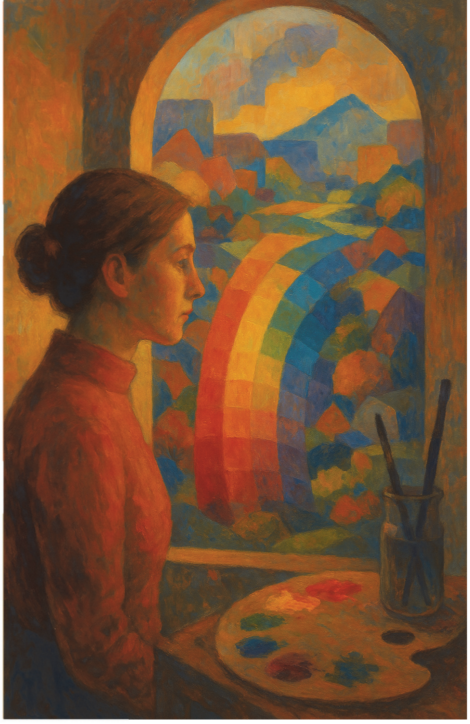

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ANVUR Agenzia Nazionale Valutazione sistema Universitario e Ricerca
APeJ Academic Publications eJournal
BASE Bielefeld Academic Search Engine
DBH Database for statistikk om høyere utdanning
DOAJ Directory of Open Access Journals
EZB Elektronische Zeitschriftenbibliothek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

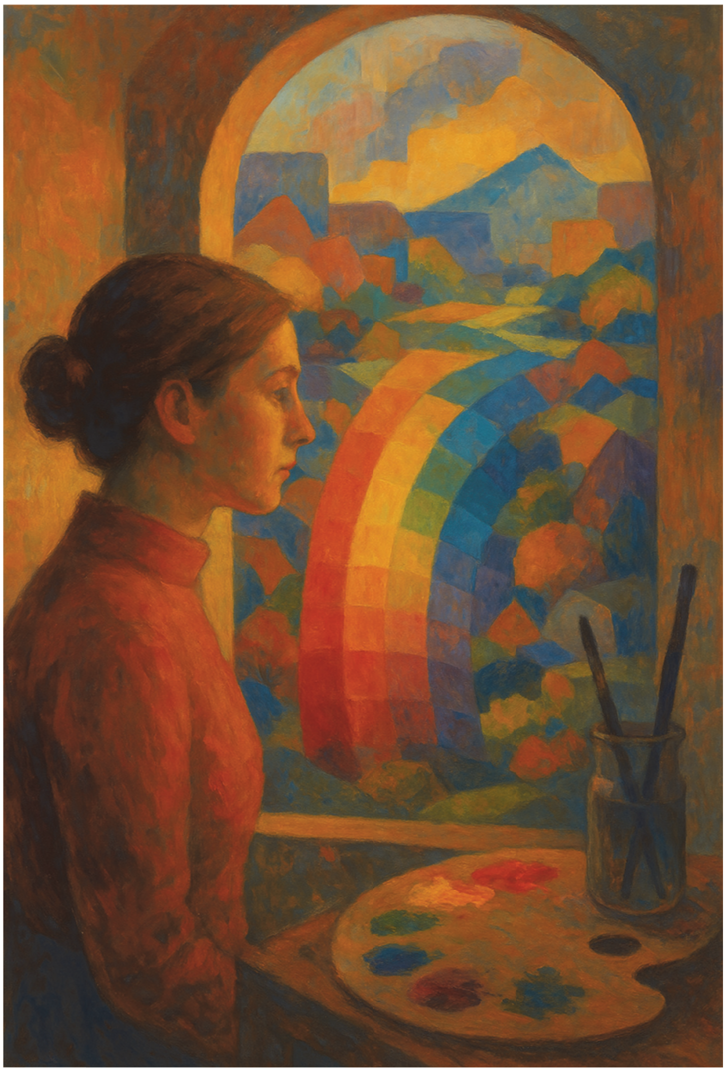
TOPICS / DISCIPLINES
The CCSJ accept papers on a wide range of topics on color, including and not limited to the following:
1. Color and Measurement/Instrumentation. Colorimetry, photometry and color atlas: method, theory and instrumentation; quality control and food coloring, dyes, organic and sustainable 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.

Table of Contents

Color Maps: Research Themes and Trajectories

Editor's note

Dear Esteemed Readers[1],



Issue 17(1) of the "Color Culture and Science – Cultura e Scienza del Colore Journal – CCSJ" brings together nine contributions that testify to the vitality and plurality of approaches with which color continues to be the object of study and reflection in the most diverse disciplinary fields. The essays presented here embrace a broad and articulated thematic arc, ranging from visual perception and sensorial correspondences to sustainable and inclusive design aesthetics through communication strategies in the financial, marketing, and cultural fields, up to the conservation of photographic heritage and critical reflection on chromatic symbolism. A common thread emerges clearly: the centrality of color as a tool of meaning and as a mediator between perception, culture, and technology.

The set of contributions offers an updated and in-depth overview of current research on color, through methodologies that intertwine empirical investigation, semiotic analysis, visual experimentation, study of design practices, and technical-scientific evaluation of materials. This variety reflects the intrinsically transdisciplinary nature of color studies, which are fueled by the dialogue between the hard sciences and the human sciences, between laboratory experimentation and

[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.

field applications, and between the most advanced technologies and the symbolic and anthropological dimension.

This issue features both studies that explore new applications and meanings attributed to color in emerging fields — such as the economics of sustainability or sensory marketing — and research that delves into consolidated but still little-investigated phenomena, such as the color experience of people with visual impairments or the preservation of photographic materials of great artistic value. The picture is completed by a dense and culturally sophisticated monograph on the color pink and its connection with gender issues, as well as pioneering research on color symbolism in the financial field.

The issue is, therefore, configured as a coherent and stimulating mosaic, capable of reflecting the wealth of perspectives with which color continues to be questioned in contemporary times.

The fact that color is more than just a visual phenomenon is becoming increasingly apparent. Rather, it is a multifaceted prism that allows us to perceive, speak, and comprehend the world. As we examine the diverse fields of color science and its many uses, this becomes clear. In addition to fostering a deeper comprehension of the intricate web of life and its profound impacts on science, society, and culture, the papers in this issue aim to encourage more research, dialogue, and collaboration.

Colorful regards,

April 2025
The Editor-in-Chief
Maurizio Rossi, MSc, PhD
Full professor of Design
Politecnico di Milano

Interpreting colour symbolism in finance-insights of financial experts

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ABSTRACT

The main objective of this study is to identify the perception of colour meanings with 'finance' among a group of financial experts. As the research method a diagnostic survey conducted using the Computer-Assisted Web Interviewing (CAWI). The analysed colours included the 11 basic colour terms in English (black, white, red, green, yellow, blue, brown, orange, pink, purple, grey) plus two others (silver and golden). After cleaning up the primary results 60 responses were obtained. For 9 out of 13 colours, significant associations with ‘finance’ were obtained with the following meanings: black - Illegal/Unethical Financial Activities and Black Market, blue - Marine/Ocean Conservation Finance, brown - Non-Ecological/Non-Green Finance, green - Environmentally Friendly Finance/Ecological Finance and ESG Finance, grey - Shadow Economy and Unregulated Markets, golden - Long-term Savings, Wealth, Luxury, Leading Financial Products, pink - Gender-related financing, red - Negative Financial Results/High Risk/Insolvency, silver - Elderly Finance/Silver Economy. In addition, a large number of respondents associated the colour white with Ethical/Transparent Finance. The remaining three colours did not show any significant connotations with finance. To the best of the author’s knowledge, this is the first study of colour symbolism in finance conducted among financial experts and one of the few in this scientific field.

KEYWORDS colour symbolism in finance; behavioural finance; visual finance

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1. Introduction

Among the primary purposes which accompany the use of colours are aesthetics and decoration. However, colours also have a symbolic meaning, i.e. they can carry their own semantic spiritual and social expression, present a message, create identity, depict psychological states, and act as a symbol of specific ideas and a value paradigm (Mikitchenko, 2016; Kaimal et al., 2022; Kudrya-Marais and Olalere, 2022a).

It is worth mentioning that colours are considered not in isolation, but mainly in contrasting pairs or sequences (Hunt, 2006). In line with Kudrya-Marais and Olalere (2022c), colour has three different sources: emotional, socio-economic and cultural. Novikova and Novikov (2021), for example, emphasise that the features of the cultural codes of multilingual space indicate that both positive and negative connotations of each colour are linked to socio-mental determinants of sociocultural factors. According to Pansat and Khalikova (2023), the realm of colour symbolism goes beyond the linguistic sphere to offer insights into human civilisation, the natural world, moral values, emotions and the human psyche. Colours can take on various connotations in different situations, and in diverse societies, change over time and influence human behaviour and cognitive processes in different ways (Elliot & Maier, 2014). Moreover, in various cultures the same colour can have a positive or negative meaning (Yu, 2014). Similarly, colours can have varying meanings in different areas, e.g. finance, literature, art, etc.

There are three main theories of colour association, i.e. 1) colour-emotion association theory; 2) colour-object association theory and 3) colour-in-context theory (Tham et al., 2019). In line with the first theory, specific colours are associated with the perception of a particular type of emotion and influence psychological functioning (Gil and Le Bigot, 2016). This is culturally dependent, but, for example, according to the Global Color Survey, yellow is most associated with happiness (Global Color Survey - Colorcom, https://www.colorcom.com/global-color-survey). Based on the second theory, it can be inferred that people associate given colours with objects, whereby their meaning can, among other things, be culturally conditioned (e.g. in Chinese, "wearing a green hat" symbolises unfaithfulness - Tham et al., 2019) or colour preferences arise from people's average affective responses to colour-associated objects (Ecological Valance Theory) - people like/dislike colours associated with objects they like/dislike (Palmer and Schloss, 2010). According to the third theory, the meaning of colours changes with a specific context. For example, green in finance, from the point of view of investment projects, will signify financial decisions related to implementing environmentally friendly investments. In the stock market, on the other hand, green marks investments whose prices are rising. However it is worth to mention that in Asia countries the meaning is opposite, i.e. green is used to show that prices are decreasing.

Colour symbolism dates back to prehistoric times and is present everywhere (Watts, 2015). Research into the meaning of colours has been undertaken in many scientific fields, but numerous unidentified areas can still be identified. Among these, finance, where colours play an essential role. To date, there has not been much research on the meaning of colours in the aforementioned scientific discipline, meaning there is a research gap. The authors undertook this task, and the study's main aim was to identify the perception of colour meanings with “finance” among a group of financial experts. Accordingly, the following research questions were posed: 1) What colours show meaning with “finance”? 2) What is the meaning of individual colours with “finance”? 3) Are the meanings of the individual colours universal (a particular colour has only one meaning) or are they diverse (in the case of multiple meanings, the aim was to identify dominant and secondary meanings)? A diagnostic survey conducted using the CAWI (Computer-Assisted Web Interviewing) method on a purposive sample was used as the research method. The findings add value to colour symbolism theory, behavioural finance and visual finance.

Besides the introduction, the structure of the article is as follows. The second part contains the research results in the literature review field on colour symbolism in various scientific areas. The next section presents the empirical research of this paper, divided into a methodological part and results. The last part discusses the study’s findings and limitations.

2. Literature Review

A significant role in the study of colour symbolism is attributed to Michel Pastoureau, who analysed the meaning of colours and how it changed over time. His studies include the colours red, black, blue, yellow, white and green, among others, and his findings are included in monographs (Pastoureau 2023, 2019, 2018, 2017, 2014, 2008). A major contribution to the development of colour theory and its influence on the formation of emotions and mood was made by Johannes Itten (1970, 1997). Faber Birren (1988) and John Gage (1999) have also addressed color symbolism in different areas of life and science. Research on colour symbolism is also presented at conferences organised under the auspices of the International Colour Association, and the results are included in proceedings (see, e.g., Kwiatkowska-

Lubanska 2022, Singh 2022, Pereira 2000, Bonnardel et al. 2018). Professional journals, i.e., Color Research and Application (see e.g., publications: Epicoco et al. 2024; Baniani 2022; Demir 2020; Güneş & Olguntürk 2019) and Color Culture and Science Journal (see e.g., publications: Broeder 2022; Barbato et al. 2019; Tallarita 2017), also play an essential role in disseminating knowledge about colour symbolism. However, in the authors' known publications (except Prusak and Mushafiq 2023), research on colour symbolism in finance has not been recorded. To deepen the literature research, a systematic literature review was additionally carried out to verify whether there are publications on this topic.

The two most popular and reputable databases in science, i.e. Web of Science and Scopus, were used as the primary sources. The publication search process was performed as of 26.10.2023. In the Web of Science database, the search was performed with consideration of All Fields, while in the Scopus database, the search was performed according to the field Article Title, Abstract, Keywords. The search was not limited in terms of time nor the type of publication and language. Publications that directly addressed the issue of colour symbolism in finance were searched for first, using the following search strategies: 1) "Color Symbolism" AND Finance, 2) "Colour Symbolism" AND Finance. The use of both approaches was due to different spellings of the word "colour" in American (color) and British English (colour). Unfortunately, no result was obtained. Therefore, the second focus was to search publications from the field of colour symbolism to identify possible indirect relationships with the word finance. In this case, 1) "Color Symbolism" and 2) "Colour Symbolism" were used as search strategies. The selection of publications to conduct the literature review was done using the PRIMSA statement 2020 concept (Page et al., 2021), as shown in Figure 1. Ultimately, 107 publications were analysed. In many cases, the publications were interdisciplinary, i.e. related to different scientific disciplines. Table 1 summarises basic information about the analysed publications, grouping them into key areas of interest (from the largest to the smallest number of publications). Publications not directly reflected in the identified areas are shown in the group 'Others' at the end of Table 1. It can be seen that colour symbolism applies to many research areas and goes back many years. Among the most popular are: literature; anthropology; linguistics; art; psychology; architecture and landscapes; costumes; film, musical and theatre.

Of these publications, none of them dealt with colour symbolism in finance. Only two articles mentioned broad economic issues regarding the topic under study. These dealt with marketing issues in the cosmetics industry (Bryce et al., 2023) and the influence of socio-economic factors on perceptions of the importance of medicines in Zambia (Schumaker and Bond, 2008).

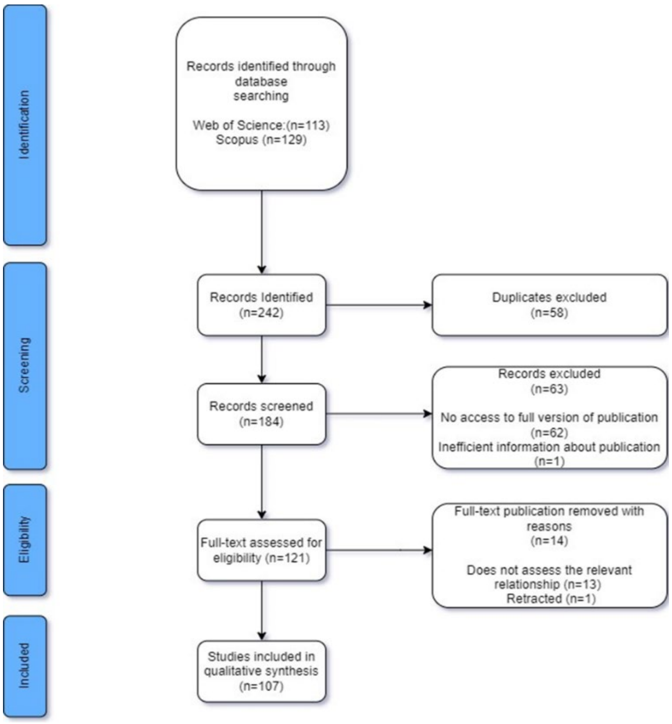

Fig 1. PRISMA flow chart of the conducted systematic literature review
Source: Authors' elaboration.

Scientific fields	Literature sources
Literature (n=25)	(Beckman, 1976); (Ryan, 1976); (Monk, 1977); (Pollard, 1981); (Biggam, 1993); (Yildirim, 2006); (Agırel, 2009); (Mikhalenko, 2014); (Tarasova, 2014); (Ziod and Zawahreh, 2014); (Hristu, 2015); (Schmiesing, 2016); (Tolasova and Abisalova, 2017); (De Argüelles, 2018); (Bozick, 2019); (Østermark-Johansen, 2020); (Khotamovich and Turonovich, 2020); (Brzozowska, 2021); (Cong and Chistyakov,

	2021); (Yoon, 2021); (Darder, 2022); (Klypina and Shestakova, 2022); (Wijitsopon, 2022); (Hashemi, 2023); (Voronichev and Voronicheva, 2023).
Nations, communities and societies (anthropology) (n=22)	(Urry, 1969); (Breidenbach, 1976); (Needham, 1979); (Searle-Chatterjee, 1981); (Milicic, 1989); (Kiernan, 1991); (Wickler and Seibt, 1995); (Hutchings, 1997); (Hunt, 2006), (Hunt and Chenciner, 2006); (Tao, 2007); (Mamynova et al., 2014); (Mikitchenko, 2016); (Sagiv, 2017); (Batyanova, 2018); (Russell, 2019); (Derzhavina et al., 2020); (Motsamayi, 2020); (Andreevich, 2021); (Kudrya-Marais and Olalere, 2022 a,b,c).
Linguistics (n=13)	(Gabysheva, 2016); (Mukhamadiarova, 2016); (Guryanov, 2017); (Yakovleva et al., 2017); (Driga, 2018); (Blinova, 2019); (Grodska et al., 2020); (Novikova and Novikov, 2021); (Elewa, 2022); (Kartashkova and Belyaeva, 2022); (Khassenov, 2022); (Alharbi, 2023); (Rambiert-Kwasniewska, 2023).
Art (n=10)	(Plog, 2003); (Geschwind, 2013); (Brecoulaki, 2014); (Hollmann, 2015); (Muthesius, 2016); (Petzold, 2018); (Tsyganova and Mannin, 2018); (Zuiddam, 2018); (Kass, 2020); (Patton, 2022).
Costumes (n=6)	(Hayward, 2015); (Bakaeva, 2016); (Bakieva and Popova, 2019 and 2022); (Bakieva, 2020); (Minina, 2021).
Architecture and Landscapes (n=5)	(Jones, 1999); (Erdogu and Ulubey, 2011); (Couacaud, 2016); (Miller et al., 2022); (Lavrenova, 2023).
Psychology (n=5)	(Obonai and Matsuoka, 1956); (Oyama et al., 1963); (Duckitt et al., 1999); (Karotovskaya, 2019); (Kaimal et al., 2022).
Film, musical, theatre (n=4)	(Lee, 2000); (Evans, 2005); (Candel, 2018); (Shirieva and Dyganova, 2015).
Others (n=17)	
Colour symbolism can also be used to create toponyms, including oikonyms. Research in this area was carried out using Bashkir toponyms and Polish oikonyms.	(Bukharova, 2016); (Stachowski, 2018); (Khisamitdinova et al., 2019).
The articles address the use of various symbols, including colour symbolism, in electoral campaigns (presidential and Europarliamentary elections) in Romania.	(Buja, 2015); (Tocia, 2019).
Colour symbolism also plays an essential role in cartography, i.e. in the creation of maps, including crisis maps.	(Kaye et al., 2012); (Divjak and Kuveždić, 2018).
Regarding cultural, historical research on colour, with examples from Hungary, the author proves that specific colours, such as yellow, show differentiated meanings in connection with other colours, such as black and green.	(Bálizs, 2021)

The author analysed the official colours of 29 Chinese regimes. Based on the results, the official colour can sometimes be naturally determined according to the substance of the ruling population, sometimes politically determined according to the fifth property of Chinese metaphysics or some national or revolutionary symbols.	(Gao, 2012)
Within this article, the authors attempt to prove from the ochre record from Qafzeh Cave that colour symbolism can go back to prehistoric times, i.e. around 92,000 years ago.	(Hovers et al., 2003)
This article shows the results of a study on the association of odour and colour in three nationality groups (French, Lebanese, Taiwanese). Based on the research, the authors highlight the role of culture and culinary habits in evaluating edibility and colour associations of certain odours in different nationalities.	(Nehmé et al., 2016)
The article refers to the analysis of colour symbolism in the cosmetics industry. It deals with branding and packaging design concerning the use of so-called sakura in this industry.	(Bryce et al., 2023)
The increased presence of 'ochre' in the African Middle Stone Age context, along with changes in human biology and behaviour, has been used to support the hypothesis that 'modern' cognitive abilities originated in Africa. The consistent use of ochre has been interpreted as evidence of colour symbolism, an alternate source of language origins and a defining aspect of 'modern' human behaviour.	(Rifkin, 2012)
The socio-economic context influences, among other things, the perceived importance of drug colours. Differences in the colour of medicines in relation to patients' expectations raise concerns about their efficacy, toxicity, side effects, etc. An analogous effect is associated with the shape and size of medicines. This was the conclusion reached by the authors of a study conducted in Zambia.	(Schumaker and Bond, 2008)
The paper examines the symbolism of the colour blue through the example of Leicester City Football Club. The study shows that colour could give place to identity through branding practices, identity mediation, and visual culture formation.	(Xu, 2019)
Colour symbolism plays an important role when designing interiors. It is essential to consider individual preferences when designing interiors, including cultural, geographical, economic and psychological contexts.	(Haller, 2017)
In this chapter, the author refers to various evolutionary theories to show early colour symbolism.	(Watts, 2015)

Tab 1. Summary of results from the systematic literature review
Source: Authors' elaboration.

3. Empirical Research

3.1. *Methodology*

The study aims to fill a research gap in colour symbolism, behavioural finance and visual finance. Colour symbolism plays a significant role in the financial industry, influencing decision-making processes, branding and overall communication (Leong et al., 2019; Bazley et al., 2021). As the main objective of our study, we proposed to identify the perception of colour meanings with 'finance' among a group of financial experts. Accordingly, the following research questions were posed: 1) Which colours show meaning with 'finance'? 2) What are the meanings of the individual colours with 'finance'? 3) Are the meanings of the different colours universal (a colour has only one meaning) or are they diverse (in the case of multiple meanings, the aim was to identify dominant and secondary meanings)? We included academics working in the field of finance and people working in the financial sector or in the finance departments of various organisations. A diagnostic survey conducted using the Computer-Assisted Web Interviewing (CAWI) method on a purposive sample was used as the research method. The survey questionnaire was developed in English, considered the lingua franca of business and academia, and is presented in the Appendix. In addition to the metric section, open-ended questions on the perceived meaning of the different colours with the word 'finance' were used. This form of question was used because the study's authors wanted to avoid suggesting any answers to the respondents. The analysis included the 11 basic colour terms in English (black, white, red, green, yellow, blue, brown, orange, pink, purple, grey) (Davis & Corbett, 1995) plus two others (silver and golden) which, based on the knowledge and 23 years of experience of one of the authors of this study in academic work covering the areas of economics, finance and management, had connotations with other academic disciplines related to finance. In addition, respondents were allowed to indicate additional colours that show meaning in association with the word finance. Each respondent was able to provide more than 1 association of a specific colour with finance and there was a possibility to skip the question if the respondent could not think of any association. The maximum number of answers for each colour was equal to 3. To analyse the colour associations, we have divided the responses into given groups of responses called clusters and each response is treated as a standalone response. The threshold for creating a cluster is two similar responses. Apart from typical clusters, we created two specific clusters called “Other” and “Lacks a single association”. The cluster titled “Lacks a single association” is similar to the cluster “Other”; however, it is used instead of the “Other” cluster as it is the most dominant in comparison to all other clusters. This distinction allows us to show whether there are any relevant meanings for a given colour or not. Moreover, in order to determine that a given colour meaning is relevant, two boundary conditions were defined, which should be met simultaneously, i.e. responses as a percentage of total responses should be higher than 25% and responses as a percentage of total respondents should exceed 20%. This approach is based on the fact that the connotation should be relevant to the colour but should also account for a fair number of responses among all respondents. The request to complete the survey and to disseminate information about this study to other colleagues and acquaintances was sent by email to academics working in the broad field of finance, including: heads of finance departments, scientists and lecturers, editors of academic finance journals, national and international finance associations, ministries of finance, major global financial institutions. In total, over 1000 requests to experts from all continents except Antarctica were sent. Information about the survey was also posted on the authors' profiles on ResearchGate and LinkedIn. The survery was conducted in two rounds, i.e., 1) September 2023 – Feburary 2024; 2) August 2024- October 2024 and 75 completed questionnaires were obtained. Bearing in mind that respondents could only indicate meaning for the colours they selected, this means that the number of responses for each colour varies. Out of the above-mentioned, 15 surveys were discarded as they were erroneous. Moreover, we cleaned up the results by removing unintelligible answers.

3.2. *Results*

The demographics of 60 responses are presented in Figures from 2 to 7. Majority respondents are from the age group 35 to 54. Relatively few young and elder people took part in the survey (Figure 2).

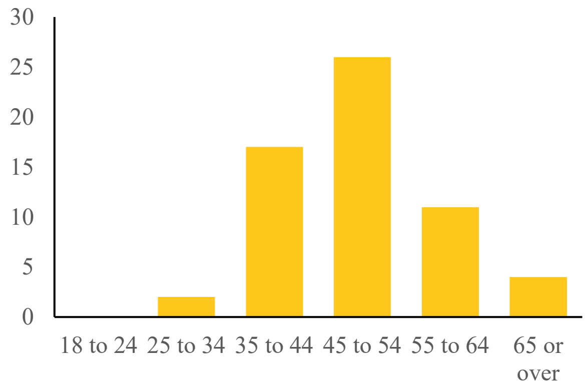

Fig 2. Age groups of the respondents
Source: Authors’ elaboration.

Figure 3 presents the nationality of the respondents. The majority of the respondents are from Poland, comprising 26 responses from the total sample. Most of the others are from European countries. This means that Europeans dominated among the respondents. However, this study also included responses from Brazil, China, Chile, India, Pakistan, Jordan and United States.

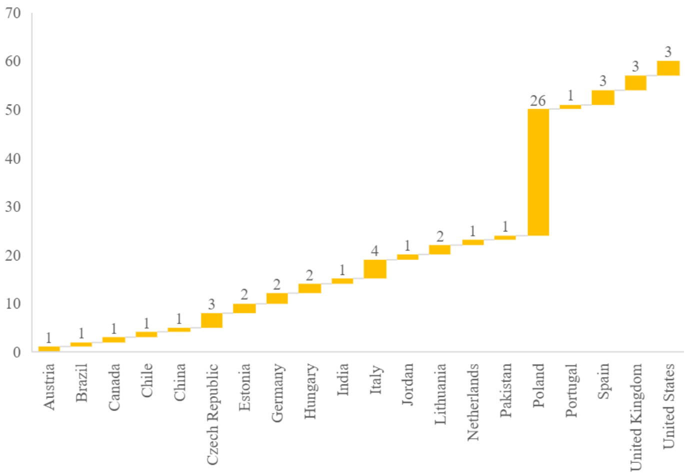

Fig 3. Nationality of the respondents
Source: Authors' elaboration.

Figure 4 shows the gender of the respondents; in total 36 respondents were male (60%) and 24 respondents were female (40%). Figure 5 shows the highest level of education of the respondents. The majority, 51 (85%), of the respondents had a doctorate (PhD) degree, 5 (8%) respondents had habilitation (DSc) after a doctorate and 4 (7%) respondents had a master's (MA, MSc) degree.

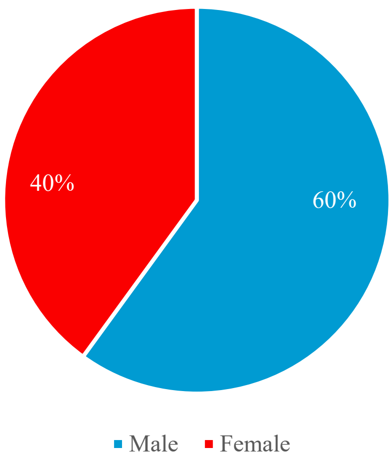

Fig 4. Gender of the respondents
Source: Authors' elaboration.

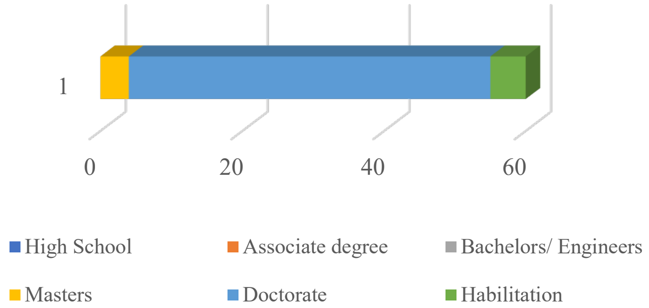

Fig 5. Education of the respondents
Source: Authors' elaboration.

According to Figure 6, 90% of the respondents belonged to academia and 10% of the respondents are from industry, which means a clear advantage of the former.

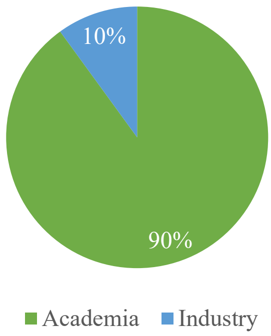

Fig 6. Field of work of the respondents
Source: Authors' elaboration.

Lastly, Figure 7 presents the respondents' experience in the field of work. The majority (63%) of the respondents had more than 15 years of experience, followed by respondents with 10 to 15 years (15%) and 5 to 10 years (10%) of experience. The remaining respondents had experience of under 2 years (5%) and of 2 to 5 years (7%).

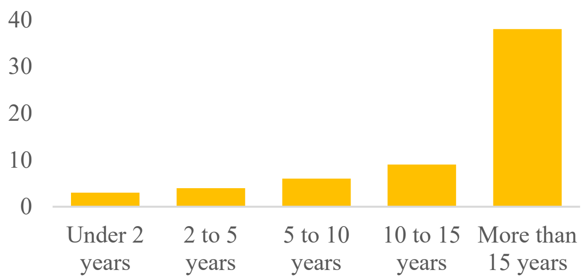

Fig 7. Work experience of the respondents
Source: Authors' elaboration.

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Table 2 presents the responses of each colour meaning in accordance with "finance". Bold font indicates relevant colour associations.

The colour *black* had major responses for 5 clusters, the most dominant cluster being "Illegal/Unethical Financial Activities and Black Market" with 37 responses. In this context, respondents mainly mentioned illegal transactions, including but not limited to financial fraud and money laundering. In addition, also mentioned were: giving wrong recommendations by banks with the aim to maximise earnings; economic activities that occur outside the official channels and are typically unregulated and untaxed; finance associated with crime, narco business, human and arms trafficking and terrorism; double accountancy; unreported transactions; tax avoidance. Another three clusters with fewer responses included the association of the colour black with: 1) the concept of the black swan proposed by Nasim Taleb [According to Taleb (2015), it is an event characterised by three attributes, i.e. it is unusual and very rare, it has a very large impact on its environment, and explanations are created for it after the fact, so that it becomes explainable and predictable.], 2) financial services dedicated for black people, 3) positive results in accounting (the idiom *in the black* refers to the situation where there is a profit or positive balance). Individual associations included: financial markets in less developed countries, credit cards, derivatives, safe financial services, financial products related to accounting.

The colour *blue* had 4 clusters and one "Other" cluster representing responses that had no similarities with other responses. 1) "Marine/Ocean Conservation Finance" was formed based on 14 responses and it is the most dominant cluster. It refers to financial activities done in the marine industry. Blue is associated with water (sea, ocean) in this context. Individual respondents, in addition to indicating an association of this colour with water, also mentioned sky and gas. Several indicated that blue finance is part of socially responsible finance. The second cluster "Traditional Finance Activities" is based on 8 responses and respondents mentioned here: financial activities realised by Deutsche Bank, associations with the classical financial sector (banks, investment firms), bonds and loans, corporate finance and normal financing tasks in business. The third cluster "Innovation and Technology in Finance" had 5 responses and the colour blue is associated with innovative finance, in which AI and big data are used. It also refers to start-ups and new businesses. Three responses indicated a reference to climate as the main symbolism. In eight cases, the associations were isolated from previous ones and people pointed to: financing electricity; blue collar workers; high risk; promising and complex investments; blue-chip finance; finance associated with heaven; blue ocean strategy applied to finance; finance associated with stability, trust and reliability; excellent results in finance.

Colour	Cluster	Response count	Responses as a percentage of the total responses of each colour	Responses as a percentage of the total respondents
Black	**Illegal/Unethical Financial Activities and Black Market**	**37**	**67%**	**62%**
	Black Swan Concept	4	7%	7%
	Financial Services for Black People	4	7%	7%
	Positive Results in Accounting	3	6%	5%
	Other	7	13%	12%
	Total Responses	55	100%	93%
Blue	**Marine/Ocean Conservation Finance**	**14**	**37%**	**23%**
	Traditional Finance Activities	8	21%	13%
	Innovation and Technology in Finance	5	13%	8%
	Climate Finance	3	8%	5%
	Other	8	21%	13%
	Total Responses	38	100%	62%
Brown	**Non-Ecological/Non-Green Finance**	**14**	**54%**	**23%**
	Risk, Investment and Financing	7	27%	12%
	Other	5	19%	8%
	Total Responses	26	100%	43%

Green	**Environmentally Friendly Finance/Ecological Finance**	**36**	**59%**	**60%**
	ESG Finance	**18**	**30%**	**30%**
	Positive Results, Prosperity	3	5%	5%
	Other	4	6%	7%
	Total Responses	61	100%	102%
Golden	**Long-term Savings, Wealth, Luxury, Leading Financial Products**	**21**	**57%**	**35%**
	Investment in Gold	9	24%	15%
	Other	7	19%	12%
	Total Responses	37	100%	62%
Grey	**Shadow Economy and Unregulated Markets**	**23**	**74%**	**38%**
	Saving for Retirement and Finances of the Elderly	4	13%	7%
	Other	4	13%	7%
	Total Responses	31	100%	52%
Orange	Lacks a Single Association	8	53%	13%
	Banks/Banking related Products	5	33%	8%
	Finance of Young People	2	14%	3%
	Total Responses	15	100%	24%
Pink	**Gender-related financing**	**14**	**64%**	**23%**
	Leisure/Fashion Financing	2	9%	3%
	Other	6	27%	10%
	Total Responses	22	100%	36%
Purple	Lacks a Single Association	7	60%	12%
	Church Financing	2	20%	3%
	Finance related to Luxury	2	20%	3%
	No association	2	20%	3%
	Total Responses	13	100%	21%
Red	**Negative Financial Results/High Risk/Insolvency**	**16**	**52%**	**27%**
	Communist Finance	3	9,5%	5%
	Finance in Erotic Business	2	6,5%	3%
	Activities of Banks and other Financial Institutions	2	6,5%	3%
	In China, red signifies success or good luck, including in financial markets. The colour red depicts price increases in the financial markets.	2	6,5%	3%
	Other	6	19%	10%
	Total Responses	31	100%	51%
Silver	**Elderly Finance/Silver Economy**	**22**	**81%**	**37%**
	Other	5	19%	8%
	Total Responses	27	100%	45%
White	Ethical/Transparent Finance	11	55%	18%
	Other	9	45%	15%
	Total Responses	20	100%	33%
Yellow	Lacks a Single Association	9	82%	15%
	No association	2	18%	3%
	Total Responses	11	100%	18%

Tab 2. Cluster formation based on the responses.
Source: Authors' elaboration.

When it comes to the colour *brown*, it was mostly collocated with non-ecological finance, that is, with investments in CO2-emitting projects, including those related to coal mining and the extraction of other fossil fuels. Several respondents referred to risk, financial investment and financing as those areas associated with the colour brown in finance. For them, the colour was associated with: risk, rather safe investments, hedged financial instruments, foreign direct investments or sources of financing in the form of shares. One expert indicated that there were no connotations, while four others associated this colour with energy, the circular economy, personal finance or recycling.

The primary association for the colour *green* is investment in and the financing of environmentally friendly projects. Some experts understand green finance more broadly, i.e. as sustainable finance, which includes financial activities in the area of ESG factors. In three cases, this colour is associated with positive financial performance or prosperity. This may be due to the fact that on financial portals, price increases in financial instruments are usually shown in green. The other three experts associate this colour with: DGS (deposit guarantee scheme)-oriented financing, financial instruments for less experienced investors and stock market brokers. One respondent, from China, pointed to a decline in stock prices. As mentioned earlier, this is a characteristic of this region.

The colour *golden* in finance was most often seen by experts through the prism of wealth, long-term investments, financial products prepared for VIP clients, luxury goods, and earning high income. To a lesser but nonetheless quite significant extent, it is associated with investments in gold, which are also an indicator of wealth. Among other meanings of the colour *golden* in finance, respondents perceived: the golden rule in financial analysis (fixed assets should be financed by equity capital), the Fibonacci golden sequence which is used for the creation of investment strategies, gold parity, top financial decisions, golden age (long-term economic prosperity), the Warren Buffet portfolio, big opportunities in finance.

The colour *grey* is most often associated with the shadow economy, the grey zone, activities often conducted on the edge of the law that are ethically questionable, and financial products offered on the unregulated market. In addition, four respondents pointed to connotations of saving for retirement and finances of the elderly. Other respondents indicated no relationship, options, derivatives and the financing of declining projects.

In the case of *orange*, no significant symbolism was noted. Five respondents mentioned banking products or associated the colour *orange* with the logo of a specific financial institution. Two indicated that this colour is related to young people's finances. In the other responses, this colour was associated with: funding to support Ukraine, media financing, financial services related to criminal activities, funds, financing of promising projects, self-employment and informal customer segment, finance requires caution. One respondent pointed out a lack of connotation.

The colour *pink* in finance is seen from a gender perspective. It is most often identified with women's finances. Some respondents additionally stressed that it is identified more with young females. For several experts, they indicated that it relates to the LGBT community. Two respondents indicated that it was related to the leisure and fashion industry. Other individual experts pointed to: no association, financial instruments which are bought and sold on the OTC (over-the-counter) market rather than major stock exchanges, highly ideologically backed financial products, an untrustworthy financing offer that requires vigilance, good news in finance, advisory.

No significant connotation in finance was noted for the colour *purple*. Two respondents from each cluster indicated no association, finance of the church and finance related to luxury. The other seven experts associated this colour with: finance for people with disabilities, complex and often ambiguous types of financial products, consistent returns, high risk, start-up financing, modernity and cautions.

The association of the colour *red* with finance is rather negative and is mainly considered in three overlapping aspects, i.e. losses, insolvency and high risk. To a much lesser extent, this colour is associated with communist finance and erotic business. For two experts, it is associated with the activities of banks and other financial institutions [Santander and “Sparkassen" (savings banks) in Germany]. This is most likely due to the use of the colour *red* in the logos of these organisations. Two experts pointed out cultural differences that may be due to the meaning of the colour *red*, namely in China, *red* also signifies success or luck in capital markets and finance. Other individual respondents indicated: no associations, market abuse, something prohibited, “diamond finance”, red flags in financial management, anger.

Silver finance is mostly related to elderly people’s financial activities. Many experts referred to saving for retirement. Individual respondents, meanwhile, indicated: no association, the silver rule in financial analysis (fixed assets should be financed by long-term capital), other types of commodity-linked finance, the silver age in economics that followed the golden age (a pretty good time for companies), sophisticated.

The colour *white* in finance is associated with ethics and transparency. However, other individual respondents pointed to other connotations, i.e.: liquidity management, finance for white people, finance of non-profit organisations, climate finance, accounting and due diligence, finance of healthcare, white-label solutions especially in connection with fintechs, microeconomics. One expert mentioned a lack of connotation.

The colour *yellow* lacks a main single association with finance. Two experts indicated that there are no connotations. Other individual respondents indicated: activities of "Commerzbank" (this is most likely due to the use of *yellow* in this institution's logo); finance supporting yellow businesses (entrepreneurial, innovative); derivative trading and related markets; shiny stocks; finance referring to Asians; good investment opportunities, investment in commodities and precious metals; yellow can symbolise optimism, energy and creativity, public (government) finance, attention.

4. Conclusion

The traditional and systematic literature reviews on colour symbolism show that this is an important issue, but practically not discussed in the area of finance. Therefore, the authors of this study decided to fill this research gap. The obtained results show that 9 of the 13 colours (black, blue, brown, green, golden, grey, pink, red, silver) are relevant in the area of finance. For the colours black and green, most respondents pointed to their symbolism in finance. In the case of the colour white, its perception by experts was also identified as quite important. Only for the colours orange, purple and yellow, did experts not indicate any universal connection. In addition to important areas of meaning, many experts identified secondary meanings of individual colours in the field of finance.

It is also worth mentioning that in the case of many colours, respondents gave different meanings, although some of them were dominant and others were subordinate. This may result from cultural differences or be justified by colour-in-context theory. For example, the relevant meaning for the colour red is Negative Financial Results/High Risk/Insolvency, but two of the respondents indicated that in China this colour has the meaning of prosperity and success. The colour green was most often associated with ecological and sustainable finance, but, for example, on the financial market it is associated with an increase in the prices of financial instruments. The exception again is China and other Asian countries, where green indicates a decline in stock prices.

When it comes to practical implications, this study enables understanding of the meaning of colours in finance and can be helpful in: communication, for example, the choice of colours when preparing business reports, financial cartography, impacting decision-making processes, the selection of colours for financial institution logos.

The limitations of this study should also be mentioned. Despite sending over 1000 e-mails asking people to complete the survey, only 60 completed questionnaires were included in the study. The answers obtained, among other things, did not allow: the full identification of differences in the perception of colours in finance by different groups of respondents (cultural diversity, gender, age, experience, etc.). Moreover, the results of the study concern only a group of finance experts, especially those working in academia. Similar studies are planned for other target groups in the future.

5. Appendix

Area	Survey Questions
Preface	We kindly invite you to participate in this study. It is conducted for academic purposes and is anonymous. The study is being carried out as part of the 'Colour Symbolism in Finance' project and aims to explore the perception of the meaning of colours in combination with the word 'finance'. It is aimed at people who interact with finance daily in their professional lives.
Demographic	What is your age? What is your nationality? What is your gender? What is your highest level of education? What industry do you belong to? How much work experience do you have?
Association of Colours in Finance	Instructions: Each respondent can identify between 1 and 3 meanings of a particular colour in combination with the word 'finance'. Please number each definition such as 1)... 2)... 3). If you do not associate a particular colour with the word finance, please leave the fields for that colour blank. If, in addition to the colours suggested in the questionnaire, you perceive another colour in combination with the word "finance", please add this colour and its meaning in point XIV. As an example, let us use the definition of the combination of the colour 'silver' with the word 'economy', i.e. 'silver economy' - "covers economic opportunities arising from the public and consumer expenditure related to population ageing and the specific needs of the population over 50" (The Silver Economy. Opportunities from Ageing, 2015).

Black finance
Blue finance
Brown finance
Green finance
Gold finance
Grey finance
Orange finance
Pink finance
Purple finance
Red finance
Silver finance
White finance
Yellow finance
“Other color” finance: (please write below the name of the colour and the meaning of this colour in combination with the word ‘finance’)

Table A1. Survey conducted for the study.
Source: Authors’ elaboration.

6. Conflict of interest declaration

The authors have no conflicts of interest to declare.

7. Funding source declaration

The authors did not receive any funding for this research.

8. Short biography of the author(s)

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References

Agırel, S. (2009) ‘As contributions to this section, the Editors welcome comment and debate on topical issues or on recent articles or reviews appearing in the journal. Shorter accessibly written items of general interest, reports on work in progress, notes and queries are also welcome. Colour Symbolism in Turkish and Azeri Folk Literature’, Folklore, 120(1), pp. 92-101. Doi: 10.1080/00155870802647858.

Alharbi, A.S. (2023) ‘Socio-Cultural Perspectives on Color Semantics: A Semiotic Analysis of Color Symbolism in English and Arabic’, International Journal of Society, Culture & Language, 11(3), pp. 146-158. Doi: 10.22034/ijscl.2023.2009122.3131.

Andreevich, B.A. (2021) ‘Image and Symbolism of the Wolf in the Worldview and Ritual of the Buryats’, Tomsk Journal of Linguistics and Anthropology, 2(32), pp. 93-101. Doi: 10.23951/2307-6119-2021-2-93-101.

Bakaeva, E.P. (2016) ‘The Colour Symbolism of the Oirat National Costume Revisited’, Oriental Studies, 26(4), pp. 48–58. Doi: 10.22162/2075-7794-2016-26-4-48-58.

Bakieva, O.A. (2020) ‘Color in the Traditional Costume Art of Indigenous Small Nations in Tyumen North’, Vestnik Tomskogo gosudarstvennogo universiteta. Kul'turologiya i iskusstvovedenie, 39, pp. 226–40. Doi: 10.17223/22220836/39/21.

Bakieva O.A. and Popova O.A. (2019) “Features of color mentality of the indigenous small nationalities of the Arctic (on the example of the analysis of the traditional Khanty people costume)”, IOP Conf. Ser.: Earth Environ. Sci., 302 012157.

Bakieva, O.A. and Popova, O.A. (2022) ‘Color in the art of the traditional costume of the indigenous small nations of the Tyumen North (on the example of the analysis of museum exhibits)’. Vestnik Tomskogo gosudarstvennogo universita. Kul’turologiya i iskusstvovedenie – Tomsk State University Journal of Cultural Studies and Art History, 46, pp. 237–249. Doi: 10.17223/22220836/46/20.

Bálizs, B. (2021) ‘Meanings of the Color Yellow and Its Color Associates, Yellow-Black and Yellow-Green’, Hungarian Cultural Studies, 14, pp. 100-120. Doi: 10.5195/ahea.2021.430.

Baniani, M. (2022) ‘The association between colors, color preferences, and emotions among Japanese students: From elementary school to university’, 47(4), pp. 992-1004. Doi: 10.1002/col.22774.

Barbato, G., Bellia, L. and Morone, A. (2019) ‘How the colours of objects and light affect human emotions, performance and health. The need for a holistic approach to design indoor environment’, Cultura e Scienza del Colore / Color Culture and Science Journal, 11(1), pp. 67-73. Doi: 10.23738/CCSJ.110108.

Batyanova, E.P. (2018) ‘Visual images in the worldview, mythology and folklore of peoples of the North’, Bulletin of Ugric Studies, 8(4), pp. 695-704.

Bazley, W.J., Cronqvist, H. and Mormann, M. (2021) ‘Visual Finance: The Pervasive Effects of Red on Investor Behavior’, Management Science, 67(9), pp. 5616-5641. Doi: 10.1287/mnsc.2020.3747.

Beckman, S. (1976) ‘Color Symbolism in "Troilus and Criseyde’, CLA (College Language Association) Journal, 20(1), pp. 68-74.

Biggam, C. P. (1993) ‘Aspects of Chaucer's Adjectives of Hue, The Chaucer Review, 28(1), pp. 41-53.

Birren, F. (1988) ‘The Symbolism of Color’, Citadel Press, Secaucus, New Yersey.

Blinova, O.A. (2019) ‘Scottish Regionalist Discourse in British Press’, Nauchnyi dialog, 7, pp. 39-55. Doi: 10.24224/2227-1295-2019-7-39-55.

Bonnardel, V., Amos, N., Séraphin, H. and Cheung, V. (2018) ‘Colour-word associations: University undergraduate prospectus as a case study’ Proceedings of the International Colour Association (AIC) Conference 2018, Lisbon, Portugal, 25-29 September 2018, pp. 473-478.

Bozick, M.M. (2019) ‘Green May in Against Women Unconstant’, The Chaucer Review, 54(2), pp. 162-190.

Brecoulaki, H. (2014) ‘"Precious Colours" in Ancient Greek Polychromy and Painting: Material Aspects and Symbolic Values’, Revue Archéologique, Nouvelle Série, Fasc. 1, pp. 3-35.

Breidenbach, P.S. (1976) ‘Colour Symbolism and Ideology in a Ghanaian Healing Movement’, Africa: Journal of the International African Institute, 46(2), pp. 137-145. Doi: 10.2307/1158757.

Broeder, P. (2022) ‘Colours of Emotion, Trust, and Exclusivity. A Cross-Cultural Study’, Cultura e Scienza del Colore / Color Culture and Science Journal, 14(2). pp. 14-21. Doi: 10.23738/CCSJ.140202.

Bryce, M., Scholes, K.E. and Simon, J. (2023) ‘Sakura imagery and cosmetics: Colour symbolism, aesthetics and cultural significance in an Australian context’, East Asian Journal of Popular Culture, 9, Issue Chinese Popular Culture in Translation and Transmission, pp. 261 – 280. Doi: 10.1386/eapc_00098_1.

Brzozowska, S. (2021) ‘Necklace Strung from Blood Drops - Władysław Reymont’s “Peasants” as a Study of Passion’, Pamiętnik Literacki, 112(4), pp. 131-146.

Buja, E. (2015) ‘Iohannis and Ponta: The Winner and the Loser. A Non-Verbal Communication Approach to the 2014 Presidential Election Campaign in Romania,’ Redefining Community in Intercultural Context, 4(1), pp. 18-30.

Bukharova, G.K., Samsitova, L.K., Tagirova S.A., Davletkulov, A.K., Davletbajeva, R.G. and Usmanova M.G. (2016) ‘Color symbolism in the Bashkir toponymy’, International Journal of Environmental and Science Education, 11(18), pp. 12281-12288.

Candel, O. (2018) ‘The Colors of the Romanian New Wave. Symbolism and psychological significance’, Swedish Journal of Romanian Studies, 1(1), pp. 132-145. Doi: 10.35824/sjrs.v1i1.16806.

Cong, G and Chistyakov, A.V. (2021) ‘The Color Symbolism in the Works of M.A. Bulgakov’, Revista Entelinguas, 7, Special Issue No. 5, pp. 984-993.

Couacaud, L. (2016) ‘Does Holiness Have a Color? The Religious, Ethnic, and Political Semiotics of Colors in Mauritius’, Signs and Society, 4(2), pp. 176-214.

Davies, I.R.L. and Corbett, G.G. (1995) ‘A practical field method for determining basic colour terms’, The World's Languages, 9, pp. 25-36.

De Argüelles, C. L-F. (2018) ‘Los colores en la heráldica de los libros de caballerías’, JANUS, 7, pp. 19-54.

Demir, Ü. (2020) ’ Investigation of color-emotion associations of the university students’, 45(5), pp. 871-884. Doi: 10.1002/col.22522.

Derzhavina, O.A., Smirnov, A.V., Ivanova, E.Y., Gribkova, G.I. and Korshunova, N.N. (2020) ‘Color Symbolism in the Cultures of the North American Indians’, Journal of Advanced Research in Dynamical and Control Systems, 12(5), pp. 1339-1345. Doi: 10.5373/JARDCS/V12SP5/20201893.

Divjak A. and Kuveždić L.M. (2018) ‘Crisis Maps—Observed Shortcomings and Recommendations for Improvement’, ISPRS International Journal of Geo-Information, 7(11), pp. 436. Doi: 10.3390/ijgi7110436.

Driga, S. (2018) ‘Creolized Text As An Object Of Interdisciplinary Analysis’, Denisova, I.V. (Ed.), Word, Utterance, Text: Cognitive, Pragmatic and Cultural Aspects, Vol. 39, European Proceedings of Social and Behavioural Sciences, pp. 543-547). Doi: 10.15405/epsbs.2018.04.02.77.

Duckitt, J., Wall, C. and Pokroy, B. (1999) ‘Color Bias and Racial Preference in White South African Preschool Children’, The Journal of Genetic Psychology, 160(2), pp. 143-154. Doi: 10.1080/00221329909595388.

Elewa, A. (2022) ‘The semiology of colors in scripture translation: Arabic-English’, Semiotica, 246, pp. 117-138. Doi: 10.1515/sem-2021-0075.

Elliot, A.J. and Maier, M.A. (2014) ‘Color Psychology: Effects of Perceiving Color on Psychological Functioning in Humans’, Annual Review of Psychology, 65, pp. 95-120. Doi: 10.1146/annurev-psych-010213-115035.

Epicoco, D., Mohr, C., Uusküla, M., Quiblier, M., Meziane, M.B., Laurent, E., Spagnulo, G.F.M. and Jonauskaite, D. (2024) ‘The PURPLE mystery: Semantic meaning of three purple terms in French speakers from Algeria, France, and Switzerland’, Color Research and Application, 49(1), pp. 93-112. Doi: 10.1002/col.22908.

Erdogu, B.; Ulubey, A. (2011) ‘Colour symbolism in the prehistoric architecture of central Anatolia and Raman spectroscopic investigation of ochre in Chalcolithic Çatalhöyük’, Oxford Journal of Archaeology, 30(1), pp. 1 – 11. Doi: 10.1111/j.1468-0092.2010.00356.x.

Evans, G. (2005) ‘Synaesthesia in Kieslowski's Trois couleurs: Bleu’, Studies in French Cinema, 5(2), pp. 77-86. Doi: 10.1386/sfci.5.2.7/1.

Gabysheva, L.L. (2016) ‘The Food Code in the Yakut Culture: Semantics and Functions’, International Journal of Environmental & Science Education, 11(18), pp. 11485-11493.

Gage, J. (1999) ‘Color and Meaning. Art, Science and Symbolism’, University of California Press, Berkeley and Los Angeles.

Gao, J. (2012) ‘Official Colours of Chinese Regimes: A Panchronic Philological Study with Historical Accounts of China’, Trames. A Journal of the Humanities and Social Sciences, 16(3), pp. 237–285.

Geschwind, R. (2013) ‘The colors of seduction: New thoughts on color symbolism in Michelangelo's Temptation and expulsion from paradise’, Finkel, J.H., Morford, M.D. and Woodall, D.M. (Eds.), Renaissance Studies: A Festschrift in Honor of Professor Edward J. Olszewski, Vol. 9781433115882, Peter Lang Publishing Group, pp. 89 – 103.

Gil, S. and Le Bigot, L. (2016) ‘Colour and Emotion: Children also Associate Red with Negative Valence’, Development Science, 19(6), pp. 1087-1094. Doi: 0.1111/desc.12382.

Grodska, E., Machulianska, A. and Shapa, L. (2020) ‘Cultural-Linguistic Aspect of Teaching and Learning Spanish Colour Idioms and Symbols’, Revista Romaneasca pentru Educatie Multidimensionala, 12 (1Sup1), pp. 213-231. Doi: 10.18662/rrem/12.1sup1/232.

Güneş, E. and Olguntürk, N. (2019) ‘Color-emotion associations in interiors’, 45(1), pp. 129-141. Doi: 10.1002/col.22443.

Guryanov, I.O.; Rakhimova, A.E, and Rudnick, A. (2017) ‘Socio-Cultural Aspect of Coloristic Components of Idioms in German Discourse’, QUID, Special Issue No. 1, pp. 800-805.

Haller, K. (2017) ‘Colour in interior design’ Best, J. (Ed.), Colour Design. Theories and Applications (Second Edition), Woodhead Publishing Series in Textiles, pp. 317-348.

Hashemi, F. (2023) ‘Color Symbolism in the Description of Scenes and Emotions in Wolfgang Borchert’s Short Stories’, Research in Contemporary World Literature/ Pazhuhesh-e Zabanha-ye Khareji, 27(2), pp. 1150-1171.

Hayward, M. (2015) ‘Dressed in Blue: The Impact of Woad on English Clothing, c. 1350-c. 1670’, Costume-The Journal of the Costume Society, 49(2), pp. 168-185.

Hollmann, J.C. (2015) ‘Bees, honey and brood: southern African hunter-gatherer rock paintings of bees and bees’ nests, uKhahlamba-Drakensberg, KwaZulu-Natal, South Africa’, Azania: Archaeological Research in Africa, 50(3), pp. 343-371. Doi: 10.1080/0067270X.2015.1079378.

Hovers, E., Ilani, S., Bar-Yosef, O. and Vandermeersch, B. (2003) ‘An Early Case of Color Symbolism Ochre Use by Modern Humans in Qafzeh Cave’ Current Anthropology, 44(4), pp. 491-522.

Hristu, N. (2015) ‘Imaginary vs. Imaginal in Max Blecher’s Prose’, International Conference on Literature, Discourse and Multicultural Dialogue, DEC 03-04, 2015, Tirgu Mures, Romania, pp. 457-467.

Hunt, D. (2006) ‘Colour Symbolism in the Folk Literature of the Caucasus’, Folklore, 117(3), pp. 329-338. Doi: 10.1080/00155870600928989.

Hunt, D. and Chenciner, R. (2006) ‘Colour symbolism in the folk literature and textile tradition of the Caucasus’, Optics & Laser Technology, 38(4-6), pp. 458-465. Doi: 10.1016/j.optlastec.2005.06.009.

Hutchings, J. (1997) ‘Folklore and Symbolism of Green’, Folklore, 108, pp. 55-63.

Itten, J. (1997) ‘The Art of Color: The Subjective Experince and Objective Rationale of Color’, John Wiley & Sons.

Itten, J., van Hagen, E. (translator) and Birren, F. (editor), (1970) ‘The Elements of Color: A Treatise on the Color System of Johannes Itten Based on His Book the Art of Color’, John Wiley & Sons.

Jones, A. (1999) ‘Local Colour: Megalithic Architecture and Colour Symbolism in Neolithic Arran’, Oxford Journal of Archeology, 18(4), pp. 339-350. Doi: 10.1111/1468-0092.00088.

Kaimal, G., Walker, M.S., Herres, J., Berberian, M., and DeGraba, T.J. (2022) ‘Examining associations between montage painting imagery and symptoms of depression and posttraumatic stress among active-duty military service members’, Psychology of Aesthetics, Creativity, and the Arts, 16(1), pp. 16–29. Doi: 10.1037/aca0000316.

Karotovskaya, L.V., Shatalova, L.I., Maslakov, S.I. and Syrovatskaya, T.A. (2019) ‘The symbolism of colour in the interpretation of a drawing in Gestalt’, Opcion, 36(24), pp. 63-74.

Kartashkova, F.I. and Belyaeva L.E. (2022) ‘Colour Meaning in English Literary Pieces’, RUDN Journal of Language Studies, Semiotics and Semantics, 13(1), pp. 201-212. Doi: 10.22363/2313-2299-2022-13-1-201-212.

Kass, L.A. (2020) ‘Picturing Melancholia in Estonian Decadent Art’, Baltic Journal of Art History, 19, pp. 7-50. Doi: 10.12697/BJAH.2020.19.01.

Kaye, N.R., Hartley, A. and Hemming, D. (2012) ‘Mapping the climate: guidance on appropriate techniques to map climate variables and their uncertainty’, Geosci. Model Dev., 5, pp. 245–256. Doi: 10.5194/gmd-5-245-2012.

Kiernan, J.P. (1991) ‘Wear 'n' Tear and Repair: The Colour Coding of Mystical Mending in Zulu Zionist Churches’, Africa: Journal of the International African Institute, 61(1), pp. 26-39. Doi: 10.2307/1160268.

Khassenov, B., Adilova, A. and Rapisheva, Z. (2022) ‘Colour Symbolism in Turkic Culture: A New Look in the Reconstruction of Colour Designation’, Pertanika Journal of Social Science and Humanities, 30(4), pp. 1753-1766. Doi: https://doi.org/10.47836/pjssh.30.4.15.

Khisamitdinova, F.G., Muratova, R.T., Yagafarova, G.N. and Valieva, M.R. (2019) ‘Color Terms in Bashkir Toponymy’, Voprosy onomastiki, 16(1), pp. 140–159. Doi: 10.15826/vopr_onom.2019.16.1.008.

Khotamovich, T.B. and Turonovich, M.K. (2020) ‘Green-Blue World Of Uzbek Dastan “Alpamysh»”’, International Journal of Advanced Science and Technology, 29(8s), pp. 140 - 145.

Klypina, I.V. and Shestakova, E.U., (2022) ‘The Image of Childhood in the Short Stories by Fyodor Sologub’, Проблемы исторической поэтики /The Problems of Historical Poetics, 20(1), pp. 254–274.

Kudrya-Marais, E.V., and Olalere, F.E. (2022a) ‘Semiotics of Color in Hinduism: A Visual Guide to Its Application in Design Practices’, The International Journal of Visual Design, 16(2), pp. 69-84. Doi:10.18848/2325-1581/CGP/v16i02/69-84.

Kudrya-Marais E.V. and Olalere F.E. (2022b) ‘The Spiritual Language of Colour: A Case Study of Colour Symbolism in Hindu Community in South Africa’, Pharos Journal of Theology, 103(1), pp. 1-15. Doi: 10.46222/pharosjot.103.201.

Kudrya-Marais E.V. and Olalere F.E. (2022c) ‘Globalisation and its effects on Religious Practices: A Case Study of the Hindu Community in Durban, South Africa’, Pharos Journal of Theology, 103(2), pp. 1-14. Doi: 10.46222/pharosjot.103.202.

Kwiatkowska-Lubańska, A. (2022)’ The Symbolism of Colour for Gen Z. Visual Communication Through Images and Hashtags’ PROCEEDINGS OF THE INTERNATIONAL COLOUR ASSOCIATION (AIC) CONFERENCE 2022 SENSING COLOUR JUNE 13-16, pp. 653-658.

Lavrenova, O. (2023) ‘Color Semantics of the Cultural Landscape’, Arts, 12(3), pp. 111. Doi: 10.3390/arts12030111.

Lee, S.-K., (2000) ‘Edward Gordon Craig and Japanese Theatre’, Asian Theatre Journal, 17(2), pp. 215-235.

Leong, K., Sung, A., Williams, T., Andoniou, C. and Sun, F. (2019) ‘The Importance of Colour on the Communication of Financial Data in Management’, Journal of Work-Applied Management, 11(1), pp. 92-100. Doi: 10.1108/JWAM-06-2019-0013.

Mamynova, B., Anessova, U., Satkenova, Z. and Shalabay, B. (2014) ‘Symbolism of white and black colours in Kazakh culture’, Life Science Journal, 11 (10 Special Issue), pp. 300-303. Doi: 10.7537/marslsj1110s14.54.

Mikhalenko, N.V. (2014), ‘The Iconographic Colour Symbolism in Biblical Poems by Sergei Yesenin’, Problemy Istoricheskoi Poetiki, 12(9), pp. 455-470. Doi: I 10.15393/j9.art.2014.757.

Mikitchenko, E. (2016) ‘Effect of Colour Symbolism of Native Culture on Image Display in Association Experiment’, PROCEEDINGS OF THE 2016 3RD INTERNATIONAL CONFERENCE ON EDUCATION, LANGUAGE, ART AND INTER-CULTURAL COMMUNICATION (ICELAIC 2016), pp. 675-677.

Milicic, B. (1989) ‘A Group Model of NDEMBU Color Symbolism’, Semiotica, 73(1-2), pp. 121-132. Doi: 10.1515/semi.1989.73.1-2.121.

Miller, E., May, S.K., Goldhahn, J., Taçon, P.S.C. and Cooper, V. (2022) ‘Kaparlgoo Blue: On the Adoption of Laundry Blue Pigment into the Visual

Culture of Western Arnhem Land', Australia, International Journal of Historical Archaeology, 26, pp. 316–337. Doi: 10.1007/s10761-021-00603-w.

Minina, Y.D. (2021) 'Symbolism of Colour of the Vietnamese National Garment AO DAI: Historical Foundations, Development and Interpretations', Russian Journal of Vietnamese Studies-VYETNAMSKIYE ISSLEDOVANIYA, 4, pp. 106-117. Doi: 10.54631/VS.2021.54-106-130.

Moll, A.D. (2022) 'Colour Symbolism in two Majorcan Poems of the Seventeenth Century', CAPLLETRA, 73, pp. 15-33. Doi: 10.7203/Caplletra.73.24631.

Monk, D. (1977) 'Colour Symbolism in James Dickey's Deliverance', Journal of American Studies , 11(2), pp. 261 – 279. Doi: 10.1017/S0021875800003601.

Motsamayi, M.F. (2020) 'Cattle culture and colour symbolism as reflected in selected artworks of Sotho-Tswana in South Africa', South African Journal of African Languages, 40(3), pp. 297-307. Doi: 10.1080/02572117.2020.1855723.

Mukhamadiarova, A., Safina, R. and Sharipova, A. (2016) 'Cognitive aspects of actualization of metaphorical meaning of color name "red" in German, Russian and Tatar Languages', Journal of Language and Literature, 7(N3), pp. 232-235. Doi: 0.7813/jll.2016/7-3/43.

Muthesius, A. (2016) 'Cloth, Colour, Symbolism and Meaning in Byzantium (4th-15th Centuries)', Δελτίον της Χριστιανικής Αρχαιολογικής Εταιρείας, 37, pp. 181-198. Doi: 10.12681/dchae.10695.

Needham, R. (1979) 'Colour symbolism in the lower Congo', Ethnos, 44(3-4), pp. 259-264. Doi: 10.1080/00141844.1979.9981182.

Nehmé, L., Barbar, R., Maric, Y. and Jacquot, M. (2016) 'Influence of odor function and color symbolism in odor–color associations: A French–Lebanese–Taiwanese cross-cultural study', Food Quality and Preference, 49, pp. 33-41. Doi: 10.1016/j.foodqual.2015.11.002.

Novikova, M.L. and Novikov, F.N. (2021) 'Cultural codes of the new reality in the multilingual space and interlingual contacts (through the lens of color term research)', Filologicheskie Nauki, 6(2), pp. 184-191. Doi: 10.20339/PhS.6-21.184.

Obonai, T. and Matsuoka, T. (1956) 'The Color Symbolism Personality Test', The Journal of General Psychology, 55(2), pp. 229-239. Doi: 10.1080/00221309.1956.9920314.

Oyama T.; Tanaka Y. and Haga J. (1963) 'Color-affection and color-symbolism is Japanese and American students', The Japanese Journal of Psychology, 34(3), pp. 109-121. Doi: 10.4992/jjpsy.34.109.

Østermark-Johansen, L. (2020) 'Symphonies in black and grey, harmonies in iron and steel: Walter Pater painting the French Wars of Religion in Gaston de Latour', Word & Image, 36:1, pp. 27-36. Doi: 10.1080/02666286.2019.1651993.

Palmer, S.E. and Schloss, K.B. (2010) 'An Ecological Valance Theory of Human Colour Preference', The Proceedings of the National Academy of Sciences (PNAS), 107(19), pp. 8877-8882. Doi: 10.1073/pnas.0906172107.

Pansat, Z. and Khalikova, N. (2023) 'Semantic features of color in emotional, expressive words: The concept of "blue" in the Kazakh language', International Journal of Society, Culture and Language, 11(2), pp. 85-93. Doi: 10.22034/ijscl. 2023.556420.2676.

Pastoureau M. (2023) 'White: The History of a Color', Princeton University Press, New Jersey.

Pastoureau M. (2019) 'Yellow: The History of a Color', Princeton University Press, New Jersey.

Pastoureau M. (2018) 'Blue: The History of a Color', Princeton University Press, New Jersey.

Pastoureau M. (2017) 'Red: The History of a Color', Princeton University Press, New Jersey.

Pastoureau M. (2014) 'Green: The History of a Color', Princeton University Press, New Jersey.

Pastoureau M. (2008) 'Black: The History of a Color', Princeton University Press, New Jersey.

Patton, P.A., (2022) 'What Did Medieval Slavery Look Like? Color, Race, and Unfreedom in Later Medieval Iberia', SPECULUM-A JOURNAL OF MEDIEVAL STUDIES, 97(3), pp. 649-697. Doi: 10.1086/720119.

Pereira, C. (2020). 'The meaning of colors in Brazilian food packaging' Proceedings of the International Colour Association (AIC) Conference 2020, AIC2020 Symposium Natural Colours - Digital Colours 20, 26-27 November 2020 pp. 268-272.

Petzold, A. (2018) 'The use of colour in Romanesque manuscript illumination', Duckworth, C. and Sassin, A. (Eds.), Colour and Light in Ancient and Medieval Art, Routledge, New York, pp. 92-102.

Plog, S. (2003) 'Exploring the Ubiquitous through the Unusual: Color Symbolism in Pueblo Black-on-White Pottery', American Antiquity, 68(4), pp. 665-695. Doi:10.2307/3557067.

Pollard, P. (1981) 'Color Symbolism in 'ROUGE ET LE NOIR'', Modern Language Review, 76, pp. 323-331. Doi: 10.2307/3726414.

Prusak, B. and Mushafiq, M. (2023) 'Colour Symbolism in Finance', Financial Internat Quaterly, 19(4), pp. 49-62. Doi: 10.2478/fiqf-2023-0026.

Rambiert-Kwasniewska, A. (2023) 'The Little Known Language of Biblical Colors: The Example of melas in the Septuagint and the New Testament', Biblical Theology Bulletin, 53(2), pp. 122-134. Doi: 10.1177/01461079231177692.

Rifkin, R.F. (2012) 'Processing ochre in the Middle Stone Age: Testing the inference of prehistoric behaviours from actualistically derived experimental data', Journal of Anthropological Archaeology, 31(2), pp. 174-195. Doi: 10.1016/j.jaa.2011.11.004.

Russell, N. (2019) 'Spirit Birds at Neolithic Çatalhöyük', Environmental Archaeology, 24(4), pp. 377-386. Doi: 10.1080/14614103.2017.1422685.

Ryan, P.M. (1976) 'Color Symbolism in Hausa Literature', Journal of Anthropological Research, 32(2), pp. 141-160. Doi: 10.1086/jar.32.2.3629660.

Sagiv, G. (2017) 'Dazzling Blue: Color Symbolism, Kabbalistic Myth, and the Evil Eye in Judaism', Numen, 64(2-3), pp. 183-208. Doi: 10.1163/15685276-12341459.

Schmiesing, A. (2016) 'Blackness in the Grimms' Fairy Tales', Marvels & Tales, 30(2), pp. 210-233.

Schumaker, L.L. and Bond, V.A. (2008) 'Antiretroviral therapy in Zambia: Colours, 'spoiling', 'talk' and the meaning of antiretrovirals', Social Science & Medicine, 67(12), pp. 2126-2134. Doi: 10.1016/j.socscimed.2008.09.006.

Searle-Chatterjee, M. (1981) 'Colour symbolism and the skin: Some notes', Journal of Ethnic and Migration Studies, 9(1), pp. 31-35. Doi: 10.1080/1369183X.1981.9975657.

Shirieva, N. and Dyganova, E. (2015). ''Alleluia' by Sofia Gubaidulina as a Synaesthetic Experiment', European Journal of Science and Theology, 11(5), pp. 207-216.

Singh, N. (2022) 'Stories of Color Symbolism and its Significance in Indian Weddings' PROCEEDINGS OF THE INTERNATIONAL COLOUR ASSOCIATION (AIC) CONFERENCE 2022 SENSING COLOUR JUNE 13-16, pp. 747-750.

Stachowski, K. (2018) 'On colour oppositions in Polish oikonymy', Acta Onomastica, 59, pp. 197-214.

Taleb, N.N. (2015) The black swan: the impact of the highly improbable, Polish Edition, KURHAUS Publishing, Warszawa.

Tallarita, A.L. (2017) 'Red: the symbol in history', Cultura e Scienza del Colore / Color Culture and Science Journal, 7, pp. 7-11. Doi: 10.23738/ccsj.i72017.01.

Tao, W. (2007) 'Shang ritual animals: Colour and meaning (part 2)', Bulletin of the School of Oriental and African Studies, 70(3), pp. 539-567. Doi:10.1017/S0041977X07001036.

Tarasova, A.N. (2014) 'Philosophic and Aesthetic Principles of J.D. Salinger's Poetics and Means of Their Expression in the Book 'Nine Stories'', World Applied Sciences Journal, 30(11), pp. 1552-1555. Doi: 10.5829/idosi.wasj.2014.30.11.14208.

Tham, D.S.Y., Sowden, P.T., Grandison, A., Franklin, A., Lee, A.K.W., Ng, M., Park, J., Pang, W. and Zhao, J. (2019) 'A Systematic Investigation of Conceptual Colour Associations', Journal of Experimental Psychology, 149(7), pp. 1311-1332. Doi: 10.1037/xge0000703.

The Silver Economy. Opportunities from Ageing (July 2015).European Union.

Tocia, M.B. (2019), 'Métaphores ou ressources symboliques dans le discours politique. Symbolique des sigles électoraux et des événements locaux (Metaphors or symbolic resources in political discourse. Symbolism of electoral logos and local events)', The Annales of Ovidius University of Constanța, Philology Series, XXX(2), pp. 376-390.

Tolasova, I.B. and Abisalova, R.N. (2017) 'About an Ossetian Translation of a French Poem', Oriental Studies,10(4), pp. 165-172.

Tsyganova, L. and Mannin, A. (2018) 'Heraldic Sign System in Modern Logos. Communication Approach Experience', Istoriya, 9[2(66)]. Doi: 10.18254/S0002143-6-1.

Urry, J.W. (1969) 'Cherokee Colour Symbolism', Man, 4(3), p. 459.

Voronichev, O.E. and Voronicheva A.O. (2023) 'White colour symbolism in the poem "A Cemetery near Paris" by R. Rozhdestvensky: a linguoculturological aspect', Russian language at school, 84(3), pp. 38-44. Doi: 10.30515/0131-6141-2023-84-3-38-44.

Watts, I. (2015) 'Early Color Symbolism', Elliot, A., Fairchild, M. and Frankin, A. (Eds.), Handbook of Color Psychology, Cambridge University Press, pp.319-339.

Wickler, W. and Seibt, U. (1995) 'Syntax and Semantics in a Zulu Bead Colour Communication System', Anthropos, 90, pp. 391-405.

Wijitsopon, R. (2022) 'Corpus stylistics and colour symbolism in The Great Gatsby and its Thai translations', Language and Literature, 31(3), pp. 267-295. Doi: 10.1177/09639470211048159.

Xu, J. (2019), "Colour in urban places: A case study of Leicester City Football Club blue", Color Research & Application 44(4), pp. 613-621. Doi: 10.1002/col.22378.

Yakovleva, S., Soldatkina, T. , Pershina, M., Fliginskikh, E. and Badyina, K. (2017), 'The Semantics of 'White/Black' in Phraseology: English, German, French, Spanish and Russian Languages', Proceedings of INTCESS 2017 4th International Conference on Education and Social Sciences, 6-8 February 2017- Istanbul, Turkey, pp. 722-729.

Yildirim, A. (2006) 'Colour symbolism and three colours of Sheihk Gâlib', Milli Folklor, 9(72), pp. 129-140.

Yoon, S. (2021) 'Color Symbolisms of Diseases: Edgar Allan Poe's "The Masque of the Red Death', The Explicator, 79(1-2), pp. 21-24. Doi: 10.1080/00144940.2021.1891014.

Yu, H.-C. (2014) 'A Cross-Cultural Analysis of Symbolic Meanings of Color', Chang Gung Journal of Humanities and Social Science, 7:1, pp. 49-74.

Ziod A.A.-B. and Zawahreh T. (2014) 'Color symbolism in the poetry of Bader Shaker Al-Sayyab: ""The rain song"" collection as an example', Dirasat: Human and Social Sciences, 41(2), pp. 589-600.

Zuiddam, B. (2018) 'Biblical colour symbolism and interpretation of Christian art', South African Journal of Art History, 33(1), pp. 66-89.

Effect of display techniques on simultaneous color contrast

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ABSTRACT

In previous studies, simultaneous color contrast (SCC) was investigated using different display techniques, such as colored papers, electronic displays, and the two-rooms technique. The results suggested that the SCC effects varied depending on the techniques used. The strongest effects were obtained using the two-rooms technique, and the weakest when colored papers were used. However, the results of such studies may be affected by stimulus conditions such as size, chromaticity, and luminance. In the present study, we investigated the effects of three different display techniques on SCC, with the stimuli carefully set up, including with or without objects in the experimental space. Four carefully controlled color stimuli were used. The chromaticity, luminance, chroma, and size of these stimuli remained constant, regardless of the display techniques used. The elementary color-naming method was used to assess the color appearance of the SCC. The results suggested that the SCC effect is device-dependent and that any differences in the effect depend on the underlying mechanisms involved. When paper or LCD techniques are used, the SCC effect is caused by contrast induction from the surrounding colors; when the two-rooms technique is employed, the SCC is caused by chromatic adaptation and contrast induction at the same time.

KEYWORDS Simultaneous color contrast, Display techniques, Contrast induction, Chromatic adaptation, Recognized visual space of illumination, Elementary color naming

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1. Introduction

Simultaneous color contrast (SCC), also known as chromatic induction (Krauskopf *et al*., 1986; Lotto and Purves, 2000; Wu and Wardman, 2007), refers to the effect in which an area of color that is surrounded by another color is perceived differently when the surrounding color changes. A classic example of simultaneous contrast is a gray patch placed at the center of a surrounding color. The gray patch appears as either an opponent color (Jameson and Hurvich, 1959; 1961) or a complementary color (Pridmore, 2007; Phuangsuwan and Ikeda, 2017) relative to the surrounding color.

Researchers have explored this phenomenon using various experimental methods to present color stimuli, including paper (Land, 1959), electronic displays (Arend and Reeves, 1986; Webster and Mollon, 1994; Ekroll *et al.*, 2004; Klauke and Wachtler, 2015), and the two-rooms technique (subject and test rooms) (Ikeda *et al*., 1998; Pungrassamee *et al*., 2005; Ikeda *et al*., 2006; Srirat *et al*., 2014; Phuangsuwan and Ikeda, 2017). Other studies compared the SCC effect between different techniques, such as electronic displays and fabrics (Wu *et al*., 2005), and electronic displays and paper (Jinphol *et al*., 2019). An interesting result was found in a study comparing the SCC effect across techniques, including the two-rooms technique (adaptation to the color of illumination), the paper technique (adaptation to the color of the object's surroundings), and the LCD technique (adaptation to the color of a self-luminous display) (Phuangsuwan and Ikeda, 2018; 2019). The results suggest that the differences in SCC effects were device-dependent, with the strongest effect observed using the two-rooms technique, where the observer directly adapts to the illumination according to the recognized visual space of illumination (RVSI) theory (Ikeda, 2004; Pungrassamee *et al*., 2005; Ikeda *et al*., 2006). In contrast, the weakest effect was observed using the paper technique. Similar results have been found by researchers who compared the effects of chromatic adaptation using colored paper and the two-rooms technique (Ikeda *et al*., 2014; Chitapanya *et al*., 2018).

The RVSI theory explains our color appearance when entering an illuminated room, referred to as the subject room. First, the observer recognizes and understands the illumination and then adapts to its color. Following this, the observer accurately perceives the colors in subject room. To prove this understanding, the two-rooms technique is commonly used. The test room refers to the room where the test patch, which is seen through a window from the subject room, is placed. The advantage of this technique is that it allows for independent control of the lighting between the subject room and the test room. This allows for the clear measurement of the color appearance of the test area of which colorimetric values are constant because it is set in the test room, based on the recognition of illumination in the subject room.

In this work, we aim to study the effects of different display techniques on the SCC effect, using three types of display techniques, as mentioned in Phuangsuwan and Ikeda (2018, 2019). The stimulus conditions and environmental settings in the previous work were not exactly consistent each other. In this study, the stimuli were carefully set to be as similar as possible across the three techniques in terms of chromaticity, luminance, chroma, and size.

Additionally, the information about the display technique was hidden from the observer during the presentation. We also investigated the effect of the environment by adding various colored objects to the scene to simulate daily life (complex scene), comparing this with a scene with no objects to explore the effect of SCC. Many researchers have found that if the colors of objects near the test area harmonize with each other, it is possible to create a consistent set of colors within a subject room, thereby revealing a strong SCC effect (Mizokami *et al*., 2000). In contrast, if the colors of the objects are complex, the effect in the test area seems to decrease (Shevell and Wei, 1998).

2. Methodology

2.1. Stimuli

The classical SCC pattern used in our previous study (Mepean *et al.,* 2023) was also used in this experiment, as shown in Figure 1(a). We simulated the SCC pattern by printing on uncoated paper, through presentation on an LCD screen, and by mixing LED light in two rooms. The five surrounding colors used were red, yellow, green, blue, and gray, with a gray surround as the control condition. The chromaticities of the stimuli are shown in Figure 1(b). For all display techniques, the surrounding colors were the same or closely alike, with constant luminance. The chromaticities and luminance were measured using a Konica Minolta Spectroradiometer CS-2000 with CIE1931 color-matching functions for a 2° observer. A gray patch (x = 0.332, y = 0.351) with dimensions of 4 × 4 cm^2 was placed at the center of each surrounding area. The chroma of the colors was quantified using CIE C^*_{ab} 3-43, and the luminance was in the range of 18–37 cd/m^2, depending on the color (see Table 1A, Appendix A). The stimulus size was 21 × 31 cm^2. The distance between the stimulus and the observer was 0.7 m. The visual angle of the stimulus was 17° × 25° for the surround and 3.3° × 3.3° for the gray patch.

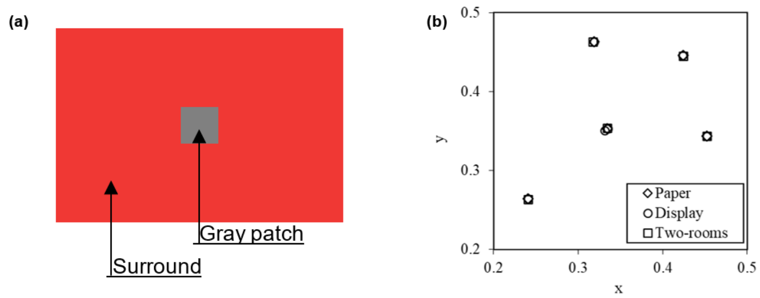

Figure 1. (a) Scheme of SCC stimulus; (b) chromaticities of stimuli among three display techniques plotted in the CIE 1931 chromaticity diagram. (Mepean et al., 2023)

2.2. *Apparatus*

As shown in Figure 2, for all three display techniques, our experiment was conducted in the same room. The room had dimensions of 1.2 m width, 3.0 m length, and 2.0 m height, and included a separating wall so that the single room was divided into a "test room" and a "subject room". The devices were placed in the test room so that the observers were unaware of the apparatus being used, and the stimuli were presented through a window in the wall. This window was designed to slope inward to reduce shadows and make the stimuli appear as if they were part of the wall.

When the paper and LCD techniques were used, the subject room was illuminated by fluorescent lamps in the ceiling; these had an illuminance of approximately 1000 lx measured on the horizontal plane of the observer's eye position, a correlated color temperature (CCT) of 5500K (x = 0.332, y = 0.366), and a color rendering index (CRI) of 80. For the two-rooms technique, a gray uncoated piece of paper, approximately Munsell N6, attached to cardboard was used as the surround stimulation. The center was a 4 × 4 cm^2 window through which the observer viewed the gray patch in the test room. The surrounding color was mixed using LED light in combination with the fluorescent ceiling lamps, which were covered by color filters. This allowed for the simulation of surrounding colors that were the same as the paper stimuli. The two-rooms technique also involved the simulation of the gray patch by placing a whiteboard on the test-room wall opposite the window, with fluorescent lamps mounted parallel to the top and bottom of the window. The luminance on the whiteboard was controlled so that it was equal to that of the gray patch when the paper and LCD techniques were used. In the subject room, black walls were used to reduce the amount of color information resulting from reflected light, and also to define the stimulus presentation area. To this end, the front and side walls were covered with black cardboard (Y = 5.6 cd/m^2, x = 0.322, y = 0.347). When the two-rooms technique was employed, the chromaticities and luminance of the black wall were changed, depending on the subject-room illumination color simulated in the surrounding area, as follows: red (Y = 2.0 cd/m^2, x = 0.494, y = 0.332); yellow (Y = 5.7 cd/m^2, x = 0.429, y = 0.446); green (Y = 4.5 cd/m^2, x = 0.314, y = 0.459); blue (Y = 2.6 cd/m^2, x = 0.225, y = 0.239); and gray (Y = 4.5 cd/m^2, x = 0.327, y = 0.343).

To investigate the effect upon chromatic adaptation of the initial visual information in the space, we asked the observers to judge the color of the stimulus under the conditions of "without objects" and "with objects" such as books, dolls, and artificial flowers; these were placed on a shelf installed on the front wall of the subject room, as shown in Figure 3, and were arranged in such a way as might be witnessed in an everyday indoor setting such as a living room.

2.3. Observers

Ten observers participated in the experiment: two males

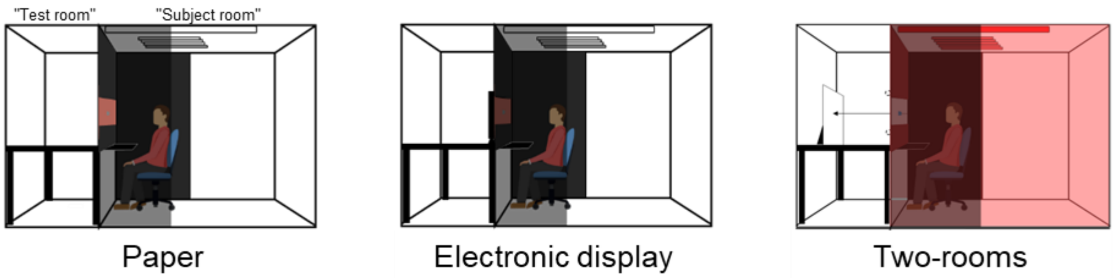

Figure 2. Three display techniques. (Mepean et al., 2023)

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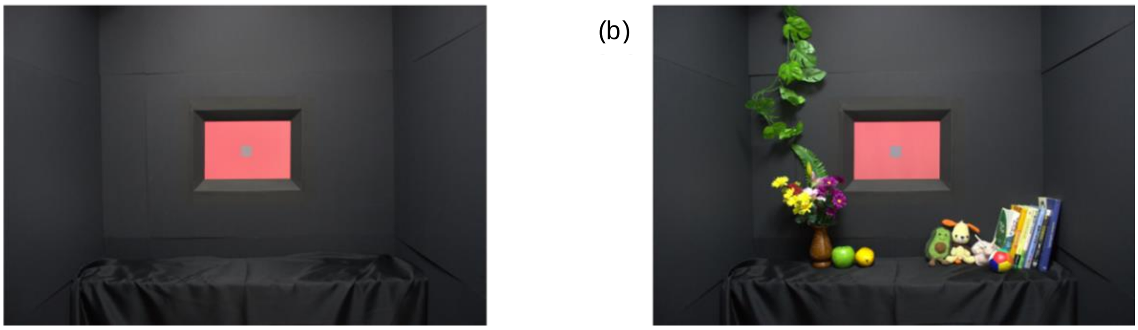

Figure 3. Front view of displayed stimulus in subject room (a) without objects and (b) with objects.

and eight females, ranging in age from 19 to 46 years, with normal color vision as determined by Ishihara testing. Informed consent was given by all participants. Two of the observers were the authors of the present paper, both of whom have many years of experience in psychophysical experiments using the elementary color naming method for assessing color appearance. The eight naive observers were all trained to use this method before commencement of the experiment proper.

2.4. Procedure

Each observer was first asked to look around the room for two minutes, so that they could adapt to the experimental environment. They were then asked to assess the color of gray patches and surrounding areas using the elementary color naming method, giving percentage estimates of chromaticness, whiteness, and blackness, which summed to a total of 100 percent. The apparent hues were then assessed based on the four unique hues of red, yellow, green, and blue, as specified in opponent color theory, again giving a total of 100 percent. The observers were allowed to evaluate apparent hues as one color or as a combination of two colors; however, combinations of opposing colors (red vs. green, yellow vs. blue) were not allowed. We also wanted to check whether the observers would perceive stimuli in different color appearance modes with different display techniques. Thus, we asked the observers to report the mode of appearance of stimuli at the gray patch and the surrounding area using three color appearance modes: “object mode," in which the color appeared as the color object; “self-luminous mode," in which the color appeared as the emitted light from itself or as a light source color; and “unnatural mode," in which the color looked brighter than the object (shiny) but was not the same as the light source color.

After these assessments, the observers were asked to close their eyes for one minute while the experimenter randomly changed the stimulus color within the same technique. Following this, the experimenter changed to another display technique in random order. When all three techniques had been evaluated, this was counted as one round. Each observer performed a total of five rounds.

3. Result and discussion

The results for appearance, such as apparent hue angles and color coordinates, were calculated using equations (see Equations 1–4 in Chitapanya *et al*., 2021) and plotted on polar diagrams that are normally used in studies involving opponent color theory, as shown in Figure 4. The origin of the diagram indicates an absence of chromaticness, and the circumference indicates 100% chromaticness. The R, Y, G, and B axes indicate the unique colors of red, yellow, green, and blue, respectively. The average of the results obtained from the 10 observers was then used to indicate the color appearance of the SCC effect on the gray patch induced by each of the surrounding colors using the three display techniques. The mean values and standard deviations (SDs) for the ten observers are shown in Appendix A (Table 2A). In the absence of objects, for all four colors, the levels of chromaticness perceived in surrounding areas were similar when the paper and LCD techniques were used. However, these values were lower when the two-rooms technique was used. For the four colors, the mean $\pm$ SD values were 59$\pm$3%, 56$\pm$3%, and 26$\pm$2%, for the paper, LCD, and two-rooms techniques, respectively. Moreover, the levels of chromaticness perceived from the gray patches indicated that the SCC effect occurred for all display techniques, with higher levels being obtained when the two-rooms technique was used. In this case, for the four colors, the mean $\pm$ SD values were 19$\pm$5%, 19$\pm$2%, and 50$\pm$4%, using the paper, LCD, and two-rooms techniques, respectively.

It can be seen that, as a result of the SCC effect, the observers’ perception of the color appearance of the gray patch was dependent on the color of the surrounding area. A red surrounding area induced the gray patch to appear green+blue (or cyan); a yellow surrounding area induced the gray patch to appear close to unique blue; a green surrounding area induced the gray patch to appear red+blue (or magenta); and a blue surrounding area induced the gray patch to appear close to unique yellow. Similar results were obtained for all three display techniques when objects were present.

The variation in chromaticness obtained using the different display techniques may now be considered. The RVSI theory suggests that the SCC effect is stronger when an observer is able to adapt to the color of the illumination in the subject room (Ikeda, 2004; Ikeda *et al*., 2006). It may be expected that lower levels of chromaticness will be perceived in surrounding areas when the two-rooms technique is used because the subject room is illuminated by colored light, and chromatic adaptation to illumination occurs by recognition of space and by understanding the illumination based on initial visual information (Mizokami *et al*., 2000). Under such conditions, color constancy is maintained because objects are perceived in their true colors, regardless of any changes in illumination. However, in our experiment, even though chromatic adaptation was not complete (because the color of illumination in the subject room could still be seen, as shown by the chromaticness of the surroundings), a stronger color contrast nevertheless appeared on the aperture at the center; this finding is in line with the results obtained by Phuangsuwan and Ikeda (2018; 2019) in their study of the SCC effect conducted using the two-rooms technique. We anticipated that the effect of chromatic adaptation would be weakest when the paper technique was used. However, we found that the LCD technique produced an SCC effect that was similar to that obtained using paper. Both techniques involved the same stimulus condition and the same viewing condition, and the perception of SCC appeared to have been due to the same mechanism, namely, the chromatic induction of the surrounding areas. These results differ from the findings of Phuangsuwan and Ikeda (2018; 2019), who found that SCC was lower when using the paper technique compared with the LCD technique. However, this difference may be

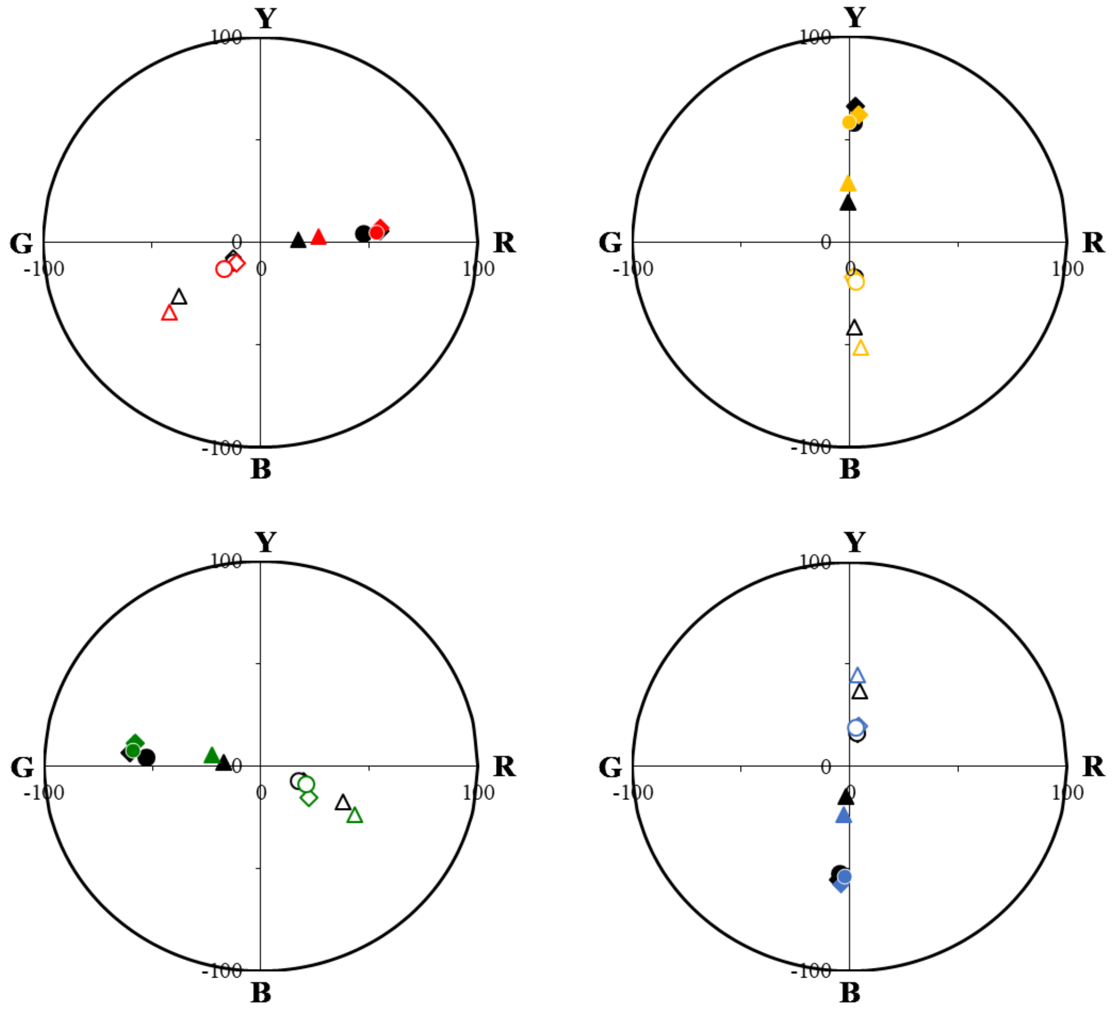

Figure 4. Polar diagram showing an average of 10 observers. The color appearance for the paper (◇), LCD (○), and two-rooms (△) techniques for surrounds (filled symbol) and gray patch (open symbol) in the "without objects" condition indicated by filled color, and in the "with objects" condition by filled black symbols.

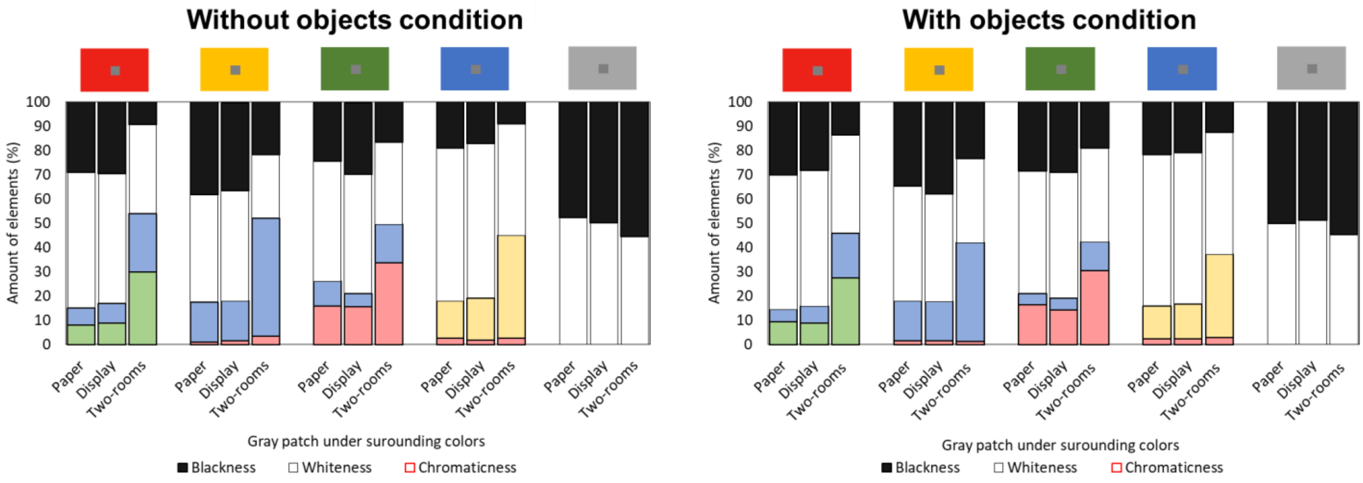

Figure 5. Comparison of mean by elements, chromaticness, whiteness, and blackness of SCC among three display techniques and under "with objects" and "without objects" conditions.

explained by factors such as different experimental conditions and numbers of observers.

In terms of chromaticness, as shown in Figure 4, we found that the results obtained using the paper and LCD techniques differed from those obtained using the two-rooms technique. However, any increase in chromaticness must also correspond to a decrease in either whiteness or blackness.

Figure 5 shows the chromaticness (colored bar), whiteness (white bar), and blackness (black bar) elements of the SCC effect. The mean and SD values for the ten observers are provided in Appendix A (see Table 3A). No SCC effect was observed under gray surrounding conditions. A three-way ANOVA with 95% confidence was applied to check the SCC effect on the chromaticness in the four colors' surrounding conditions in the display techniques. The three factors are display techniques, objects (with and without), and colors. The results indicated a significant difference between techniques ($F(2, 216) = 116.11$, $p < .001$). Tukey's HSD post hoc analysis revealed that the two-rooms technique was significantly different from both the paper ($M = -28.13$, $SE = 2.12$, $p < .001$) and LCD ($M = -27.87$, $SE = 2.12$, $p < .001$) techniques. However, there was no significant difference in chromaticness between the paper and LCD techniques ($p = .99$) (see Appendix A, Table 5A, post hoc Comparisons—Technique). There were also no significant differences in chromaticness among the color surround conditions within techniques ($F(3, 216) = 1.29$, $p = .27$). The average results of the SCC for the four color surrounds are shown in Figure 6, which were compared between the conditions of with and without objects; the mean and SD values are shown in Appendix A (see Table 4A). It was found that the chromaticness between the conditions of with and without objects showed a slight difference ($F(1, 216) = 4.70$, $p = .03$); however, this is due to the differences between the paper and two-rooms techniques, as well as between the LCD and two-rooms techniques.

We assumed that the addition of objects to the subject room would help observers to better perceive the illumination in the space, and then adapt to it. More simply, we hypothesized that the observers would perceive an increase in SCC in the gray patch with objects condition. However, we found that there were no significant differences between the conditions of with and without objects for the paper, LCD, and two-rooms techniques, at $p > .05$ (see Appendix A, Tables 5A-6A: post hoc Comparisons—Techniques ✻ Objects). Although the two-rooms technique showed a *p*-value of 0.06, meaning no significant difference between the "with objects" and "without objects" conditions, if we look at Figure 6, the chromaticness appears to be slightly different. In the "with objects" condition, the chromaticness is smaller than the "without objects" condition; this may be due to the surrounding object colors in the complex scene. With many highly saturated objects, the test stimulus was likely judged to have lower chromaticness. This result is consistent with the findings of previous studies, which indicated that chromatic induction from a surrounding area into a central patch decreases when there is an inhomogeneous region outside the surrounding area (Jenness and Shevell, 1995; Shevell and Wei, 1998; Barnes *et al*., 1999). Although the previous results were obtained using an electronic display, our findings showed similar results upon adding colorful objects to the scene illuminated by a single color

Initially, we suspected that the color appearance mode might have been one of the factors affecting the SCC. However, the results indicated that the observers' color

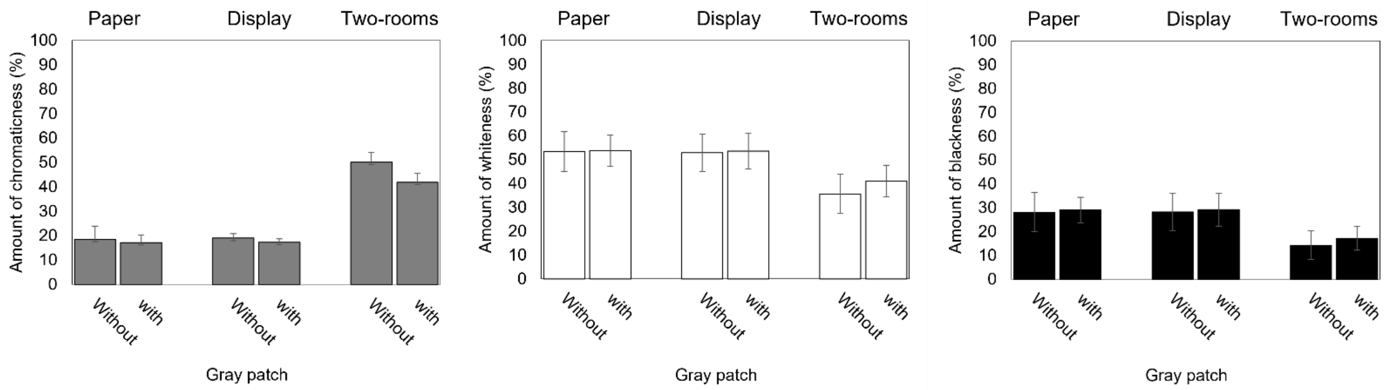

Figure 6. Comparison of elements, chromaticness, whiteness, and blackness of the SCC with and without objects for three display techniques. Error bars denote SD values for ten observers.

appearance mode was the object mode for those techniques. This suggests that the highest chromaticness in the two-rooms technique is not influenced by the color appearance mode.

The results for the SCC hues obtained using the three display techniques were plotted, as shown in Figure 7. The ordinate represents the hue angle of the SCC and the abscissa represents the hue angle of the surrounding area. We also compared the relationship between the SCC hue, which was induced by the surrounding hue in the present study, to the arrangements expected using opponent color theory and complementary color theory (see Figure 10 in Phuangsuwan and Ikeda, 2017). The display techniques chosen to present the stimuli appear to have little influence on the perception of SCC hue, either with or without objects. We compared the SCC hues for each of the four surrounding colors across different display techniques, considering three factors: display technique, objects (with or without), and color. The results showed no significant difference in SCC hues ($F(6, 204) = 0.155$, $p = .988$) (see Table 7A in Appendix A). This finding is similar to the findings of other studies of color appearance conducted using different devices, which found that the hue does not change (Wu, 2005; Billger, 2000; Kutas *et al.*, 2005; Phuangsuwan and Ikeda, 2018; 2019).

Pridmore (2007) suggested that SCC hues on gray patches induced by surrounding colors are understood in terms of complementary color theory. Pridmore also analyzed the SCC data obtained by Luo *et al*. (1995) and Wu and Wardman (2007), and asserted that the SCC can be better interpreted in terms of complementary colors theory. Therefore, in Figure 7, we compare the relationship between the surrounding hue and SCC hue as estimated by both opponent color theory and complementary color theory, based on information from Phuangsuwan and Ikeda (see Figure 10 in Phuangsuwan and Ikeda, 2017). The sum of squared differences (SSD) indicates that the

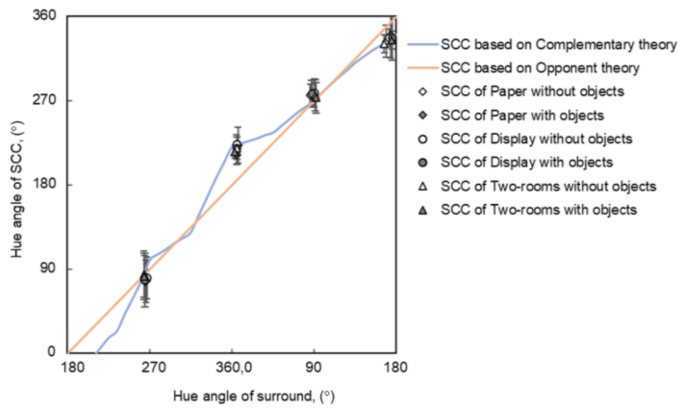

Figure 7. Relationship between surrounding hue and SCC hue (gray patch), compared to opponent color theory and complementary color theory. Error bars denote SD values for ten observers.

SCC hue corresponded more closely with complementary color theory (blue line), which consistently outperformed opponent color theory (orange line) for red (SSD = 206 vs. 7046), green (SSD = 125 vs. 162) and blue surrounds (SSD = 70 vs. 142). In the yellow surround, both models performed almost equally (SSD = 353 vs. 354), supporting supports Pridmore's assertion (Pridmore, 2007). Our results strongly suggest that complementary color theory provides a more accurate prediction of SCC hue shifts compared to opponent color theory.

Furthermore, we found that, with yellow surrounds, observers who perceived the surrounding area as yellow + red perceived the SCC color as blue + red. Similar results have been reported in previous research, including studies on afterimage color (Wilson and Brocklebank, 1995) and chromatic adaptation using the two-rooms technique (Phuangsuwan and Ikeda, 2017). This finding is surprising because, according to both opponent color theory and complementary color theory, yellow + red induction would be expected to cause a blue + green perception.

4. Conclusion

The results of the present study suggest that the SCC effect is device dependent, and that variations in the SCC effect obtained using different display techniques may be caused by two mechanisms:

1. When either the paper or LCD technique is used, the SCC effect seems to be caused by the color of the surrounding area. This may be understood as chromatic induction from the color of the surrounding area, leading to the appearance of contrast color at the center.

2. When the two-rooms technique is used, the SCC effect seems to be caused by chromatic adaptation and contrast induction at the same time.

3. It is suggested that SCC relies on the complexity of the scene in the two-rooms technique, as the various color attributes of objects in the subject room provide visual information to the observer.

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6. Conflict of interest declaration

The authors declare no conflict of interest.

7. Funding source declaration

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Licensing terms

References

Arend, L., and Reeves, A. (1986). Simultaneous color constancy. *Journal of the Optical Society of America,* 3(10), pp. 1743-1751.

Barnes, C. S., Wei, J., and Shevell, S. K. (1999). Chromatic induction with remote chromatic contrast varied in magnitude, spatial frequency, and chromaticity. *Vision Research*, 39(21), pp. 3561-3574.

Billger, M. (2000). Evaluation of a colour reference box as an aid for identification of colour appearance in rooms. *Color Research & Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur*, 25(3), pp. 214-225.

Chitapanya, P., Ikeda, M., and Phuangsuwan, C. (2018). Comparison of the simultaneous color contrast determined by colored paper and colored illumination. *Supplement in Journal of the Color Science Association of Japan (CSAJ)*, 42(3+), pp. 57-60.

Chitapanya, P., Phuangsuwan, C., and Ikeda, M. (2022). Color appearance of color chips under light-emitting diode lamps. *Color Research and Application*, 47(3), pp. 585-604. doi: 10.1002/col.22744.

Ekroll V., Faul F., Niederée R. (2004). The peculiar nature of simultaneous colour contrast in uniform surrounds. *Vision Research*, 44, pp. 1765–1786.

Ikeda, M. (2004). Color Appearance Explained, Predicted and Confirmed by the Concept of Recognized Visual Space of Illumination. *Optical Review*, 11(4), pp. 217–225.

Ikeda, M., Naksuwan, W., and Phuangsuwan, C. (2014). Chromatic adaptations not for object but for illumination. *J Col Assoc Jpn*., 38, pp. 174-175.

Ikeda, M., Pungrassamee, P., Katemake, P., and Hansuebsai, A. (2006). The Brain Adaptation to the Color of Illumination and not the Retinal Adaptation to the Color of Objects that Determines the Color Appearance of an Object in the Space. *Optical review*, 13, pp. 388-395.

Ikeda, M., Shinoda, H., and MIzokami, Y. (1998). Three dimensionality of the recognized visual space of illumination proved by hidden illumination. *Optical Review*, 5, pp. 200-205.

Jameson, D., and Hurvich, L. M. (1959). Perceived color and its dependence on focal, surrounding, and preceding stimulus variables. *Journal of the Optical Society of America*, 49(9), pp. 890-898.

Jameson, D. and Hurvich, L. M. (1961). Opponent chromatic induction: experimental evaluation and theoretical account. *Journal of the Optical Society of America*, 51(1), pp. 46–53.

Jenness, J. W., and Shevell, S. K. (1995). Color appearance with sparse chromatic context. *Vision Research*, 35(6), pp. 797-805. doi: 10.1016/00 42-6989(94)00169-M.

Jinphol, S., Ikeda, M., Phuangsuwan, C., and Mizokami, Y. (2019). Effect of haze value and materials on the color appearance in the tissue experiment of the simultaneous color contrast. *Proceeding of the 5th Asia Color Association Conference, Nagoya*, pp. 226-231.

Klauke, S., and Wachtler, T. (2015). "Tilt" in color space: Hue changes induced by chromatic surrounds. *Journal of vision*, 15(13), pp. 1-17. doi: 10.1167/15.13.17.

Krauskopf, J., Zaidi, Q., and Mandlert, M. B. (1986). Mechanisms of simultaneous color induction. *Journal of the Optical Society of America*, 3(10), pp. 1752-1757. doi: 10.1364/JOSAA.3.001752.

Kutas G, Gocza K, Bodrogi P, Schanda J. (2005). Color size effect. *In: Proceedings of 10th Congress of the International Color Association, Spain*, pp. 887-890.

Land, E. H. (1959). The retinex theory of color vision. *Scientific American*, 200(4), pp. 24-29. Available at: http://www.jstor.org/stable/24953876 (Accessed: 5 March 2024)

Lotto, R. B., and Purves, D. (2000). An empirical explanation of color contrast. *Proceedings of the National Academy of Sciences*, 97(23), pp. 12834-12839.

Luo, M. R., Gao, X. W., and Scrivener, S. A. (1995). Quantifying colour appearance. Part V. Simultaneous contrast. *Color Research and Application*, 20(1), pp. 18-28. doi: 10.1002/col.5080200105.

Mepean, J., Phuangsuwan, C., and Ikeda, M. (2023). Effect of Display Technique on Simultaneous Color Contrast. *Proceeding of the 15th Congress of the International Colour Association, Thailand*, pp. 224-229.

Mizokami, Y., Ikeda, M., and Shinoda, H. (2000). Color property of the recognized visual space of illumination controlled by interior color as the initial visual information. *Optical Review*, 7, pp. 358-363. doi: 10.1007/s10043-000-0358-5.

Phuangsuwan, C. and Ikeda, M. (2018). Simultaneous Color Contrast Demonstrated on Different Devices. *Supplement in Journal of the Color Science Association of Japan (CSAJ),* 42-3, 54-56.

Phuangsuwan, C. and Ikeda, M. (2019). Device dependent simultaneous color contrast. *Supplement in Journal of the Color Science Association of Japan (CSAJ)*, 43-3, pp. 121-124

Phuangsuwan, C. and Ikeda, M. (2017). Chromatic adaptation to illumination investigated with adapting and adapted color. *Color Research and Application*, 42, pp. 571-579. doi: 10.1002/col.22117.

Pungrassamee, P., Ikeda, M., Katemake, P., and Hansuebsai, A. (2005). Color appearance determined by recognition of space. *Optical review*, 12, pp. 211-218. doi: 10.1007/s10043-005-0211-y.

Pridmore, R.W. (2007a) Chromatic induction: Opponent color or complementary color process?, *Color Research and Application*, 33(1), pp. 77–81. doi: 10.1002/col.20363. doi:10.1002/col.20363

Shevell, S. K., and Wei, J. (1998). Chromatic induction: border contrast or adaptation to surrounding light?. *Vision Research*, 38(11), pp. 1561-1566.

Srirat, P., Phuangsuwan, C., and Ikeda, M. (2014). 2B-6 Chromatic adaptation to illumination investigated with two rooms technique *Supplement in Journal of the Color Science Association of Japan (CSAJ)*, 38(3), pp. 176-177.

Webster, M. A., and Mollon, J. D. (1994). The influence of contrast adaptation on color appearance. *Vision research*, 34(15), pp. 1993-2020.

Wu, R. C., and Wardman, R. H. (2006). Lightness and hue contrast effects in surface (fabric) colours. *Color Research and Application*, 32(1), pp. 55-64. doi: 10.1002/col.20285.

Wu, R. C., Wardman, R. H., and Luo, M. R. (2005). A comparison of lightness contrast effects in CRT and surface colours. *Color Research and Application: Endorsed by Inter-Society Color Council, The Colour Group (Great Britain), Canadian Society for Color, Color Science Association of Japan, Dutch Society for the Study of Color, The Swedish Colour Centre Foundation, Colour Society of Australia, Centre Français de la Couleur*, 30(1), pp. 13-20.

Xiao, K., Luo, M. R., Li, C., and Hong, G. (2010). Colour appearance of room colours. *Color Research and Application*, 35(4), pp. 284-293. doi: 10.1002/col.20575.

Appendix A

Color	Device	Y (cd/m^2)	*x*	*y*	C^*_{ab}
Red surround	Paper	23	0.453	0.342	42
	Display	23	0.453	0.343	41
	Two-rooms	22	0.452	0.344	42
Yellow surround	Paper	37	0.424	0.442	42
	Display	37	0.424	0.449	43
	Two-rooms	36	0.424	0.446	43
Green surround	Paper	28	0.315	0.465	38
	Display	26	0.321	0.464	36
	Two-rooms	26	0.318	0.464	35
Blue surround	Paper	18	0.239	0.262	32
	Display	18	0.242	0.263	32
	Two-rooms	18	0.241	0.264	31
Gray surround	Paper	27	0.335	0.353	3
	Display	27	0.335	0.35	5
	Two-rooms	27	0.335	0.354	3
Gray patch	Paper	24	0.332	0.351	5
	Display	24	0.335	0.351	5
	Two-rooms	24	0.333	0.352	5

Table 1A. Luminance values, chromaticities, and chroma CIE C^*_{ab} of colors in the paper and display stimuli.

Mean value of color appearance with SD in polar diagram (without objects condition)					
Technique	Color	Surround		Gray patch	
		x	*y*	*x*	*y*
Paper	Red	55±11	7±15	-11±15	-10±15
	Yellow	4±5	62±9	2±9	-17±9
	Green	-57±8	11±11	21±11	-15±11
	Blue	-4±9	-58±9	4±9	18±9
Display	Red	53±12	5±12	-13±12	-11±12
	Yellow	0±3	59±10	3±10	-18±10
	Green	-59±8	8±12	19±12	-8±12
	Blue	-3±2	-54±14	3±14	19±14
Two-rooms	Red	27±15	3±2	-42±2	-34±2
	Yellow	-1±14	28±19	5±19	-52±19
	Green	-23±1	5±18	43±18	-24±18
	Blue	-3±1	-24±1	4±1	45±1

Mean value of color appearance with SD in polar diagram (with objects condition)					
Technique	Color	Surround		Gray patch	
		x	*y*	*x*	*y*
Paper	Red	55±16	5±13	-12±12	-8±8
	Yellow	3±5	66±16	3±4	-18±9
	Green	-60±13	6±7	20±13	-7±7
	Blue	-5±6	-56±18	4±5	16±10
Display	Red	47±13	5±11	-12±7	-10±11
	Yellow	2±3	58±17	2±4	-18±10
	Green	-53±12	4±8	18±10	-7±6
	Blue	-5±5	-53±20	3±5	16±10
Two-rooms	Red	18±8	1±3	-37±19	-27±23
	Yellow	-1±2	19±8	2±7	-42±13
	Green	-17±6	1±7	38±16	-18±16
	Blue	-2±0	-15±1	5±8	37±16

Table 2A. Mean values of color appearance in polar diagram with SD in Figure 4.

Mean values of amount of elements with SD (without objects condition)								
Technique	Color	Chromaticness	Whiteness	Blackness	Red	Yellow	Green	Blue
Paper	Red	15±12	56±16	31±14	0	0	52±25	48±30
	Yellow	18±14	44±19	38±19	6±13	0	0	94±38
	Green	26±14	50±18	25±17	61±26	0	0	39±19
	Blue	18±11	63±18	19±17	14±18	86±17	0	0
	Gray	0	52±15	48±15	0	0	0	0
Display	Red	17±14	53±18	30±16	0	0	52±29	48±26
	Yellow	18±15	45±19	36±20	9±11	0	0	91±29
	Green	21±17	49±16	29±17	74±28	0	0	26±18
	Blue	19±13	64±15	17±14	10±8	90±30	0	0
	Gray	0	50±17	50±17	0	0	0	0
Two-rooms	Red	54±12	37±9	91±1	0	0	56±20	44±20
	Yellow	50±7	26±11	22±15	7±9	0	0	93±8
	Green	52±6	34±7	17±9	68±9	0	0	32±9
	Blue	45±18	46±11	9±7	6±9	94±7	0	0
	Gray	0	45±12	56±12	0	0	0	0

Mean values of amount of elements with SD (with objects condition)								
Technique	Color	Chromaticness	Whiteness	Blackness	Red	Yellow	Green	Blue
Paper	Red	14±13	56±22	30±24	0	0	64±38	36±31
	Yellow	18±10	47±19	35±18	9±12	0	0	91±12
	Green	21±14	50±22	29±18	78±15	0	0	22±15
	Blue	16±10	62±16	55±17	14±27	86±26	0	0
	Gray	0	50±20	50±19	0	0	0	0
Display	Red	16±14	56±21	28±21	0	0	57±39	43±33
	Yellow	18±10	44±19	38±16	9±10	0	0	91±10
	Green	19±11	52±22	29±18	74±28	0	0	26±20
	Blue	17±9	62±18	21±17	13±24	87±23	0	0
	Gray	0	51±20	49±18	0	0	0	0
Two-rooms	Red	46±17	40±18	14±9	0	0	60±27	402±7
	Yellow	42±13	35±14	23±13	3±8	0	0	97±8
	Green	42±20	39±24	19±12	72±18	0	0	28±18
	Blue	37±17	50±6	13±13	8±11	92±11	0	0
	Gray	0	46±15	54±16	0	0	0	0

Table 3A. Mean values of amount of elements with SD in Figure 5.

Technique	Condition	Mean values of amount of elements with SD		
		Chromaticness	Whiteness	Blackness
Paper	Without objects	19±10	53±11	28±3
	With objects	17±11	54±20	29±19
Display	Without objects	19±12	53±10	28±5
	With objects	17±11	54±20	29±18
Two-rooms	Without objects	50±16	36±17	14±9
	With objects	42±17	41±15	17±13

Table 4A. Mean values of amount of elements with SD in Figure 6.

ANOVA - Chromaticness

	Sum of Squares	df	Mean Square	F	p
Techniques	41834.8	2	20917.4	116.1136	< .001
Objects	847.5	1	847.5	4.7045	0.031
Color	699.7	3	233.2	1.2947	0.277
Techniques ✻ Objects	619.9	2	309.9	1.7204	0.181
Techniques ✻ Color	1361.6	6	226.9	1.2597	0.277
Objects ✻ Color	38.6	3	12.9	0.0714	0.975
Techniques ✻ Objects ✻ Color	99.3	6	16.5	0.0918	0.997
Residuals	38911.5	216	180.1		

Post Hoc Comparisons - Techniques

Comparison							
Techniques		Techniques	Mean Difference	SE	df	t	p_{tukey}
Paper	-	Display	-0.262	2.12	216	-0.124	0.992
	-	Two-rooms	-28.137	2.12	216	-13.259	< .001
Display	-	Two-rooms	-27.875	2.12	216	-13.135	< .001

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Objects

Comparison							
Objects		Objects	Mean Difference	SE	df	t	p_{tukey}
With	-	Without	-3.76	1.73	216	-2.17	0.031

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Color

Comparison							
Color		Color	Mean Difference	SE	df	t	p_{tukey}
R	-	Y	-1.00	2.45	216	-0.408	0.977
	-	G	-3.28	2.45	216	-1.340	0.539
	-	B	1.40	2.45	216	0.571	0.941
Y	-	G	-2.28	2.45	216	-0.932	0.788
	-	B	2.40	2.45	216	0.979	0.761
G	-	B	4.68	2.45	216	1.911	0.226

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Techniques ✻ Objects

Comparison									
Techniques	Objects		Techniques	Objects	Mean Difference	SE	df	t	p_{tukey}
Paper	With	-	Paper	Without	-1.3250	3.00	216	-0.4415	0.998
		-	Display	With	-0.1000	3.00	216	-0.0333	1.000
		-	Display	Without	-1.7500	3.00	216	-0.5831	0.992
		-	Two-rooms	With	-24.6500	3.00	216	-8.2133	< .001
		-	Two-rooms	Without	-32.9500	3.00	216	-10.9789	< .001
	Without	-	Display	With	1.2250	3.00	216	0.4082	0.999
		-	Display	Without	-0.4250	3.00	216	-0.1416	1.000
		-	Two-rooms	With	-23.3250	3.00	216	-7.7719	< .001
		-	Two-rooms	Without	-31.6250	3.00	216	-10.5374	< .001
Display	With	-	Display	Without	-1.6500	3.00	216	-0.5498	0.994
		-	Two-rooms	With	-24.5500	3.00	216	-8.1800	< .001
		-	Two-rooms	Without	-32.8500	3.00	216	-10.9456	< .001
	Without	-	Two-rooms	With	-22.9000	3.00	216	-7.6302	< .001
		-	Two-rooms	Without	-31.2000	3.00	216	-10.3958	< .001
Two-rooms	With	-	Two-rooms	Without	-8.3000	3.00	216	-2.7655	0.067

Note. Comparisons are based on estimated marginal means

Table 5A. Results of the SCC effect in terms of chromaticness using a three-way ANOVA and post hoc test with display techniques, objects (with and without), and colors.

ANOVA - Whiteness

	Sum of Squares	df	Mean Square	F	p
Techniques	12175.9	2	6087.9	20.5056	< .001
Objects	281.7	1	281.7	0.9487	0.331
Color	9920.7	3	3306.9	11.1384	< .001
Techniques ✻ Objects	309.3	2	154.7	0.5209	0.595
Techniques ✻ Color	93.9	6	15.7	0.0527	0.999
Objects ✻ Color	67.4	3	22.5	0.0756	0.973
Techniques ✻ Objects ✻ Color	140.6	6	23.4	0.0789	0.998
Residuals	64128.6	216	296.9		

Post Hoc Comparisons - Technique

Comparison							
Techniques		Techniques	Mean Difference	SE	df	t	p_{tukey}
Paper	-	Display	0.362	2.72	216	0.133	0.990
	-	Two-rooms	15.287	2.72	216	5.611	< .001
Display	-	Two-rooms	14.925	2.72	216	5.478	< .001

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Objects

Comparison							
Objects		Objects	Mean Difference	SE	df	t	p_{tukey}
With	-	Without	2.17	2.22	216	0.974	0.331

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Color

Comparison							
Color		Color	Mean Difference	SE	df	t	p_{tukey}
R	-	Y	9.53	3.15	216	3.03	0.014
	-	G	4.22	3.15	216	1.34	0.538
	-	B	-8.05	3.15	216	-2.56	0.054
Y	-	G	-5.32	3.15	216	-1.69	0.331
	-	B	-17.58	3.15	216	-5.59	< .001
G	-	B	-12.27	3.15	216	-3.90	< .001

Note. Comparisons are based on estimated marginal means

Post Hoc Comparisons - Techniques ✻ Objects

Comparison									
Techniques	Objects		Techniques	Objects	Mean Difference	SE	df	t	p_{tukey}
Paper	With	-	Paper	Without	0.450	3.85	216	0.1168	1.000
		-	Display	With	0.250	3.85	216	0.0649	1.000
		-	Display	Without	0.925	3.85	216	0.2401	1.000
		-	Two-rooms	With	12.825	3.85	216	3.3287	0.013
		-	Two-rooms	Without	18.200	3.85	216	4.7238	< .001
	Without	-	Display	With	-0.200	3.85	216	-0.0519	1.000
		-	Display	Without	0.475	3.85	216	0.1233	1.000
		-	Two-rooms	With	12.375	3.85	216	3.2119	0.019
		-	Two-rooms	Without	17.750	3.85	216	4.6070	< .001
Display	With	-	Display	Without	0.675	3.85	216	0.1752	1.000
		-	Two-rooms	With	12.575	3.85	216	3.2638	0.016
		-	Two-rooms	Without	17.950	3.85	216	4.6589	< .001
	Without	-	Two-rooms	With	11.900	3.85	216	3.0886	0.027
		-	Two-rooms	Without	17.275	3.85	216	4.4837	< .001
Two-rooms	With	-	Two-rooms	Without	5.375	3.85	216	1.3951	0.730

Note. Comparisons are based on estimated marginal means

Table 6A. Results of the SCC effect in terms of whiteness using a three-way ANOVA and post hoc test with display techniques, objects (with and without), and colors.

ANOVA - SCC hue

	Sum of Squares	df	Mean Square	F	p
Techniques	52.9	2	26.4	0.0941	0.910
Objects	172.7	1	172.7	0.6152	0.434
Color	2.10e+6	3	698343.5	2487.4964	< .001
Techniques ✻ Objects	37.4	2	18.7	0.0667	0.936
Techniques ✻ Color	546.0	6	91.0	0.3241	0.924
Objects ✻ Color	1011.3	3	337.1	1.2007	0.311
Techniques✻ Objects ✻ Color	261.0	6	43.5	0.1550	0.988
Residuals	57271.3	204	280.7		

Table 7A. Results of three-way ANOVA for SCC hue with display techniques, objects condition (with and without), and colors.

Exploring crossmodal color correspondences through neuromarketing

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ABSTRACT

It is now well known that marketing is evolving. In this context, sensory marketing can be defined as a revolutionary approach to consumer engagement that leverages the five human senses to create immersive and memorable product experiences. This strategy aims to build stronger emotional connections and enhance interactions with the brand or the product itself by tapping into the complex web of sensory perception. A key concept in sensory marketing is crossmodal correspondence, which explores how the activation of one sense can influence the perception of another. For example, the perceived sweetness of a product can be heightened when associated with the color red. Integrating neuromarketing principles, which utilize insights from neuroscience, further enhances the effectiveness of sensory marketing. This integration allows marketers to understand the subconscious decision-making processes that drive consumer behavior. Visual elements, particularly color, play a crucial role, with studies showing that color significantly impacts initial product judgments. Sensory marketing transcends traditional sales tactics by fostering deep, lasting relationships with consumers through multi-sensory experiences that engage sight, sound, touch, taste, and smell. This holistic approach requires a comprehensive understanding of target demographics, consumer psychology, and the art of creating personalized, engaging experiences. As the marketing landscape evolves, sensory marketing stands at the forefront of innovation, offering a pathway to more meaningful consumer engagement and greater brand loyalty.

KEYWORDS Color, Neuromarketing, Sensation, Perception, Emotion, Behavioral Economics.

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1. Introduction

In the increasingly fast-paced world of marketing and advertising, companies are constantly seeking new ways to capture consumer attention and consequently boost their sales (Krishna et al., 2016; Wörfel et al., 2022). Based on this, in his 1999 article, Schmitt explores a new approach to marketing called "Experiential Marketing" with the same approach as behavioral economics (Thaler, 2016). Traditional marketing tends to view consumers as rational decision-makers who focus primarily on the functional characteristics and benefits of products. However, Schmitt introduces Experiential Marketing, which sees consumers as both rational and emotional beings who seek enjoyable and memorable experiences (Schmitt, 1999). Schmitt outlines five distinct types of experiences that marketers can create for their customers. The first type is sensory experiences (SENSE), which engage the consumer's senses—sight, sound, touch, taste, and smell. Imagine walking into a store where the lighting is just right, the music is soothing, and there's a pleasant scent in the air. All these elements work together to create a welcoming and enjoyable atmosphere (Hultén, 2011). Next, we have affective experiences (FEEL), which aim to evoke emotions and feelings. Think of an advertising campaign that tells a heartwarming story, making you feel joy, nostalgia, or empathy. These emotional connections can make a brand more memorable and meaningful to consumers (Brakus, Schmitt, & Zarantonello, 2009). Creative cognitive experiences (THINK) are designed to stimulate the consumer's thinking and creativity. For example, a company might host a contest where customers can submit their ideas for a new product, or they might organize a workshop that encourages creative problem-solving. These activities engage the intellect and foster a deeper connection with the brand (Zaltman, 2003). Physical experiences, behaviors, and lifestyles (ACT) encourage consumers to take action and change their behaviors or lifestyles. A fitness brand, for instance, might offer interactive workout classes that motivate people to adopt healthier habits. By integrating the brand into their daily routines, consumers form a stronger bond with it (Pine & Gilmore, 1998). At the end, there are social identity experiences (RELATE), which are based on social relationships and group identity. A brand might create an online community where customers can share their experiences and feel part of a group with common interests. This sense of belonging and identity can enhance the overall brand experience (Muniz & O'Guinn, 2001). Schmitt in his work also discusses how these experiences are facilitated by what he calls experience providers (ExPros). These include elements like communication, visual and verbal identity, product presence, and electronic media. The ultimate goal of Experiential Marketing is to create holistic experiences that integrate these individual elements into a cohesive and engaging whole. By focusing on creating these rich, multi-faceted experiences, marketers can move beyond the traditional emphasis on functional benefits and instead build strong emotional connections with their customers. This approach not only makes the brand more memorable but also fosters loyalty and long-term engagement (Schmitt, 1999).

Starting from this, since 2010, and perhaps experiencing its peak of interest today from both a scientific and non-scientific standpoint, one of the most effective strategies has been "Sensory Marketing" (Krishna & Schwarz, 2014). This tactic engages human senses to forge deeper emotional connections between brands, products, and consumers, ensuring that the product/brand-consumer interaction is an increasingly unique and memorable experience (Krishna, 2011; Hultén, 2011). The consideration and use of senses as an essential part of marketing strategies has a long history. However, the concept of "Sensory Marketing" or "Multisensory Marketing", or even "Sensehacking" (Spence, 2021), only emerged when branding and marketing professionals began to focus on the use of the senses of smell and hearing, in addition to sight, touch, and taste (Krishna et al., 2016). This demonstrated how senses interact with and influence our mind, body, and behaviours (Spence, 2021). Sensory marketing has proven to be particularly effective in creating lasting impressions and influencing consumer behavior. As Lindstrom (2005) notes, "The more sensory touch points consumers can access when buying a product, the higher the number of sensory memories activated, and the stronger their bond with the product." This multisensory approach can lead to what Hultén (2011) calls a "multi-sensory brand-experience," where consumers engage with a brand on multiple sensory levels simultaneously.

The power of sensory marketing lies in its ability to tap into subconscious processes. Zaltman (2003) argues that "95% of all cognition occurs below awareness in the shadows of the mind," highlighting the importance of targeting these unconscious processes through sensory cues. This aligns with findings from neuroscience, where studies have shown that sensory stimuli can activate specific brain regions associated with emotions and memory (Reimann et al., 2012). Moreover, sensory marketing can be particularly effective in differentiating products in crowded marketplaces. As noted by Spence and Gallace (2011), "In many mature product categories, traditional marketing approaches are no longer sufficient to differentiate brands." By leveraging unique sensory experiences, brands can create a distinct identity that sets them apart from competitors. The application of sensory marketing extends beyond just product design and packaging. It can also be used to create immersive retail environments. As Pine and Gilmore (1998) famously stated, we are moving towards an "experience economy" where "experiences are the economic offerings that have shown the greatest ability to create value." Retailers who can create engaging sensory experiences in their stores are likely to see increased customer loyalty and sales (Doucé & Janssens, 2013).

Focusing on color, it plays a pivotal role in marketing, and obviously in sensory marketing (Bortolotti et al., 2023; Labrecque et al., 2013), and the role it plays on emotion is equally well known (Bortolotti et al., 2022). Color is not just a visual element, according to Hine (1995), color impacts consumers in three distinct and interconnected ways: physiological (Siniscalco & Bortolotti, 2022), associative (Spence, 2018), and cultural (Bortolotti, 2023; Shavitt & Barnes, 2020). Physiologically, humans display specific responses to certain colors, such as the alertness linked to exposure to the blue light of dawn (Lehrl et al., 2007). Another example involves pinkish-red skin tones, like bubble-gum pink, which provide insights into the emotional state of individuals (Changizi, et al., 2006). There's a suggestion that exposure to hues within this range, like the well-known Baker-Miller pink, can influence us at a physiological level (Alter, 2013). The assumption that color meanings remain fixed across consumers and time due to common affective valence might not be accurate, given cross-cultural variations and historical shifts in color meanings (Labrecque et al., 2013; Madden et al., 2000). Abstract concepts might easily be associated with colors, while concrete concepts might have more rigid color representations. Furthermore, abstract concepts may carry underlying semantic meanings (Adams & Osgood, 1973). Color is a powerful communication tool that can influence our mood, feelings, and even consumer behavior. Brands strategically use color to evoke specific emotions and sensory experiences that align with their brand identity. For instance, warm colors like red or yellow can evoke feelings of warmth and comfort, while cool colors like blue or green can create a sense of calm and trust (Bakhshi & Gilbert, 2015). By understanding the psychology of color, marketers can create more impactful and memorable brand experiences for consumers. This focus on color in sensory marketing highlights its importance in creating deeper emotional connections between products -or brand- and consumers. The impact of color in marketing extends beyond mere aesthetics. As noted by Elliot and Maier (2014), color can significantly influence consumer perceptions and behaviors. Their color-in-context theory suggests that the meaning and effects of color are context-dependent, emphasizing the importance of considering the specific marketing environment when selecting colors. Moreover, the associative power of color can be leveraged to create strong brand identities. Bottomley and Doyle (2006) found that the appropriateness of a color for a brand depends on the product category and the brand's positioning. For example, functional products are often associated with functional colors, while sensory-social products are linked with sensory-social colors.

The cultural aspect of color perception adds another layer of complexity to sensory marketing strategies. As highlighted by Aslam (2006), color meanings and preferences can vary significantly across cultures. For instance, while white is associated with purity and weddings in Western cultures, it's often linked to mourning in many Eastern cultures. This cultural dimension underscores the importance of tailoring color strategies to specific target markets and cultural contexts. In the digital age, the role of color in sensory marketing has taken on new dimensions. Research by Gorn et al. (2004) suggests that color can influence the perceived speed of website downloads, with warmer colors leading to perceptions of longer waiting times. This highlights the need for marketers to consider the holistic impact of color choices across various touchpoints in the consumer journey.

Understanding the full potential of sensory marketing through neuromarketing tools serves a dual purpose. On one hand, elucidating the processes underlying sensory integrations is undoubtedly of interest to current research in cognitive neuroscience and consumer psychology (Spence et al., 2019; Plassmann et al., 2015). On the other hand, comprehending how these intense sensory experiences can influence choices is invaluable to companies seeking to optimize their products and sales strategies (Krishna, 2012; Zaltman, 2003). In the early years of marketing strategies, the primary goal for many companies was predominantly to increase sales through traditional advertising methods. However, today we observe a paradigm shift; for many businesses, creating a lasting bond between the consumer and the brand has become as crucial as generating immediate purchases (Hultén, 2011; Lindstrom, 2005). This evolution reflects a deeper understanding of consumer behavior and the recognition that emotional and sensory connections play a pivotal role in decision-making processes (Damasio, 1994; LeDoux, 1996). Sensory marketing now takes into account human perception and its subjectivity, becoming a key component in the business strategy of companies (Krishna, 2012). This approach primarily focuses on customer experiences, embracing a holistic view of the brand, be it a product or a service (Schmitt, 1999; Pine & Gilmore, 1998). We recognize that human senses play a fundamental role in consumer purchasing behavior and are therefore at the center of marketing strategies that aim to create engaging sensory experiences (Peck & Childers, 2008; Krishna & Schwarz, 2014). Expanding on this concept, it's important to note that sensory marketing has evolved from being a mere sales booster to an essential tool for building brand identity and customer loyalty (Brakus et al., 2009). It's no longer just about enticing customers to make an immediate purchase; it's about creating an immersive brand experience that resonates with customers on a deeper, more personal level. This shift in focus reflects a broader change in the business landscape, where customer experience and brand loyalty are becoming increasingly important (Lemon & Verhoef, 2016). Moreover, sensory marketing recognizes the subjectivity of human perception. It understands that each individual may perceive and interpret sensory stimuli differently, influenced by factors such as culture, personal experiences, and cognitive biases (Gentile et al., 2007; Yoon et al., 2012). Therefore, successful sensory marketing strategies are those that can cater to this diversity of sensory experiences and create personalized customer experiences (Puccinelli et al., 2009). Furthermore, sensory marketing embraces a holistic view of the brand. It's not just about the product or service; it's about the entire brand experience—from the initial interaction with the brand to post-purchase engagement. This holistic approach ensures that all aspects of the brand—its visual identity, its voice, its values—are aligned and contribute to a consistent and engaging sensory experience (Hultén et al., 2009; Krishna et al., 2010).

The purpose of this paper is to provide a comprehensive overview of the role of sensory marketing and how neuroscience, through neuromarketing, can help study the complex interactions between sensory stimuli and consumer behavior. This interdisciplinary approach has become increasingly crucial to understanding and shaping consumer experiences in today's competitive marketplace.

2. Sensory Marketing, Neuromarketing, and Crossmodal Correspondence: An Integrated Approach

Sensory marketing is a sub-discipline of marketing that aims to build a brand and its product through targeted stimulation of consumers' senses, employing a variety of techniques and technologies. It's not just a tool for understanding consumer emotions, but also a means to address emerging market challenges, thus contributing to the long-term success of a product (Bortolotti et al., 2023, 2024; Erenkol & Merve, 2015). The importance of engaging all human senses is clear, as this can create a unique perception of a product compared to its competitors in the customer's mind. This approach can significantly contribute to creating a psychological competitive advantage for the product in the market. We can say that sensory marketing focuses on observing how a customer's different senses influence their purchasing behavior and buying decisions. This discipline leverages the five human senses—sight, hearing, smell, taste, and touch—to influence consumer purchasing decisions. This strategy is based on the understanding that the human brain is wired to respond emotionally and instinctively to sensory stimuli (Panksepp, 1982; Perlovsky, 2006). Adding focus on color, it's important to note that color is one of the most powerful elements of sensory marketing (Bortolotti et al., 2023). Research has shown that changing the hue or intensity/saturation of the color of food and beverage items can exert a sometimes dramatic impact on consumers' expectations (Spence, 2024; Spence et al., 2016; Spence, 2015). Warm and cool colors can drive consumer indulgence and interact with other visual cues. Furthermore, color temperature can affect consumption. Therefore, understanding the role of color in sensory marketing can provide valuable insights into consumer behavior and decision-making processes. Sensory marketing and neuromarketing are two emerging fields that have gained significant attention in recent years. While sensory marketing focuses on engaging the consumer's senses to influence their purchasing behavior, neuromarketing leverages insights from neuroscience to understand the underlying brain processes involved in consumer perception and behavior. Crossmodal correspondence, on the other hand, refers to the tendency of one sensory attribute to be associated with an attribute in another sense. This part aims to explore the connection between these three concepts and how they can be integrated to enhance marketing strategies.

3. Sensory Marketing and Neuromarketing: A Synergistic Relationship

Sensory marketing aims to engage all five human senses—sight, hearing, smell, taste, and touch—to influence consumer purchasing decisions. This approach is grounded in the understanding that the human brain responds emotionally and instinctively to sensory stimuli. Companies leverage this knowledge to create memorable brand experiences that leave a lasting impression on consumers. For instance, the scent of freshly baked bread in a supermarket can evoke feelings of warmth and comfort, potentially increasing the likelihood of purchasing (Hultén, 2011). Neuromarketing, on the other hand, is closely linked to sensory marketing as it helps us understand the brain processes involved in perception and behavior. It employs techniques from neuroscience, such as functional magnetic resonance imaging (fMRI) and electroencephalography (EEG), to study consumers' neural responses to marketing stimuli (Bortolotti, 2023). These insights provide a deeper understanding of cognitive and affective responses, revealing how sensory inputs can trigger specific brain regions associated with emotions and decision-making (Gallace & Spence, 2010). The relationship between sensory marketing and neuromarketing is synergistic. While sensory marketing strategies are designed based on an understanding of how different sensory stimuli influence consumer behavior, neuromarketing provides the scientific basis for these strategies by uncovering the underlying brain processes. This synergy allows marketers to create more effective and targeted campaigns. For example, by understanding that certain colors can evoke specific emotional responses, marketers can design packaging that not only attracts attention but also enhances the overall consumer experience (Krishna, 2013).

4. The Role of Crossmodal Correspondence

Crossmodal correspondence plays a crucial role in both sensory marketing and neuromarketing. It refers to the tendency of one sensory attribute to be associated with an attribute in another sense (Spence &Gallace, 2011; Nayak & Satpathy, 2024; Huang & Wan, 2019). For example, consumers might associate high-pitched sounds with bright colors or small shapes. In the context of sensory marketing, crossmodal correspondences can be leveraged to create a more immersive and memorable brand experience. For instance, a study on online sensory marketing found that background music that was crossmodally congruent with the online store environment led to more positive consumer reactions than music that was incongruent. In neuromarketing, understanding crossmodal correspondences can provide insights into how different sensory stimuli interact in the brain to influence consumer perception and behavior.

This theme is another relevant aspect in visual marketing. It refers to the general concept that a brand or a store wants to communicate to consumers through visual elements such as logo, style, colors, images, and graphics. Theme should be consistent with the brand personality and consumer expectations (Bortolotti et al., 2023). Theme can also affect the associations and emotions that consumers have towards the brand or the store. For instance, a nature-related theme can convey a sense of well-being, tranquillity, and sustainability. A technology-related theme can convey a sense of innovation, modernity, and quality. Spatial layout is another important element in the visual experience. It refers to the arrangement of objects and spaces in a physical or virtual environment. Spatial layout can influence the ease of navigation, the perception of variety and quality of products, and the involvement and satisfaction of consumers (Siniscalco et al., 2022). Spatial layout should be designed to create an optimal flow among the visual elements, avoiding information overload or confusion. Spatial layout should also be adapted to the type of product and consumer. For example, a linear and orderly spatial layout may be more suitable for functional products or task-oriented consumers. A more free and creative spatial layout may be more suitable for experiential products or exploration-oriented consumers. Visual marketing is a discipline that uses visual elements to create engaging and distinctive brand experiences. Visual marketing is based on understanding how consumers perceive and respond to visual stimuli such as color, light, theme, graphics, and spatial layout. These elements can influence sensory, cognitive, and emotional perceptions of consumers as well as interact with other sensory stimuli from other senses. Visual marketing can thus contribute to creating a competitive advantage for the brand or store in the market.

Visual marketing is a multifaceted discipline that leverages various elements to create engaging and distinctive brand experiences. One of the key aspects of visual marketing is the theme, which refers to the overarching concept that a brand or store aims to communicate to consumers. This is often conveyed through visual elements such as logos, style, colors, images, and graphics. The theme should be consistent with the brand's personality and align with consumer expectations (Bortolotti et al., 2023). It can also influence the associations and emotions that consumers have towards the brand or store. For instance, a nature-related theme may evoke feelings of well-being, tranquillity, and sustainability, while a technology-related theme may convey a sense of innovation, modernity, and quality. Another crucial aspect of the visual experience is spatial layout. This refers to the arrangement of objects and spaces within a physical or virtual environment. The spatial layout can influence various factors such as ease of navigation, perception of product variety and quality, and consumer engagement and satisfaction (Siniscalco et al., 2022). It should be designed to create an optimal flow among visual elements, avoiding information overload or confusion. Moreover, the spatial layout should be adapted to suit the type of product and consumer. For example, a linear and orderly spatial layout may be more suitable for functional products or task-oriented consumers. Conversely, a more free and creative spatial layout may be more appropriate for experiential products or exploration-oriented consumers. Visual marketing relies on understanding how consumers perceive and react to visual stimuli such as color, light, theme, graphics, and spatial layout. These elements can influence sensory, cognitive, and emotional perceptions of consumers. They can also interact with other sensory stimuli from other senses. Therefore, visual marketing can contribute significantly to creating a competitive advantage for a brand or store in the market.

5. The role of sight as the most dominant sense

Sight is undoubtedly the most used sense in marketing. Colors, product and packaging design, logos, and images are all visual elements that can influence consumer perceptions (Bortolotti et al., 2023). Sight is one of the most powerful and crucial senses in human experience, providing up to 80% of the information we receive from the surrounding world (Bortolotti et al., 2024; Hutmacher, 2019; Spence & Deroy, 2013; Palmer et al., 2013). The connection between the brain and the eyes is incredibly fast, with humans taking only a few milliseconds to visually identify an object in their field of vision. Within sensory marketing, visual marketing focuses on visual elements such as color, light, theme, graphics, and spatial layout, which together contribute to the creation and evaluation of brand identity. Color is one of the main aspects in visual marketing. Consumers perceive colors subliminally, creating associations and shaping opinions before they even realize it consciously (Bortolotti et al., 2023). Color perception can vary from person to person and can change over the course of each individual's life (Bortolotti et al., 2022). However, colors also have symbolic meanings, often rooted in cultural traditions, that can influence perception. The careful choice of colors can help shape the brand identity positively and elicit positive feelings in customers, as well as facilitate brand recognition. The use of colors can also affect other sensory perceptions, such as the link between color and scent or between color and sound (Spence et al., 2010). For example, the combination of a specific color with a particular scent can create a consistent sensory connection. Moreover, the choice of color can influence the perception of weight, area, or volume of an object. Light intensity is another important element in the visual experience (Siniscalco et al., 2022). Lighting in a store has multiple purposes, including achieving the required level of light for safety and hygiene, creating a pleasant atmosphere for customers, and attracting attention to the displayed products.

6. Conclusion

To sum up, sensory marketing, neuromarketing, and crossmodal correspondence are interrelated concepts that can be combined to create effective marketing strategies. By understanding how different sensory stimuli interact with each other (crossmodal correspondence) and how they affect brain processes (neuromarketing), marketers can design strategies that engage all five senses (sensory marketing) to influence consumer behavior and create memorable brand experiences (see Figuere 1). Sensory marketing is a powerful strategy to engage consumers emotionally and create lasting connections with brands. By using the five human senses, companies can create unique experiences that positively influence consumer purchasing decisions. So, the next time you buy a product or enter a store, pay attention to your senses: you might be a victim of an effective sensory marketing strategy. Traditional marketing assumes that consumers systematically consider concrete factors of the product such as price, features, and utility. Sensory marketing, on the contrary, tries to use the consumer's life experiences and feelings. These life experiences have identifiable sensory, emotional, cognitive, and behavioral aspects. Sensory marketing assumes that people, as consumers, act according to their emotional impulses rather than their objective reasoning. In this way, an effective sensory marketing effort can lead consumers to choose to buy a certain product, rather than an equal but cheaper alternative. The application of sensory marketing to the brand building processes has become an essential strategy in the competitive global market. This approach offers companies the opportunity to differentiate themselves from the competition and create deeper emotional relationships with customers. In a world where consumers are constantly bombarded by information and choices, stimulating the senses through sensory marketing becomes an effective way to capture attention and create lasting connections. Sensory marketing is not just a sales tactic, but a philosophy that involves all senses to offer a unique shopping experience.

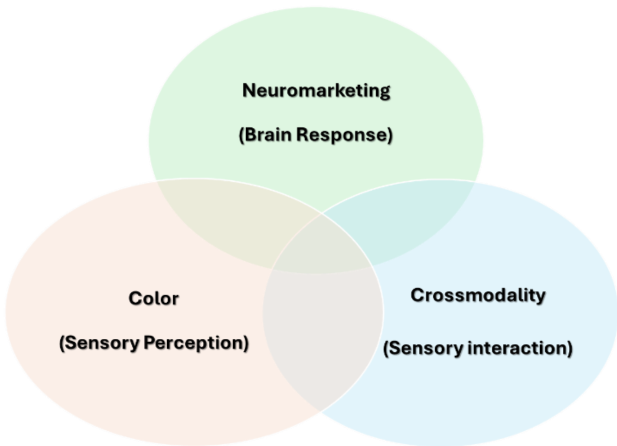

Figure 1. The concept of crossmodal color correspondences in marketing

This approach requires a deep knowledge of the market and customers, as well as the ability to adapt creatively to meet consumer needs. Many successful companies have already adopted this strategy, strengthening their corporate identity and customer loyalty.

8. Conflict of interest declaration

The author declares that there is no conflict of interest regarding the publication of this paper.

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9. Short biography of the author(s)

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Licensing terms

References

Adams, F. M., & Osgood, C. E. (1973). A cross-cultural study of the affective meanings of color. Journal of cross-cultural psychology, 4(2), 135-156. https://doi.org/10.1177/002202217300400201.

Alter, A. (2013). Drunk tank pink: The subconscious forces that shape how we think, feel, and behave. Simon and Schuster.

Aslam, M. M. (2006). Are you selling the right colour? A cross-cultural review of colour as a marketing cue. Journal of marketing communications, 12(1), 15-30. https://doi.org/10.1080/13527260500247827.

Bakhshi, S., & Gilbert, E. (2015). Red, purple and pink: The colors of diffusion on Pinterest. PloS one, 10(2), e0117148. https://doi.org/10.1371/journal.pone.0117148.

Bortolotti, A. (2022). Neuromarketing e scelte inconsapevoli: il ruolo del colore. economiacomportamentale.it.

Bortolotti, A. (2023) Neuromarketing and unconscious choices in the wine market: The role of color, Free Press. ISBN:979-8852729538.

Bortolotti, A., Cannito, L., Anzani, S., & Palumbo, R. (2023). The promise of color in marketing: use, applications, tips and neuromarketing. Cultura e Scienza del Colore-Color Culture and Science, 15(01), 76-85. https://doi.org/10.23738/CCSJ.150110.

Bortolotti, A., Cannito, L., Anzani, S., & Palumbo, R. (2024). Wine Chromatics: The Colorful Language of Wine's Characteristics. Cultura e Scienza del Colore-Color Culture and Science, 16(01), 15-22. https://doi.org/10.23738/CCSJ.160102.

Bortolotti, A., Cannito, L., Anzani, S., Rossi, M., & Palumbo, R. (2022). About the influence of color perceived lightness on psychological functions. Cultura e Scienza del Colore-Color Culture and Science, 14(01), 112- 122. https://doi.org/10.1016/j.actpsy.2025.104785.

Bortolotti, A., Chen, N., Spence, C., & Palumbo, R. (2025). Color–taste correspondences influence visual binding errors. Acta Psychologica, 254, 104785.

Bottomley, P. A., & Doyle, J. R. (2006). The interactive effects of colors and products on perceptions of brand logo appropriateness. Marketing theory, 6(1), 63-83. https://doi.org/10.1177/1470593106061263.

Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand experience: What is it? How is it measured? Does it affect loyalty? Journal of Marketing, 73(3), 52-68. https://doi.org/10.1509/jmkg.73.3.052.

Changizi, M. A., Zhang, Q., & Shimojo, S. (2006). Bare skin, blood and the evolution of primate colour vision. Biology letters, 2(2), 217-221. https://doi.org/10.1098/rsbl.2006.0440

Damasio, H., Grabowski, T., Frank, R., Galaburda, A. M., & Damasio, A. R. (1994). The return of Phineas Gage: clues about the brain from the skull of a famous patient. Science, 264(5162), 1102-1105. https://doi.org/10.1126/science.8178168

Doucé, L., & Janssens, W. (2013). The presence of a pleasant ambient scent in a fashion store: The moderating role of shopping motivation and affect intensity. Environment and Behavior, 45(2), 215-238. https://doi.org/10.1177/0013916511410421.

Elliot, A. J., & Maier, M. A. (2014). Color psychology: Effects of perceiving color on psychological functioning in humans. Annual review of psychology, 65(1), 95-120. https://doi.org/10.1146/annurev-psych-010213-115035

Erenkol, A. D., & Merve, A. K. (2015). Sensory marketing. Journal of Administrative Sciences and Policy Studies, 3(1), 1-26. https://doi.org/10.15640/jasps.v3n1a1

Gallace, A., & Spence, C. (2010). The science of interpersonal touch: an overview. Neuroscience & Biobehavioral Reviews, 34(2), 246-259. https://doi.org/10.1016/j.neubiorev.2008.10.004

Gentile, C., Spiller, N., & Noci, G. (2007). How to sustain the customer experience:: An overview of experience components that co-create value with the customer. European management journal, 25(5), 395-410. https://doi.org/10.1016/j.emj.2007.08.005.

Gorn, G. J., Chattopadhyay, A., Sengupta, J., & Tripathi, S. (2004). Waiting for the web: how screen color affects time perception. Journal of marketing research, 41(2), 215-225. https://doi.org/10.1509/jmkr.41.2.215.28668.

Huang, J., & Wan, X. (2019). The color–flavor incongruency effect in product evaluation and brand perception. Journal of Consumer Behaviour, 18(6), 484-495. https://doi.org/10.1002/cb.1787.

Hultén, B. (2011). Sensory marketing: The multi-sensory brand-experience concept. European Business Review, 23(3), 256-273. https://doi.org/10.1108/09555341111130245.

Hultén, B., Broweus, N., Van Dijk, M., Hultén, B., Broweus, N., & van Dijk, M. (2009). What is sensory marketing? (pp. 1-23). Palgrave Macmillan UK. https://doi.org/10.1057/9780230237049_1.

Hutmacher, F. (2019). Why is there so much more research on vision than on any other sensory modality? Frontiers in Psychology, 10, Article 2246. https://doi.org/10.3389/fpsyg.2019.02246.

Krishna, A. (2011). Sensory marketing: Research on the sensuality of products. Routledge. https://doi.org/10.4324/9780203892060.

Krishna, A. (2012). An integrative review of sensory marketing: Engaging the senses to affect perception, judgment and behavior. Journal of consumer psychology, 22(3), 332-351. https://doi.org/10.1016/j.jcps.2011.08.003.

Krishna, A. (2013). Customer sense: How the 5 senses influence buying behavior. Springer. https://doi.org/10.1057/9781137346056

Krishna, A., & Schwarz, N. (2014). Sensory marketing, embodiment, and grounded cognition: A review and introduction. Journal of Consumer Psychology, 24(2), 159-168. https://doi.org/10.1016/j.jcps.2013.12.006.

Krishna, A., Cian, L., & Sokolova, T. (2016). The power of sensory marketing in advertising. Current Opinion in Psychology, 10, 142-147. https://doi.org/10.1016/j.copsyc.2016.01.007.

Krishna, A., Elder, R. S., & Caldara, C. (2010). Feminine to smell but masculine to touch? Multisensory congruence and its effect on the aesthetic experience. Journal of Consumer Psychology, 20(4), 410-418. https://doi.org/10.1016/j.jcps.2010.06.010.

Labrecque, L. I., Vor Dem Esche, J., Mathwick, C., Novak, T. P., & Hofacker, C. F. (2013). Consumer power: Evolution in the digital age. Journal of Interactive Marketing, 27(4), 257-269. https://doi.org/10.1016/j.intmar.2013.09.002.

LeDoux, J. (1996). Emotional networks and motor control: a fearful view. Progress in brain research, 107, 437-446. https://doi.org/10.1016/S0079-6123(08)61880-4.

Lehrl, S., Gerstmeyer, K., Jacob, J. H., Frieling, H., Henkel, A. W., Meyrer, R., ... & Bleich, S. (2007). Blue light improves cognitive performance. Journal of neural transmission, 114, 457-460. https://doi.org/10.1007/s00702-006-0621-4.

Lemon, K. N., & Verhoef, P. C. (2016). Understanding customer experience throughout the customer journey. Journal of marketing, 80(6), 69-96. https://doi.org/10.1509/jm.15.0420.

Lindstrom, M. (2005). Broad sensory branding. Journal of Product & Brand Management, 14(2), 84-87. https://doi.org/10.1108/10610420510592554.

Lindstrom, M. (2005). Brand sense: Build powerful brands through touch, taste, smell, sight, and sound. Free Press.

Madden, T. J., Hewett, K., & Roth, M. S. (2000). Managing images in different cultures: A cross-national study of color meanings and preferences. Journal of international marketing, 8(4), 90-107. https://doi.org/10.1509/jimk.8.4.90.19795.

Muniz, A. M., & O'Guinn, T. C. (2001). Brand community. Journal of Consumer Research, 27(4), 412-432. https://doi.org/10.1086/319618.

Nayak, A., & Satpathy, I. (2024). The Sensory Marketing Theory: A Journey Into Multisensory Marketing. In Sensible Selling Through Sensory Neuromarketing (pp. 43-67). IGI Global.

Palmer, S. E., Schloss, K. B., & Sammartino, J. (2013). Visual aesthetics and human preference. Annual Review of Psychology, 64, 77-107. https://doi.org/10.1146/annurev-psych-120710-100504

Panksepp, J. (1982). Toward a general psychobiological theory of emotions. Behavioral and Brain sciences, 5(3), 407-422. https://doi.org/10.1017/S0140525X00012759.

Peck, J., & Childers, T. L. (2008). Sensory factors and consumer behavior. Handbook of consumer psychology, 4, 193-219.

Perlovsky, L. I. (2006). Toward physics of the mind: Concepts, emotions, consciousness, and symbols. Physics of Life Reviews, 3(1), 23-55. https://doi.org/10.1016/j.plrev.2005.11.003.

Pine, B. J., & Gilmore, J. H. (1998). Welcome to the experience economy. Harvard Business Review, 76, 97-105.

Plassmann, H., Venkatraman, V., Huettel, S., & Yoon, C. (2015). Consumer neuroscience: applications, challenges, and possible solutions. Journal of marketing research, 52(4), 427-435. https://doi.org/10.1509/jmr.14.0048.

Puccinelli, N. M., Goodstein, R. C., Grewal, D., Price, R., Raghubir, P., & Stewart, D. (2009). Customer experience management in retailing: understanding the buying process. Journal of retailing, 85(1), 15-30. https://doi.org/10.1016/j.jretai.2008.11.003.

Reimann, M., Zaichkowsky, J., Neuhaus, C., Bender, T., & Weber, B. (2012). Aesthetic package design: A behavioral, neural, and psychological investigation. Journal of Consumer Psychology, 20(4), 431-441. https://doi.org/10.1016/j.jcps.2010.06.009.

Schmitt, B. H. (1999). Experiential marketing. Journal of Marketing Management, 15(1-3), 53-67. https://doi.org/10.1362/026725799784870496.

Shavitt, S., & Barnes, A. J. (2020). Culture and the consumer journey. Journal of retailing, 96(1), 40-54. https://doi.org/10.1016/j.jretai.2019.11.009.

Siniscalco, A., Bortolotti, A., & Rossi, M. (2022). Do color and light affect physiology and psychology in proportional ways?. Research Culture And Science Books, 6, 105-110.

Spence, C. (2018). Background colour & its impact on food perception & behaviour. Food Quality and Preference, 68, 156-166. https://doi.org/10.1016/j.foodqual.2018.02.012.

Spence, C. (2021). Sensehacking: How to use the power of your senses for happier, healthier living. Viking.

Spence, C. (2024). On the psychological effects of food color. In Handbook on natural pigments in food and beverages (pp. 33-60). Woodhead Publishing.

Spence, C. On the psychological impact of food colour. Flavour 4, 21 (2015). https://doi.org/10.1186/s13411-015-0031-3

Spence, C., & Deroy, O. (2013). How automatic are crossmodal correspondences? Consciousness and Cognition, 22(1), 245-260

Spence, C., & Gallace, A. (2011). Multisensory design: Reaching out to touch the consumer. Psychology & Marketing, 28(3), 267-308.

Spence, C., & Piqueras-Fiszman, B. (2016). Food color and its impact on taste/flavor perception. In Multisensory flavor perception (pp. 107-132). Woodhead Publishing.

Spence, C., Reinoso-Carvalho, F., Velasco, C., & Wang, Q. J. (2019). Introduction to the special issue on auditory contributions to food perception and consumer behaviour. Multisensory Research, 32(4-5), 267-273.

Thaler, R. H. (2016). Misbehaving: The making of behavioral economics. W.W. Norton & Company.

Wörfel, D., Schumann, J. H., & Wangenheim, F. V. (2022). The impact of digital transformation on marketing and consumer behavior. Journal of Business Research, 123, 520-532.

Yoon, S. J., & Park, J. E. (2012). Do sensory ad appeals influence brand attitude?. Journal of Business Research, 65(11), 1534-1542.

Zaltman, G. (2003). How customers think: Essential insights into the mind of the market. Harvard Business School Publishing.

Is there a color for sustainability in fashion products? A case study with Brazilian slow fashion footwear

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ABSTRACT

This study investigates the intersection of slow fashion and the semiotics of color in the context of Brazilian footwear. Slow fashion, as a counterpoint to fast fashion, emphasizes sustainability, quality, and ethical practices, advocating for timeless designs and conscious consumption. Within this framework, the research explores how Brazilian slow fashion brands, Vegalli and Urban Flowers, utilize color to communicate sustainability and engage eco-conscious consumers. Using visual analysis and semiotic theory, 33 footwear items were examined to classify colors by hue, saturation, and color lightness. The results highlight a predominance of achromatic and earthy tones, reflecting principles of durability, functionality, and a connection to nature. Selective use of vibrant hues, such as green and orange, introduces environmental and emotional resonance, while neutral tones enhance versatility and longevity. These findings underscore the aesthetic and symbolic role of color in reinforcing sustainability narratives, contributing to brand identity and consumer engagement. This research enriches the discourse on sustainable design and cultural dimensions in fashion, offering perspectivas and contributions for designers, brands, and scholars.

KEYWORDS Slow fashion, Sustainability, Brazilian footwear, Color semiotics, Sustainable design, Ethical fashion, Color meaning

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1. Introduction

The fashion industry, one of the most dynamic and influential sectors globally, plays a significant role in shaping consumer behavior and cultural narratives. However, this industry is also known for its substantial environmental impact, characterized by excessive waste generation, high water consumption, and chemical pollution. In recent years, the rising demand for sustainable practices has urged the fashion industry to reevaluate its production processes and communication strategies, fostering a new wave of environmentally and ethically driven innovations.

Within this shift, the slow fashion movement has emerged as a counterpoint to the fast-paced, mass-production-driven fast fashion model. Rooted in principles of sustainability, slow fashion emphasizes quality over quantity, promoting longer product lifespans, ethical labor practices, and eco-conscious materials. In this context, visual communication, particularly color, plays a pivotal role in aligning products with the values of sustainability and in influencing consumer perceptions of environmentally friendly practices.

Color, as a fundamental element of design, extends beyond its aesthetic appeal to function as a powerful semiotic tool. It communicates symbolic and cultural meanings that can evoke emotions, shape consumer preferences, and establish brand identities. In sustainable fashion, specific colors, such as green, blue, and earthy tones, have been associated with environmental consciousness and ethical practices. However, the cultural and regional dimensions of these associations remain underexplored, especially in countries with unique socio-environmental contexts like Brazil.

Brazil, recognized for its biodiversity and cultural diversity, provides a compelling backdrop for examining sustainability in fashion. The growing interest in sustainable fashion practices within the Brazilian market has led to the development of slow fashion brands that integrate local craftsmanship, natural materials, and environmentally friendly production processes. Despite these advancements, there is limited research on how these brands use color to convey sustainability in their products, particularly in footwear—a category often overlooked in sustainability studies.

Given the environmental challenges posed by the global fashion industry and the unique potential of slow fashion in Brazil, this study seeks to fill a gap in the literature. Thus, understanding how Brazilian slow fashion brands utilize color to communicate sustainability in footwear not only sheds light on local design practices but also contributes to broader discussions about sustainable fashion communication strategies. By focusing on color as a semiotic and cultural element, this study provides perspectives into how design choices can enhance sustainability narratives.

Therefore, the primary objective of this study is to investigate whether specific colors are associated with sustainability in Brazilian slow fashion footwear and to analyze how these associations influence consumer perceptions. Through this case study, the research aims to deepen the understanding of color's role as a visual and symbolic element in sustainable fashion, ultimately contributing to the advancement of more effective and culturally relevant design strategies within the industry.

2. Theoretical framework

This topic presents the theoretical foundations that support the research proposal. Initially, we present the concept of slow fashion and its developments. Next, we discuss the aesthetic attributes of sustainable products. Finally, we highlight the role of color as a sign and its influence on the communication of sustainability in fashion products.

2.1. *Slow fashion*

The textile and fashion industry, from an economic perspective, is of great importance to the country's development. According to the Brazilian Textile Industry Association (ABIT, 2021), it "represents 16.7% of jobs and 5.7% of the revenue in the manufacturing industry," with Brazilian fashion being present "among the five largest fashion weeks in the world." Furthermore, the country has more than 100 fashion schools and colleges. However, this industry is also one of the most environmentally degrading (Silva, 2014), particularly because it involves a production process that has grown at the same rate as its accessibility to the masses over the years.

Given that the essential raw materials for the production of fashion items are extracted from nature, large-scale production is directly responsible for numerous environmental impacts—such as the disposal of textile waste in landfills, the release of chemical residues into rivers, increased consumption, among many other issues. From this perspective, the textile and fashion industry is considered one of the most polluting in the world (Berlim, 2012; Menegucci et al., 2015). Within the logic of an overconsumption-driven society, the fashion industry creates artifacts characterized by their ephemerality, often resulting in products that are practically disposable. In this sense, trend-producing fashion has long been responsible for seasonal clothing consumption, spreading the idea that what is "in fashion" today may be considered outdated tomorrow (Lipovetsky, 2009; Berlim, 2012).

In light of these impacts, it is increasingly essential to seek more ecological ways to produce and consume more consciously, aiming for a more sustainable production chain (Solino, Teixeira, & Dantas, 2020). As a result, initiatives have been developed to focus on creating products through creative means that extend the life cycle of fashion items. In this context, techniques are grounded in intertwining themes of creativity, economy, and sustainability (Fletcher & Grose, 2002).

Fashion design, when it bases its products on sustainable production methods, results in actions that help reduce environmental impacts, consequently improving people's quality of life. Thus, sustainability becomes fundamental in the conception of new products, as it emphasizes reuse and the reduction of natural resource extraction, minimizing environmental degradation (Menegucci, 2015). Within this framework, many fashion brands design their products with the intent to prolong their life cycle and usability, adhering to the principles of slow fashion—a term translated as "slow fashion."

The slow fashion movement emerged in 2003 at the University of London's Fashion Design course, comprising a "[...] political-ideological repertoire strictly linked to the premises of social and environmental sustainability and simultaneously organizing and expressing ethical and aesthetic criticisms" (Berlim, 2016, p. 11). According to the author, this movement opposes the fast fashion model—characterized by accelerated serial production of items—while addressing issues that range from creativity to the politicization of consumption, culminating in political activism. Slow fashion is understood as a movement that integrates other critical movements within the fashion system, such as sustainable and ethical fashion (Solino, Teixeira, & Dantas, 2020). In this sense, it represents both an ideological and practical condition for the fashion field (Berlim, 2016).

Fashion produced slowly aspires to sustainable fashion, as it opposes the hegemonic production system and the challenges posed by companies—a notable difficulty since slow fashion has broader concerns than the product itself. This model focuses on practices and consumption modes, contrary to the goals of businesses solely driven by profit and predominantly oriented by the fast fashion model (Solino, Teixeira, & Dantas, 2020). Slow fashion proposes more than slowing down clothing production; it envisions new and conscious consumption practices that extend the lifespan of products. Additionally, it fosters empowerment and political activism within fashion (Berlim, 2016).

Thus, slow fashion is an initiative aimed at raising awareness about reducing the pace of accelerated production to create sustainable fashion products. Unlike mass-market production, a garment gains added value when produced in limited quantities following sustainability principles and when its quality ensures significant longevity. Beyond the sustainable qualities of this type of production, small-scale manufacturing also addresses another constant issue in the fashion field: usability. Through this process, custom-made garments can be created, with designs based on the anthropometric measurements of the intended wearer (Nishimura & Gontijo, 2016).

2.2. *Aesthetic attributes of sustainable products*

The aesthetic aspect of sustainable products, especially regarding design issues, has proven to be of extreme importance at various stages of decision-making processes (from design conception to commercialization). Particularly, aesthetics within the realm of sustainable products has emerged as a factor that is difficult to delineate due to its qualitative, fluid, and complex nature. Broadly speaking, the origin of the term "aesthetics" dates back to Ancient Greece, where it was understood as "sensory perception," and later as "sensory pleasure," emphasizing not only issues related to what is perceived as beautiful but also sensations, emotions, meanings, and tastes. Thus, aesthetics, when associated with sustainable products, is challenging to define, often being labeled with terms such as Green Design, Eco Design, among others, aiming to establish a relationship between aesthetics and product design with its "potential" for sustainability (Moreira, Jaques, & Pizzato, 2018; Clementino & Arruda, 2018; Petersen & Brockhaus, 2017; Jardim & Pavan, 2014; Chim & Blebea, 2013).

The issues surrounding the design and aesthetics of products significantly influence consumer behavior since the communicative aspect of products, especially the visual aspect, is, to a large extent, an essential factor in attracting and capturing the attention of potential consumers. It is through this initial visual contact that consumers identify themselves, as this contact is crucial in the relationships and perceptions of consumption between people and objects, making it an important marketing strategy (Moreira, Jaques, & Pizzato, 2018; Clementino & Arruda, 2018; Petersen & Brockhaus, 2017; Jardim & Pavan, 2014; Chim & Blebea, 2013).

As emphasized earlier, the aesthetic appearance of a product should not be limited to beauty or "superficial" elements; it should relate to the product's success, sustainability, and longevity. According to Chim & Blebea (2013), the aesthetic aspects of products should be linked to emotional factors that inspire consumers and induce attachment. In the authors' view, this aesthetic should "attract" and "stimulate" a variety of impulses in individuals, giving them sensations of durability, desirability, attractiveness, among other positive aspects..

2.3. *Color as a sign and its role in communicating sustainability*

Color, as an integral part of visual communication, goes beyond aesthetic appeal to function as a semiotic tool for delineating and conveying messages. According to Pereira (2023), color operates within a system of signs where its attributes—hue, lightness, and chroma—serve as meaningful units contributing to the construction of meaning. This systemic view aligns with Saussure's semiology, which defines language as a structured set of signs and emphasizes the relational nature of meaning-making (Santaella, 2002). In this context, color assumes syntactic, semantic, and pragmatic dimensions that dictate its interaction with other visual elements and its interpretative potential (Caivano, 1998).

In the syntactic dimension, color relationships, such as contrasts or harmonies, structure visual compositions. These relationships, highlighted by Caivano (1998), are fundamental for perceiving color as a system of signs. The semantic dimension addresses the connection between color and the objects or ideas it represents. This connection is often based on cultural conventions, exemplified by the use of red to signal danger or passion. Lastly, the pragmatic dimension explores the impact of color on viewers, shaping their interpretations and emotional responses. Pereira (2023) emphasizes the triadic nature of the sign—comprising the sign itself, its object, and its interpretant—when analyzing the role of color in product design.

The cultural specificity of color associations further expands its semiotic function. As noted by Heller (2013), colors carry varied meanings across cultures, requiring designers to adapt their choices to the cultural context of their target audience. This adaptability is crucial, as mismatches in color symbolism can lead to misinterpretations and reduce the communicative effectiveness of a design (Holtzschue, 2012). Similarly, Arnkil (2013) highlights the potential of color to evoke strong, culturally embedded symbols, especially when effectively combined with form and text.

Considering the informational role of color in fashion (Guimarães, 2000; Dantas & Silva, 2022), Heller (2013, p. 18) asserts that no color is devoid of meaning, as "[...] context is the criterion that will reveal whether a color will be perceived as pleasant and correct or wrong." In the field of sustainability, colors that most evoke this idea are generally shades of green, widely associated with nature and trees (Pastoureau, 1997; Farina et al., 2006; Aballí, 2010; Pastoureau, 2011; Heller, 2013). Clementino, Barbosa, and Fernandes (2017, p. 260) emphasize that "when the goal of using color is to communicate sustainability, some studies highlight the relevance of green hues, which the literature points to as associated with this theme." Beyond green, literature also identifies other colors linked to sustainability, such as yellow (associated with the sun and light), brown (associated with the earth), and blue (evoking the sky). These tones collectively reinforce the connection between sustainability and representations of nature (Farina et al., 2006).

While green and blue are traditionally associated with sustainability and environmental responsibility, recent marketing strategies have exploited this symbolism through practices like greenwashing and bluewashing (Szabo; Webster, 2021; Sailer; Wilfing, 2022). Greenwashing occurs when companies misleadingly present their products or policies as environmentally friendly (Szabo; Webster, 2021; Sansoni Torrens; Downs, 2023), while bluewashing refers to the strategic use of sustainability narratives to enhance corporate image without substantial commitments (Sundar; Kellaris, 2015; Sailer; Wilfing, 2022). These phenomena highlight the importance of critically analyzing the use of colors in branding and communication, as the symbolic attachment to these hues may not always reflect genuine sustainable practices (Burgh-Woodman; King, 2013). Incorporating this perspective reinforces the need for a nuanced understanding of color associations in the context of sustainability (Worakittikul; Saenwerm; Naruetharadhol, 2024).

In fashion, there is evidence of the role of color in communicating sustainability, particularly in building narratives that connect consumers to environmental and ethical values. Song and Choi (2010) note that neutral, pale, and low-saturation tones are widely used in eco-design due to their association with functionality and sustainability, as well as their aesthetic connection to nature. This approach is complemented by Dong et al. (2023), who highlight consumers' preference for low-purity and low-brightness colors, such as teal, which evoke feelings of tranquility and harmony. These chromatic choices reflect a convergence between aesthetics and the perception of sustainable value, as consumers tend to associate these colors with a more conscious experience aligned with environmental preservation (Song & Choi, 2010; Dong et al., 2023).

Additionally, Dogar et al. (2023) expand this discussion by emphasizing the role of colors in promoting ethical and sustainable practices through a visual narrative that highlights earthy and natural tones, such as greens, browns, and blues. These hues enhance brands' environmental appeal by aligning with natural dyeing practices and the use of eco-friendly materials, reducing the environmental impact of the production cycle (Dogar et al., 2023). By connecting consumers' preferences outlined by Dong et al. (2023) with the practical applications described by Dogar et al. (2023) and the discussions of Song and Choi (2010), it becomes evident that sustainable colors play a strategic role in strengthening brand identities and amplifying conscious consumption.

There are few studies focusing on colors in slow fashion artifacts, with none specifically addressing footwear. In clothing, it is observed that the perception of product colors is strongly influenced by symbolic associations that link tones to sustainable practices, as previously discussed. According to Dantas et al. (2021), colors like brown and blue are often associated with sustainability due to their relationship with natural elements, such as earth and sky, and the appearance of more natural dyeing processes with less industrial intervention. Additionally, in other dimensions, medium saturation levels and high brightness reinforce the idea of less artificial and more environmentally conscious products, as they convey a sense of reduced pigment use and lower environmental impact (Dantas et al., 2021).

3. Methodology

This research is based on applied research, aiming to be exploratory-descriptive (Gil, 2008). The methodological procedure guiding this study involves a case study (Yin, 2014), focusing on the Brazilian footwear industry, specifically brands that produce slow fashion.

3.1. *Definition of the brands and footwear studied*

For the analysis of the visual language of slow fashion footwear, the process began with the selection of brands to be studied. This initial step allowed us to obtain images of the artifacts, which were subsequently subjected to analysis. As a reference, we used a report published by Meio Sustentável (2024) regarding Brazilian sustainable footwear brands highlighted in the same year. Specifically, nine Brazilian brands were identified: Vegalli, Insecta Shoes, Kasulo, Urban Flowers, Ahimsa, Vegano Shoes, Havaianas, Yellow Factory, and Margaux.

Next, we individually analyzed each brand to determine whether they positioned themselves as slow fashion on their website or Instagram, aiming to maintain consistency in the research proposal. From the nine initial brands, seven were eliminated—either because they positioned themselves only as ecological or sustainable or because they were no longer in the market. Ultimately, only Vegalli and Urban Flowers were retained.

The Brazilian slow fashion sector remains relatively small, which posed a challenge in selecting brands that strictly align with this concept. A common issue in the market is the conflation of slow fashion with sustainability—while sustainable footwear aims to minimize environmental impacts through material choices and production efficiency, slow fashion extends beyond environmental concerns to include ethical production, local manufacturing, small-scale operations, and timeless design, fostering mindful consumption. Our study was strictly focused on slow fashion artifacts, and many brands were excluded because they positioned themselves solely as sustainable rather than fully embracing the slow fashion philosophy. Additionally, some brands were no longer in operation at the time of data collection, further reducing the sample. These exclusions, while limiting the statistical weight, ensured that the selected brands genuinely represented the slow fashion movement and allowed the study to shed light exclusively on this specific market scenario.

In the end, to define the artifacts to be analyzed, we opted to focus on products that both brands had in common. This criterion led to the selection of boots as the object of study, as it is the only type of footwear sold by Vegalli and one of the types offered by Urban Flowers. A total of 8 images of artifacts from Vegalli and 25 from Urban Flowers were collected, all showing the product from a lateral view (Figure 1).

The product images used in this study were sourced directly from the official websites of the selected brands, ensuring that the colors analyzed were those presented by the manufacturers themselves. Since the Meio Sustentável (2024) portal does not provide product images, it was used solely as a reference for identifying brands aligned with slow fashion principles. To maintain image consistency, all selected visuals adhered to predefined criteria, including uniform lateral perspectives and a preference for high-resolution images without evident overlays or excessive filters. However, we acknowledge that variations in lighting, post-processing, and display settings may introduce discrepancies in color representation. While such inconsistencies are a known limitation, our methodological approach—focusing on official brand imagery and using the Adobe Color eyedropper tool for extraction—aimed to minimize distortions and ensure that the analysis captured the closest possible representation of the colors intended by the manufacturers

3.2. *Data analysis*

To analyze the use of color in slow fashion footwear, a methodology is proposed that focuses on identifying, mapping, and classifying the colors present in the selected products. The aim is to understand how color choices align with sustainability narratives and how these colors contribute to the perception of slow fashion values.

The analysis begins by extracting the official colors of the footwear using the eyedropper tool in Adobe Color software, ensuring precision in identifying the exact hues represented in the product images. Each artifact is analyzed from a lateral perspective, as previously defined, to maintain consistency across the dataset.

The identified colors are then mapped into an Excel table, classified according to three key attributes (Clementino et al., 2021):

- **Hue:** The pure color, categorized into standard color groups (e.g., red, blue, green).
- **Saturation:** Differentiating between neutral (muted or subdued tones) and intense (vivid or vibrant tones) colors.
- **Color lightness:** Evaluating whether the colors are desaturated (lighter, washed-out tones) or darkened (reduced brightness).

Fig. 1. Brazilian footwear mapped as "slow fashion" by the brands Vegalli and Urban Flowers.

For multicolored or patterned footwear, each visible color was considered individually. This approach ensures that all hues present in the design are accounted for and analyzed separately in the classification process.

To ensure a precise identification of colors, both monochromatic and patterned products were analyzed together, with each individual color extracted and classified separately according to hue, saturation, and lightness.

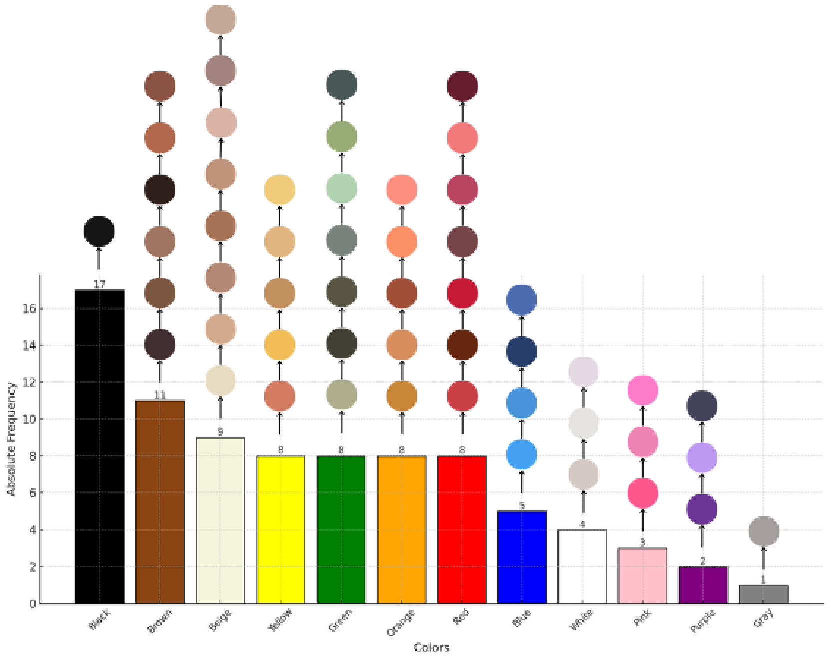

Fig. 2. Frequency of colors in the studied slow fashion footwear.

This approach allowed for a consistent mapping of chromatic choices across all footwear samples. However, for the evaluation of the semantic dimension of color—considering its symbolic and communicative aspects—monochromatic and patterned products were treated as distinct categories. This differentiation aimed to account for the potential differences in perception between solid colors and those integrated into patterns, ensuring a more nuanced interpretation of their role in conveying sustainability narratives. For example, we notice that the semantic interpretation of a multicolored shoe could be associated with a sense of exclusivity, as the combination of different colors may evoke uniqueness or a personalized design, which adds a layer of meaning beyond the individual colors themselves.

Once the data is collected and organized, visualizations will be created to provide a comprehensive overview of the color trends in the selected slow fashion footwear. These visualizations, such as bar graphs, will highlight the distribution and frequency of specific color attributes across the analyzed products.

4. Results and discussions

This topic will initially present the results of the analysis conducted with slow fashion footwear. Next, we will discuss how their results converge or diverge from the evidence presented in the literature in the area.

4.1. *Results: Color patterns in Brazilian slow fashion shoes*

The analysis of the colors of the 33 slow fashion footwear items revealed a predominance of achromatic and earthy tones, reflecting the aesthetic and functional characteristics associated with the movement. In the analysis presented, each product was considered individually, taking into account all the colors present in it. For each item, the visible shades were identified, and the frequencies of occurrence of these colors were calculated based on their presence in each product. Therefore, the graph reflects the sum of the absolute frequencies of the colors across all the analyzed products. The analysis, thus, considers the color diversity present in products from both brands, providing a more comprehensive view of the most recurring shades across the entire set of items evaluated.

Furthermore, among the most frequent hues, black was found in 17 models, followed by brown (11 models) and beige (9 models) (Figure 2). These colors are often associated with versatility and durability, key characteristics for footwear that emphasizes timelessness and a connection to nature.

Additionally, yellow, green, orange, and red hues appeared with the same frequency, each present in 8 models (Figure 2). These tones add vibrancy to the palette and introduce contrasting visual elements, though they were used in a balanced way to maintain the overall sobriety. Blue (5 models), white (4 models), pink (3 models), purple (2 models), and gray (1 model) were less frequent, suggesting a more selective application—often found in patterns, possibly targeting specific audience niches or exclusive designs.

Regarding the saturation of the hues present in the footwear, the majority featured neutral colors (20 footwear items) while 13 displayed intense colors (Figure 3). Additionally, from the perspective of color lightness, most footwear items were darkened (23 footwear items)—that is, when black is added to the base color—while 10 were washed-out tones, achieved by adding white to the base color.

Fig. 3. Saturation of colors in slow fashion footwear and examples.

4.2. *Discussions: Hue, saturation and color lightness, a path for the nature*

The analysis of the 33 slow fashion footwear models highlights a predominant use of achromatic and earthy tones, such as black (17 models), brown (11 models), and beige (9 models). These tones are deeply tied to the functional and aesthetic principles of the slow fashion movement, which emphasizes timelessness, durability, and a connection to nature (Jung & Jin, 2014). As Holtzschue (2011) posits, neutral colors like black and brown act as anchors in design, offering a sense of stability and versatility while enhancing the longevity of a product's relevance in an ever-changing market.

Furthermore, the predominance of black in the analyzed slow fashion footwear, underscores its strong connection to atemporality and functionality—key principles of the movement. Black is widely recognized as a versatile color, offering adaptability across various contexts and styles, which reinforces its durability and relevance over time (Holtzschue, 2011). In the context of slow fashion, this aligns with the idea of creating pieces that transcend seasonal trends and emphasize long-term usability (Jung & Jin, 2014). Furthermore, black's association with elegance and sophistication contributes to its ability to maintain visual appeal while supporting the movement's focus on sustainability, as it allows for reduced consumption by fostering prolonged use and wearability (Şener et al., 2019). This strategic use of black exemplifies how slow fashion leverages color to integrate aesthetic appeal with environmental and social responsibility.

Moreover, the balanced inclusion of vibrant hues—yellow, green, orange, and red, each appearing in 8 models—introduces a dynamic visual appeal without compromising the movement's foundational emphasis on moderation and simplicity. These colors often evoke natural elements, with green symbolizing growth and sustainability, as noted by Heller (2013) in her exploration of color psychology. Additionally, their controlled use aligns with Dogar et al.'s (2023) perspective on eco-friendly design, where thoughtful color application fosters emotional resonance and environmental consciousness.

Thus, we observed a combination of those colors with low saturation and lightness in the prints on some of the shoes, featuring embroidered floral motifs. This combination evokes a sense of craftsmanship, creating a nostalgic ambiance reminiscent of an anachronistic yet familiar setting (Figure 4).

The use of purple (2 models) and pink (3 models), primarily in bold and attention-grabbing patterns (Figure 5), highlights their role in promoting exclusivity within the slow fashion movement. These vibrant colors, often associated with creativity, individuality, and luxury, stand out against the predominantly neutral and earthy palette, offering a unambiguous contrast that appeals to niche markets seeking unique and expressive designs (Heller, 2009). In slow fashion, exclusivity is a valued dimension, as it fosters a sense of rarity and personalization in products (Jung & Jin, 2014). The incorporation of such effecting hues in patterns (Figure 5) amplifies their visual impact, aligning with Şener et al.'s (2019) observation that slow fashion balances aesthetic boldness with ethical values. These choices cater to consumers who prioritize sustainability and also distinctiveness design, positioning slow fashion as a movement capable of delivering both understated and statement-making products.

Fig. 4. Low saturation prints with a craftsmanship and nostalgic sense

Fig. 5. Prints that use pink and purple in intense saturation, in order to achieve exclusivity and differentiation

From a saturation perspective, 20 models featured neutral hues, while 13 incorporated intense colors. Neutral tones are central to the ethos of slow fashion, facilitating adaptability across various settings and enhancing perceived longevity. Dong et al. (2023) highlight that low-purity colors resonate strongly with environmentally conscious consumers, as they evoke a sense of calm and understated elegance. Meanwhile, the use of intense colors, particularly in the context of the Vegalli brand (VX products), projects a sense of adventure and bold identity. This strategy reflects the dual nature of slow fashion, where exclusivity and personal expression are balanced with universal appeal (Şener et al., 2019).

The predominance of darkened hues (23 models) over lightened ones (10 models) might underscores a preference for designs with grounded and sophisticated aesthetics. Darkened tones, achieved by adding black to the base color, reinforce the perception of durability and elegance, echoing Holtzschue's (2011) assertion that darker values add visual weight and maturity to a product. Lightened tones, while less common, bring an air of freshness and optimism, potentially appealing to consumers who value uniqueness within sustainable frameworks (Jung & Jin, 2014).

The intentional application of colors by Vegalli, particularly the more intense hues, represents an alignment with the brand's adventurous and bold identity. Such designs likely target consumers seeking vibrant expressions of individuality within a sustainable context. Heller's (2013) discussion on color associations supports this interpretation, with warm tones like red and orange evoking excitement and energy.

These findings also align with the broader objectives of slow fashion, which strives to balance aesthetic diversity with ecological responsibility. As noted by Jung & Jin (2014), this balance is achieved through careful material and color selection that promotes longer product lifespans while appealing to diverse consumer preferences. Moreover, the integration of vibrant hues within a predominantly neutral palette exemplifies how slow fashion merges functional simplicity with artistic sophistication, thereby fostering a deeper consumer connection to the product and its values.

5. Final considerations

This study analyzed the context of sustainability in fashion products, particularly focusing on Brazilian slow fashion footwear. The main objective was to map the colors used in slow fashion footwear and understand how these choices align with sustainability narratives. Employing a mixed methodology based on case studies, the research combined visual analysis and semiotic theory to unravel the symbolic connections between color and sustainable values in the 33 selected products from Brazilian footwear slow fashion brands.

The findings revealed that achromatic and earthy tones, such as black, brown, and beige, dominate the color palettes of slow fashion footwear, aligning with principles of functionality and timelessness. Additionally, the use of low-saturation tones contributes to a sense of nostalgia and craftsmanship, reinforcing the artisanal essence of the products. While vibrant hues, such as purple and violet, appear selectively, they stand out as symbols of exclusivity. These results underscore the importance of deliberate color choices in reinforcing the values of slow fashion and appealing to environmentally conscious consumers.

The conclusions drawn from this study highlight the dual role of color as an aesthetic and semiotic element in sustainable fashion. By leveraging symbolic associations, designers can enhance the narrative of sustainability, creating products that not only appeal visually but also resonate with the values of eco-conscious consumption. Moreover, the study emphasizes the cultural dimensions of color symbolism, suggesting that designers must consider local contexts to optimize their communication strategies. This approach fosters a deeper connection between products and consumers, ultimately strengthening the movement toward sustainable practices in the fashion industry.

The results of this study highlight how color choices in Brazilian slow fashion footwear reflect not only aesthetic and functional concerns but also deeper geo-cultural influences. The recurrence of specific hues aligns with local material traditions and artisanal practices, suggesting that sustainability communication in fashion is intrinsically linked to regional visual languages. This perspective raises an important consideration: can a culturally embedded chromatic pattern enhance consumer trust in sustainable fashion, or does it risk homogenizing the visual discourse of sustainability? While colors associated with nature and longevity strengthen the narrative of ecological responsibility, their strategic use must also account for contemporary concerns about greenwashing. The extent to which these colors are perceived as authentic indicators of sustainability, rather than marketing devices, depends on a broader engagement with transparency in production practices and consumer awareness. Future research could further explore how these chromatic strategies interact with local and global sustainability perceptions, refining the role of color as both a cultural marker and a semiotic tool in slow fashion.

The research objectives were achieved, providing perspectives into the intersection of color, sustainability, and design strategies. However, the study faced certain limitations, where color analysis was based on product images rather than direct examination of the physical products, which may introduce variations due to lighting conditions, image quality, and digital rendering. Additionally, the limited number of products analyzed may restrict the generalizability of the findings. Furthermore, the results are inherently tied to the specific context in which the study was conducted, including the selection of products, the platform from which the images were sourced, and the methodological approach used, which may limit their applicability to different settings or market conditions.

Future research should explore a wider array of sustainable fashion artifacts, including garments and accessories, while considering diverse cultural and regional contexts. Expanding the scope to include a comparative analysis of consumer preferences across different demographics would also be valuable. Quantitative approaches, such as surveys and experimental studies, could complement qualitative analyses, providing a more comprehensive understanding of how color influences perceptions of sustainability in fashion.

6. Conflict of interest declaration

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

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Notes

[1] https://meiosustentavel.com.br/sapatos-sustentaveis/. Accessed on: December 26, 2024. We used "Meio Sustentável" considering the platform's reach in the sustainability field for Brazil and the relevance of the published news, allowing us to identify brands that are still operational.

Licensing terms

References

Aballi, I. (2010) *Sobre a cor: tratado em preto e branco para seu uso e aplicação [On Color: A Treatise in Black and White for Its Use and Application].* São Paulo: Projeto Octógono Arte Contemporânea. Pinacoteca do Estado de São Paulo. Catálogo de exposição.

ABIT (2020) *Perfil do Setor. Dados gerais do setor referentes a 2019 (atualizados em dezembro de 2020) [Sector Profile. General Data for 2019 (updated December 2020)].* Available at: https://www.abit.org.br/cont/perfil-do-setor (Accessed: 15 February 2021).

Arnkil, H. (2013) *Colours in the visual world.* Helsinki: Aalto.

Berlim, L. (2012) *Moda e Sustentabilidade: uma reflexão necessária [Fashion and Sustainability: A Necessary Reflection].* São Paulo: Estação das Letras e Cores.

Berlim, L. (2016) *Transformações no Campo da Moda: crítica ética e estética [Transformations in the Field of Fashion: Ethical and Aesthetic Critique].* Doctoral thesis. Programa de Pós-graduação de Ciências Sociais em Desenvolvimento, Agricultura e Sociedade, UFRRJ, Rio de Janeiro.

Burgh-Woodman, H. and King, D. (2013) 'Sustainability and the human/nature connection: a critical discourse analysis of being "symbolically" sustainable', *Consumption Markets & Culture*, 16(2), pp. 145–168.

Caivano, J. L. (1998) 'Color and semiotics: A two-way street', *Color Research & Application*, 23(6), pp. 390–401.

Chim, I. S. and Blebea, I. (2013) 'The aesthetic value: a green attribute of sustainable product design', *Acta Technica Napocensis*, 56(2), pp. 367–374.

Clementino, T. O. and Arruda, A. J. V. (2018) *'Por uma estética voltada à sustentabilidade: estudos para configuração de novos artefatos ecologicamente orientados' [Towards an Aesthetic Oriented to Sustainability: Studies for the Configuration of New Ecologically Oriented Artifacts],* in Design, Artefatos e Sistema Sustentável. São Paulo: Blucher, pp. 87–106.

Clementino, T. O., Barbosa, E. B. and Fernandes, T. K. S. (2017) 'Menos é mais: a percepção dos consumidores sobre o uso da cor em embalagens sustentáveis' [Less is More: Consumers' Perception of Color Use in Sustainable Packaging], *Revista Educação Gráfica*, 21, pp. 257–277.

Clementino, T. O., Silva, I. F. and Arruda, A. J. V. (2021) 'Ferramenta para auxílio à análise visual' [Tool for Visual Analysis Assistance], *Educação Gráfica*, 25(1), pp. 28–48.

Dantas, Í. J. M. and Silva, C. A. P. (2022) 'Correlação entre a intenção dos designers e a interpretação das cores de uma coleção de vestuário por pessoas da Geração Z' [Correlation Between Designers' Intentions and the Interpretation of Colors in a Clothing Collection by Generation Z], *Modapalavra e-periódico*, 15(36), pp. 8–34.

Dantas, Í. J. M., Batista, F. E. A., Júnior, G. S., Oliveira, I. F. and Silva, C. A. P. (2021) *'Matiz, saturação e claridade, o reflexo da natureza: o papel da cor na configuração estética de produtos de moda slow fashion' [Hue, Saturation, and Lightness, the Reflection of Nature: The Role of Color in the Aesthetic Configuration of Slow Fashion Products]*, ENSUS 2021, 130–141. Available at: https://repositorio.ufsc.br/handle/123456789/228860 (Accessed: 7 October 2021).

Dong, Z. J., Liang, J. F., Zhang, Z. J. and Wei, S. S. (2023) 'The Perceptual Evaluation of Clothing Sustainable Color in Clothing Design', *Journal of Fiber Bioengineering and Informatics*, 16(3), pp. 229–241.

Farina, M. et al. (2006) *Psicodinâmica das cores em comunicação [Psychodynamics of Colors in Communication*]. São Paulo: Edgar Blucher.

Fletcher, K. and Grose, L. (2011) *Moda e Sustentabilidade: Design para mudança [Fashion and Sustainability: Design for Change].* Translated by Janaína Mendonça. São Paulo: Editora SENAC.

Gil, A. C. (2008) *Métodos e técnicas de pesquisa social [Methods and Techniques of Social Research].* 6th edn. São Paulo: Editora Atlas SA.

Guimarães, L. (2000) *A cor como informação: a construção biofísica, linguística e cultural da simbologia das cores [Color as Information: The Biophysical, Linguistic, and Cultural Construction of Color Symbolism].* São Paulo: Annablume.

Heller, E. (2013) *A psicologia das cores: Como as cores afetam a razão e a emoção [The Psychology of Colors: How Colors Affect Reason and Emotion].* Translated by L. L. da Silva. São Paulo: Gustavo Gili.

Holtzschue, L. (2012) *Understanding color: an introduction for designers.* Hoboken: John Wiley & Sons.

Jardim, P. K. S. and Pavan, L. D. (2014) 'O mercado sustentável e a valorização do ecoproduto: algumas perspectivas' [The Sustainable Market and the Valorization of Eco-Products: Some Perspectives], *Revista Eletrônica Diálogos Acadêmicos*, 7(2), pp. 123–137.

Jung, S. and Jin, B. (2014) 'A theoretical investigation of slow fashion: sustainable future of the apparel industry', *International Journal of Consumer Studies,* 38(5), pp. 510–519.

Lipovetsky, G. (2009) *O império do efêmero: a moda e seu destino nas sociedades modernas [The Empire of the Ephemeral: Fashion and Its Fate in Modern Societies].* São Paulo: Companhia das Letras.

Menegucci, F. et al. (2015) *'Resíduos têxteis: análise sobre descarte e reaproveitamento nas indústrias de confecção' [Textile Waste: Analysis of Disposal and Reuse in the Clothing Industry],* in Congresso Nacional de Excelência em Gestão, Rio de Janeiro. CNEG&OINOVARSE, pp. 1–12.

Monte, K. D., Yousaf Gill, I., Mashooq, N. and Haider Durrani, A. (2024) 'How Shapes and Colors Drive Sustainable Fashion and Eco-Friendly Graphic Design', *Journal of Policy Research*, 10(2), pp. 165–173. doi: 10.61506/02.00219.

Moreira, A. C., Jacques, J. J. and Pizzato, G. Z. A. (2018) 'Atributos estéticos e sustentabilidade: estudo de caso com mochilas de marcas gaúchas' [Aesthetic Attributes and Sustainability: Case Study with Backpacks from Gaucho Brands], *Revista Educação Gráfica*, 22(2), pp. 334–348.

Nishimura, M. D. L. and Gontijo, L. A. (2016) *'Slow fashion e o produto de moda com enfoque no usuário' [Slow Fashion and Fashion Products Focused on the User],* in 12° Congresso Brasileiro de Pesquisa e Desenvolvimento em Design, São Paulo. São Paulo: Editora Blucher, pp. 4796–4804.

Pastoureau, M. (1997) *Dicionário das cores do nosso tempo: simbólica e sociedade [Dictionary of the Colors of Our Time: Symbolism and Society].* Translated by M. J. Figueiredo. Lisboa: Editorial Estampa.

Pastoureau, M. (2011) *Preto: história de uma cor [Black: History of a Color].* Translated by L. P. Zylberlitch. São Paulo: Editora Senac São Paulo.

Pereira, C. (2023) 'A cor como signo: fundamentos para uma abordagem semiótica das cores no design' [Color as a Sign: Fundamentals for a Semiotic Approach to Colors in Design], *Estudos em Design,* 31(1).

Petersen, M. and Brockhaus, S. (2017) 'Dancing in the dark: Challenges for product developers to improve and communicate product sustainability', *Journal of Cleaner Production*, 161, pp. 345–354.

Sailer, A., Wilfing, H. and Straus, E. (2022) 'Greenwashing and bluewashing in Black Friday-related sustainable fashion marketing on Instagram', *Sustainability*, 14(3), p. 1494.

Sansoni, S., Torrens, G. and Downs, S. (2023) 'The role of graphic design in promoting sustainability and ethical responsibilities against greenwashing', in *DS 123: Proceedings of the International Conference on Engineering and Product Design Education (E&PDE 2023)*.

Santaella, L. (2002) *Semiótica aplicada [Applied Semiotics].* São Paulo: Thomson/Cengage Learning.

Şener, T., Bişkin, F. and Kılınç, N. (2019) 'Sustainable dressing: Consumers' value perceptions towards slow fashion', *Business Strategy and the Environment,* 28(8), pp. 1548–1557.

Silva, C. M. S. (2014) *'Moda e Sustentabilidade: reuso de jeans para o desenvolvimento de produtos comerciais com valor agregado do Design' [Fashion and Sustainability: Reuse of Jeans for the Development of Commercial Products with Added Design Value],* in 2° Contexmod - Congresso Científico Têxtil e de Moda. São Paulo: [s.n.].

Solino, L. J. S., Teixeira, B. M. L. and Dantas, I. J. M. (2020) 'The sustainability in fashion: a systematic literature review on slow fashion', *International Journal for Innovation Education and Research*, 8(10), pp. 164–202.

Song, J. E. and Choi, K. H. (2010) 'Eco-design color trends in fashion', *Journal of the Korean Society of Clothing and Textiles*, 34(3), pp. 492–507.

Sundar, A. and Kellaris, J. J. (2015) 'Blue-washing the green halo: how colors color ethical judgments', in *The Psychology of Design*, pp. 63–74. Routledge.

Szabo, S. and Webster, J. (2021) 'Perceived greenwashing: the effects of green marketing on environmental and product perceptions', *Journal of Business Ethics*, 171, pp. 719–739.

Yin, R. K. (2014) *Case Study Research Design and Methods*. Canadian Journal of Program Evaluation, 30(1), pp. 108–110.

Tactile coloration for inclusive fashion: the role of *“See Color”* in enhancing autonomy for individuals with visual impairments

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ABSTRACT

Color has historically played a pivotal role in design and fashion, serving as a tool for identity, communication, and aesthetic expression. However, the interplay between color and accessibility, particularly for individuals with visual impairments, remains underexplored. This study investigates how the tactile language “See Color” enables autonomy and inclusivity in fashion for individuals with acquired visual impairments. Drawing from qualitative methodologies, including ethnographic approaches and usability testing, the research proposes a tactile color chart as a practical solution for facilitating independent clothing choices. Findings indicate that tactile systems, such as “See Color”, not only democratize access to personal coloration but also foster social belonging and cultural expression. By bridging the gap between aesthetics and accessibility, this research contributes to the historical narrative of color in design, highlighting its evolving role in inclusive practices. The results underscore the importance of integrating accessible design principles to broaden the scope of fashion's cultural and social impact.

KEYWORDS Fashion inclusion. Tactile coloration. Accessibility. Visual impairment. "See Color" system. Inclusive design. Autonomy.

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1. Introduction

Color plays a central role in fashion and design, functioning as a powerful tool for personal identity, communication, and aesthetic expression. From its use in everyday clothing choices to its prominence in high fashion, color influences how individuals perceive and present themselves to the world. Historically, color has carried symbolic meanings, served as an indicator of social status, and reflected cultural trends. Despite its universal significance, the relationship between color and accessibility remains largely unaddressed, particularly for individuals with visual impairments. For this group, the inability to perceive or identify color creates significant barriers to making independent and expressive choices in fashion.

Moreover, fashion has long been a platform for self-expression, offering individuals the means to communicate their identities and values. However, the experience of fashion is not universally accessible. Individuals with visual impairments often face limitations in accessing key elements of design, such as color, that are essential to clothing selection and personal styling. While technological advances have improved tactile recognition of shapes and textures in design, accessible tools for understanding and engaging with color remain scarce. This exclusion reinforces a broader issue of invisibility for people with disabilities in fashion and challenges their autonomy in daily life.

In recent years, the fashion industry has made progress in addressing diversity and inclusion by creating adaptive solutions tailored to the needs of individuals with disabilities. Initiatives such as Tommy Hilfiger's "Tommy Adaptive" line have demonstrated how inclusive fashion can merge functionality with aesthetics, catering to a broader range of consumers. However, these advancements have primarily focused on physical adaptations, such as adjustable closures and ergonomic designs, with limited exploration of how aesthetic elements like color can be made accessible. This gap highlights the need for inclusive strategies that not only address mobility or fit but also empower individuals with visual impairments to engage with the symbolic and emotional aspects of fashion, particularly color.

Fashion serves as more than a medium for personal expression; it is also a social and cultural connector. Clothing choices often signal membership in certain groups, reflect cultural heritage, or align with current trends. For individuals with visual impairments, barriers to engaging with color restrict their ability to participate in these broader social and cultural narratives. The absence of accessible tools for color recognition further marginalizes these individuals, creating an unmet need for innovations that enable independence and inclusion in the fashion space. Addressing this need would not only improve individual autonomy but also broaden the societal understanding of inclusion in design.

Furthermore, the growing importance of accessibility in design has prompted new conversations about how inclusive principles can be applied across various industries, including fashion. While research on adaptive fashion has highlighted its role in improving functionality and comfort, there remains a significant lack of focus on the aesthetic dimensions of clothing, particularly color.

In this context, image consulting, particularly the personal color analysis method, has gained prominence as a tool for enhancing self-expression and self-esteem through the strategic use of color. This process involves identifying hues that harmonize with an individual's skin tone, hair, and eyes to create a cohesive and flattering appearance. However, for individuals who are blind or visually impaired, this method poses unique challenges. The traditional reliance on visual assessment excludes these individuals from participating in an experience that significantly influences personal style and identity. This raises the need for adaptive approaches that enable blind individuals to access and engage with personal color analysis, ensuring that they too can enjoy its aesthetic and emotional benefits.

Therefore, we argues that the "See Color" tactile language emerges as a promising solution to bridge this gap, offering a system that allows individuals with visual impairments to identify and interact with colors through touch. By translating color into a tactile code of lines and points, "See Color" empowers users to independently engage with their personal style. In the context of image consulting, this system can transform how blind individuals perceive and select clothing, enabling them to participate actively in processes traditionally dominated by visual cues. This integration might enhances autonomy while reinforces the broader goal of inclusive fashion, ensuring that aesthetic practices like color analysis are accessible to all, regardless of visual ability.

This gap represents a missed opportunity to create solutions that are not only functional but also culturally meaningful. Tactile color systems, such as the "See Color" language, offer a promising avenue for bridging this divide by providing individuals with visual impairments the means to independently engage with color.

Therefore, this study seeks to explore the potential of the "See Color" tactile system as a tool for promoting autonomy and inclusion in fashion for individuals with acquired visual impairments. By examining how tactile color recognition can facilitate independent clothing choices, this research aims to demonstrate the broader cultural and social benefits of integrating accessibility into aesthetic design. The objective of this paper is to highlight the importance of inclusive strategies that connect aesthetics and functionality, fostering a more equitable and participatory approach to fashion.

2. Theoretical frameworks

2.1. *Fashion and inclusion*

Fashion is a cultural and social phenomenon with profound influence on individuals and societies. Lipovetsky (2009) argues that fashion is a hallmark of modernity, shaped by individuality and transience, and reflects social transformations and personal identity. Beyond functionality, fashion embodies cultural, aesthetic, and historical dimensions, making it an essential tool for expressing societal values and individual preferences.

Fashion operates not only as an aesthetic expression but also as a marker of cultural and social belonging. Miranda (2008) describes fashion as a form of visual communication that enables individuals to construct their identities and participate in social groups. By engaging with the symbolic language of clothing, people navigate social expectations while expressing personal narratives, highlighting the dual role of fashion in integrating and distinguishing individuals within society (Piacentini & Mailer, 2004).

This dynamic relationship between fashion and identity is further illustrated by Crane (2006), who emphasizes that clothing, as one of the most visible forms of consumption, is central to the construction of social identity. Fashion choices reveal how individuals interpret cultural norms while adapting them to their unique expressions (Barnard, 2013). Crane (2006) argues that fashion acts as both a reflection of societal structures and a medium through which individuals negotiate their place within them.

Inclusive fashion builds on this understanding by seeking to extend these opportunities for expression and belonging to individuals who have historically been marginalized. Machado (2017) underscores the importance of acknowledging diverse perceptions and experiences within fashion, emphasizing that inclusion involves more than physical accessibility; it requires creating spaces for all individuals to participate in cultural and social dialogues through clothing (Busch, 2018).

As Auler and Sanches (2017) note, inclusive fashion is rooted in the recognition of diversity and aims to address the specific needs of various individuals, particularly those with disabilities. This approach involves rethinking traditional fashion norms to create designs that not only accommodate but celebrate differences (Busch, 2018). By doing so, inclusive fashion expands the possibilities for self-expression and fosters greater social integration (Busch, 2018).

The concept of inclusive fashion challenges conventional standards that often prioritize exclusivity. Pereira and Cruz (2016) highlight how traditional fashion systems have historically excluded certain body types and abilities, perpetuating a narrow ideal of beauty. Inclusive fashion, by contrast, seeks to dismantle these barriers, advocating for designs that embrace a broader spectrum of bodies and identities, thereby promoting equity and representation (Busch, 2018).

Fashion also plays a critical role in fostering a sense of social belonging. For marginalized groups, the ability to participate in fashion is tied to their recognition and acceptance within society (Joo & Wu, 2021). By creating inclusive designs, the fashion industry contributes to this process, enabling individuals to express their identities and connect with others through shared cultural symbols (Busch, 2018). This approach reaffirms that fashion is not merely a tool for personal aesthetics but a vital medium for social inclusion and dialogue (Busch, 2018; Joo & Wu, 2021).

Ultimately, inclusive fashion is more than a design philosophy; it is a commitment to equity and representation within a cultural and social framework (Busch, 2018). By recognizing the diverse needs and preferences of all individuals, inclusive fashion redefines the boundaries of the industry, ensuring that clothing serves not only as a form of personal expression but also as a means of fostering community and belonging (Busch, 2018).

2.2. *Acquired Blindness and Colors: The Path to Inclusive Fashion*

Acquired blindness refers to the loss of vision at some point in life after an individual has already experienced the world visually (Wong, 1991; Collignon et al., 2013). Almeida and Araújo (2013) emphasize that this condition is particularly traumatic as it disrupts previously established patterns of communication, mobility, work, and leisure. Adapting to this new reality often requires a painful process of identity reconstruction and reorganization of sensory and motor skills. The individual must relearn how to navigate their environment, relying on other senses such as touch and hearing, which can lead to feelings of frustration and anxiety (Wong, 1991; Almeida & Araújo, 2013 Collignon et al., 2013; Tomasello et al., 2024).

The experiences of individuals with acquired blindness vary according to the timing and manner of vision loss. Almeida and Araújo (2013) note that sudden vision loss can lead to an intense shock, followed by a gradual adaptation phase, during which emotional recovery is a challenging process. In cases of progressive blindness, the emotional impact may be less abrupt due to the psychological preparation for eventual total vision loss (Wong, 1991; Almeida & Araújo, 2013 Collignon et al., 2013 Tomasello et al., 2024). However, the constant threat of losing vision often generates prolonged anxiety, further contributing to depersonalization processes and directly impacting self-esteem and identity as a social subject (Wong, 1991; Almeida & Araújo, 2013 Collignon et al., 2013; Tomasello et al., 2024).

In this context, Almeida and Araújo (2013) argue that individuals with blindness can utilize the vision of others as an instrument to perceive the world, enabling the formation of a renewed sense of self. Nonetheless, this process requires proper orientation, training, and lived experiences that help individuals improve their quality of life and reorganize their motor abilities (Wong, 1991; Almeida & Araújo, 2013 Collignon et al., 2013; Tomasello et al., 2024). Fashion emerges as a valuable tool in this journey, providing opportunities for autonomy and self-esteem (Alsabhi, 2024). While traditionally centered on visual aesthetics, fashion can play a central role in the adaptation process for individuals with acquired blindness by fostering a renewed relationship with clothing as a means of social reintegration and self-discovery (Alsabhi, 2024).

Bononi, Domiciano, and Menezes (2016) suggest that clothing design for visually impaired individuals should prioritize tactile experiences, as touch becomes the predominant sense in the absence of vision. They highlight the need for fashion design to adapt to this sensory reality, where tactile elements offer a new way of engaging with the world. Fabrics with varied textures, embroidery, and raised surfaces become essential tools to facilitate interaction with clothing. Similarly, Krone, Oliveira, and Rizzi (2020) stress the importance of incorporating universal design principles into the development of inclusive fashion pieces, ensuring accessibility for all individuals regardless of sensory abilities.

The relationship between fashion and acquired blindness also involves notions of both social and emotional inclusion. Oliveira et al. (2015) underline that fashion can serve as a means of reconnecting individuals with their environment and society, particularly for those who experience sudden or progressive vision loss. Clothing featuring raised patterns, Braille labels, and other sensory details not only facilitates autonomy in dressing but also acts as a medium for restoring self-esteem (Alsabhi, 2024). For individuals who have lost their vision, fashion becomes a means of expressing identity and regaining a sense of belonging to the world, which has been abruptly altered by the loss of sight (Alsabhi, 2024).

The challenge of associating blind individuals with color is further discussed by Bianchi, Ramos, and Barbosa-Lima (2016), who explore how to teach colors to individuals blind from birth. These authors view learning as a multisensory process, arguing that while colors are traditionally linked to vision, their meaning can also be understood through other sensations and social associations. They conclude that even without visual perception, knowledge of colors can be constructed through interactions with other senses and shared social experiences (Kim et al., 2021).

Bianchi, Ramos, and Barbosa-Lima (2016) also argue that the conceptualization of colors in blind individuals involves the mobilization of senses such as touch, hearing, and even smell, enabling meaningful associations that compensate for the lack of vision. Their study revealed that blind students associated colors with tactile and emotional elements, illustrating that understanding colors is not exclusively a visual process but rather a complex intellectual and social activity. This multisensory approach to teaching colors contributes to an inclusive education adapted to the needs of blind individuals.

2.3. *Personal coloring and the perspective of inclusion*

In the context of fashion, one of the most prominent contemporary areas is image consulting (Wellington and Bryson, 2001; Marks, 2021). This field focuses on guiding and informing consumers about the best choices for clothing, accessories, makeup, and other items to effectively communicate a self-image aligned with their interests, personality, professional roles, and social positioning consulting (Wellington and Bryson, 2001; Marks, 2021). Within this framework, personal color analysis stands out as a technique designed to identify and harmonize colors with an individual's skin undertone. This process directly influences self-image and self-esteem by providing a palette that enhances natural features and improves personal perception (Medeiros, 2022).

Personal color analysis, as a service, explores the impact of colors on self-esteem, revealing a strong connection between appearance and self-perception. Medeiros (2022) highlights that personal color analysis can significantly influence how individuals perceive themselves and how they are perceived in social contexts. The appropriate use of a personalized color palette can transform the way individuals view their physical characteristics, boosting confidence and elevating self-esteem. Research on the impact of colors on personal image supports these claims, showing that using harmonious colors fosters a positive self-image (Ulrich, 2019).

This perspective is further reinforced by Silveira and Soratto (2022), who discuss how fashion consulting promotes self-awareness and serves as a key tool for building self-esteem. They argue that understanding one's personal style and learning to use colors effectively not only enhances appearance but also fosters a deeper sense of self-confidence and well-being. Thus, personal color analysis transcends aesthetics, contributing to emotional and psychological growth by helping individuals construct a more positive self-image (Silveira & Soratto, 2022).

As highlighted by Medeiros (2022), personal color analysis has proven effective in delivering the benefits outlined in theoretical reviews. Her study shows that participants who underwent in-person consultations using the expanded seasonal method reported increased self-esteem, greater use of colorful clothing, improved makeup techniques, and enhanced ability to combine colors effectively (Medeiros, 2022).

Ulrich (2019) emphasizes that the impact of colors on personal and professional image, while subjective, can be amplified through a technical color analysis that harmonizes colors with skin pigmentation. By combining this analysis with a personalized approach considering personality and environment, individuals can positively influence their self-esteem. Ulrich highlights how the proper use of colors not only enhances aesthetics but also strengthens confidence and improves social positioning in diverse contexts.

In the context of this research, it is understood that while personal color analysis is widely used as a tool to improve self-image and self-esteem, it poses challenges when applied to inclusive fashion, especially for individuals with visual impairments. The concept of harmonizing colors with skin tone, as described by Medeiros (2022), heavily relies on the visual perception of colors and the non-verbal communication they convey. For visually impaired individuals, this perception is limited or absent, creating barriers to fully benefiting from this resource. This raises the need to adapt personal color consulting to include those who cannot "See Color"s but still wish to express themselves aesthetically and enhance their self-esteem through fashion.

In this regard, inclusive fashion must be reimagined to integrate visually impaired individuals into processes such as personal color analysis, which traditionally depends on visual cues. To date, no research has been identified that connects personal color analysis with inclusive fashion concepts. However, we argues that Ulrich's (2019) technical analysis of skin pigmentation could be adapted using tactile technologies and detailed descriptions, allowing individuals to sense and understand the relationship between colors and their appearance without visual input.

Furthermore, as Lazzarin (2022) notes, self-awareness can significantly elevate self-esteem. For visually impaired individuals, image consulting could focus on other sensory aspects of fashion, such as textures, shapes, and comfort, offering alternative ways to express identity and personality without relying exclusively on vision.

2.4. *Tactile Methods for Color Identification: The ""See Color"" System*

Tactile methods for color identification have been developed to provide autonomy to visually impaired individuals in choosing clothing, services, and other products, recognizing the central role of color in design and fashion consumption. Among the available systems, solutions range from simple geometric shapes and Braille codes to more complex systems requiring the memorization of various symbols and their combinations. These systems enable colors to be interpreted through touch, offering an inclusive and sensory experience. According to Brogin et al. (2024), tactile methods allow for color recognition without visual support, bridging the gap between inclusive design and accessible fashion.

Brogin et al. (2024) identify simplicity and ease of memorization as key features of effective tactile methods (Figure 1).

For instance, the ColorADD system uses simple geometric shapes to represent different colors, while the "See Color" Tactile Color Language relies on points and lines to create an intuitive and practical code for clothing. Additionally, other approaches, such as QR codes and Braille tags, are discussed, although many users exhibit low adherence to solutions dependent on digital technology. These tactile methods collectively aim to make color identification accessible and user-friendly (Brogin et al., 2024).

Systems such as ColorADD and the "See Color" language strive to create visual codes that are easily recognizable and applicable in various settings, whether for educational, commercial, or communicational purposes (Brogin et al., 2024). The Gagne Todd system, for example, involves memorizing geometric shapes and abbreviations for colors in English, while the Constanz system requires the retention of geometric shapes and seven different types of lines (Brogin et al., 2024).

In addition to these, other methods, such as the Universal Color Code and the FOCO system, focus on expanding accessibility and universality in color recognition. ColorADD, for instance, utilizes combined geometric shapes to represent colors inclusively, especially for individuals with color blindness. Similarly, the FOCO system employs overlapping figures and colors for a more intuitive identification process. These strategies aim to create visual and tactile codes that are universally understandable, transcending linguistic and sensory barriers to foster inclusivity (Brogin et al., 2024)

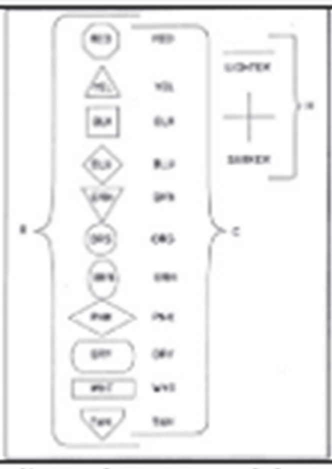
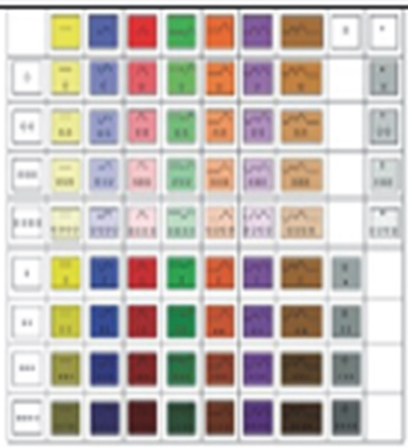
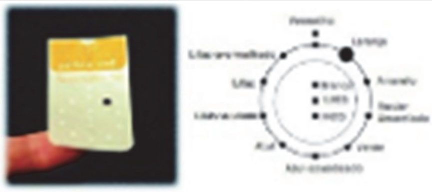
Sistema Gagne Todd (Todd, 2006)	Sistema Constanz (Monroy, 2012)	Sistema ColorADD (Santos, 2008)
		
It requires memorizing geometric shapes and color abbreviations in English.	It requires the memorization of geometric shapes as well as 7 different types of lines.	It requires the memorization of simple geometric shapes and their juxtaposition.
Código FOCO (Pires, 2011)	Sistema Ramsamy-Iranah (Ramsamy-Iranah et al., 2015)	Sistema Iro-pochi (Sagawa, Okudera, Ashizawa, 2019)
		
It requires the memorization of simple geometric shapes and their juxtaposition.	Requires memorization of all 14 symbols presented.	Requires memorizing the position of 14 points on the circle.
Linguagem tátil das cores *See Color* (Marchi, 2019)	Universal Color Code Código Universal de Cores - CUDC (Pereira, Ferronato, 2019)	
		
It requires memorizing the stitch and line, as well as the positions of 8 colors.	Requires understanding of two Braille cells, i.e. 12 dots.	

Fig. 1. Color recognition methods mapped by Brogin et al. (2024)

Among the methods discussed, the "See Color" system stands out as an innovative tactile language designed by Marchi (2019) specifically for visually impaired individuals (Figure 2). This system is based on the combination of points and lines inspired by Braille, allowing users to perceive colors through tactile interaction. The code features a central point indicating a reference position and a line pointing to the corresponding color, resembling a clock hand. This structure facilitates memorization and enables users to create a tactile mental map of colors, offering an accessible solution rooted in the principles of Universal Design (Marchi, 2019)

Fig. 2. Tactile Language ""See Color""

Testing of the "See Color" system with 18 participants demonstrated the simplicity of its forms and its alignment with Color Theory, making it easier to learn and remember. The small dimensions of the code (ranging from 1.6x1.6 cm to 1.8x1.8 cm) allow it to be applied to virtually any surface, making it a practical tool for identifying colors. This method supports learning about color relationships, including secondary and neutral tones, providing visually impaired individuals with a guide to understanding and choosing colors in various domains such as fashion, education, and daily life (Marchi, Brogin & Okimoto, 2022).

The effectiveness of the "See Color" system lies in its simplicity and proven functionality. According to Marchi (2019), it enables quick and accurate color identification in an average time of 18.5 seconds, with an accuracy rate of 82.86%. Its adaptability to different surfaces broadens its application in fashion, education, and everyday products, fostering greater autonomy for visually impaired users. By allowing for tactile color identification, "See Color" can democratize access to personal color analysis, enabling visually impaired individuals to participate in image consulting and style processes more independently.

Marchi (2019) highlights the potential of "See Color" for use in clothing labels and accessories, suggesting that it could also be implemented in color palettes for fashion consulting. This integration would make the color selection process more accessible and aligned with inclusive design principles. By enabling visually impaired individuals to actively participate in the discovery and use of colors, the "See Color" system opens new opportunities for inclusion within the fashion industry, fostering personalization and autonomy in the use of colors.

3. Methodology

This research is classified as applied, as it seeks to develop practical solutions for specific challenges within the context of inclusive fashion. According to Prodanov and Freitas (2009), applied research is oriented towards addressing real-world problems, producing knowledge with a direct application. The inductive method was chosen, progressing from particular observations to broader generalizations, which enables conclusions to be drawn directly from empirical evidence.

From a methodological perspective, the study is exploratory, aiming to deepen understanding of tactile color systems and their applications in promoting inclusion. Prodanov and Freitas (2009) argue that exploratory research is fundamental when the objective is to clarify concepts, investigate new approaches, or provide more information about a subject. Additionally, the research is descriptive, a methodology often employed in the social sciences to observe, analyze, and describe phenomena within their natural context.

The first phase of the research involved a bibliographic review, defined by Cervo and Bervian (1983) as a systematic process for identifying and analyzing theoretical contributions relevant to a specific subject. This stage focused on academic works related to inclusive fashion, tactile methods for color identification, and issues faced by visually impaired individuals. The review provided the theoretical basis for developing the field research and understanding existing gaps in the literature.

Field research was conducted using a case study approach, which Yin (2015) identifies as an effective method for detailed investigation of complex phenomena in real-life contexts. This approach allowed for an in-depth exploration of the lived experiences of a single participant, enabling a nuanced understanding of her needs and interactions with tactile color systems. The participant was a 31-year-old woman with acquired blindness, residing in Campo Bom, Rio Grande do Sul (Brazil). Her experiences provided valuable perspectives into how inclusive fashion and tactile systems can be applied to enhance autonomy and self-expression.

Data collection involved participant observation and semi-structured interviews, methods that Minayo (2001) considers essential for capturing subjective experiences and the meanings individuals attribute to their actions. The interviews aimed to understand the participant's perceptions of tactile color systems and their relevance to her daily life, while the observations focused on her interaction with these tools in practical contexts.

This study focuses on a single participant, referred to by the pseudonym "Rosa," to ensure anonymity and uphold ethical research standards. The decision to work with one subject stems from the need for depth and specificity in exploring the nuances of her lived experiences with acquired blindness. A single-case approach enables a detailed, contextualized analysis of her interactions with tactile color systems and inclusive fashion, highlighting her challenges, adaptations, and perspectives. However, a key limitation of this research is its small sample size, which, while allowing for an in-depth and personalized analysis, restricts the generalizability of the findings to a broader population of individuals with visual impairments. Furthermore, the study was limited to the implementation of a specific color palette (Winter, in Rosa's case), which may not fully address the diverse needs and preferences of all individuals with acquired blindness.

Moreover, this methodology aligns with the research's objective to investigate personal and subjective dimensions, prioritizing quality and depth of data over breadth. By centering on Rosa's unique narrative, the study captures the complexities of her experience, offering valuable contributions to the broader discussion on inclusion and accessibility.

Data analysis was interpretative, grounded in the principles of qualitative research. According to Geertz (1973), the interpretative approach seeks to uncover the meanings behind actions and social interactions, emphasizing the context in which they occur. The analysis involved construct a comprehensive narrative of the participant's experiences.

4. Results

4.1. *Participant profile: a perspective on four meetings*

The field research with Rosa began in August 2023, offering insights into her personal journey with acquired blindness and its impact on her daily life and identity. The first meeting occurred in Novo Hamburgo, following a walk advocating for disability rights, organized by the Municipal Council for the Rights and Citizenship of Persons with Disabilities. During this initial interaction, Rosa shared her story of losing her vision at 31 due to a bacterial infection of unknown origin. At the time, she was working as a retail assistant in a sporting goods store and preparing for university entrance exams in Social Work. Her medical journey was fraught with misdiagnoses and uncertainty, with suspicions of cancer complicating her quest for answers. This period was marked by emotional resilience and perseverance, despite the stigma and skepticism she faced, even from family members, who initially misunderstood her symptoms.

Rosa's experience reflects the challenges of navigating health systems while dealing with invisible disabilities. She found support through a social worker from ADEVIS (Association for the Visually Impaired) and a network of friends and family, which proved instrumental in her acceptance of her condition. Her narrative highlights resilience, as she gradually rebuilt her life by engaging in physical activities, learning traditional dance, participating in scientific projects, and advocating for others with similar conditions.

Subsequent meetings further enriched the understanding of Rosa's life. In a visit to her residence, she shared details about her daily routines and the adjustments she has made to maintain her physical and mental well-being. Rosa emphasized the importance of regular exercise and balanced nutrition as strategies to cope with the challenges of her visual impairment. These conversations deepened the researcher-participant relationship, transitioning from formal observation to a collaborative partnership. Rosa's reflections on inclusive fashion emerged naturally, revealing practical challenges such as selecting socks of the same color, discomfort with certain clothing designs like loose gym shorts, and difficulties handling zippers on jackets. Her comments underscore the need for functional and aesthetic considerations in inclusive fashion design.

Rosa's participation in cultural and community activities further showcased her ability to transcend her limitations. At a traditional dance graduation event, Rosa embodied how cultural expression can foster inclusion and belonging, demonstrating that visual impairment does not preclude participation in meaningful social activities. Her involvement in these settings reinforced the importance of accessibility in fashion, particularly in the context of formal attire, where she faced difficulties relying on others to navigate clothing choices.

The final meeting, focused on accessibility in museums and art spaces, sparked an open discussion on Rosa's experiences with fashion and the broader challenges faced by visually impaired individuals. She expressed frustrations with the lack of accessible options and the reliance on third-party perceptions during shopping. Rosa highlighted the significance of accessible labels and adaptive designs that cater to visually impaired consumers. These conversations revealed her preference for practical and comfortable clothing, such as sportswear, while also exposing the emotional and social implications of her fashion choices, particularly regarding color and style.

Rosa's journey illustrates the intersection of resilience, autonomy, and social inclusion. Her reflections on clothing choices, reliance on neutral tones, and need for accessible solutions reflect both the limitations imposed by her condition and her proactive efforts to navigate these barriers. Rosa's story emphasizes the critical role of inclusive design in fostering independence, dignity, and participation for individuals with visual impairments. Through her experiences, the research captures the intricate relationship between disability, identity, and the transformative potential of inclusive fashion.

4.2. *Interaction with the "See Color" System: fifith meeting*

The fifth meeting with Rosa, held in February 2024, marked a pivotal step in the research, as it involved conducting a personalized color analysis using the tactile language of "See Color". This encounter took place at the researcher's residence, approximately two months after the previous observation and interview. The objective was to explore how a tactile color system could offer an inclusive approach to personal color analysis, tailored to the specific needs of visually impaired individuals.

Personal color analysis is a process that identifies the most harmonious colors for an individual based on their natural features, such as skin tone, hair, and eyes. Traditionally, this method relies on visual cues to enhance appearance, but in Rosa's case, the "See Color" tactile system was introduced to translate these visual elements into a tactile format. This adaptation aimed to empower Rosa to engage with her color palette through touch, making the process accessible and meaningful.

The analysis began with an explanation of personal color theory and the tactile language of "See Color" (Figure 3). The "See Color" system, inspired by the color wheel, uses tactile symbols arranged in a clock-like format to represent primary and secondary colors. Rosa described the tactile structure, formed by overlapping triangles, as resembling a "Star of David," which helped her conceptualize the arrangement of colors. By aligning the tactile system with tangible fabrics, Rosa could connect the tactile symbols with the characteristics of different colors.

Fig. 3. Instructional material for teaching the tactile language ""See Color"".

The practical phase involved placing colored fabrics close to Rosa's face to evaluate the harmony between her natural features and the colors (Figure 4). Through tactile exploration, she interacted with the "See Color" symbols associated with each fabric, allowing her to engage with the process of determining her personal color palette. The analysis revealed Rosa's warm olive skin tone, brown eyes, and hair, leading to the diagnosis of a "Cool Winter" seasonal color palette. This palette includes deep and rich shades such as navy blue, moss green, burgundy, dark purple, charcoal gray, and black, avoiding overly light or pastel tones that do not complement her natural features.

Throughout the session, the tactile system facilitated Rosa’s understanding of color relationships, enabling her to perceive and differentiate colors through touch. This interaction not only provided her with practical tools for wardrobe selection but also fostered a deeper sense of self-awareness and confidence. Rosa expressed enthusiasm about integrating this knowledge into her daily life, emphasizing the importance of feeling comfortable and self-assured in her clothing choices.

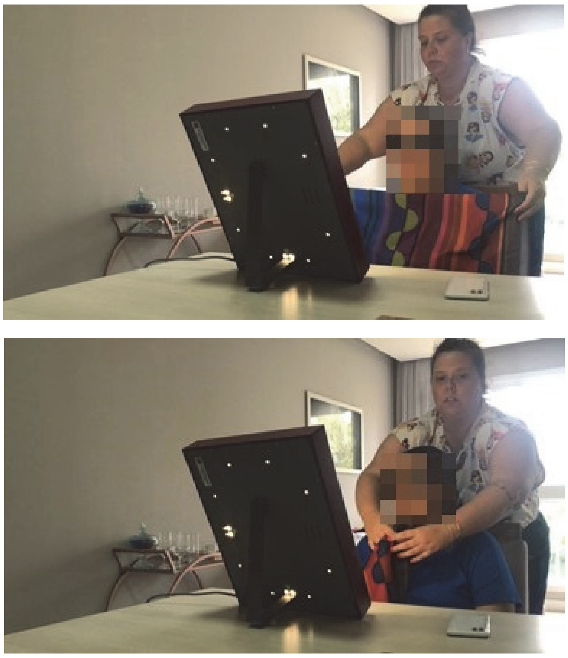


Fig. 4. Personal Color Analysis in Rosa.

The analysis concluded with a comprehensive explanation of her color palette (Winter) and guidance on how to apply it to clothing, accessories, and overall styling. The “See Color” system proved to be an effective and inclusive tool, bridging the gap between aesthetics and accessibility while enhancing Rosa’s autonomy in navigating her personal style. Furthermore, we notice that this experience underscores the potential of tactile systems in inclusive fashion, highlighting their role in empowering visually impaired individuals to engage actively with color and self-expression.

4.3. *Development of inclusive tactile color palettes based on Rosa’s experience*

Leveraging perceptions from the research sessions with Rosa, a tactile Winter color palette was created by the Feevale University Design Center to provide a practical and inclusive tool for visually impaired individuals. This initiative aimed to incorporate the tactile symbolism of the ““See Color” language”, enabling Rosa to independently select clothing, accessories, makeup, and even hair colors that harmonize with her natural features, such as skin tone, hair, and eyes.

The design process began with a detailed study of Rosa’s Cool Winter color palette, guided by the principles of personal color analysis. Using the Pantone color system as a reference, the tones of the palette were carefully mapped and validated in conjunction with the “See Color” tactile symbols. This initial stage was instrumental in aligning visual and tactile elements, ensuring compatibility with Rosa’s needs (Figure 5).

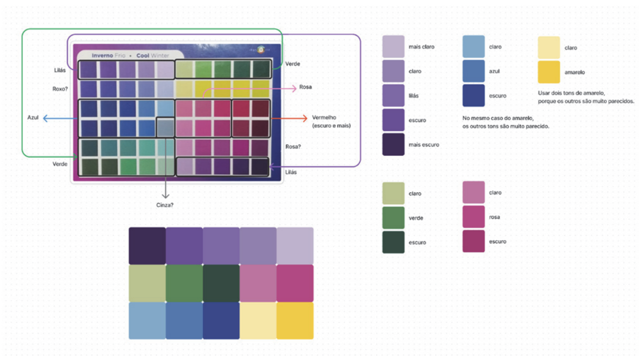


Fig. 5. Tactile color chart proposal.

The tactile palette was structured to categorize colors into universal Winter tones, further distinguishing optimal primary, secondary, and neutral shades. Each color was labeled using Braille, while the “See Color” symbols provided a tactile representation, making the palette accessible and intuitive for visually impaired users. The first prototype was printed on 180g offset paper, with raised tactile symbols created using a digital pen and EVA sheets to shape the “See Color” markings (Figure 6). The finalized tactile palette was designed to be foldable, creating a compact, portable format for practical daily use. This user-friendly adaptation ensures that Rosa can confidently refer to her palette when shopping or styling, fostering a greater sense of autonomy and control.

Fig. 6. Printed prototype of the tactile color chart.

Building on Rosa's case study, the project expanded to include generalized seasonal palettes—Winter, Spring, Summer, and Autumn—offering a versatile solution for a broader audience. These generalized palettes synthesize the overlapping colors of each season's subcategories (e.g., Cool Winter, Deep Winter, Bright Winter), providing a cohesive yet inclusive tool (Figure 7). This synthesis simplifies the system, making it accessible to visually impaired individuals who may not require highly detailed subcategories. A summary of the results for the generalized palettes is presented in Figure 8.

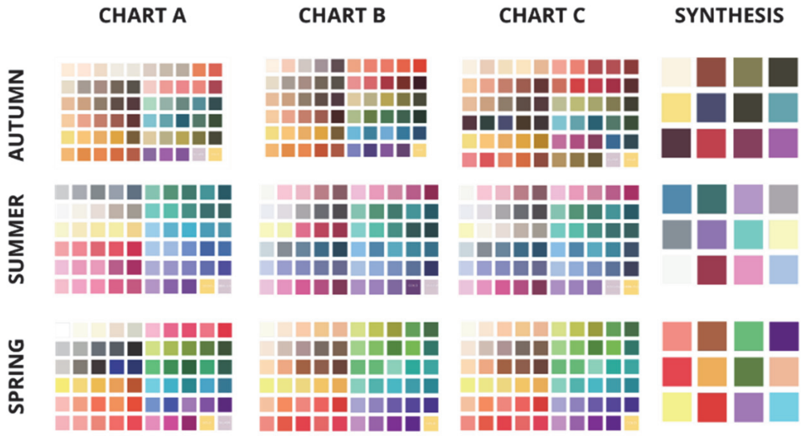


Fig. 7. Color synthesis for creating general tactile charts

Fig. 8. Expansion of tactile color palettes to other possibilities – Winter, Spring, Summer, and Autumn (in order of appearance).

4.4. *Field research: validation of the Rosa color chart in a clothing store*

A usability test was conducted in a real-world setting, specifically a clothing store, to evaluate the functionality of the personalized tactile color palette designed for visually impaired individuals. The participant, Rosa, was accompanied to the store to observe how the tool could facilitate her decision-making process in selecting garments aligned with her personal color palette.

Upon entering the store, Rosa began the process by engaging directly with a sales assistant, introducing her personalized color palette. This initial interaction established a clear communication channel between the customer and the salesperson, enabling a collaborative approach to exploring the store's inventory.

During the shopping experience, the sales assistant selected clothing items that matched the tones outlined in Rosa's color palette. Meanwhile, Rosa revisited the tactile and verbal elements of her palette to recall the colors it included. Using touch, she assessed the fabrics, textures, and silhouettes of the garments, ensuring her final choices adhered to both her color harmonies and her personal style preferences. This collaborative process emphasized the importance of integrating both color guidance and individual tastes, resulting in a more inclusive and personalized shopping experience (Figure 9).

Fig. 9. Process of using the color chart in a clothing store

The sales assistant expressed positive feedback about the tool, noting that the palette's clear and objective structure streamlined the selection process. The predefined color harmonies eliminated uncertainties, allowing for a more efficient and confident decision-making process. This interaction demonstrated that adapted tools such as the tactile color palette have the potential to transform the shopping experience, fostering greater autonomy for visually impaired customers while enhancing the efficiency of retail services.

By the end of the test, Rosa selected a blue blouse, one of the colors featured in her personalized palette. This choice underscored the tool's effectiveness in aligning her personal preferences with a strategic chromatic selection. The outcome highlighted how inclusive approaches can enhance satisfaction and build confidence in the consumer experience (Figure 10).

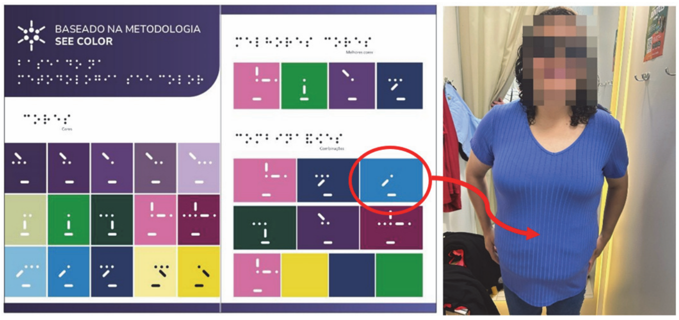


Fig. 10. Final product purchased by Rosa, aligned with her tactile color palette

5. Inclusion, personal and cultural expression in fashion: implications of the color palette in users' daily lives and inclusive fashion research

The findings highlight how fashion inclusion is enhanced through adaptive tools such as the tactile color palette based on the "See Color" method, designed for individuals with acquired visual impairments. By incorporating tactile senses into color recognition, this solution fosters essential autonomy in clothing choices, allowing users to exert greater control over their personal and aesthetic expression. As noted by Mariano (2017) and Kukiełko (2024), fashion can serve as a vector for self-esteem and social belonging, particularly by enabling individuals with disabilities to engage with traditionally visual aesthetic codes. This approach redefines the role of fashion, transforming it into a means of empowerment.

The application of the tactile color palette in users' daily lives demonstrates the ability of inclusive fashion to address specific needs, as highlighted by Brogin et al. (2024). The research participant illustrated that color selection is not solely aesthetic but also involves practical considerations, such as avoiding social discomfort and simplifying routines. In this context, the tactile approach helps translate complex color concepts into accessible sensory experiences, fostering greater autonomy for individuals. Furthermore, by expanding the understanding of the relationship between color and identity, the palette encourages conscious consumption practices, aligning with sustainable fashion trends as argued by Busch (2018).

The research also underscores the cultural significance of inclusion in fashion. As Miranda (2008) suggests, clothing serves as a tool for social communication, enabling individuals to construct and express their identities. For visually impaired individuals, access to personalized color palettes facilitates a dialogue between individual aesthetics and the cultural meanings of fashion, increasing their participation in a historically exclusionary field. This process of cultural inclusion is reinforced by the research methodology, which prioritizes the co-participation of subjects, as advocated by Moraes (2022). This approach emphasizes that inclusion must go beyond technical solutions to actively involve individuals in design processes.

Finally, the findings reveal promising pathways for future research on inclusive fashion. By addressing visual impairment as a central factor of exclusion and developing tools that reframe this experience, the research demonstrates how functionality and aesthetics can be integrated into innovative solutions. Studies like those of Almeida and Araújo (2013) and Kukiełko (2024) emphasize that the reconstruction of sensory and motor autonomy is critical for the social reintegration of individuals with disabilities, and initiatives in inclusive fashion can play a significant role in this process. The tactile color palette, by enabling multisensory interaction with fashion, emerges as a potential innovation that transcends barriers, bridging design and inclusion from a transformative perspective.

6. Final considerations

This study addresses fashion and social inclusion for individuals with visual impairments, focusing on the following research question*: how can fashion, particularly through a tactile color tool, contribute to the autonomy and inclusion of individuals with acquired visual impairments, enabling them to make more independent and expressive clothing choices?* To answer this question, the study explores data on visual impairment, identifies the specific needs of an individual with visual impairments in selecting clothing, conceptualizes inclusive fashion and social inclusion, and develops a color palette based on the tactile "See Color" language. This tool offers adaptive and innovative solutions to meet needs often overlooked by the fashion industry.

The resulting product highlights the importance of empowering visually impaired individuals to express their identity and personal style through color. By incorporating tactile stimuli into the process, this research creates a meaningful experience that enhances autonomy and self-esteem. Inclusive solutions such as the tactile color palette significantly contribute to social inclusion, enabling more active and confident participation in daily and social activities while raising awareness about the importance of accessibility in product and service design.

This study advances the field of inclusive fashion and color studies by addressing the underexplored intersection of fashion and autonomy for individuals with visual impairments and the personal color analysis service. The tactile color palette proposal based on the ""See Color"" method goes beyond traditional approaches that focus solely on physical adaptations of clothing. Instead, it introduces a sensory dimension that transforms how visually impaired individuals interact with clothing and express their identity. Unlike previous methods prioritizing ergonomic and functional adjustments, this research broadens the concept of inclusion by incorporating a practical and pedagogical tool that empowers visually impaired individuals to actively engage in selecting colors for their wardrobe.

Future research should expand the sample size to include a more diverse group of participants with varying types and degrees of visual impairment, allowing for a broader and more representative analysis of their needs and preferences. Furthermore, future studies could explore the effectiveness of different personal color systems adapted for individuals with acquired blindness, comparing them with other inclusive methodologies. Research could also investigate the perspectives of professionals in personal color analysis, fashion, and design regarding the feasibility and challenges of implementing tactile color palettes in consultancy practices.

Ultimately, inclusive fashion becomes viable through understanding individual needs and creating tools that promote autonomy and self-esteem. The adaptation of the "See Color" tactile language exemplifies how accessible design can transform the daily lives of visually impaired individuals, contributing to a more inclusive and equitable world.

7. Conflict of interest declaration

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

8. Funding source declaration

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Licensing terms

References

Almeida, T. S. and Araujo, F. V. (2013) 'Diferenças experienciais entre pessoas com cegueira congênita e adquirida: uma breve apreciação' [Experiential differences between individuals with congenital and acquired blindness: a brief overview], Revista Interfaces: Saúde, Humanas e Tecnologia, 1(2).

Alsabhi, R. (2025) 'Tactile and Sensory Fashion Garments for the Visually Impaired—Challenges and Opportunities', *International Journal of Fashion Design, Technology and Education*, pp. 1–9.

Auler, D. and Sanches, G. (2023) *9º Concurso Moda Inclusiva* [9th Inclusive Fashion Contest]. São Paulo: Editora SENAC São Paulo.

Barnard, M. (2013) '*Fashion as Communication'*. Routledge.

Bianchi, C., Ramos, K. and Barbosa-Lima, M. D. C. (2016) 'Conhecer as cores sem nunca tê-las visto' [Knowing colors without ever having seen them], Ensaio Pesquisa em Educação em Ciências, 18(1), pp. 147–164.

Bononi, J., Domiciano, C. L. C. and Menezes, M. D. S. (2016) 'A criança com deficiência visual: a contribuição do vestuário e do Design de Superfície na percepção tátil infantil' [The visually impaired child: the contribution of clothing and surface design to tactile perception], DAPesquisa, 11(16), pp. 212–227.

Brogin, B. (2019) *Método de Design para cocriação de moda funcional para pessoas com deficiência* [Design method for co-creation of functional fashion for people with disabilities]. Curitiba.

Brogin, B., Marchi, S. R. and Schemes, C. (2024) 'Consumo de moda com cores acessíveis para pessoas com deficiência visual' [Fashion consumption with accessible colors for visually impaired individuals], Projetica, 15(1), pp. 1–29.

Busch, O. (2018) 'Inclusive fashion—an oxymoron—or a possibility for sustainable fashion?', *Fashion Practice*, 10(3), pp. 311–327.

Cervo, A. L. and Bervian, P. A. (1983) *Metodologia Científica* [Scientific Methodology]. 3rd edn. São Paulo: McGraw-Hill do Brasil.

Collignon, O., G. Dormal, G. Albouy, G. Vandewalle, P. Voss, C. Phillips, and F. Lepore. (2013) 'Impact of Blindness Onset on the Functional Organization and the Connectivity of the Occipital Cortex', *Brain,* 136 (9), pp. 2769–83.

Crane, D. (2006) *A moda e seu papel social: classe, gênero e identidade das roupas* [Fashion and its social role: class, gender, and identity of clothing]. São Paulo: Editora Senac São Paulo.

Geertz, C. (1989) *A Interpretação das Culturas* [The Interpretation of Cultures]. Rio de Janeiro: Guanabara.

Joo, B., and Jungok W. (2021) 'The Impact of Inclusive Fashion Advertising with Plus-Size Models on Female Consumers: The Mediating Role of Brand Warmth', *Journal of Global Fashion Marketing*, 12 (3), pp. 260–73.

Kim, J. S., B. Aheimer, V. Montané Manrara, and M. Bedny. (2021) 'Shared Understanding of Color among Sighted and Blind Adults', *Proceedings of the National Academy of Sciences*, 118 (33), pp. e2020192118.

Krone, S. M. F., Oliveira, A. H. P., and Rizzi, S. (2020) 'Desenvolvimento de vestuário para crianças com deficiência visual: uma abordagem inclusiva' [Clothing development for visually impaired children: an inclusive approach], Projetica, 11(1supl), pp. 246–275.

Kukiełko, K. (2024) 'Adaptive Fashion. Clothing as a Tool for the Inclusion of People with Disabilities', *Podstawy Edukacji,* 17, pp. 119–28.

Lipovetsky, G. (2009) *O Império do Efêmero: A moda e seus destinos nas sociedades modernas* [The Empire of the Ephemeral: Fashion and its fates in modern societies]. São Paulo: Companhia de Bolso.

Machado, I. (2017) *O olhar expandido e a moda* [The expanded gaze and fashion]. São Paulo: Estação das Letras.

Marchi, S. R. (2019) 'Design universal de código de cores tátil: contribuição de acessibilidade para pessoas com deficiência visual' [Universal design for tactile color coding: accessibility contributions for visually impaired people]. Doctoral Thesis. Universidade Federal do Paraná, Curitiba.

Marchi, S. R., Brogin, B., and Okimoto, M. L. L. R. (2022) '"See Color": Desenvolvimento de uma linguagem tátil das cores para pessoas com deficiência visual' ["See Color": Development of a tactile color language for visually impaired individuals], Estudos em Design, 30(1).

Mariano, R. (2017) *A moda como agente de inclusão social para a pessoa com deficiência visual* [Fashion as a social inclusion agent for visually impaired individuals]. São Paulo: Estação das Letras.

Marks, L. (2021) 'Self-Confidence an Executive Presence an Image Consulting Process', *Cuadernos del Centro de Estudios en Diseño y Comunicación. Ensayos*, (97), pp. 29–44.

Medeiros, N. N. (2022) 'A influência da coloração pessoal na autoestima e autoimagem' [The influence of personal coloring on self-esteem and self-image]. Undergraduate Thesis. Universidade do Extremo Sul Catarinense, Criciúma.

Miranda, A. P. (2008) *Consumo de moda: a relação objeto-pessoa* [Fashion consumption: the object-person relationship]. São Paulo: Estação das Letras e Cores.

Moraes, M. (2022) ‘PesquisarCOM: permanências e reparações’ [PesquisarCOM: continuities and reparations], in Silveira, M., Moraes, M., and Quadros, L. C. de T. (eds.) *Pesquisar.COM: caminhos férteis para a pesquisa em psicologia* [Pesquisar.COM: fertile paths for psychology research]. Rio de Janeiro: FAPERJ/Nau Editora.

Oliveira, D. V. et al. (2015) ‘Aspectos inclusivos da moda com foco nas pessoas com deficiência visual’ [Inclusive aspects of fashion focused on visually impaired people], *ModaPalavra e-periódico*, pp. 115–139.

Pereira, A. and Cruz, M. A. X. (2016) 'Moda inclusiva: a necessidade da moda inclusiva no mundo hoje' [Inclusive fashion: the need for inclusive fashion in today’s world], *Revista Tecnológica da Fatec Americana*, 4(1), p. 26.

Piacentini, M., and Greig M. (2004) ‘Symbolic Consumption in Teenagers' Clothing Choices’, *Journal of Consumer Behaviour: An International Research Review*, 3 (3), pp. 251–62.

Prodanov, C. C. and Freitas, E. (2009) *Metodologia do Trabalho Científico* [Scientific Work Methodology]. Novo Hamburgo: Editora Feevale.

Silveira, D. L. D. and Soratto, R. B. (2022) 'Consultoria de moda: um estudo de caso sobre autoconhecimento e autoestima' [Fashion consultancy: a case study on self-knowledge and self-esteem]. Undergraduate Thesis. Instituto Federal de Santa Catarina, Ararangua.

Tomasello, R., M. Carriere, and F. Pulvermüller. (2024) ‘The Impact of Early and Late Blindness on Language and Verbal Working Memory: A Brain-Constrained Neural Model’, *Neuropsychologia,* 196, pp. 108816.

Ulrich, L. (2021) 'O impacto das cores na imagem pessoal e profissional' [The impact of colors on personal and professional image], *Cuadernos del Centro de Estudios en Diseño y Comunicación. Ensayos*, (97), pp. 55–64.

Wellington, C. A., and J. R. Bryson. (2001) ‘At Face Value? Image Consultancy, Emotional Labour and Professional Work’, *Sociology,* 35 (4), pp. 933–46.

Wong, V. C. (1991) ‘Cortical Blindness in Children: A Study of Etiology and Prognosis’, *Pediatric Neurology,* 7 (3, pp. 178–85.

Predicting the Light Stability of Contemporary Photographic Print Materials

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ABSTRACT

The light stability of six contemporary photographic print materials was investigated. Two silver halide, one dye sublimation transfer, one liquid toner electrophotographic, one dye based and one pigment based inkjet material on nanoporous RC paper were exposed by a set of narrow band LED covering the visible spectrum. In the accelerated ageing chamber, the samples are exposed at ambient environmental conditions. The colorants in the prints exhibit different fading properties, but all colorants are most sensitive in the wavelength range 400 to 550 nm. Pigment based systems are considerably more stable than dye based systems. The absorbance losses of the colorants per unit of exposure (1 kJ/ cm^2) represent the sensitivity of the colorants to the specific wavelength of light.The sensitivities at different wavelengths are used to predict fading of a white light LED. The method assumes that the changes of narrow band wavelength exposures are additive and that a white light exposure can be simulated by adding photon-energy corrected intensities of narrow wavelength light. Significant fading of at least one colorant is observed for all investigated print materials at 70 kJ/cm^2 exposure.The method predicts absorbance changes of the colorants well for most of the investigated print materials except for silver halide photographic prints. In silver halide prints, fading at longer wavelength is not independent of the presence of light around 400 nm and absorbance losses are not additive. The fading of the colorants depend also on the destruction of sacrificial UV absorbers which are present in the top layer. It is important to clearly identify a material as predictions are only valid for a specific colorant on a particular base material. The method can proabably be extended to other types of print materials, particularly fragile materials, but may not be suitable for complex image structures such as paintings. The conclusions from of the LED exposures can help to select the least destructive lighting for prints on display.

KEYWORDS (light stability testing, contemporary photographic print materials)

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1. Introduction

Colour photographic prints are among the more delicate objects in museum collections and require particular care when on display (Beltran et al.2021). If display lighting is kept low, it reduces the visual impact intended by the artist. Prolonged exposure to light will degrade the colours. Particularly for LED lighting, the choice of acceptable light levels, duration of display and best relative spectral irradiance (RSI) are of concern. Some institutions try to balance the visual impact and the degradation by adapting the lighting individually to certain objects (Kore and Durmus, 2024). Others optimize the RSI to reduce degradation (Lunz et al., 2017) for particular objects. There have been approaches to predict photodegradation for classes of materials by looking at the energy of the exposure light (Luo et al., 2018) as the only cause for fading. Yoo at al.(2023) find that different materials have different fading characteristics that have to be taken into consideration. Photodegradation of print colorants is a photoactivated chemical reaction that depends on the excitation energy, but also on the presence of oxygen and other environmental gases (Zhao et al., 2021). The individual properties of the colorants, their particular excitation states and photodegradation pathways are important. As Groenevelt et al (2023) remarks "Additionally, it was found that oxygen is required in the photodegradation of these specific dyes with VIS light, but not with UV radiation, again indicating that the photofading mechanism can be different depending on the irradiation wavelength". Many researchers find that light with shorter wavelength is more destructive than light with longer wavelength (Saunders and Kirby, 1994). A general recommendation is that for accelerated ageing, the exposure light source RSI should closely match the display light in the final application. There is a wealth of accelerated ageing test data of photographic print materials with different light sources, such as fluorescent and Xenon light for silver halide materials (Wilhelm and Bower, 1993) or inkjet prints (Wilhelm, 2004), fluorescent light for face mounted inkjet prints (Blaschke-Walther and Dobrusskin, 2015), and UV radiation for UV curing inkjet materials (Maretić et al. 2021). There are few studies with white light LED exposure (Ishizuka et al., 2019a). As there are many different types of LED lighting currently available, many fading experiments with different LED would need to be done to represent the many different RSI of commercial LED.

The following study investigates the light stability of contemporary photographic prints in different spectral regions. Based on the measurement of the sensitivity of colorants to different wavelength of light, it is possible to predict fading for different types of white light exposure, allowing to select light sources that lead to slower fading of colorants. The study also allows to rank the light stability of typical contemporary photographic print materials, in particular when exposed to LED light.

2. Materials and Method

The method was previously described by Hofmann and Hofmann-Sievert (2022 and 2024.).

2.1. *Experimental set-up*

The exposures were done in an accelerated ageing chamber with 18 narrow band LED and 6 white LED.

A diagram of the experimental set up and an enlargement of the optical path for one LED are given in Fig 1 and b.

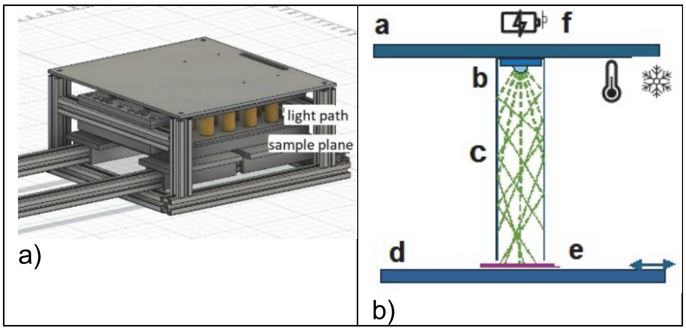


Fig. 1) a) view on exposure chamber b) illumination spot of single LED: (a) cooled optics mounting plate (b) LED on support, with lens, (c) hollow light guide with liner, (d) sample support (sliding) (e) flat sample, (f) regulated power supply

The chamber is kept in an air conditioned room. The light guides for the LED lamps in Fig 1b) are designed to homogenously illuminate the area of the test patch shown in Fig 3 a. Each patch is illuminated by a different LED. Two LED each had the same centre wavelength. All narrow band LED had a typical width at half maximum of 30 nm. The narrow band LED spun a wavelength range of 380 nm to 620 nm. Fig. 2 shows their emission characteristics and the white light LED 4000 K emission as a comparison. The RSI of the LED was measured by an Ocean Optics 2000® spectrometer with UV-VIS radiation guide fibre. A thin polyester foil protected the prints against pollutants. Some of the photographic materials have open porous surfaces that absorb environmental pollutants, particularly ozone, which degrades colorants fast (Reber and Hofmann, 2005).The total irradiance of each LED was measured offline at the sample plane and through the protective foil with a Gentec XLP12–3S–H2–INT-D0® power meter. The narrow band LED had irradiances in the range of 15 to 40 mW/cm^2. Four different white LED were used in the chamber. The LED with a correlated colour temperature (CCT) of 5000 K had an irradiance of 77 $mW/cm^{2.}$, the others had irradiances between 19 and 26 mW/cm^2.

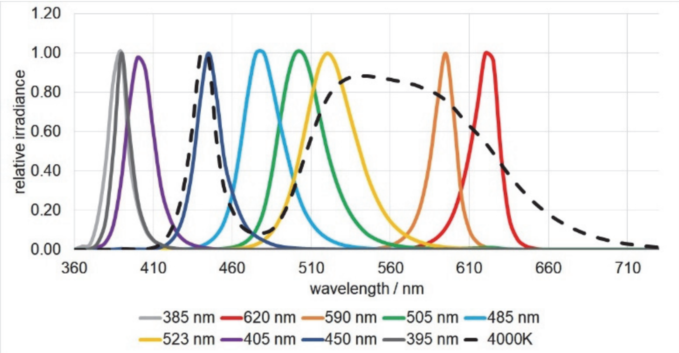


Fig. 2) Emission wavelength of the narrow band LED and of the white LED 4000 K.

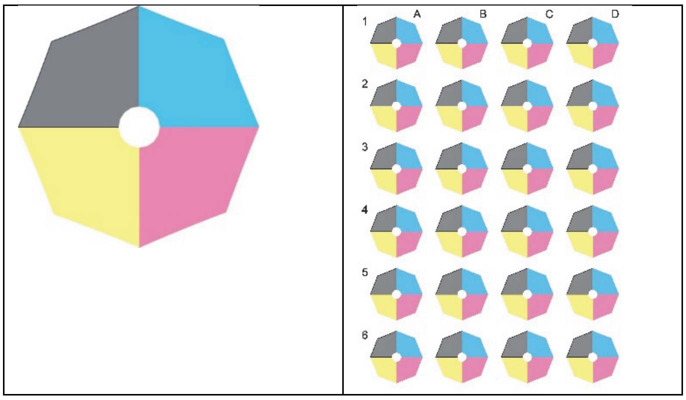


Fig. 3. a) Individual print patch b) test samples with 24 patterns to accommodate the 24 LED exposure spots of the accelerated ageing chamber.

The exposure chamber was held at 24 °C ± 2 °C by water cooling. The relative humidity range was 38% to 52%. These conditions are close to typical environmental conditions in homes (Bugner et al, 2006) and in agreement with (ISO 18937, 2023).

2.2. *Materials*

Six different contemporary photographic print materials were investigated: two inkjet (IJ) materials, a dye-based IJ print (IJD)(Epson ET2650® printer on HP Everyday Photo Paper®) and a fine art pigment print on lustre RC paper (IJFA), two chromogenic photo papers (Photo A and Photo B) on glossy RC paper, a dye sublimation transfer print (D2T2) and a liquid toner electrophotographic pigment print (EP) on glossy 200 g/m^2 paper. The samples were provided without further detail by participants of an ISO TC42, WG5 committee's Interlaboratory Test to validate a new version of a standard. They are current commercially available products.

2.3. *Test pattern and homogeneity*

The test sample consisted of paterns with a medium Y,M,C and greywedge shaped patch as shown in Fig 3a. The maximum absorbance of the main colorant before exposure (Amax 0) was about 0.7, the value of a medium light colour as recommended by (ISO 18950, 2021). A white patch in the center was measured in addition. The test pattern was repeated in 6 rows (1-6) and 4 columns (A-D) on the sample page as shown in Fig. 3 b . Each of the 24 patterns was exposed by a different LED.

For some materials, the print patches of yellow, magenta, cyan, and grey were made by pure colorants, for others they consisted of one predominant colorant with smaller amounts of the other colorants. For silver halide prints, grey is a mixture of the three dyes in the layers. Although the dye based ink set for IJD had a black dye, the grey print patch was a mixture of Y,M,C only (see Fig. 4 c). In the case of the IJFA and the D2T2 print, black/grey was a mix of all four colorants. A typical example of the enlarged print patterns of two magenta patches and one grey are shown in Fig. 4 a-c.

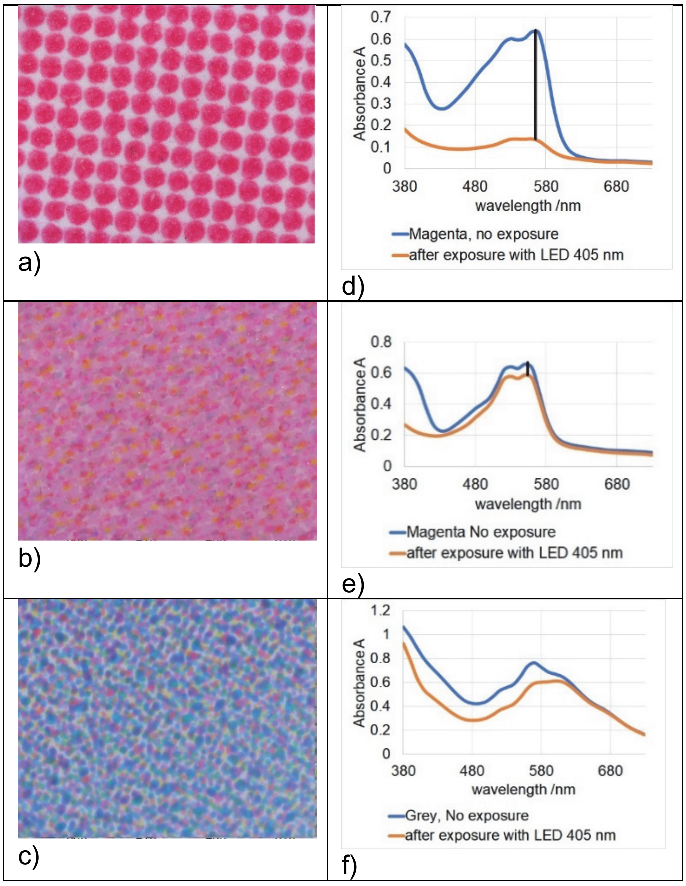


Fig. 4. a) - c) enlargements of an original printed patch with 0.4 mm spot a) EP magenta b) IJFA magenta, c) IJD grey- d)-f) corresponding absorbance spectra before and after exposure d) EP 60 kJ/cm^2 exposure e)IJFA 70 kJ/cm^2 exposure f) IJD 35 kJ/cm^2 exposure. The black line indicates where ΔA_{max} is measured.

The patches were measured in reflectance with a Gretag Macbeth iPro spectral densitometer, which has a fixed filter condition of 'no UV' M2 according to ISO 2009. The measurement range of the reflectance spectrum is 380 nm to 700 nm and the optical measurement geometry is 0°/45°

on a 4.5 mm aperture. A white Melinex® backing was used. To estimate the homogeneity of the test patterns the reflectance spectra were converted into colour coordinates (D50, 2°) The calibration of the iPro is done on a certified, Gretag Macbeth proprietary and instrument specific white tile in absolute white on all 36 wavelengths. Short term reproducibility for this instrument is given by the manufacturer as 0.1ΔE* (D50, 2°) and inter instrument error as 1.0 ΔE* (max), both in CIE 1994 colour space. Colour differences on the test samples were calculated in CIE 1976 space according to recommendations from Ishizuka et al.(2019b).

Before the first exposure, the CIELAB values of the Y,M,C,B wedge patches of 24 colour patterns were averaged respectively. The deviations from the average of the individual colour patches were between 0.2 and 1.2 colour difference in the CIE 1976 (ΔE*) colour space. These variations are small enough to not have a major effect on the fading curves. Colour coordinates were only used to determine the homogeneity of the unexposed print patches.

As colour coordinates do not discriminate between the different dyes present in certain print patches (Fig 4 b and c), they could not be used for the evaluation of colorant fading. The change of the maximum absorbance of the colorant, ΔA_{max} , as shown for magenta in Fig 4 d and e, is used as the y-value of the fading curve. The yellow dye present in the magenta print patch Fig 4 b has no absorbance at the wavelength of 560 nm such that changes at this wavelength are only due to magenta dye reactions.

If the spectra of the pure colorants are known, the analytical spectral densities of dyes in a mixture can be calculated (Kowaliski, 1977) for any mixture, for example for a grey shown in Fig 4 c. However, in our study we focused on colour patches with one predominant colorant and a maximum of 20% of other colorants present. The grey colour patches were not used for the prediction of white LED fading.

2.4. *Test procedure*

All test patches on a sample were measured before exposure, positioned in the light exposure chamber and exposed at subsequent intervals of time. After each exposure interval, the sample was pulled out, measured and repositioned for the next exposure cycle. The intervals were selected according to the light stability of the sample. The test was continued until a significant change in A_{max} on all colorants could be observed for at least one narrow band wavelength exposure. Typical experiments took 2 to 6 weeks for any one material.

We define ΔA_{max} as the absorbance after exposure with x kJ/cm² ($A_{max\,x}$) minus the absorbance before exposure ($A_{max\,0}$). ΔA_{max} was plotted for each colorant and for each narrow band exposure source against the total exposure to derive the fading curves for each wavelength. Two typical fading curves of the exposure of D2T2 with 385 nm radiation are shown in Fig. 5. At a very small exposure, the signal stays below the noise level of the experiment. With further exposure, the absorbance loss becomes linear. The negative slope of this linear part is the sensitivity to the exposure wavelength (Sensi). Further exposure leads asymptotically into bleaching towards the white paper background.

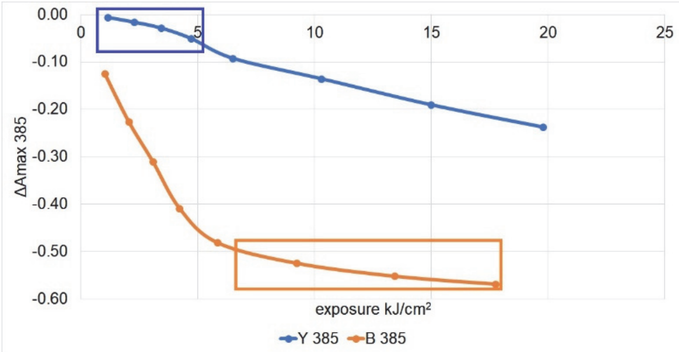


Fig. 5: Fading curves of D2T2 Y and B colorants at 385 nm. The blue rectangle shows measurement noise level, the orange rectangle shows bleaching to white.

The plot of Sensi as a function of exposure wavelength is referred to as the action spectrum.

3. Results

3.1. *Action spectra*

Action spectra and absorbance spectra are related. The first prerequisite for a photochemical reaction to occur is the absorption of light. Most of the absorbed energy is dissipated as heat and only some will lead to chemical reactions (Groeneveld et al., 2023). The action spectrum represents the part of the absorbed light that leads to a reaction, in our case changes in A_{max}. The action spectra and the absorption spectra of different colorants are plotted in Fig. 6 a-d.

While for the yellow colorant, light absorbed over the whole absorption range leads to changes in A_{max}, for the magenta colorant, the maximum of the A_{max} changes is shifted to the lower wavelength of the absorption range. Weyermann et al (2006) find that all colorants are most sensitive at their maximum absorption, others report that certain colorants only react when exposed to light in the blue green wavelength range.

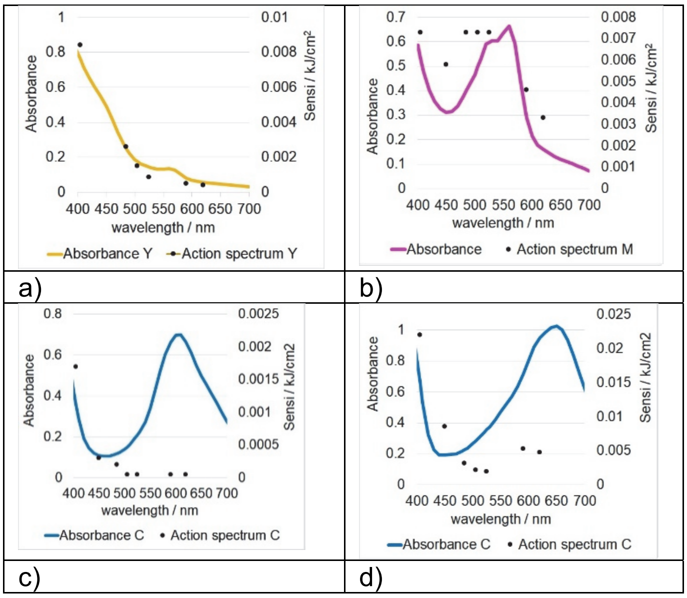


Fig. 6 a-d. Absorbance spectra (solid lines) and action spectra (black points) of a) Y IJD b) M IJD c)C IJD d) C Photo B.

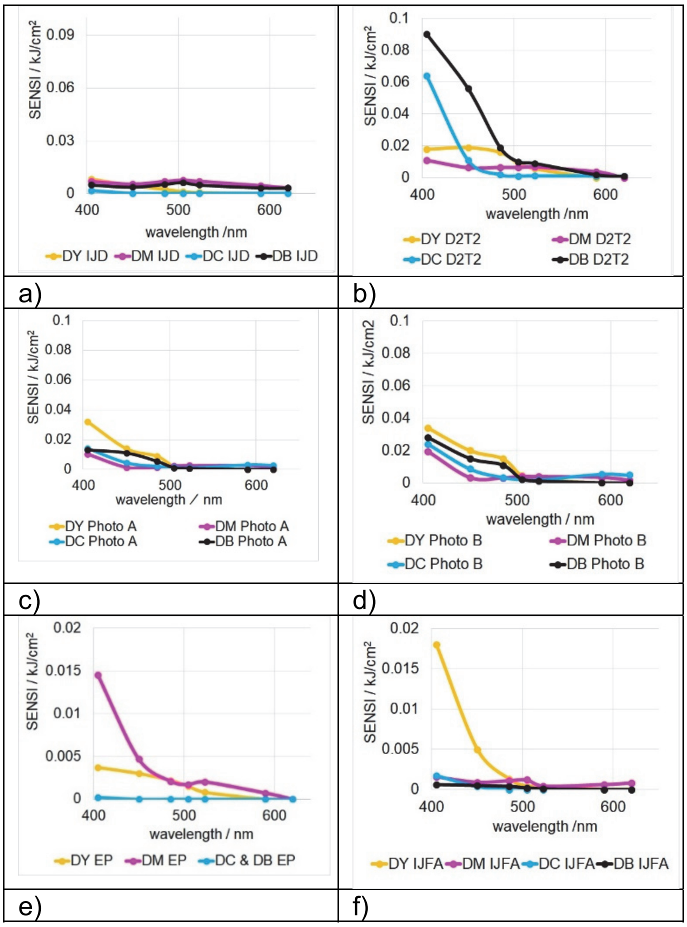


Fig. 7 a-f. Action spectra of the colorants of photographic print materials, a) IJD b) D2T2 c) Photo A d)Photo B.e) EP f) IJFA.

For the particular IJD cyan colorant shown in Fig. 6 c, degradation reactions are caused solely by exposure of light below 450 nm which is typical for phthalocyanines (Lerwill et al., 2015; Hattori et al., 2012). The behaviour depends on the chemical structure of the colorant. The Photo B cyan in Fig. 6 d also reacts partially to light in the range 550 to 600 nm and probably belongs to a different class of dyes.

The action spectra for the Y, M, C and Grey patch (DY,DM,DC,DB) of all investigated print materials are plotted in Fig. 7 a-f. D2T2 is the least light stable print material due to cyan and grey that are quite sensitive to the short visible wavelength range between 400 and 500 nm. Silver halide (Photo A and Photo B) and IJD prints have rather similar fading properties. The colorants fade at comparable rates, thus lightening the print.

The y-axis scale of the action spectra of the pigment prints in Fig. 7 e and f is one fifth of the scale in Fig. 7 a-d, which means the fading is about five times smaller. The fading of the pigment prints is not very balanced, though. The IJFA sample loses the yellow colorant and the EP loses the magenta colorant, while the other colorants are very stable, leading to a visible colour shift. In many of the materials tested, most of the degradation is caused by light in the wavelength range 400 to 520 nm, even if the maximum of the absorbance of a colorant is higher than 520 nm.

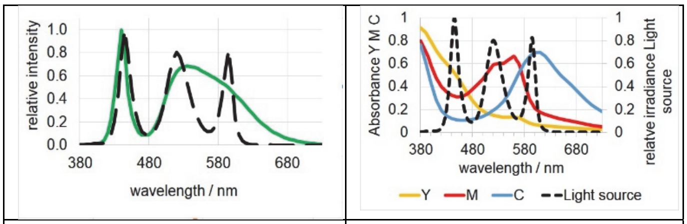
3.2. *Prediction of fading under white light exposure*

The goal of this study was to develop a tool which can predict fading for a white light LED exposure. Two steps are needed to make a prediction based on the action spectra. In a first step, the amount of narrow band exposure which can simulate the white light has to be determined. In a second step, ΔA_{max} has to be derived from the action spectra of the colorants for a virtual exposure to the white light source.

3.2.1. *Simulation of white light exposure*

With the narrow band LED emission spectra as factors and the white light LED spectrum as target, a (Generalized Reduced Gradient (GRG) nonlinear fit was done.The results for the LED 5000 K are shown in Fig. 8 a.

With a limited number of narrow band LEDs it is not possible to exactly match the white light LED spectrum. For the purpose of colour reproduction, such a match would be unacceptable. However, the exact relative irradiance of the exposure light is less important for degradation reactions as long as the light causes the same electronic excitation of the colorant as the reference light (Feller, 1994) and (Groenevelt et al., 2023).



a) b)

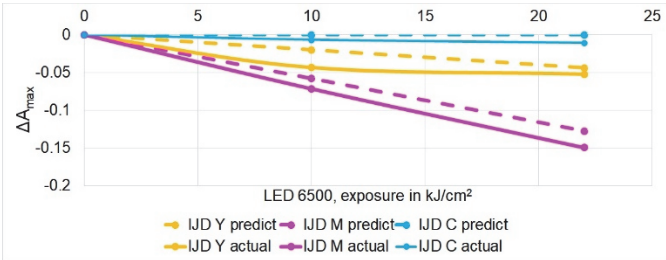
Fig. 8 a) spectrally matched curve (dashed line) compared to the RSI of the actual LED 5000 K (green solid line), b) spectrally matched curve (dashed line) and absorbance of the IJD Y,M,C colorants (solid lines).

Imaging colorants have broad absorption spectra (Aceto et al, 2014) and the narrow band LED do essentially excite one of the absorption bands of the three colorants as shown in Fig. 8 b. It is known from laser fluorescence spectroscopy (Zaffino et al., 2017) that the exposure light does not have to illuminate the whole absorption range, or even the maximum absorbance, to excite colorants.

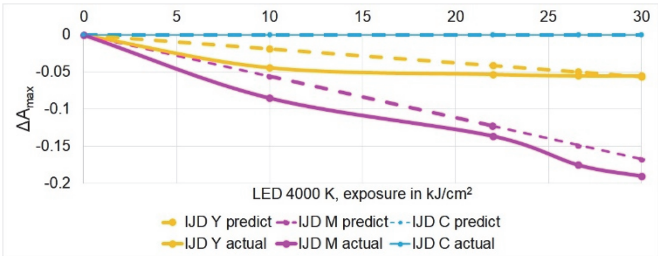
Apart from the appropriate wavelengths, the GRG fit provides a factor for each narrow band LED which represents how much that LED contributes to the white light spectrum. In the case of the LED 5000 K shown, the factors are 0.01 at 405 nm, 1.0 at 450 nm, 0.8 at 523 nm and 0.81 at 590 nm. As the intention is to match electronic excitation by the white light and not colour, the factors are weighted by the photon energy (Yoo et al., 2023). To predict absorbance changes, they need to be multiplied by the value of the action spectrum and by the overall total exposure at which the comparison is done.

3.2.2. *Prediction of absorbance changes for three LED*

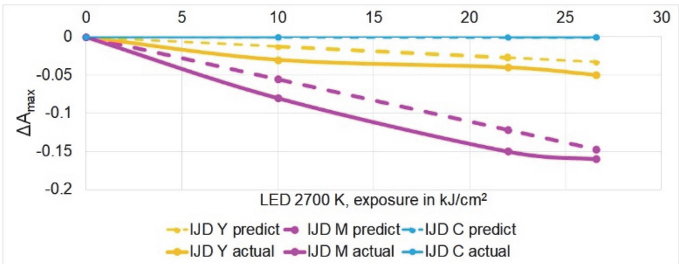
To predict the overall ΔA_{max} change of a white light total exposure of x kJ/cm^2, one needs to calculate the corresponding $\Delta A_{max\ ,\ nm}$ loss for each of the narrow band LED. The weighted factors from 3.2.1 are multiplied with the value of the action spectrum at the particular wavelength, $\Delta A_{max,nm.}$ One unit of the action spectrum is equivalent to the loss of A_{max} at 1 kJ/cm^2 exposure at that exposure wavelength. For a total exposure of 50 kJ/cm^2, for example, one needs to multipliy the value of the action spectrum by 50. This calculation is repeated for each of the narrow band LED and the $\Delta A_{max,nm}$ losses for each excitation wavelength are added to the total change of ΔA_{max} for each exposure. Fig. 9 shows the results of the predicted losses for one material, IJD, compared to the actual losses (ΔA_{max}) measured in the exposure unit for the three white LED (5000 K, 4000 K, 2700 K). Experimental errors can be estimated from the exposures made with the two LED of the same RSI. Those errors were about ±0.02 for all colours. The action spectrum method predicts qualitatively and quantitatively the fading of all three colorants for the three LED with different RSI. As can be seen in Fig. 9 a-c , the predictions agree quite well with the actual fading.



a)



b)



c)

Fig. 9. Predicted (dashed line) vs. actual (solid line) fading of IJD colorants under white light exposure a) LED 6500 K, b) LED 4000 K c) LED 2700 K

The case of an LED with CCT 5000 K was selected for the prediction of fading of the different photographic materials of this study. Bright LED 5000 K are often found in offices and in general lighting but also sometimes in museum lighting (Feltrin et al, 2019).

For most of the print materials shown in Fig. 10 a-d, the prediction of fading based on action spectra works well for all colorants. For the pigment material IJFA, the tested white light exposure was too small for a reliable comparison. For the silver halide print Photo A the predictions are acceptable for yellow and magenta but not for cyan.

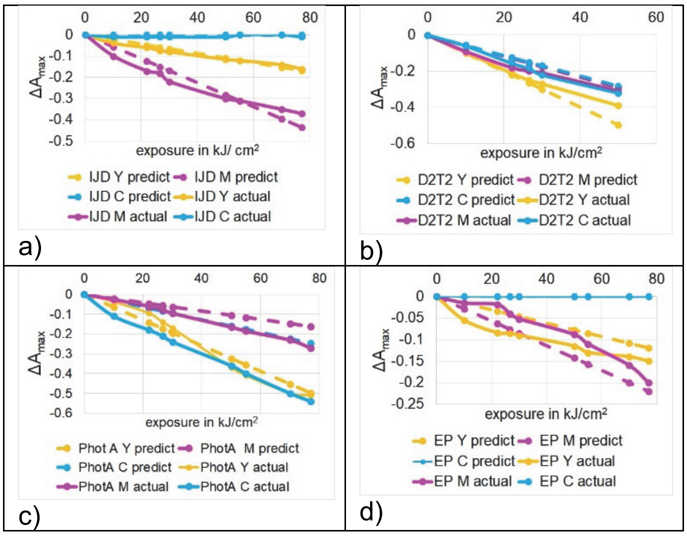


Fig.10. Predicted (dashed line) vs. actual (solid line) fading of print materials for LED 5000 K exposure a) IJD, b) D2T2, c) Photo A, d) EP.

4. Discussion of Results

Many silver halide colour materials have a UV protective layer (Marchesi, 2005; Pénichon, 2013; Rogers, 2007), which is slowly degraded by short wavelength light (García et al, 2010). When the cyan colorant is exposed with the narrow band LED at 620 nm, there is no degradation of the UV protection and the actual density loss is underestimated compared to a white light exposure where red light and short wavelength light are present and the UV protection is degraded.

The example of the silver halide prints points to one of the limits of stability prediction. The method assumes additivity of narrow band fading over a specific exposure range. Decomposing protective colourless additives, strong interactions with other colorants or strong interference with the layer matrix are non-additive factors that hamper prediction. Furthermore, the predictions are only valid if the light degradation is the only factor of destruction of the imaging colorant. In some locations other reactants could attack the colorants in the dark, for example the pollutants that Thickett and Grøntoft (2023) have found in the museum environment.

The prediction can only be made for a specific colorant of a print and only applies to this specific material. It is thus important to unambiguously identify photographic print techniques (Cattaneo et al., 2022; Eom and Lee, 2023) and even colorant types of prints (Silva, 2022) to use it.

The method is particularly suited to print materials with thin layers and a limited number of colorants. The method will probably not be applicable to very complex image structures such as paintings (Dal Fovo et al, 2024). On the other hand, it is suited to very fragile and heat sensitive materials as the exposure takes place at ambient conditions.

Apart from testing a method to predict fading, another aim of this study was to provide quantitative data for the fading of contemporary photographic print materials when exposed to LED light. There are very few published data for fading of photographic prints under LED light as there is no commercial equipment for such tests. One study (Ishizuka et al., 2019a) looks at certain of the materials investigated here with a LED 5000 K and LED 4000 K accelerated light fading chamber. Unfortunately, the authors average the results over all types of materials as their aim is to compare the two light sources. The same set of photographic print materials as in our study was investigated by Duan (Duan, 2024) with a microfadometer (MF). The MF with a Xenon light source was set up to only expose to very small, nearly invisible colour changes, a range of exposure which cannot be reliably tested in our equipment. The ranking of colorant stability in the MF experiment did not agree with long-term Xenon exposures and with the stability ranking of this study. In a paper of Luo et al (Luo et al 2018) inkjet and photographic samples were exposed, but it is not specified if the inkjet sample was a pigment or a dye based print. In addition, the exposure was stopped at about 1.5 Mluxh, about a 5th of the smallest exposure step used in our study, which does not allow a comparison. Eric Luden (Luden, 2018) presents ranges of stability for contemporary photographic materials that are mainly based on Wilhelm Imaging Research studies (Wilhelm, 2025). The Wilhelm data are based on a variety of tested paper and ink combinations of a particular photographic print class, exposed with fluorescent light. The author specifies light stability in years of expected display life before clearly visible fading occurs. Clearly visible fading in this context corresponds to about an average colour difference of 7 in the CIE 1976 (ΔE*) colour space (Ishizuka, 2019b). The average colour difference is the sum of the colour differences of the Y,M,C,B colour patch before and after the expsoure, devided by the number of colours. The display condition of Wilhelm (Wilhelm, 2025) is specified as 450 lux for 12h/day. The LED 5000 data of this study were converted to these conditions and are shown below in comparison to the data from Luden and Wilhelm (Luden, 2018).The condition 'no UV' was selected, as the LED 5000 K has no UV emission.

The ranking of stability derived from the two different test methods correlates quite well, bearing in mind that the same class of materials was tested but not exactly the same material types, and that the two light sources have a different RSI.

Tabel 1 Comparison of LED 5000 K fading data with published fluorescent light fading data, units are years until visible degradation occurs.

Material	This study	Wilhelm data /no UV
IJD	13-16	0.3-82
D2T2	11-12	0.3-82
IJFA	137-142	>200
EP	62-66	29-54
Photo	23-25	20-60

The comparison also suggests that a reasonable ranking can be done by accelerated ageing of only a few critical colours. The current study works with only one lightness level per primary colour channel, where as the Wilhelm test target consists of 135 colour patches distributed over the whole colour space. The restriction to very few test patches helps in testing historic photographic materials. As it is not possible to reprint test targets on historic materials that are no longer commercially available, existing and rare expendable printed samples have to be used for testing. The ISO 18950 standard (ISO, 2021) describes how to sample a very limited number of test patches on historic expendable print samples. This study suggest that for a rough ranking of stability, even fewer test patches could be useful.

Though action spectra Fig 7 a-f have been determined by LED exposure, the sensitivity to the particular wavelengths of light are valid for all light sources and some general conclusions can be drawn for museum lighting. Conservators limit the illuminance levels of lighting for prints on display depending on the print light stability. This approach worked well as long as incandescent halogen and indoor daylight were the predominant light sources. New types of light sources, such as LED, have widely varying spectral irradiance. Luminance in combination with spectral irradiance should be taken into account to select the most benign display lighting. We can conclude from the action spectra that most photographic colorants exhibit much stronger fading in the wavelength range from 400-450 nm than at higher wavelengths. To improve display print life, blue light should be kept to the absolute minimum needed for acceptable colour reproduction. For daylight and halogen light sources, the use of cut-on filters with wavelegths of 420 nm is general practice in museum display. Using even longer cut-on wavelengths such as 430 to 440 nm would protect prints even more. An interesting case is the dye sublimation print, D2T2 of this study. According to it's action spectrum in Fig. 7 b, when exposed with white light in the range from 400-600 nm, for example daylight, the cyan colorant will fade rather fast, as the cyan is very sensitive in the wavelength range 400-450 nm. This would lead to a strong red cast. However, as there is no light below 450 nm in most white LED, the D2T2 cyan stability much improved when displayed under LED lighting. This shows that for certain materials appropriate display light sources can be found that reduce degradation.

Many LED lamps have an excitation wavelength with a maximum at 450 nm, a part of which is converted to longer wavelengths by phosphors. For museum display, LED with a very high conversion to green and red light (warm LED light) should be used. Additional filtering as for daylight sources should be envisaged. The use of high luminosity blue LED is very detrimental to print stability and should be avoided. Particular care should be taken for all dye based photographic prints as they are considerably more light sensitive than pigment based systems.

5. Conflict of interest declaration

The authors declare no conflict of interest..

6. Funding source declaration

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Manfred Hofmann - • Dr. Manfred Hofmann has worked for the Swiss chemical society Ciba as analytical chemist, later directed a laser laboratory to investigate light based materials processing. After a novel laser marking project, he developed photopolymer materials and process parameters for 3D Printing, As the business shifted he cofounded a separate company, which later became a part of 3D Systems Inc.

Licensing terms

References

Aceto, M., Agostino A., Fenoglio, G., Idone, A.,Gulmini, M., Picollo, M, Ricciardie P. and Delaney , J.K, (2014) 'Characterisation of colourants on illuminated manuscripts by portable fibre optic UV-visible-NIR reflectance spectrophotometry' *Analytical methods*, DOI: 10.1039/c3ay41904e

Beltran, V.L.; Pesme, C.; Freeman, S.K. and Benson, M. (2021) *Microfading Tester: Light Sensitivity Assessment and Role in Lighting Policy Guidelines;* Getty Conservation Institute: Los Angeles, CA, USA, Available online: https://www.getty.edu/conservation/publications_resources/pdf_publications/pdf/Microfading_Tester.pdf (accessed on 30 April 2023).

Blaschke-Walther and K., Dobrusskin, S., (2015)' Unmounted Versus Face-Mounted Inkjet Prints' *Journal of Paper Conservation* ,16 (1), pp 9-17.

Bugner, D., LaBarca, J., Phillips, J. and Kaltenbach, T. (2006), 'A Survey of Environmental Conditions Relative to the Storage and Display of Photographs in Consumer Homes', *Journal of Imaging Science and Technology* 50(4), pp.309–319, 2006. DOI: 10.2352/J.ImagingSci.Technol.(2006)50:4(309.

Cattaneo, A., Sarti, B., Plutino , A. and Rizzi,A. (2022) 'On the Identification of Colour Photographic Processes', *Heritage* ,5, pp4074–4088 DOI: 10.3390/heritage5040210.

Dal Fovo, A, Morello,M., Mazzinghi, A., Toso, C., Galeotti , M. and Fontana, R. (2024) 'Spectral Mapping Techniques for the Stratigraphic and Compositional Characterisation of a 16th-Century Painting', *Heritage*,7, 1320–1333. https://doi.org/ 10.3390/heritage7030063.

Duan, H, (2024),' Predicting Light Stability of Color Photographic Prints:Comparing Macro and Micro-fade Testing Results' *, Microscopy & Microanalysis*, I July 28 – August 1, 2024, Cleveland, Ohio, Microscopy Society of America.

Eom, T.H.and Lee, H.S. A (2023) Study on the Diagnosis Technologyfor Conservation Status of Painting Cultural Heritage Using Digital Image Analysis Program. *Heritage* 6, pp.1839–1855. DOI:10.3390/heritage6020098.

Feller, R.L. (1994) *Accelerated aging: Photochemical and Thermal Aspects*; del Rey, M., Ed.; Research in conservation, 4; Los Angeles, CA, USA; Getty Conservation Institute

Feltrin, F., Leccese, F., Hanselaer, P and Smet, K.A.G,(2019) 'Impact of Illumination Correlated Color Temperature, Background Lightness, and Painting Color Content on Color Appearance and Appreciation of Paintings' *LEUKOS* 16(1),pp.1-20 DOI: 10.1080/15502724.2018.1522261.

García Parejo , P., Zayat , M. and Levy, D.(2010) 'Photostability and retention of UV absorber molecules in sol–gel hybrid UV-protective coatings', *J. Sol-Gel Sci Technol* ,53, pp.280–286 DOI 10.1007/s10971-009-2088-x.

Groeneveld; I., Kanelli , M., Ariese; F, and van Bommel, M.R. (2023) 'Parameters that affect the photodegradation of dyes and pigments in solution and on substrate – An overview' *Dyes and Pigments*, 210, 110999, DOI:10.1016/j.dyepig.2022.110999).

Hattori, H., Yoshizumi , K. and Cox Crews, P.(2012)' Wavelength sensitivity of AATCC Blue wool lightfastness standards under light radiation', *Dyes and Pigments*, 92, pp.936–941. DOI:10.1016/j.dyepig.2011.05.015

Hofmann, M.and Hofmann-Sievert, R. (2022) 'Spectral Light Fading of Inkjet Prints' *Heritage*,5, 4061–4073. DIO:10.3390/heritage5040209.

Hofmann, M.and Hofmann-Sievert, R. (2024), 'Light Sensitivity of Contemporary Photographic Print Material ',3rd international conference on "Colour Photography and Film: analysis, preservation, and conservation of analogue and digital materials", Amsterdam 2024, in press

International Organization for Standardization [ISO] (2009) ISO 5-3:2009 *Photography and graphic technology — Density measurements — Part 3: Spectral conditions* International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization [ISO] (2021) ISO/TS 18950:2021(E), *Imaging materials — Photographic prints — Effect of light sources on degradation under museum, conditions*, section 5.2.3, International Organization for Standardization, Geneva, Switzerland

International Organization for Standardization [ISO] (2023) ISO 18937-1:2023 (2023) *Imaging materials. Methods for measuring indoor light stability of photographic prints General guidance and requirements*, International Organization for Standardization, Geneva, Switzerland

Ishizuka, H.; Groen, E.; Uchino, N.; Shibahara, Y. and Soejima, S. (2019a) 'Image Permanence of Photographic Prints under LED lighting' *Proceedings of the NIP & Digital. Fabrication Conference*, San Francisco, CA, USA, 29 September–2 October 2019; pp. 192–196, DOI:10.2352/issn.2169-4451.2019.35.192

Ishizuka, H.; Groen, E.; Uchino, N.; Shibahara, Y.; Soejima, S. and der Kinderen, W. (2019b) 'Endpoint criteria for evaluation of image permanence of photographic prints', *Proceedings of the NIP & Digital Fabrication Conference*, San Francisco, CA, USA, p 29 September–2 October September 2019; pp. 197–202.

Kore, R. and Durmus, D. (2024): 'Optimizing Light Source Spectra for Art Conservation: Exploring Basic Color Groups', p.1-12, *LEUKOS*, DOI:10.1080/15502724.2024.2366479

Kowaliski, P.(1977) , Sensitometry of Colour Films and Paper' in Jamesh, T. H. (ed.) 'The Theory of the Photographic Process', 4th ed, Macmillan Publishing Co., New York, USA, pp. 518-535

Lerwill, A.; Brookes, A.; Townsend, J.H.; Hackney, S.; Liang, H. (2015) Micro-fading spectrometry: Investigating the wavelength specificity of fading. Appl. Phys. A 2015, 118, 457–463.

Luden, E., 2018 https://digitalsilverimaging.com/, Digital Silver Imaging, last viewed 09 March 2025, https://digitalsilverimaging.com//wp-content/uploads/2018/02/Print-Permanence-Chart-v2-9-19.pdf

Lunz, M., Talgorn, E., Baken, J., Wagemans,W. and Veldman, D.,(2017) 'Can LEDs help with art conservation? – Impact of different light spectra on paint pigment degradation.' *Studies in Conservation*, pp. 62 (5), 294-303

Luo, H.W.; Chou, C.J.; Chen, H.S.and Luo, M.R. (2018) 'Museum lighting with LEDs: Evaluation of lighting damage to contemporary photographic materials' *Light. Res. Technol*.,0, pp. 1–15, DOI:10.1177/1477153518764538

Marchesi, J.J, (2005) *Handbuch der Fotographie (3), Die Technik der Farbfotografie* , Gilching, Germany, Verlag Photographie

Maretić, K-P., Rudolf,M., Plazonić,I,Seleš, V.R., Jungwirth,S.and Bates, I.,(2021) 'The effect of natural and artificial ageing on optical properties of laboratory papers with triticale pulp printed using UV ink technique, *Journal of International Scientific Publications*,15,p.78-88

Pénichon, S.(2013) *Twentieth-Century Color Photographs: Identification and Care*, Los Angeles, USA, Getty Publications, p187

Reber, J and Hofmann, R.(2005) 'Correlation of ozone test chamber data with real-life Permanence of Ink-jet prints'*, NIP & Digital Fabrication Conference 22* (1), pp 231-234 DOI: 10.2352/ISSN.2169-4451.2006.22.1.art00059

Rogers, D. (2007). *The Chemistry of Photography: From Classical to Digital Technologies*. Royal Society of Chemistry, London

Saunders, D. and Kirby, J. (1994) 'Wavelength-dependent fading of artists' pigments' *Stud. Conserv.*, 39 (Suppl. 2), pp.190–194.Doi:10.1179/sic.1994.39.Supplement-2.190

Silva, J.; Parola, A.J.;Oliveira, M.C.; Lavédrine, B.and Ramos,A.M. (2022) 'Contributions to the Characterization of Chromogenic Dyes in Color Slides. *Heritage*, 5, pp.3946–3969. DOI:10.3390/heritage5040203

Thickett, D. and Grøntoft, T. (2023) 'Review of Interpreting Gaseous Pollution Data Regarding Heritage Objects' *Heritage*, 6,pp. 6917–6930. DOI:10.3390/heritage6100361

Weyermann, C., Kirsch, D., Vera, C-C.and Spengler, B. (2006) 'Photofading of Ballpoint Dyes Studied on Paper by LDI and MALDI MS' *J Am Soc Mass Spectrom*. 17, pp.297–306 DOI:10.1016/j.jasms.2005.11.010

Wilhelm, H.G.; Brower, C. (1993), *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides and Motion Pictures*, Grinnell, IA ,USA, Preservation Pub. Co. USA

Wihelm, H.G.2025, *www.Wilhelm-research.com,* Wilhelm Imaging Research, last viewed 09 March 2025, http://www.wilhelm-research.com/WIR_Reference_Collection/The_Wilhelm_Analog_and_Digital_Color_Print_Materials_Reference_Collection_1971_to_2025_v26_(2025-02-01).pdf

Wilhelm, H. (2004) 'A Review of Accelerated Test Methods for Predicting the Image Life of Digitally-Printed Photographs—Part II'. *Proceedings of the IS&T's International Conference on Digital Printing Technologies*, Salt Lake City, UT, USA, 31 October 31–5 November; pp. 664–669

Yoo, W.S.; Kang, K.;Kim, J.G.; Yoo, Y. A. (2023) Novel 'Approach to Quantitative Characterization and Visualization of Color Fading'. *Technologies*, 11,108. DOI:10.3390/ technologies11040108

Zaffino, C., Bertagna, M., Guglielmi, V., Dozzi, M.V., and bruni, S. (2017) ' In-situ spectrofluorimetric identification of natural red dyestuffs in ancient tapestries, Microchemical Journal, (132), Pp. 77-82 https://doi.org/10.1016/j.microc.2017.01.002

Zhao, Z., Zhang, P., Liu, X., Lei, X., Luo,Y. (2021) 'Analysis of photoaging characteristics of Chinese traditional pigments and dyes in different environments based on color difference principle', *Color research and Application*, 46,(6) pp.1276-1187, DIO:/10.1002/col.22680.

An investigation into the structure and color stability of Polaroid 20×24 prints

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ABSTRACT

Polaroid 20×24 prints, renowned for their distinctive large format and use by artists, have received limited attention within the conservation community. This study, conducted at the Art Institute of Chicago, examines the materials, structure, and stability of different generations of Polaroid 20×24 film, including Polacolor ER (P3), Polacolor Pro 100 (P6), Polacolor 7 (P7), and hybrid Chocolate prints. Utilizing a combination of non-invasive and micro-invasive analytical techniques, such as scanning electron microscopy with energy dispersive spectroscopy, Fourier transform infrared spectroscopy and pyrolysis gas chromatography mass spectrometry, the research aimed at characterizing the prints' structure and material composition, and investigates light stability through microfading testing (MFT). Complementary analyses showed some variations in the prints' structure and allowed the characterization of a specific degradation product; while comparative MFT analyses of various dye colors across generations revealed vulnerabilities to color fading. These findings contribute valuable insights into the material composition of Polaroid 20×24 prints and inform display and preservation strategies, ensuring the longevity of these culturally significant artworks.

KEYWORDS Instant Prints, Dye Diffusion, Polaroid 20×24, Polacolor, Microfading Testing, Light Stability, Polaroid Chocolate

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1. Introduction

The Polaroid 20×24 (inches, or 50×60 cm) revolutionized instant photography since the 20×24 camera, unlike smaller Polaroid formats, allowed for large-scale prints that captured exceptional detail. These qualities made it an attractive choice to notable artists such as Andy Warhol, William Wegman, Chuck Close, and David Levinthal, among many. Thanks to the Polaroid Artists Support Program [1]; artists embraced the format's combination of immediacy, size, and vibrant color to create iconic works that continue to be celebrated in fine art collections today. Despite their artistic significance, perhaps in part because of the complexity of the materials and processes involved in their creation, Polaroid 20×24 prints have received limited attention from the conservation community (Casto and Valverde, 2019; Pietsch and Gierstberg, 2016; Pénichon, 2013; Mesquit and Lemmen, 2005; Rebourt, 1997).

Research was undertaken at the Art Institute of Chicago to investigate the material and structural composition of three generations of Polaroid 20×24 color films: Polacolor ER (P3), Polacolor Pro 100 (P6), Polacolor 7 (P7), and the hybrid Polaroid Chocolate. In addition to characterizing the materials through thickness, texture, gloss and colorimetric measurements, scanning electron microscopy with energy dispersive spectroscopy (SEM-EDS), Fourier transform infrared spectroscopy (FTIR), pyrolysis gas chromatography mass spectrometry (Py-GCMS), and microfading testing (MFT) were used to investigate the nature of the materials, their layer structure, and the light stability of the prints.

2. Historical background and development of the Polaroid 20×24

The production of large Polaroid materials spanned approximately three decades, as shown in detail in Figure 1. Introduced by Polaroid Corporation in the late 1970s, the Polaroid 20×24 camera and films (Reuter, 2008, Reuter 2020) was initially conceived as a tool to demonstrate the capabilities of Polacolor 2 film during a shareholders' meeting (Bonanos, 2012).

Originally designed for smaller instant film systems, Polacolor 2 presented improvements over the previous generation of peel-apart color materials, including metallized dyes that had been developed for the Polaroid SX-70 integral film: specifically, chromium complexed azo dyes for the yellow and magenta and copper phthalocyanine for the cyan (Walworth and Mervis, 1989; Wilhelm, 1978). These dyes provided vivid and more stable colors, although the yellow dye still proved vulnerable to fading under prolonged exposure to light (Wilhelm and Brower, 1993; Adams and Baker, 1978).

With the advent of Polacolor ER (or P3) in 1980, additional modifications to the dyes further enhanced the longevity and stability of the P3 prints, offering more vibrant color reproduction, lower contrast, deeper blacks and increased saturation (Rebourt, 1997). P3 also possessed a distinctive property that the dye image layer could be separated from its support by soaking the print in warm water, enabling the transfer of the image layer onto alternative supports (Bonanos, 2012). This technique was embraced by artists to create unique Polaroid artworks.

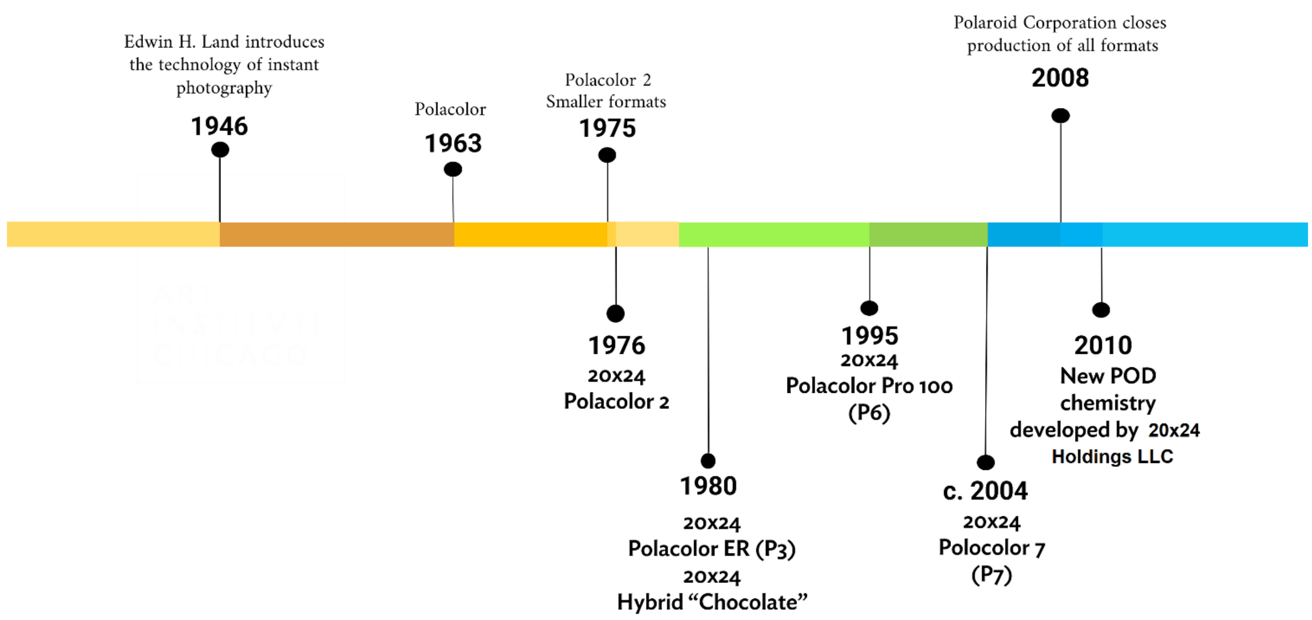

Fig. 1. Timeline for 20×24 peel-apart Polaroid film (Walworth and Mervis, 1989; Image Permanence Institute, 2010; Pénichon, 2013).

Chocolate prints, characterized by their split-tone effect and sepia tones, emerged as a hybrid system combining color and black-and-white peel-apart materials. This cross-process was the result of an accidental combination of Polacolor ER negative with Polapan 100 positive and reagent (Pryme Magazine, 2015). With the 20×24 format, Chocolate prints were produced by combining Polapan 400 black-and-white positive support with P3 negative sheet (Holmquist, 2024).

In 1995, Polaroid introduced Polacolor Pro 100 (P6) that incorporated over thirty functional consumer-driven improvements, including three new emulsions, four new developers (in negative), and a new receiving layer (Rebourt, 1997). According to Polaroid literature, this new generation of material featured higher concentrations of metalized dyes, particularly in the cyan and magenta layers, which resulted in enhanced image clarity and more precise color reproduction (Polaroid Corporation, 2002; Rebourt, 1997). A significant development was the modification of the reagent chemistry where hybrid formulations with temperature-sensitive inhibitors acting as molecular thermostats were introduced, allowing for greater chemical stability under varied environmental conditions (Rebourt, 1997).

Polacolor 7 (or P7), released in the early 2000s, was the last iteration of Polaroid 20×24 film. This generation incorporated numerous technical improvements, including increased brightness and contrast in the finaimages (Gomes, LaPointe and Manning, 2005). It also featured further enhancements to the structure of both positive and negative, and to the processing chemistry. However, P7 proved to be more chemically unstable than its predecessors, particularly in humid environments, as discussed further below (Gomes, 2024; Miąsik and Pénichon, 2024).

The production of 20×24 film and all other Polaroid materials came to an official halt in 2008, when the Polaroid Corporation filed for bankruptcy. The company 20×24 Holdings LLC acquired the remaining rolls of film and some production equipment, allowing artists to continue using the format long after production ceased (Reuter, 2012; Panzer, 2008). Through the efforts of the 20x24 Studio in New York, led by John Reuter, and the 20×24 Studio Berlin, operated by Markus Mahla, the 20×24 format continues to live on today (Asto, 2019; Reuter, 2008).

3. Materials characterization

3.1. *General physical properties*

A total of 87 prints, including identified samples of various 20×24 print generations (P3, P6, P7 and Chocolate) from the Art Institute's photography conservation study collection and prints of undetermined generation from the collections of the Art Institute of Chicago, the Museum of Contemporary Photography in Chicago, and the Museum of Fine Arts Boston, were examined, measured and compared. Measurements consisted of colorimetric values, thickness, texture, and gloss. Because of the lack of Polaroid 2 samples in the study collection and their rarity in museums' collections, this generation was not included in the study.

All examined Polaroid 20×24 prints share a glossy surface finish and exhibit no discernible differences in texture, maintaining a consistent aesthetic and tactile quality across generations. The thickness of P3, P6 and P7 supports is remarkably consistent, varying between 0.260 and 0.273 mm. Their visual appearance under magnification is also similar, although the Chocolate print exhibits a linear pattern of blurry dots.

The colorimetric values taken from the 87 prints were used to create scatter plot diagrams of L*a*b* readings from the white margin on the recto and the backcoat of the verso, shown in Figure 2a and 2b respectively. For some prints it was not possible to perform both readings due to the absence of white margins or to the presence of mounts which hindered access to the verso.

Figure 2a shows broadly scattered groups that do not separate as cleanly as when using data from the verso. The greatest spread is in the vertical (b*) axis, with the Chocolate prints (indicated by red dots) forming a distinct group at the top left of the diagram with highest b* values (most yellow). P3, P6, and unidentified prints (blue, pink and black dots) are scattered in the middle of the diagram, with P6 showing the lowest b* values (least yellow). P7 print samples (green dots) created a group on the lower left side of the diagram, with slightly higher L* values (greater lightness).

Figure 2b shows data obtained from the verso of the prints. Three distinct groups can be discerned: a first one including samples from the Chocolate prints (red dots) at the bottom; a second one including the prints of unknown generations (black dots) in the upper left; and a relatively more scattered third group that includes P3, P6, and P7 prints (blue, pink, and green dots) and a few unidentified (black) in the upper right. This distinction is expected as three different colors of the backcoat were observed: Chocolate prints are characterized by a dark gray backcoat, while most of the unknown samples have a light gray backcoat. The generation of Polaroid 20×24 associated with the light gray backcoated prints requires further investigation.

This method is therefore promising for the differentiation of undetermined generations of prints, but an extended database including data from more samples of known types of 20×24 Polaroids is required.

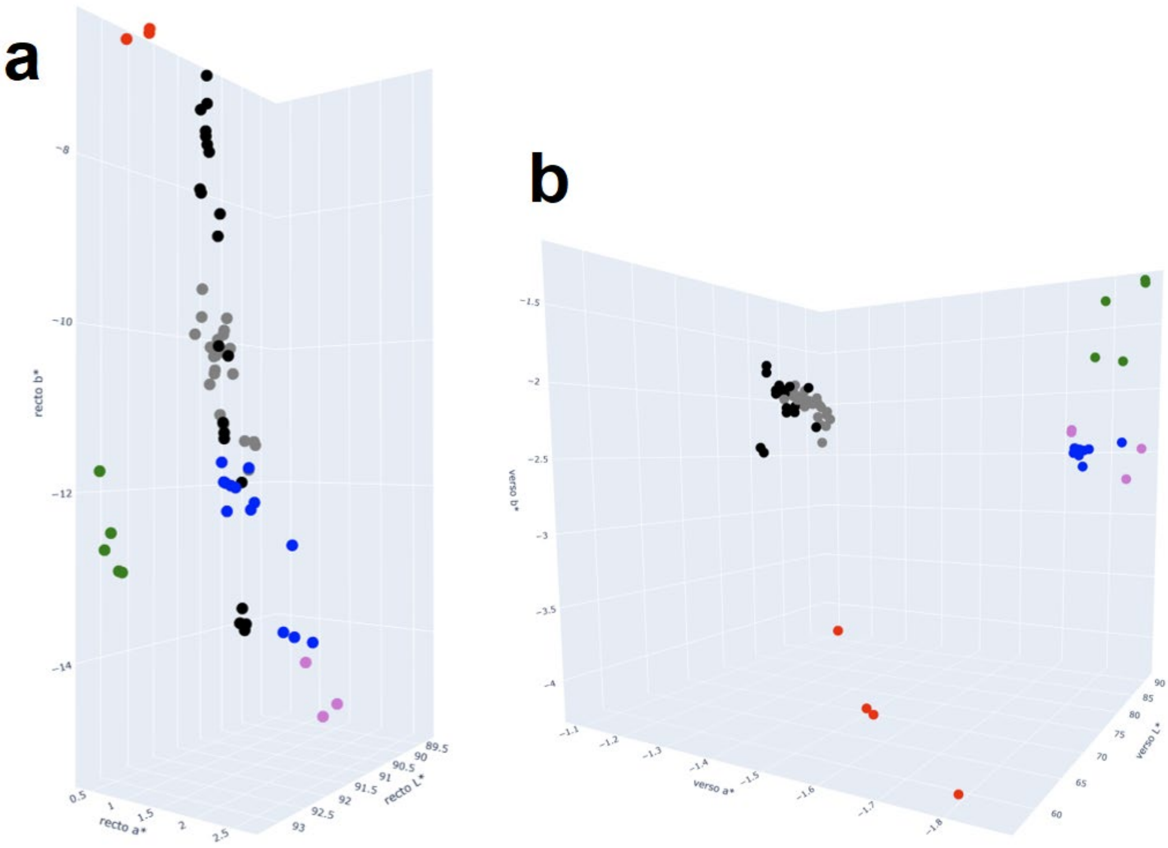

*Fig. 2. Colorimetric values (L*a*b*) taken from Polaroid 20×24 photographs (a) in the white margins, recto, and (b) on the backcoats, verso; (blue) P3, (pink) P6, (green) P7, (black) unknown generation, (red) Chocolate.*

3.2. *Print structure and composition*

Cross-sections from P3, P6, and P7 prints were examined using optical and electron microscopy to provide a better understanding of their respective layering structures (Figure 3). The cross-section of P6 is not shown, being very similar to that of P7.

A comparison of the cross-sections revealed that the three generations of Polaroids consist of the same number of layers. However, the image receiving layer (1) and polymeric acid layer (2) in P7 (and P6) are thinner than in P3.

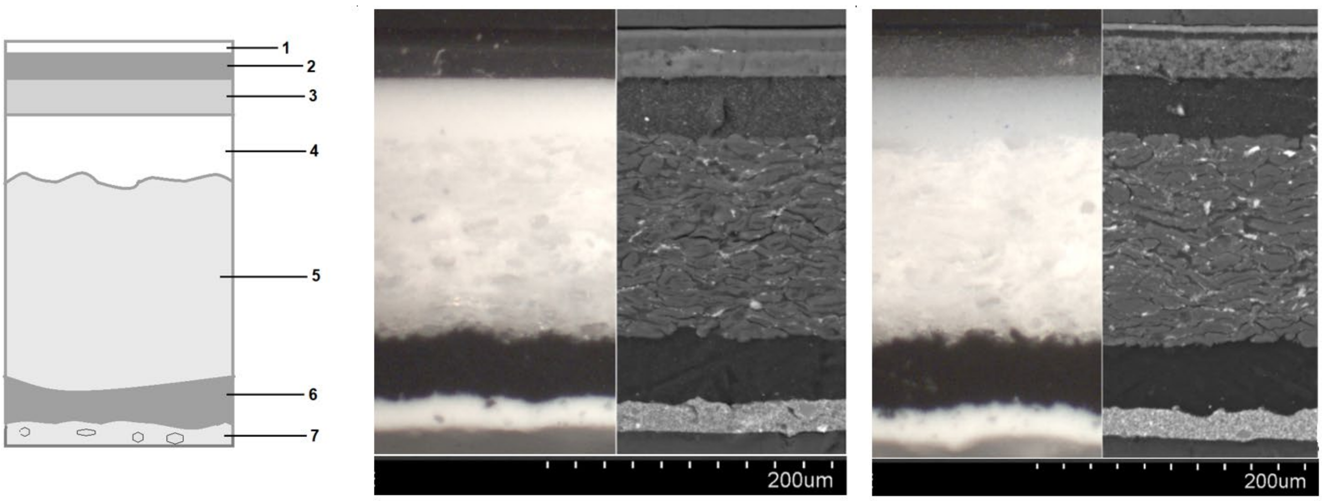

Fig. 3. Left: Schematic diagram of Polaroid cross-section showing (1) Image receiving layer, (2) Polymeric acid layer, (3) Timing layer, (4) Polyethylene layer, (5) Paper support, (6, 7) backcoats. Center: Micrograph and SEM backscatter image of P3 sample. Right: Micrograph and SEM backscatter image of P7 sample.

SEM-EDS spot analysis and elemental mapping of the cross-sections provided information on the inorganic materials used in some of the Polaroids' layers (Figure 4). In both P3 and P7 samples, titanium (Ti) was detected in multiple layers: the polyethylene layer (4), the paper support (5), and the backcoat (7). This suggests the presence of titanium dioxide (TiO_2), or titanium white, a material commonly used in photographic paper as a filler and brightener (Stulik and Kaplan, 2012). It might have been added to the polyethylene layer possibly as an opaque barrier (Fujita, 2004). Silicon-rich particles in the paper support (5) and backcoat (7) suggest an additional clay filler. Bromine (Br) was detected in correspondence with the image receiving layer (1), possibly transferred from the silver bromide (AgBr) emulsions in the negative or coming from the other bromine-based compounds used as counter ions in the positive and negative sides. Potassium (K) appeared predominantly in the timing layer(3) as well as the image receiving layer (1), confirming the use in Polaroid films of potassium hydroxide (KOH) as a developing chemical and as mordant (Wilker, 2004; MSDS No. M-0579, 1998). Chromium (Cr) was detected at trace levels in the image-receiving layer (1) of both samples, likely corresponding to the metallized organic dyes used in these films (Walworth and Mervis, 1989). One of the major differences between the two generations is the presence of blue particles in the polyethylene layer (4) of Polaroid P7 (Figure 3). SEM-EDS analysis detected the presence of sodium (Na), aluminum (Al), silicon (Si) and sulfur (S) in these particles, which suggest the presence of ultramarine blue, a complex sodium-silicate, likely used as an optical brightener. In comparison to cross sections reported in the literature (Image Permanence Institute, 2010), the application of SEM-EDS analysis provided enhanced insight into the Polaroids' structure and material composition.FTIR was used to better characterize some of the layers, in cases where it was possible to physically separate them for analysis, complementing the SEM-EDS information. Results from the white backcoats, which were observed to contain titanium dioxide, showed the use of polyvinyl alcohol (PVA) in P3, and a combination of PVA and polyethylene in both P6 and P7 generations, as suggested by the sharper C-H bands at 2919 and 2851 cm^{-1} (Figure 5). The presence of polyethylene in P6 and P7 was also supported by the detection of a series of straight-chain alkanes and alkenes by pyrolysis gas chromatography mass spectrometry (Py-GCMS) (Tsuge, 2011). Different materials, including PVA and polyethylene, often in combination with other compounds, can be used in the support, depending on the desired nature of the final print (Fehervari and Manning, 2002; Walworth and Mervis, 1989). Despite analyzing only one sample per generation, the FTIR results suggest a variation in the backcoat material choice between generations. The image-receiving layer was also investigated by FTIR. Besides the confirmation of PVA in all three generations, the likely presence of multiple dyes and other materials made the spectral interpretation complicated and hindered the conclusive identification of individual components. These results seem promising to differentiate the various generations; however, non-invasive techniques such as reflectance-FTIR should also be explored when investigating prints held in collections.

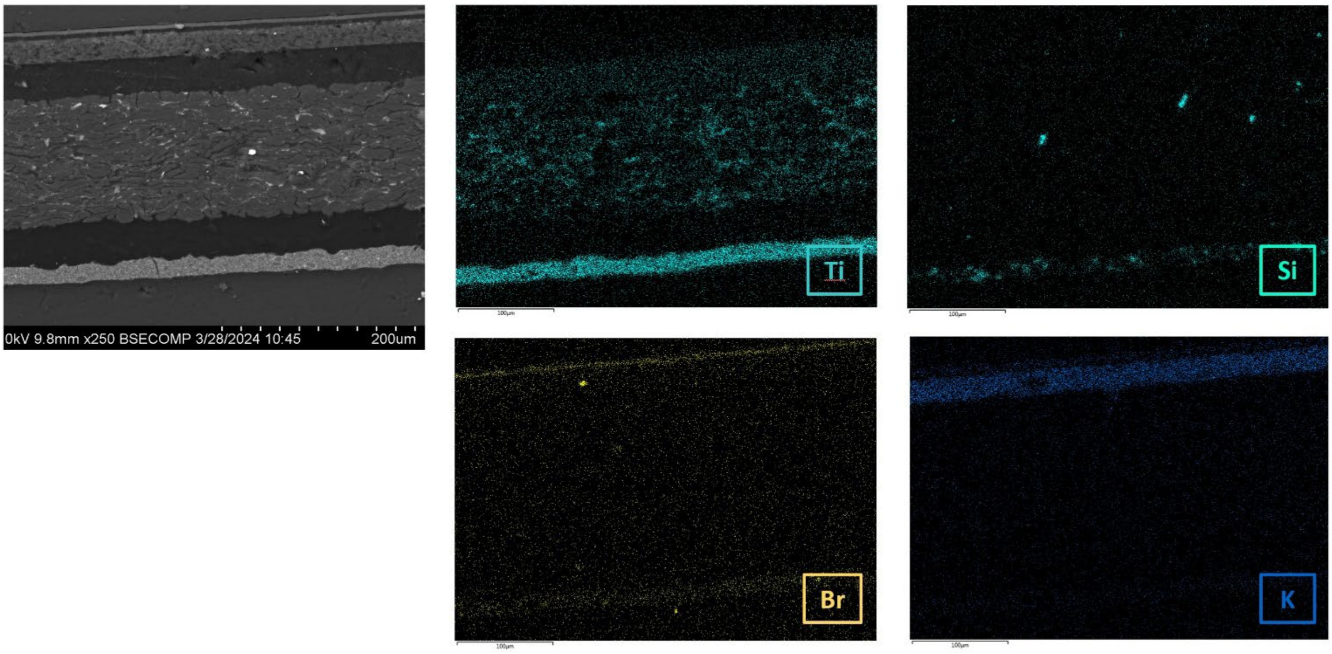

Fig. 4. SEM backscatter image of cross-section sample from Polaroid P3 (left) and EDS elemental maps for titanium (Ti), silicon (Si), bromine (Br) and potassium (K).

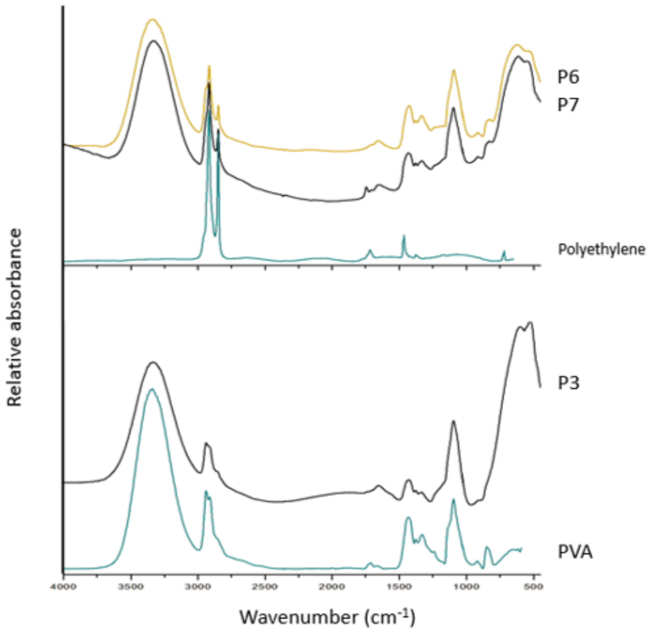

Fig. 5. FTIR spectra of the white backcoats from P3, P6, and P7, compared with reference spectra of polyvinyl alcohol (IRUG database, SR00092) (Price, 2007) and polyethylene (Fiveash Data Management, Polymers FTIR database).

Fiber analysis of the samples' paper cores revealed that the composition across generations P3, P6, and P7 was largely consistent, with slight differences attributable to different batches. The core of the samples was composed primarily (80 to 82%) of bleached hardwood fibers, such as maple, beech, or eucalyptus, with smaller amounts (18 to 20%) of bleached softwood fibers, including white or red pine, spruce, and hemlock (Bushner and Ranten, 2024).

Close examination of P6 and P7 prints from the study collection revealed the presence of a white powder formation on their surface (Figure 6a). P7 prints are notably susceptible to chemical instability and are known to develop a white haze within two years after the prints were made. This degradation, first noted by Reuter, manifested itself as small, salt-like particles embedded in the surface, giving it a matte and uneven appearance (Reuter, 2024). FTIR spectra of the white powder showed features that closely resemble those of the purine compound hypoxanthine (Figure 6b). Together with inosine, hypoxanthine was a component of the aqueous alkaline processing solution and was involved in the image transfer and development (Eckert et al., 1998; Kliem and Mass 1988; Gomes, LaPointe and Manning 2005). It is soluble in alkaline environments and insoluble in a neutral one. The detection of potassium (K), as well as bromine (Br), chlorine (Cl) and sulfur (S), in the white powder sample by SEM-EDS analysis suggests that hypoxanthine may be present as its potassium salt, or in combination with other salts, possibly resulting from re-solubilization and crystallization of hypoxanthine on the surface of the final image. This phenomenon might have been triggered by a change in pH and/or humidity in the Polaroid micro and macro environment (Gomes, 2024). More research is necessary to better understand the exact mechanism behind the crystal formation.

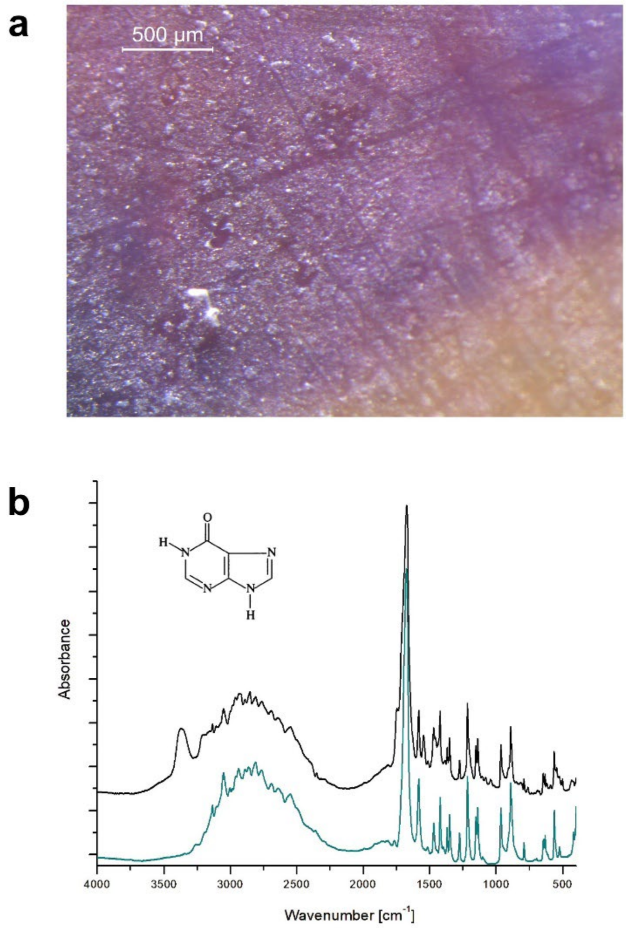

Fig. 6. (a) micrograph of the white powder formation on the surface of a P7 print; (b) FTIR spectra of the white powder (top) and a reference hypoxanthine (bottom) (Sigma, H9636).

4. Light Stability

Polaroid marketed its materials as being "among the most permanent and fade resistant ever developed in photography" (Wilhelm and Brower, 1993). However, this assertion was effectively debunked by Henry's Wilhelm's research on the light stability of photographic materials (Wilhelm and Brower, 1993; Wilhelm, 1978). Results of accelerated tests published by Wilhelm revealed that Polacolor 2 and P3 exhibit relatively low light stability, with Polacolor 2 being especially prone to yellowing, even in dark storage. P3 showed improved resistance, though it remained susceptible to light-induced fading, particularly in yellow dye areas (Wilhelm and Brower, 1993). Wilhelm's research did not address later generations, such as P6, P7, or Chocolate prints. Observations by Reuter indicate that Chocolate prints are especially sensitive to light exposure, thus requiring careful display practices (Reuter, 2024).

MFT was employed in this study to assess the light sensitivity of materials with minimal damage, by inducing controlled, localized color fading in microscopic areas [2] (Beltran et al., 2021; Łojewski and Grzelec, 2020; Pesme, 2016; Whitmore and Bailie, 1999). Overall, results suggest that dyes across generations may fade at slightly different rates, but all exhibiting curves between blue wool BW2 and BW3 references, indicating a sensitivity to light.

The yellow staining residue, typically found along the lower edge of each Polaroid 20×24 print as a result of processing chemistry outside the image area during development, was also tested. This area proved to be the least stable, with high susceptibility to color shifts over time, across all tested generations. The hybrid Chocolate print was also tested; both light and dark areas were tested near the BW3 standard. Further studies on 20×24 chocolate prints in museum collections would be necessary to validate these results.

Fig. 7. Above: Representative graph for P6 showing MFT results for yellow, cyan, and magenta dyes. Below: MFT results for yellow stain for P3, P6, and P7.

5. Conclusion

This research is the first scientific study to comprehensively analyze the material composition and light sensitivity of Polaroid 20×24 prints across multiple generations, as well as a specific degradation phenomenon observed in the P7 prints. Because P3, P6 and P7 generations of materials have been used concurrently, one cannot rely on the dates artworks were created for the identification of individual generations, and so analysis of their physical properties and chemical constituents provides critical evidence. Measurements of thickness, gloss and texture showed a remarkable consistency of these physical attributes across generations, precluding their differentiation. On the contrary, color measurements of the white margins of the images or of the versos of the prints showed potential in distinguishing one generation from another, but a more extensive dataset of known Polaroid generations is needed to further develop these preliminary results.

Microphotographs of cross-section samples, combined with SEM backscatter images and EDS elemental mapping, facilitated discrimination of the various layers and gave insights on their chemical composition. The presence of ultramarine pigment in the polyethylene layer of the P7 sample, and the detection by FTIR of polyethylene in combination with PVA in the backcoat of the P6 and P7, were distinctive features in this study, but would require analysis of a wider sample set to confirm their diagnostic value. FTIR analysis also allowed the identification of hypoxanthine as a degradation product on P7, which can be related to residues of the chemical processing solution. MFT analysis showed that light sensitivity, while showing some variation among the samples tested, remains consistent across Polaroid 20×24 generations.

These findings underscore the necessity of careful light management when displaying 20×24 prints. Given that light-induced degradation is cumulative and irreversible, conservators and curators should interpret this data as a strong recommendation for exhibition conditions appropriate for light sensitive objects, for all generations. The necessity of proper storage conditions is also emphasized, ideally a cold storage environment, to preserve color stability and minimize chemical deterioration.

6. Conflict of interest declaration

The authors declare there is no conflict of interest concerning the research presented in this paper.

7. Funding source declaration

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9. Short biography of the authors

Paulina Miąsik - Current Mellon Conservation Fellow in the Conservation and Science Department at the Art Institute of Chicago. She holds a master's degree from the Faculty of Conservation and Restoration of Works of Arts of the Academy of Fine Arts in Warsaw, Poland, where she trained in the conservation and restoration of books, paper objects, and photographs. Her professional experience includes positions as a paper and photograph conservator at The Museum of Warsaw and The Central Military Library, Warsaw, as well as internships at the Museum of Photography in Krakow and at the Memorial and Museum Auschwitz-Birkenau German Nazi Concentration and Extermination Camp.

Sylvie Pénichon - William E. Urschel Family Director of Paper, Photography and Media Conservation at the Art Institute of Chicago. She is the author of *Twentieth-Century Color Photographs: Identification and Care* (2013), a comprehensive guide to understanding color photographs. In 2024, she joined Barbara Flueckiger as co-curator of the website *Timeline of Historical Colors in Photography and Film*.

Clara Granzotto - Associate Conservation Scientist in the Conservation and Science department at the Art Institute of Chicago. She received her Ph.D. in chemical sciences from the University of Venice, Italy, and the University of Lille, France. Clara conducted post-doctoral research at Northwestern University, the Metropolitan Museum of Art and the University of Copenhagen. She specializes in the analysis of traditional binding media by mass spectrometry, with a focus on polysaccharides and proteins.

Ken Sutherland - Andrew W. Mellon Director of Scientific Research in the Department of Conservation and Science at the Art Institute of Chicago. His main research interests concern the characterization of organic materials in works of art, using mass spectrometric and other analytical techniques, to inform an understanding of their technique, condition and appearance.

Notes

[1] The Polaroid Artists Support Program was an initiative by the Polaroid Corporation to engage artists in exploring and expanding the creative possibilities of instant photography. Established in the 1960s, the program provided selected artists with access to Polaroid cameras, film, and studio time, enabling them to experiment with the medium and offer feedback on Polaroid products. In return, many artists contributed their works to the Polaroid Collection, which eventually amassed over 16,000 fine-art photographs.

[2] MFT results are typically compared to the ISO Blue Wool Scale (BW1 to BW8, BW1 being the most fugitive and BW8 the most stable) to measure the permanence of colored materials. By analyzing these effects, conservators can effectively forecast the potential risks of light exposure to materials and formulate preventive conservation strategies (Whitmore, 1999, Michalski, 2017).

Experimental

1. Visible and fluorescence light microscopy: Samples were prepared as cross sections using a methacrylate resin (Technovit 2000 LC) and examined using a Zeiss Axioplan 2 research microscope with reflected light and UV fluorescence illumination; images were captured using a Zeiss AxioCam MRc5 digital camera.

2. Scanning Electron Microscopy with Energy Dispersive Spectroscopy (SEM-EDS): An Hitachi S-3400N was used in the EPIC facility of the NUANCE Center at Northwestern University (Evanston, IL). The uncoated cross-sections were analyzed in low-vacuum mode at 80 Pa pressure and 20 kV accelerating voltage.

3. Fourier transform infrared spectroscopy (FTIR): Micro-samples were mounted on a diamond cell. Analysis was performed with a Bruker Hyperion 3000 FTIR microscope with a mercury cadmium telluride D315 detector interfaced to a Tensor 27 spectrometer. Samples were analyzed in transmission mode between 4000-400 cm^{-1} at 4 cm^{-1} resolution and collecting 128-512 scans per spectrum.

4. Pyrolysis gas chromatography mass spectrometry (Py-GCMS): Micro-samples were analyzed via direct pyrolysis in splitless mode, using an Agilent Thermal Separation Probe, which was inserted in an Agilent 7890B GC interfaced to a 5977B mass spectrometer. For analysis parameters see Sutherland et al. (Sutherland 2022).

5. Micro Fading Tester (MFT): The Micro Fading Tester manufactured by Instytut Fotonowy with LED light source (3200 K), spot diameter 0.5 mm, spectral resolution 2.50 nm.

6. Color: Color of the prints was measured using the X-Rite Exact spectrophotometer. This instrument produces color measurements using the L*a*b* color space (CIELAB, The International Commission on Illumination, 1976), where L* measures lightness (0 = black, 100 = white), a* measures green and red (positive values for red, negative values for green), and b* measures yellow and blue (positive values for yellow, negative values for blue). The reported results represent an average of three measurements.

7. Thickness: Thickness of the photographs was measured using a Mitutoyo Digimatic Micrometer Series 293 with a resolution of 0.001mm. Six measurements were made on each print at the top and bottom edges. Reported values are the averages of these measurements.

Licensing terms

References

Adams, A. and Baker, R. (1978) *Polaroid Land Photography*. Boston: New York Graphic Society, pp. 58–59.

Asto, J. C. (2019) *20x24 Studio Berlin: Keeping Large Format Instant Photography Alive*, The Phoblographer. Available at: https://www.thephoblographer.com/2019/02/10/20x24-studio-berlin-keeping-large-format-instant-photography-alive-today (Accessed: 11 October 2024).

Beltran, V.L., Pesme, C., Freeman, S.K. and Benson, M. (2021) *Microfading Tester: Light Sensitivity Assessment and Role in Lighting Policy*. Los Angeles: Getty Conservation Institute.

Bonanos, C. (2012) *Instant: The Story of Polaroid*. New York: Princeton Architectural Press, pp. 75–84.

Bushner, J. J. and Rantanen, W. J. (2024) *Analysis of Three Photographic Paper Samples.* SGS North America, Inc, pp. 1–8.

Casto, S. and Valverde, F. (2019) ‘Hinging and Float Mounting 20×24” Polaroid Prints and Negatives’, *Topics in Photographic Preservation* 18, pp. 1–3.

Eckert, R.D., Filosa, M.P., Gomes, G., Layne, A.R., Schwarz, M.C. and Taylor, L.D. (1998) ‘Photographic Element and Method’, U.S. Patent 5,756,253.

Fehervari, A.F., and Manning, J.J. (2002) ‘*I*mage-Receiving Element’, U.S. Patent 6,403,278 B1.

Fujita, S. (2004) *Organic Chemistry of Photography*. Berlin, Heidelberg: Springer-Verlag, pp. 341–372.

Gomes, G., LaPointe, G.S. and Manning, J.J. (2005) ‘Image-Receiving Element’, U.S. Patent 6,946,232.

Gomes, G., (2024) Emails to Paulina Miąsik about Polaroid chemistry (September 2024-February 2025).

Holmquist, C. (2024) Email to Paulina Miąsik about Chocolate prints, (August 2024).

Image Permanence Institute (2010) *Film Type Chart Dates, Graphics Atlas*. Rochester, NY: Image Permanence Institute (IPI). Available at: http://www.graphicsatlas.org/media/images/id/Polaroid_Films.pdf (Accessed: 20 February 2025).

Kliem, P.O. and Mass, W. (1988) ‘Hybrid Color Films With Dye Developer and Thiazolidine Dye Releaser’. U.S. Patent 4,740,448.

Łojewski, T. and Grzelec, M. (2020) ‘Światłotrwałość i światłonietrwałość – o możliwościach wykorzystania wyników badań mikrofedometrycznych w ochronie zbiorów’, *Notes Konserwatorski*, 22_2020, p. 79, DOI:10.36155/NK.22.00003.

Mesquit, T. and Lemmen, B. (2005) ‘Coatings on Polaroid Prints’, in McCabe, C. (ed.) *Coatings on Photographs: Materials, Techniques, and Conservation*. Washington, D.C.: American Institute for Conservation, pp. 180–199.

Miąsik, P. and Pénichon, S. (2024) ‘Polaroid 20×24: Characterization and Investigation of Treatments and Preservation Methods’, *Expect The Unexpected*, *52nd Annual Meeting*, May 20–24, Salt Lake City, Utah, American Institute for Conservation.

Michalski, S. (2017) *Agent of Deterioration: Light, Ultraviolet and Infrared*. Government of Canada. Available at: https://www.canada.ca/en/conservation-institute/services/agents-deterioration/light.html (Accessed: 11 Oct. 2024).

MSDS No. M-0579. *Developer fluid contained in pod of film types 668, 668H, 108, 669, 661W, 669S, 108S, 669HS, 88, VIVA (COLOR), 661, 559, 559S, 58, 59, 808, 809, PCID ULTRAVIOLET; POLACOLOR ER; PRO-VIVID*; Polaroid Corporation, Waltham, MA, July 7, 1998.

Panzer, M. (2008) ‘Big Artists, Big Camera: Not a Typical Polaroid’, *The Wall Street Journal*, Available at: https://www.wsj.com/articles/SB121797626872014909 (Accessed: 21 January 2025)

Pénichon, S. (2013) *Twentieth-Century Color Photographs: Identification and Care*. Los Angeles: Getty Conservation Institute.

Pesme, C. (2016) ‘Presentation of Tools Helping to Set a Preservation Target for Displaying Light Sensitive Collection item’, *Nuevo Mundo Mundos Nuevos* [online], doi: https://doi.org/10.4000/nuevomundo.69241.

Pietsch, K. and Gierstberg, F. (2016) Ulay: what is this thing called Polaroid? Amsterdam: Valiz, pp. 81–115.

Polaroid Corporation (2002) ‘20×24 Worldwide’, pp. 1–7.

Price, B.A., Pretzel, B. and Lomax, S.Q. (2007) *Infrared and Raman Users Group Spectral Database*, Philadelphia.

Pryme Magazine (2015) 'The History of Polaroid Chocolate Film', *Pryme Magazine - Annual Journal for Instant Photography*. Available at: https://www.tumblr.com/prymemagazine/127239423535/the-history-of-polaroid-chocolate-film. (Accessed: 11 October 2024).

Rebourt E. (1997) *La Restauration de trois Polacolor ER (Photographies à dévelopment instantané). Étude de la compatibilité du Polacolor ER avec les solvants organiques*. MA dissertation. pp. 20–40. Available at: https://mediatheque-numerique.inp.fr/documentation-oeuvres/memoires-diplome-restaurateurs-patrimoine/restauration-trois-polacolor-er-photographies-developpement-instantane-etude-comptabilite-polacolor-avec-solvants-organiques (Accessed: 20 February 2025).

Reuter J. (2008) 'Preserving the Polaroid Legacy ', 20x24 STUDIO. Available at: https://20x24studio.com (Accessed: 3 October 2024).

Reuter, J. (2012) 'The Fall of Polaroid, The Rebirth of 20×24', *View Camera*, May/June, pp. 54–56.

Reuter, J. (2020) '20×24 Studio FAQs. Polaroid 20×24 Camera System', 20×24 Studio. Available at: https://20x24studio.com/?page_id=1653) (Accessed: 20 January 2025).

Reuter, J. (2024) Email to Paulina Miąsik about observations on the stability of Polaroid large-format prints (September 2024-February 2025).

Sutherland, K., Kokkori, M. (2022) 'Investigating formulations of cellulose acetate plastics in the collections of the Art Institute of Chicago using pyrolysis gas chromatography mass spectrometry', *Journal of Analytical and Applied Pyrolysis* 163(2022), pp. 105484.

Stulik, D.C. and Kaplan, A. (2012) 'Application of a Handheld XRF Spectrometer in Research and Identification of Photographs', in Shugar, A.N. and Jennifer, L. (eds) *Handheld XRF for Art and Archaeology*. Vol. 3. Leuven: Leuven University Press, pp. 75–130. DOI: https://doi.org/10.2307/j.ctt9qdzfs.7.

Tsuge, S., Hajime O. and Chuichi W. (2011) *Pyrolysis-GC/MS Data Book of Synthetic Polymers Pyrograms, Thermograms and MS of Pyrolyzates*. Amsterdam: Elsevier.

Walworth, V.K. and Mervis, S.H. (1989) 'Instant Photography and Related Reprographic Processes', in Struge J.M., Walworth V.K. and Shepp, A. (eds) *Imaging Processes and Materials; Neblette's Eighth Edition*. New York: Van Nostrand Reinhold, pp. 181–215.

Wilhelm H. (1978) 'Color Print Instability: A Problem for Collectors and Photographers', in Norris, D.H., Gutierez, J.J. (2010) I*ssues in the Conservation of Photographs,* Los Angeles: Getty Conservation Institute, pp. 467-468.

Wilhelm, H. and Brower, C. (1993) *The Permanence and Care of Color Photographs: Traditional and Digital Color Prints, Color Negatives, Slides, and Motion Pictures*. Grinnell, Iowa: Preservation Publishing Company, pp.124–137. Available at: http://wilhelm-research.com/pdf/HW_Book_01_of_20_HiRes_v1c.pdf (Accessed: 20 February 2025).

Wilker, A. (2004) *The Composition and Preservation of Instant Film*, University of Texas, Austin.

Whitmore, P.M. and Bailie, C. (1999) 'Predicting the Fading of Objects: Identification of Fugitive Colorants Through Direct Nondestructive Lightfastness Measurements', *Journal of the American Institute for Conservation 38*(3), pp. 395–409

Contemporary Views on Color: Research and Applications between Science, Culture and Design

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ABSTRACT

This review analyzes contributions that testify to the vitality and plurality of approaches with which color remains the object of study and reflection in the most diverse disciplinary fields, which embrace a broad and articulated thematic arc. It ranges from visual perception and sensory correspondences to the aesthetics of sustainable and inclusive design through communication strategies in the financial, marketing, and cultural fields to the conservation of photographic heritage and critical reflection on chromatic symbolism. A common thread emerges clearly: the centrality of color as a tool of meaning and mediator between perception, culture, and technology. The set of research offers an updated and in-depth cross-section of current research on color through methodologies that intertwine empirical investigation, semiotic analysis, visual experimentation, study of design practices and technical-scientific evaluation of materials. This variety reflects the intrinsically transdisciplinary nature of color studies, which are nourished by the dialogue between the hard sciences and the human sciences, between laboratory experimentation and field applications, and between the most advanced technologies and the symbolic and anthropological dimension. The text is, therefore, configured as a coherent and stimulating mosaic, capable of reflecting the richness of perspectives with which color continues to be questioned in contemporary times.

KEYWORDS (Color, Transdisciplinarity, Perception, Symbolism, Inclusion, Sustainability)

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1. Introduction: Research Themes and Trajectories

1.1. *Color, Perception, and Multi-sensory Communication*

The topic of the visual and sensorial experience of color is addressed by two studies that, although with different methodologies, share an interest in subjective perception and the role of display technologies in determining chromatic effects. The research by Phuangsuwan, Mepean, Ayama, Mizokami, and Ikeda, (Phuangsuwan *et al.*, 2025) and analyzes the effects of Simultaneous Color Contrast (SCC) through three different display techniques: printed paper, LCD display, and the so-called "two-rooms technique". The results highlight how the display device and the perceptual mechanisms involved strongly influence simultaneous contrast. While in the cases of paper and LCD, the phenomenon seems to depend on the chromatic induction of the surrounding colors, in the case of the two-rooms technique, a combination of chromatic adaptation and induction is observed, which generates more marked effects (Phuangsuwan & Ikeda, 2018). The data obtained, analyzed with ANOVA, and compared with the theories of opposing and complementary colors show how the complementary color theory provides a more accurate prediction of hue shifts than the opponent color theory, in accordance with Pridmore (2007).

In a similar field but oriented to the sensorial and applicative dimension of marketing, Alessandro Bortolotti explores the cross-modal correspondences between color and other senses through the lenses of neuromarketing. The research highlights how color, especially red, can amplify the perception of sweetness or sensorial intensity and underlines the importance of an integrated multi-sensory strategy to build memorable experiences and lasting emotional relationships with the brand. Spence and Gallace (2011) observed that multi-sensory design is configured as a powerful tool to influence consumer behavior in a profound and often unconscious way. Sight, which conveys up to 80% of environmental information (Hutmacher, 2019), is confirmed as the key sense in designing products' visual and chromatic identity.

1.2. *Color, Sustainability, and Inclusion in Design and Fashion*

This section collects themes that deal with color concerning sustainable and inclusive design practices, focusing on fashion and the representation of diversity. The study by Dantas, Curth, Teixeira, Soares Junior, and Batista (Dantas *et al.*, 2025) focuses on the role of color in communicating sustainability values in two Brazilian slow fashion footwear brands, Vegalli and Urban Flowers. The semiotic and visual analysis of 33 models reveals a prevalence of achromatic and earthy tones, such as black, brown, and beige, associated with durability, functionality, and connection with nature (Jung & Jin, 2014; Holtzschue, 2012). The calibrated use of bright colors — green, orange, red — helps to evoke emotions and exclusivity, significantly when declined in low-saturation artisanal patterns, which generate a nostalgic and familiar atmosphere. This chromatic strategy expresses an effective synthesis between aesthetics and environmental responsibility, in line with the reflections of Şener et al. (2019) and Dong et al. (2023).

The research by da Ribeiro, Schemes, and Dantas, (Ribeiro, Schemes and Dantas, 2025) instead, proposes an innovation in the field of inclusive fashion for people with visual impairment. Through qualitative and ethnographic methodologies, the authors present the tactile system "See Color", which allows blind people to independently select clothing colors, enhancing personal identity and promoting social participation. The device, which introduces a multi-sensory dimension in color analysis, strengthens the autonomy and self-esteem of users, transforming fashion into a tool for cultural inclusion (Kukiełko, 2024; von Busch, 2018). The approach is distinguished by the direct involvement of stakeholders in the design process, underlining the importance of accessible and co-participatory design.

In the review by Renata Pompas (Pompas, 2025) — Rose. Une couleur aux prises avec le genre (Bideaux, 2023) — an encyclopedic reflection on the color pink and its links with gender, sexuality, social class, and identity politics. The author's dense analysis of the book crosses different fields, from feminist movements to queer culture, from children's marketing to contemporary art, questioning the polysemy of pink: the color of submission and rebellion, of marginality and vindication. As highlighted, pink has gone from a symbol of "feminization" to a potential tool for cultural "re-signification" within the framework of a critical reflection on the relationship between aesthetics, power, and representation.

1.3. *Colour, Symbolism, and Conservation in Cultural Heritage*

Two studies address the issue of color in the context of the conservation of photographic materials and symbolic interpretation in specialized fields, with a technical-scientific and analytical approach.

The study by Hofmann and Hofmann-Sievert (Hofmann and Hofmann-Sievert, 2025) proposes a method to predict contemporary photographic materials' light stability through controlled exposure to monochromatic LEDs. The results show that pigment systems are more stable than dye systems and that light sensitivity is concentrated in the 400–550 nm range. The predictive approach proved effective for all the materials tested, except silver salt prints, indicating that selecting the least harmful exposure light can help preserve the works over time. The research follows the investigations of Wilhelm (2004) and the more recent works by Ishizuka et al. (2019) and Thickett and Grøntoft (2023), contributing to the definition of good practices for museum lighting, in particular for fragile or historical materials.

In a related field, Miąsik, Pénichon, Granzotto, and Sutherland (Miąsik *et al.*, 2025) present an in-depth technical-material analysis of the famous Polaroid 20×24, large-format instant photographs used by artists such as Warhol or Wegman. Through non-invasive and micro-invasive techniques, such as SEM-EDS, FTIR, and Py-GCMS, the study characterized the different layers and components of the materials, also identifying specific degradation products, such as hypoxanthine in P7 prints. Micro-discoloration tests highlighted a constant vulnerability to light in all generations analyzed, suggesting precautionary exposure and conservation conditions. The interdisciplinary approach employed contributes significantly to the knowledge and protection of these iconic artistic objects, which are at the center of modern research in the field of conservation (Pénichon, 2013; Casto & Valverde, 2019).

Of particular importance is the research by Prusak and Mushafiq (Prusak and Mushafiq, 2025), which addresses a still little-traveled research field: the symbolism of color in finance, studied through a CAWI survey on a sample of 60 experts in the sector. The survey revealed significant associations between colors and financial concepts, such as black for illegal activities, green for ecological finance, or gold for long-term savings.

These results, although preliminary, suggest that color can act as a non-verbal semantic code even in professional and highly codified contexts, opening new perspectives for visual communication in the economic field. As Broeder (2022), Barbato et al. (2019), and Tallarita (2017) recall, color symbolism has deep cultural roots, but its application in the financial field remains an area to be explored more systematically.

2. Transversal thematic reflections

The review of the research proposed in the previous section offers a rich and varied overview of color as an object of study and an operational tool. Beyond the disciplinary specificities and applicative contexts, it is possible to identify some common trends that testify to the emergence of new theoretical and methodological trajectories in color studies.

2.1. *Color as a cultural and codified language*

In several contributions, the idea of color as a stratified cultural code, which conveys social, political, economic, and symbolic meanings, emerges forcefully; this is the case, in particular, of Prusak and Mushafiq's work on chromatic symbolism in finance, which highlights how professionals in the sector attribute functional and shared meanings to specific shades, even without an official codification (Prusak and Mushafiq, 2025). Black, for example, is associated with the underground economy and illegal practices. At the same time, green takes on the dual meaning of sustainability and economic growth, with significant cultural variations between the West and the East.

Renata Pompas' review of Kevin Bideaux's volume also bears witness to the complexity of the color pink as a multivalent symbolic device, which crosses gender constructions, marketing strategies, social movements, and artistic representations. Pink reveals itself to be both a color of exclusion and affirmation, of stereotype and claim, confirming its profoundly polysemic nature, capable of reflecting identity and cultural tensions (Bideaux, 2023; Pompas, 2025).

Similarly, Dantas et al.'s contribution on color in Brazilian slow fashion shows how color choices are never neutral but reflect a conscious communicative intent rooted in ethical, aesthetic, and territorial values. The use of natural and desaturated tones, as well as the targeted use of vibrant colors, is part of a visual narrative that articulates sustainability, craftsmanship, and local identity (Dantas *et al.*, 2025).

2.2. *Color as a relational and situated phenomenon*

A second recurring dimension is that of color as a situated experience, strongly dependent on the perceptual, environmental, technological, and sensorial context. The studies on Simultaneous Color Contrast (SCC) by Phuangsuwan et al. and on cross-modal correspondences in neuromarketing by Bortolotti, although with different approaches, converge in underlining how color perception is not an objective fact but a dynamic and relational process, influenced by the configuration of space, the presence of objects, lighting conditions and interactions with other sensorial stimuli (Bortolotti, 2025; Phuangsuwan *et al.*, 2025).

In particular, research on SCC shows how the same color composition can generate different effects depending on the visualization medium, visual adaptation, and environment characteristics, offering relevant implications for lighting design, exhibition design, and digital representation of color. Similarly, Bortolotti's study highlights how cross-modal perception of color is strategically exploited in experiential marketing, where the coherence between visual, olfactory, and auditory stimuli contributes to the construction of brand identity (Bortolotti, 2025).

The situated nature of color is also at the center of the research by Ribeiro et al., where color is translated into tactile language for people with visual impairments. Here, the chromatic experience emancipates itself from the visual dimension alone, showing how color can be experienced through touch, symbolically reinterpreted, and acted as a tool for autonomy. The multi-sensory and inclusive perspective that emerges from this study opens interesting prospects for accessible design and for the redefinition of aesthetic codes in a more equitable and participatory way (Ribeiro, Schemes and Dantas, 2025).

2.3. *Color as a relational and situated phenomenon*

Finally, several contributions propose color as a technical and scientific object central to the processes of conservation and evaluation of the stability of materials. The studies by Hofmann & Hofmann-Sievert and Miąsik et al. rigorously address the issue of chromatic degradation in conditions of exposure to light, proposing predictive models and advanced analytical methods to evaluate the stability of dyes (Hofmann and Hofmann-Sievert, 2025; Miąsik *et al.*, 2025).

In both cases, the need for differentiated approaches is highlighted depending on the type of material, the structure of the supports, and the characteristics of the light used. Research shows that chromatic stability is a complex parameter that cannot be deduced solely from the nature of the dye but depends on multiple interactions, such as the presence of UV absorbers, the stratigraphy of the materials, and the spectral quality of the lighting; this requires renewed attention to the conditions of museum exhibition, suggesting the use of LED lights with calibrated spectrum and, where necessary, selective filters.

In the case of the Polaroid 20×24, the chemical-structural analysis allows not only the identification of the vulnerabilities of the materials but also the recognition of the different generations of printing, contributing to a correct attribution and valorization of the works. These results confirm the importance of integrating scientific skills in curatorial and conservation processes and strengthening the dialogue between technology and cultural heritage.

3. Conclusions

This review clearly shows the conceptual density and operational breadth of color studies in the contemporary context. The research presented — conducted by the cited authors from heterogeneous disciplinary and cultural backgrounds — outlines a complex and up-to-date panorama in which color is simultaneously configured as a perceptual phenomenon, cultural symbol, design tool, scientific object, and social vector.

The first element that emerges strongly is the transversality of color as a field of study. The research presented here is not limited to a disciplinary domain but crosses neuroscience, psychology of perception, design, fashion, marketing, economics, art history, conservation of cultural heritage, and gender studies. This transversality not only enriches theoretical perspectives but invites us to reflect on the need to consolidate interdisciplinary methodological approaches capable of grasping the complexity of chromatic phenomena in their situated, dynamic, and relational dimensions.

A second significant aspect concerns the intensification of the dialogue between scientific research and design practice. Studies on the chromatic stability of photographic materials and on the perception of color in controlled environments provide helpful evidence for defining exposure, conservation, and restoration protocols (Hofmann and Hofmann-Sievert, 2025; Miąsik *et al.*, 2025; Phuangsuwan *et al.*, 2025). At the same time, investigations conducted in the fields of fashion, marketing, and inclusion, show how chromatic design, if conscious and informed, can act as a lever for environmental sustainability, social equity, and emotional involvement (Bortolotti, 2025; Dantas *et al.*, 2025; Ribeiro, Schemes and Dantas, 2025). Of particular importance are also the reflections on color as a cultural and semiotic device capable of generating meaning, building identity, and conveying values. In this sense, the analysis of pink as a gendered color (Bideaux, 2023; Pompas, 2025) and the pioneering investigation into chromatic symbolism in finance (Prusak and Mushafiq, 2025) open up still little-explored research spaces, suggesting that color — far from being a mere aesthetic ornament — acts as a social and political code, whose meaning is always situated, negotiated and potentially transformative.

These considerations converge in outlining some future lines of development for color studies. On the one hand, the importance of deepening the link between color and digital technologies emerges, especially in the fields of visualization, artificial intelligence applied to color perception, and interactive communication. On the other, there is an urgent need to consolidate research on color and inclusion, promoting design practices that enhance perceptual and cultural diversity and that are capable of restoring agency and autonomy to historically marginalized subjects.

4. Conflict of interest declaration

The author declares that nothing has affected his objectivity or independence in producing this paper. 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 members 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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Licensing terms

References

Barbato, G., Bellia, L. and Morone, A. (2019) 'How the colours of objects and light affect human emotions, performance and health. The need for a holistic approach to design indoor environment', Cultura e Scienza del Colore / Color Culture and Science Journal, 11(1), pp. 67-73. Available at: https://doi.org/10.23738/CCSJ.110108

Bideaux, K. (2023) Rose: Une couleur aux prises avec le genre. Illustrated édition. Paris: Editions Amsterdam.

Bortolotti, A. (2025) 'Exploring crossmodal correspondences through neuromarketing', Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 36–44. Available at: https://doi.org/10.23738/170103.

Broeder, P. (2022) 'Colours of Emotion, Trust, and Exclusivity. A Cross-Cultural Study', Cultura e Scienza del Colore / Color Culture and Science Journal, 14(2). pp. 14-21. Available at: https://doi.org/10.23738/CCSJ.140202.

Casto, S. and Valverde, F. (2019) 'Hinging and Float Mounting 20×24" Polaroid Prints and Negatives', in Topics in Photographic Preservation 18, pp. 1–3. American institute for conservation - Washington, D.C.

Dantas, Í.J. de M. et al. (2025) 'Is there a color for sustainability in fashion products? A case study with Brazilian slow fashion footwear', Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 45–56. Available at: https://doi.org/10.23738/170104.

Dong, Z.-J. et al. (2023) 'The Perceptual Evaluation of Clothing Sustainable Color in Clothing Design', Journal of Fiber Bioengineering and Informatics, 16(3), pp. 229–241. Available at: https://doi.org/10.3993/jfbim02351.

Hofmann, M. and Hofmann-Sievert, R. (2025) 'Predicting the Light Stability of Contemporary Photographic Print Materials', Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 72–81. Available at: https://doi.org/10.23738/170106.

Holtzschue, L. (2012) Understanding Color: An Introduction for Designers. 4th edition. John Wiley & Sons Inc.

Hutmacher, F. (2019). Why is there so much more research on vision than on any other sensory modality? Frontiers in Psychology, 10, Article 2246. Available at: https://doi.org/10.3389/fpsyg.2019.02246.

Ishizuka, H.; Groen, E.; Uchino, N.; Shibahara, Y. and Soejima, S. (2019) 'Image Permanence of Photographic Prints under LED lighting' Proceedings of the NIP & Digital. Fabrication Conference, San Francisco, CA, USA, 29 September–2 October 2019; pp. 192–196, Available at: HTTPS://DOI.ORG/10.2352/issn.2169-4451.2019.35.192

Jung, S. and Jin, B. (2014) ‘A theoretical investigation of slow fashion: sustainable future of the apparel industry’, International Journal of Consumer Studies, 38(5), pp. 510–519. Available at: https://doi.org/10.1111/ijcs.12127.

Miąsik, P. et al. (2025) ‘An investigation into the structure and color stability of Polaroid 20×24 prints’, Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 82–91. Available at: https://doi.org/10.23738/170107.

Penichon, S. (2013) Twentieth-Century Color Photographs: Identification and Care. Los Angeles: J Paul Getty Museum Pubns.

Phuangsuwan, C. and Ikeda, M. (2018) ‘Simultaneous color contrast demonstrated on different devices’, Journal of the Color Science Association of Japan, 42(3+), p. 54. Available at: https://doi.org/10.15048/jcsaj.42.3__54.

Phuangsuwan, C. et al. (2025) ‘Effect of display techniques on simultaneous color contrast’, Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 23–35. Available at: https://doi.org/10.23738/170102.

Pompas, R. (2025) ‘Rose. Une couleur aux proses avec le genre.: BOOK REVIEW’, Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 97–99.

Pridmore, R.W. (2007) Chromatic induction: Opponent color or complementary color process?, Color Research and Application, 33(1), pp. 77–81. Available at: https://doi.org/10.1002/col.20363

Prusak, B. and Mushafiq, M. (2025) ‘Interpreting colour symbolism in finance- Insights of financial expert’, Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 7–22. Available at: https://doi.org/10.23738/170101.

Rana, Md.R.I., McBee-Black, K. and Swazan, I.S. (2024) ‘Adaptive apparel for people with disabilities: A systematic literature review and future research agenda’, International Journal of Consumer Studies, 48(3), p. e13057. Available at: https://doi.org/10.1111/ijcs.13057.

Ribeiro, F., Schemes, C. and Dantas, Í.J. de M. (2025) ‘Tactile coloration for inclusive fashion: the role of “See Color” in enhancing autonomy for individuals with visual impairments’, Cultura e Scienza del Colore - Color Culture and Science, 17(1), pp. 57–71. Available at: https://doi.org/10.23738/170105.

Şener, T., Bişkin, F. and Kılınç, N. (2019) ‘Sustainable dressing: Consumers’ value perceptions towards slow fashion’, Business Strategy and the Environment, 28(8), pp. 1548–1557. Available at: https://doi.org/10.1002/bse.2330.

Spence, C. and Gallace, A. (2011) ‘Multisensory design: Reaching out to touch the consumer’, Psychology & Marketing, 28(3), pp. 267–308. Available at: https://doi.org/10.1002/mar.20392.

Tallarita, A.L. (2017) 'Red: the symbol in history', Cultura e Scienza del Colore / Color Culture and Science Journal, 7, pp. 7-11. Available at: https://doi.org/10.23738/ccsj.i72017.01.

Thickett, D. and Grøntoft, T. (2023) 'Review of Interpreting Gaseous Pollution Data Regarding Heritage Objects' Heritage, 6,pp. 6917–6930. Available at: HTTPS://DOI.ORG/10.3390/heritage6100361

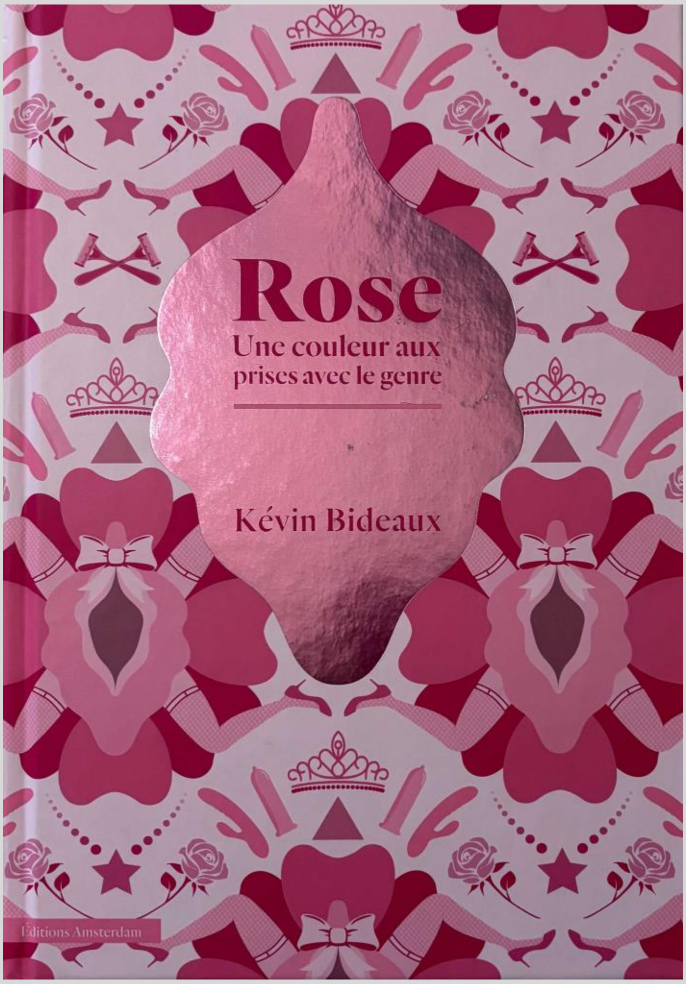
von Busch, O. (2018) ‘Inclusive Fashion—an Oxymoron—or a Possibility for Sustainable Fashion?’, Fashion Practice, 10(3), pp. 311–327. Available at: https://doi.org/10.1080/17569370.2018.1507145.

Wilhelm, H. (2004) 'A Review of Accelerated Test Methods for Predicting the Image Life of Digitally-Printed Photographs—Part II'. Proceedings of the IS&T's International Conference on Digital Printing Technologies, Salt Lake City, UT, USA, 31 October 31–5 November; pp. 664–669

BOOK REVIEW: Rose. Une couleur aux proses avec le genre.

Renata Pompas

ROSE. Une couleur aux proses avec le genre (Bideaux, 2023)**.** [French language]



Kevin Bideaux is a French artist with a master's degree in fine arts from the Université Paris 1 Panthéon-Sorbonne and a doctorate in arts and gender studies from the Université Paris 8 Vincennes-Saint-Denis. Pink is his magnificent obsession: involved in gender studies and a member of the Laboratory of Gender and Sexuality Studies, he has colored his own body, his environment, and his artwork pink.

Who better than he could have written the cultural and symbolic history of pink in relation to gender and sexuality, race, and social class? The book is dense, encyclopedic, and analytical, based on extensive written and visual documentation. A truly interesting book that I recommend reading: 527 pages, 240 iconographic references, and 568 accurate bibliographic references.

In addition to the brief Prologue, the book is divided into 9 chapters, of which I will try to sketch a very brief thematic summary, which cannot convey the cultural richness of the chapters themselves.

1. Not so old rose. At the origins of a colour

Bideaux documents how the word "rose" to indicate not only the flower but also the colour was only integrated into the lexicon during the 18th century, today considered subordinate and accessory in colour systems. Its commercial affirmation as an artificial dye in the mid-20th century transformed it into the image of the utopia of plastics, with their promise of a colourful and glossy world.

2. In the flesh and in pink. Whiteness, femininity, and (hetero)sexuality

Through the contributions of numerous scholars, the author demonstrates the link between the rosy hue with which the complexion is represented in Western culture, its universalization, and the social, cultural, and political hegemony of the white population in opposition to black skin. A sexualized hue as an image of pleasure in women and as a homoerotic feminization in men, used to represent both virginal whiteness and pornography.

3. The age (of the) rose. The emergence of rose as a symbol of femininity in the 18th century

With an original description of the visual culture of the 1950s - called "the pink decade" - in clothing, furnishings, cinema, advertising, video games, video clips, and album covers, the book demonstrates the ability of pink to be universally identified as a metaphor for the feminine.

4. Pink = woman. An aestheticization of gender

When did fashion for infants abandon white and light colors to define gender with pink and blue? In the West, this trend emerged as early as the 19th century but became widespread in the 1950s when the parental tendency to anticipate children's personalities by establishing gender differences through the preservation of heterosexuality spread. In adult fashion, the violent magenta tinged with violet of Elsa Schiaparelli's "shocking pink" from 1937 contrasts with the delicate conservative pink of Christian Dior's 1946. The many shades of pink presented in cinema contrast, among others: the soft pink of Glinda in "The Wizard of Oz" from 1939, and the magenta of Marilyn Monroe's dress in "Gentlemen Prefer Blondes" from 1953. Bideaux examines numerous animated cartoons, both Western and Eastern."

5. I looooove pink!

Deconstructing a feminine preference
It is interesting to read how certain neuroscientific, sociological, and philosophical studies have attributed women's preference for pink to genetic, biological, and physiological origins, among others, neglecting the role of education in defining gender: a "feminized" color that, if adopted by men, is often interpreted as a sign of gender nonconformity.

6. Market in pink. Pink, gender and marketing strategies

With the term "pinkification" the role of marketing in spreading the pink-feminine stereotype is indicated. Bideaux describes the phenomenon through the strategies of creation and communication of toys for girls, both in products and in advertising campaigns, and broadens his view on themed works of art. Among the toys, the history of the Barbie doll, for which the manufacturer Mattel has deposited with Pantone in 2011 the "Barbie pink", an intense and bright pink to feminize and eroticize the doll, and that of Hello Kitty, a Japanese doll that corresponds to the concept of "kawaii" (cute), referring to a set of sweetness, innocence, purity, simplicity, kindness, but also weakness and inexperience as the values that are asked of girls. Many of the themes related to the chapter are addressed by semiotics, philosophy, psychoanalysis, which demonstrate the antinomy of the meanings of pink.

7. Pink power. Pink (post) feminism and (post) feminists

This chapter offers an in-depth examination of the colors associated with the early Suffragette movements, exploring the themes of feminism, post-feminism, trans-feminism and cyber-feminism. From yellow to purple, to the green-white-purple triad, from lavender to violet, all the way to pink delicate or intense (magenta?) which opens a debate within the movements on its use as subjugation or denunciation of a stereotype. Bideaux broadens the analysis to television series, ballet choreography and celebrity self-promotion. If pink is conceived as incompatible with roles of power and responsibility, the author wonders whether the meaning of the color is undergoing a transformation: a re-signification, a de-signification or an enrichment of its polysemy within which everyone can choose to express themselves?

8. Men and pink. A symbolic incompatibility with the masculine

This is perhaps the most 'political' text, in the sense that it analyzes the contradictions of the symbolism of the rose, incompatible with masculinity, even if it is documented how in the past, when it was considered a light red and therefore did not have the same meaning, it was also present in aristocratic male clothing. 'Political' insofar as it reveals the contradictions of some artistic, cinematic, musical, and visual culture expressions that adopt pink in an apparent social criticism of gender, but in reality reinforce traditional meanings. Used by the African SAPE community in the 1950s (French acronym indicating a youth movement with a strong sense of aesthetics and elegance) and then exported to Belgium and France in the 1980s, today it is used in a male context for its communicative ability to stand out and attract attention.

9. Proud to be pink. Gay and queer demands

In the last chapter, there is a careful dissertation on the reappropriation of pink - the most serious stigmatization of which is represented by the pink triangle hat the Nazis' forced 10,000 men suspected of homosexuality, confined in Lager, to wear - and its reclamation by various civil rights movements Gay, Lesbians, Queer e Drag Queen. A symbolic polysemy that unites oppressors and activists denouncing oppression. As in the entire book, the documentation is very rich, from the writings of intellectuals to street demonstrations, from artistic performances to pinkwashing of some commercial brands.

Epilogue. The pot of roses

The author declares their ambition to deconstruct the complex, contrasting, symbolic, political, social, and artistic system of the rose analyzed thus far, to open it up to a multiplicity from which each can draw according to their own needs.

A most beautiful book which I recommend to the entire "color community".

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References

Bideaux, K. (2023) *Rose: Une couleur aux prises avec le genre*. Illustrated édition. Paris: Editions Amsterdam.