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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
SCOPUS
ZDB Zeitschriftendatenbank

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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:

1. Color and Measurement/Instrumentation. Colorimetry, photometry and color atlas: method, theory and instrumentation; quality control and food coloring, dyes, organic and sustainable color.
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.
7. Color and Restoration. Archaeometry, painting materials, diagnostics, and conservation techniques, restoration, and enhancement of cultural heritage.
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. Exploring the Spectrum: Color in Science and Society

Dear Esteemed Readers[1],

Welcome to our newest journal issue, where we take you on an insightful journey through the rich tapestry of color across a variety of disciplines, from the harmonious hues of architectural design to the perceptual dynamics of our animal companions and from the subtle intricacies of hair coloring to the sensory allure of wine.

We are welcomed into the fascinating world of hair coloring in "Assessment of Base Color Influence on the Chromatic Appearance of hair colorants," written by Simone Liberini, Roberta Suardi, Alessandro Rizzi, and Giannantonio Negretti. Their detailed analysis clarifies the intricate interactions between applied colorants and underlying pigmentation, providing critical new understandings of the perceptual processes influencing our taste in art and how we express ourselves.
Meanwhile, in "Wine Chromatics: The Colorful Language of Wine's Characteristics," Alessandro Bortolotti, Loreta Cannito, Stefano Anzani, and Riccardo Palumbo reveal the enormous influence of color on marketing and sensory experiences. They reveal the complex relationship between perception and color through well-planned tests, showing how different hues affect our expectations and preferences and how much we like wine.
Gianluca Guarini and Maurizio Rossi delve into the field of design and architecture with their paper, "A review on the open issue of color consistency in software for building information modeling systems and real-time visualization." Their investigation explores the real-world difficulties in preserving color integrity in virtual environments, providing priceless information about the instruments and procedures necessary for visual coherence between virtual and real-world representations.
In their study "The development of a color chart in conceptual fashion collections: do consumers perceive what color semantics want to convey?" Ítalo José de Medeiros Dantas, Camila Assis Peres Silva, and Marcelo Curth highlight the complex relationship between designer purpose and consumer interpretation in the fashion world. They provide new insights into the mutually beneficial link between color, communication, and cultural significance by revealing the intricate semiotic components in color selections within fashion collections through an inventive fusion of qualitative and quantitative approaches.
Francesca Valan, Pietro Paglierani, and Chiara Scopa explain "A leap in the color! " in a remarkable investigation of animal vision. How knowledge of color vision enhances the welfare and performance of horses in show jumping." Their study emphasizes the vital role that color plays in the health and performance of showjumping horses. It also advances our knowledge of interspecies communication and interaction. It provides valuable insights into how best to construct obstacles for equestrian sports.

[1] Colour (UK) or Color (US)? In our Journal, both terms are allowed as long as they are consistent within an article. The exception is given by this editorial in which I use color as on our website. Still, sometimes colour could appear to respect the original title of a paper.

In his study "Reversal film transparencies and their colors: examining the medium of an era," Nicholas Lourantos transports us to ancient times through the vivid colors of the past. Lourantos deconstructs the ongoing appeal of color reversal film transparencies through historical research and empirical analysis. He provides critical new insights into their preservation as cultural objects and their function in forming communal memory and identity.
Kine Angelo and Alex Booker provide a thought-provoking talk titled "Colour Composition and Visual Tectonics in Facades; Adapting Colour Teaching to Current Architectural Practice," which calls for a paradigm change in architectural education incorporating colour theory more deeply. With a wealth of knowledge from both academia and practice, they highlight the transformative power of color in architectural discourse and practice, providing convincing instances of how color theory can improve architectural pedagogy and professional practice.
Finally, we are delighted to present the paper concerning Clino Trini Castelli's work "The 'Color Fever' Chroma Survey 1973". In this perceptive essay, Castelli considers the revolutionary changes in color culture that occurred in the early 1970s and gave rise to the "Color Fever" phenomena. Castelli reveals the underlying changes in how society views color saturation by painstaking observation and analysis, pointing to a move away from strict mathematical paradigms and toward a more nuanced comprehension of color's qualitative aspects. This groundbreaking study provides a fascinating account of how cultural changes and historical occurrences combine to create our collective "sentiment of color," setting the stage for further investigations into color theory and aesthetics.

It is becoming clearer that color is more than just a visual phenomenon. Instead, it is a multidimensional prism through which we see, communicate, and understand the world. This is evident as we explore the varied landscapes of color science and its numerous applications. The articles in this issue are intended to stimulate more investigation, discussion, and cooperation while cultivating a greater understanding of the complex web of life and its enormous effects on science, society, and culture.

Warm regards,

April 2024
The Editor-in-Chief
Maurizio Rossi
Full professor of Design
Politecnico di Milano

Assessment of base color influence on the chromatic appearance of hair colorants

Simone Liberini[1], Roberta Suardi[1], Alessandro Rizzi[2], Giannantonio Negretti[3]

[1] Universal Beauty Products, Brescia, Italy. simone.liberini@gmail.com, roberta.suardi@beautypioneers.com

[2] MIPS Lab, Computer Science Department, University of Milan, Italy. alessandro.rizzi@unimi.it

[3] Beauticon Valley Holding – Benefit Company, Brescia, Italy. ga@nggrp.com

Corresponding author: Simone Liberini (simone.liberini@gmail.com)

ABSTRACT

Hair colorants of the so-called 'series of naturals', a scale of ten colors ranging from deep black to light blonde, are universally recognized as a reference basis for hair coloring procedures. However, it is frequently observed that application results are heavily dependent both in tone and in nuance on the underlying hair pigmentation. We hereby assess the chromatic appearance of a selection of globally marketed series of naturals, both on animal fur and on human dyed hair. Notably, the latter are chosen so to span a consistent range of melanin base, with a varying degree of interlaced depigmented strands. The analysis is carried out by means of a perceptual test based on the Munsell Book of Color, aimed at assessing the perceived tone and nuance with a special focus on the linearity of the scaling.

KEYWORDS hair coloring, cosmetic, color appearance, Munsell Book of Color

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1. Introduction

Judging the appearance of hair color is an essential task for proper salon service. Hair professionals routinely assess hair color at different stages of the coloring process including, but not limited to, once at the beginning, when hair current situation must be evaluated both in terms of tone and nuance; every time hair is rinsed from excess product; after a potential bleaching, by means of which hair basic tone is heavily lightened; after tonalization, a slight nuance correction usually employed to balance out residual and undesired undertones. These assessments leave little room for error, and in fact, customer satisfaction is reportedly low for a variety of technical reasons (Negretti, 2021).

Setting aside high-level human perceptual processing, color appearance is strictly dependent on a multitude of external factors. The artificial lightning of hair salons, for instance, is often designed around scenic impact, while its functional side leaves much to be desired. Not only are common LEDs spectral distributions unsuited to appropriate color evaluation, but their spatial placement is critical with respect to human vision. As an example, light bulbs framed behind mirrors may create glare, and directional lamps usually cast unwanted shadows over customers' heads and faces. Moreover, color blindness should be accounted for, ideally both in customers and in hair professionals (Fusari, 2021), and so should their ability to discriminate subtle color differences. Contrary to direct colors, which can be very easily told apart because of their brightness and saturation, more traditional (and vastly more requested) oxidizing products cannot. To name but an example, nuance 7.34 is golden copper blond, while 7.43 is copper golden blond: very similar to one another, yet slightly different in their predominant nuance. Finally, no actual standard exists in hair salon practice for proper color identification. A simple yet smart color naming scheme does in fact exist (Toninelli *et al.*, 2021), but its practical adoption is highly arbitrary among different color brands, so that hair color charts may very well associate different colors to the same nuance, both in terms of lightness and of predominant hue (Rizzi *et al.*, 2021).

In this paper, a method is described for assessing hair color that tries to compensate for all of these factors in a controlled environment. This method has already been detailed in (Toninelli *et al.*, 2021) for nylon swatches out of hair color charts, but this time, special emphasis is being put on the relevance of the effect of base color on the final appearance of hair colorants on actual hair samples.

2. Materials and methods

Three series comprised of ten hair swatches each were used for testing. Series number one (S_1) is composed of yak hair strands collected from Mongolian and Chinese animals, with next to no residual melanin, about 17 cm long (of which 14 cm available for coloring) and 1.4 g heavy, clipped at one end by means of a plastic zip-tie (Fig. 1-left). Series number two (S_2) is a mixture of grey hair (80%) and white hair (20%), mimicking a situation frequently occurring on the heads of beauty salon customers (Fig. 1-middle). Finally, series number three (S_3) was originally comprised of ten chestnut brown swatches (tonal height 4.0, see below), on which a preliminary depigmentation was carried out by means of a 10-tones bleaching powder (21VENTUNO by Universal Beauty Products) (Fig. 1-right). In order to attain greater consistency, all swatches in S_3 were bleached at the same time by means of a mixture of the abovementioned powder and a 40-volume oxidizing agent (21VENTUNO by Universal Beauty Products) in a 1:2 ratio. Swatches were then wrapped in tinfoil and left in a stove at 30° C for 50 minutes. Excess product was washed away in lukewarm tap water, rinsed in ~1 g of pH 5.5 shampoo (Post Color Back Bar Luxury), washed a second time and then coated in ~1 g of a pH 4.5 hair conditioner (Post color Back Bar Luxury) in order to seal cuticles. Swatches were rinsed one last time, and finally blow-dried at about 160° C temperature.

Fig. 1. Samples of the different swatches: yak hair (S_1 left); 80/20 mixture (S_2 middle); bleached 4.0 (S_3 right - original 4.0 can be seen at the top).

The series of naturals was chosen for application on these samples. Such series broadly classifies and arranges ten colors commonly occurring in human hair: '*Black*' (1.0), '*Deep Dark Chestnut Brown*' (2.0), '*Dark Chestnut Brown*' (3.0), '*Chestnut Brown*' (4.0), '*Light Chestnut Brown*' (5.0), '*Dark Blond*' (6.0), '*Blond*' (7.0), '*Light Blond*' (8.0), '*Very Light Blond*' (9.0), and '*Platinum Blond*' (10.0). In order to minimize inconsistencies, every color in the series was applied simultaneously to a single swatch out of S_1, S_2, and S_3. Thus, because no differences existed either in the mixture or in the application thereof, variations in color appearance could safely be ascribed to the base color alone.

The dyeing process was carried out in a controlled laboratory environment at 25° C, by mixing a 20-volume (21VENTUNO by Universal Beauty Products) developer in a 1:1.5 ratio. Colorants (Color Space Primary by Universal Beauty Products) were applied lengthwise on both surfaces and in both directions in order to achieve maximum penetration within the shafts—then wrapped in tinfoil and put inside a stove at 30° C. After 25 min, swatches were removed from their encasing, washed in lukewarm tap water to remove excess product, rinsed in ~1 g of pH 5.5 shampoo (see above), rinsed a second time and then coated in ~1 g of a pH 4.5 hair conditioner (see above). Swatches were rinsed one last time, dried with a dabbing cloth and a hairdryer (160° C maximum temperature), all the while straightening and disentangling them with a round hairbrush and a fine-toothed comb. Finally, they were arranged in a horseshoe-like flat shape by tying loose ends together with a thin cord after a 180° folding about the midpoint (see again Fig. 1 for reference).

In order to evaluate the predisposition to differentiate between minute hue variations, all test participants were administered the Farnsworth-Munsell 100 Hue test before the actual perceptual experiment. In it, eighty-five colored caps [1] that span the entire range of Munsell Hues at both Munsell Value and Chroma 5 needs to be arranged along four black plastic rows. Test participants were instructed to rebuild the Hue series connecting the two anchored caps at both ends of each row, one cap at a time. The rebuilt order can easily be checked by turning caps upside down, for they are unequivocally numbered. The result (called Total Error Score, TSE in short) is an integer figure that accounts for positioning mistakes: the further apart two consecutive caps are placed, the greater the score.

Perceptual experiments were carried out inside a custom-made lightbox on whose inner ceiling two LED lamps were mounted and directed towards the core of the observation chamber. These sunlike LEDs by Toshiba are meant to cast a nominal 5000 K light closely mimicking the ideal behavior a black body emitter, i.e.: the Sun. In order to better diffuse this light within the box, a frosted glass panel was securely fitted under the lamps, and inner walls were painted in uniform white. Illuminance measurements were acquired with a CL70F illuminance meter by Konica Minolta: luminance was 6900 lx; correlated color temperature was 4880 K; the visible spectrum is plotted in (Fig. 2).

At the core of the perceptual experiment lies The Munsell Book of Color, matte edition. Rather than providing the participants with entire Hue pages, a pre-emptive selection of colored chips was arranged for perceptual matching. Since each Hue page contains about thirty chips on average, providing two to three pages in order to guarantee a sufficient degree of variability with respect to Hue could have rapidly led to visual fatigue.

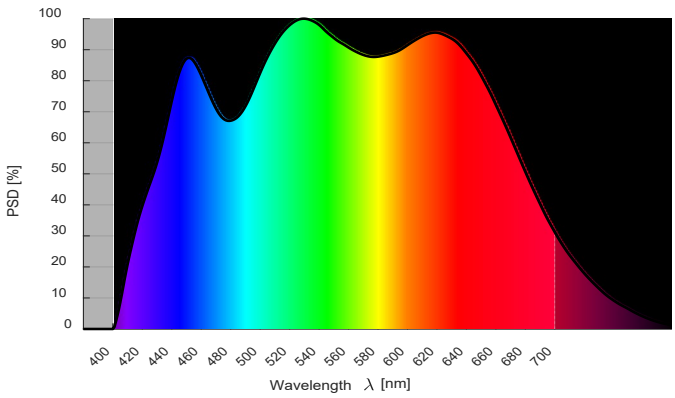

Fig. 2. Illuminance spectrum of the Toshiba LEDs used in the custom-made lightbox (normalized by its peak value around 530 nm).

Moreover, pages in the Book are consistently organized in an orderly fashion, with Values steadily increasing from bottom to top, Chromas from left to right. Such framing was feared to enable undesired patterns in the choice of chips. All this considered, fifty chips total were provided in order to encompass a sufficient variety of Hues, Values and Chromas. The final shortlist was agreed upon within the lightbox and arranged across two concentric circumferences on a white disc where slits were cut to accommodate the chips, and then numbered randomly from 1 to 50. An unbleached paper was chosen whose colour would closely match the one found on pages of the Book, which is inherently designed to be neutral [2]. On the 45°-sloped upper surface of a hollow wooden hemi prism a similar paper was affixed, and a metal peg was clasped in its center. The disc with Munsell chips was hooked on the peg, and then hair swatches on top of it, one at a time, so that the disc could be spun by participants to better match chips to swatches.

Visual matchings took place strictly inside the lightbox. The order of presentation of the swatches never followed the rightful sequence of the natural series. Instead, they were shown in steps of 3, i.e.: 1-4-7-10-2-5-8-3-6-9. This way, biases by virtue of reasoning were avoided, and actual perception was relied upon. Participants were instructed not to touch nor to remove neither swatches nor chips, and were only allowed to spin the disc. When a match was found, the test administrator recorded the corresponding number, and matched it to its Munsell nomenclature for further processing. Finally, test participants were asked a qualitative evaluation of test difficulty on a scale ranging from 1 to 5, namely: 1 - easy; 2 - somewhat easy; 3 - neither easy nor hard; 4 - somewhat hard; 5 - hard. An answer was requested after every match, but only for S_3, which was administered last. By that point participants were confident with the overall task, so judgements could be passed on the swatch matching alone.

3. Results

A total of 15 test participants was recruited, of whom six males and nine females, aged 21 y to 40 y. No subject suffered from any kind of medically certified or self-reported color anomaly or color blindness. The mean total error score (TES) of their Farnsworth-Munsell 100 Hue tests was ~17 ('*Average Discrimination*', yet very close to the range 0 to 16: '*Superior Discrimination*'). Errors made had likely little to no influence on the perceptual performance. The Munsell Colour Solid accounts for a total of 100 Hues, but in fact only 40 of them are physically available in the most complete versions of the Book. Thus, all chips there contained—which were also those displayed in the matching test—are set two and a half Hue steps apart (100 divided by 40). The original Farnsworth-Munsell's test consisted of 100 caps, which were consequently set more or less 1 Hue step apart. Because the modern version of the test is comprised of 85 caps, these are set ~1.18 Hue steps apart (100 divided by 85) [3]. Therefore, a two-steps cap misplacement is required to approach the 2.5 Hue gap typical of painted chips. Since the greatest portion of misplacements in the test was made up of one-step swaps, test-participants were expected to tell Book chips apart confidently, at least as far as Hue was concerned. Furthermore, Hues involved in the actual perceptual test (mostly desaturated oranges and yellows) were all comprised within the less misjudged row.

Dealing with results of the perceptual test requires working on Munsell alphanumerical specifications, e.g.: 5GY 4/10. Values and Chromas are always numbers (respectively 4 and 10 as per the example), whereas Hues are composite of an arabic digits (5) followed by a short character tag (GY). The latter specifies Hue itself among a set of 10 total, of which 5 primaries (Red-Yellow-Green-Blue-Purple) and 5 secondaries (YR-GY-BG-PB-RP). The former provides instead a degree of membership to such label, with 5 being the center-most eponymous step, and the remaining 2.5, 7.5 and 10 stretching both sides towards adjoining Hues on the circle. Another nomenclature also exists coined by A.H. Munsell himself (the so-called *inner loop*), that orders Hues on a purely numerical basis starting from 1 at 1R and ending at 100 at 10RP. This decimal scale is precisely the naming convention that was used for Hue calculations.

Medians and interquartile ranges (IQR: 2nd to 3rd quantiles, or 25th to 75th percentiles) were chosen over mean and standard deviation. Data are discrete, because chips are as well, but not strictly ordinal: interval scales are known, and in fact Munsell color-order system is explicitly built on the premise of having adjacent Hues, Values, and Chromas scale uniformly with respect to human perception. There is no reason to believe the distribution to be normal, and in fact data contain a few outliers. As for symmetry, IQRs often show a distinct skewness, which is useful for inferring a qualitative tendency of the data. For instance, Munsell Values for 80/20 swatches 5.0 and 6.0 are both 3, but the IQR of 5.0 is fully compressed onto the median, whereas 6.0 only has a non-zero third quartile. Therefore, 5.0 and 6.0 have about the same tonal height, but 6.0 could in fact appear slightly lighter. Results are shown for the three types of swatches on a per Hue (Fig. 3a), Value (Fig. 3b), and Chroma basis (Fig. 3c). Median values are also shown for the difficulty evaluation task: the top row in Table 1 shows results relative to swatches, the bottom row relative to test participants. Finally (Fig. 3d), the three types of swatches are grouped for a three-way comparison (again based on Hue, Value, and Chroma).

1.0	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**					
2	2	3	2	3	3	3	2	2	3					
#01	**#02**	**#03**	**#04**	**#05**	**#06**	**#07**	**#08**	**#09**	**#10**	**#11**	**#12**	**#13**	**#14**	**#15**
4	1.5	2.5	2.5	3.5	2.5	2	2	2	3	3	2.5	3	2	2.5

Table 1. Qualitative evaluation of test difficulty (only median values are reported on a scale ranging from 1 to 5, namely: 1 - easy, 2 - moderately easy; 3 - neither easy nor hard; 4 - moderately hard; 5 - hard), grouped per hair swatch (first row), and test subjects (second row).

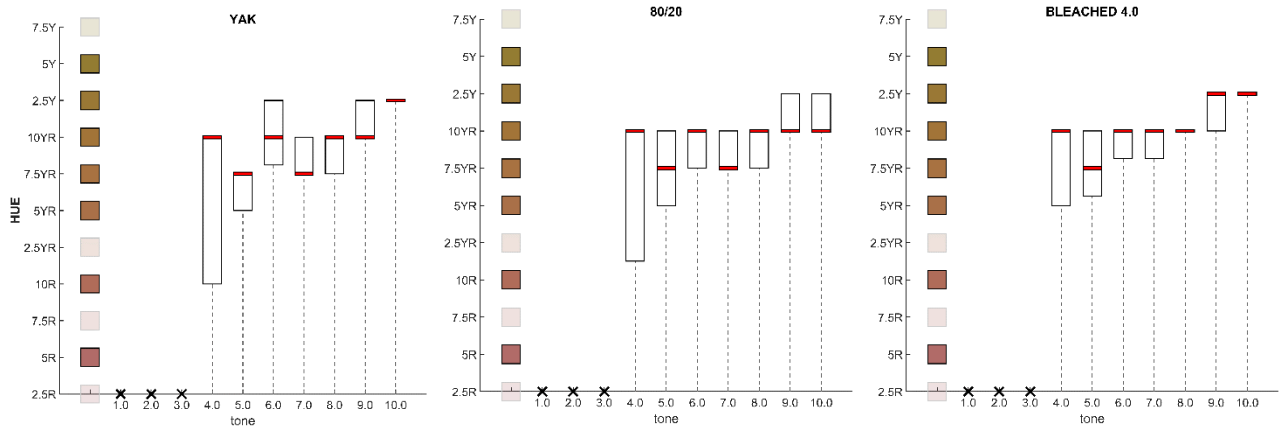

Fig. 3a. Left to right: Hue results of the perceptual experiment for Yak, 80/20, and Bleached 4.0 hair swatches. Medians are marked in red; the second and third quartiles with white vertical bars. Small black crosses indicate an absence of Hue, i.e., an achromatic swatch (here: black). Colored squares next to the y axis are approximations of Munsell chips (Value 5, Chroma 5). Colors are solid for attributes available in the chip selection, transparent otherwise.

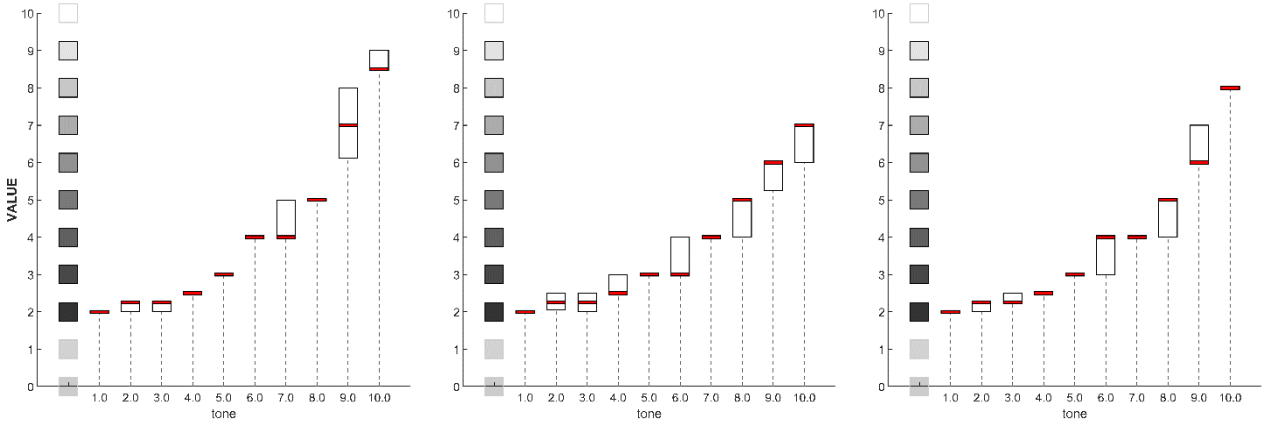

Fig. 3b. Left to right: Value results of the perceptual experiment for Yak, 80/20, and Bleached 4.0 hair swatches Medians are marked in red; the second and third quartiles with white vertical bars. Colored squares next to the y axis are approximations of Munsell chips. Colors are solid for attributes available in the chip selection, transparent otherwise (please note that Neutrals 0 and 10 represent perfect black and perfect white. As such, they are physically unavailable).

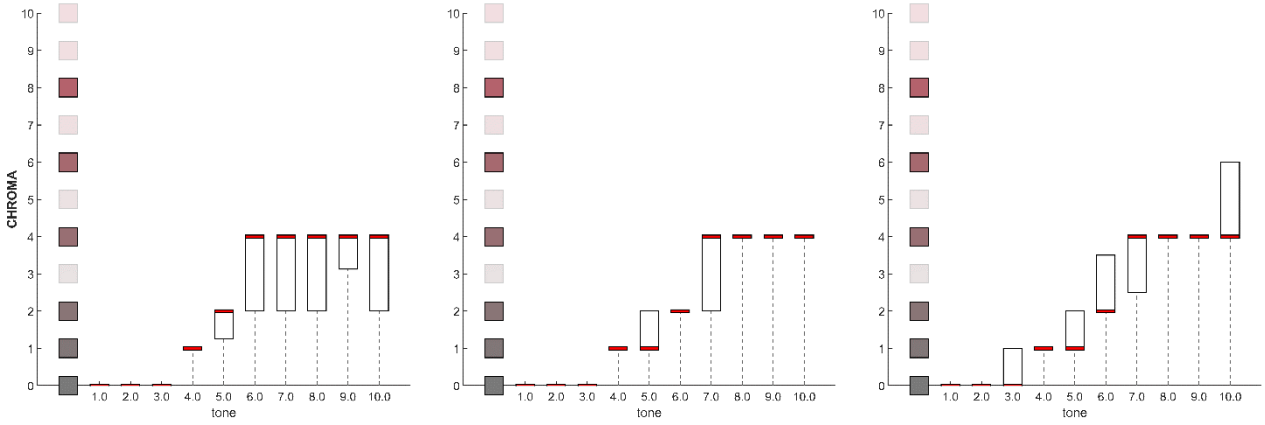

Fig. 3c. Left to right: Chroma results of the perceptual experiment for Yak, 80/20, and Bleached 4.0 hair swatches. Medians are marked in red; the second and third quartiles with white vertical bars. Colored squares next to the y axis are approximations of Munsell chips. Colors are solid for attributes available in the chip selection, transparent otherwise. The discrete nature of the chips is especially apparent here. In fact, Chroma steps are arguably too wide for this application.

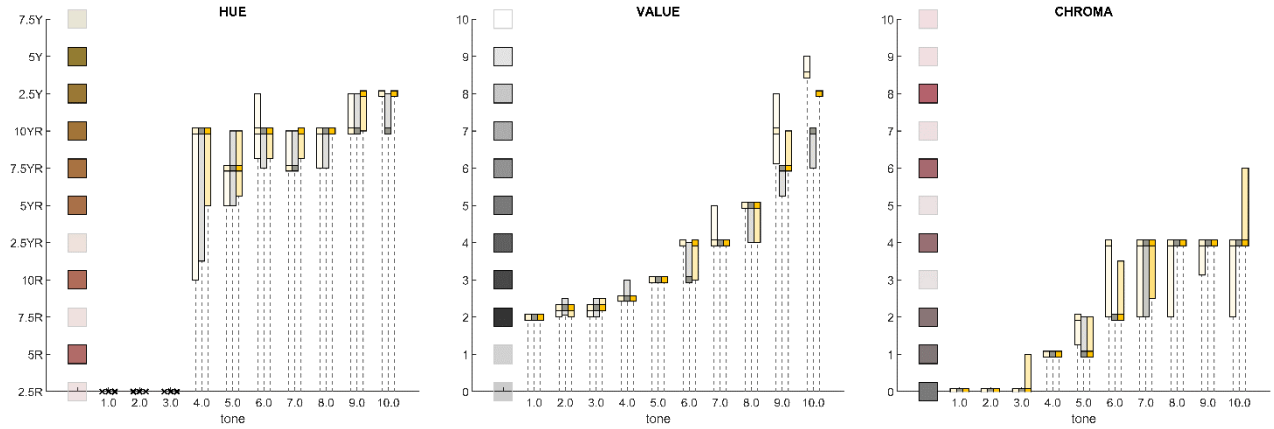

Fig. 3d. Comparison of Yak (white), 80/20 (grey), and Bleached 4.0 (yellow) hair swatches, grouped by Hue (left), Value (center), and Chroma (right). Medians are solid squares; quartiles are discolored bars.

4. Discussion

A method for the evaluation of dyed human hair color appearance has been described. Three different kinds of hair swatches were colored with the same series of naturals: yak hair; a mixture of 80% grey hair and 20% white hair; and finally, bleached brown hair. Observations were made under sunlike Toshiba LEDs by 15 participants previously tested for their ability to distinguish among colors. Results were reported in terms of the Munsell color-order system, which is widely employed worldwide for color appearance test, yet not for hair. We think, on the contrary, that its attributes Hue, Value and Chroma can be used for evaluating specific hair features such as, respectively, nuance, tone, and intensity (Liberini and Rizzi, 2022). The test has been generally well received: 10 out of 15 participants judged it overall easy, and the matching was considered moderately easy for half of the available swatches, neither easy nor hard otherwise, usually in this case due to a greater variety of undertones.

Contrary to common salon practice and color wheels depicted on hair color charts, where usually all tones of a given nuance are arbitrarily assigned a single hue (Rizzi ***et al.***, 2021), Munsell Hue suggests differences along the series. As the Munsell Book of Color clearly outlines, the generic color ‘brown’ can refer to dark and desaturated versions of either red, orange, or yellow. Considering both median values and quartiles (Fig. 3a), hair browns (2.0 to 5.0) start in the orange region and slowly drift towards the yellow region, where blonds (6.0 to 10.0) are also identified. The transition is not smooth, partly due to swatch 6.0 appearing a little too yellow both on yak and on 80/20 in this particular color line. When compared on the basis of Hue (Fig. 3d, left), the three different hair types show small differences especially in the lighter swatches: assuming yak as a reference, the same 10.0 appears slightly less yellow once applied to the 80/20 mix, and conversely more yellow on bleached hair. This is likely due to swatch 10.0 shortcomings both in removing pre-existing melanin, and in covering up its residuals. In fact, it is easier and more reliable to cover fair hair in dark colors than the opposite, where bleaching is also required. For dark hair, on the other hand, judging Hue appears more prone to error, as the generally wider IQR bars clearly show. In this case, another misjudgment appears: very dark brown 2.0, and dark brown 3.0 were, on average, perceived as blacks. This shows through the combined reading of Hue and Chroma: the latter being 0 implies the absence of the former. The fact that this holds true for all tested hair types suggests on one hand a very good coverage of the underlying hair, yet on the other hand, that 2.0 and 3.0 should perhaps be better formulated in order to appear more chromatic. That being said, failure in perceiving a weakly chromatic Hue might in this case be ascribed to the reduced ability of the human visual system to discriminate colors of dark stimuli with reference to the white of the paper sheet and lightbox walls, due to crispening. Swatch 1.0, i.e.: black, was correctly perceived as achromatic.

The most striking feature regarding Value is its perceptual non-linearity (Fig. 3b). Ideally, should the series of naturals be perfectly scaled at equal intervals, at least as far as human perception is involved, their Values would all fall along a straight line, reflecting Munsell Value linearity. Results suggest a quadratic distribution, where browns are much closer to one another than blonds are. Value is also the attribute which highlights base color effects the most. The endpoint for yak, the most neutral base, is 8.5; it is slightly lower at 8 for bleached brown; and conspicuously lower at 7 for the 80/20 mix. Again, this is due to the fact that lighter blonds have far less impact on the underlying hair color. Because of this, and contrary to Hue, a generally greater variation in Value assessment is attained in the blond half of the series, where residual natural pigment is removed more erratically than intended.

Any comment on Chroma is somewhat slightly marred by the intrinsic limitations of the Book, where this attribute is shown on colored chips in increments of 2. Also, chromatic swatches, i.e.: those from 2.0 upwards, very rarely rise above Chroma 4. All things considered, the useful Chroma range appears rather undersampled. Unfortunately, the Nearly Neutral Munsell collection we possess, on which Chroma increases in 0.5 steps, is in turn undersampled with respect to Hue, and available for Values 6 to 9 which are only really useful for swatches 9.0 and 10.0. Having said that, after a relative peak around swatch 7.0, Chroma decreases slightly for yak; it remains constant for 80/20; and it slopes up for bleached brown, possibly due to the visible residual chromaticity of the base. In any case, lighter swatches are always more chromatic (Fig. 3c).

5. Conclusions

Hair coloring is a delicate matter (Voss and Wong, 2021). Marketwise, no two color lines exists whose colors are actually the same, despite having equal names. Moreover, each head of hair bears differences, either subtle or apparent. This paper has shown how different base colors influence the overall color appearance of the series of naturals, highlighting changes both in tonal values and perceived nuance, especially for lighter tones. Because of this, the great variety of base colors must be considered by hair professionals before any coloring treatment is applied. This entails, for instance: tonalization, or a slightly different nuance choice for compensating the underlying base nuance and/or bleaching residuals; a thorough assessment of the desired bleaching level, if necessary, in combination with the required power of oxidizing agents.

6. Conflict of interest declaration

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7. Funding source declaration

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8. Short biography of the authors

Simone Liberini – MD in biomedical engineering. Consultant at Universal Beauty Products, where he is involved in the production of scientific papers and in the writing of educational and training material on color. He also collaborates with the company's research laboratory in the implementation of perceptual experiments using color atlases in a controlled observation environment.

Roberta Suardi – Professional Hairstyling Technician. Hair Color Specialist and Hair Care Expert. Universal Beauty Products in-house trainer, Color Research and Innovation Laboratory coordinator. Educational consultant for PROUD TO BE project aimed at professional training of beauty and wellness operators.

Alessandro Rizzi – Full Professor at the Computer Science Department of the University of Milano. He is researching since 1990 in digital imaging with a particular interest on color, visualization, photography, HDR. He is Senior Editor of Color Research and Applications and Associate Editor of Journal of Electronic Imaging. He has been Topical Editor of the Journal of Optical Society of America A, Secretary of CIE Division 8, IS&T Fellow and Vice President. In 2015 he received the Davies medal from the Royal Photographic Society.

Giannantonio Negretti – Entrepreneur and founder of “Beauticon Valley Holding - Benefit Company”, the entity that leads the network formed by more than 50 companies that, thanks to a unique and integrated supply chain, produces the most innovative and high-quality cosmetic products sold in more than 130 countries around the world. With him was born the idea of a new Renaissance of Beauty described in his book "Humanistic Cosmetic” in which he denounces the distance between the promise of happiness typical of cosmetics and the result that almost always disappoints expectations, proposing new attitudes and concrete solutions.

Notes

[1] Fifteen caps were removed by test creators, hence the discrepancy.

[2] Common printing sheets are often treated with chemical bleachers. Collaterally, this treatment greatly boosts reflectance within the blue spectral bandwidth, altering visual perception of superimposed colors.

[3] Adjacent Hues are actually not equally spaced.

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Wine Chromatics: The Colorful Language of Wine's Characteristics

Alessandro Bortolotti[1], Loreta Cannito[2], Stefano Anzani[1] and Riccardo Palumbo[1]

[1] Department of Neuroscience, Imaging and Clinical Sciences, University Gabriele d'Annunzio Chieti-Pescara. alessandro.bortolotti@unich.it, stefano.anzani@unich.it, riccardo.palumbo@unich.it.

[2] Department of Human Studies, University of Foggia. loreta.cannito@unifg.it

Corresponding author: Alessandro Bortolotti (alessandro.bortolotti@unich.it)

ABSTRACT

The landscape of product and service development has significantly changed recently with the aim of providing customers experiences that are more immersive and engaging. Growing understanding of the significance of sensory marketing and embodied cognition has further heightened this crucial transition. Due of its distinctive multisensory potential, the wine field presents an appealing opportunity to leverage this trend. In order to better understand the role of color in marketing, this research is focused on the relationship between colors and perceived wine's features. By conducting a series of experiments that encompassed both implicit and explicit approaches, our results confirmed that color is a powerful communication tool that significantly shapes our expectations and attention towards wine's features. The explicit approach used is that used by traditional marketing, i.e., the use of surveys with explicit questions asked to participants; as in this case, we explicitly asked the participants to specify their preferences regarding potential color preferences; however, as for the investigation of implicit behavior, a typical paradigm used by psychology was used, i.e., the Dot-Prob paradigm, which is often used to investigate attentional biases and consequently implicit responses. Therefore, acquiring a nuanced understanding of the role of color in the marketing and branding of wine can greatly improve consumer experience and offer valuable insights that can serve as industry best practices. In conclusion, as product development increasingly focuses on creating sensory and interactive experiences for consumers, the focus on understanding the role of color in marketing has intensified. Wine, with its unique potential to stimulate various senses, holds special promise in this regard.

KEYWORDS Color, Marketing, Psychology and Context

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1. Introduction

The past decade has seen a significant shift in product and service development toward creating more sensory and interactive experiences for consumers. This trend has been further emphasized by the growing importance of sensory marketing and embodied cognition, as demonstrated in recent research (Krishna & Schwarz, 2014). Sensory marketing involves engaging consumers' senses to influence their perception, judgment, and behavior, ultimately creating a multisensory experience that adds value. In the wine industry, sensory marketing and embodied cognition play crucial roles in shaping consumer perception, judgment, and behavior (Spence, 2020). Most previous sensory research in marketing has focused on the environment (e.g., store settings or atmosphere; for example, Mattila & Wirtz, 2008; Spence et al., 2014) or the product itself (such as taste, appearance, and odors; for example, Hoegg & Alba, 2007; Peck & Childers, 2003). Little attention has been paid to packaging, a situation in which this document can help improve. Packaging is a critical aspect of marketing offerings and has numerous implications for overall customer experience. Products are presented to consumers wrapped in their unique packaging; the packaging becomes the product's dress and conveys the look and feel during the customer-brand interaction. The key stages of multisensory customer-product interaction can be identified as attention, expectation formation, engagement, and consumption (Stead et al., 2022). Packaging design must consider multisensory customer experience and aim to create positive emotional connections with the brand. Given the amount of marketing stimuli consumers are exposed to on a daily basis, unconscious triggers, such as those that appeal to basic senses, can help marketers attract consumers more efficiently (Krishna, 2012). The total customer experience is the sum of the buying experience (interaction with the sales environment, salespeople, and other customers; Hui & Bateson, 1991), the product experience (interaction with the product; Hoch, 2002), the communication experience (interaction between the company, the customer, and other customers; Krishna et al., 2016), brand experience (interaction with brand-related stimuli such as colors, shapes, and characters; Brakus et al., 2009), and, finally, consumer experience (Brakus et al., 2009). Packaging design and presentation, whether for purchase or consumption, is often a key component of these experiences. From this perspective, the product that, by its nature, falls more than others as a multisensory stimulus is wine (Spence, 2020). As a stimulus, color can be a bridge between top-down (i.e., those driven by consumer experience) and bottom-up processes (i.e., those to which consumers are attracted). or as part of marketing communication. Therefore, packaging must first attract customer attention (Milosavljevic & Cerf, 2008). Extensive research in visual neuroscience has shown that visual attributes that influence the saliency of stimuli can also impact where and how long people fixate on complex displays, such as vending machines or supermarket shelves (Milosavljevic et al. 2012). Therefore, consumers tend to fixate on visually more salient items longer than on less salient ones. Second, recent neuroeconomic studies have demonstrated that the value individuals assign to stimuli when making their choice depends on how much attention they give to those stimuli during the decision-making process (Armel et al., 2008; Krajbich et al., 2010). Specifically, the longer people focus on an object, the more likely they are to choose that object and assign a higher liking score. In this context, the wine product must be able to precisely communicate what is inside the bottle or what the company wants the product to "symbolize." From this perspective, color can be a bridge between top-down (i.e., guided by consumer experience) and bottom-up (i.e., consumers being attracted to it) processes.

Supporting this hypothesis, scientific evidence suggests that regardless of preference, individuals are more likely to choose visually salient options because of the way the brain processes visual information. Furthermore, Milosavljevic et al. (2012) show that at fast decision speeds, visual salience has a greater impact on choices than preferences. The bias increases with cognitive load, especially when individuals do not strongly prefer any of the options. Much evidence suggests that colors evoke feelings (for a review, see Bortolotti et al., 2023; Labrecque et al., 2013) color studies have focused on the use of black and white (see Greenleaf, 2011; Kareklas et al., 2014; Lee et al., 2014). For example, Greenleaf (2011) noted that black and white can be used to automatically evoke a sense of nostalgia. At the cognitive level, Lee et al. (2014) observed that black and white favors the high-level construct (i.e., attention to the abstract, essential, and determinant features of a stimulus), while color triggers the low-level construct (i.e., attention to the concrete, idiosyncratic, and superficial features of a stimulus). Therefore, black-and-white graphics on the packaging would increase the perceived importance of more essential product features over ancillary ones. Visual cues are probably the most studied aspect of involvement in packaging. Given the complexity of decision making in wine selection, consumers rely on multiple sources of information when evaluating wine, including their own knowledge and experience (Barber & Almanza, 2006).

The label is a fundamental source of information for wine consumers, providing details on both intrinsic and extrinsic quality signals (Chaney, 2000; Thomas & Pickering, 2003). Intrinsic signals relate to product characteristics

such as grape variety, region, producer, and wine style. Extrinsic signals are those under the marketer's control, including price, packaging and labelling style, and brand name (Quester & Smart, 1996). Although label design and associated name are themselves external signals, they reside only as one of many quality indicators available on the label. Boudreaux and Palmer (2007) have observed that label design is a fundamental component of a wine brand's image, stating that "bottle labels are particularly relevant to the decision-making process, especially for infrequent wine drinkers." As Barber and Almanza (2006) wrote, "consumers buy with their eyes," explaining the preference of consumers to personally view wines, reading labels as they evaluate possible selections. Color is argued to be the most distinctive visual cue in packaging (Singh, 2006), but its effects depend on many factors such as attention level (Brignell et al., 2009), product consumption frequency (Lick et al., 2017), cultural context (Piqueras-Fiszman et al., 2012), consumer sensitivity to design (Becker et al., 2011), and the product itself (Zellner et al., 2018). A recent review (Spence & Velasco, 2019) summarized the multiple roles of packaging color on consumers' expectations and perception of identity, taste, flavor, fragrance, healthiness, and willingness to pay. Following the review, new contributions have reported that the color of packaging can influence the emotions evoked by a hamburger (Merlo et al., 2018), the color of the inside packaging (i.e., the side in contact with the product) can influence the desirability of yogurt (Van Esch et al., 2019), and the color of the label can influence the expected taste of specialty coffee (De Sousa et al., 2020).

There are different methods for investigating consumer preferences, and in this case, we will start with explicit preferences, as done in traditional marketing.

Through an exploratory study, we investigated which adjectives can be associated with wine characteristics, both positive and negative, in the absence of a standardized online database.

2. Study 1. Explicit experiment

Step 1. Selecting Adjectives

To address the lack of research on the association between color and adjectives related to wine, we conducted an online survey through the Qualtrics platform (Qualtrics, Provo, UT).

The survey included 127-italian adjectives (full list in English in Table 1), all potentially associated with wine, which were taken from online lists of "wine" adjectives found on wine menus (for example, those presented at a dinner table). Participants were asked to rate, on a Likert scale (from 1 = not at all to 10 = completely), the degree to which they felt each adjective was associated with wine.

Abominable	Aromatic	Expensive	Energetic	Generous	Unsatisfactory	Natural	Perfect
Cozy	Sour	Creative	Balanced	Gentle	Interesting	Negative	Dangerous
Acerbic	Bold	Curious	Exaggerated	Genuine	Pointless	Boring	Heavy
Acidic	Austere	Weak	Annoying	Joyful	Aged	Novel	Pleasant
Charming	Beautiful	Delicate	Happy	Young	Italian	Hateful	Positive
Reliable	Organic	Delicious	Fermented	Pleasant	Light	Original	Poor
Aggressive	Ugly	Disappointing	Firm	Graceful	Slow	Horrible	Practical
Cheerful	Good	Dynamic	Strong	Tasty	Fortified	Hostile	Valuable
Lovable	Warm	Messy	Fragile	Unreliable	Local	Excellent	Primitive
Ancient	Bad	Fun	Fresh	Indifferent	Melancholy	Passito	Fragrant
Antipathic	Classic	Sweet	Sparkling	Inferior	Neutral	Pasty	Stinky
Apathetic	Full-bodied	Elastic	Fruity	Insane	Wicked	Fearful	Rich
Harmonious	Short	Elegant	Sparkling	Senseless	Mature	Loser	Relaxed
Superficial	Shy	Sad	Humble	Valorous	Old	Poisonous	Winning
Lively	False	Repulsive	Robust	Romantic	Crude	Rude	Scadent
Dry	Serious	Sincere	Satisfactory	Dirty	Sporty	Extraordinary	

Table 1. Wine adjectives used.

The participant sample consisted of 303 non-expert wine consumers (mean age = 30.1 years old ± 10). Participants gender was equally distributed as 144 were male, 144 were female, and 15 chose not to disclose their gender. Similarly the sample distributed among participants living in the north, center, south, and islands of Italy. To verify any biases towards red wine (and its predominant characteristics), we also asked participants about their wine preferences. The distribution consisted of 83 preferences for white wine, 39 for rosé wine, and 181 for red wine. We then analyzed the results based on consumer preferences, and using a cut-off with of 5 (averagely associated with wine), we selected 56 adjectives related to wine (full list in Table 2), that we then employed in the following study's step.

Acerbic	Aromatized	Expensive	Firm	Pleasant	Local	Perfect	Robust
Acid	Tart	Delicate	Strong	Tasty	Mature	Heavy	Poor
Fascinating	Organic	Delicious	Fresh	Interesting	Natural	Pleasant	Dry
Cheerful	Good	Sweet	Sparkling	Aged	Novello	Valuable	Satisfying
Lovely	Warm	Elegant	Fruity	Italian	Excellent	Primitive	Extraordinary
Ancient	Classic	Balanced	Genuine	Light	Passito	Perfumed	Old
Harmonious	Stout	Fermented	Young	Fortified	Pasty	Rich	Lively

Table 2. Wine adjectives selected.

Step 2. Testing Color-Adjectives associations

In the second step, a new custom-made questionnaire was administered to a different group of participants. The questionnaire presented the preliminary selected list of 56 adjectives to the participants, who were asked to associate each of them with a color chosen from a palette of 52 colors (Figure 1., all palette-related details are found in supplementary materials). This color palette has a variability of not only in terms of hue, it was used to make the task easier for the participants, although there are different more accurate color selection software in the literature. The participant pool comprised a total of 565 participants (all non-expert wine consumers), with 190 males and 375 females (mean age = 31.3 years old ± 10.7). By dividing the 52 colors into families, e.g. red, yellow, blue, and two families of achromatic colors, black and white; explicit associative categories were formed for color-adjective wine associations; complete results are presented in Figure 4. Some interesting evidences came up. For instance, in our broad sample, some adjective-color associations had a high percentage of associations in a specific color spectrum, such as the adjective "Acido" (Acid) being associated with three color families in the following order: Yellow-Green 34.6%, Yellow 27.88%, and Green 15.49%. The fact that these colors are close in the color spectrum suggests that these associations are even stronger than they may appear at first sight. Another example pertains the adjective "Biologico" (Organic), which is almost predominant in the wine market from 2020 onwards. The results showed that this adjective was strongly associated with color families close to each other in the color spectrum, such as Green, Yellow-Green, and Green-Cyan. Overall, these congruent categories of adjective-color associations are representative, but not all 56 adjectives have such significant associations (Figure 2). The use of a diverse color palette and its categorization into families allowed for a better understanding of color-adjective associations in the wine market, which has not been studied in such detail in previous marketing literature.

Fig. 1. Color sampled used.

Particularly, our research aimed to delve into the potential influence of color associations on the perception of wine consumers. More specifically, we sought to examine the hypothesis that color could serve as a means of expressing certain wine characteristics, and that these associations may have a bearing on consumer choices regarding which wine to purchase. To the best of our knowledge, this is the first available dataset on the association between color and wine's features in an Italian sample.

3. Study 2. Implicit study

Building on the results obtained from the previous questionnaires, which explored explicit associations between colors and wine-related adjectives, we were able to create congruent categories of stimuli (color-adjective pairings). We then proceeded to test these categories, both congruent and incongruent, in an implicit manner, in order to determine whether these categories also hold implicit associations. We sought to verify whether the color-adjective pairings that emerged from explicit associations between wine-related adjectives and colors would also be confirmed through implicit associations. To achieve this, we employed a testing method that would bypass conscious awareness and directly tap into implicit associations. Our findings will provide valuable insights

into the nature of the associations between colors and wine-related adjectives, shedding light on how these associations might shape our perception and evaluation of wine. For this purpose we used the Dot Probe paradigm (Cannito et al., 2023), modifying it ad hoc by using a textual prime that triggered a mental representation linked to the adjective prime (the 56 adjectives list) that was presented centrally on the screen and was followed by two sided color stimuli (the most chosen and a not-chosen color for each adjective). In congruent condition of the task, the dot to which the participants is asked to react by pressing a key is presented on the side of the most chosen color. Contrarily, in the incongruent condition the probe appears on the side of the not chosen color. Specifically, the prime (Adjective) was presented for 1500 ms. This was followed by a fixation cross (+) for 500 ms, and then pairs of color stimuli were presented for 1000 ms each (see Figure 3). The task lasted about 30 minutes and was administered online through the E-Prime GO platform (Psychology Software Tools, Pittsburgh, PA). Participants had a total of 224 trials, divided into 112 test trials (for which color stimuli included the most chosen and a not chosen color) and 112 control trials (for which color stimuli included the second most chosen and a not chosen color). Among all trials, color stimuli (chosen and not chosen) were balanced for right and left presentation, so participants saw the each adjective four times (2 times as control trial and 2 times as test trial). Thanks to this task, it is possible to measure Attentional Bias (AB) toward one of the two color after a specific adjective, which indicates an implicit preference toward one of the two colors.

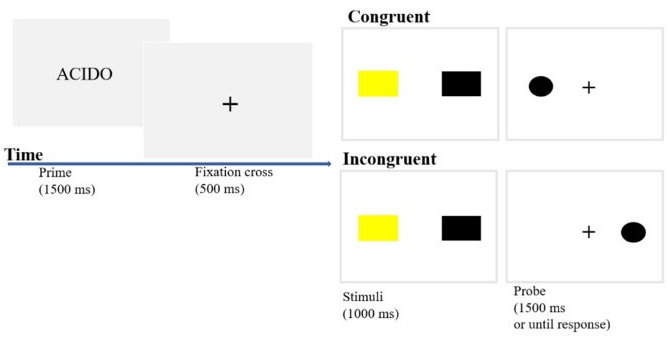

Fig. 2. Task.

The sample of participants in the experimental study were all volunteers and wine consumers, recruited through social media pages or acquaintances and was composed of 40 participants, divided into 28 female and 12 male participants. The average age of the sample was 27.1 years (with a standard deviation of 2.2 years). Participants reported no vision problems and completed the task in total silence and without distractions. The results of our study show that, with regard to accuracy, we did not find any significant differences between the congruent and the incongruent condition, with a percentage accuracy of 99.4% for congruent categories and 99.3% for incongruent categories (See Figure 3a).

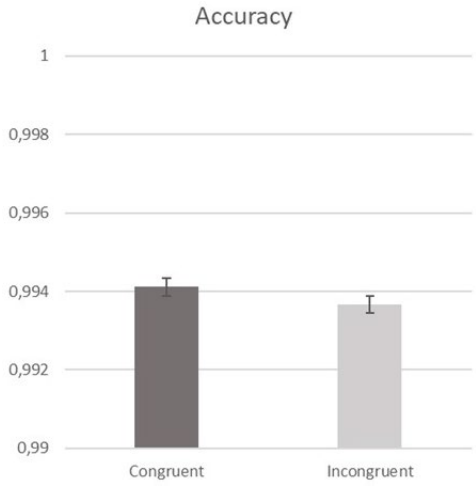

Fig. 3a. Results Mean Accuracy

On the other side, we found significant difference in reaction times (Figure. 3b), indicating that participants were faster to respond to the dot when the probe was presented behind the incongruent color (not chosen color), with an average response time of 331.46 ms for congruent categories and 316.11 ms for incongruent categories (p = .001).

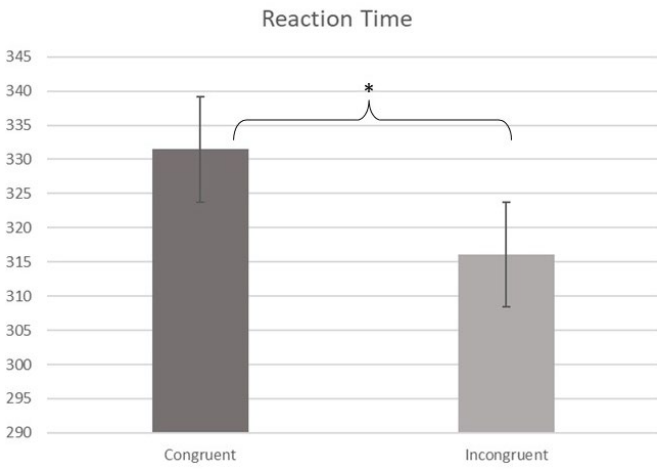

Fig. 3b. Results Mean Reaction Time.

4. Conclusion.

The findings of this study are in line with other studies on the subject (MacLeod et al., 1986). Due to the task simplicity and lack of distinctions that we expected to see, we did not discover any differences in accuracy for this assignment. When examining the variations in response times, an intriguing result demonstrated the existence of an attentional bias towards the incongruent stimuli. This

is widely explained in the literature as a form of inhibition of return (IOR), caused by the attentional capture of the congruent stimulus and the "inability" of the participant to refocus on the previously explored stimulus. More specifically, the "inhibition of return" (IOR) is defined as the poorer performance in previously signaled positions (Posner et al., 1985). The cause of IOR has been attributed to the attentional orientation towards a location and the subsequent disengagement of attention from that location. The effect has been to discourage attention from reorienting towards the originally frequented location.

5. General discussions.

Building on the results obtained from our two studies, the first of an explicit type (as done in traditional marketing), to better understand all the results look at Figure. 4, where the participants' favorite associations between color and adjective are shown in percentages; and the second more of an implicit type (carried out using techniques typical of psychology).Our work aims to optimize communication through careful use of color in the label; labels are a crucial element in wine marketing, as consumers often rely on images, layout, and color to infer the quality and personality of the wine brand (Verdu Jover et al., 2004; Boudreaux & Palmer, 2007). In fact, labels are the second most important predictor of a wine's purchase intention after price. Colors have meanings and are a fundamental tool in marketing strategies and communications, as they are often used for product and brand differentiation based on consumer perceptions. Therefore, packaging elements that quickly communicate the relevant and appropriate information about the quality of the wine become increasingly important marketing instruments (Nomisma, 2003).

The importance of color cannot be underestimated, as it plays a key role not only in conveying messages and emotions, but also in serving as a powerful tool for anticipating consumer preferences and behavior. As we have seen, the impact of color on human psychology and perception is a much-studied topic, and its influence on various aspects of our lives, including art, design, marketing and branding, is undeniable. In the field of communication, color is a powerful visual clue that can evoke different emotions and associations (Bortolotti et al., 2022), depending on the context and cultural background of the audience. However, the impact of color goes beyond communication, as it also influences consumer behavior and decision making. For example, studies have shown that people tend to prefer products and services that align with their preferred colors or color schemes, which can influence their purchasing decisions and brand loyalty. Similarly, some colors are associated with specific attributes and values, such as green with sustainability or black with luxury, which can influence how consumers perceive and evaluate a brand. In addition, color can be used to anticipate consumer preferences and trends by analyzing their expectations and cultural associations. By understanding the psychological and cultural significance of different colors, companies can adapt their products, packaging, and marketing strategies to appeal to specific audiences and differentiate themselves from competitors.

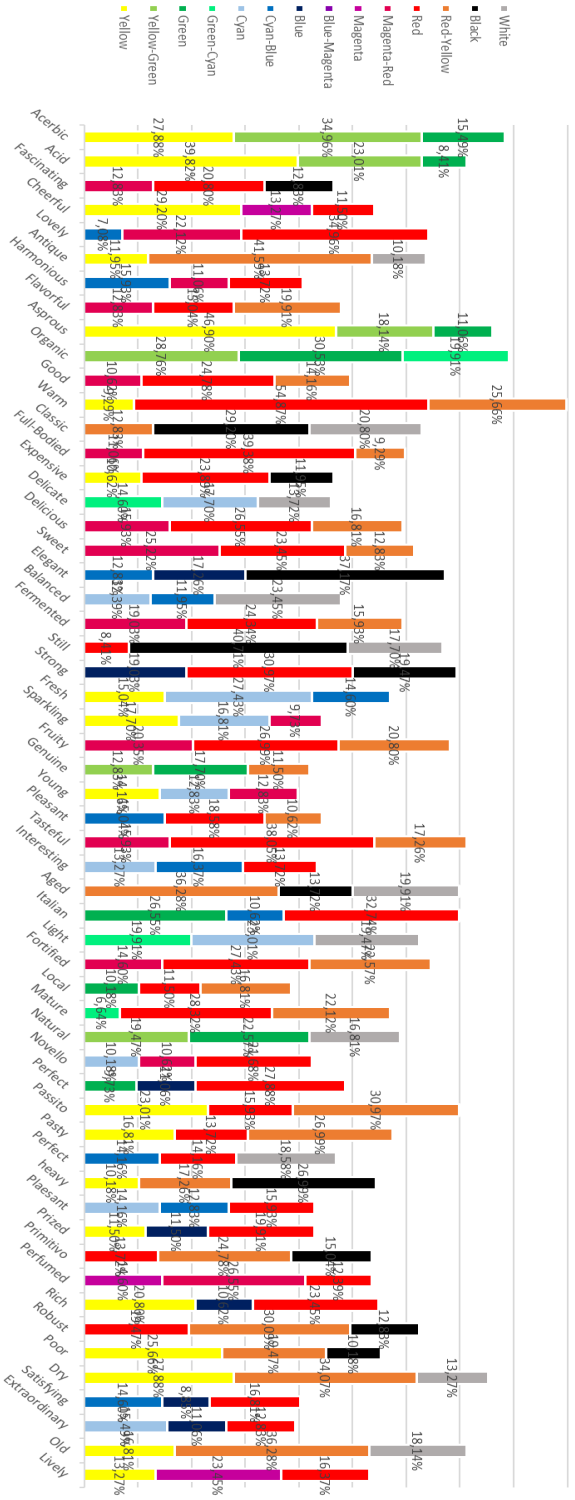

Fig. 4. Percentage of colors associated with each tested adjective.

6. Conflict of interest declaration

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7. Funding source declaration

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

8. Supplementary materials

Color sample (Figure 1.) list number (HEX code): 1(#FE66B0), 2(#FF6666), 3(#FFB166), 4(#FFFF66), 5(#B3FF66), 6(#66FF66), 7(#FF007E), 8(#FE0000), 9(#FF7F00), 10(#FFFF00), 11(#80FF00), 12(#00FF00), 13(#980050), 14(#9A0000), 15(#994B00), 16(#404040), 17(#999A00), 18(#4D9A00), 19(#009900), 20(#660030), 21(#660000), 22(#663200), 23(#000000), 24(#656600), 25(#336600), 26(#006600), 27(#660066), 28(#330066), 29(#010066), 30(#FFFFFF), 31(#003466), 32(#026666), 33(#006633), 34(#990099), 35(#4C0099), 36(#000099), 37(#C0C0C0), 38(#004C99), 39(#009899), 40(#00996B), 41(#FF00FE), 42(#7F00FF), 43(#0000FE), 44(#0080FF), 45(#01FFFF), 46(#00FE80), 47(#FF66FF), 48(#B266FF), 49(#6665FF), 50(#66B0FE), 51(#99FFFF), 52(#99FFCD)

9. Short biography of the authors

Alessandro Bortolotti – Psychologist, he obtained his doctorate in Business and Behavioral Sciences at the University of Chieti-Pescara, where he studies neuromarketing and emotion using behavioral and neurophysiological methods.

Loreta Cannito – She is Assistant Professor in General Psychology at the University of Foggia. She is author of numerous contributions on the role of attentional and emotional processes in decision making both in the clinical and applied fields.

Stefano Anzani - Studied Psychology and Cognitive Neuroscience. He obtained her doctorate in Business and Behavioral Sciences at the University of Chieti-Pescara.

Riccardo Palumbo - Is Professor of Business and Behavioural Economics and Neuromarketing at the Department of Neuroscience Imaging and Clinical Sciences of the University of Chieti-Pescara. Coordinator of the section of Behavioural Economics and Neuroeconomics and the PhD in Business and Behavioural Sciences. Co-founder and CEO of Umana Analytics

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A review on the open issue of color consistency in software for building information modeling systems and real-time visualization

Guarini Gianluca, Maurizio Rossi

Dipartimento di Design, Politecnico di Milano, Milan, Italy. gianluca.guarini@polimi.it, maurizio.rossi@polimi.it

Corresponding author: Gianluca Guarini (gianluca.guarini@polimi.it)

ABSTRACT

This text discusses the issue of color consistency in BIM and Virtual Reality. In recent years, due to an increasingly stringent regulatory imposition in public procurement, especially concerning the estimated workloads, the BIM methodology has become increasingly popular among professionals in the architectural design field. In the 2000s, the visualization of projects was mainly done through photorealistic static renderings or animations obtained from sequences of static images. However, with the evolution of Raytrace Rendering engines and the escalating computing power of available hardware, Virtual Reality and augmented reality have gained significant popularity among designers for visualizing and facilitating project comprehension among clients and other professionals involved. Once the color of a finish has been acquired through correctly calibrated devices and standard procedures, the problem of its correct representation arises. The Methods section of this paper describes the preliminary procedures used to obtain a trustful Design Visualization, in the Result section we list some currently available solutions and their characteristics, thus analyzing how the applications address the issue nowadays, providing tools that allow designers to optimize color consistency between the real world and different visualizations and guarantee imaging correctness and quality. In conclusion, we summarise the different approaches to give an overall view of the tools available for the Designers.

KEYWORDS color management, virtual reality, color consistency, BIM, real-time

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1. Introduction

Designers In the Construction field are increasingly adopting BIM methodology to create a virtual prototype of the building to be designed. This digital twin must be accompanied by detailed information on all the construction elements. At the same time, since the BIM methodology does not require great graphic detail, it can provide a low level of detail in terms of geometry, avoiding a negative impact on the weight of the file. Nevertheless, all BIM software have basic, non-highly professional Visualizing and Rendering features, and the graphic detail of the images produced as a result can't be satisfactory, especially on the furnishing elements. The BIM model's detail level is only appropriate for general external architectural visualization. In recent times, Virtual Reality and Augmented Reality applications are playing a significant role in indoor architectural visualization, surpassing the usual static renders. This is due to the evolution of real-time algorithms and rendering engines (Möller, Haines and Hoffman, 2018), AR / MR techniques (Alhakamy and Tuceryan, 2020), and the hardware capacity of modern video cards (Thoman *et al.*, 2022). Furthermore, some studies have shown that, especially in daylight simulations, the perception of space by the end-user was remarkably accurate (Chamilothori, Wienold and Andersen, 2019). Thus, integrating the BIM outcome with a VR visualization tool represents a practical solution to project presentation. This theme has been studied and good results have been obtained, especially in artificial light scenarios (Natephra *et al.*, 2017). This paper aims to find a way to represent the BIM model through new interactive techniques, improving the quality of the model without affecting the weight in bytes of the native file and respecting color fidelity between the real world and the digital visualization. The proposed solutions are numerous and various. Previous studies presented workflows with multi-software applications (Wong *et al.*, 2019).

The paper plans out as follows. In Section 2, we describe the preliminary procedures to obtain a trustful Design Visualization, specifically: a correct acquisition of a Material Color (Section 2.1), the use of a specific digital material to better reproduce the interaction of the material with light (Section 2.2), and the procedure used to have a digital replica of the light setup (Section 2.3). In Section 3, we present the different solutions available today on the market. "Revit VRay and Chaos Vantage" in Section 3.1, "Revit and Enscape" in Section 3.2, "Revit and exporting in dedicated Real-Time Visualization Software" in Section 3.3, and "Revit and Unity Reflect" in Section 3.4. In Section 4, we briefly recap the results and present advantages and drawbacks of each provided procedure.

2. Methods

The designer must consider three essential aspects to ensure color consistency in the new interactive visualization. An accurate acquisition of the material Color. A correct replica of the interaction between the light and the material. A trustful reproduction of the lighting scenario. In the following, we describe in detail each one of these aspects.

2.1. *Acquisition of the Material Color*

CAD systems usually accept textures by default in the sRGB colorspace profile. To correctly represent a material's color, users should avoid using textures downloaded from the internet, as there's no way of knowing how and if they were acquired with a standard and verified procedure. It is also uncertain whether the conversion of the relative color profile of the device to the absolute sRGB has been completed accurately. The designer should therefore opt for a live acquisition.

There are two possible procedures, one photographic and one via scanner. In either scenario, the devices must be calibrated and have a relative color profile, periodically updated in the case of the scanner (Guarini, 2020) and obtained at the time of the shooting in the case of the camera (Guarini and Rossi, 2021). The whole procedure, as well as the environmental conditions, must be standard and reproducible. Scanner acquisition is a preferable choice, especially in the case of samples with a narrow section. The acquired texture must then be converted, using dedicated software equipped with a CSM Manager, into the absolute sRGB color space. If the texture has to be repeated several times on a surface, it will then be further refined in a photo editing program to be used seamlessly.

2.2. *Interaction between Light and Material*

A correct replica of the interaction between the light and the material is crucial for a reliable Real-Time visualization of the Project. PBR materials (McDermott, 2018) are shaders, introduced in recent times, that replicate this type of interaction quickly and effectively. Revit has recently introduced this type of material, however, they are still hidden and not easily accessible by the user (Fig. 1). When assigning materials in Revit, it is preferable to use these directly to facilitate compatibility and reduce work in Real-time Rendering applications. If the sample present in the library shows an exclamation point on a yellow triangle, the Revit material is not a PBR material.

PBR materials (Pharr, Jakob and Humphreys, 2023) are based on physical parameters that can be set through values or through specific texture images. The parameters

in which to insert the texture maps are always the same, regardless of the software used. Once the designer has obtained the maps in question, he must connect them to the respective map channels of the application he wants to use. Among the most important, we mention “Albedo,” relating to diffuse reflection of light, “Roughness” relating to surface imperfections of the surface, and “Height Map”.

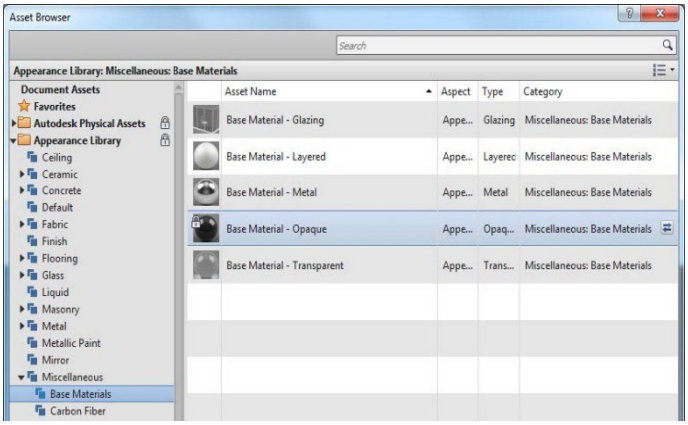

Fig. 1. Base PBR Materials in Revit

The Designer could find the textures on-line, as several sites offer pre-prepared textures for various channels. However, this workflow should be avoided due to a range of problems regarding acquisition’s fidelity of the base color. Using a texture acquired with known and standard procedures would be advisable. Obtained this, free software allows producing all other textures from the first image. An example is Materialize (*Bounding Box Software - Materialize*, 2023). We outline that procedures for obtaining images with sRGB profile to be used in Albedo property tries to return color as faithfully as possible. Materialize is a free software that renders the maps of the other material parameters and produces a more realistic appearance to the final finish by acting on the glossiness of the material and its roughness. Unfortunately, they empirically reproduce the type of finish, and the result is often left to the designer's ability.

2.3. *Lighting*

There are two lighting conditions for carrying out design simulations where it is possible to evaluate the color rendering of materials: natural light and artificial light. The first is easier to manage since each real-time simulation software has simplified commands that reproduce daytime or nighttime lighting. The parameters to set up are not numerous and essentially concern the simulation’s date and time, the project’s position and orientation, and the atmospheric conditions of the simulation. The designer must always be careful not to modify the preset physical parameters, such as the sun’s intensity and the solar disk’s size, to avoid incorrect simulations regarding the quantity of light and the visualization of shadows. The artificial light condition requires more attention since the designer should use the accurate photometric data of the lighting fixture that they want to use in the environment. This can be supplied by the appliances manufacturers. The most widespread methodology consists in entering the data relating to the light intensity through photometric files downloaded from the manufacturers’ websites and the data relating to the color temperature of the sources by entering them manually from the technical data sheets of the device. Almost all real-time viewing software supports the insertion and utilization of such files and color temperatures. It is also necessary to verify that the software has available options or tools that allow using the actual intensity distribution given by the file without this being occluded or modified by the 3D geometry of the device itself.

3. Results

After an accurate acquisition of the material Color, the utilization of the PBR shader, and a trustful reproduction of the lighting scenario, a dedicated application or plugin is still required to easily view the project in real-time.

The BIM software has a module for viewing the rendering of the project. However, it has a limited set of tools and needs to solve the problems related to the interaction of the photometric solid within the lighting fixture. Additionally, there is no module for real-time viewing. Some integrated and cloud-based solutions, such as “Revit Live" (Revit Live | Autodesk, 2020), were implemented but were subsequently discontinued.

Several alternative solutions are currently available to address this deficency, given the ever-increasing diffusion of Realtime Visualization and Augmented Reality. Some professional rendering engines developed by companies with years of experience in visualization have developed additional real-time applications to import the scenes rendered through their plugin. We can mention VRay for Revit (*V-Ray for Revit*, 2021) and Chaos Vantage (*Chaos Vantage – Pure ray tracing in real-time | Chaos*, 2022).

Some Architectural Plugin solutions allow viewing the model easily through the live synch feature. Examples are Enscape and Lumion (*Lumion 3D Rendering Software | Architectural Visualization*, 2022).

Another alternative is to import the BIM model using a standard file format into leading software in the sector, such as Unity (Unity, 2022a) and Unreal (*Unreal Engine 5*, 2004). Software companies are increasingly developing plugins to allow BIM users to take advantage of Real-Time raytraced project visualization. These plugins are simplified versions of their corresponding vertical software

of the sector. In this way, the work of the designer can be simplified. Unity Reflect (Unity, 2022b) is an example of this approach.

3.1. *Revit VRay and Chaos Vantage*

VRay for Revit is a plugin that expands the possibilities of Revit in terms of project visualization. It solves the interaction problems of the photometric solid within the luminaire and can perform lighting analysis on photometric quantities. It has photometrically correct materials, the VRay Materials, which allow importing textures acquired specifically with sRGB profile, thus guaranteeing color consistency in the representations. The software company that developed it has also implemented an application dedicated to real-time visualization, Chaos Vantage. It is possible to export the entire model from VRay for Revit in a file *.VRayscene, which can then be imported into Chaos Vantage.

In this case, the materials and natural light are managed entirely within VRay for Revit, while the lighting fixtures and photometric files are set up in Revit. Once the file has been imported into Vantage, it is possible to explore the model in Realtime and with the same rendering quality as VRay. It is also possible to apply other materials to the scene, including those previously created and assigned within VRay for Revit. The lighting fixtures can also be switched off and dimmed.

3.2. *Revit and Enscape*

Enscape (*Enscape™*, 2022) is a Real-time Rendering Plugin that can be used in various software, including BIM software and Revit. Once the plugin is installed, the user can transport the BIM model to an Enscape instance, establishing a dynamic link between the model and its visualization. In this case, the Enscape window acts as a Real-Time viewer of everything modified in Revit (Fig. 2).

The materials and the lights are then set directly in the BIM software. For this reason, to obtain consistency between the purchased color and the one represented, the procedure and the precautions to follow are the same in order to import a color and a texture into the native materials of Revit (Guarini and Rossi, 2019). PBR materials should be used as much as possible. Additionally, regarding the influence of the correct simulation of artificial light on color, following the recommendations indicated in the Methods section of the text is strongly recommended. This is generally a valid prerequisite for a solid insertion of lights into the BIM software. Regarding the simulation of natural lighting, the corresponding parameters are set directly by the user and dynamically in Enscape. To efficiently represent the project, the models should be in high detail, with a plentyful number of polygons to better represent curved surfaces

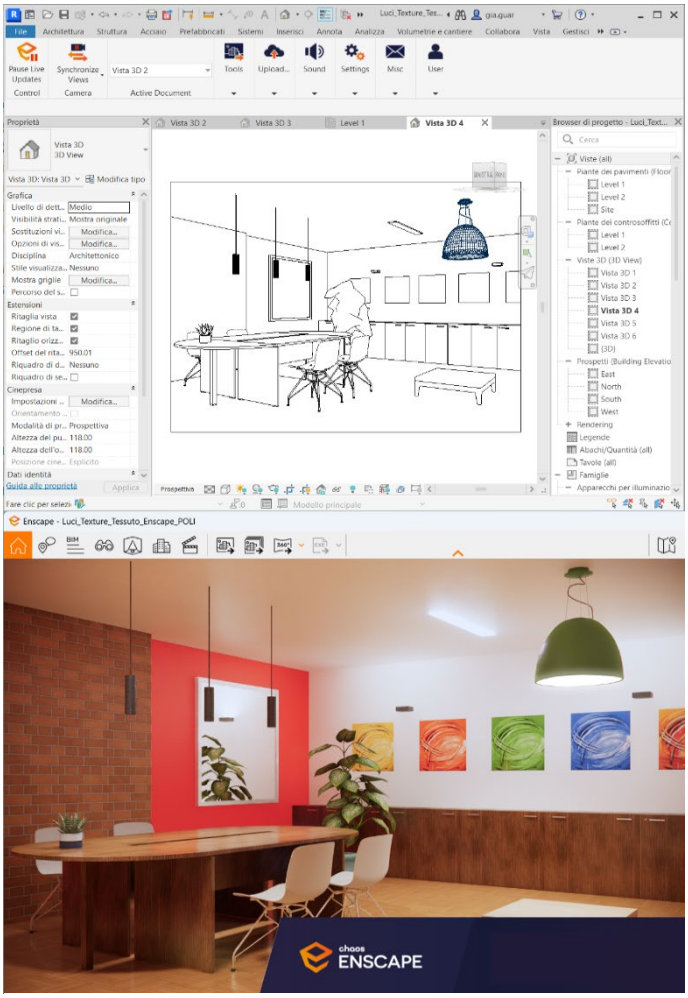

Fig. 2 – Revit model Visualized in Real-time in Enscape

and the shades of color on the various finishes. This would weigh up the BIM file. The Plugin solves this problem. The low-detailed Revit families are replaced in the rendering phase with 3D models developed within an Enscape proprietary Editor. With this expedient, the BIM file is light in Bytes, while the Real-Time representation is in high quality.

The Plugin has a custom library containing ready-to-insert templates. If the designer wants to insert models unavailable in the library, using the Enscape Editor to import different 3D file formats is possible. This solution enables overcoming the Revit mapping coordinate missing features. The BIM software has a limited set of tools for these purposes. Importing a 3D model into the Enscape Editor also imports the mesh mapping coordinates of the imported surfaces.

Regarding the color rendering in Enscape, the Plugin can use Revit materials. However, it also has tools to create dedicated materials, which replace the native materials in the Real-Time window or even directly in Revit if the designer decides to apply them permanently. These materials are configurable within the project and in the Enscape Editor for importing into objects. Materials that can be created in Enscape are PBR based. For a correct

color rendering, the texture with the sRGB color profile to be used is the one that must be inserted in the “Albedo” slot, which refers to the light reflected in a diffused way. In addition, if the designer opts to use Revit materials to view the project with Enscape without making any replacements, it is advisable to use the PBR materials directly, which have already been available in Revit since 2019.

3.3. *Revit and export in dedicated Real-Time Visualization Software*

Using vertical applications for Real-Time visualization, among which we can mention the best-known "Unity" and "Unreal,” is another possible way to view the BIM model in interactive mode. Both use PBR materials, which are, in fact, the standard for a physically correct representation of materials and their finishes. Taking up and completing what is described in the Method section, the parameters present in this type of material are several, but among the leading properties, we can mention: color (or Albedo), roughness and metalness, that is, if the material is a dielectric or metal. These three properties are present in every solution we are describing here. Each of these affects the final color perceived by the observer. Still, the one that most affects the user is the first: Albedo. If assigned as a texture, this should always be entered with the sRGB color space.

Each software may present these parameters differently. For example, the Albedo is named "Basic Color" in Unreal. The interface of the Unreal Material Editor shows an Editor of nodes connected within a tree structure. The various parameters are the nodes connected to the primary node representing the material on which the designer works. In the node relating to the texture to insert "Texture Sample" and connect to the "Basic color," it is possible to choose the texture to use. In the texture properties, it is possible to specify whether the inserted texture should be in the sRGB color space (Fig. 3). As previously explained, this option must always be activated.

Procedures for importing the BIM model into Unreal are available in several ways. The most straightforward and immediate is using the *.fbx format (Joy, R. and Raja, 2022). However, this is a geometric format, and its use can lead to the loss of information of the project's BIM database. This problem can be solved using a third-party plugin, such as "Datamisth" (*Datasmith Exporter Plugins*, 2004), which allows associating information not present after exporting the *.fbx file. Using this Plugin, that should be installed on Revit and enabled on Unreal, it is possible to keep track of the material replacements made during the import of the *.fbx file, and re-apply them automatically if needed to re-import the model following some modification or variant of the project. This procedure is longer and more complex than the Enscape Plugin alone, as it requires several steps and attention from the designer.

The visual render and Level of Detail of the BIM model exported should be more sophisticated than the native Revit model, where the furniture's level of detail and development cannot have surface models composed of excessive polygons. So even in Unreal, as with Enscape, replacing the Revit families with more complex geometries can enhance the visual result.

Like Unreal, Unity is another Vertical program dedicated to Real-Time Rendering. Also in this application the materials used are PBR and there is the possibility to specify whether the texture should be used with the sRGB color profile (Fig. 3). If the texture is assigned to the Albedo color, the sRGB profile must always be specified. A study (Wong *et al.*, 2019) has shown that in this case, a feasible calculation method of lighting illumination in Unity is lacking, since both the unit of light intensity in Unity and its

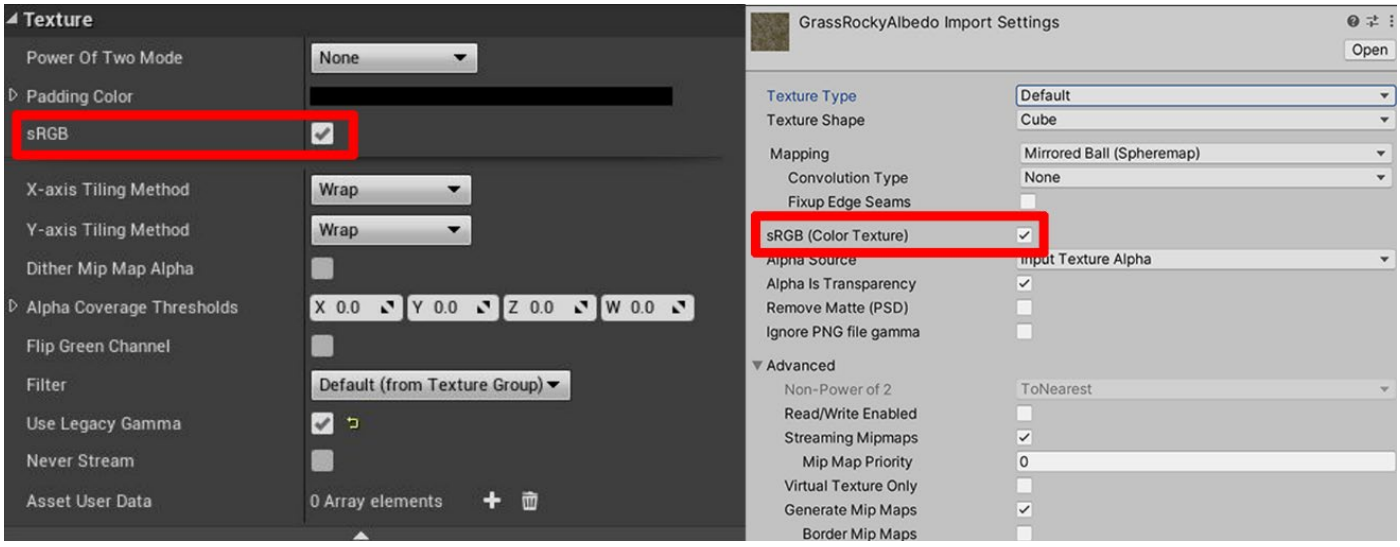

Fig. 3 – sRGB Option in the Texture Properties of Unreal Engine and of Unity

conversion relation with the real-world unit of luminous flux are not available in the official documentation. So, in this last approach the real lighting effect can't be reproduced.

3.4. *Revit and Unity Reflect*

The use of vertical software in Real-Time representation guarantees, on the one hand, high-level performance and a great variety of tools for the designer. As a downside, the export process can be counterintuitive and increase the number of skills the designer must acquire to obtain the desired result, discouraging this approach. Because of that, some Real-time software houses have decided to develop specific versions of their applications dedicated to the BIM world that interface directly with Revit and facilitate the utilization by BIM specialists. An example of dedicated application is "Unity Reflect," which is derived from the Unity application. The application installs a new tab in the Revit ribbon, from which the designer can easily export the BIM model to the Unity Reflect viewer. Any changes made in the Revit model, both in the geometry and the material, are automatically updated in the Unity Reflect model. The model imported into the viewer is completed with all BIM data without the need for third-party export programs. To be consistent, the materials' color properties must be correctly set in Revit. Also, in this case, it should be preferable to use PBR material in Revit since Unity Reflect does not have the tools of the central Unity program; it is simply a 3D viewer of the BIM model.

4. Conclusions

This Study describes some available solutions to visualize a BIM model through Real-Time rendering, trying to maintain consistency between the actual colors chosen for the finishes and those represented in the design visualization. It has been shown that to achieve this result, the methods used are: a) acquire the textures of the materials with standard procedures and periodically calibrated tools, having care to convert the relative color profile of the devices into the absolute sRGB color space; b) use the PBR materials, if possible, within the BIM software, to correctly simulate the light-material interaction; c) correctly simulate the possible lighting conditions.

The study results show alternative solutions, which can compensate for the lack a module dedicated to Real-Time in the BIM software. One solution is to use the "VRay for Revit" plugin, which in addition to creating traditional professional renderings, can export the scene to the "Chaos Vantage" Real-Time application of the same software house. Another solution is using rendering engines such as "Enscape" or "Lumion", which allow a live connection with the BIM software through a special plugin for Revit. It is also possible to export the BIM model to programs specifically dedicated to the Game Engine and Real-Time Visualization, such as "Unreal" and "Unity". Finally, we can mention the possibility of using specific BIM versions of previously listed vertical Real-Time software, such as "Unity Reflect".

These are just some of the possible solutions in the designer's toolset, which can vary in terms of typology and applications available. Indeed, with the evolution of current technologies in a dynamic and rapidly expanding field, we hope there will be a convergence towards a reduced number of solutions for professionals.

5. Conflict of interest declaration

The author declares that nothing has affected his objectivity or independence in producing this work. Neither the author nor his immediate family member has any financial interest in the people, topics, or companies involved in this article. Neither the author nor his immediate family member had a professional relationship with the people and companies cited in this article. Neither the author nor his immediate family member are involved in a legal dispute with the people and the companies mentioned in this article. No conflict of interest, including financial, personal or other relationship with other people and organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, this work.

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7. Short biography of the author(s)

Gianluca Guarini - MSc in Construction Engineering in 1999. Freelance 3D Artist, Teacher of AutoCad and 3DSMax in private training companies. Expert in 3D modeling and Rendering. Tutor of the Master in Lighting Design and LED Technology of Politecnico di Milano. Professor of Politecnico di Milano at the School of Design. Ph.D. Student at Politecnico di Milano at the School of Design. Fields of interest are CAD 2D Design, BIM and computer graphics applied to Design Visualization.

Maurizio Rossi - Maurizio Rossi, MSc, PhD. Full professor of Design at Politecnico di Milano where he is also the scientific manager of Lab. Luce, director of the Master program in Color Design & Technology, the Master

program in Lighting Design & Technology, and faculty member of the Design Ph.D. He is 2022-23 vice-president of the AIC International Colour Association (president-elect 2024-25).

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The development of a color chart in conceptual fashion collections: do consumers perceive what color semantics wants to convey?

Ítalo José de Medeiros Dantas[1], Camila Assis Peres Silva[2], Marcelo Curth[1]

[1] Department of Cultural Processes and Expressions, Feevale University, Novo Hamburgo, Brazil. italodantasdesign@hotmail.com; marcelocurth@feevale.br

[2] Department of Design, Federal University of Campina Grande, Campina Grande, Brazil. silva.camila.assis@gmail.com

Corresponding author: Ítalo José de Medeiros Dantas (italodantasdesign@hotmail.com)

ABSTRACT

This paper is part of a master's in design research that aims to identify whether potential fashion consumers' interpretation of the colors of clothing collections was aligned with the intention of their designers/coders. Fashion designers face the task of making conceptual and thematic choices to convey a message effectively. Within the various elements of visual language employed for this purpose, color plays a crucial role due to its symbolic significance in visual communication. Hence, this paper aims to delve into the interpretive possibilities associated with the semantic dimension of a color chart. This exploration involves assessing the extent to which the designers' intentions are realized in the visual message conveyed by the colors within a clothing collection, as perceived by potential Generation Z consumers. To achieve this, we employed the Semantic Differential (SD) and Free Word Association (FWA) methods in our research. We interviewed eight designers responsible for coding the two fashion collections under investigation and gathered responses from 108 potential Generation Z fashion consumers to gain insight into their interpretations. According to the results, the effectiveness in delivering color messages varied between medium and high. It was concluded that fashion designers employ two strategies for coding the color chart: maintaining chromatic symbologies already widespread in society and subversion of color codes. Meanwhile, potential consumers interpret colors according to their propagated sociocultural meanings.

KEYWORDS Fashion design. Semiotics. Colors. Visual communication. Information Design.

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1. Introduction

Visual elements construct information and deliver a message more effectively on products (Silveira, 2018). Therefore, visual signs that are characterized in the academic literature as elements and principles of design (Silveira, 2018). These elements will guide the observers' eyes through its development, generating the process of illumination and recognition according to their connection points (Lupton; Phillips, 2008; Pires, 2008; Sorger and Udale, 2009).

When interacting with Fashion artifacts, consumers mainly notice their colors, which are responsible for purchasing decisions (Jones, 2005; Guo et al., 2020). Quattrer (2013) explains that color perception in this context is easily hierarchical, standing out to the detriment of other elements. Pereira (2011) relates this effect to its rapid assimilation. Within fashion collections, Doris Treptow (2013) points out that colors must refer to the concept being worked on, while Farina (2006) adds that their use should not be made considering aspects of aesthetic preferences and personal tastes. With this, we understood color as a visual sign applied in the stages of a product project, enhancing possible contextual meanings (Dondis, 2003; Niemeyer, 2003).

Color symbolism is an area that deals with the meanings that colors evoke based on individuals' perceptions from psychological, cultural, and sensory perspectives. Through social conventions passed down through generations and transformed throughout history, most meanings are projected in colors (Kandinsky, 2000; Mehta; Zhu, 2009; Barros, 2011; Goethe, 2013).

Colors are one of the main communication elements in products or graphic pieces, with their dimensions linked to the most diverse symbolism, widely diffused in societies. It is known that there are correspondences between black and the senses of mourning or sadness, with red being associated with issues such as passion or sensuality or pink, with sweet and feminine symbolism. It is worth highlighting the modernity of these symbols, as from the Middle Ages, through periods such as the Renaissance, until the mid-1800s, blue was seen as a chromatic element representing femininity and purity (Silva, 2017; Jonauskaite et al., 2018).

The adequate understanding of what is intended to be communicated will vary depending on the contexts experienced, their cultural insertion, and the influences of the people and media surrounding them. Therefore, bringing geographical and cultural sections makes it possible to obtain different interpretations of the colors in the artifacts and their elements (Guimarães, 2000; Arnheim, 2011; Cardoso, 2012; Heller, 2013).

The symbolisms identified in color studies also apply to the Fashion context; however, these socially accepted meanings will not always make sense in the clothing sets produced. Designers are predisposed to develop their assertions about what a particular color represents in a composition, reflecting an idea that is sometimes arbitrary and playful, which does not directly connect with the object represented. Therefore, the color inserted in the Fashion collection will bring the narrative power of portraying new information, creating its language, and penetrating new visual codes (Pina, 2009; Treptow, 2013; Moreira, 2016).

In a fashion collection, the set of symbols projected in colors is used to model the concept that guides the theme of the work and to attract the target audience. In clothing design, we commonly work with a color palette that varies from 4 to 12 colors; these are sets of more prominent colors that will influence each other in a composition (Dondis, 2003; Jones, 2005; Treptow, 2013).

Therefore, methods of transposing the generating concept to materialize it in a color chart may not be satisfactorily applicable to all cases in Fashion Design, making it necessary to increasingly specific and innovative approaches centered on the interpretation of clothing consumers. Löbach (2001, p. 105) explains that the difficulty lies in finding an adequate set of aesthetic means to produce the intended symbolic effect, which is why Queiroz (2004) demonstrates that exploring concepts present in other sciences is done as a path promising to discover new ways of solving problems; From there, the role of semiotics in this research is elucidated.

Fashion goes beyond the pragmatic function of dressing people. These products also generate codes and laws (Lipovetsky, 2009). It is related to major global meetings for decision-making with references to fashion trends or even in a chromatic scope, prospecting the marketing colors of each season (Svendsen, 2010). Lúcia Santaella (2012) conceptualizes semiotics as the science that investigates the phenomena of the development of meaning and meaning. Charles Sanders Peirce (1998), in his studies around the year 1867, considers the sign as a relative object, just like the colors and language of fashion, thus being polysemic and moldable through time and its interpretative contexts (Lipovetsky, 2009; Holtzschue, 2011; Heller, 2013).

Using semiotics as a study method makes it possible for new possibilities to explore the production of meaning through clothing, which can consequently adhere to society and culture (Niemeyer, 2003). In this way, we start from the hypothesis that the conceptual information of clothing collections is intrinsically elaborated to its symbolic representation by the color palette, focusing only

on its emission. This reflects a semiotic process of coding a color chart. Therefore, we notice that there was no impetus on the part of fashion collection developers to identify whether there was an understanding of these color semantic visual messages regarding the aesthetic-symbolic dimension of the products when related to the interpretative extent of consumer perception.

In the same sense, Krippendorff (1989, p. 15) explains that "No one can assume that the form (the meaning objectified by the designer), and the meaning (of the user) are the same; consequently, the need for product semantics to study how they relate to each other." Based on this statement, reality is understood when discussing the experience of sharing ideas in cyberspace, such as the internet for Generation Z, where a network for sharing ideas is built. This aligns with what Cardoso (2012) states, in which groups attribute the final meanings in a sociocultural environment to products and colors.

1.1. *Color as visual information*

Visual information is one of the main factors delimiting experience when observing the relationship between human beings and the world, defining pleasures, preferences, and fears. Dondis (2003, p. 7) expresses that "seeing is a direct experience, and using visual data to transmit information represents the maximum approximation we can obtain concerning the true nature of reality." Therefore, color is responsible for carrying a great informative value, given its symbolic qualities, being one of the most profound human visual experiences (Dondis, 2003).

Among the functions of colors, they excite and awaken sensations in their observers, widely used as a marketing strategy to evoke certain impressions and guide purchases. Rathee and Rajain (2019, 210) explain that color is integral to sensory marketing tactics. It influences consumer behavior and perceptions, induces moods and emotions, and helps companies position themselves or differentiate themselves from competitors." In this sense, we observe the possibilities for fashion designers to construct visual messages. Sherin (2012) states that people's responses to colors can affect how visual information is received.

Color has a powerful relationship with sensory perception. Lima (2020, p. 40) expresses, "The visualization of colors can evoke experiences in human beings and, as a result, they are usually described with words related to emotions and sensations, such as 'vibrant' and 'relaxing.'" Therefore, the area of color psychology becomes relevant for understanding the use of colors by designers, allowing it to shape how people will relate to products (Sherin, 2012) and dealing with issues such as interpreting these messages and visuals.

Therefore, all this planning that develops around an artifact, enhanced by using chromatic elements in the design, explores an extensive visual communication endowed with creative possibilities for a visual coder (Guimarães, 2000; Arnheim, 2005; Farina, 2006). This process is closely related to the observer's cognition, exploring a visual message, or elucidating a positive emotion that will lead them to purchase the product (Nogueira, 2017).

In the fashion creative process, one of the designers interviewed in Moreira's master's work (2016, p. 110) expresses that "the collections are carriers of very colorful registers, which involve many patterns, fantasy [...]. It adds textures and scales to the color option as reinforcement to communicate and stimulate emotion." Considering the sensorial relationship that the clothing product has with people when this information is combined with color, it is observed that it influences decision-making.

According to Scully and Cobb (2012), this process is subjective. Based on the research of Tonetto and Da Costa (2011), the authors comment that the emotions products evoke are predictable and moldable. Based on this, it is argued that there is a need for an in-depth investigation into the interpretative responses of observers/consumers when they meet only the colors of a clothing collection. This will allow it to expand what is known about using colors in current fashion product designs.

The broad informative potential of color allows it to pass through different areas of the creative process, translating in a non-verbal way a speech that is intended to be transmitted within graphic pieces, industrial products, and, as a focus, clothing. Pedrosa (2007, p. 33) comments, "Information colors are visual data endowed with meaning, capable of causing the information process for the individual, which can result in the development of new knowledge." The development of clothing products is one of the first to adopt this idea, generating meaningful associations between the artifact's configured shape, color, and content.

1.2. *Content and elements of visual language in clothing: interpretation as information for design*

In the creation process, the shape of clothing products is a mediator between the visual message intended by the fashion designer and the perception and interpretation of the final receiver/consumer (Barnard, 2003; Treptow, 2013). Therefore, developing the formal configuration of these products is an activity that is carefully worked on in the design stages. Silveira (2018) explains that understanding visual elements, their organization, composition, and interrelationships, as well as the

cultural signs present in the artifacts, is at the heart of successful design practices. This relationship is in line with the process of visual literacy, addressed by Dondis (2003, p. 227), where "it implies understanding, and means of seeing and sharing meaning at a certain level of universality."

Therefore, the artifice of human decoding and visual reading is the primary way a product is understood, so symbolic and aesthetic associations can be made with the observer's cultural background. Dondis (2007) expresses that visual decisions dominate much of what we examine and identify. This process goes against the fact that we live in a society where a product's visual and aesthetic aspects make the first contact with the target audience and, therefore, guarantee the generation of emotional values (Baxter, 2000; Dondis, 2003).

When an artifact is visually read in everyday life, it has a series of communicative constructs, whether psychological, social, or cultural, that relate to how it was configured and connect to the observer's cognition. Dondis (2003, p. 131) comments that "content and form are the basic, irreducible components," where "content is never dissociated from form." Therefore, it is understood that the products that designers plan are equipped to channel a visual message. That is, it is part of what is called visual communication.

According to Pereira (2016, p. 29), "The process of observing information, decoding it, and being able to issue a response is called Visual Communication," or visual language. To be categorized as communication or language, it follows a series of rules called visual grammar. Silveira (2018, p. 33) explains that "a basic "vocabulary" of visual elements (points, lines, shapes, textures, colors) can be organized and combined in different ways, composing a kind of "visual grammar."

In more depth, these elements, which configure visual language, are brought up in the discussions by Dondis (2003, p. 22), who defines it as necessary to "recognize that everything we see and create is made up of the basic visual elements that represent the structural visual force, of enormous importance for meaning." For these visual messages, also called information, to be transmitted to their observers in their structures, visual planning takes place through these elements, called visual support, which influence each other in a composition (Munari, 1997).

Therefore, even if, within the process of visual analysis, these elements are deprived, they must be considered from the point of view of a correlation, as "the perceptions of meaning provoked by the artifact will only be effective if the formal/visual support is organized," that is, now of visual perception, the object will be read (Sanches, 2016, p. 58).

Although this research focuses on color in transposing the visual message, it is essential to identify its intersections with the other elements because, as explained previously, the construction of the composition helps deliver the visual message. The factors influence each other simultaneously in the visual composition of an artifact (Dondis, 2003; Sherin, 2012).

Concerning the sign in the interpretant dimension, these analogies will indicate certain aspects of how the target audience/user of the product will receive and decode specific visual messages conveyed through the products' technical, aesthetic, and symbolic constructs. Therefore, Crilly et al. (2008, p. 438) express, "Although the interpretation of any artifact cannot be fully predicted, in any population, some interpretations are more likely or prevalent than others." By comparing and correlating with the designers' intention, it is possible to obtain a new picture of how a given product is socially and culturally perceived within a context analyzed compared to its original intentionality. This makes it possible to generate discussions in the communication process through products.

Research has been investigating aspects related to interpretative responses in the emotional, semantic, and affective aspects of consumers in interaction with brands, labels, packaging, and other types of products, especially those in the food sector; in this universe, all research indicates the validity of obtaining this information for the design process (Celhay; Remaud, 2017). Crilly et al. (2008, p. 439) conclude that "designers must try to influence the consumer's interpretation actively, and anticipating the factors that may lead to problematic interpretations is an important part of this process." Although this information is also relevant to fashion design (Barnard, 2003), among the studies found, it was not possible to identify any that transpose the concept of identifying the relationship between intention and interpretation for fashion consumers.

In the scope of colors, Csillag (2013a; 2013b; 2017) divides the perception of chromatic elements into three dimensions, which he calls SENS (sensation), ORG (organization), and INT (interpretation). They co-occur in the human brain but can be removed for didactic purposes. In this way, the INT dimension refers precisely to the interpretation, the response, which is inferred from contact with the product, where emotional, cultural, and personality values act on one's perception of a specific color in context. Csillag (2013a, p. 42) discusses this dimension: "This aspect of perception provides personal variations and interpretations of the images that each person creates based on their repertoire." When this model is applied to product analysis, this dimension deals

with the relationships between iconic, indexical, and symbolic elements that configure the visual language of the artifact and emerge in aesthetic-symbolic interpretations primarily based on a cultural nature and subjective preferences (Csillag, 2013b; 2017).

1.3. *Characteristics of Generation Z*

Age groups typically conduct the definitions surrounding generation delimitation, a chronological order that groups everyone into their corresponding generation. However, there are deeper characteristics that mark the existence of each generation and that go beyond a simple age categorization. Oliveira (2016, p. 15) explains that "it has been more common to consider the generational classification taking into account the events collective social and cultural aspects, especially the behavioral aspects that are easiest to identify." Therefore, each generation is analyzed according to the social, cultural, and technological events surrounding them.

This information is essential and is mainly used in Marketing and product development, so an artifact, service, or advertising strategy can be targeted at a specific market niche based on their age, behavior, and preferences. According to Cruz and Lima (2020, p. 72), "The time in which people grow up can define how they interact with other individuals". Therefore, people of the same age "have common memories of cultural icons, relevant facts in history." In short, when looking at each of these generations, they are people with a similar repertoire relative to their age and who consequently interpret and perceive the world around them in different ways when compared to the generations.

Name	Periods of birth	The centre of generation	Features	Main anxiety
Belle Époque	Before 1946	75 years	Idealists Dreamers	Discipline
Baby Boomers	1946 – 1964	60 years	Structured Builders	Revolution
Generation X	1965 – 1980	45 years	Skeptics Tolerant	Facilities
Generation Y	1981 – 1994	22 years	Unstructured Contesters	Innovations
Generation Z	1995 – 2010	10 years	Online Relational	Balance?

Fig. 1. Synthesis of the generational classification. Adapted by the authors according to Ceretta and Froemming (2011), Oliveira (2016), Mindminners (2018), Cruz and Lima (2020), and Ferrari and Alvares (2020)

Although people who work with this information intuitively know how to define generations, there are a series of inconsistencies in the academic literature regarding the unification of how they could be divided chronologically. Based on this, a summary was prepared based on studies by Ceretta and Froemming (2011), Oliveira (2016), Mindminners (2018), Cruz and Lima (2020), and Ferrari and Alvares (2020), as they consider the scenario Brazilian in its demarcations (Figure 1).

Generation Z (1995-2010), in the generational context, presents a powerful characteristic for contemporary times that differentiates it from all others: its period of birth encompasses the height of the spread of globalization and the internet, consequently having a solid relationship with technological artifacts, with a worldview based on them. According to Ceretta and Froemming (2011, p. 19), "People from Generation Z never conceived of a world without computers, chats, and cellphones [...]. Since birth, his way of thinking has been influenced by the complex and fast-paced world that technology has engendered." Thus, it is observed that for this generation, the environment, relationships, people, and artifacts are volatile, inconstant, and reconfigurable and, in this sense, Generation Z has behavior that differs from the others (Schlossberg, 2016; Ferrari; Alvares, 2020).

2. Objectives

This research's main objective is to investigate the possible interpretations of the color messages in two

conceptual clothing collections from the perspective of Generation Z and whether these, in turn, are understood effectively compared to the designers' intentions.

3. Methodology

This research is based on applied research, aiming to be exploratory-descriptive. The central procedure that guided the development of this work took place through analysis, survey, and interview, relying on a quantitative-qualitative method approach (Gil, 2008; Fowler, 2014).

3.1. *Survey process*

We applied two central data collection strategies in developing this research: (i) interviews with designers and (ii) virtual surveys with potential clothing consumers. Nevertheless, we use two research techniques to construct both research instruments: (i) semantic differential (SD) and (ii) free word association (FWA).

Having initially been developed by Osgood, Suci, and Tannenbaum (1957), the SD tool aims to serve as a possible method of quantifying the possible connotations of a word or concept. According to the consumer's view, the tool can delimit the subjective semantics of artifacts (Holdschip, 2015).

More specifically, the SD method comprises the presentation of equidistant/opposite pairs of words divided into categories (also called descriptors, e.g., good-bad (evaluation), hot-cold (activation), and strong-weak (power)) in a questionnaire or experiment followed by request for classification from the perspective of the visual-interactional relationship of the respondents concerning the visual stimulus being presented (Osgood; Suci; Tannenbaum, 1957). These pairs of words are arranged in a table with diametrically mirrored or sequential numbering, using a 7-point Likert scale for classification, organized as (-3; -2; -1; 0; +1; +2; +3) (Osgood; Suci; Tannenbaum, 1957; Holdschip, 2015).

This method was adapted in this research, where categories were not considered but independent terms related to the semantic dimension of the collection. Furthermore, a 5-point Likert scale was used for better guidance, presenting an ascending order (1, 2, 3, 4, 5).

Another method this work applies is the Free Word Association. As Alves et al. (2021, p. 3) explain, word association "is one of the most commonly used methods for evaluating conceptual structures and studying beliefs or attitudes in consumer psychology and sociology, used to understand attitudes and predict the people's behavior." One of the validities of applying the method is precisely to access more spontaneous responses from its volunteers.

In short, free word association involves presenting a visual stimulus and telling respondents to express all the associations (images, sensations, emotions, ideas) that come to mind when they observe it. For data collection, we applied the strategy presented in Figure 2.

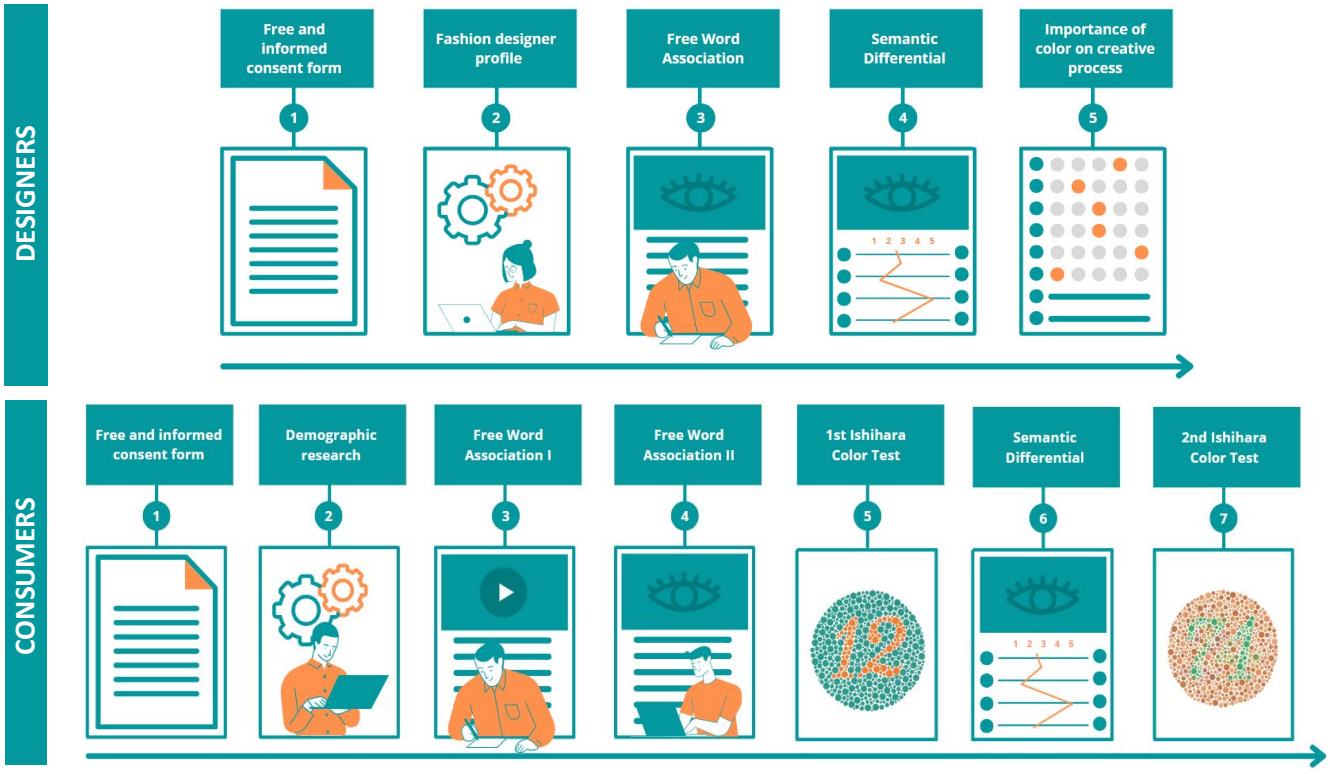

Fig. 2. Structured data collection sequence with designers and consumer

The interview and questionnaire were created using the Google Forms platform, directed individually to each designer interviewed, and disseminated on social networks seeking to reach potential Generation Z consumers. All volunteers agreed to a Free and Informed Consent Form, and Generation Z responded to 4 panels of the Ishihara test that aimed to identify deficiencies in color visualization so that the answer was eliminated and did not influence the database.

3.2. *Collections used as objects of study and preliminary semiotic analysis*

Regarding the object of study, the focus was on two conceptual collections that won the New Designers Competition of the authorial fashion event "Dragão Fashion Brasil" in the years 2017 and 2019, called "Shibipo" and "Ilha de Marajó," respectively. This competition is configured as a competition that mixes the conceptual proposal with specific commercial characteristics, such as the requirement to produce some pieces that can be reproduced on an industrial scale. This competition defines a general conceptual theme each year: Fashion schools in Brazil must send proposals to be shown in person if selected.

The first collection studied won first place in the New Competition 2017 called "Shipibo: Digital Artesania." The winning team was made up of five students (Elyenai Fernandes, Meguy Araújo, Bruna Santos, Maria Pessoa, and Giulia Lins), guided by two professors (Gabriela Maroja and Victoria Fernandez), and came institutionally from the João Pessoa University Center (Unipê - Brasil).

Concerning 2017, the base theme was *"Latin Soul of Peru,"* designers from Brazilian Fashion schools should work on their creations within this perspective (Table 1).

The second clothing collection that served as the object of study for this research was the one that held the title of first place in the 2019 New Designers Competition called "Ilha de Marajó." The collection, unlike the previous ones, was structurally presented on the Iracema beach embankment, as it comprised a unique and commemorative edition of the event, also located in the city of Fortaleza, in the state of Ceará (Basil), between the 15th and May 18, 2019. The collection was developed by a team of 4 students (Larissa Yumi, Lucas Nogueira, Raissa Marquetto, and Zuri Kennedy) from the Federal Technological University of Paraná (Table 1).

To analyze the collection's color choices and compare them with the designers' intentions, images of the clothing collection available on the DFHouse website, the organizer of the New Designers Contest, were used. In this case, the researchers did not have access to the colors of the fabrics or physical materials in the collection. Therefore, they did not have contact with the Pantone codes used initially in the color chart. Accordingly, to conduct a comparative color study between the intention and final product, the image was taken to the graphic software Adobe Color, where it was possible to extract, using the eyedropper tool, the possible colors used in the collection (Table 1).

YR	WINNING FASHION SCHOOL	TEAM	BASE THEME
2017	*João Pessoa University Center (Unipê)*	*Elyenai Fernandes, Meguy Araújo, Bruna Santos, Maria Pessoa, and Giulia Lins*	*Latin Soul of Peru*
FASHION COLLECTION/COLOR CHART			

YR	WINNING FASHION SCHOOL	TEAM	BASE THEME
2019	*Federal Technological University of Paraná (UTFPR)*	*Larissa Yumi, Lucas Nogueira, Raissa Marquetto, and Zuri Kennedy*	*Beach*

FASHION COLLECTION/COLOR CHART

Tab. 1. Fashion collections used in empirical research.

To define the pairs of descriptors that would be applied in the semantic differential, a preliminary semiotic analysis was conducted using a model presented in the research by Dantas e Silva (2020), which is constructed according to the concepts of material, syntactic, semantic and pragmatics from the semiotics of design, found in the work of Niemeyer (2003). This model focused on observing the construction of visual color messages based on possible relationships between the generating concept used in creating the collection and how this was reflected in the production of meanings in its color palette. Then, after the semiotic analysis was completed, this information was gathered into a synthetic table (Table 2).

YR	Fashion collections	Main message (the central theme of the collection)	Product characteristics, feelings, and emotions transmitted by the collection
2017	**Shipibo: Artesanal Digital** *(Shipibo: Digital Artesania)*	Peru, tribe, llamas, Panchamama (mother nature), regional, tea from the ayahuasca vine, crafts	Sky, deep seas, nature, cold, lightness, comfort, melancholy, kindness, frivolity, bitterness, supernatural, infinite, purity, resurrection
2019	**Ilha de Marajó** *(Marajo Island)*	Marajoara Ceramics, Beach, Ilha de Marajó, Carimbó, dance	Craftsmanship, dignity, modesty, endurance, earth, forest, mud, sand, joy, sunset, and strength

Tab. 2. Synthesis of the visual messages of the colors of the fashion collections studied.

The associations identified in Table 2 were used within the interviews and questionnaires, applying them as descriptors and their possible opposite pairs in the semantic differential method.

To mitigate the influence of other elements of visual language on the responses to this research, during the survey, we briefly highlighted the interest only in color. First, we present the image of the collection with squares at the bottom that highlight the color of the piece, as can be seen in Table 1. Second, the question asked to the volunteers was "*the collection below was created from x main colors, arranged below the images of the models. We want to know your opinion about these colors. What do you think they convey?*", therefore, we highlight the interest in color semantics.

3.3. *Participants*

Regarding the interview with the designers, the collections were developed by two different teams, containing 5 (2017 collection) and 4 (2019 collection) people, respectively, who in turn are not all part of Generation Z. Three of them were interviewed for the first collection, and all four for the second. We focused the interviews on those who actively participated in creating the color palette and the creative process of the fashion collection. We use intentional non-probabilistic sampling.

The virtual questionnaires were active on social media for six consecutive days, specifically between October 12th and 17th, 2021. We collected 108 responses from people with no expertise in the fashion or design area aged

between 18 and 26: 56 for Questionnaire A (Shipibo – 2017 fashion collection) and 52 for Questionnaire B (Ilha de Marajó – 2019 fashion collection). All participants were geographically from Brazil, especially from the northeast and southeast regions. No individual was identified as disabled in visualizing colors or who was familiar with the clothing collections studied, so there was no need to exclude responses due to non-compliance with the pre-established inclusion criteria.

3.4. *Data analysis and processing*

For the semantic differential, the medians of the results were considered, both for the designers' intention and for the interpretation of Generation Z respondents. This decision is based on the explanation by Reis and Reis (2002, p. 33), where "As a measure of central tendency, the median is even more intuitive than the mean, as it represents, in fact, the center (middle) of the set of ordered values." Therefore, according to the previously conducted normality test on the collected data, none of the collections presented a normal distribution. Thus, the averages do not reflect a reliable result, and medians should be used in this case (Field, 2018).

For free word association, all terms expressed by each group of respondents were considered from a word cloud. However, to obtain more robustness in the data, it was necessary to mine the responses received, translating as much as possible all the words expressed into common synonyms, which will be called the stage for developing synonym categories.

Considering the words collected, the leading researcher created synonym categories to obtain results robustness. Then, this document containing the categories was sent to three Generation Z evaluators for approval or reconstruction according to their recommendations. Thus, the categories of synonyms will be formulated and allow analyzing the words from a set.

4. Results: do consumers perceive what color semantics want to convey in fashion collections?

This topic will be organized based on the presentation and discussion of results from a comparative analysis of intention (designers) and interpretation (consumers).

4.1. *Comparative Analysis - 2017 Fashion Collection (Shipibo)*

Comparing the results mapped for the interview with the designers with the questionnaire with potential Generation Z consumers, for the semantic differential (SD), an intention centered on neutrality between traditional and modern (3.00 Md) was identified. ; neutrality between cold and hot (3.00 Md); global (5.00 Md); supernatural (2.00 Md); melancholic (2.00 Md); purity (2.00 Md); sweetness (2.00 Md); natural (1.00 Md); infinity (2.00 Md); neutrality between fauna and flora (3.50 Md); and, lightness (1.00 Md).

In turn, these intentions were interpreted by potential Generation Z consumers as neutrality between traditionalism and modernity (3.00 Md); neutrality between cold and hot (3.00 Md); globality (4.00 Md); neutrality between supernatural and physical (3.00 Md); melancholic (2.00 Md); purity (2.00 Md); sweetness (2.00 Md); natural (1.50 Md); neutrality between infinite and finite (3.00 Md); neutrality between fauna and flora (3.00 Md); and, lightness (3.50 Md) (Figure 3).

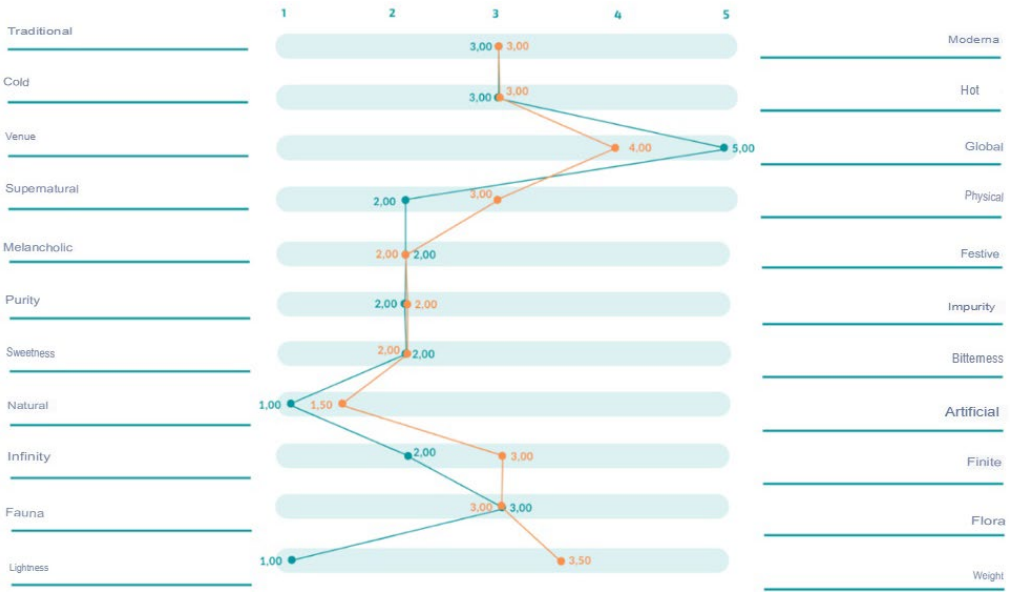

Fig. 3. Comparison between designers' intention (blue) and potential consumers' interpretation (orange) for the visual message of the 2017 Fashion Collection – Shipibo colors.

Considering the responses obtained for the SD, high effectiveness in interpreting color messages from the 2017 fashion collection (Shipibo) was identified, with most of the convergence, even at different levels of intention and interpretation. Six were detected among the 11 pairs of descriptors, where the medians of intention and interpretation met at an exact point (traditional-modern; cold-hot; melancholic; purity; sweetness; and fauna-flora). Another three pairs of descriptors showed a positive correlation between intention and interpretation, differing by only 0.50 or 1.00 in the median, but the answers were in the same direction in the SD (global; natural).

On the other hand, it was observed that the other 3 of the 11 pairs of semantic descriptors studied presented divergences in the SD, varying from 1.00 (supernatural-physical; infinite-fine) to 2.50 (lightness-heaviness) of differences in reported medians (Figure 4).

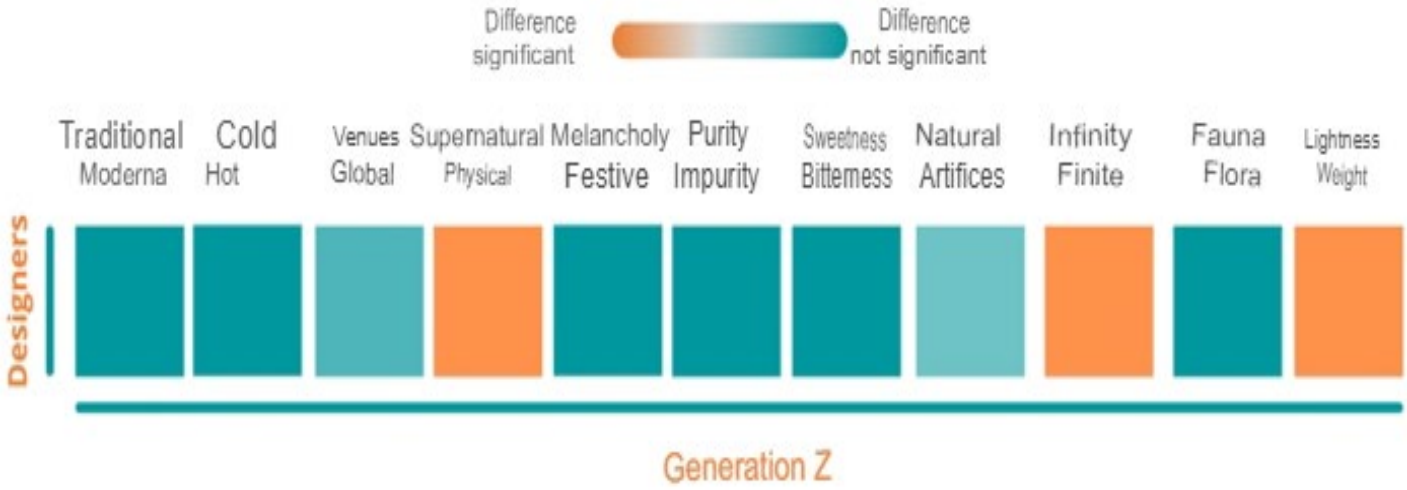

Fig. 4. Comparison between intention and interpretation – 2017 Fashion Collection – Shipibo.

Next, the associations potentially developed by potential consumers for the SD result will be briefly discussed. In the case of the Shipibo collection, it was observed that around half of the pairs of descriptors were initially interpreted as neutral (3.00 Md). For the first pair of descriptors, where it was interpreted as "neutrality between traditional and modern," and for the result that tended towards "natural," one can speculate an association with the saturation of colors present in clothing products, as well as the colors found in nature that are present in the configuration of the card. According to Clementino's master's research (2017, p. 92) for packaging design, in color, "low saturation quality [is] widely cited as indicative of sustainability," being a phenomenon also observed in clothing, such as seen in the work of Dantas et al. (2021, p. 140), where the authors conclude that "saturation, when too much, can be related to artificiality, as it is obtained using a greater amount of pigment."

Potential consumers may have developed a semantic association of clothing products from the Shipibo fashion collection, with low saturation and colors present in nature (such as blue, green, and brownish white/sand), with the natural production of pigments and, therefore, with traditional and natural techniques for materializing the color palette. Although this observation focused on the traditional/natural speculated, it was impossible to identify why semantic neutrality concentrated on the modern. There may have been an influence from the unusual shapes of the clothes, that is, the subversion of dress codes, an effect commonly seen in conceptual clothing products, considering that color and shape are interpreted simultaneously, inseparable in the observers' decoding process.

In constructing the pieces, one can find the proportional presence of colors with warm characteristics (pink and brownish white/sand), cold ones (pure white, blue, and gray), and different low saturation levels that also suggest a cold aspect. (Pastoureau, 1997; Farina, 2006; Aballí, 2010; Heller, 2013; Goethe, 2013). Based on this thought, it is observed that the association constructed for "neutrality between hot and cold" may have been derived from this set of motivations.

For the "neutrality between supernatural and physical," the supernatural may have been evoked from blue (Pedrosa, 2004) or pink with low saturation, eliciting mysticism and unrealism (Heller, 2013); on the other hand, blue also contributes to neutrality, inserting this context into the interpretation by evoking the physical, considering the low light in which it is presented in the Shipibo collection, capable of influencing the perception of a specific visual weight when approaching a sub-black color. , given its low clarity, as discussed by Pastoureau

(1994; 2011). This context is confirmed when potential consumers also interpret "weight" as one of the descriptors of this collection.

When it comes to the meaning of "melancholy" interpreted by the volunteers, it could be one of the possibilities evoked by blue, as expressed by the reference authors (Pastoureau, 1997; 2011; Aballí, 2010), as well as the sensitivity and sentimentality of the pink (Heller, 2013). Regarding "purity," this may have been mainly influenced by white (Pedrosa, 2004; Farina, 2006; Aballí, 2010; Heller, 2013), a socially familiar context for this color, but this meaning is also associated with blue, following the pointed by Pedrosa (2004) and Aballí (2010).

Although bitterness was a meaning highlighted in the semiotic analysis for the Shipibo collection, potential consumers associated the colors of this collection more with "sweetness." This context is mainly related to the meanings evoked by pink; as discussed by Heller (2013, p. 405), pink is sweet from thread to wick, the color of confectionery. No color matches desserts better. It is the color of delight, of rejoicing. Sweet and smooth, this is the flavor you expect from a rose."

Regarding the following two pairs of semantic descriptors, both evoked neutrality: "infinite-finite" and "fauna-flora." Regarding the first pair, it was impossible to identify a possible semantic relationship between the colors for the "finite" descriptor. However, authors such as Pastoureau (1994), Pedrosa (2004), Farina (2006), and Heller (2013) indicate an association between blue and the meaning of "infinity," interpreted by potential Generation Z consumers, as well as the contexts of distant and distant. For "fauna-flora," considering the plurality of colors found in the Shipibo collection chart, the interpreted meanings can be focused on the individual associations of colors with some elements of nature, ranging from animals (such as white/sand from the llamas observed as potential meaning in the semiotic analysis) to the rivers (blue), the flowers (pink) and the trees (green).

Comparing the results for Free Word Association (FWA), a total of 1104 words were cited (potential consumers + designers), of which 727 were different terms (65.85%). The designers significantly expressed seven words, "deconstruction, structure, nature, depth, sobriety, earth, and transparency." On the other hand, potential consumers mentioned "nature, comforbt, earth, lightness, calm, love, harmony, and peace" more quantitatively. The words "nature" and "earth" were the only ones that presented correspondences between intention and interpretation for the colors of the Shipibo collection.

Afterward, this set of collected words was transformed into categories of synonyms. Therefore, the 1104 terms were categorized into 72 groups. The designers cited 87 words comprising 37 categories of synonyms. On the other hand, potential Gen Z consumers mentioned 1017 words, containing all 72 categories.

Considering the results, the groups of synonyms most mentioned for the designers' intention were "nature," "transformation," "tranquil," "novelty," "intensity', "harmony," and "delicacy," respectively, in terms of frequency, with a greater focus on the first category. On the other hand, among potential consumers, the most mentioned categories were "nature," "tranquil," "affection," "delicacy" and "simple." The results can be visually compared in Figure 5.

"Nature" was the most significant category both in terms of designers' intentions and potential consumers' interpretation, indicating that there was, in fact, a compelling interpretation of this specific meaning. It is worth noticing how the designers made chromatic choices that deviate from the stereotypical Brazilian nature, for example, green and brown, moving towards a meaning-oriented construction that uses less saturated colors to refer to the colder landscapes of Peru, with low light and which, although they are found in nature, are only more interpreted in this Brazilian cultural context when the idea of a beach is seen, such as the yellowish-white of the sand, the blue of the sea and the pink of the corals. Although this scenario was observed, potential consumers could interpret the planned meanings effectively.

In addition to this, some correspondence was also identified for the "delicacy" category, possibly having been influenced by the already widespread meaning of pink used by designers, demonstrating that exploring an approximation with the pre-existing symbolic language of each of the colors can make the process of decoding intended visual messages easier.

Therefore, considering the results presented so far through the questionnaires and interviews conducted, it can be concluded that there was high effectiveness in the visual interpretation of colors for the collection Shipibo. This conclusion can be drawn from the observation that 8 of the 11 pairs of semantic descriptors investigated showed a positive correlation between intention and interpretation. As for FWA, it was revealed that the most widely significant category among the designers' intentions, the one considered most relevant to the generative concept worked among the interviewees, was also effectively decoded by potential Generation Z consumers.

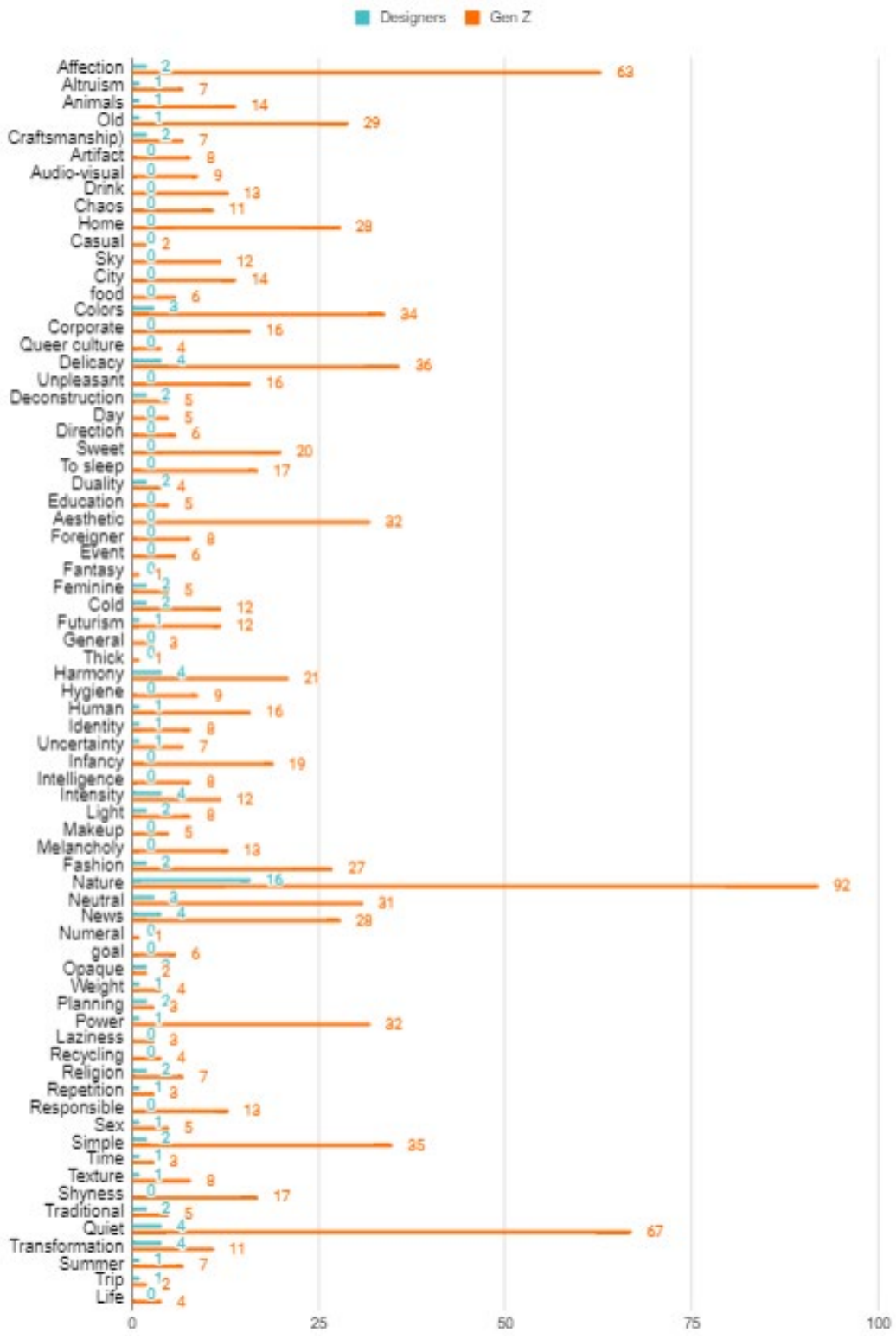

Fig. 5. Free word association intention and interpretation results for the 2017 fashion collection – Shipibo.

4.2. *Comparative Analysis – 2019 Fashion Collection (Ilha de Marajó)*

Weaving a comparative analysis between intention and interpretation for the 2019 fashion collection (Ilha de Marajó), initially dealing with SD, it was observed that the designers intended with the colors the visual messages of neutrality between traditional and modern (3, 00 MD); hot (4.50 Md); localism (1.00 Md); perseverance (2.00 Md); strength (1.00 Md); neutrality between dawn and dusk (3.00 Md); joy (5.00 Md); natural (1.00 Md); beach (2.50 Md); neutrality between modesty and vanity (3.00 Md); and, artisanal (1.00 Md).

Meanwhile, potential Gen Z consumers interpret these visual color messages as neutrality between traditional

and modern (3.00 Md); hot (4.00 Md); localism (2.00 Md); perseverance (2.00 Md); strength (2.00 Md); dawn (2.00 Md); neutrality between sadness and joy (3.00 Md); natural (1.00 Md); neutrality between beach and urban (3.00 Md); neutrality between modesty and vanity (3.00 Md); and, artisanal (1.00 Md). These results can be visually compared by observing Figure 6.

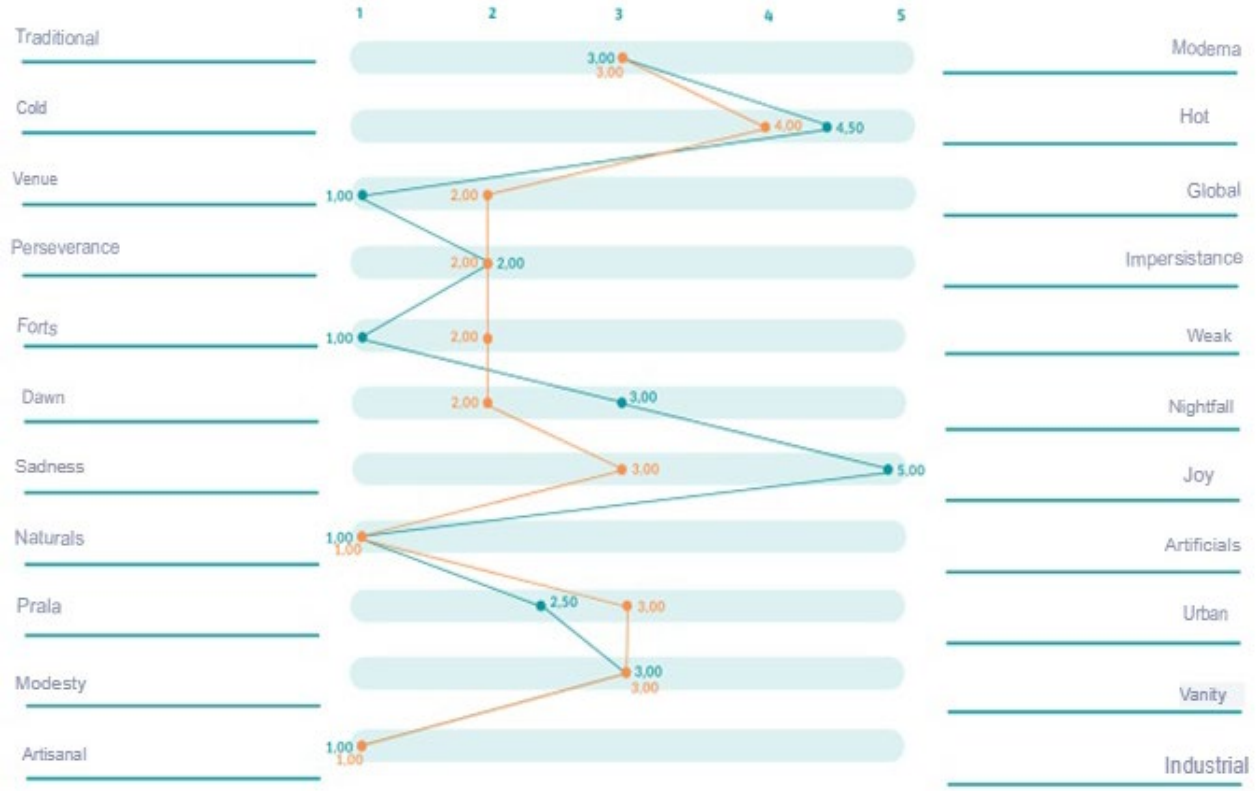

Fig. 6. Comparison between designers' intention (blue) and potential consumers' interpretation (orange) for the visual message of the colors of the 2019 Fashion Collection – Ilha de Marajó.

It was possible to observe a high correlation between intention and interpretation of visual color messages in the Ilha de Marajó fashion collection context. We identified five among the 11 pairs of descriptors studied, where the results of the median responses from both groups met at an exact point (traditional-modern; perseverance; natural; modesty-vanity; and artisanal). In addition to exact semantic matches, three other pairs of descriptors showed relative proximity in their medians (hot; local; and strong). In contrast to this dominance, three pairs of descriptors were not interpreted as intended (dawn-dusk; sadness-joy; and beach-urban) (Figure 7).

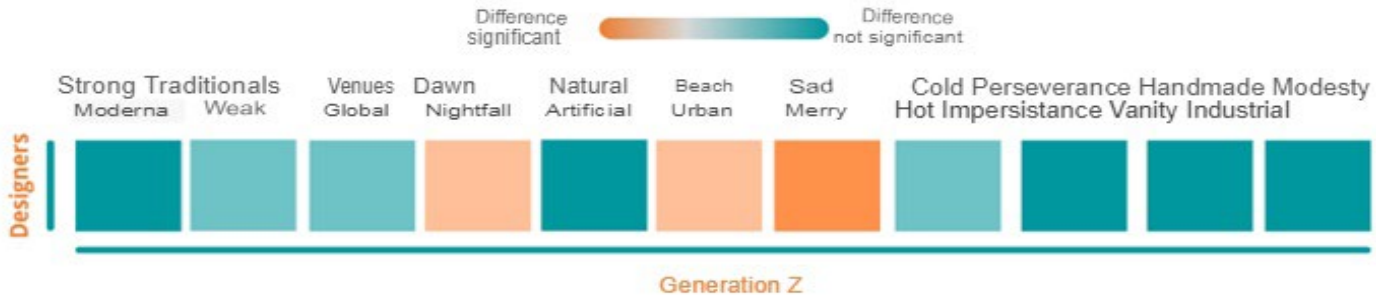

Fig. 7. Comparison between intention and interpretation – 2019 Fashion Collection – Ilha de Marajó.

Therefore, it can be concluded that, even at different levels, 8 of the 11 pairs of descriptors effectively interpreted visual color messages from the perspective of Generation Z for the Ilha de Marajó collection. Thus, a satisfactorily positive result.

In the 2019 fashion collection context, Ilha de Marajó was configured as the research object that presented the least neutral semantic association (3.00 Md). Concerning the first descriptor, interpreted as "neutrality between traditional and modern," one can explore, again, the dispute between color

and shape; for the meanings of "traditional," "local," "natural," and "artisan" interpreted by Generation Z respondents, there is a possible exploration of the different levels of saturation and lightness of brown used in the collection which, according to Heller (2013), it is the color of rustic materials, such as wood, leather and cotton.

Therefore, one of the possible associations is the interpretation of brown as a color that connotes naturalness, localism, undyed fabrics, and artisanal products. On the other hand, the meaning of "modern" is also perceived in the interpretation of potential consumers; this may have been derived from applying the colors in clothing products with unusual shapes for the repertoire of current society, consequently making them modern. Another possibility of association is the observation of dark brown present in low quantities in the collection's pieces, which can be read as black and, according to Pastoureau (1997; 2011), refers to the context of modernity.

The meanings of "warm" and "dawn" may have been related to the set of colors seen as warm by the literature in the area (Pastoureau, 1997; Pedrosa, 2004; Farina, 2006; Aballí, 2010; Pastoureau, 2011; Heller, 2013), for example red, yellow, and orange, visually, and sensorial correlated with brown (Pastoureau, 1997; 2011). Furthermore, white itself can also confer an association with the context of dawn, given its senses of awakening, clarity, daytime, active, and visual expansion (Farina, 2006; Aballí, 2010; Goethe, 2013; Heller, 2013).

When it comes to the meanings of "perseverance" and "strong," these may have been associated with the context of humility, penance, and resistance, symbolically suggested by brown, according to Pedrosa (2004) and Farina (2006). There may also have been specific associations evoked from the color white, considering the senses of hope, optimism, pity, and redemption, as discussed by Pedrosa (2004), Farina (2006), and Aballí (2010).

Regarding the interpretation of "neutrality between modesty and vanity," it was not possible to establish semantic connections between the meanings of the colors seen in the literature review and the descriptor "vanity" for the color palette of the Ilha de Marajó collection, considering since this context is more related to the different levels of clarity and saturation of pink and violet colors (Heller, 2013). On the other hand, for the meaning of "modesty," Pedrosa (2004) associates brown with humility, while Farina (2006) and Heller (2013) express that white is related, in fact, to the meaning of modesty.

Regarding the interpretation of "neutrality between sadness and joy," this result may derive from the different brightness levels in the collection's color palette. It is expected to observe colors with low clarity, such as black and dark blue, relating to sadness and melancholy (Pedrosa, 2004; Heller, 2013), while colors with high transparency, such as yellow and orange, relating to joy (Pastoureau, 1997; Farina, 2006; Aballí, 2010). Therefore, the contrast between these different levels of lightness in the color palette of the Ilha de Marajó collection may have evoked a feeling of neutrality for these two descriptors.

Finally, according to previously conducted semiotic analysis, it was observed that beach was one of the most substantial meanings for the Ilha de Marajó collection, considering it was the basis for codifying its generating concept. However, potential Generation Z consumers interpreted this set of colors as "neutrality between beach and urban."; It was not possible to establish a semantic relationship between the colors of the collection and the meaning of "urban," possibly being derived from dark brown, which refers to black (Pastoureaou, 2011), or being mainly influenced by the shapes of the clothes where the colors are used.

On the other hand, for the "beach" context, the association may have resulted from the brownish white that refers to beach sand, as well as the different levels of saturation and clarity of brown that may have been associated with mud, earth, and muddy waters (Pedrosa, 2004; Farina, 2006; Heller, 2013). Still, in this sense, these colors can be found in rocks and cliffs. Therefore, there may be an influence of these objectives involved in the process of decoding and visual interpretation.

Regarding FWA, in the collection of general data (potential consumers + designers), mentions of 718 words were identified for the colors of collection Ilha de Marajó, of which 384 were different (53.48% of the words mapped). It was observed that the designers mentioned more quantitatively words such as "Brazil, ceramics, identity, lightness, north, and earth." Meanwhile, potential consumers noted "earth, nature, colors, culture, peace, clay, warmth, beauty, comfort and skin." Therefore, only the word "earth" showed a correlation between intention and interpretation, and no other correspondence was identified for the most mentioned words between both group of individuals.

Next, all identified terms were transformed into synonymous categories. With this, the 718 words collected resulted in a total of 72 categories of synonyms for the color palette of the Ilha de Marajó collection. The four designers interviewed mentioned 126 words, comprising 39 of the 72 categories of synonyms, while the 52 potential Generation Z consumers questioned in the survey said 592 words, including 69 of the 72 categories.

Regarding the results obtained, the categories of synonyms most mentioned among designers were "regional," "identity," "earth," "nature," "affection," and

"cultural artifacts," respectively, in terms of frequency. Meanwhile, among potential consumers, the categories of "peace," "aesthetic," "earth," "nature," and "affection" were most quantitatively mentioned, respectively, in number of mentions (Figure 8).

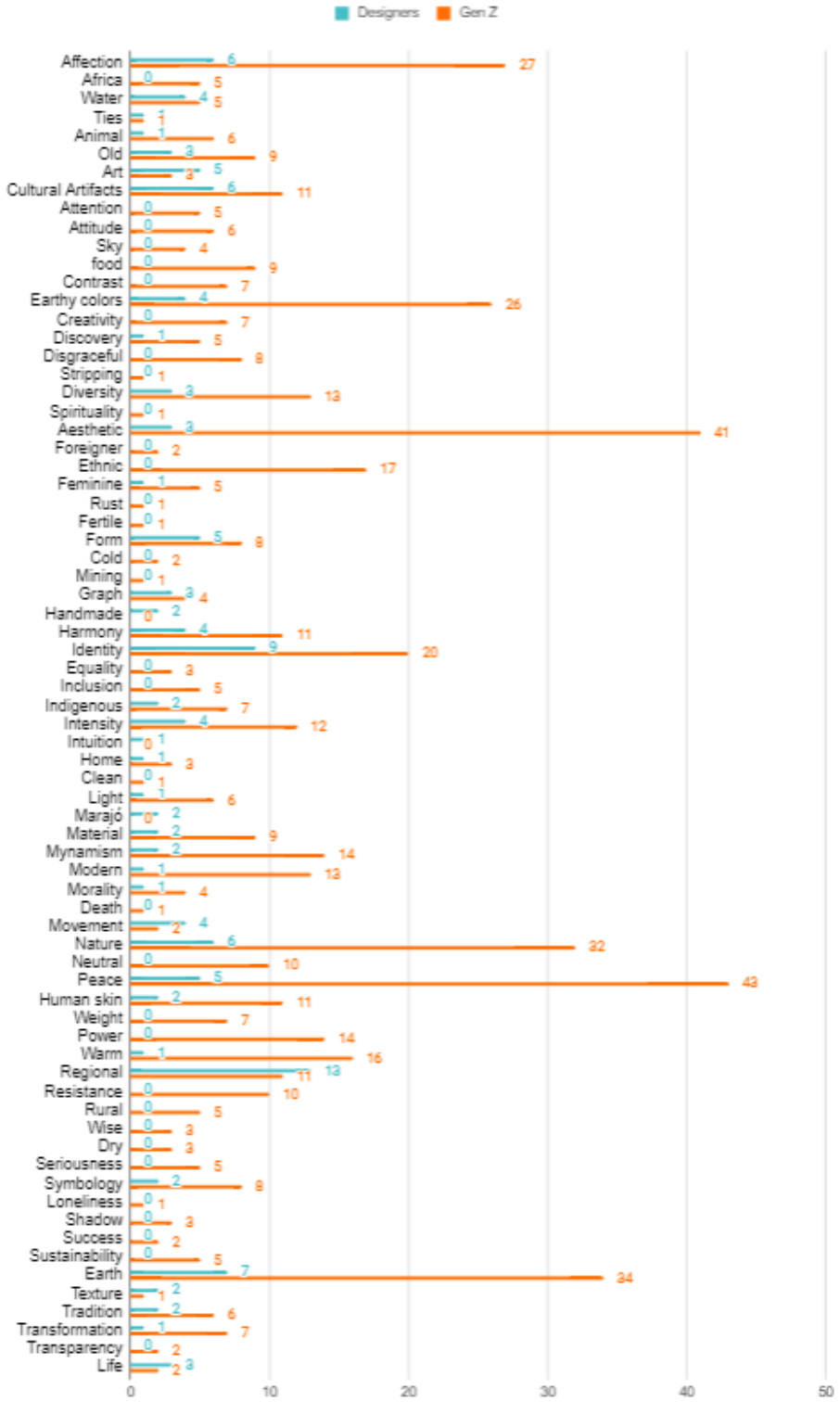

Fig. 8. Free word association intention and interpretation results for the 2019 fashion collection – Ilha de Marajó.

The categories of synonyms "earth," "nature," and "affection" showed a compelling correlation of interpretation between the designers' intention and the understanding of potential consumers, appearing among the most cited in both groups researched. The "regional" category (n = 13), widely significant for the group of four designers interviewed, presented a similar number among potential consumers (n = 11). However, in proportion to the 52 respondents from Generation Z, this was not configured as one of the most significant categories.

It was observed that both the designers and potential consumers of the Ilha de Marajó collection used the widespread cultural meanings of the colors used in the fashion collection (different levels of saturation and lightness of brown and white) to construct the semantic associations informed by the responses. It is essential to highlight the influence of color dimensions on interpreting the meanings of visual messages. With this, we notice that shades of brown with lower color lightness are decoded with intentions more focused on black, such as heavy and dark. In contrast, shades of brown with higher color lightness presented meanings close to white, such as purity, lightness, and calm, demonstrating the influence of color dimensions on the interpretation of visual messages in clothing products.

In this way, it is identified that it is not in all cases of clothing production that there is a subversion of social codes; quite the contrary, what we noticed was the maintenance of symbolic standards that are already widely used in society, as can be seen in the connection between earth, clay, nature, and the color brown chosen to compose the collection's color palette. These strategies can make it easier to understand the visual messages of colors in fashion collections, as they are senses that are already part of the color semantics of the studied public cultural vocabulary.

Therefore, considering the results presented so far, in the context of the 2019 fashion collection Ilha de Marajó, it can be concluded that there was high effectiveness in the interpretation of color messages compared to what was established by the designers, even at different levels, at certain times. This conclusion could be verified for the SD and FWA results, showing positive and satisfactory correlations between intention and interpretation.

5. Final considerations

In this research, we studied two winning fashion collections from a Brazilian fashion competition, in the years 2017 and 2019, the New Designers Competition, from Dragão Fashion Brasil, with a focus on evaluating the interpretation of color messages by Generation Z based on a survey and compared with interviews conducted with the same designers who codified the collection.

Regarding the first fashion collection (Shipibo: digital artesania), it was concluded, in general, about high effectiveness in the interpretation of color messages by Generation Z. In SD, 8 of the 11 pairs of descriptors were interpreted as intended, with levels entirely positive and accurate in almost all. The collection's color palette included white, blue, pink, green, and different saturation levels and clarity of a brownish-pink tone. Generation Z interpreted these colors as "nature," "tranquil," "affection," "delicacy," and "simple." Of these, the only meanings initially intended by the designers were "nature" and "delicacy."

In the case of the second fashion collection (Ilha de Marajó), it was concluded that, in general, there was also a high effectiveness in interpreting the color messages. For the DS results, it was observed that 8 of the 11 pairs of descriptors were analyzed according to the designers' intention, with positivity in large part. The collection's color palette included white and brown, the latter varying in lightness and saturation, going from a lower level, approaching black, to a higher level, forming a light brown. Generation Z interpreted these colors as "peace," "aesthetic," "earth," "nature," and "affection," where "earth," "nature." and "affection" were among the designers' intentions.

In general, it was concluded that different color combinations could evoke similar meanings, such as nature, having been interpreted both by brown and by the set of colors white, pink, blue, and green.

It is worth highlighting that color is not the only isolated factor responsible for interpreting visual messages in the context of the clothing collections investigated. It is recognized that the other elements of visual language, mainly shapes and textures, actively helped color achieve its communicative purpose, outlining specific meanings. This can be proven by observing how the idea of nature was interpreted in the 2017 collection (Shipibo), considering the use of colors such as pink and white in products with fur texture, which helped in an interpretation focused on animals.

The method used in this study derives from a synthesis of interdisciplinary research techniques from areas such as Food Sciences, Advertising, Engineering, Semiotics, and Design, all seeking to investigate the relationship between the production and interpretation of meanings in food, products, and graphic pieces. Regarding the semantic differential, it proved to be satisfactory for obtaining the visual understanding of color meanings more generically and superficially, considering the use of pre-defined terms that cannot access such a deep level of interpretation. Therefore, free word association adds to research by collecting responses at more subjective levels.

Moreover, the present study possesses certain limitations that merit careful consideration in interpreting its findings. Firstly, the color palette analysis relies on the extraction from the collection itself, lacking direct information from the designer. This approach introduces the possibility of misinterpretation and may not fully capture the designer's intended color choices.

Secondly, participant engagement with the collection's image, rather than isolating the evaluation of colors or textile patterns, exposes the study to potential influences from other elements such as models, outfits, and accessories. This raises concerns regarding the specificity of comments and semantic interpretations related specifically to color. It is advisable to further explore and elaborate on the extent of influence exerted by colors versus other design elements. To mitigate such impacts, we try to emphasize the specific interest only of color during the survey.

Lastly, the use of non-calibrated monitors by participants introduces variability, as monitor calibration can significantly differ. This divergence may impact the accurate perception of colors, leading to potential discrepancies in participant responses. These limitations underscore the need for a nuanced interpretation of the results, considering the inherent challenges associated with the methodology employed in this research.

For future research, we recommend replicating the method of this study but focusing on generations X and Y to determine whether there is a significant difference in the visual interpretation of colors in clothing collections between the different age groups and their coders (fashion designers).

6. Conflict of interest declaration

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

7. Funding source declaration

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8. Short biography of the authors

Ítalo José de Medeiros Dantas - PhD student in Cultural Processes and Expression at Feevale University (Brazil); master's in design from the Federal University of Campina Grande. Multidisciplinary researcher with academic and professional interests in different areas, with an emphasis on Design, Fashion and Statistics.

Camila Assis Peres Silva – Design Professor at the Universidade Federal de Campina Grande. Doctor of Science (USP), master's in design (UERJ) and bachelor's in industrial design (UFRJ). Specialist in Marketing and E-learning (UFF). Conducts research and teaches in the areas of packaging design, color, visual perception, user-centered design, usability, history, and design theories.

Marcelo Curth – PhD in Administration from the University of Vale do Rio dos Sinos, master's degree in administration and business from the Catholic University of Rio Grande do Sul, and degree in Sports Sciences from the Lutheran University of Brazil (ULBRA). He is a professor in the Graduate Program on Cultural Processes and Expression at Feevale University, working as a researcher on the topic of Marketing: Identity and Culture.

Licensing terms

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A leap in the color! How understanding horses' color perception improves their performance and welfare in show jumping

Francesca Valan[1], Pietro Paglierani[1], Chiara Scopa[2]

[1] Valan Studio, Milano, Italy, francesca@francescavalan.it, pietro.paglierani@gmail.com

[2] Department of Medicine and Surgery - Unit of Neuroscience University of Parma, Italy, chiara.scopa@unipr.it

Corresponding author: Francesca Valan (francesca@francescavalan.it)

ABSTRACT

In horse showjumping, the probability of falls at jumps can depend on the horse capacity to see obstacles. Experimental works have confirmed the correlation between obstacle colors and jumping performance. Horses are dichromats: they can see blue and yellow, but they are not able to clearly distinguish red, orange, and green. The available results in this field, however, can be hardly compared, because the different authors have not characterized colors in terms of any standard system. Furthermore, even when the obstacle colors considered in the different research works look similar, the corresponding computer-simulated colors (i.e., how colors would be seen by the horse's eye) appear significantly different. Color design can contribute to fill some of these gaps. To this end, this paper first summarizes the horse visual system. A state-of-the-art survey on color impact on the jumping performance is reported, highlighting inconsistencies and problems that can be ascribed to a lack of familiarity with color science. A color analysis of a real jumping competition is finally presented, showing some key aspects that could be advantageously considered when the obstacle sequence is designed. The results reported in this paper represent a starting point to define a systematic approach in the color design of jumping obstacles in horse competitions.

KEYWORDS horse vision, horse-rider synergy, contrast measure

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1. Introduction

Collecting information about the surrounding environment is crucial for survival, and most animals process that information primarily through the visual system. Ecology and life conditions shaped animal visual abilities and stimuli perception leading to a wide inter-species and inter-individual variability (Veilleux and Kirk, 2014). This mostly occurs in color discrimination, which varies based on the number and type of photopigments located in the eye cones (Bowmaker, 2008). Knowing how animals perceive colors becomes essential to design products or environments for domestic species or in those activities involving human-animal coordination (Adamczyk *et al.,* 2015; Rørvang *et al.*, 2020). Showjumping is one of the most popular equestrian disciplines, attracting increasing attention on horses' welfare and safety. The probability of falls or injuries at jumps also depends on the capacity of the horse to see and respond to obstacles (Górecka-Bruzda *et al.*, 2011). The contrasting colors of obstacles with surrounding has been found to be decisive in perceiving the presence, the distance, and the size of the hurdle (Paul and Stevens, 2019). Horses (*Equus caballus*) are dichromats, with two eye cone types, sensitive to short and medium wavelengths. They can see blue and yellow, while they are not able to distinguish red, orange, and green, unless brightness, shade, texture, and other features are well integrated (Hanggi *et al.*, 2007).

The analyses of jump faults (obstacle knock-down or run-out) reported in literature confirm the correlation between obstacle colors and performance (Stachurska *et al*., 2002). More recently, Stachurska *et al*., (2015) and Paul and Stevens (2020) have further highlighted the relevance of other aspects, such as background colors, hurdle color schemes (monochromatic or polychromatic) and Light Reflectance Value (LRV) contrasts (Wyszecki and Stiles, 2000). However, in most of the available works the analyzed colors have not been expressed in terms of a standard color system, but only by means of generic names (like red, yellow or orange) or through pictures. Also, the models used to predict the horse color vision are, in most cases, not specified. Finally, the chromatic vision of riders, enabling them to safely navigate obstacles, could have a role as well in the performance. Nonetheless, this aspect has received little attention by researchers. This paper initially introduces the main features of the horse visual system. A literature revision on the impact of color on the horse jumping performance is reported, highlighting inconsistencies and problems that can be ascribed to a lack of familiarity with color science. Examples of obstacle color schemes (acquired by means of instrumental measurements) commonly used in jumping competitions or during training are analyzed. Finally, the paper proposes a framework with few procedural rules that can help in the design of obstacles for competitions and training. The results reported in this paper can represent a starting point to define a systematic approach in the color design of jumping obstacles in horse competitions.

1.1. *The Horse Visual System*

As prey animals, horses have evolved a visual system that allows them to constantly monitor the nearby environment; they need to detect potential predators in the long distance, to get ready to escape anytime. Their visual field has fostered a panoramic viewing system, with limited binocular capability (Timney and Keil, 1999). The binocular field of vision, which is 120° in humans, is only 55° to 65° in front of the horse (Hughes, 1977), and the overlap is predominantly below the head, extending down ~75° (Timney and Macuda, 2001). The visual input is stretched and wide, conferring a panoramic view with only a small blind spot at the rear. Horses have poorer acuity than most other terrestrial mammals, due to a low density of cones in the retina. Unlike the human's retina, the equine retina has no central fovea, while it presents what is known as a "visual strip" (Harman *et al*., 1999). This region, projecting towards both nasal and temporal directions, is characterized by a high-density of ganglion cells (Evans and McGreevy, 2007). On the other hand, horses are hyperopic (Murphy *et al*. 2009), a characteristic which allows them to have good visual acuity for distant objects. To bring objects into focus, horses must lift, lower or tilt their heads. Whether the over-arched neck of the ridden horse in sports like dressage or showjumping would inhibit its ability to see what is directly in front of it, is a debated topic from more than a decade (Harman *et al*. 1999). Recent studies indicate that they can compensate for some head and neck rotation by rotating eyeballs; however, this does not counteract few hyperflexed positions (McGrevy *et al*., 2010). The recent increased awareness about horse welfare and the factors affecting the performance has induced riders in showjumping to allow their horses choose their own head carriage, for a better perception of the obstacle. Finally, another anatomical feature can influence horses' perception of obstacles. The tapetum lucidum is a light-reflective tissue present in the eyes of both vertebrates and invertebrates. It serves as a biological reflector system with the primary role of boosting visual sensitivity in low-light conditions by offering a secondary chance for photon-photoreceptor interaction to the light-sensitive retinal cells (Braekevelt, 1998; Lesiuk and Braekevelt, 1983). However, while beneficial in dim lighting (Shinozaki *et al*., 2013; Ollivier *et al*. 2004; Schwab *et al*. 2002), the tapetum lucidum can compromise visual acuity when exposed to bright illumination and potentially alter the discrimination of colors.

1.1.1. *Horses' color perception in relation to obstacles in showjumping*

Human color vision is trichromatic, i.e. photons absorb light in three classes of cones, whose peak sensitivity lie in the long-wavelength (L), middle- wavelength (M), and short-wavelength (S) regions of the visible spectrum. Total color blindness, an exceedingly uncommon condition, typically manifests as rod monochromacy, wherein the individual lacks any functional cones and therefore experiences complete absence of color vision. Alternatively, cone monochromats may possess restricted color perception, observable under circumstances where both the rods and their sole type of cones are concurrently active (Joesch and Meister, 2016). Reduced forms of color vision occur from the actual deficiency of one of the retinal photopigments (L, M, or S). Dichromatism results when the peak sensitivity of one of the primary cones shifted, and the amount of shift defines the color spans perceived. The majority of individuals with color vision deficiency exhibit dichromatic vision, where they either lack or possess a mutated form of the red (protanopia), green (deuteranopia), or blue opsin (tritanopia) receptors. Consequently, they can perceive colors, but, for instance, a protanope may find red and green objects to appear very similar in color, while being able to distinguish between blue and green (or red) objects. Similarly, most mammals, such as dogs, cats, horses, goats, sheep, and swine, are dichromats, akin to human protanopes or deuteranopes (Jacobs, 2018; Gelatt *et al.*, 2021). Horses, for instance, possess cone opsins with peak absorbance in the blue and green regions of the spectrum, resulting in color vision that resembles that of human deuteranopes (Hanggi *et al*., 2007). Along with the anatomical peculiarity of horse's eye, color perception is a pivotal aspect of the showjumping performance, most importantly for the selection of obstacle colors, as these may not be perceived by horses as they appear to the human eye, and vice versa.

In the literature, only few recent studies are available, comparing different obstacle colors without elaborating on the variability in color schemes or specific colors features. Stachurska *et al*. (2002) suggested that using white resulted in a largest takeoff distance, while bright blue produced a larger angle of takeoff; jumps over fluorescent yellow fences had shorter landing distances compared to orange. Later, Stachurska *et al*. (2015) highlighted the potential difficulty for horses to jump obstacles which are all light or all dark, since these may cause an optical illusion that leads to overestimating the obstacle size. Uniform dark may make the horse disregard the obstacle altogether. Paul and Stevens (2019) provided a comprehensive analysis of different colors and characteristics of colors in show jumping. Authors tested orange, fluorescent yellow, bright blue, or white obstacles, and found a correlation between obstacle color and both the jump angle and the jumped distance. Also, they took into consideration shade, texture, and/or brightness properties of specific colors such as white, yellow, or blue, which impact the attractiveness of these colors. Matt fluorescent yellow reliably has the highest contrast, in terms of luminance, of all the colors tested. Unfortunately, in all the available works discussed above, the authors have not adopted a standard color system to define the used colors, which are usually referred to with generic names or just shown in pictures. Moreover, the computer simulations of how the colors applied to obstacles could appear to the dichromat horses seem to provide quite different outputs, even when the input colors are similar. Sometimes the simulated colors do not seem to be reliable representations of color-blind vision, at least compared to the results commonly obtained with available color blindness simulators. This lack of uniformity and proper color references could be overcome by the adoption of standard color systems and by defining a common model for color blindness simulations.

2. Methods

To analyze the color schemes of the obstacles used in a real showjumping competition, instrumental color measurements were performed at Gorla Maggiore, Italy, 13-15 May 2022, during the "Nazionale a 5 Stelle" Jumping Trophy. Specifically, the colors of all the obstacles used in the Trophy were acquired by means of a commercial colorimeter. To further characterize the color patterns used for the obstacles, a Color Presence and a Color Distribution analysis were performed, as discussed in the following subsections.

2.1. *Color presence analysis*

In color design, the color presence analysis determines the set of colors used for a specific object. To this aim, a measurement campaign was initially performed (see Fig. 1) to acquire the colors of all the obstacles available in the competition site at Gorla Maggiore, both before and during the Jumping Trophy.

The instrumental measurements were performed using a Datacolor colorimeter, combined with the companion ColorReader software application. Fig.2 shows a screenshot of a Datacolor measurement obtained during the measurement campaign. Since obstacles are usually painted using the RAL system as a reference, all the measurements were transformed from the CIE Lab system to RAL, by exploiting the matching capability of the ColorReader application, which can provide the RAL color sample perceptually closest to the obtained color measurement (Wyszecki and Stiles, 2000). Furthermore,

anomalous color vision simulations were obtained using the software tool described in (Paglierani and Valan, 2018). Fig. 3 shows an example of the color acquisition and analysis process. On the left, it shows two acquired colors, expressed according to the RAL color systems – with codes RAL 4003 and RAL 6004; on the right, the corresponding simulation, which shows how obstacle colors would presumably appear under protanopy conditions (Paglierani and Valan, 2018), with the corresponding RAL codes – RAL 5014 and RAL 6004, respectively. As already discussed, the horse visual system presents spectral sensitivity curves with peaks not far from the human ones for blue and green, and the used simulation tool allows to emulate this condition: while yellow, blue and neutrals remain almost unaffected, the pink and the green bands on the shown obstacles appear significantly modified (Paglierani and Valan, 2018).

Fig. 1. Some examples of the obstacle color acquisition process during the measurement campaign carried out in Gorla Maggiore, Italy.

Fig. 2. Screenshot of a DataReader color measurement. The corresponding RAL code is provided by the ColorReader application as the closest RAL color sample.

Fig. 3. Obstacle color acquisition and processing. On the left: obstacle colors seen by human normal vision. On the right: dichromat vision simulation.

The overall analysis showed that the obstacle colors seem to be chosen randomly, i.e. the visual features of the horse do not seem to influence in any way the color choice. Thus, the color scene as observed by the horse and the rider can result significantly different, and this could lead to a non-optimal perceptual agreement between them. Furthermore, this random choice in the chromatic composition of obstacles could lead to combinations of obstacle and background colors that can be clearly perceived by the rider, but that could result problematic to the horse. This possibility seems to be further suggested by the color distribution analysis summarized in the next subsection.

2.2. *Color distribution analysis*

The color distribution analysis identifies how colors are applied to objects. In this case, it allows characterizing the patterns used for coloring obstacles. The analyzed obstacles present a variety of different patterns, with one, two or three colors, as shown in Figure 4.

Fig. 4. Examples of obstacles with different chromatic patterns.

Quite complex shapes are sometimes included in the barriers, as well as decorations (shapes of flowers, leaves, etc., as shown in Figure 5). One fundamental aspect to consider is the contrast that the obstacle color pattern can present w.r.t. the background. Notwithstanding the complexity of most of the adopted color schemes, in some cases the obstacle results not well visible to the rider with normal vision or to the dichromat horse. In other cases, the obstacle is well visible to a normal visual system but could be less identifiable to a dichromat.

Fig. 5. Obstacle components of different shapes

Also, the role of the background seen by the couple horse-rider plays a fundamental role. The background can in fact create a visual disturbance, interfering with the barrier perception of both the horse and the rider (Figure 6).

Fig. 6. Combined visual effect of the barrier and the background.

A careful choice of the obstacle colors that considers the visual background could render the barrier more easily perceivable by horses and riders.

2.3. *Obstacle analysis examples*

To start investigating the possible impact of obstacle color on the horse jumping performance, the colors of all obstacles used in two races during the "Nazionale a 5 Stelle" Jumping Trophy were analyzed, together with the final score of each horse/rider couple, officially recorded in the report released by the race judges. Although the carried-out survey is clearly non-significant from a statistical point of view due to the small sample set, the analysis can provide useful hints for future research activities, and can sketch a methodology that, applied to a significantly larger number of competitions, will provide more reliable results. Pictures of the obstacles were also acquired in the field, together with the official obstacle sequence maps. Fig. 7 shows the number of errors for each obstacle during the first analyzed competition (May 14, 2022, time: 11 a.m., obstacle height: 135 cm; lighting conditions: sunlight, no clouds, participants: 45). The histogram clearly shows that errors are not uniformly distributed among obstacles: in particular, obstacle number 5 originated 14 errors, while at obstacle number 7 no error occurred. It must be remarked that obstacle 5 was a combination, i.e. a sequence of two obstacles judged as one jump. This type of obstacles could cause more errors than simple fences or other types of obstacles, requiring a double jump in a constraint space. However, it could be observed that in other competitions during the considered event such combinations were not the obstacles with the highest number of errors. Nonetheless, the obstacle type should be considered as a variable in the statistical analysis. Moreover, also the position of the obstacle in the field can have a role in the analysis. In this paper, however, the scope is a preliminary overview of the problem, and the impact of obstacle types and positions, as well as other factors of potential interest, will be considered only in a qualitative and comparative way. Type and position of the obstacle in the overall sequence will be further discussed in the following.

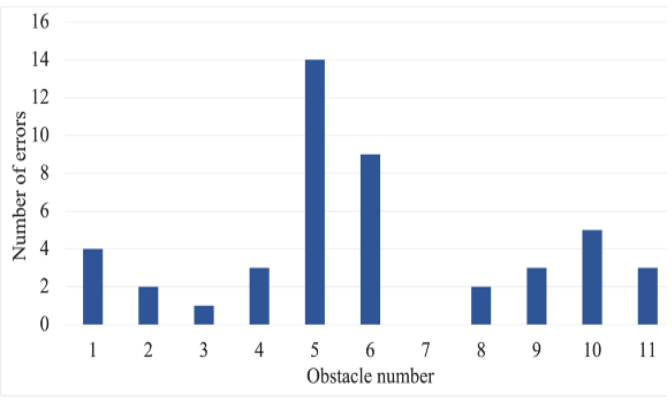

Fig. 7. Histogram of the errors observed at each obstacle (first competition).

Fig. 8. Obstacle 5 (left, max. error number), and 7 (right, min. error number) in the first analyzed competition.

Fig. 8 shows obstacles number 5 and number 7. As one can clearly see, obstacle number 5 is not easily perceivable w.r.t. the background and the ground (see also Fig. 6). This may have contributed to increase the difficulty of the jump. Conversely, obstacle 7 seems to be better perceivable to a normal visual system, and less to the dichromat horses. However, even for dichromats, obstacle 7 stands out quite clearly from the background. The results of a second jump competition are shown in Fig. 9. In this case, the obstacles were the same used in the previous competitions, but positioned differently in the race field, and in a different sequence. The height of the obstacles was 130cm, the starting time was approximately the same (11 a.m.), as well as the lighting conditions (sunlight, no clouds). The number of participants was 48. In this race also, the error distribution was not uniform, even if with a less pronounced peak than in the previous one. The highest number of errors was observed at obstacle number 7, while the obstacle with the lowest number of errors was number 3 (see Fig. 10). Quite interestingly, the same black obstacle 7 had had a low number of errors in the previous race (where it was obstacle number 9, with 3 errors) - when placed in a different position. Obstacle 7 was an oxer in this second competition, i.e. a double vertical fence with a space in the middle. Obstacle 7 was a simple fence in the previously analyzed race. The gray obstacle 3 that here had the lowest number of errors, was the one with the highest number of errors in the previous competition (obstacle number 5). However, in this race this gray obstacle was used as a single fence, and not as a combination. Also, its position in the two race paths was different, and therefore so was the contrast with the background.

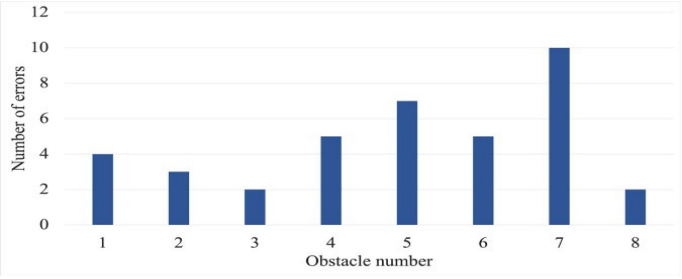

Fig. 9. Histogram of the errors observed at each obstacle (second competition).

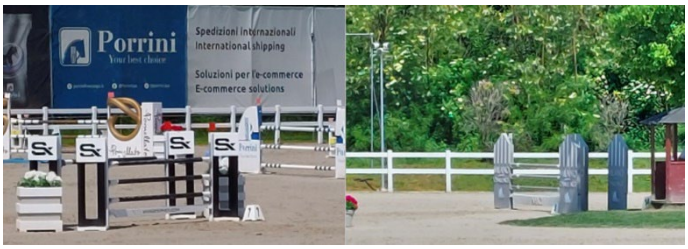

Fig. 10. Obstacle 7 (left, max. error number), and 3 (right, min. error number) in the second analyzed competition.

3. Conclusions and future perspectives

The horse jumping performance can be influenced by several parameters: color of the obstacle, contrast with the background, lighting conditions, type of obstacle (fence, oxer, combination, etc.), position in the field and in the sequence, etc. (Paul and Stevens, 2020; Stachurska *et al*., 2015). In general, the performance can be the result of a complex combination of such factors, which could be difficult to predict. The contrast of an obstacle against its surroundings and the ground seems to play an important role: it can influence the determination of obstacle presence, size, and the distance between the viewer and the obstacle (Bruce *et al*., 2003). The analyzed examples have shown that the same obstacle, positioned in different places in different races with similar lighting conditions, can originate a significantly different number of errors. Moreover, the study of the horse visual system suggests that horses could be particularly sensitive to lightness. Thus, lightness, and in particular lightness contrasts, could play an important role in the jumping performance. The finishing of the obstacle, particularly its gloss, could be also important, as gloss typically plays a role in the vision of dichromats. Nonetheless, the impact of lightness contrasts and/or gloss and finishing of obstacles on the jumping performance, to the best of the authors' knowledge, have received minor attention from researchers. The horse color vision has been analyzed for the impact it could have on the jumping performance. Conversely, less attention has been paid to the color vision of riders. Since 8% of the male population is affected by color vision deficiency, a non-negligible fraction of riders could have color vision problems, and this could affect the jumping performance or the relationship horse-rider. To the best of the authors' knowledge, this aspect has never been considered in the literature.

Some basic rules for the design of obstacle colors and their use in competition paths can be provided. The selection of colors for the obstacles that result invariant under the specific horse color blindness can help control in a more accurate way the difficulty of obstacles.

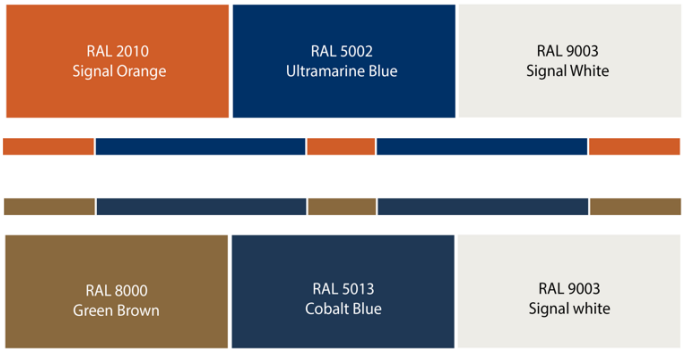

Fig. 11. Dichromat invariant obstacle design.

Fig. 11 illustrates an example of obstacle color design that considers horse color vision capabilities. The upper obstacle is a real obstacle pattern, whose vision by the dichromat horses would result distorted w.r.t. normal human vision. The lower obstacle is the simulated version of the upper one (i.e. it represents how the upper obstacle would appear to a dichromat). The color cards on the top and on the bottom of Fig.11 report the colors of the real and simulated obstacle, respectively. Using the colors of the simulated obstacle, one would obtain a real obstacle appearing invariant both to normal and to dichromat observers. Such type of obstacles could be used in experiments on the impact of colors on the jumping performance, as well as during training, to create paths with controlled visual difficulties and improve the harmony in the human-horse interaction (Scopa C., *et al*. 2019). Investigating the color vision of riders is a future line of research for this activity. This aspect has received minor or no interest from researchers. Color deficiency of the rider could offer an advantage in creating a better harmony between rider and horse, resulting in improved racing performances. One of the planned activities in the follow up of this research will be rider color vision testing to verify a possible competitive advantage of riders with color deficiency. A hint on this comes from the famous horse rider and trainer M. Roberts, who suggests that his color blindness could have helped him in his relationship with horses (Roberts, 1997).

4. Conflict of interest declaration

The authors declare that there is no conflict of interest.

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6. Short biography of the authors

Francesca Valan - Francesca is an Industrial designer specialized in Colors, Materials, and Finishes design. She graduated in Industrial Design at IED, Milan, in 1989, and received her Master in Surface Quality in 1990. She collaborated with Società di Ergonomia Applicata, investigating the aspects of visual ergonomics. She founded her studio in 1998 and she teaches Color Design Technology at Milan University.

Pietro Paglierani - Pietro received the Master degree and the Ph.D. degree in Electronic Engineering from the University of Padua. He is a scientist at the NATO Center for Maritime Research and Experimentation (CMRE) in La Spezia, Italy. His main research interests are in underwater acoustic/optical communications, underwater quantum communications and image and color processing.

Chiara Scopa - Chiara is a Ph.D. student in Neuroscience, Behavioral Biology at the University of Parma. She has conducted behavioral analysis on different aspects of horses' behavior, from self-awareness to emotional interactions with humans. She is now working on a multidisciplinary project, aiming at determining the relation between the level of maternal milk exposure to environmental chemicals and infants' neurobehavioral development.

Licensing terms

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Reversal film transparencies and their colours: examining the medium of an era.

Nicholas Lourantos

Maritime Tradition Museum (Perama, Greece). nlourandos@gmail.com

Corresponding author: Nicholas Lourantos (nlourandos@gmail.com)

ABSTRACT

Colour reversal film transparencies (slides) are a medium that seems to have, almost, disappeared. They gained their prominence mostly between the 1950s to 1970s, as a preferable photographic choice, since their vibrant colours gave them an edge over negative film photographs, not only as a professional option but also as a means of recording family moments. Slide showing became a social activity. The gathering of people, cinema-like conditions and interaction made them quite popular. The question which we will concentrate on is about their colours and how this is consistent with the colour palette of their era. In the current study source material, from a family collection, is utilised and an empirical approach and analysis is applied. The study concludes that the medium employs the colours of their times, and how this helps with the preservation of these items, not only as family archives but as cultural objects enriched with semiotic elements.

KEYWORDS slides, transparencies, colour, images, semiotics, social interaction

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1. Introduction

Colour reversal film transparencies, short for colour reversal film transparencies slides, were, predominately, a 1960s and 1970s phenomenon. Transparencies were presented, usually, in a session known as slide show. They were a single framed pieces of 35 mm film, framed in a 2x2 cardboard or plastic casing which could be viewed usually on a screen, through the usage of a specialised projector.

In the case of image analysis, when examining transparencies, the pivotal question which arises is whether transparencies can be examined and analysed in the same way as paper printed photographs. They could be labelled as an easy and affordable alternative to home movies, in a society where images are important, and moving ones doubly so. And since amateur photography boomed in the 1950s and 1960s, with the mass production of cheap and easy-to-operate photographic cameras, images started flooding the home moments scene. Their main purpose was displaying family moments and holiday snapshots. This of course does not mean that amateur photographers did not record everything they could: their houses and gardens, their children growing up, country fairs, new additions to their surroundings and much more. Thus, the produced items were a welcome addition to the printed images, which constituted the main bulk of the recorded family moments. But the crucial difference with photographic images was the act of slide showing. Printed photographs were stacked in albums, which could be seen by many, but was a static process or at least a one-on-one happening, usually. And they were smaller than life. Transparency showing, on the other hand, was orchestrated along different lines. The whole event included, almost always, a commentary along with the projection of every image shown. All this took place in a semi-dark room, with a group of people, almost like a private cinema screening and the free flow of everyone participating in this happening, with their own comments about the images, something which made it something more than an informal gathering. It was a social interaction event.

The research question of this paper can be formulated as whether the colour attributes of the transparencies are in synch with their era. The transparencies examined here are simple images created with one thing in mind: an archive of a Moment in Time. A semantic approach to the transparencies involves understanding what exactly we see in them. The interesting fact is that the researcher is in the unique position to understand, to a great degree, the creator of these transparencies as he is the researcher's father. Almost all were shot between 1968 and 1972. The images involve two kinds of participants: represented and interactive. The choice of using this approach can be understood better if we try and understand the relation between the original producer and the original intended viewers. This is especially true in the first transparency, taken in early 1968 (Fig. 1). The image is a view of a small town's main street. Collaborating information can be gathered by studying the surroundings, but as both the date and the place are known it is not necessary to go into those details. The represented participants are not people, it is the place itself.

Fig. 1. Neal Street, Harden, NSW, Australia.

The second transparency examined (Fig. 2) also contains involvement and detachment. It is another typical tourist holiday snapshot. Here there are represented participants, which are people, but the place is also of importance.

Fig. 2. Chora, Kythera, Greece.

The picture was shot during the producer's holiday back to his birthplace island and village. Depicted are family members residing on the island. The angle is frontal, at eye level. Yet he is a tourist. He does not reside in this place. He is visiting. The depicted participants may not be the interactive ones. The persons shown will not see their image, probably, but others will.

In trying to understand how photographs representing loved ones act in many ways Barthes' notion of *punctum* (1993 p. 27) is decisive. This allows a bridging to the past, towards the structure of memory or *postmemory*. The personal feelings, subjectivities and memories become more pressing than the actual memory, not for the creator but mostly for the viewer. And since these images are the creator's attempt to create a direct message to the viewers, himself included -at a later time, the "image is not the reality but at least it is its perfect analogon" (Barthes

1977 p.17). In the case of these transparencies, which are naturalistic images, the connoted message is what the interactive participant is trying to invest in it. Thus, transparencies can be examined as photographic images, but with a twist.

2. Data Collection and Choosing

Both the slides and the Super 8 Home movie stills (photograms) data used in this research are part of the researcher's family visual archive. They were created by the researcher's father from the 1950s to the 1970s. Private photographic archives have a unique quality since the documentation of a family's moments in time is more than a mnemonic device, as we have already suggested. It also connects the members and strengthens family networks. As memory and photographs are fundamentally connected, we can cite Bate (2010) who argues that photographs belong to both public and private memories creating a breakdown of the duality between cultural and individual memory.

The slides were shot by an Agfa Optima 35mm photographic camera, while the Super 8 videos by a Canon Auto Zoom 518. They were developed in specialised Kodak laboratories, the slides in Australia whilst the Super 8 in Germany since Kodachrome film required a specialised developing process. Both are part of the visual archive, along with their projectors and other paraphernalia. As the slides and Super 8 films were stored carefully and are in excellent condition, providing us with pristine material. We did not notice any colour deterioration or distortion.

The slides were scanned by means of a Canon ScanJet G4010 flatbed scanner, utilising the VueScan software (https://www.hamrick.com/). The scanner was chosen as it was of the last models which had film scanning capabilities incorporated. The original scanning took place during our thesis research period (2017-2019). No enhancements or alterations were employed during the scanning progress, preferring to use basic settings. The slides produced were of various dimensions (3168x2176, 2080x3168, 3136x2144 pixels), no less than 600 dpi, a bit depth of 24 bits (2^{24} = 16.7 million tones) and colour representation of sRGB. The saturation was automatically chosen to low, since these were slides, while sharpness was switched to soft, and the average size was between 1,5 to 3 MB (or more) per slide. We downsized them to specifics for publication, that is to equal or less than 300 dpi.

The Super 8 films had been digitised during the later part of 2015. We did not have access to any film digitising apparatus; thus, they were given to a photographer who had, and they were delivered to us in unencrypted VOB format. We did not have any involvement to their scanning specifics. But since we were trying to make the films available for family gatherings it seemed adequate. Their properties were: dimension 720x576 pixels, at 25.00 frames/second, a data rate of 8500kbps and 8724 total bitrates, as an average. The stills were acquired by way of the GOM Video player (https://www.gomlab.com/gomplayer-media-player/), which allows screen capturing. These still images were saved as PNG files, of 710x480 pixels dimensions, a colour bit depth of 24 bits and an average of 400 Kb in size.

3. Research Methodology

Choosing the slides was an arduous undertake since the depictions were part not only of the collection but of our own childhood memories. Subjectivity crept in but as Rubin and Rubin (2011) claim naturalist researchers are active participants of their research (p.17) and need not be neutral and still produce credible results (p.234). The choices were natural: some from life in Australia and some from life in Greece. The dates varied but covered the late 1960s and early 1970s. The Home Movie stills were chosen randomly and were from the early 1970s, since the camera was bought in 1972. Still the chromatic attributes were those of the 60s, more than the 70s, which influenced our choice of the 1960s pallet in analysis.

In choosing a methodology to the research question, the choice between quantitative and qualitative approaches was considered. A quantitative approach would seem appropriate, as the total of the transparencies collection examined in our case study is not large in number, since it consists of about 60 transparencies. But such a method is suited to mechanistic 'what?' queries. The study's question demanded an approach founded in the special characteristics the source material was invested with, and which is definitely not mechanistic, per se. In contrast a qualitative approach to the query seems a much better suited one, as it helps understanding the 'why?' and 'how?' questions. We decided that the qualitative approach was preferable and a naturalistic one at that. The study's question focuses on the fact that transparencies are an item which is and is not an image, like an ordinary negative film printed photograph. There is therefore a need to have a small, yet representative sample. This study adopted a convenience combined with a judgment one, as it was decided that certain transparencies would be more productive than others, and specific choices had to be made. The choices could be challenged as biased, but they are not. The viewing of any image associated with one's early ages, whether their own or not, is emotionally moving and invested with denotation and connotations and emotional impact. Sampling for qualitative research is

something of a confusing part for any researcher. The aims of such an approach have to do more with trying to comprehend human issues rather than producing answers, with general attributes. In the case of this study only a minute number of transparencies was selected: no more than seven, in total (one was used both for chromatic as well as semiotic analysis). Results produced may seem a little generalised but an empirical qualitative approach, with convenience and judgement sampling, seems to have produced enough data to analyse them, by utilising a fundamental theoretical semantic background and a chromatic relativity approach.

4. Colour of the transparencies

The chromatic approach of this study's transparencies will concentrate on colour relations. Transparencies contain information and can be treated as any other photographic image. Their dualism is a result of the extra quality of their projection.

The field of Plastic Visual Semiotics was an attempt to make sense of the confusion of the visible with the speakable (Floch, 1985). Barthes through his semiotic approach is a way, yet not the only one in a sociological analysis, which may try to connect these different ideas and understand its links with specific eras (Skarpelos, 2018). Greimas (1989) talks about visual plastic semiotics containing a chromatic category, which beyond colour may refer to attributes such as luminosity and texture. Žemaitytė (2017) points that here we may have categories with graded characteristics, related to the perception of colour and matter. There seem to be different three origins, which Mohammadzadeh (2012) labels as colour semiotics. The first is the emotional impact of colours, the second is colours having socioeconomic origins and the third that certain colours meanings are cultural in origin. This case study stands on the fact that colours do have an emotional impact, as when transparencies introduced colour on a wide scale it was a novelty. And since the images were not only coloured but larger than life, they did have an impact, when viewed in the correct conditions. From that point the study elaborates that in the 1960s and 1970s colour images had all kinds of impact on people. Technology enabled colour to become a major part of everyday life: textiles, magazines, and photographs. This made transparencies a major force in the image game, as printed film colour photographs still lagged. Colour, consequently, was the factor which enabled the ascendancy of the transparency medium. And as it is still present, and has not faded, from our images examined, it allows us to see exactly what the viewers of the 1960s saw: vibrant, colourful moments on a big screen. While examining how professionals' utilized transparencies the thought of experimenting with colour palettes and comparing transparencies with other, similar, images of the era arose. The fact that every era has a chromatic palette is not new. Best (2012, pp. 366) notes that through time there's a need to have "the right colour and design for the right period".

Barthes (1977, p. 39) introduced the idea of the "terror of uncertain signs", when he noted that images need linguistic messages, in order to fight of their own polyseme. But transparencies do not have a textual linguistic message. In their initial presentation the linguistic was present through the usage of the interpreter-creator, but this in not textual. So, when trying to analyse such images, after finishing with the morphological analysis we end up having to deal with their extra attributes and we stand still as he has talked meagrely of them. Barthes' essays on Pop Art and Edwin Parker "Cy" Twombly Jr. are important as examples on the aesthetics of colour. Riley (1995, p.57) comments on these saying "Barthes allows color to expand into a broad-ranging role in aesthetics. Its deployment can be enough to confer "*artistic*" status even on an object that has been deliberately categorized as unartistic or antiartistic" Colour is a part of the visual narrative of the transparencies. We would go as far as supposing that the 1960s pop colour boom created a new idiom, in items such as transparencies, something which has not been approached systematically, from a semantic point of view. This made us consider the possibility of trying and exploring the idea of a chromatic era palette, for the transparencies studied.

Consequently, the need to compare transparencies with other cultural artefacts of the same era arose. The only logical choice to compare them with is film stills, from Home Movies of the period. Both are part of what Chalfen (1987) terms as Home Media. When researching photographs of the same era, it was quite disappointing to find that colour printed ones were faded, to the point that they would be useless in a chromatic comparison. And as this study wanted to focus on colour, they were discarded, as a comparison item. The decisive, final, point for choosing Super 8mm Home Movies was Kodachrome, the same type of colour transparencies used. For the purposes of the research four random transparencies were chosen and compared with four random film stills, all from the said collection.

In the study's chromatic comparison, the help of the visual tool Image Color Summarizer (http://mkweb.bcgsc.ca/colorsummarizer/?home) was employed. The report contains the average, median, minimum, and maximum of each component of RGB, HSV, LCH and Lab. Average hues are calculated, by using the mean of circular quantities. Some of the

questions this tool can answer are what the average colour hue, saturation and value are in an image, the colours which are most representative of the image, the image's human readable colour description. The process contains a concise visual information table, which allowed easy comparison of the images we had chosen to experiment with.

We chose a small number of Super-8 Home Movie stills along with more transparencies to acquire the necessary data we wanted. Below we show two groups of the images examined: The first is four movie stills, three recorded on the island of Kythera and one in Athens (Fig. 3).

Fig. 3. Super 8 Home Movie stills.

The next group contains four of the transparencies examined. Three were recorded in Australia and one in Greece. They were taken between 1968 to 1973 (Fig. 4).

Fig. 4. Random transparencies.

The tables (1-3) which follow, visualise the chromatic relations, with the help of the abovementioned software. It must be noted that both the Home Movie stills as well as the transparency images have not been tampered in any way. The first table (Table 1) contains detail information about the colour palette of the transparencies.

Colour palette of figures 3-10

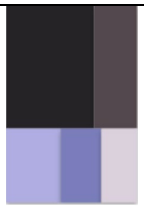
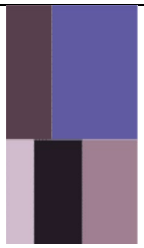
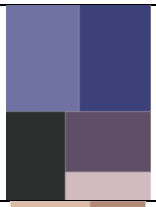
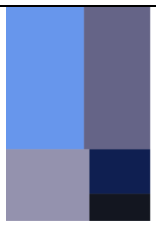
No.	image no.	Colour analysis information			
1.	**3**		pixel density %	colour name	hex number
			41,86	raisin black	#252326
			20,52	emperor	#53474c
			15,54	pale light greyish blue	#afade2
			11,84	masquerade	#7a7dbb
			10,24	lola	#dbd0dd
2.	**4**		pixel density %	colour name	hex number
			36,78	scampi	#5e5aa2
			19,77	dark greyish rose	#53474c
			18,23	mountbatten pink	#9f7f90
			16,16	very dark rose	#221a23
			9,06	maverick	#d0bbcd
3.	**5**		pixel density %	colour name	hex number
			41,86	kermadec	#192826
			17,78	swans down	#d9e6db
			14,57	masquerade	#6b7eb6
			13,4	true blue	#31405b
			12,39	storm dust	#62605c
4.	**6**		pixel density %	colour name	hex number
			27,64	kimberly	#7172a4
			27,1	torea bay	#3d4179
			18,55	silhouette	#2b242d
			18,23	aurora	#5e4f66
			8,47	kidman	#d1bac0
5.	**7**		pixel density %	colour name	hex number
			40,78	just right	#252326
			28,5	brandy rose	#b28977
			16,26	zambezi	#635153
			7,46	night rider	#1f130e
			7,01	stratosphere	#8d9dd2
6.	**8**		pixel density %	colour name	hex number
			35,74	blue moon	#7494ac
			23,82	magic carpet	#8595cc
			22,24	spinmaker	#2a536d
			10,01	celectial blue	#0c1d30
			8,1	burnished brown	#a47e74
7.	**9**		pixel density %	colour name	hex number
			36,21	cornflower	#6796ec
			30,61	norwegian blue	#656487
			19,23	birdcage	#9492ae
			8,65	downriver	#0f1f51
			5,31	vulcan	#131620
8.	**10**		pixel density %	colour name	hex number
			32,31	skydiver	#4d82cf
			27,49	wave rider	#4b4276
			22,52	ceil	#94abdb
			15,26	deep saphire	#1d205f
			2,53	jaguar	#060410

Table 1 Colour palette of figures.

After acquiring the colour data from the images (Table 1), the next step was to compare random colours from the chromatic palettes generated. The usage of the Color Matcher tool from the Color Tools webpage (http://www.colortools.net/color_matcher.html) allowed us to draw very interesting conclusions, since it compares given colour relations and produces a closeness percentage (Table 2).

Selective colour comparison of figures 3-10 (random picks)					
closeness percentage	image no.	pixel density %	colour name	hex number	colour
95%	3	20,52	emperor	#53474C	
	7	16,26	zampezi	#635153	
81%	4	18,23	mountbatten pink	#9F7F90	
	7	28,50	brandy rose	# B2B977	
89%	4	36,78	scampi	#5E5AA2	
	10	27,49	wave rider	#4B4276	
84%	5	14,57	masquerade	#6B7EB6	
	10	32,21	sky diver	#4D82CF	
84%	6	27,10	torea bay	#3D4179	
	9	8,65	downriver	#0F1F51	
95%	6	18,55	silhouette	#2B242D	
	8	10,10	celestial blue	#0C1D30	

Table 2. Selective colour comparison of figures

The results demonstrate that there are definitely aesthetic colour relations. The colours are similar, though not identical, which is something expected. But both transparencies and film stills are part of the eras' chromatic palette. In all cases examined we have colour relation percentage results ranging between 81 to 95%. These are high because the colours are closely related, as we already pointed out, but the aim was not to find the precise same colours but their aesthetic relation.

5. The extra step

The claim that the colours compared are part of the era's palette seemed to be an overstatement. What was needed was a comparison with other material. This is quite challenging as the standards of the chosen studied material were carefully controlled. Yet there must be a way to find the broader palette of the times. After examining several sites dealing in colour, such as: https://www.onyxcreative.com/blog/2020/9/popular-color-palettes-by-decade, https://www.housebeautiful.com/design-inspiration/a44075764/color-trends-by-decade/, https://looka.com/blog/every-pantone-color-of-the-year/, https://www.dunnedwards.com/pros/blog/popular-color-palettes-through-the-decades-1970s-2010s/.

Although they were quite informative, almost all colour palettes shown were created leaning on interior design colour choices or focusing on one colour instead of a broader colour palette per decade. We finally chose Juicebox Interactive's site (https://juiceboxinteractive.com/blog/color/) where we encountered a database claiming that they have captured the colours of the last 100 years. Its significance is that its chromatic references are drawn from a diverse background including interior design colour images but also record covers, magazine article photographs andcinema posters. The choice of sticking with the 1960s palette was naturally dictated by the fact that the images we were examining had been produced during the said decade, thus were a product of their times, and even the ones from the early 1970s still reflect the 1960s colours.

With the intention of gaining information from the palette a total of seven colours was chosen during the usage of Image Color Summarizer. This was done as we have a six-colour palette plus the lettering in them. Then by employing the Color Matcher Tool, as done before for the transparency and Home Movie comparison, colour relations between transparencies and the 1960s palette were drawn. The results can be seen in the following table (Table 3):

Random colour comparison of transparencies and the 1960s palette				
closeness percentage	image no.	colour name	hex number	colour
86%	6	mountbatten pink	#9F7F90	
	16	double haystack (natural)	#CFB285	
84%	3	emperor	#53474C	
	16	hawaiian tan (teak)	# 995B17	
89%	6	torea bay	#3D4179	
	16	teal blue (blue mustang)	#2F768D	

Table 3. Random colour comparison of transparencies and the 1960s palette

Although only three colours were chosen for the comparison, of the total six acquired, the fact is that the chromatic relation attributes range between 84 to 89%. Thus, we can conclude that the colours of the transparencies correspond aesthetically closely to the chromatic palette of the era. At this point we feel we should point out certain facts about the final comparison. Yes, this is a small-scale, random empirical approach. But in the end result the palette seems to be representative of the era's dominant colours. We are not very sure about the amount of data collected which produced the palette, but it does fall inside certain parameters: the data is diverse and ranges from actual photographic images to, carefully designed, movie posters. The overall feeling produced is quite convincing.

6. Conclusions

Bate (2010) suggests that since photographs belie meanings with far more potential significance attributed to them, they demand analysis rather than hypnotic reverie. Our study tried to approach transparencies through their eclectic colour relations with the major colour palette of their era. The research proved that this is true, by employing colour analysis and software comparison. Consequently, these methods can be used as a helping tool to researchers who have no information about their images. Transparencies were a medium for their era. The practise of using transparencies, instead of printed photographs, is a rather important factor, and not only to the photographers themselves. It moves them from pure photographic items to the testament sphere and they subsequently become part of family history archives, much like paper printed photographs. But it is their colour and presentation which sets them apart. The slide show transforms them into something akin to movie film projection, even though there is no actual movement of the images -apart from their succession. Film and transparency presentations are, almost, identical. They feel as a continuation of the silent film era, which itself was a step away from the magic lantern or phantasmagoria shows. They were, like all photographic images, a glimpse in Time, but they were colour ones, when colour was scarce. Their saturated colours and contrasty makes them almost a pop image. And pop is a 1960s (and 1970s) byword, being all the rage in the cultural scene, both in the public as well as the private fields. Our belief is that as some elements of the transparencies are, usually, missing that does not stop us from studying them as images, same as if they were negative film printed ones. After conducting this small-scale empirical case study, we reach the supposition that transparencies should be labelled as a communication device, with a social interaction angle, but furthermore they ought to be considered and examined as cultural items, with invested metadata and emotional impact as well. Transparencies are a novel item in the field of Visual Culture, but we feel confident that more will try their hand in contributing to their study.

7. Declaration of funding sources

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8. Declaration of conflict of interest

The author has declared that no competing interests exist.

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10. Short author biography

Nicholas Lourantos - PhD in Visual Culture and MSc in Cultural Management. Worked for the Hellenic Ministry of Culture (1991-2022). Seconded to National Centre of Audiovisual Media and Communication (Greece). Research interests include Visual Culture and Sociology, the Greek Diaspora, and Greek Maritime History (19th & 20th c).

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Colour Composition and Visual Tectonics in Facades; Adapting Colour Teaching to Current Architectural Practice

Kine Angelo, Alex Booker

Department of Architecture and technology, University of science and technology, Trondheim, Norway. kine.angelo@ntnu.no, alex.booker@ntnu.no

Corresponding author: Kine Angelo (kine.angelo@ntnu.no)

ABSTRACT

In Norway, this last decade has seen a steadily increasing demand for knowledge of how to use colour in an architectural context, and this paper will focus on the application of colour theory in building façade design. In architecture, colour theory is a body of practical guidance to the visual effects of a specific colour combination creating a logical structure for colour, how we can organize them, and how colours can be used to enhance architectonic intent. Current architectural education largely focusses on the *tectonic,* as in relating to building and construction, and on the formal aspects of the *visual tectonic,* but until very recently, the teaching has devoted little focus to the visual tectonics of colour. As most research estimates that approximately eighty percent of our perception, learning, cognition, and activities are mediated through vision, with form and colour being a key feature, it could be argued that we should put more emphasis on the visual qualities of colour of architecture, i.e., inherent or applied. This paper will discuss how developing an under-standing of colour theory and implementation relevant to architectural education and practice in Norway is changing both students and professional practitioners' attitudes towards the use of colour in architectural projects, giving examples from the recent years colour teaching at NTNU and professional implementation by the authors.

KEYWORDS colour in architecture, colour theory, façade design, visual tectonics, advancing and receding colours.

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1. Introduction

The authors observe that the general paucity of colour understanding in architectural education and the profession leads to serious deficiencies in the built environment. The lack of knowledge of colours' actual qualities and functions across all architectural scales leads, at best, to an appeal to aesthetics without the necessary structural argument to convince developers or clients, and to "best guess" intuition late in a project without confidence in the outcome and with unpredicted and unfortunate effect. Often the colour knowledge gap means that colour is dismissed as merely a secondary phenomenon of little cultural or design importance resulting in an indiscriminate following of whatever trend is dominant. The authors along with other colleagues have worked to develop an educational structure that addresses these deficiencies.

"… to take an aesthetic interest in a building is to attend to it in all its completeness, to see it, not in terms of narrow or predetermined functions, but in terms of every visual significance that it will bear" (Scruton, 1979)

The following course descriptions outline how colour teaching is integrated in the curriculum at NTNU. This shows how the teaching of colour in architecture is extended from a theoretical component to crossing the implementation gap by emphasising colour as a material quality that engages in, and contributes to, the formal, structural, and aesthetic discourse in architectural and urban practice. The first colour teaching starts in the second semester (Architecture 2) and progresses with varying levels of interaction and into the master's level.

2. Architecture 2: Tectonic

In the second semester, students are introduced to the most important basic building materials and gain a basic understanding of architecture's most important design principles as well as experience of how architecture affects place and how a place influences the architecture. Colour is introduced as one of the key aspects of identity of place (Angelo, K. and Booker, A., 2018) on their first excursion abroad, i.e., Vienna and Graz. Students are given an assignment of studying the nominal and perceived colours (Fridell Anter, 2000) of buildings, when learning how to measure specific building facades.

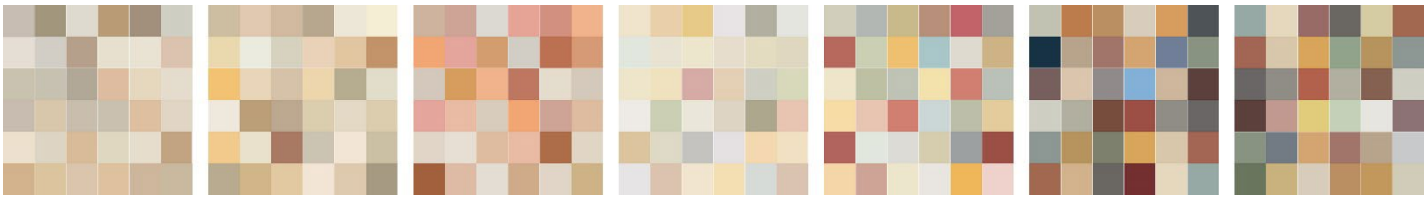

Fig. 1. Examples of colour spaces of different European cities; Paris, Florence, Rome, Vienna, Graz, Copenhagen, and Trondheim.

3. Architecture 3: Housing

The third semester focuses on architectural design for urban housing, the basic typologies, and organisational principles, dimensioning of architectural elements and space, light, construction, and form in relation to the urban fabric, outdoor spaces, and facades. This course runs parallel to the *Form and Colour, module 1*.

Form and Colour, module 1 start with an introduction to perception, light and colour and how colour can be used to enhance or conceal form. As all building materials have colours, inherent or applied, students are given examples of how colours affect the formal aspect of existing buildings, discussing how architects can use colour as an aid in the visual tectonic appearance (Ostwald, 1969).

Colour theory cannons, such as Goethe and Itten, and relevant colour reference systems used in the architectural profession (NCS and RAL) are addressed on the basis of their strengths and weaknesses, with the goal of extracting viable, practical advice. The aim is to introduce basic concepts of colour and relevant terminology to create a common platform for comparative experimentation and discussion.

The colour education is structured to have relevant transfer and implementation value to architectural practice across all building scales and locations. At first emphasis is placed on the key aspects of human colour vision; light, object/surface, and perception. Students are given an introductory assignment of exploring the elementary colours through painting and arranging colour samples according to their main visual character of whiteness, blackness, yellowness, redness, blueness, and greenness. This is the core of the natural colour system (NCS)

Concepts addressed: colour reference systems in practice, colour properties and characteristics, lightness, darkness, chromaticity.

3.1. *Assignment A) Colour and form*

Students focus on composition with colour and are given a specific 2D composition with the task of making three visually balanced compositions, working with achromatic colours, equiluminant colours and complementary colours to explore the optical quality and its impact on the formal composition.

Concepts addressed: simultaneous contrast, advancing and receding colours, quality, quantity, proportion, balance, orientation, gestalt principles of colour.

3.2. *Assignment B) Colour and light*

Students are given one colour with the task of designing a composition with nine variations of surface structure with the aim of generating a variance of perceived colour that is as wide as possible through use of texture, relief, and light reflectance properties.

Concepts addressed: structure, texture, relief, the spectral properties of daylight and artificial light, light temperature, light reflection, light dispersion, light, and shadow.

3.3. *Assignment C) Colour and space*

Students are given a specific 3D scale model with the task of making a spatial composition that is visually balanced when seen in all directions. The starting point is the colour palette from one of the 2D-compositions from assignment A, by experimenting in smaller sketch models before painting the final proposal.

Concepts addressed: simultaneous and successive contrast, spatial aspects of colour, advancing and receding colours, colour perspective, aerial perspective, visual boundaries, zoning, overall gestalt.

3.4. *Impact on Architecure 3*

Students begin to have a deeper appreciation of colour and material as an architectural design tool and are starting to understand colour's capacity in proportional and spatial articulation. Through a more methodological application in projects, they are starting to evolve more sophisticated arguments for material and colour choices in dialogue with context and the production of urban identity.

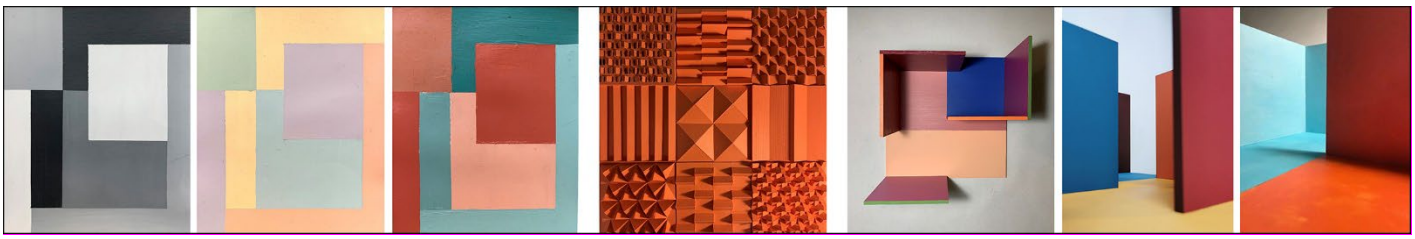

Figure 2: Example from Form and Colour, module 1, assignment A, B and C.

4. Architecture 4: Transformation

The examination and analysis of existing buildings through hands-on investigation. Developing projects on the basis of field investigation in conservation, reuse, and transformative adaptation with relevant choices of change based on careful attention to resource use and sustainability. This course runs parallel with Form and Colour module 2 which focuses on working within a specific colour pallet of a place and pattern formation from 2d to 3d.

Form and Colour module 2 further develop the understanding of how to implement colour in architectural practice through exploring the development of colour, material, gestalt, and the understanding of pattern structure in facade design; facades are composed of elements that result in an overall gestalt.

4.1. *Assignment D) The Trondheim Palette*

Students make their own “Trondheim palette” by mixing colours, selecting colour samples to represent the wider range within the colour space of the city. For this assignment, they have access to NCS tools (Indexes, atlases and colour pins) as colour reference for comparison. Their selection should represent the width and depth of the colours hues and nuances of the city.

Concepts addressed: colour and context, colour and place, colour guidelines, colour reference systems, colour in practice, Norwegian standard for colour reference (NCS).

4.1. *Assignment E) Colour, form and pattern structure – 2D*

The students are given a specific “module” and tasked to experiment in creating different patterns by repetition vertically, horisontally, around the axis, by displacement, mirroring, etc. They first start in black and white and then introduce colour to their achromatic designs to explore the theme further and to experience how colour can visually change the perception of form and pattern structure.

4.2. *Assignment F) Colour, form and pattern structure – 3D*

Students develop a 3D-module out of the 2D-module and use the surfaces of the 3D-element to experiment with colour and how it affects form, and then make compositions based on repetitions of nine of these identically coloured elements/modules. The final task is either to make three different compositions where the element has the same colours but placed differently or use the same model composition making different compositions through three different colour schemes.

Concepts addressed: one element/module in repetition, format, rhythm, direction, orientation, size, scale, open, closed, positive, negative, facade design, overall gestalt, visual tectonics of colour.

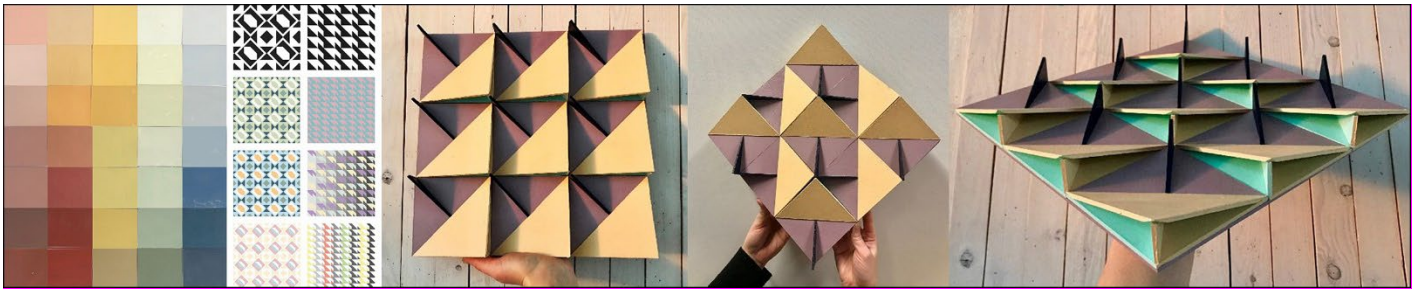

Figure 3: Example from Form and Colour, module 1, assignment D, E and F.

4.3. *Impact on Architecure 4 - Traditional Colour Practice in Norway*

Students implement the acquired understanding directly in the semester's main project, and there is a sustained discourse on colour and material in heritage identity and adaptation throughout the semester. The Trondheim colour palette is used in all design projects, and plug-in colour assignments are set in the area the students are working in, with the task of experimenting with the effect of colours have on visual tectonics of the façade; advancing and receding colours and how active and passive the building elements are perceived in the overall gestalt of the façade (Fig. 4). Traditions in previous architectural styles and an understanding of the evolution of material in both heritage and more modern structures are also encountered. This develops increased appreciation for the craft aspect of colour and colours cultural role in heritage and epoch identity.

Concepts addressed: visual tectonics, formal aspects of colour, advancing and receding colours, perception of gravity in optical weighting.

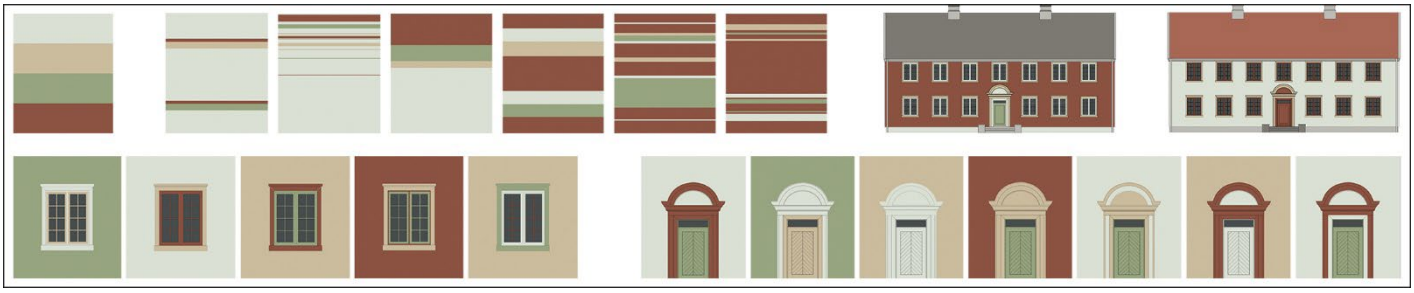

Figure 4: Example of assignment on visual tectonics of colour.

5. Architecture 5: City and Town Planning

Developing sustainable conceptual urban design proposals and urban planning strategies including a general understanding in sustainability and ecology. Methods for analysis and design of urban settings and landscapes space, form/ typologies, and functions. Input on the history and contemporary practice in urban colour plans with particular emphasis on identity, ambience and wayfinding, extended discussion on the importance of climate, solar angle, geographic position, and locality in colour and material perception.

6. Architecture 6: Large Buildings

The course develops the knowledge for designing large, sustainable buildings. The course focuses on situational

analysis and awareness, application of given context, program, functionality, concept and expression, the structure and elements of buildings, regulations and safety, construction principles, and technical infrastructure. The form and colour component are substantial with extended discussion of gestalt structure in relation to colour and materials in facade and body form and its impact on, and relation to, urban and regional identities and the objects communication in relation to publicness and everyday aesthetics. Students are encouraged to think with colour and material as a contextual and idea generating tool from the first conceptualisation stage. This is maintained throughout the course by the availability of colour expertise for student project teams. It is expected that students show both colour and material implementation in their final presentation.

Figure 5: Example of project on Architecture 6: Large building, where knowledge from Form and Colour is implemented in façade design.

7. Summary of colour teaching at BA level

At the conclusion of their first six semesters (BA level) all students have encountered colour in multiple contexts and through this have developed an understanding of colour's role and relevance in architectural and urban design, at each stage the potentials of implementation have as far as possible been brought from theory into practice. A significant number of students continue to develop their interest at master's level.

Tectonics in architecture is defined as "the science or art of construction, both in relation to use and artistic design". It refers not just to the "activity of making the materially requisite construction that answers certain needs, but rather to the activity that raises this construction to an art form." (Maulden, 1986)

8. Master Design Course: Architectural Design with Light and Colour.

Architectural design with Light and Colours is a design course with a specific focus on the perception and practice of light and colour in an architectural context, and the course is taken parallel with the theory course *Light and Lighting*. The theory course focuses on daylight in buildings, both quantitatively and qualitatively, and the knowledge is used in the design course when designing the final infill project. The use of daylight in the final assignment on the design course is not discussed in this paper.

The design course has particular focus on application of natural light, building materials and colours in architectural design. The course builds on colour teaching at BA level and aims to further develop practice-related design skills in colour design in public spaces. It focuses on exteriors in the urban realm and universal design in interiors, building up aesthetic argumentation and at the same time complying with building regulations and requirements for public spaces. The specific sites for the design projects change as the course co-operates with municipalities in different towns and cities in Norway, and with various partners in the paint, render and cladding industries (Fig. 6). The aim of the course is to apply learned concepts, methodology and terminology to argue functional and aesthetical aspects of architecture in an urban context.

Figure 6: Example of exercises on the master design course with real clients in making new colour selection for linseed oil paint for a company in Oslo, interior palette for client with focus on universal design and LRV, and façade colour palette for new building block in a specific area of Trondheim.

The design projects aim to reflect and respond to contemporary architectural challenges, i.e., identity of place, urban densification, infill projects or building rehabilitation in a specific overall gestalt of a site/street/area/city. The Norwegian Directorate for Cultural Heritage (Riksantikvaren) declared in 2017 a change from the earlier strategy of *contrast* between old and new to emphasis on *dialogue* between the old and new, e.g., dialogue between building materials, overall gestalt of pattern structure, typology and colours. However, the question of *what a good dialogue between existing buildings and new additions is,* is not particularly well exemplified or specified. To achieve this good dialogue the knowledge developed at BA level in colour and form, pattern structure, relief, material colour, building elements and sequential structural order and context are essential.

The final design project starts with on-site registrations, e.g., light, natural context, building materials and typologies, colours, building pattern structures, how the area is used and what functions are there, to identify the *status quo* of the dialogue. Counter to most current practice of approaching the project from the inside and out by starting with a programme – students instead respond to the site as to what would be a good function of a building in the area and what would be a good aesthetic addition to the context, i.e., from the outside and in. The aim is to establish the functional and aesthetic "frame" of the context at the beginning rather than as an adaptation at the end of a project, and that all choices of building materials, colours and visual tectonics, respond to the overall gestalt of a specific place. Students are encouraged to respond and explore by inclination and ability but are required to professionally argue all of their choices, both for building design and its relation to the context.

Concepts addressed: context registrations, visual tectonics, pattern structures, dialogue between old and new, identity of place, dogmas of contemporary practice, urban hierarchy.

Figure 7: Example of registrations of colours, materials and overall gestalt for the final design project.

Figure 8: Example of student projects and studies of brick-and-mortar colours, and of the variation of facade elevation model in 3D of several student projects.

9. Diploma level

At the masters (M.A.) and the Diploma (final examination) level we see students who chose to specialise on architectural colour and an increased number of students who address colour as an important design factor and actively seek further consultation on colour issues. Indirectly: an increased number of graduates move into practice as architects or consultants that actively address colour as an important architectural and urban design factor or have been engaged on the basis of their demonstrated colour competence.

10. Conclusions

We conclude from our experience that a meaningful re-weaving of colour into architectural design is dependent on colour teaching that has direct and transferable value in supporting continual semantic development and practical

implementation at every stage in the student's trajectory towards professional practice.

Gestalt, colour and tectonics are treated as descriptive and discursive rather than as exclusively explanatory in nature, the integration of their principles provide part of the semantic vocabulary that allow students to grasp and discuss compositional propositions, it is understood as a form of analysis describing perceivable tendencies in visual organisation, as such it provides the students with a set of tools for analysing, understanding, and manipulating the cumulative qualities of elements and objects in a coherent way in the visual field and in three-dimensional space. The tendencies of colour and tectonics are understood as a set of qualities that interact to variable degrees at any given time, and that they may be manipulated to generate hierarchies of proportion, position and balance, dynamics of rhythm, order, flow, and variation. An understanding of these combined gestalt tendencies equips the students with a set of actions and understandings that enable a deeper structural discourse on the dynamics of composition at a formal level (how elements work together) towards a more complex emergent function in visual, spatial, and structural rhetoric and contextual cultural implications.

Sustaining discourse on colour throughout the study with input that is relevant produces results that are visible both in the quality of the individual work and in understanding of the function and purpose of colour in an aesthetics of structure, furthermore, graduating students have the grammar and experience to confidently explain and argue for their decisions with a rational, formal, architectural and contextual language that goes beyond a purely subjective, expressive feeling and is more firmly anchored in a relational understanding.

11. Conflict of interest declaration

The research leading to this paper has been obtained through the authors academic employment at Department of Architecture and Technology, Faculty of Architecture and Design, Norwegian University of Science and Technology (NTNU), as well as through own design practice.

12. Funding source declaration

The authors declare no conflict of interest in publishing this paper.

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14. Short biography of the authors

Kine Angelo - Associate Professor Kine Angelo joined the Faculty of Architecture and Design at NTNU in 2010 where she is currently a full-time lecturer and researcher. Building on previous and ongoing design practice of architectural projects, her research activities are devoted to promoting colour and material gestalt in architecture and urban space through architectural education and public outreach.

Alex Booker - Professor Alex Booker trained in the United Kingdom as a fine artist and has exhibited widely in Europe as well as completing a number of major public commissions. In 1995 he joined the Faculty of Architecture and Design where he teaches two and three dimensional form grammar, colour and visual communication for both product design and architecture students.

Licensing terms

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The *"Color Fever"* Chroma Survey 1973

Clino Trini Castelli

Castelli Design. memo@castellidesign.it

Corresponding author: Clino Trini Castelli (memo@castellidesign.it)

ABSTRACT

Fifty years have passed since the author, observing a series of developments related to the evolution of color culture in the early 1970s, realized that major historical events often coincided with epochal changes capable of giving rise to new global color languages. In those years the selection of a color was based not so much on the subjective choice of hues, as on the objective vivacity of the color's saturation (chroma). Each color was thus selected at its maximum intensity, further accentuated by the monochromatic scheme inherited from the historical trend of the 1960s. That decade had been characterized by increasingly saturated primary colors, which precisely in 1973 led to a chromatic outburst whose maximum peak was reached in a sort of "color fever". As we know, a fever is not itself an illness, but a symptom that reveals the presence of a pathology. In this case the peak of saturation, already detected in the field in 1973 and then measured and depicted in 1979 with the tracing of a new diagram: the *"Color Fever" Chroma Survey* (Figure 1). The peak registered the symptom of a crisis in the by-then obsolete quantitative dynamics that still regulated the choice of colors in use according to a rigid linear progression, lacking in other possible evolutions. These dynamics were no longer sustainable on a *qualistic* plane, and above all they proved to be unsuitable to grasp the signs of the appearance of a new "sentiment of color."

KEYWORDS AIC2023 Chiang Rai Thailand, CMF Design Forecasting, 1973 Oil Shock, 1973 "Color Fever", Advent of Ecology Concept, Conceptual Inversion, Emotional Experience, Umbrella Diagram, Qualistic, World-wide "Sentiment of Color", Fragments.

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1. Introduction

Since the beginning of the 1970s, the color offering (*color presence*) of some new industrial products began to show obvious anomalies in the forecasting models. In fact, although still very primitive, they were changing under the influence of historical upheavals triggered by epochal events (such as in 1973, with the Arab-Israeli *Yom Kippur War*), which would lead us to experience the “oil shock”: a sudden energy crisis that led to significant shortages throughout the western countries. For a rapidly growing society like ours, founded however on limited fossil energy resources and even more problematic nuclear alternatives, it was a heavy blow. The crisis and the resulting austerity led to a quadrupling of fuel costs and other grave limitations which, however, lasted only one season, from the winter of 1973 to the spring of 1974. We had experienced a historic event that would radically change our future, even if we did not realize the energy dependence to which we were exposed and the influence on the patterns of our material culture. For example, until then the growth of color saturation on industrial products had followed a linear increase, with a rise in saturation already underway in the late 1960s. This was a *quantitative* effect connected to the demand for color typical of chromatic languages which did not suggest changes in a *qualitative* sense, such as the choice of new color shades (hue). What really mattered then was in fact only the strength of the color itself (chroma), i.e., its saturation (Figure 2).

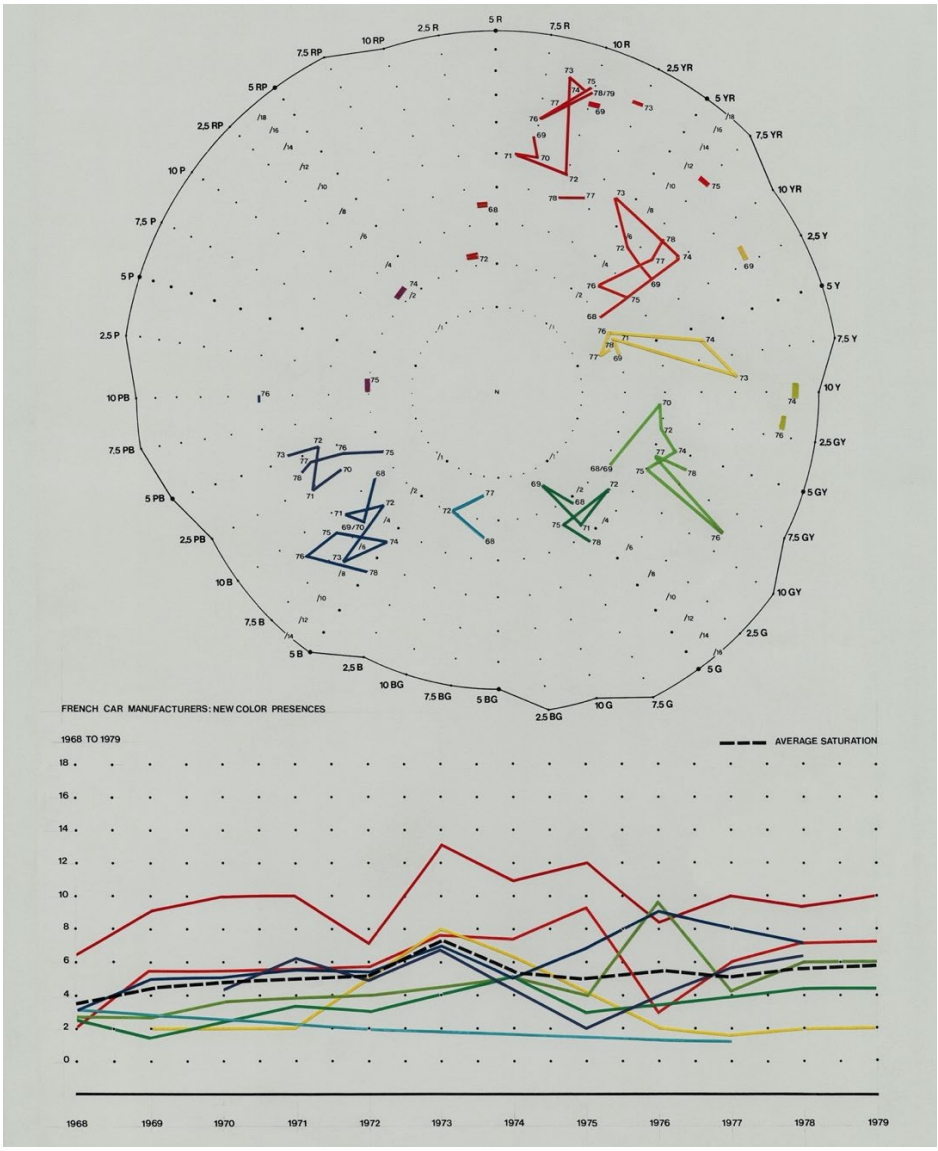

Figure 1. The original "Color Fever" Chroma Survey 1973.

In 1973 the “Color Fever” Chroma Survey *diagram revealed a sudden peak on the line that indicated the average saturation of colors of automotive paints on the French market. France was chosen for the study because of the number of auto brands already active in that country. This peak, already detected through the first observations in the field, was shown on the saturation diagram of 1979, on the basis of data gathered from 1968 to 1979.*

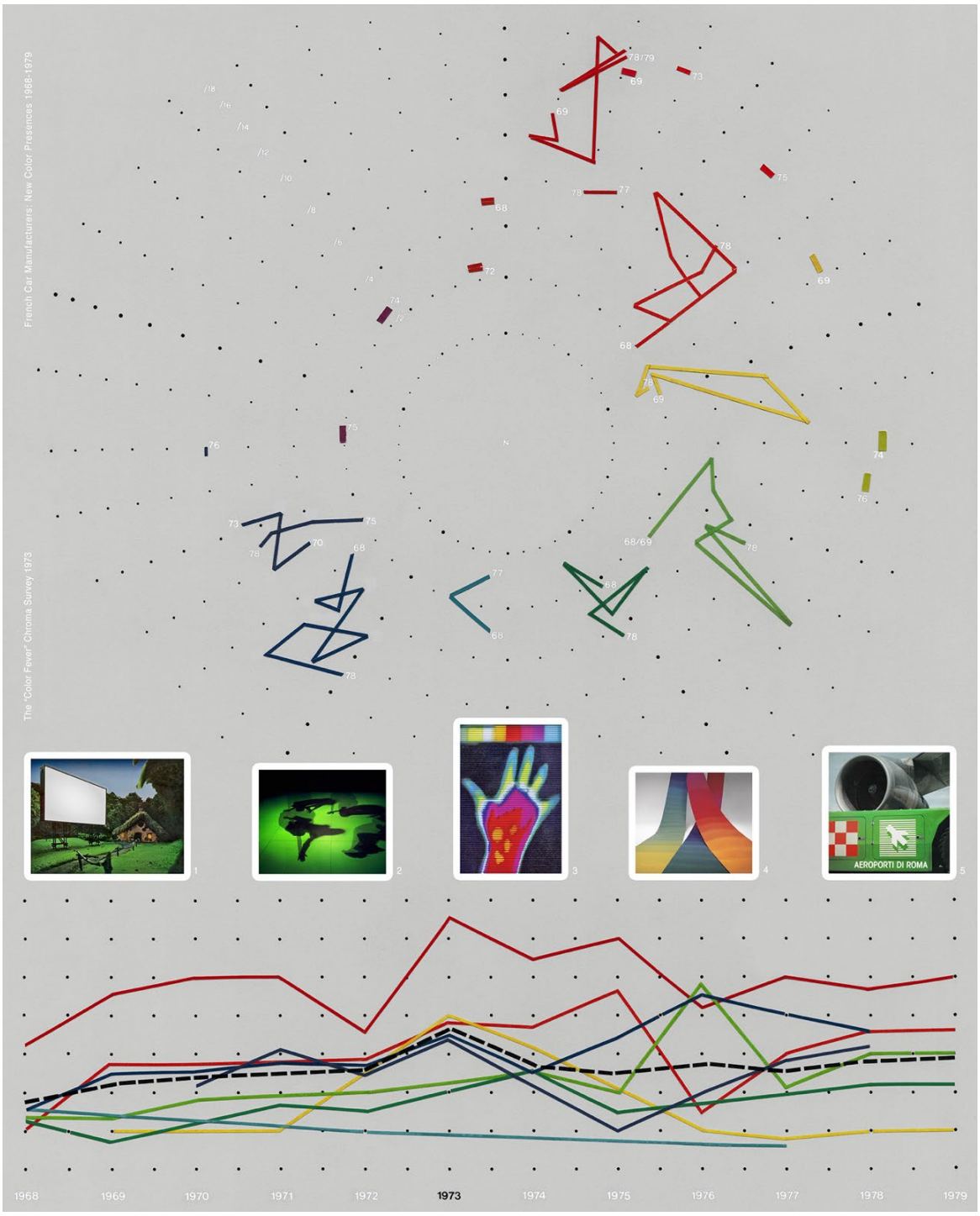

Figure 2. The "Color Fever" Peaks and the Early 1970s Project Scenarios.

The “Color Fever 1973” diagram combined with images of several project scenarios made by Trini Castelli in the first half of the 1970s. In those projects, the high levels of saturation of the start of the decade are still evident, shortly before the rise of the new color presence with the appearance on the market of color schemes having nuances typically found in nature (the new 70s natural colors, which in fact would replace the previous 60s primary colors). In 1976 we can also notice the progressive growth of the peak of a medium blue, and the sudden surge of the peak of a saturated green, which then became a fleeting fashion trend on the automotive market in that moment.

The real mutation would then be triggered spontaneously, precisely with the shock caused by the effects of that distant conflict which almost immediately led to the sudden collapse of the color saturation of most of the products on the markets. Thus, a surprising effect was created, a sudden “conceptual inversion” which brought confusion between the colors and emotional languages which until that moment seemed to be completely stable and consolidated.

2. The chroma survey focus

In the early 1970s the end of the growth of saturation in paints seemed improbable, especially in a sector like that of automobiles, which amazingly enough was still operating with the color offerings of the previous decade. I should point out, however, that the 1960s had immediately stood out for the unprecedented use of a single highly saturated *primary color* (but also totally *neutral* tones like white, gray and black) which was applied to the entire body of the product, making it typically *monochromatic* (*color distribution*). An eloquent example of this historical trend was the Olivetti *Valentine,* the typewriter designed by Ettore Sottsass in 1968, entirely in red ABS (one of the first products on which I was to work). Among the typical color presences of that decade, besides red and orange there were also yellow and blue. These colors were only used individually, and their brightness was always balanced by the juxtaposition with *generic colors* (neutral finishes in white, gray, black or chrome) applied to the generic parts of the products themselves, such as the legs of chairs or the bumpers of cars (Figure 3).

Figure 3. Leart Safety Lamp, 1965.

The Leart *safety lamp for garages was the first industrial product entirely designed by Trini Castelli in 1964. It was without metal parts (except for the electrical gear) and was made entirely in polypropylene, in N7 gray (apart from the functional details in red). This lamp is also a good example of the* historical trend *of the 1960s, which favored a* monochromatic color presence *that was typically very saturated or - as in this case - totally neutral. That revolutionary polymer* (Moplen) *- created by the Nobel laureates for chemistry in 1963, Giulio Natta and Karl Ziegler - was the same resin utilized by Montedison to produce the new polypropylene fiber* Meraklon*, a material at the base of the prize-winning chromatic system of textile flooring* Fibermatching 25 *(Figure 4).*

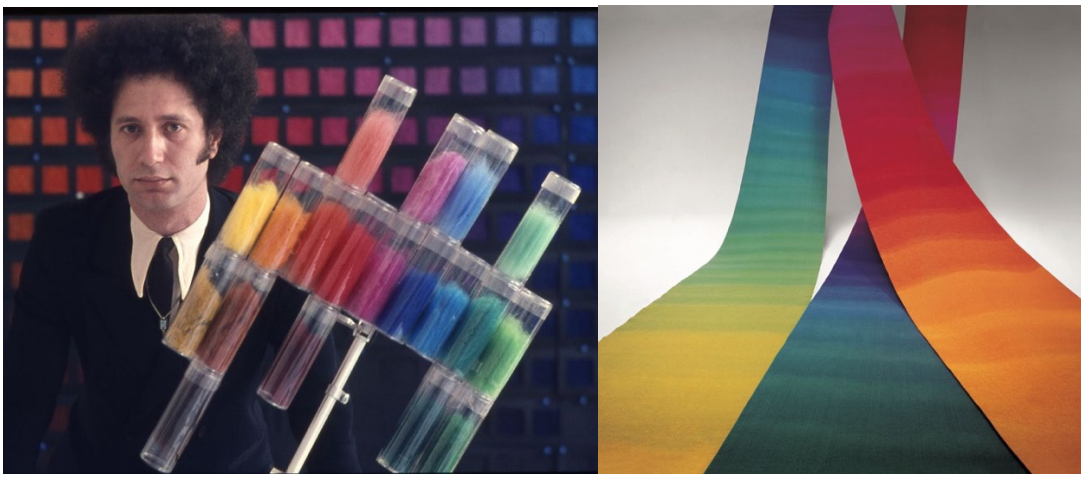

Figure 4. The Meraklon Fibermatching 25 System, 1975.

In the early 1970s, with Massimo Morozzi and Andrea Branzi, Clino Trini Castelli founded the Centro Design Montefibre *of Gruppo Montedison, which was to mark the beginning of "*Design Primario"*, comprising innovative ideas and systematic projects for new materials and processes in the "chemical-textile" sector. One of them was the* Fibermatching 25 *system, a new method of color formulation based on the inner mixture of* Meraklon *polypropylene fibers,* "mass-dyed" *or colored in full depth. That idea, based on the* "partitive synthesis" *of a limited series of special base colors, made it possible to create wide chromatic ranges with an* eco-sustainable *method, avoiding the pollution caused by the dyeing process. The* physical synthesis *of particles in the form of filaments of suitable chromaticity exploited the capacity for "visual discrimination" of the human eye, and had never been applied until then on an industrial scale. That method, having become an industrial process, was then re-applied twenty years later by Trini Castelli in Japan, this time utilizing nylon fibers, again batch-dyed, to produce other millions of square meters of textile flooring, which thus prevented any pollution from water used in the dyeing operation. In practice, starting with a limited number of fibers with very vivid based colors, these were simply de-saturated, mixing them closely with a range of other neutral-base gray fibers, in paler or darker blends. The project won the* Compasso d'Oro ADI *award in 1979.*

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3. The new "Sentiment of color"

The trend towards a progressive increase of color saturation of products in the industrial sector continued, in any case, with the introduction of new categories of super-saturated pigments. Nevertheless, precisely with the overall retreat from high saturation in 1973, new schemes of *color presence* spread on the market with neutral tones, whose identity could be associated with forms of *proto-ecology*. The intensity of the *primary colors*, seen until this point as the reflection of energy optimism, was increasingly rejected by the emerging environmentalist sensibility. The colors of materials and coatings utilized in various sectors thus became more imitative of nuances that could be found in nature (the 1970s *natural colors* would replace the 1960s *primary colors*). That drastic change also triggered a crisis in the various sectors of the automotive chain of design and production. It was a true debacle for major investors in the sector, which had focused only on quantitative programs of forecasting. This painful lesson would lead the entire sector into new forms of "design awareness" and to the passage from a linear perception of the flow of time towards a cyclical and evolutionary vision.

While in fashion changes in tastes and emotional languages seemed to mutate spontaneously, adapting to the new realities already at the start of the 1970s, the big chemicals industry had stubbornly clung to its saturated tones, although they had been rendered obsolete by a new "sentiment of color". In the end, that industrial sector squandered at least 10 years of massive investments for the production of new and very costly pigments, which due to their long development processes would systematically reach the market with major lag times with respect to current trends.

The exaggerated chromatic choices, no longer suited to the new emotional demands of the market, were immediately and totally rejected, in spite of last-minute attempts to enact shrewd marketing strategies, always with scant results. One of the first came from the insurance companies, which offered large discounts to car buyers who opted for high-visibility paint jobs that would be effective even in dense fog. I too, in 1976, in a corporate identity project for Aeroporti di Roma, had applied an apple green paint, almost fluorescent, for the entire fleet of ground support equipment: a choice dictated by the need for an image, but also by concerns of safety (Figure 5).

Figure 5. The "Green Peak", 1976.

The super-saturated colors developed at the start of the decade found new applications, dictated by necessities of image and safety, as in the case of the "green peak" *of 1976 shown in the diagram, which sees the super-saturated signal-green applied to the bodywork of the ground support vehicles of* Aeroporti di Roma*. The same green was then used only for the bumpers and other generic parts of the* Fiat Racing 131*, combined instead with totally neutral bodywork.*

Many sizeable investments went up in smoke, in fact, simply because no one wanted the new colors that were being produced. This was the outcome of the above-mentioned "conceptual inversion" that was rapidly becoming very obvious: people no longer wanted the super-saturation of "emergency" colors; everyone wanted only natural, intimate, non-assertive tones: nothing poisonous, nothing like the hues of the heavy metals. For the first time, the industry that stubbornly insisted on those old paints was automatically associated with the emerging problematic issues of environmental pollution.

I should point out, however, that already in 1964, when I began working for Olivetti in the Milan studio of Ettore Sottsass, at the headquarters in Ivrea the new CEO of Olivetti, Aurelio Peccei, made his appearance. Like him, I too came from the FIAT group in Turin, and like him I would remain with Olivetti only for the three subsequent years. Peccei, who did not appear to be particularly operative in the company, however, was one of the founders of the historic *Club of Rome* in 1968 (the non-governmental association created with the mission of catalyzing global changes). Aurelio Peccei, thanks to his early vision, is now considered one of the originators of the idea of *ecology* itself. In 1972 he was to write the famous preface to the MIT report on *The Limits to Growth* [Meadows *et al.*, 1972], influencing international public opinion by foreseeing the issues and consequences of the first worldwide oil crisis of 1973. His position also helped to raise awareness among Italian companies of the importance of the environmental question.

Shortly thereafter, in May 1974, came the initiative of the historic magazine *Domus*, presenting the exhibition *Environment '74* [Casati, 1974] precisely in Turin. I participated with the entire section *Eco'74* (Figure 6), where I presented the themes of "*Design Primario*", with *Le Superfici Reattive* (Reactive Surfaces) [Trini Castelli, 1972] and *Camera Riverberante* (Reverberating Room): works and installations entirely made with *Lumiphos*, a luminescent HPL laminate from Abet Print. This was one of the very first international expositions in Europe on the new theme of ecology and environmental qualities.

Figure 6. Eco '74. La Radura Pubblicitaria e Le Superfici Reattive, 1974.

Lumiphos*, in 1971, was the first true design of a new material developed in the form of a semi-finished product. It consisted of large totally photoluminescent HPL panels, which were then produced for over forty years by Abet Print. The choice of working on the design of materials instead of forms was already the start of a meta-design intention, oriented towards dematerialization of products and spaces. The idea was to design while remaining outside the traditional figurative culture, which took the "compositional aspects" of form as its ideal referent.*

4. The International Scenarios

The surprising diagram of the *"Color Fever" Chroma Survey* is the most illustrative result of wide-ranging research on saturation in the paints made for the European automotive market. Begun in the early 1970s, that effort - conducted at first only in the field - had to do with the evolution of colors of the entire decade and stemmed from local observations made during my first trips in Europe and the United States. Actually it all began in July 1967, when at an early age I had the unmissable opportunity to travel to New York with my authoritative colleague Flavio Lucchini, who had just been appointed as art director of *Vogue Italia*, on his first visit to the editorial offices of *Vogue America*. Grace Mirabella was the editor at the time, and she introduced us to some of the most outstanding celebrities in New York, including Andy Warhol at his *Factory*, and visits to the studios of great Vogue photographers, from Richard Avedon to Hiro and Bert Stern. For me, the encounters with Irving Penn and Diane Arbus were unforgettable. Finally, we were invited to the opening of the *Electric Circus*, an amazing occasion that confirmed, from my viewpoint, the new format of international club culture, which I had already explored one year earlier at the *Piper Club* in Turin [Trini, 1968], with art events and design programs that became legendary in that historic context.

My second trip to the United States came two years later, in 1969, when I went to Berkeley by way of San Francisco, and was able to observe firsthand the protest movements of the students in California, which met with extensive media coverage. That trip continued with the discovery of the icons and colors of the Beat Generation and the "Flower Children," thanks to the local contacts of Fernanda Pivano, a writer and the translator of the leading American authors. "Nanda" had already introduced me, from the early 1960s, to those new literary genres and the captivating psychedelic imagery of the new underground magazines of California. Finally, with a detour to the Astrodome in Houston - courtesy of NASA - I was able to celebrate the return of the astronauts from the moon, after which I returned to Italy, passing through New York. That metropolis would soon become the true center of the world, and it was no coincidence that the most lucid interpretation of the events of the start of the decade came from the futurologist from New York, Alvin Toffler, who with his book *Future Shock* in 1970 [Toffler, 1970] pertinently described the condition of impermanence and the prospects of that whole decade, foreseeing the crisis of technocracies and already envisioning the abandonment of the still dominant techno-centric culture. We need only recall the unexpected developments of the oil shock of 1973 to understand just how precise and farsighted Toffler's forecasts were at the time.

With the arrival of the new decade there were multiple signals of change. Fashion was the first field to be involved in the phenomenon that was then to trigger the collapse of saturation of colors in other sectors. In London, in fact, we had passed from the minimalist vivacity of Mary Quant to the languid and dreamy intimism of Sarah Moon, and to the seductive scenarios of Biba, with the transgressive mini department stores of Barbara Hulanicki on Kensington High Street. In cinema, Stanley Kubrick would pass, instead, from the lysergic imagery of *2001: A Space Odyssey* (1968) to the nascent youthful deviations of *A Clockwork Orange* (1971). The new decade began with more frequent trips, on my part, between the Olivetti offices in Milan and London, where I was developing my ambitious project on the *Red Books* (Figure 7), the institutional identity manuals of Olivetti. London, besides being the city where my children were born, from 1970 to 1972, had become the worldwide capital of many of the events that were to influence the history of music and entertainment, as well as the production of new glamour merchandise for young tastes, at the two centers of Kings Road and Carnaby Street.

Figure 7. Olivetti Red Books, 1969-1974.

The Corporate Identity manuals of Olivetti, known as the Red Books*, were the first operative manuals developed in a meta-design form by Trini Castelli. They are therefore true "cookbooks" capable of guiding other designers in the combination and measurement of the identifying ingredients of Olivetti. These were manuals prepared in an extensive and propositional way, full of "open" operative solutions, quite different from the intensive "menu-manuals" of Paul Rand for IBM. The latter imposed only choices between "closed" design solutions, which though they were extraordinary in quality were also limited to a few preset options. The new concepts would make the formula of operating manuals a true novelty in the sector.*

5. CMF Design & Forecasting

In the meantime, Milan was preparing to become an international focal point for fashion, as well as for industrial design and the emerging *CMF Design (Color, Materials, Finishes).* This activity was indicated with the acronym, which since 1981 I would use to define the projects on "*soft redesign*" of systemic products, such as those of Herman Miller for the office. With that company, at the XV Neocon in Chicago in 1983, I received the *Best in the Mart* award for the installation of the *Cathedral Office* (Figure 8). John Naisbitt immediately grasped the innovation of that project-setting created for Neocon. In his book *Megatrends. Ten New Directions Transforming Our Lives* [Naisbitt, 1982], Naisbitt suggested a vision of the future which he defined as "High Touch", in keeping with my principle of "emotionally touching," aimed at the humanization of technology through the deep touch of qualistics. In this way, the transcendent image of the Cathedral Office was released from the current of technicism of the time, entering a sort of celebration of nature that was better suited to the new rituals of work in the office, as opposed to the accent on "High Tech" performance.

Figure 8. The Cathedral Office. Dark and Light Versions, 1983.

Details of the installation of the Cathedral Office of Herman Miller for the Chicago Merchandise Mart at Neocon 15, 1983. Awarded as the showroom Best in the Mart, the large installation by Trini Castelli - through the theatrical and transcendent use of the components of the office furnishing system - visualized the aspects of the new composite High Touch language. This was based on the novel principle of a profound touch of emotions, aimed at the humanization of technology. In this way, the transcendent image of the Cathedral Office was shifted away from the technicism of the time, instead entering a sort of celebrative nature, better suited to the rituals of a new idea of office work.

Returning from Chicago to Milan, leafing through Color & Human Response [Birren, 1978], a book by Faber Birren on color in psychedelic culture, I found an image that left me speechless: it showed a young couple dancing on a cube at the Electric Circus in New York, a woman in a long lace gown, and a man in a two-tone jacket. The book, headed for the nascent library of the ColorTerminal, had been published in 1978, the same year in which I had invited Birren to Milan for the Seminari Colordinamo (Figure 9). Birren, who was known as a true guru of modern chromatic culture, had chosen that image for the colors of the jacket, though it was then published in black and white. It was an incredible coincidence, because I was the young man with the blue and apple green jacket in the image. When I pointed this strange fact out to Faber Birren, he hinted at a sort of predestination: in his entire book there were only about a dozen recognizable people, at a time when the population of the world was already four billion!

Fig. 9. Operazione Colordinamo, 1975-1977

The Operazione Colordinamo (Colordinamo Operation), which took place mostly from 1975 to 1978, is one of the first examples in Italy of research and development of color culture in the environmental field. Initiated with the Centro Design Montefibre, the Operazione Colordinamo operation gave rise to seminars, exhibitions and the well-known manuals for professional use, which were the first tool of orientation in the field of color design in Italy, published from 1975 to 1977. The first Colordinamo manual [*Trini Castelli et al., 1975*]*, in 1975, from which the poster is taken, was entirely devoted to the color of energy and the advent of RGB additive synthesis.*

All the research conducted in the context of these Chroma Surveys had the main aim of identifying the “driving” chromatic languages of historical trends, which from the 1920s onward could be connected to their respective decades. The analysis of the variations of those chromatic trends, detected from their earliest manifestations, had already permitted me to observe how the color presences changed in the passage from one decade to the next, offering an effective way of understanding the origin and evolving nature of color languages as they emerge. This research would then lead to the development of the Umbrella Diagram [Trini Castelli, 1983], a tool owned by Castelli Design that was introduced at the start of the 1980s, which has enabled me to predict - far in advance - the changes that would take place regarding the identity of colors, new materials and emerging finishes.

The research has also had the aim of orienting designers in the assignment of colors to products, according to proper criteria of sustainability, in both industrial design and space design. This is also a response to the large quantities of discarded products, caused by errors in the strictly subjective chromatic choices in areas of consumption that are sometimes lacking in sufficient awareness. In 1986 all this led to the formulation of Qualistics (initially defined as an “ecology of emotional consumption”), which has effectively proven to be useful to orient unresolved project themes, addressed by new qualifying practices which today we would define as “eco-sustainable”.

From the mid-1970s to the end of the 1990s, the world of design - not just in Italy - was faced by the need to define new qualitative standards (today we would say “qualistic”) for products whose identity had to be increasingly articulated in a subjective sense. The challenge, as always, was to remain within the “design culture”, adopting CMF design strategies, such as the introduction of the Color Matrix, appropriately modulated according to the inclusive strength of the meta-project (Figure 10).

Fig. 10. Herman Miller Color Library (based on the Color Matrix), 1981

The Color-Matrix was introduced by Trini Castelli in 1978 and applied for the first time to the Lancia Color System, a CMF design project entirely based on this innovative meta-project tool. The Color Matrix is also the basis of the Herman Miller Color Library, the first major CMF project created for the entire production of Herman Miller furniture and systems (1981-1984). It allowed multiple alternative color combinations aimed at satisfying the different aesthetic preferences of users. A paradigmatic change, which has allowed us to exploit coded color families to create alternative combinations in a systemic way, overcoming the old "intensive" concept of the color chart to adhere to the new "extensive" vision of the Color Matrix, fully logical and practicable only through the meta-project. The colors of the matrices were finally conceived as immanent entities, as independent color notations that could adhere to any shape and whose application remained open and well-coordinated.

6. Chroma Survey – Modes and Methods

From those years, it is worth recalling two authoritative viewpoints in the debate on how to approach the practice of design: for Ettore Sottsass it was important to steer clear of the “underpinning” of the methodology, with its corollary of previously established rules. For Alessandro Mendini, on the other hand, it was necessary to “deconstruct” the concept of modality. He consolidated this position in 1977 with the founding of the design magazine Modo, through the idea of looking more closely at the “making”, the direct experience of reality, a property that upon closer examination was already intrinsic precisely to the themes of color design [Trini Castelli, 2021]. This research began, in fact, with the observation of a clear variance between the figurative languages of fashion and those of design, which tended to diverge more and more. A theme to investigate more deeply, on a professional level, through a simple but effective format, capable of permitting the carrying out of activities in keeping with conventional modes, such as research “in the field,” elaboration “in the studio,” and development “in the laboratory.”

The activities in the field, conducted in alternating phases and across very wide time spans, were fundamental to make this survey, which began with the above-mentioned travels in the United States, which enabled an intense activity of collection of design data and materials. After this, from 1970 to 1973, all the activities in the field and those in the studio continued, for the most part, in Milan and London. The development in the studio of the “Color Fever” Chroma Survey was instead completed in just one year, 1978, with the gathering of data and the related documentation. In 1979, there was also added the incredible experience of my mission in China [Trini Castelli, 2019] for the chemical corporation Montedison. This was at the beginning of the opening of China’s borders to foreigners, and in an area of the trade fair of Wuhan, a series of pilot plants were launched for the molding of small and large articles in plastic, the first objects of that type produced in the thousands of years of Chinese history.

From 1978, the observations of the initial Chroma Survey of the early 1970s were reapplied in relation only to the colors of automotive paints, visualized through the “Color Fever” Chroma Survey diagram. This had the aim of detecting the levels of saturation of paint in the cars available on the French market from 1968 to 1979, a choice based mainly on the variety and number of automotive brands still active in that country at the time. Finally, the development in the laboratory was instead a totally new activity, begun in 1978 with the creation of the ColorTerminal and the use of the Graphicolor tool, which made it possible to exploit the digital processing of RGB color synthesis, applied in a nascent state.

7. Chroma Survey Conclusion

In the 1960s, with the advent of color television, and in the 1970s, with the further spread of new electronic media, we passed from the exclusive use of subtractive color synthesis to the widespread application of RGB additive synthesis, a way of generating color that had never previously been utilized. Rarer in nature, additive synthesis revealed its efficacy as a new mode of chromatic interaction. This was an event that was to impact the history of art and design with substantial changes, also on an anthropological level. With the use of additive synthesis, color forcefully entered the kingdom of darkness, also saturating the hours of the night with autogenous chromatic shadings never seen before.

8. Acknowledgment

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A special thanks in memory of my assistant Antonio Petrillo, who developed the original collection and reporting of the data from the Automotive Chroma Survey in 1979.

I would also like to thank Esperanza Nunez and Daniela Domina, who at different times contributed to the completion of the history of this research, and to Stephen Piccolo for his English translations of all my texts over the decades.

9. Short biography of the author(s)

Clino Trini Castelli - (b. 1944) designer, artist and design theorist lives and works in Milan. Internationally known for CMF design (Color, Material and Finishes) of which he was the initiator, Castelli introduced the "No-form" renewal of plastic languages applied to industrial products through the tools of Design Primario. As opposed to traditional compositional methods, Clino Trini Castelli has focused on the design of the more intangible aspects of figuration, like color and material, light and sound, emphasizing the virtues of a sensorial approach to art and design. Since the early 1970s this has made him a pioneer in research on the emotional identity of products in the industrial sector. His work has received important European, American, Japanese prizes, including two ADI Compasso d’Oro awards and the AIC Award for Color in Art, Design and Environment.

Licensing terms

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