, 2018).

Finally, a fourth characteristic concerns the "integration of technologies into teaching". However, making

available and using technologies does not imply better learning, if one is not aware of how technological devices act on both the teaching content and the learner's mind.

These features, which pinpoint four different ways of integrating knowledge to be taught and learned, are assumed to be "invariants" of the variety of situations that fall under the STEM/STEAM label. From an educational perspective, the question at hand is how to ensure that these "invariants" are fulfilled. Indeed, as they are formulated, these invariants are still too vague and abstract to provide teachers with some useful operational guidelines for designing effective teaching situations. To achieve our goal, we decided to manage the problem of constructing teaching situations consistent with the invariants by identifying for each of them some didactic variables. Since teaching action affects the relationships that are built within the Teacher-Student-Knowledge system (the so-called didactic triangle used to conceptualize teaching and learning), both epistemic and learning variables play a key role in this representation. If we agree to represent the problem in this way, then the compliance with the invariants will depend on the variables considered and their relationships. In schematic terms, we can interpret each of these invariants as a function of the relationship between some epistemic and learning variables.

If we denote by I_{id} the "integration between disciplines" invariant, by v_{ex} a certain epistemic variable x, and by v_{ly} a certain learning variable y, then we can write

$$I_{id} = f\,[R\,(v_{ex}, v_{ly})]$$

Similarly, for the other invariants:

$I_{itp} = f\,[R\,(v_{ex}, v_{ly})]$ Integration of theory and practice
$I_{idr} = f\,[R\,(v_{ex}, v_{ly})]$ Integration of disciplinary knowledge into real world contexts
$I_{itt} = f\,[R\,(v_{ex}, v_{ly})]$ Integration of technologies into teaching

3. Operationalizing the invariants: the identification of the didactic variables

This phase of the research consisted in identifying the didactic variables that allow us to consider both the aspects related to the object of learning and the aspects related to the subject of learning. Once the didactic variables were identified, they were combined to give rise to some procedural principles that can provide teachers with some useful tips for designing teaching activities on light and color that are consistent with the four invariants characterizing the STEM/STEAM approach.

The didactic variables were drawn from the educational literature and from the analysis of some concrete teaching activities labeled as STEM/STEAM and published in scientific journals or made public on dedicated web portals. Here we refer, by way of example, to three experiences aimed at students at different school levels (Koyunkaya *et al.*, 2019; Dark, 2019; www.stem.org.uk/resources/community/collection/286171/colour) as they enabled us to evaluate the STEM/STEAM approach to the teaching of content related to light and colors that differ in the degree of depth with which they are covered (simpler or more complex). We also examined the different types of activities and learning environments (e.g., whether they were more or less structured, whether they involved the use of some more or less advanced technological devices, etc.) designed under this approach.

The analysis led to the identification of the didactic variables shown in Tab. 1. We distinguished between epistemic variables, related to the object of teaching/learning, and learning variables, related to the subject who learns. The former identifies the factors that constrain the teacher's choices about the transposition of scholarly knowledge; the latter refer to the factors on which the learning of each student depends. The latter are therefore crosscutting to all the four invariants.

4. Definig some procedural principles for designing color STEM/STEAM activities

In the last phase of our research, we formulated some instructional procedural principles based on epistemic and learning variables, which can provide operational guidance for fulfilling the "invariants" that characterize the STEM/STEAM approach, according to our hypothesis. We point out that the invariants and consequently the procedural principles have been isolated from a strictly logical point of view. However, they are closely intertwined, which is why in teaching practice almost every activity exemplifies more than one.

In the following, we provide examples of possible procedural principles that can be developed from the didactic variables shown in the table.

Each of them is discussed with reference to experiences in color education, to clarify the meaning of the four invariants and to support teachers with operational guidelines and practical examples for the design of color learning activities.

STEM/STEAM Approach	**Didactic variables**	
INVARIANTS	**Epistemic variables**	**Learning variables**
Integration between disciplines (interdisciplinarity)	- Disciplines involved (which and how many) - Level of depth and complexity of the teaching content involved" (basic/advanced) - Interplay between disciplines (curricular continuity/discontinuity) - Forms of disciplinary reasoning (analogy, induction, deduction, abduction, by trial and error, probabilistic, by falsification, by models, probabilistic, etc.)	- Level of students' prior knowledge - Ability level - Skill level - Language mastery - Learning pace - Preferred learning modes (different sensitivity to didactic mediators) - Interest and motivation - Misconceptions - Ability to use technology
Integration of theory and practice (knowing and doing)	- Types of knowledge to be integrated - Type of practical knowledge (expert practice and practice as teaching expedient) - Degree of formalization of knowledge	
Integration of disciplinary knowledge into real world contexts.	- Historical evolution of the discipline (problems and contexts of genesis and development of knowledge) - Degree of complexity of the problem-situations	
Integration of technologies into teaching	- Type of technologies (non-digital, analogical, and digital) used as a means to learn certain content - Technologies used to represent knowledge - Technologies used to construct knowledge	

Tab. 1. The didactic variables referred to each invariant.

4.1*. Integration between disciplines*

1.1 Given equal individual learning factors, a teaching activity is consistent with the STEM/STEAM approach, if it involves multiple disciplines whose different perspectives combined make a specific piece of instructional content more comprehensible than it would be when tackled by any one of them independently.

1.2. Given equal individual learning factors, a teaching activity is consistent with the STEM/STEAM approach, if the contribution of the disciplines involved is targeted to the specific teaching content.

1.3. A teaching activity is consistent with the STEM/STEAM approach if the selected topics are covered at the same level of depth within each discipline and if such level of depth is appropriate to students' prior knowledge.

1.4. A teaching activity is consistent with the STEM/STEAM approach if it has different degrees of complexity that allow it to promote various forms of disciplinary reasoning in learners.

A typical integration between disciplines involves Science and Art. This pairing, though potentially fruitful, requires precise control of the content and its relationships. For example, placing the explanation of the mechanisms of color vision alongside the explanation of pigment mixing without distinguishing the different perspectives from which color is approached is ineffective for both teaching and learning. On the one hand, the content of color

teaching is not organized in a logically coherent way. On the other, learning is prone to generating cognitive conflicts that risk turning into stubborn misconceptions (Martini *et al*., 2019). Therefore, procedural principles (1.1. and 1.2) require us to examine whether and how Science and Art contribute to the understanding of different "descriptions" of color. In other words, we need to make explicit the difference between colored lights and chromatic pigments, as well as what we mean by primary colors, specifying whether we are referring to additive or subtractive synthesis processes, respectively.

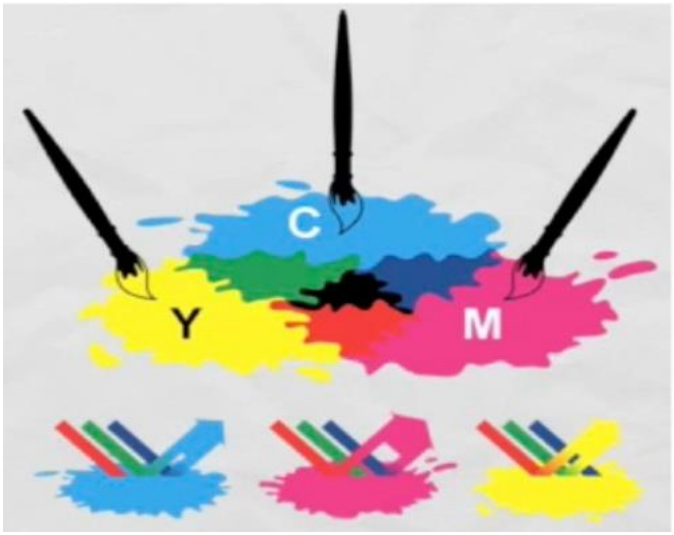

Fig. 1. Subtractive color mixing

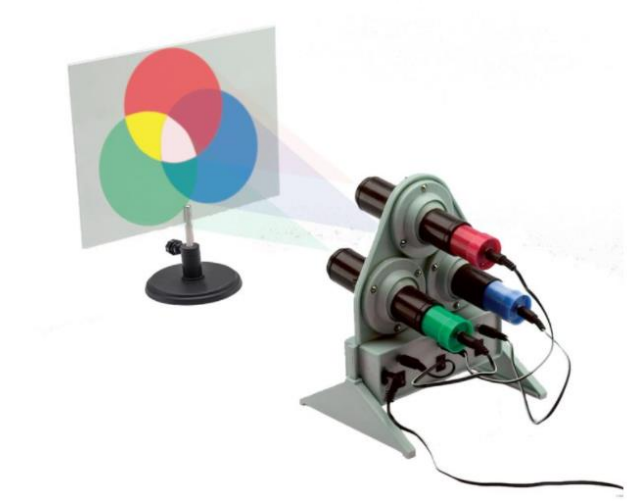

Fig. 2. Additive color mixing

Another example involves the integration of Science and Mathematics. The possibility of integrating these disciplines to promote meaningful learning in students requires controlling the levels of mastery of the knowledge involved (1.3 and 1.4). For example, additive and subtractive synthesis are usually represented through graphical diagrams, such as Euler-Venn diagrams, which students must be able to understand from a logical standpoint (e.g., Koyunkaya *et al*., 2019, where shadows are represented with three sets and their intersections). If students are not comfortable enough with this type of set representation, they will fail to grasp the rules behind the processes of additive and subtractive color mixing.

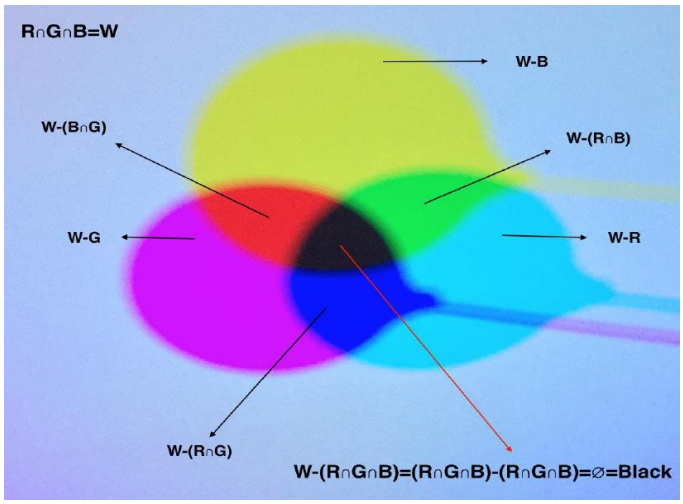

Fig. 3. Representing subtractive color mixing with sets (Koyunkaya et al. 2019, p. 114).

Likewise in a teaching situation that proposes a diffraction experiment. To fully understand the quantitative relationship between perceived color and the wavelength of light, students must know the basic concepts of trigonometry and be able to work with them enough to calculate the wavelengths of individual light rays. In this regard, an example of good practice is the open lab on light and color described in Dark (2019), where students grasp the relevance of trigonometry as they attempt to answer the challenging question "Can light be modeled as a wave?".

4.2. *Integration of theory and practice*

2.1 A teaching activity is consistent with the STEM/STEAM approach if it consistently involves disciplinary content and student-performed practices.

2.2 A teaching activity is consistent with the STEM/STEAM approach if it integrates the theoretical knowledge and practical experience of students in a suitable way to capture their interest and motivation.

2.3 A teaching activity is consistent with the STEM/STEAM approach if it integrates the theoretical knowledge and practical experience of learners in a suitable way to their preferred mode of learning.

2.4. A teaching activity is consistent with the STEM/STEAM approach if the degree of formalization of knowledge is appropriate to students' prior knowledge and if it considers their different sensitivity to the use of didactic mediators (active, iconic, symbolic mediators).

Regarding the integration of theory and practice, the procedural principles suggest that we should check for consistency between the theoretical content of instruction and the activities in which the teacher engages students to exemplify or represent that content (2.1, 2.2, 2.3, and 2.4). E.g., it is common for teachers to use Newton's disk and colored reflectors to help students understand additive color mixing. We endorse these learning strategies because they are likely to capture students' attention and match their different preferred learning modes through the employment of various didactic mediators. However, if these hands-on activities are not consistent with the theoretical explanation, they can generate misconceptions and false beliefs. For this reason, it is necessary to make students aware of the epistemic goal of the teaching activity by providing them with the relevant knowledge to correctly interpret what they see. For example, in the case mentioned above, you need to make explicit the difference between emitted and reflected light and the different effect you obtain as a result.

4.3. *Integration of disciplinary knowledge into real world contexts*

3.1. A teaching activity is consistent with the STEM/STEAM approach if it involves real-world problem situations that allow students to make sense of disciplinary knowledge.

3.2. A teaching activity is consistent with the STEM/STEAM approach if it involves monitoring the degree of "similarity" between the phenomenon reproduced during the activity and the target phenomenon.

Integrating disciplinary knowledge into real-world contexts requires strong disciplinary, epistemological and instructional expertise on the part of the teacher. A virtuous example of such integration is accomplished by Dark (2019) in her *Physics and the Arts course* at Spelman University. The connection between arts and science throughout history allows us to become aware of the real problems that scientists and artists had to solve and to grasp the complex relationship between perceived reality and scientific theorizing (3.1 and 3.2).

E.g., in secondary and higher education, history can be deployed to help students understand how and to what extent the evolution of scientific understanding of light as a physical phenomenon changed painting techniques and, conversely, how art contributed to the advancement of physics (Shlain, 2007). Another example of this third type of integration could be the design of a lab in which students must find the best solutions to illuminate a picture with certain characteristics and located in a certain environment, providing theoretical and empirical evidence to justify their choices.

Fig. 4. Children making Newton's disk

Fig. 5 Children experiencing additive color mixing with Newton's disk

4.4. *Integration of technologies into teaching*

4.1. A teaching activity is consistent with the STEM/STEAM approach if it is supported by technology.

4.2. A teaching activity is consistent with the STEM/STEAM approach if technologies are used by

teachers to present knowledge content in a format that is engaging to students and that fosters their understanding.

4.3. A teaching activity is consistent with the STEM/STEAM approach if technologies are used by students in knowledge-building practices.

Regarding the use of technologies in color education, some devices allow us to support the teaching practice in a way that ensures consistency with the logical organization of the theoretical content. For example, the representation of additive and subtractive synthesis processes, which usually generate multiple misconceptions due to the inadequacy of the devices employed, can be supported using monochromatic spotlights of adjustable intensity and high reflective screens.

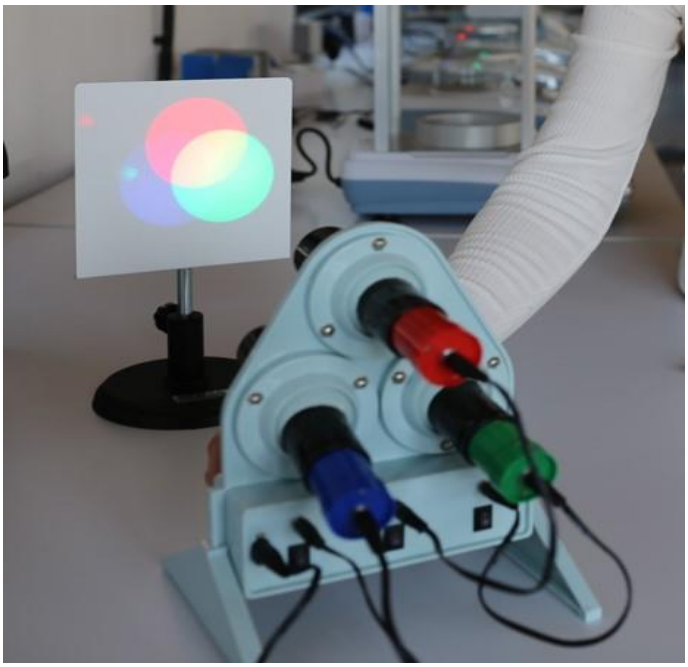

Fig. 6. Experimenting with RGB Spotlights

As an alternative to the pigment mixture usually proposed in classes, an example of subtractive synthesis can be obtained by illuminating an object from three monochromatic light sources (red, green, blue) simultaneously. The presence of the obstacle allows the formation of shadows that overlapping make available a dynamic representation of the static image usually used to represent the subtractive color mixing. Specifically, the areas where the shadows intersect are black, while the areas surrounding the black shadow are colored shadows composed of primary and secondary colors (Koyunkaya *et al*., 2019). In this case, the use of technological devices helps us to highlight the close relationship between the color of the light and the pigment color that many people fail to grasp. Indeed, the different types of shadows that appear with the obstruction of light correspond to the absorption of the colors of the light according to the "rules" of pigment mixing.

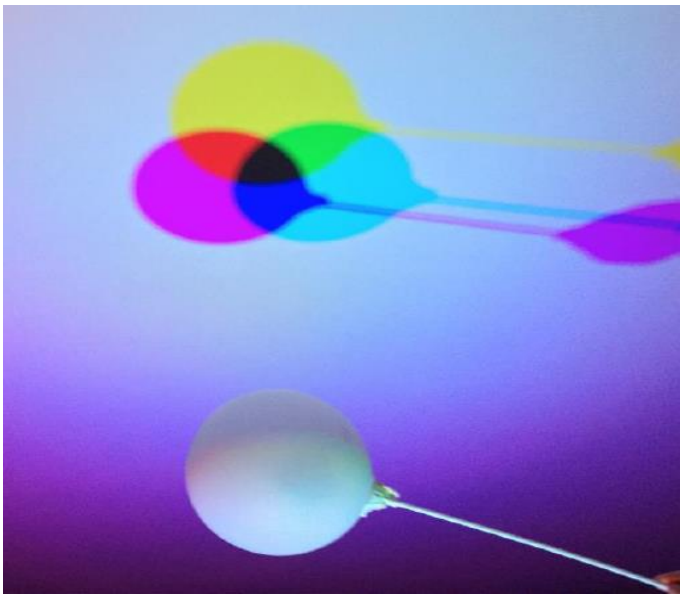

Fig. 7. The shadow experiment (Koyunkaya et al. 2019, p. 113).

5. Conclusion

In our contribution, we sought to better define the STEM/STEAM approach to color education by providing teachers with some procedural principles for designing effective instructional activities about color. These principles, conceived as pragmatic patterns of behavior, were formulated by combining epistemic and learning variables that can be traced to the four invariant features of the STEM/STEAM approach previously identified. The research is still ongoing and next goals include identifying more epistemic variables and formulating additional procedural principles to be discussed in relation to color STEM/STEAM activities carried out at different school levels.

6. Conflict of interest declaration

The authors declare that nothing affected their objectivity or independence and original work. Therefore, no conflict of interest exists.

7. Funding source declaration

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8. Short biography of the authors

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Notes

[1] The paper was written by the authors jointly. Specifically, B. Martini wrote section 1; R. D'Ugo wrote sections 2; M. Tombolato wrote sections 3, 4 and 5.

[2] By epistemic practices we mean those practices enacted by members of different scientific communities to construct, validate, evaluate, and justify knowledge within a specific field.

Licensing terms

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Digital applications to train color ordering in three dimensions for architects and designers

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ABSTRACT

Gamification is one of the main motivation and learning strategies of current generations. On the other hand, the study of color from the creation of the Bauhaus through the exercises developed by Joseph Albers has always had an undeniable component of experimentation. Motivated by this double idea, from the Color in Architecture Research Group we have studied the use of games in the training of architects for color discrimination. Among all the games aimed at training colour discrimination, puzzles are probably the most widespread. It is noteworthy that almost all of them use flat geometries, ignoring the fact that colors have three perceptual variables, and the main colour notation systems render 3D solids. It is enough to name Munsell or NCS color solids to recognise this spatial variable. So space will be a variable to be taken into account in our study, becoming one of the characteristics more intimately related to the profession of architecture. Maybe one of the most important skills that an architect must have is the mastery of spatial vision. In this way, the studio tries to combine gamification, training in colour discrimination and 3D management for architects.

KEYWORDS architecture, geometry, color order system, gamification, puzzle, app

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1. Introduction

In the acquisition of skills to work with the color for an architect or an interior designer, it is important to train the visual discrimination of colors and to gain the sensitivity to display different colors in order. Both learnings are on the roots of the different color curricula in the architecture schools since the beginning of the XXth Century and are considered essential knowledge.

Gamification demonstrates to be a good way of involving students in the acquisition of these skills that not only need a rational understanding of color theory, but also need to be naturally integrated as an instinctive skill, something that happens after a dedicated training. Among all the types of games used for learning, digital color puzzles are good alternatives to train these abilities. But it is noteworthy that, despite having color three perceptual variables, most of the available color puzzles keep working with just two dimensions of color. For this reason, the app ColorDoku 3d, aims to ease the understanding that color has three perceptual variables, and to train the visual discrimination of these variables. The app also gives the opportunity to get familiar with interesting and difficult to understand polyhedron.

2. The teaching of color order systems in architecture curricula

The description of color as a visual phenomenon with three perceptual variables, hue, value and saturation, allowed the proposition of different three-dimensional models since the beginning of the XIXth century, with different shapes depending on the arrangement of the fundamental colors and specific nomenclatures for the variables.

The time for using linear systems or two-dimensional diagrams such as the ones developed by Goethe in his Theory of Colors (1810) or by Neewton in his chromatic circle (1704) is far behind us. At present, among all the three-dimensional models, two are the most popular for art and design: The Munsell Color System, and the Natural Color System (NCS) [1]. At the Munsell Color System, colors are identified by three parameters, hue, value and chroma. With this data, you can obtain the coordinates of any color in the Munsell solid. Color Solid has an irregular three dimensional shape as a consequence of this system based in visual color perception. On the other hand, the structure of the NCS color solid is based in three pairs of opponent colors: white-black, green-red and yellow-blue. Its geometry is a regular symmetric double cone (Nemcsis and Caivano 2015) (Figure 1).

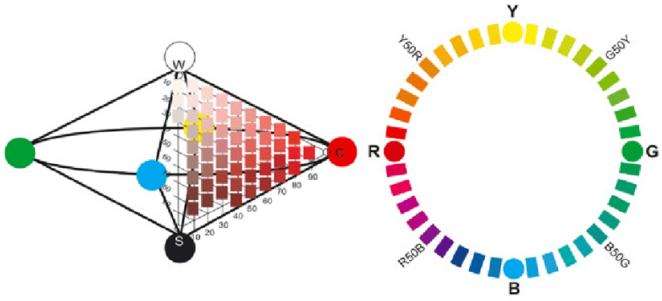

Figure 1: The NCS Natural Color System (The Natural Colour System is the copyright and trademark property of NCS Colour AB) (1979) by Anders Hård and Lars Sivik.

The ability to discriminate colors and organize them in the right order is a worth training for architects and artists, as it improves their sensitivity and expands their color abilities. For these reasons, almost all the modern color curricula for architects included the study of color circles and other similar organizations of colors with a certain logic (Hirschler et al. 2018). This was also the case of the basic courses at the Bauhaus Dessau and the Hochschule für Gestaltung Ulm, with important academics such as Albers, Itten, Maldonado, etc. Later on, Annie and Joseph Albers kept training students in color skills with interesting experiences at the Black Mountain College inNorth Carolina (Tóth, Molnár and Kárpáti 2021, Campos and Moya 2021).

In recent years, some of the traditional color exercises shifted into a digital version, as it happened with the perennial Interaction of Color by Joseph Albers (Franco Taboada 2015). This book has been developed as an iPad application, surpassing the original format in content. This App published by Yale University Press has been widely awarded and recognized (Figure 2). Nevertheless, some of these traditional exercises need personal involvement, are time-consuming, and not always are easy for generations of students and professionals that are becoming more impatient and less persistent. When waiting has become an intolerable matter, the impatience syndrome appears. This syndrome affects not only the current generation of students but seems to extend to future generations (Bauman 2015).

At the same time, in a completely digitalized society, gamification gives an opportunity to improve the color skills, and the pleasure of organizing colors in order is on the roots of a big number of digital games: Blendoku (Lonely Few 2015), Chroma Rush (Lonely Few 2017), I Love hue (Zut 2017), Blendoku 2 (Lonely Few 2019), Chromatic: Color Puzzles (2019), Tinge: A Color Game (Suwao LLC 2019), Chroma (Noisy Duck 2021), I Love Hue Too (2021), etc. Gamification is the use of non-

game-in-context game mechanics, elements, and design techniques to engage users and solve problems (Zichermann & Cunningham, 2011; Werbach & Hunter, 2012).

In general, this type of game provides a series of colours to be included in an incomplete two-dimensional pattern. The patterns used in these games are usually simple rows and columns of colour gradations, like in the game Blendoku. In this case the difficulty level increases with the inclusion of more pieces to place in the puzzle, and having a smaller chromatic variation. In the case of I Love Hue Too, the puzzles are based on complex mosaics and the level difficulty level increase, as in the other games, with the number of colors to fill, and the geometry complexity.

As indicated, all these apps have a two-dimensional interface and forget that color is a three-dimensional perceptual phenomenon. Nevertheless, the spatial representation of colors with their three perceptual variables results in some non-regular solids like spheroids, cylinders, double cones and many other geometries depending on the color system used. Being most of them not regular bodies, the colour discrimination learning can benefit from using three dimensional solids, as well as the understanding of complex regular bodies can be boosted by playing with the three variables of colors. For all these reasons, a puzzle in three dimensions to order colors onto regular bodies might be beneficial for architecture students.

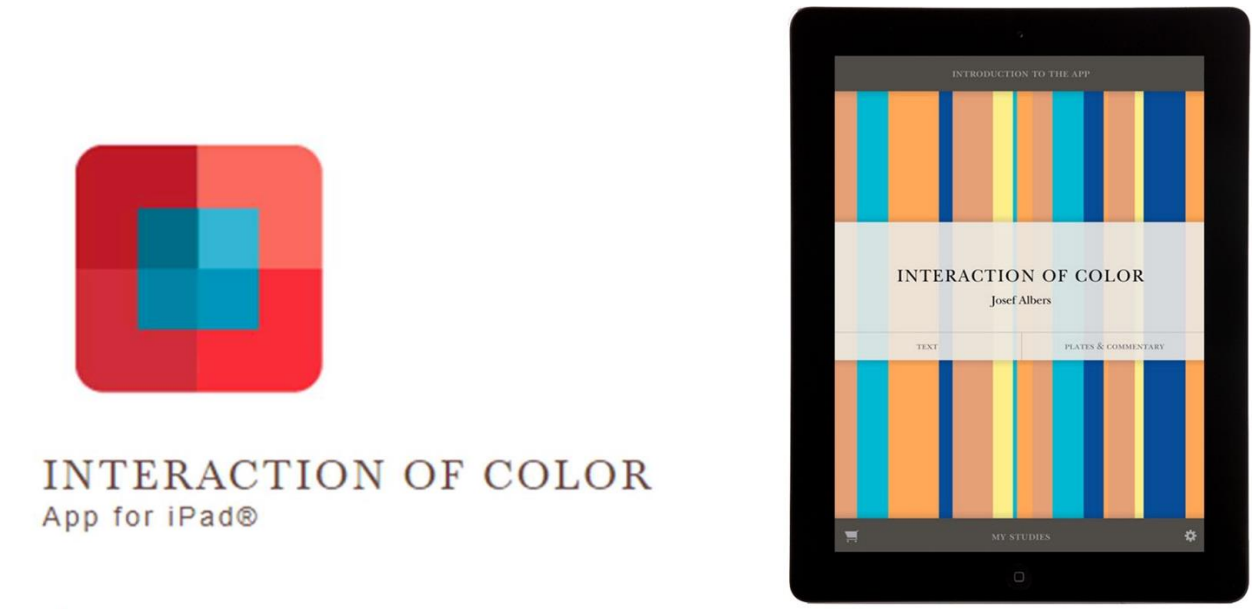

Figure 2: Interaction of Color, is a digital version of the traditional exercises of J. Albers in a digital way.

3. The teaching of regular bodies in architecture curricula

To have a robust spatial imagination is an essential skill for an architect, and so it is the understanding and manipulation of three-dimensional objects. If we review the European history of architecture, this ability has traditionally been cultivated with the study of regular polyhedra with complex geometries that we find since the most important treatises of geometry belonging to the Renaissance period. Even today we can find the study, drawing and analysis of these geometries forming a fundamental part of the theoretical "corpus" of Graphic Expression subjects. Books as Beyond the Cube: The Architecture of Space Frames and Polyhedra by Jean-François Gabriel (1997), continue to maintain the interest and relationship between polyhedrons and architecture. Works of Louis Kahn (1910-1974), Buckminster Fuller (1895-1983) and Philip Johnson (1906-2005), among other, are a clear example of this idea.

One of the fundamental and first books that study and analyse this subject it's the De Divina Proportione (1509) written by the mathematician Luca Pacioli and illustrated by Leonardo da Vinci. This mathematical treatise praises mathematics as the basis of science and architecture. The book contains a small section on architecture, but undoubtedly one of its main assets is the study of regular polyhedra. These polyhedra are represented using the most cutting edged graphic resources of that period to help in the understanding of

its geometries. By alternating the drawing of solid geometries and solids represented in wire frame in more than 60 draws, it was possible an easy distinction between front and back edges, (Figure 3a).

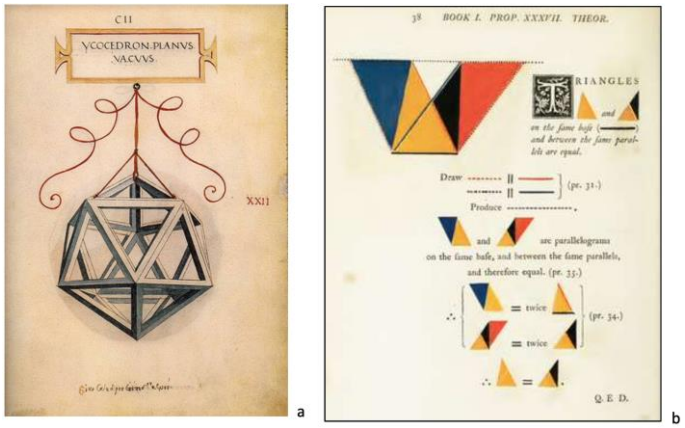

Figure 3: a) Representation of an icosahedron, Ycocedron Planus Vacuus, by Leonardo da Vinci for De Divina Proportione (Luca Pacioli, 1509); b) Oliver Byrne, The First Six Book of the Elements of Euclid, London, 1847. Book I Prop. XXXVII "Triangles on the same base and between the same parallels are equal".

In the XIXth century, the color was also used as a graphic resource for a better understanding of geometry. This is the case of the founding text of geometry The Elements (Στοιχεῖα) written by Euclides (325-265 bC), that was reedited by Oliver Byrne in 1847 with graphical codes of colors replacing the original text. As the same Byrne wrote in his foreword “we do not introduce colour for the purpose of entertainment, or to amuse by certain combinatios of tint and form, but to assist the mind in its researches after truth, to increase the facilities of instruction, and to diffuse permanent knowledge” (Byrne 1847, quoted in Higón-Calvet 2013). The combination of colors and geometry resulted in a very beautiful and easy to understand publication (Figure 3b). Nowadays, as we have already explained, as it has happened with other colour-related knowledge, the videos and animated graphics with continuous movement seem to be the most adequate means of expression to explain and understand geometries, with interesting websites explaining geometric concepts in three dimensions. [2]

4. Description of the app ColorDoku 3d

To merge the knowledge about regular bodies and color understanding, a group of academics and students developed a digital app called ColorDoku 3d, that is available for free at the web page of the Color Research Group in Architecture UPV. [3] By the moment, it contains four regular solids with triangular faces: icosahedron (20 triangular faces), triacysthetrahedron (12 triangular faces), tetrahexahedron (24 triangular faces) and hexaquisocta-hedron (48 triangular faces) (Figure 4).

The icosahedron is a polyhedron that belongs to the Platonic solids, and has been widely represented and used since antiquity. Platonic solids are those that have all faces equal and are a regular polygon. There are only five, for this app we choose the only one that represented a certain complexity for the game.

The other three polyhedra belong to the family of Catalan solids. These polyhedra were published in 1865 for the first time by the Belgian mathematician Eugène Charles Catalan after whom they are named. There are only thirteen and are generated with two Archimedes solids. So, their faces have irregular polygons but equal dihedric angles. This type of polyhedra, besides being part of the basic teaching in architecture for the control of geometry, has also had practical applications in the use of vaults (Mallo 2013). We chose for the puzzle the triacysthetrahedron, tetrahexahedron and hexaquisoctahedron. These solids have faces with triangular bases, so they were more suitable for programming.

The triacysthetrahedron is a truncated tetrahedron, the tetrahexahedron is a truncated octahedron and the hexaquisoctahedron is a truncated cuboctahedron.

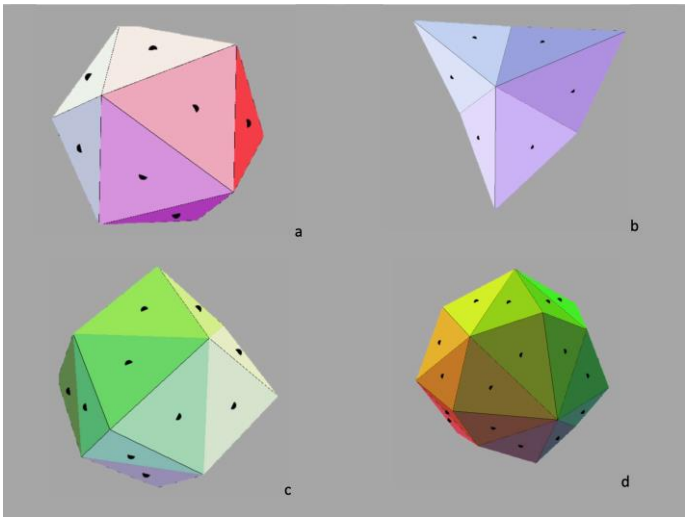

Figure 4: The four regular bodies implemented in ColorDoku 3d: a) icosahedron, b) triacysthetrahedron, c) tetrahexahedron and d) hexaquisoctahedron.

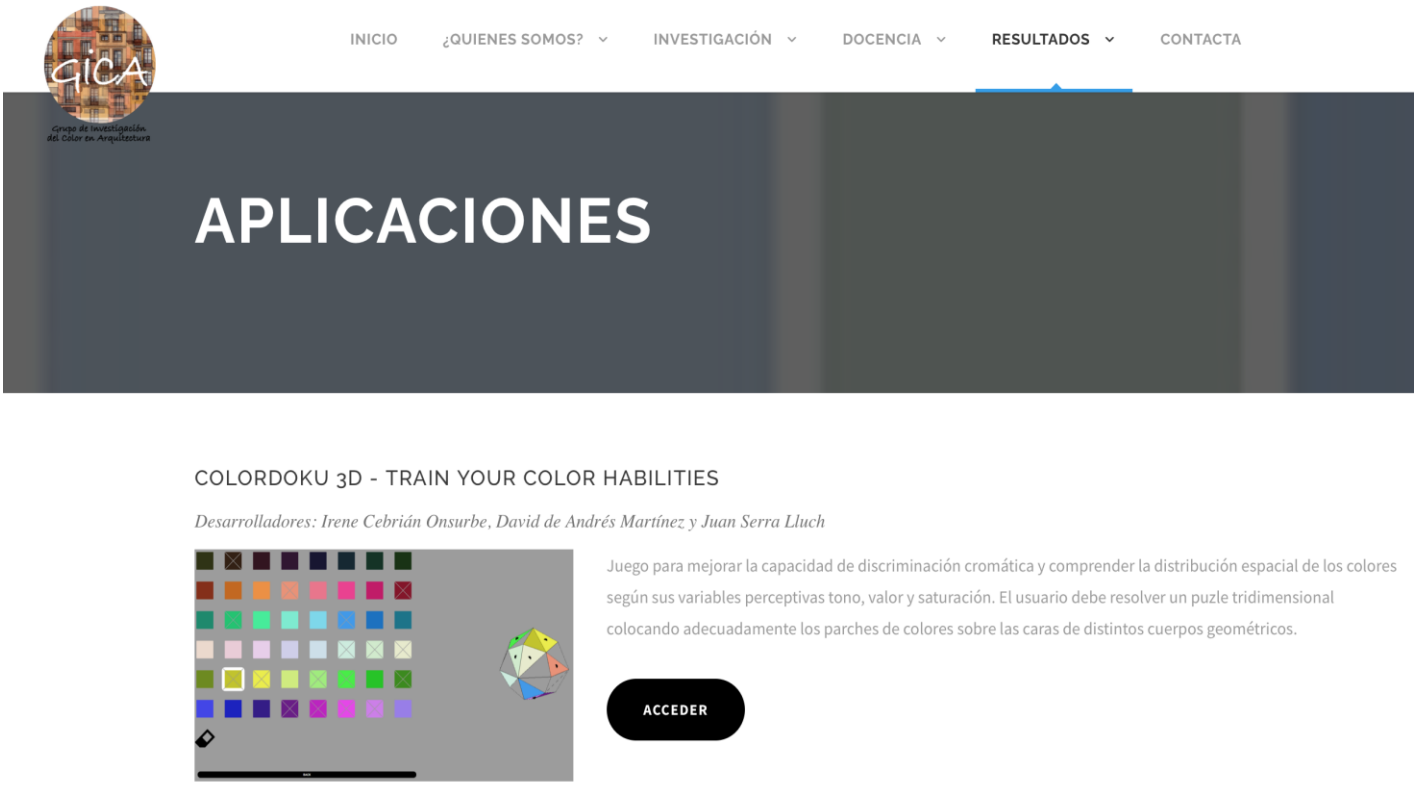

Figure 5: View of the research group's website (GICA). Application login screen. https://grupocolor.webs.upv.es/?page_id=3021

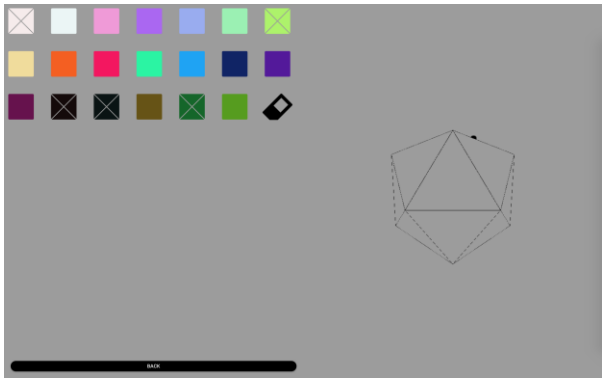

Figure 6: Interface of ColorDuku 3d with an uncompleted puzzle of an icosahedron.

In the initial screen of the app, users can choose between the four aforementioned polyhedra, and set different parameters depending on the expected level of difficulty for the game, such as the scale of the solid, its position inside the color space, and the number of faces of the figure that will appear with the colors already set. With this information, a color palette is displayed and the 3d puzzle is launched. Turning the figure round in any direction and increasing its size if needed, users can drag and drop the colors provided in the color palette into the right faces of the solid to complete the 3d puzzle.

The level of difficulty increases with the number of faces of the selected solid and with the scale of the selected solid. The difficulty is directly proportional to the number of faces and inversely proportional to the scale of the chosen solid.

In the screen of the settings, and when the scale of the regular body is under 100%, it is possible to place it in different positions inside a virtual cube. This cube represents the color space HSL (Hue, Saturation, lightness), which is an alternative model to RGB, and therefore a useful color space for digital displays. When the user selects different values between 0% and 100% for the three spatial directions X, Y and Z, is placing the solid in a different position into the HSL space. The app will automatically generate a color palette assigning to each triangular face of the solid the color corresponding to the barycenter of such a face in the HSL model.

When the 3d puzzle is launched, the interface is divided into two parts (Figure 6). On the left side there is a color palette with all the colors of the puzzle in a random order, and on the right side the user can rotate and scale the solid. Those colors preset have a grey cross on the color palette and a black dot on the corresponding face to indicate that they are locked. The rest of the colors in the color palette can be dragged and dropped onto the corresponding faces. With the

help of an eraser, the user can remove a color placed in a wrong position that will automatically move back to the color palette. When the 3d puzzle is correctly completed the indication “puzzle completed” appears.

We hope that this new app will help to improve at the same time the perceptual color discrimination ability together with the spatial vision.

5. Results and conclusions

Durint the 2020/21 course we invited the students enrolled in the subject Graphic and Chromatic Design of the Master in Architecture of the UPV to train with ColorDoku 3d and give their opinion. A total of 18 students (12 females, 6 males; Mean age= 23) played with the app for a couple of days and gave feedback via an online questionnaire. Regarding the selection of the polyhedra, icosahedron was the most selected (50%), followed by tetrahexahedron (27.8%), hexaquisoctahedron (16.7%) and triacysthetra-hedron (5.6%), therefore the selection of the polyhedra seemed to be rooted in a personal attachment and not in the number of faces of the solid or its difficulty. According to the answers, 33.3% of the respondents considered the random colors combination provided beautiful, 22.2% not beautiful and 44.4% indifferent. Considering the difficulty of the 3d puzzle, 44.4% considered it easy, 33.3% intermediate and 21.7% difficult or very difficult, with this assessment dependent on the puzzle settings of each participant. In an informal interview in the classroom, students expressed their interest in the app, indicating that it was fun and engaging, but also pointing out some aspects to improve, particularly related with the interface and the general user-friendliness of the app. Students seemed to be in favor of having an automatic preset of the parameter of the puzzle.

We conclude that ColorDoku 3d can be a useful tool for the education of students in the improvement of their perceptual color discrimination ability and spatial vision, being a complementary resource to train their color abilities out of the classroom via gamification. In the future, the app will need some upgrades to make it more user-friendly and engaging, considering the information provided by a target group of users. In future developments, it will be important to have more evidences to evaluate the improvement of knowledge of solids and colors after training with ColorDuku 3d.

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7. Conflict of interest declaration

The autors declare that they have not actual or potencial conflict of interest including financial, personal, or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

8. Funding source declaration

All authors declare that the investigation has not been supported or paid by any funding sources or research grants

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Notes

[1] There are many other systems for ordering colours in a three-dimensional space organised by three perceptual variables. Among

them, the Coloroid System developed by Nemecsis between 1962 and 1980 stands out. This system uses hue as an angular coordinate, saturation as a radial coordinate and luminosity as a vertical coordinate.

[2] http://www.matematicasvisuales.com/index.html

[3] https://grupocolor.webs.upv.es/

Licensing terms

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More Than a Tube of Color - The Emotion

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ABSTRACT

The relationship a colorist builds with their chosen products is deeply emotional and is heavily dependent on trust and confidence in their performance. With this confidence a colorist's focus can remain on their ability to ensure consumers' happiness through proper product choice, which directly affects the livelihood of a colorist. When a person sits in the colorist's chair, there can be trepidation, anxiousness, eagerness, or excitement. As with all relationships, understanding these emotions builds trust between consumer and colorist. How people feel about their hair color is intimate and unique to each individual. Color creates a connection to how people see themselves, and thus a reflection of how one is perceived. We will look at the perception and psychology behind different colors of hair, such as blonde, red, brunette, and grey. These intended consumer benefits – confidence, happiness, comfort - are often derived from this sacred service.

KEYWORDS: Relationship**,** Psychology**,** Hair Color**,** Emotional connection**,** Trust

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1. Introduction

A tube of hair color has a broad impact on lives. Like most products used in the beauty industry, hair color is utilized as a relationship and confidence builder. The emotional connection to hair color is intrinsic to these relationships. A connection to the colorist, from the colorist to the consumer, and from the consumer to their chosen hair color, drives the color product choice, and our chosen hair color result.

2. Theory

Hair Color service is a relationship of the colorist and the consumer, achieved through a tube of hair color. Product choice creates trust and confidence in this relationship. The sacred hair color service triggers emotions and influences the perception of an individual.

3. Method

Two questionnaires were developed to investigate the behaviors and opinions of hair color consumers and professional hair colorists. Questions are formatted in multiple choice and short answer form. A total of 500 hair color consumers, including 281 professional hair colorists were surveyed. Data collection was conducted between May 17, 2021 to June 17, 2021.

4. Results and Discussions

4.1. *Product Choice*

When selecting a hair color line, the most important factors to a colorist are the performance, the customizability, and the environmental impact. Survey respondents are prompted to select top deciding factors when selecting a hair color line. Figure 1 is an illustration of the result.

Critical objective for a hair colorist is to ensure the consumer is happy with the hair color service and the hair color results. The ability to communicate, understand, and deliver the consumer's needs is the cornerstone for the consumer to trust the colorist and the colorist's ability to execute the sacred service - the hair color service.

Beautiful, healthy, shiny hair is always the goal. A happy consumer will share the hair service experience with others, which is one of the most important ways a colorist builds business.

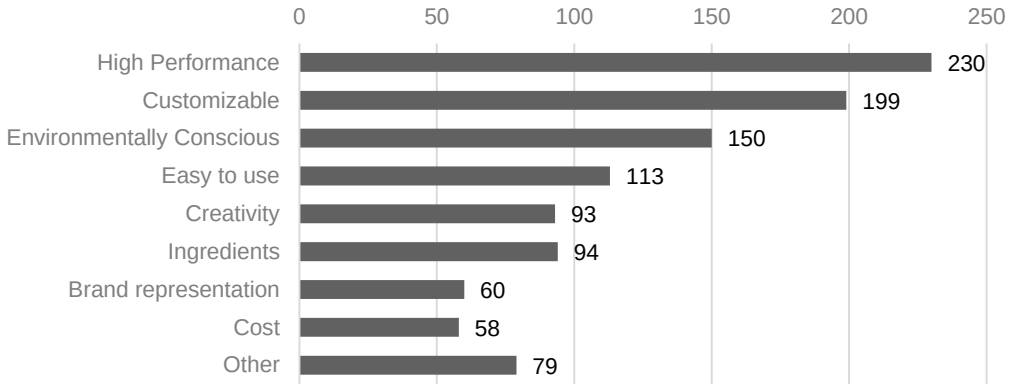


Fig. 1. Important Deciding Factors to Selecting a Hair Color Line

4.1.1. *High Performance*

When a colorist is choosing a hair color product to represent their work, quality is vital. Trusting that the hair color will perform as expected builds confidence in the colorist to achieve what the consumer expects. Amongst the surveyed professional hair colorists, 19% of the respondents experience 100% success rate; 58% of the respondents experience 90% success rate; 19% of the respondents experience 75% success rate; and 4% of the respondents only experience 50% success rate. No surveyed colorists use a hair color line that delivers below 50% success rate. Hence, performance of hair color provides the confidence for colorists to deliver consumer's needs (Table 1, left).

Along with trust, hair color performance builds loyalty in both the colorist and consumer. The colorist is loyal to the hair color brand and the consumer is loyal to the colorist. Analysis shows that 51% of the respondents, who are professional hair colorists, use a single hair color line. This is an indication of colorists trusting the performance of their selected choice of hair color product (Table 1, right).

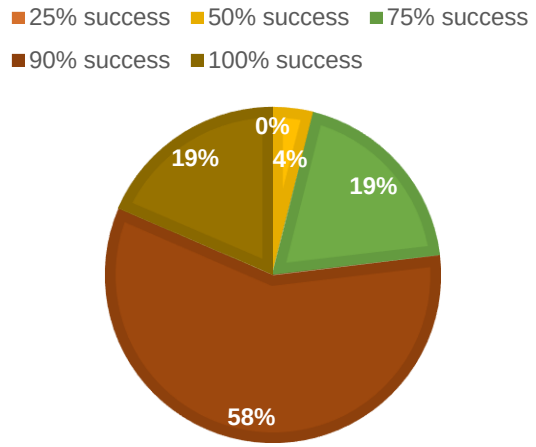
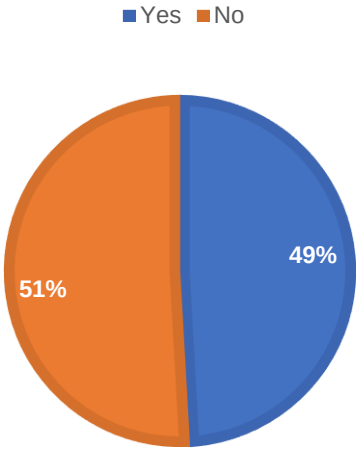
Success Rate of Existing Hair Color Line(s) In Achieving Anticipated Hair Color Results	Percentage of Hair Colorist Using Multiple Hair Color Lines
	

Table 1. Analysis of Hair Color Lines

Confidence in a product connects directly to a colorist on an emotional level. Quality components within the tube of hair color, supported by a foundation of strong education, create predictable and consistent results. When predictable results occur, the colorist trusts the product performance, and confidence is established.

4.1.2. *Customizable Hair Color*

The ability to be creative with hair color is very appealing to a colorist. Marketing a customizable hair color to consumers is a natural fit with the current trend of "individuality". Colorist needs to assess a series of variables when formulating hair color (Fisher, et al., 2016). In order to create the desired outcome, variables affect a color formula and need to be considered. Using the same formula on different clients will not produce the same results.

Variables in hair color formulation are Natural Remaining Pigment, Developer Choice, Hair Texture, Hair Type, Hair Density, Percentage of Grey.

Natural Remaining Pigment, or Underlying Pigment, is the pigment exposed in the hair when lifting or lightening natural hair color during a hair color service. Natural Remaining Pigment will contribute to the result if not neutralized, enhanced, or refined with the right hair color product (Fisher, et al., 2016).

Developer choice is an important element in formulation because it acts as a time control of product activation. Developers, with a pH of 2.5 to 4.5, are oxidizing agents used with demi-permanent and permanent colors, lighteners, and toners (Fisher, et al., 2016). Hair color developer is a hair color activator with different processing times and power strengths. Hair color developers come in a variety of processing times and strengths. This product is mixed in various ratios for specific formulas. Developers are also known referred to as catalysts to activate the process of hair color.

Hair texture is referred as the movement in the hair. Straight, wavy, and curly hair indicates the natural hair color level to use when creating a hair color formula. Straight hair is reflective of light. Therefore, the colorist will utilize a hair color formula that would match the desired level of hair color. Wavy hair is reflective and shadowed within the movement of the texture hair. A formula for this hair texture would be adjusted one-half to one shade lighter than the desired level of hair color. Curly hair is absorbent of light and should be adjusted one to two levels lighter than the consumer's desired result (Color Space™, 2021).

Hair Type is referred as the diameter of the hair shaft. Hair Type determines what developer to utilize in order to achieve the correct lift or deposit of hair color within the formula. Fine hair does not need as much strength in the formula. This hair type is also fragile compared to medium or coarse hair types. Medium hair would be is considered the standard hair type, and usually a standard catalyst can be utilized. Coarse hair requires

more developer strength; a stronger catalyst is required to achieve the final desired outcome (Color Space™, 2021).

Hair Density is the quantity of hair per square inch. Thinner hair has lesser hair per square inch; and thicker hair has more hair per square inch. Hair Density indicates to the colorist the hair's natural starting level. The colorist identifies how many levels to lift or deposit hair color. The colorist also determines the correct product to achieve the desired result while maintaining the integrity of hair after the service. The thinner the hair, the more light is reflected through, and the hair appears lighter. Thicker hair can appear darker because the light cannot travel through as easily (Color Space™, 2021).

Percentage of grey tells the colorist how much of the grey coverage additive to be included in the formula (Fisher, et al., 2016).

The ability to customize hair color allows the colorist to efficiently address important variables in each formula, and to remain unique and creative while regularly being challenged to elevate their craft to the next level.

Product performance and formulation ease are a must when working with customizable hair color. A colorist works with tight schedules and cannot spend extra time adjusting an unexpected hair color result. In the beauty industry, time has a direct correlation to revenue.

4.1.3. *Environmental Impact*

Because of the current state of the global environment, more companies in the beauty industry are focusing on sustainability. Pioneering beauty brands focusing on positive impact innovation and creativity are paving the way for eco-conscious products and green companies to take over the market and showing their less sustainable siblings that green is not only the new glamorous — it's also a mean to preserve the well-being of our planet and the people who live in it (Sparknews Report in collaboration with Cosmoprof Worldwide Bologna, 2019). Colorists connect to hair color companies that advocate the following beliefs: clean ingredients, plant-based ingredients, vegan, PETA friendly, innovations to make color easier to use.

Search engines are widely accessible. It is not uncommon for colorists and consumers to research where ingredients are sourced. One also expects the cleanest ingredients that give a quality performance while remaining sensitive to environmental impact. A clean product that is sensitive to the environment should be the goal for all hair color manufacturers.

4.2. *Confidence and Trust*

4.2.1. *The Confidence a consumer has in their colorist*

The relationship between the colorist and the consumer is a strong emotional connection. Majority of the consumers, represented by 97% of the respondents in the questionnaire, trusts that the colorist is knowledgeable and competent to give recommendations and create suitable outcomes (Table 2, left). There can be a lot of emotions connected to this trust. Until this trust is established, there can be fear and anxiety before a hair color service. Such emotions can return when adjustments are required. Having a consistent, reliable product will help colorists to be successful; hence maintaining the established trust. Trust in the colorist is established through different stages of the relationship.

Stage 1 - Before the first hair color appointment

The consumer gets introduced to a colorist through avenue such as referral and research. 18% of the survey respondents trust their colorists through word-of-mouth reputation.

Stage 2 – After the first hair color appointment

In the first appointment, the consumer and colorist are both getting to know each other. A solid consultation kicks off the relationship between the colorist and consumer. The consumer is anxious, fearful, insecure, and vulnerable sitting in the colorist's chair. This fear is alleviated with each question a confident colorist asks during the consultation, and as the consumer feels heard. 57% of the survey respondents trust their colorists after the first appointment.

Stage 3 – After the second and third hair color appointments

During the second appointment, any adjustments needed stemming from the previous service is addressed. This appointment can be pivotal in the colorist/consumer relationship. The consumer assesses how well the colorist performs the second service and understands the consumer's needs. A consumer returning for their third appointment indicates that trust has been established. It is also apparent at this appointment that the colorist understands the consumer, and the consumer knows what to expect from the colorist. The consumer has built trust in the colorist to do what is right and that the colorist can adjust or correct anything the consumer does not like. 20% of the survey respondents trust their colorists after the second and third appointments.

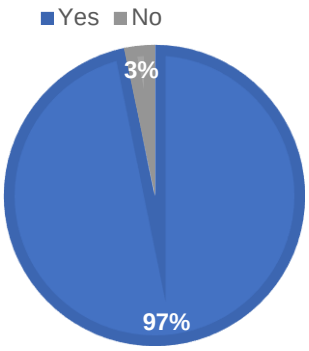
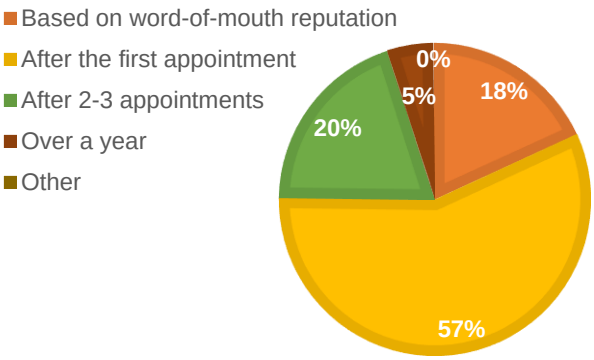
Percentage of hair color consumers trusting the knowledge and competency of their colorists	Moment a consumer started to trust their colorist
	

Table 2. Analysis of consumer's Trust towards their colorists

Stage 4 – Trust established

95% of the surveyed respondents would have established trust to their colorists upon reaching Stage 3 of the relationship (Table 2, right). Once trust is established, consumers will start to feel confident to the recommendations from the colorists. From the questionnaire surveying professional colorists, 22% of colorists agreed that 100% of their clients will allow them to select hair color for the clients with absolute trust. 38% of the colorist agreed that 75% of their clients will allow them to choose hair color for the clients with absolute trust. This is a significant indication that the established trust empowers the colorist to make appropriate recommendations to the consumer.

When there is trust in the hair colorist, the consumer will return for future services. This trust is vital for the service provider since this is how revenue is generated. There are different benchmarks a service provider can review to measure the loyalty of the consumer. Rebooking appointments for future hair color services is one of the benchmarks. Studies found that an 80% rebooking rate on existing hair services will lead a hair professional to the top 10% of all earners in the hair industry (Zoot, 2017). Trust is one way to ensure consistent future revenue for colorists.

A consumer bases their trust on the skill of the colorist and the performance of the product. The consumer wants to leave the salon with an experience of having expectations met, holding their head high, and feeling great. The colorist's livelihood relies on the customer happily paying for the provided service. Hence, having a high-performing and reliable product is critical.

4.2.2. The Confidence of a Colorist

There is a learning curve when starting to use a new hair color line. Confidence is created through education, practice, and competency. Knowledge is the key to overcoming fear of failure and learning how the product performs.

There are two factors affecting the commitment to education - Time and Money. As a service provider, taking time to attend education means taking time away from work and the potential of generating revenue working behind the chair and creating revenue. The commitment for a colorist to attend education is significant as earnings can be affected.

Paradoxically, education is crucial for the colorist to grow skills and increase future earnings. The decision to attend ongoing education is critical for the colorist to create future revenue. 98% of the surveyed colorists attend at least one class per year, and 84% of the surveyed colorists attend at least two classes per year. In addition, 81% of the surveyed colorists spend at least $100 USD on education annually.

Attending education can strike up insecurities of failure and build confidence in a hair colorist (akesha, 2017). Colorists may be vulnerable to the educator's judgement of the colorist's current technical skills sets. However, education establishes necessary knowledge and strengthens the confidence of colorists, which also results in the assurance of consumer's confidence in a colorist.

4.3. *Perception and Emotion*

Beauty consumers search for ways to look their best and feel beautiful. This personal quest can create specific

individual emotional responses which can in turn drive this search for tools that will help one feel more beautiful. Hair color is a tool that can be utilized in fulfilling the emotional responses. Examples of emotional responses include confidence, acceptance, self-expression, individuality, and self-representation.

There is an intense psychological connection to hair color as well. There are two ideas to consider; how we perceive ourselves and how others perceive us. Table 3 illustrates some preconceived ideas of an individual's personality or characteristics connected to hair color.

Words can be definitive in our perception. As we go through this world of opinions, we have heard how people see blondes, brunettes, reds, and grey hair. These perceptions and preconceived ideas of who we are influences employment, relationships, emotions and how we perceive ourselves.

4.3.1. Perception of Hair Color and Employment

Studies found that biases regarding personal appearance may affect judgement about a female's applicant's ability in a job application process (Kyle & Mahler, 1996). Researchers from the University of Queensland found blonde-haired women generally make salaries that are 7% higher than those of women with other-color tresses. They also learned that blonde women marry men who earn about 6% more than the husbands of non-blondes (Shontell 2011). Other studies also found that blonde women earn $870 more on average than brunettes and redheads (Rosen 2011). However, these studies do not show a direct correlation between an individual's hair color and their ability.

When it comes to employment opportunity, physical appearance, specifically hair color, does influence the opinions and perceptions of hiring managers (Watson, Griggs and Szeman 2020). It is important to recognize that preconceived perceptions of an individual's hair color have a significant impact on the employment opportunity and their employment terms.

	Positive	**Negative**
Blondes	Blondes, have more fun Blondes always get their way Popular Glamourous	Low IQ / Weak Blondes are only interested in their looks Mean
Reds	Red heads are passionate Wild / Libidinous / Impulsive Quick-tempered	Hot-blooded / Hot-tempered / Angry Get thing done Funny / Personality
Brunettes	Brainy brunette / smart Sophisticated Clever/witty Down-to-earth / wholesome / sensible Girl-next-door	Serious Plain-looking / dull Mousy Villains
Grey	Knowing Wise Confident Grey	Unrelatable Grandmother / Grandfather Old Unfavorable

Table 3. Perceptions of Blonde, Red, Brunette, Grey

4.3.2. Perception of Hair Color and Relationships

Attraction is an important factor when we develop a new relationship. We are attracted to individuals with certain hair color, eye color, and body types. Our personal experience with individuals of specific hair color impacts our perceptions on others who wear that same hair color. A study conducted by the Badoo social network found that 60% of the men find brunette to be the most desirable. 33.1% said they think the most attractive hair color is brown hair, 28.6% preferred black hair, 29.5% of men preferred blondes, and 8.8% of them preferred redheads. Results show that 61.7% of men prefer women with dark hair (Weaver 2015).

Most individuals are attracted to the type they are familiar with, or curious of the type that is the extreme opposite. Even if they have been comfortable dating blondes or redheads their entire dating years, they might still choose to meet and marry a brunette. The choice in a relationship is personal, but one can see

that the choice is often influenced by the perception of the perceived personality and characteristics of hair color.

4.3.3. Perception and Emotion behind grey hair

A personal weighing of emotions is involved when the consumer decides when to cover grey hair and when to stop. In our survey, 40% of the total respondents do not have grey hair; 60% have grey hair. 78% of this grey hair population uses hair color to cover their grey hair; and the remainder 22% embrace their grey hair.

Emotionally, the decision to cover or grow out is individualized. The top two reasons our surveyed respondents choose to cover their grey hair is because covering greys makes them feel better and more youthful. There is a balance of feeling insecure with appearing old or appearing desperate to look young. In contrary, the top two reasons our surveyed respondents choose to grow out their grey hair is because it is less maintenance and like how they look. The decision to embrace the grey will arrive when a person is emotionally prepared.

4.3.4. Perception of Ourselves and Emotion

Hair color plays a role in our identity. How we regard ourselves is paramount to our hair color choices. Choosing the hair color that best suits our perception of who we are, blonde, red, brunette, or grey, is about self-identification. How we think others perceive us is affected by our biases learned from our experiences. The emotional connection by how others regard us stirs in fear, insecurity, and uncertainty. Most consumers strive for social acceptance and approval. There is often a feeling of joy when someone compliments our hair, as the compliment is a validation of the consumer's hair color choice.

5. Conclusions

The hair color service that evokes emotions such as confidence, happiness, and comfort, is an important moment that changes how we feel about ourselves. These emotions are derived from the sacred hair color service and start with a tube of hair color. The relationship of a hair color product to the colorist, the colorist to the consumer, and the consumer to their hair, is profound. The relationship involves building trust and understanding, which results in an emotional impact to the consumer. The celebration of individuality is unique to how a consumer feels about their hair color choice. Consumers show the world how they want to be perceived - their statement and their self-expression. Become aware of all the different hair colors surrounding you and see how you perceive them. Know that there is a trusted tube of hair color that performs perfectly and is emotionally contributing to personal acceptance and happiness.

6. Conflict of interest declaration

The Authors declare that there is no conflict of interest. No financial or personal interests have affected the author's objectivity.

7. Funding source declaration

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9. Short biography of the authors

Lupe Voss - • Lupe is a salon owner, professional hair color educator, and one of the founders of Color Space™ hair color. Lupe has been advocating the need for reimagined and inspired hair color education in the hair industry. She dedicates herself to developing hair color education programs that inspire hair industry professionals.

Sherman Wong - Originally a computer engineer who worked in Silicon Valley, Sherman found his passion lie in the hair industry. Sherman is a passionate beauty industry professional who is always in pursuit to inspire. His enthusiasm for developing leading education programs is matched by his focus on sharing his knowledge of the craft.

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