9th Conference
Information and Graphic Arts Technology

University of Ljubljana
Faculty of Natural Sciences and Engineering
Department of Textiles, Graphic Arts and Design
Chair of Information and Graphic Arts Technology

9th Conference on Information and Graphic Arts Technology

PROCEEDINGS

11.–12. April 2024, Ljubljana, Slovenija

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Faculty of Natural Sciences and Engineering

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PUBLISHER
University of Ljubljana, Faculty of Natural Sciences and Engineering in Ljubljana Department of Textiles, Graphic Arts and Design
Chair of Information and Graphic Arts Technology

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June 2024

Kataložni zapis o publikaciji (CIP) pripravili
v Narodni in univerzitetni knjižnici v Ljubljani.

COBISS.SI-ID **197157891**

ISBN 978-961-7189-12-4 (PDF)

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University of Ljubljana, Faculty of Natural Sciences and Engineering in Ljubljana
Department of Textiles, Graphic Arts and Design
Chair of Information and Graphic Arts Technology

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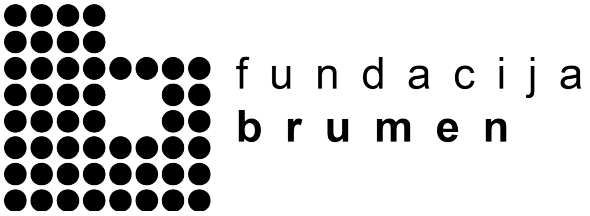
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STATE AND FUTURE OF PRINT AND THE ROLE OF THE GWG IN THE PRINT COMMUNITY

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Abstract: With the shifting market directions of print procurement and manufacturing, and the evolution of production equipment and processes, a lot needs to be addressed to satisfy the new requirements and facilitate the current and future processes of the Print Manufacturer and their customers base. Many workflow software and professional service offerings are being developed to support newer disparate technologies and markets. Ultimately solutions need to fit the specific needs of a PSP their offerings, their customers and partner relationships, and the increased growth rates.

1. GLOBAL ECONOMY

According to the International Monetary Fund (IMF), the post pandemic inflation and the drivers that created it are moderating and they expect a »soft landing and projected continued global growth of 3.1% in 2024 and 3.2% in 2025«. This is good news for print manufacturing, and especially packaging and industrial print, provided we are in a place to take advantage of it. Of course, the amount of growth projected varies by region.

The global pandemic has and will continue to have an impact due to lessons learned from disruptions in the supply chain, shifts in consumer purchasing, and labor availability pressures in the short and medium term, with some affects in the longer term. Packaging and industrial print will continue to be important and will ensure the evolution of print manufacturing is secure during the transition and beyond.

2. THE STATE OF THE PRINT INDUSTRY

The print industry, which in the minds of many has been in decline, has actually been going through a major evolution since the introduction of digital technologies. This evolution has not just evidenced itself in the development of new equipment, it has also altered the way that print is manufactured, used and the applications it is used for. In the past, the vast majority of print was manufactured by dedicated printing companies, publishers and packaging converters, yet today it is also being performed as an integral part of manufacturing in many fields. These shifts are adding to the growth of print manufacturing in general.

The 9th drupa Printer Barometer, which is developed based on polling over 600 printers and suppliers, projects »very positive expectations for 2024«. While the expected growth enthusiasm is positive, the degree of growth will be commensurate with regional economic growth. Since Flexographic printing is still the predominant printing technology, it would be good to look at the Smithers Report; The Future of Flexographic Printing Markets to 2027 to help gage some of the growth drivers. »The rise of urban living and mega-cities mean packaging-based supply chains are critical in serving these growing population centers and driving flexo volumes«.

Furthermore, »Population growth and the expansion of the middle class in the newly industrializing economic growth areas will continue to provide a strong balance against the more stagnant growth in the well-established economies. The increase in consumer demand for product segmentation and personalization combined with the rise in the number of households with decreasing occupancy, will result in the increase in new products and packaging growth. Since packaging is the predominant product for flexo output, population growth and habits provide the fuel for growth«. Add to this the increase in print in non-traditional industrial print applications, and you can begin to see the true picture of print manufacturing,

3. INDUSTRY TRANSFORMATION

In order to support the shifting requirements, there is a need to develop technologies and processes that will support a connected world and the demands it brings. Today, there is little data sourcing or supply chain collaboration and production is predominantly comprised of silos of automation. Most of this can be attributed to the state of the individual process partners and their adoption of a more holistic view. However, even taking that into account PSPs should be preparing their businesses to support the inevitable future.

Recently many of the industry hardware manufacturers have started to develop the necessary data connectivity support into their products and moved to the cloud, providing communication between products and systems. Many of these are standalone systems that exist with integration provisions. While many of these manufacturers are envisioning systems that will support supply chain and production automation, understandably they are developing solutions that tend to be weighted toward using their own products in an end-to-end solution. This can only be accomplished at scale with the development and introduction of data standards and best practices.

4. THE HEART OF AI IS MACHINE LEARNING

Business and production data has significant value and will become even more important in the future. In addition to automating and connecting processes, you can also use this captured downstream and upstream data for longer term machine learning. Data is really the life blood of machine learning, and machine learning is what will ultimately pave the way to full Artificial Intelligence (AI) supply chain automation and i4.0 and i5.0.

Most of the AI that we see today in print and packaging systems are based around Machine Learning (ML), which is really the lifeblood of AI. In ML, today the primary product is process analysis, although the machine or software could have the ability to modify its behavior dynamically when exposed to more data. The ‘learning’ part of machine learning describes the ML algorithms which attempt to optimize behavior along a certain dimension. There are quite a few machine learning and connection platforms, and more in development. Many large organizations are capable of building machine learning models on these platforms in-house, using open-source frameworks.

5. THE ‘SMART’ FACTORY

Connecting and automating devices in production is really not new, however using machine learning and artificial intelligence (AI) to interpret the data and convert it into actionable information to make automated business and production decisions is, and we are now seeing more solutions that are either including or envisioning that enhanced functionality.

6. STANDARDS AND BEST PRACTICES FACILITATE

The Ghent Workgroup (GWG) has been envisioning many of these developments for decades and developing standards and best practices that can support these new and shifting requirements. These are all targeted at ‘blind exchange of data’ in support of more automated production and business processes.

Keywords: connected processes, machine learning, print transformation, standards

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PREFLIGHT AND ITS ROLE IN PRINT PRODUCTION

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Preflight is a concept of evaluation of the quality of submitted material and verification of its adequation to the print conditions.

Since the graphic chain consists of many stakeholders throughout the creative, layout, prepress and printing process, from the design agency to the printer, it is essential that the original design intent is not damaged by the various actions that need to be applied to make the document suitable for printing and that the printed result conforms to the original idea.

The idea of preflighting emerged in the early 1990s with the aim of checking the technical aspects of a file to ensure that are no problems during RIP processing of the file. It began as a list of items that experienced prepress operators should check to eliminate costly errors and facilitate smoother production. The first commercial application, Markzware FlightCheck, appeared in 1995 and focused on checking native files from authoring applications, mainly QuarkXPress at the time.

At the end of the 1990s, the PDF format became the main medium for exchanging files between players in the graphics chain, offering a universal file format between the different applications used in the chain and transferring control actions from native files to PDF files.

The need for preflight was therefore to offer the assurance that the PDF files exchanged would be perfectly usable in the rest of the process in order to avoid production downtime or backtracking. Each player in the chain could both check their file against a defined set of specifications to verify the quality of their work and, when a file was received by a previous player, to guarantee that the file received complied with the specifications to ensure smooth operation afterwards.

This technical preflight focused on key technical issues such as font encapsulation, color reference systems and knockout and overprint information. With the introduction of web2print platforms, end customers were able to choose directly from a catalog the finished product they wished to have produced (business card, flyer, brochure, etc.), and attach the source file required for production to their order. As a result, the web2print system was able to attach a job ticket describing the product to the source file received by the platform and submitted to the workflow.

Access to this essential production information has enabled the introduction of a completely new approach to preflight, with the addition of content verification to purely technical checks. Indeed, thanks to the use of information contained in the job ticket, it is now possible to check that the document, in addition to being technically correct, corresponds to the product ordered. In particular, it is now possible to check that the document size is as expected, that the number of pages supplied is correct, etc. In addition to making workflow more fluid, these new controls facilitate communication with the end customer, offering more responsive customer service.

Is it perfect? No, there are still areas to be explored to facilitate the use of customer files, which are not always perfect, and contain problems which, for some, are still very difficult to correct without manual action by a prepress operator. We could mention, for example, bleed generation, necessary to guarantee a good result when cutting the finished product, or the image resolution, which may be too low to offer an excellent rendition of the finished product.
In a world where margins are shrinking sharply on orders with equally shrinking quantities, even down to the production of single-unit prints (in the case of customized products), it is obviously unthinkable to devote operator time to solving these problems, and it is key to be able to use an automated mechanism to address them in an economically viable way.
In an upcoming future, this is where the use of artificial intelligence (e.g. generative AI) will come into play to, for

example, generate the missing bleed content in a natural way without the intervention of an operator, or to be able to extrapolate information from a low-resolution image to improve rendering. As a result, even with lower-quality source documents, or those produced by non-professional users with no particular knowledge, it is possible to produce top-quality printed documents with minimum effort.

Keywords: preflight, automation, web2print, AI

References:

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PDF 2.0 AND PDF/X-6

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PDF, Portable Document Format, was originally developed by Adobe Inc. and first introduced in 1993. The format was enhanced with new features over the years until Adobe transferred ownership of the format to the ISO organization in 2008. It was released as ISO 32000-1, and it was equivalent to version 1.7 of the format.

On the 28th of July 2017 ISO 32000-2 was published, also known as PDF2.0. It was the first revision that was entirely developed by the ISO organization.

At the low level the format is unchanged. The changes fall into four categories: documentation changes, extensions of existing functionality, new functionality, and deprecated functionality.

The documentation changes represent the bulk of the changes. Next to the inevitable typing errors and wrong references for a document of that length and complexity, there were quite a few aspects of the format specification that were open to interpretation and that required clarification. The chapters on Rendering (10.1 – 10.3), Transparency (11) and Metadata (14.3), to name just the chapters that are the most important ones for the graphic arts industry, were substantially rewritten.

Here are some examples of existing functionality that was extended. The document encryption may now use 256-bit AES encryption, it was 128-bit before. Annotations may now use transparency and blend mode attributes. Defining an output intent was only allowed at the document level, PDF2.0 now allows it at the page level as well. PDF1.7 did not specify an encoding for font names and spot colour names, which could lead to a misinterpretation when non-Latin characters were used. PDF2.0 specifies that such names must be UTF-8 encoded.

Among the new functionality we find the introduction of a geospatial coordinate system, the possibility to reference output intents instead of having to embed them in the PDF document, the graphics state dictionary can now include information about the halftone origin and the use of black point compensation.

For the first time features have been deprecated. The most notable change is that the Info dictionary, the place where information like the title, the author, the subject, the producer, etc. should no longer be added to a PDF; this should now be added to the XMP section. The other deprecated features that have a bearing on the printing industry: OPI information, transfer functions in the graphics state, the TrapNet annotation, and arrays of blend modes.

The PDF/X specifications define a subset of PDF for use as a graphics eXchange format. This entails two aspects: PDF/X specifies features that must be present in a file even though they are not mandatory in generic PDFs, e.g. an output intent, and features that must not be present in a file although they are allowed in generic PDFs. Video, sound, and 3D are obvious examples. There are different versions of PDF/X, and they all base themselves on a specific version of PDF: PDF/X-1a:2001 was based on PDF 1.3, PDF/X-3 was based on 1.4, PDF/X-4 on 1.6. The PDF/X version that is based on PDF2.0 is PDF/X-6.

Keywords: PDF, printing

References:

Online

ISO 32000-2:2020: Document management, Portable document format, Part 2: PDF 2.0
https://www.iso.org/standard/75839.html

ISO 15930-9:2020: Prepress digital exchange using PDF, Part 9: PDF/X-6
https://www.iso.org/standard/77103.html

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THERMOCHROMIC MATERIALS FROM COMMERCIAL PRODUCTS TOWARDS THE INNOVATION

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Several decades ago, the term “smart materials” was unknown. However, research in different areas such as spectroscopy, materials chemistry, solar selective coatings, pigmented coatings, effect coatings and the like helped to become familiar with the new term. Materials are smart if they change one or more of their properties under controllable conditions. For use in graphics arts, materials that change their colour are particularly important. The interest in thermochromic materials was sparked in 2008 when our group at National Institute of Chemistry started to analyse the dynamic colourimetric properties of commercially available leuco dye-based thermochromic inks. Although the materials were introduced decades ago, there were no publications with such measurements. The first report on temperature-dependent colour changes was awarded the best paper at the IARIGAI congress in Stockholm in 2009. Shortly afterwards, the concise study was published in the journal Dyes and Pigments[1]. It became one of the most cited articles of 2010, although no new insights into mechanism of thermochromism was given. Instead, it was the first time when the dynamic colour change was properly analysed and evaluated. After this success, many studies were conducted on commercially available thermochromic inks[2,3]. The research included not only the leuco dye-based thermochromic inks but also those based on liquid crystals. The later have different properties and many unexpected characteristics that have not yet been investigated, and virtually no publications on dynamic colour properties have been found in the scientific literature[4,5].

Our biggest challenge was to prepare our own functional leuco dye-based thermochromic material, understand its basic properties and be able to manipulate the smart properties. Our goal was then to incorporate this material into microcapsules and use it as thermochromic pigments in inks. It has been a long and exciting journey involving many researchers[6-8].

All investigated thermochromic materials were reversible, meaning the colour change can be repeated as long as the functional material in the microcapsules retains its thermochromic properties. If protected from UV light and if not heated to excessively high temperatures, the reversible colour change can last for years without major changes[3].

Nevertheless, reversible leuco dye-based thermochromics did not find many applications except in advertising, decoration, and increasing the product’s attractiveness. One of the reasons for this could be the presence of colour hysteresis, which makes the appearance dependent not only on the temperature but also on how it was achieved – by heating or cooling. This “intrinsic memory” makes more precise applications complex and relatively impossible. These disadvantages can be overcome with irreversible thermochromics, in which the colour change occurs only once and remains permanent. This means that there is no colour hysteresis and no “intrinsic memory”, but only proof that the temperature has exceeded a characteristic value that causes a permanent colour change. In 2017, we undertook our first successful trials of irreversible thermochromic printing ink, laying the foundation for establishing the start-up company Mysteria Colorum – MyCol d.o.o. With our patent-pending technology, we can produce irreversible thermochromic indicators for colouration temperatures that can be selected in the range from −70°C to almost 180°C[9].

To tune the ink recipes in terms of colour contrast and the smallest temperature interval in which the colour change appears, proper specification of dynamic colour change has to be based on reliable measurement techniques. First of all, a good heating/cooling plate must be available. Any heating of the sample by excess light needed for spectroscopic measurements has to be avoided. In extreme temperature conditions (too hot or too cold), contact spectrometers can’t be utilised since the spectrometer detectors are affected. At low temperatures, moisture can condense on the samples, requiring dry ambient. The measurement should be protected from any ambient light. Tailor-made, unique solutions have successfully solved these problems. The unique measurement setup is an excellent experimental tool for colour measurements of temperature-sensitive prints over a wide temperature range, from −100°C to 250°C, in which our computer-controlled heating-cooling units operate[10,11].

Colour-changing smart materials are diverse, and the utilisation of “smartness” is based on sound interdisciplinary knowledge. We have contributed to the science and technology of thermochromic smart materials by properly defining the dynamic colour properties and by associating them with structural and phase changes of the material, thus uncovering some unknown details about this type of smart materials. The knowledge obtained by the research led to the introduction of innovative solutions that have been commercialised.

Keywords: smart materials, thermochromics, colour hysteresis, temperature-dependent colour measurement

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USER INTERFACE AND USER EXPERIENCE

COLORS AND COLOR HARMONIES FOR BETTER VISUAL SEARCH ON THE USER INTERFACE

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Abstract: *The paper aims to examine the impact of the use of color and color harmony in the interface design phase and review the literature on major factors that influence visual search on the interface. The research is motivated by the pivotal role of color in preattentive search and directing attention, crucial for effective visual search in interfaces. Issues related to the use of user interfaces arise from inadequate visual representation, which can lead to safety-related consequences for operators. Color is a key factor that addresses some of the problems related to visual search on the interface. Grouping interface elements by color can either facilitate or hinder the search within the interface, resulting in a higher or lower number of errors. The use of color combinations on symbols can either assist or hinder the use of the interface. This paper aims to analyze relevant literature on the aforementioned issues, providing recommendations for color usage in user interface design.*

Keywords: *color harmonies, user interface, visual search, aesthetics*

1. INTRODUCTION

The need for further research in the area of color usage in user interface design arises from the fact that numerous factors influence and interact with each other. The challenge of defining rules or standards related to colors in the interface is due to the presence of numerous influential factors. These factors cannot be easily isolated, compiled, and applied in a concise form. This paper aims to review the literature on the aforementioned issues and challenges in user interface design.

Issues related to the use of user interfaces for various purposes, including interfaces on digital printing machines, are reflected in inadequate visual representation, which can lead to safety-related consequences for operators. Interfaces such as air traffic control, military stations, and the management of systems in nuclear power plants require a very high level of cognitive resources and concentration (Andersen, 2019; Tabart, 2007). Also, in everyday situations, people may lack the attention or cognitive capacity to consciously process feedback (Bargh, 2006).

Color itself is a key factor that needs to be used appropriately to address some of the problems related to visual search on the interface. Color is one of the determining factors in the success of UI design in interaction with the audience (Hartadi, 2020). There are many color theories, systems, and color spaces that try to organize, explain, and put color into practical use. It is not mere beauty that rules and directs human behavior toward the user interface. Color harmony refers to the overall effect of two or more colors juxtaposed in the same time and space (Wang, 2006). In particular, the concept of color harmony emerged following centuries of evolution in the art of painting. In the Renaissance era, Leonardo da Vinci (Cast, 1979) introduced a theoretical approach to color harmony, while the German poet Goethe (Kohlhammer, 2004) also penned his theory on the subject. So far, no color harmony theory can cover all aspects of color harmony and solve all the problems in color harmony design (Wang, 2022b). During the 20th century, color science developed a quantitative and rational system for representing colors, establishing a precise relationship and systematic order among them. This laid a solid foundation for the formulation of contemporary color harmony theory. Prominent examples include Munsell's color harmony theory (Zhang, 2003), Ostwald's color harmony theory (Sakahara, 2002), and Moon-Spencer's color harmony theory (Moon, 1944) (Granger, 1953). The development of these color harmony theories transitions color design from subjective artistic expression, aligning it, to a certain extent, within the realm of engineering.

2. REVIEW OF THE SELECTED LITERATURE

2.1 Contemporary Studies on Color

Besides color theories developed in history, at present, the theory of color harmony continues to evolve, and color systems are constantly improved and perfected. Due to the intricate and comprehensive nature of color harmony, developing convincing mathematical rules that fulfill aesthetic criteria remains a challenging aspect in color harmony research, not yet reaching a comprehensive and practical stage.

Szabó F. et al. formulated multiple color harmony equations to articulate observers' perceptions of color harmony in both two- and three-color combinations. They also introduced a novel metric for light source color quality, termed the 'color harmony rendering index' (Szabó, 2009). Kim et al. introduced an approach for achieving a harmonious blend of an image and a color element. This method involves enhancing hue similarity between them, drawing on insights from designers (Kim, 2018). Hu et al. condensed color combination features into a six-dimensional model, including parameters like hue, chroma, brightness, and their respective spans. Recognizing individual preference as a key factor, they restructured the preferred color scheme to meet individual needs (Hu, 2015). To address the limitations of color harmony models relying solely on classical rules and overlooking image semantic information, Lu et al. incorporated image semantic features (multi-color perceptual and emotional features) to represent image content. This approach resulted in a color harmony prediction model more aligned with human visual perception than traditional models (Lu, 2016). Wu et al. leveraged color preference as prior knowledge, employing a multi-objective interactive genetic algorithm to autonomously generate color combinations aligning with individual preferences. The outcomes demonstrate the algorithm's efficacy in streamlining designers' workflows and accelerating the design process (Wu, 2018).

2.2 Color Emotion, Cognition, and Association

The study of color emotion is a widely explored topic in color cognition, typically conducted within specific contexts and among particular groups to account for individual variations in emotion (Wang, 2022b). When designing a human-machine interface, the designer should consider both usability and emotional appeal because users' feelings could influence operational performance (Sonderegger, 2010). The results showed that users spent more time on websites with warm colors than on those with cool colors (Bonnardel, 2011). Valdez et al. investigated the correlation between various color attributes and emotions, demonstrating that highly saturated colors could induce feelings of happiness with increased arousal (Valdez, 1995). Hanada investigated the generation mechanism of color emotion through consistency analysis, uncovering the correlation between color temperature perception and emotion (Hanada, 2018). Ou et al. discovered that the universal model of color emotion exhibits greater independence from culture compared to the model of color harmony. This marks the initial exploration into the connection between color emotion and color harmony through modeling (Ou, 2018). Additionally, the influence of color is manifested through color associations, a significant phenomenon impacting human behavior. Prior research has indicated the importance of color associations in tasks related to object recognition. This includes detecting a target object, such as an animal, in both color and grayscale natural scenes (Otsuka, 2009).

2.3 Preattentive Search

People deploy selective visual attention because we are unable to fully process everything in the scene at the same time. From a psychological standpoint, color is a primary factor in preattentive search and directing the viewer's attention (Wolfe, 2017), which is particularly important in cases of visual search in the interface. Besides color, the undeniable attributes that direct the viewer's attention (preattentive search) are movement, orientation, and size (Wolfe, 2017). The role of preattentive processing is undoubtedly important in many day-to-day activities and, of course, is of great significance in the field of human-computer interaction. Some screen design recommendations proposed in the form of well-known Gestalt theory laws (Change, 2002), such as proximity, similarity, or closure, are related to display attributes that have an early vision nature.

Table 1: The guiding attributes for feature search

Undoubted guiding attributes	Probable guiding attributes	Possible guiding attributes
Color	Luminance onset (flicker)	Lighting direction (shading)
Motion	Shape	Number
Orientation	Closure	Glossiness
Size	Curvature	Aspect ratio

2.4 Aesthetics and Color

Users often perceive an aesthetically pleasing interface as more usable. The concept of aesthetic usability was initially explored in the field of human-computer interaction in 1995. Researchers (Kurosu, 1995) from the Hitachi Design Center tested 26 variations of an ATM user interface, with a total of 252 participants in the study evaluating both ease of use and the aesthetic component. The research results demonstrated a strong correlation between participants' ratings of the perceived aesthetic component and the perceived ease of use, as well as a correlation between the perceived aesthetic component and the actual ease of use. Kurosu and Kashimura concluded that users are significantly influenced by the aesthetic component of any interface under examination, even when assessing the basic functionality of the system.

Visual aesthetics and design play crucial roles in shaping perceptions of website and interface quality. The use of visual aesthetics can modify viewers' perceptions by manipulating visual elements such as colors, text style and size, images, and animations (Zettl, 1999; Hoffmann, 2004). In this way, users become unknowingly or unconsciously engaged with the message of the website (Krauss, 2004; Hoffmann, 2004). Robins and Holmes (Robins, 2008) demonstrated a link between page aesthetics and a user's judgment about the site's credibility formed within the first few seconds of viewing a page. As the authors explain, a page with high aesthetic treatment was judged as having higher credibility.

2.5 Research Related to the Use of Color on the User Interface

Many studies confirm the effectiveness of using color as an element that facilitates finding the desired object on the interface, contributes to a better understanding of commands, attracts attention, and speeds up searching (Brawn, 1999; Christ, 1975; Starke, 2018; Tabart, 2007). Numerous works, through their experiments, affirm the importance of color for enhancing screen use and working with digital content, such as reading text on a web page, using applications, and managing machine control systems, and software (Bauer, 1997; Bhattacharyya, 2014; Bodrogi, 2003; Boulhic, 2018; Huang, 2008; Michalski, 2014; Nagy, 1990; Shieh, 2000). Nagy (1990) investigated the optimal color difference between the search object and the distractor object to achieve the minimum search time. It was concluded that search times were longer for smaller color differences and shorter for large color differences, i.e., for colors that are most distant from each other in the CIElab chromaticity diagram. The authors also inferred that visual search time can be a function of the color difference between the target and surrounding objects (distractors). When viewed from the perspective of the object's perceptibility, the results of the experiment by Einakian (2019) show that colors at a distance of 150 degrees, as well as opposing colors, are perceived as the most noticeable by subjects during the task of visually searching a geographic map.

The notion that the difference between the searched object, distractor objects, and the background should be greater when a shorter search time is required is supported by experiments related to the brightness of the elements, as well as the pattern and orientation of the elements. Concerning brightness, De Vries (2013) demonstrated in a visual search task that the time to find the desired object is shorter when the background brightness value lies between the brightness of the desired object and the distractor objects, thus clearly separating these two groups of objects.

Research by Wang (2022a) yields interesting results on human perception and the sense of color harmony. In the lightness category, the findings indicate that within identical color pairs, a higher degree of lightness in both the main and assistant colors results in increased color pair harmony. Regarding the distance category, studies reveal a connection between the color difference formula and color harmony. Specifically, the data demonstrate

that in identical color pairs, a reduced color difference between the main and assistant colors corresponds to a higher level of color pair harmony. Furthermore, results for subjective factors, such as the direct psychological effect, show a correlation between the “soft/hard” sense and color harmony. The data illustrate that color pairs featuring a softer color combination tend to exhibit higher levels of harmony. In terms of the indirect psychological impact, there is a positive correlation between pleasure and color harmony. However, the sense of arousal and dominance evoked by a color pair does not exhibit a clear relationship with color harmony.

Some studies focused on grouping interface elements by color to achieve a shorter time to find a specific interface element and to reduce errors during visual search and selection of the required interface element (Michalski, 2014). Numerous studies have demonstrated that error rates are sensitive to differences in the visual environment (Baker, 1960; Downing, 1987; Hwang, 2008). Toolbars containing two colors enabled a shorter search time compared to single-colored toolbars without color accentuation (Michalski, 2014). The conclusions of this work indicate that grouping interface elements by color contributes to improving the speed of user interface utilization, as well as increasing work efficiency. The experiment revealed that larger areas accented with color, which are not overly present on the interface, contribute to the shortest search time and the least number of search errors (Michalski, 2014).

Furthermore, the correct use of color combinations, i.e., well-chosen colors, enhances the screen’s effectiveness and can lead to faster user engagement (Christ, 1975; Wang, 2010), while poorly chosen colors can result in worse usability and an increased risk of visual fatigue (Galitz, 2007; Travis, 1991). It is also asserted that color can be used to select a stimulus to attract attention and facilitate the process of performing search tasks (Friedman-Hill, 1995; Kaptein, 1995). Color coding (Lennie, 2005) can segment the display into task-relevant parts, allowing the observer to learn to attend to them most attentively while ignoring other parts of the display (Brawn, 1999). Regarding the primary colors from the additive mixing system (red, green, and blue), research has shown that these primary colors provide higher search accuracy than non-primary colors (Bhattacharyya, 2014).

3. CONCLUSIONS

This paper aims to elucidate the complexity of the color phenomenon and the utilization of color harmony in creating user interfaces or other elements designed for visual search on the screen. The research endeavors to comprehend and broaden the process of color selection for various purposes. Numerous studies affirm the significant impact of color on enhancing user interface interaction. Colors facilitate object identification, contribute to better command comprehension, attract attention, and expedite search processes. As indicated by the research review, color and color harmony cannot be observed separately from their environment, including target and distractor objects, background, and the relationship between objects on the screen (closure, size, shape, contour, etc.). In addition to the general rules of color harmony, psychological factors need to be included in studies, such as the influence of color preference on color harmony. Additionally, parameters of personalization should be introduced into color harmony studies. Regarding color features, there is significant research and conclusions on individual color features such as hue, saturation, and lightness, which can be used as practical guidelines.

Experiments conducted by various researchers underscore the importance of color in improving screen usage across different digital contexts, such as web page reading, application navigation, and machine control systems. Studies notably emphasize the correlation between color differences and visual search times, highlighting the effectiveness of distinct color contrasts. Moreover, investigations into brightness, pattern, and orientation elements corroborate the idea that appropriate color choices contribute to shorter search times and reduced error rates. Insights from research on human perception and color harmony, as well as the grouping of interface elements by color, emphasize the significance of well-chosen color combinations in improving user efficiency and minimizing visual fatigue. The correct use of color not only enhances usability but also plays a crucial role in directing attention and expediting search tasks. Overall, the strategic application of color, taking into consideration factors like lightness and color differences, proves instrumental in creating harmonious and effective user interfaces.

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5. ACKNOWLEDGEMENT

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-65/2024-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project “Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad” (No. 01-3394/1).

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THE IMPACT OF VIRTUAL LIGHT EFFECTS ON OBSERVER EMOTIONS

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Abstract: *The paper aims to examine the impact of light on virtual 3D scenes on human emotional responses. The theoretical section of the paper covers the historical evolution of this influence through various artistic disciplines, the characteristics of light, the principles of its placement in space, and its effect on the human brain. In the practical part of this paper, a 3D scene with different light sources was created. Three series of renders were generated and used for survey-based research. The survey was conducted on 29 respondents of different ages and social groups. The survey included three series of renders to study the respondents' emotional reactions. The research results suggest that a phenomenon of desensitization has occurred in society with the popularisation of the internet and exposure to various videos and images online.*

Keywords: *virtual light, lighting design, light effects, emotional response*

1. INTRODUCTION

Light is one of the critical elements that shape a person's perception of space through reflection, refraction, and shadows, and it also significantly impacts the observer's emotions (Sánchez, 2023). Light represents a critical factor in creating atmosphere and mood, and it is inseparable from space. Lower light intensity can create feelings of warmth, anxiety, calmness, or mystery, while more vigorous intensity can evoke aggression. Similarly, light passing through the windows of tall glass buildings can create a sense of space, openness, and freedom; on the other hand, dark and enclosed spaces can evoke discomfort (Pallasmaa, 2023).

The paper includes research on the impact of changing parameters, such as the intensity and colour of virtual light, to assess their influence on people's emotional reactions. This preliminary study will focus on analysing static images (renders) of three-dimensional scenes to determine whether only changes in lighting, as a critical factor in architectural and artistic design, can elicit changes in emotional reactions among observers.

The limitation of this study is the broad scope of capturing observers' emotions, both positive and negative. If there are noticeable changes in their responses depending on changes in lighting, then directions for further research with reduced error in the design of the experiment can be defined. Also, it is essential to note that the study does not investigate the positioning of light sources to evoke specific feelings through the drawing of shadows on scene elements but rather relies solely on changes in light intensity present in the scene.

1.1 The use of light and its impact throughout history

As an element that offers opportunities for playing with shadows, light has been a powerful tool through which artists and creators achieve the desired emotional response. From painting, theatrical and film scenes to video games and CGI (computer-generated imagery) environments, light is crucial in conveying emotions and creating atmosphere. Lighting has a substantial impact on how people react to specific environments, even on individuals themselves. Light goes beyond mere functionality and enters the deep sphere of emotional experience.

In addition to architecture, the development of lighting was encouraged by the evolution of theatrical arts. The actual experience of a scene is not possible without adequate lighting. From ancient Greek amphitheatres to Shakespearean plays, lighting has always played a role in dramatic performances, even before the advent of modern technology (Eaton, 2023).

During the Italian Renaissance, experimentation was conducted with various colourations of light achieved with the help of glass vessels filled with different liquids. The colour of the light depended on the content of the liquid: red wine produced a red colour, saffron yellow, and ammonia chloride in a copper vessel gave a blue colour.

The discovery of electricity enabled the development of more efficient systems for transmitting and distributing electrical energy (Novaonline, 2023). The approach to detailed lighting and precision in light design has become a common practice in the stage industry, setting a new standard in stage lighting (SidmartinBio, 2023). Despite significant technological advancements, there is still no true soft light in stage lighting today (Brown, 2008).

The film industry continued the development of lighting in service of storytelling. Each lighting setup in a film has its specific functions and objectives. One of the most significant lighting techniques used in this context is the "three-point lighting," which utilises three primary light sources: key light, fill light, and backlight. (Ramaeker, 2014). This approach has become the foundation for all lighting setups in real and virtual scenes.

2. EXPERIMENTAL PART

The main question raised in this research is whether virtual lights in a virtual environment can simulate the same experiences and stimulate the same stimuli at the observer as film or theatre lighting can.

To address this question, presentations of differently illuminated 3D scenes, which will be created and rendered, will be used. To establish a detailed analysis and better control of lighting conditions, it was chosen to work with an indoor scene instead of an outdoor one. This choice allows for better focus on each modification and more efficient manipulation and control of lighting in a closed environment.

Therefore, when analysing how a person reacts to a given image or 3D space with specific lighting, it is essential to consider their life experiences, movies, games, and narratives they have experienced, as well as their imagination and creativity. These factors contribute to their unique perception of the experience and can significantly influence their emotional response, making research of this kind quite challenging.

2.1 Stimulus creation

Creating the scene and experimental environment started in the 3Ds Max 2022 software. The first step in creating the scene was selecting appropriate 3D models. These models were downloaded from the website "Sketchfab.com," along with their respective materials. The "Sketchfab.com" website is a wide source of 3D models that can be used in various applications and projects. Each model was placed in the scene at an appropriate position, allowing for their integration into the environment. For each model, a new VRayMtl material was created in the Slate Material Editor window. After the materials were created, appropriate texture maps were added to each, which were provided together with the model. These maps include bump maps, diffuse maps, roughness maps, and transparency maps. For rendering and displaying these materials, as well as later lighting effects, V-Ray renderer version 6.10.08, based on physics, was used.

The experimental part consisted of creating two series of renders presented to the participants. Each series consisted of five renders, with only one light source parameter changed in each render. This allowed for a precise analysis of the test results. Both series of renders consists of four different light sources: weak daylight from outside (afternoon light), light from the lamp next to the couch, main room lighting, and accent light on the piano.

2.2 First set of renders

An HDRI map was used to create the lighting entering through the window into the room. A Vray Light with an intensity of 100 was employed for the lamp lighting. The main interior lighting utilised an Omni light with Inverse Square decay. The fourth light was a Vray Light with a temperature of 5200K, accentuating the piano. The exposure could be adjusted according to the following parameters by placing a physical camera in the scene. The first render had a camera exposure set to a value of 6.5, and the final value was 10, creating varying lighting scenes, the impact of which was determined by a survey shown in Figure 1.

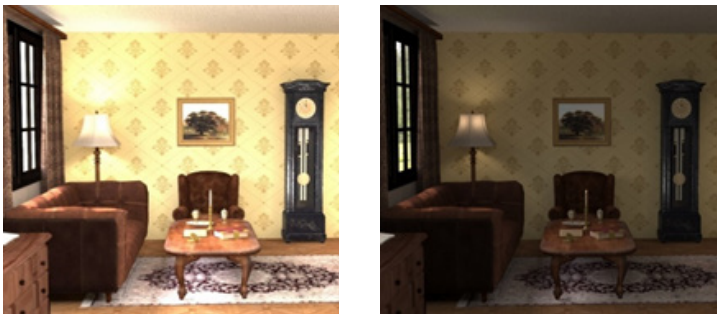

Figure 1: An example of renders from the first series with a camera exposure of 6 and 10

2.3 Second set of renders

Light particles entering the scene were added in the next set of renders. The temperature of the incoming light varies within the range of colour temperature from 1000K (reddish light) to 8000K (bluish light), with increments of 1000K. The entry of blue-toned light is expected to give the room a mystical atmosphere and an uncertain feeling, while the render with orange hues will make the scene warm and pleasant.

Vray Sun light was used along with Vray Sky environment to generate particles, to which the VrayEnvironmentFog effect was added within the Atmosphere effect. The Fog Distance was set to 800. The variable parameters in this render set were fog colour (ranging from 1000 to 8000 K) and fog emission, shown in Figure 2.

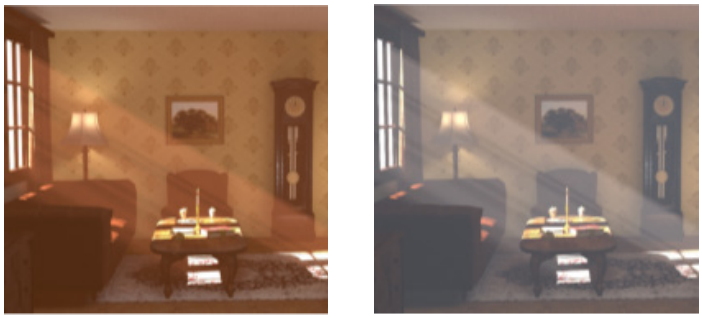

Figure 2: The appearance of a portion of the final first and last render with fog colour and fog emission parameters of the VrayEnvironmentFog effect set to a) 1000 Kelvin and b) 8000 Kelvin

2.4 Survey

The survey was conducted with a total of 29 participants from various age and social groups. The percentage of the female population is 62.1%, with the highest number of individuals falling into the age group of 20 to 24 years (51.7%). The participants viewed the renders on a desktop computer using a 24-inch monitor (Eizo CG241W).

This experiment focused on generally defined positive and negative emotions in order to first determine changes in the broadest sense and then, in further studies, to focus on a narrower spectrum of emotions.
The participants rated their emotions on a scale from 1 to 7, where a score of 1 indicates no emotional reaction, while a score of 7 represents a strong emotional reaction. This question aimed to analyse and determine the degree of emotional responses of the participants to each of the presented renders.

The participants first provided their ratings for negative emotional reactions, followed by, using the same principle, evaluations of positive emotions elicited by each render.

3. RESULTS AND DISCUSSION

In the first series of renders, the intensity of light in the scene and its potential impact on the participants' emotions were analysed. The renders were arranged from the highest to the lowest light intensity. Consistent responses were observed for the render with the highest light intensity. Participants (58.6%) rated that the render with higher lighting does not have a negative impact on their emotions. As the render depicts ordinary household furniture, it is expected that there won't be exceptionally negative emotions among the participants' responses. However, when asked about the presence of positive emotions, things changed.

Opinions were divided when participants were asked whether the first render evoked a positive emotional reaction. Therefore, two opposite responses were obtained: 29.6% of participants rated that the render had no positive impact, while 27.6% rated a positive reaction with a score of 7. Already in the first render, we can see that participants will be divided in terms of positive emotions. Such a result confirms the thesis that the emotion elicited by specific lighting is very subjective and that the same lighting can evoke different feelings in different people. However, it is interesting to see how this relationship (neutral and positive responses) will change with the decrease in light intensity in the render.

Participants did not express negative emotions in any of the other renders. In fact, 52% rated negative emotions with a score of 1. On all renders, participants were entirely consistent when it came to the absence of negative emotions.

Ratings for positive reactions varied depending on the render. For the second render, 31% of participants gave the maximum rating for positive emotion, while 20.7% rated it as 6. A slight positive reaction (rated with 1) was given by 27.6% of participants. For the third render, 27.6% of participants rated it as 6. In the case of the fourth and fifth renders, participants mostly rated them as 5 - 37.9% and 34.5%, respectively.

From the aggregate ratings for all renders, we can conclude that high values of render brightness had the most significant impact on extreme values of positive emotions. The softer the lighting in the render, the closer the ratings of emotions expressed by the participants were to the mean values. Participants who did not react positively to the initial renders, just like those who had high positive reactions, later showed mild positive emotions.

In the following graph, we can see the results for all participants who evaluated the first set of renders, Figure 3.

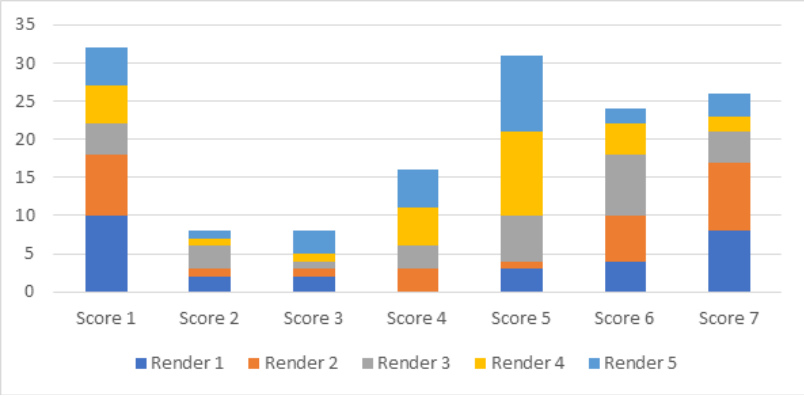

Figure 3: Results of the participants for the first set of renders

The graph depicts the ratings of all renders from bottom to top. Renders with the most light were rated the most positively. As the light intensity decreased, the ratings moved towards the middle values, indicating a decrease in positive emotions. Additionally, what's interesting is that the number of participants without positive emotions also decreased.
In the second set of renders, the impact of coloured light on the rendered scene was analysed. Renders were arranged according to light colour, ranging from 1000 K to 8000 K, with a step of 1000 K. Figure 2 shows the first and last renders used in the survey.

Regarding the negative emotional reaction, the majority of participants, 31%, indicated that the render did not evoke negative emotions (rated with 1). As for the positive response, a significant portion, 72.3% of participants, rated the render as having either no positive or moderately positive emotional impact. Based on these results, it can be concluded that most participants have a very mild positive reaction. However, only when we examine the results for the next render does the influence of the warmth of light on the viewers' emotions become apparent.

The results for the last render with the coolest colours are as follows. The analysis of positive emotional reactions to the last render shows that 86% of participants rated the render with a score of 1-4 (indicating no positive to moderate positive reaction). This result indicates that positive ratings decrease with the percentage of cool colours in the render, supporting the notion that the colour of light impacts participants' emotions.

4. CONCLUSION

The impact of light on human emotions is a well-known fact. Unlike natural light, virtual light doesn't have such an immersive effect, and investigating its influence is complex. By using established methods for measuring emotions (such as SEM analysis), emotions are measured in observers exposed to stimuli much more extreme in content than in an "ordinary" room rendered with natural light. The results of the experimental part of the research show that most renders with varying light did not have a significant emotional impact on the participants, neither positive nor negative. This result suggests a phenomenon of desensitisation (Sandoval, 2022) that has occurred in a society with the popularisation of the internet and exposure to various videos and images online.

The experiment demonstrated that the change in virtual lighting in the scene has a subtle effect. Still, it can be determined through a comparative analysis of a series of renders that differ only in altering one parameter.

To depict a scene with many emotions in the render, lighting with a higher exposure (exposure value of 10) should be chosen. Renders with higher exposure tended towards higher values of positive emotions. Regarding the colour of light, the experiment showed that approaching the light colour to 8000 K reduces positive emotions, so it is preferable to use it when the scene needs to add drama or depict a lack of emotions.

The fact is that visual content, such as video recordings, has a greater potential to influence emotional reactions than 2D pictures. Additionally, suppose a 3D scene were modeled based on scenes from horror films or comedies. In that case, it can be expected that the renders would have a more significant impact on the participants' emotions. In future experiments, standard light sources and everyday interiors can be used, but the questionnaire will be adapted so as not to focus on emotional changes. Instead, the questions will focus on the realism of the renderings and the specific emotion that different lighting parameters will influence. Additionally, more diverse scenes could be considered, evoking a wider range of emotions through their content. The results of this study clearly suggest that lighting in rendered scenes can influence the participants' emotions, which was the study's goal. This guides further research directions into the impact of virtual lighting on viewers.

5. ACKNOWLEDGEMENT

This research has been supported by the Ministry of Science, Technological Development and Innovation (Contract No. 451-03-65/2024-03/200156) and the Faculty of Technical Sciences, University of Novi Sad through project "Scientific and Artistic Research Work of Researchers in Teaching and Associate Positions at the Faculty of Technical Sciences, University of Novi Sad" (No. 01-3394/1).

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IDENTIFICATION OF GAZE PATTERNS IN THE OBSERVATION OF GRAPHIC ELEMENTS ON THE PACKAGING USING EYE TRACKING ANALYSIS

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Abstract: *The visual aesthetics of packaging wield substantial influence in shaping the initial impression and capturing the attention of prospective consumers. To meet market demands and consumer preferences, packaging design must thoroughly consider consumer behavior, particularly their perceptual tendencies. This entails investigating whether distinguishable patterns exist in how consumers perceive packaging, taking into consideration characteristics of displayed pieces of information, such as the type of information, the arrangement of information, and color variations. This preliminary research included 20 people, divided into two groups, who participated in the eye tracking analysis. Each group of participants had a different set of stimuli, depending on whether the subject of the test was a change in the position of graphic elements or a change in the color of graphic elements, and all of them looked at three key areas of interest: logo, product title, and illustration. The results of the test showed that, regardless of the color change or the change of position of the graphic elements, the respondents spent the most time gazing at the illustration.*

Keywords: *packaging, graphic design, eye tracking, gaze patterns, dietary supplements*

1. INTRODUCTION

Packaging serves various functions, including protection and transportation, but it also assumes a pivotal role in product promotion and branding across diverse industries. It plays a crucial role in the overall consumption experience. Impulsive purchasing constitutes a crucial phenomenon within marketing and economics. Presently, there is a growing trend of impulsive shopping, wherein consumers make on-the-spot decisions regarding product acquisition. Spontaneous consumer behavior is inherently responsive and, consequently, influenced directly by stimuli. This implies that consumers predominantly react to stimuli within the purchasing context (Weinberg, Gottwald, 1982, Park, Dhandra, 2017, Mittal et al., 2016). According to the POPAI shopper engagement study (2012), 76% of all shopping decisions are made in-store, with 55% of unplanned purchases. With the growing trend of online shopping, there is a massive expansion of the market of products that are available to customers, and therefore a greater possibility of impulse shopping (Zheng et al., 2019). An increasing array of diverse products, including clothing, personal care items, dietary supplements, electronics, etc., are presented to consumers daily across various platforms such as websites, webstores, mobile applications, social media, and diverse advertising banners. However, according to Coppola (2023), more than 85% of all purchases are still made in stores, while slightly less than 15% are made online.

This is precisely why the responsibility of packaging design has become increasingly important. Packaging serves as the first point of contact between the consumer and the product and often forms the basis for initial judgments. Visual stimulation caused by packaging design improves consumer perception and fosters aesthetic appreciation, thereby increasing product visibility (Kuo et al., 2021, Chitturi et al., 2021). Perceived product quality significantly shapes consumer-brand relationships. Elevated product quality establishes brand trust, nurturing enduring connections between consumers and the brand. The quality of packaging itself plays a pivotal role in cultivating brand trust and, consequently, fostering mutually beneficial consumer-brand relationships. This is why designers have a multitude of graphic elements, including colors, typography, shapes, and images, at their disposal when creating packaging design. With the use of graphic elements, it is possible to influence many of the consumer‘s senses, including the sense of sight, touch, and in many cases even the sense of smell and taste, which is most often the case with the packaging of food products (Krishna et al., 2016). Regardless of their easy availability in drugstores and pharmacies, dietary supplements and other products of the pharmaceutical industry are no

exception to this theory. Many studies have shown that choosing the color of graphic elements on the packaging of dietary supplements, and the color of the packaging itself can have a placebo effect on users in terms of expected pharmaceutical effect (Spence, 2021). It was also found that the presence of a picture or illustration on the packaging can increase the consumer‘s desire to buy the product (Delivett et al. 2020).

The analysis of eye movements, known as eye-tracking analysis, hinges on the correlation between human gaze patterns and the processes of visual attention and information acquisition. These aspects are intricately linked to higher-order cognitive processes (Ares et al., 2014). Additionally, the application of eye tracking addresses issues related to objectivity by circumventing reliance on participants‘ sensory capabilities, memory, and communication. This method allows for the collection of objective data on participants‘ behavior swiftly and with minimal intrusion when exposed to visual stimuli, thereby facilitating the exploration of unconscious mechanisms involved in the observation of product packaging (Rebollar et al., 2015). This preliminary research aims to determine and explain whether there are certain patterns in the perception of graphic elements of packaging of dietary supplements, such as the logo, product title, and illustration, to determine whether the type of information affects the perception of consumers, whether the alteration of the position of graphic elements packaging affects consumer perception and whether the color variation of graphic elements affects consumer perception.

2. EXPERIMENTAL

Within this study, two main independent factors were defined: the position of graphic elements on the front of the packaging (logo, product title, and illustration), and the color of graphic elements on the front of the packaging (primary color of the graphic elements, secondary color and tertiary color of the graphic elements), therefore, it was necessary to prepare two different sets of stimuli for two different groups of participants. Dependent variables in this study included Time Viewed in seconds, Number of fixations, and Revisits number for each area of interest.

2.1. Participants

Eye tracking analysis was conducted within two distinct groups, each comprising 10 participants, resulting in a total sample size of 20 individuals. The participants, aged between 20 and 25 years, were exclusively drawn from student demographics. The first group, focusing on the repositioning of graphic elements, comprised 60% female and 40% male participants. In contrast, the second group, emphasizing alterations in the color of graphic elements, included 60% male and 40% female participants. It is important to note that, due to the accuracy and objectivity of the research itself, the participants were intentionally kept unaware of the purpose of the research. Participants were informed, however, that the presented samples represented prototypes of the front-facing packaging design for five distinct dietary supplements.

2.2. Samples

It was necessary to prepare samples of the front of the packaging for five different dietary supplements so that they would be adequate for eye tracking research. Although many studies confirm the importance of packaging shape on consumer perception (Vladić et al., 2015, Spence, 2016, De Sousa et al., 2020) as part of this research, we decided to display the image of the front of the packaging only, and not for a three-dimensional display, so that the shape, background, and sense of depth achieved by the display of shadows, as well as the possible display of information on the side of the packaging, would not affect the movement of the examinee‘s gaze, and thus negatively affecting the subject of the research. For this preliminary research, we used a logo that consists only of text, so that the logo itself would be sufficiently readable. Subsequent to the aforementioned procedures, samples were prepared for each group. The first group entailed the alteration of the position of graphic elements, including the logo, title, and illustration, on the front of the packaging. Meanwhile, the second group encompassed the modification of the color of the graphic elements, including the logo, title, and illustration, on the front of the packaging.

In order to adequately prepare samples for researching the impact of changing the position of elements on the perception of the participants, it was necessary to define the primary position of the logo, product title, and illustration. Based on the primary position of graphic elements, secondary and tertiary positions are defined (Figure [1]). The remaining graphic elements on the front of the packaging (product information and product quantity)

remained the same as on the original packaging and did not change their position. These elements were not taken into consideration when defining areas of interest and during statistical data processing.

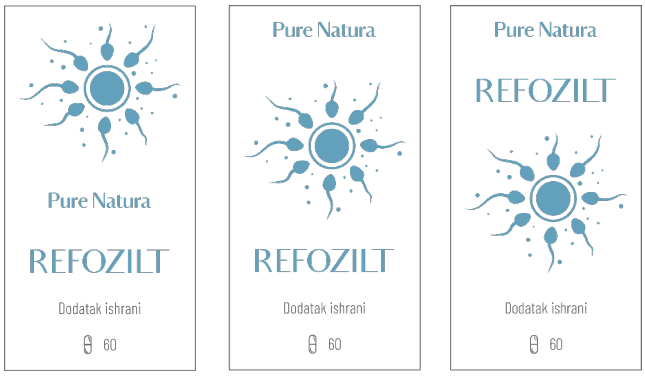


Figure 1: Alteration of the position of graphic elements for one of the dietary supplements

In order to confirm or challenge the hypothesis set at the beginning of the research, it was necessary to prepare the samples adequately. For this preliminary research, previously defined color palettes were used as primary colors, and based on this palette the color triades, i.e. secondary and tertiary colors, were defined. Defined color pairs (Figure 2) were used to display the graphic elements of interest, while the remaining elements (product information and product quantity) remained the same as on the original packaging. These elements were not taken into consideration during statistical data processing.

Figure 2: Defined color palette for primary, secondary, and tertiary colors for one of the dietary supplements

2.3. Procedure

The data was collected with the help of the Gazepoint eye tracking device. All subjects had to undergo a 9-point screen-based calibration, in order for the test to be adequately performed, and then they were shown samples from the subordinate group. Each group contained a total of 15 samples. The display of each sample lasted a total of 6 seconds, which, after conducting preliminary testing, turned out to be quite enough display time to get a good look at the front of the packaging. The samples were presented in a random order, in order to additionally guarantee the objectivity of the examination itself. After examining the entire group, it was necessary to define the area of interest for each graphic element of interest individually (logo, product title, and illustration) and collect data on the gaze movement of all participants.

3. RESULTS WITH DISCUSSION

One-way ANOVA tests were used to examine for statistically significant differences in the alteration of the position and color variations across the experimental comparisons. Differences with p-values less than 0.05 were considered statistically significant.

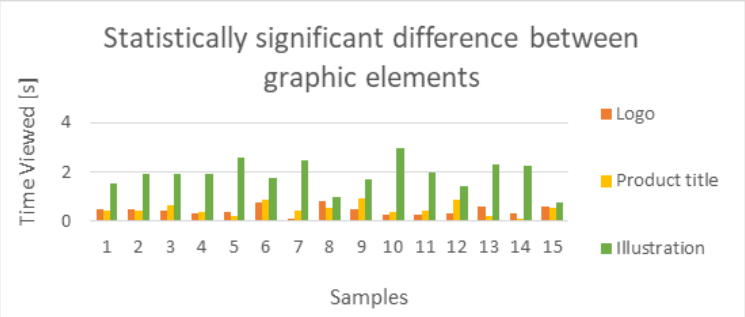
3.1. Alteration of the position of graphic elements

A one-way ANOVA was performed to compare the effect of each area of interest, including logo, product title, and illustration, on time viewed, fixation number, and revisits number (Table 1).

Table 1: One-way ANOVA results for defined areas of interest that represent each graphic element

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
TimeViewed	Between Groups	194.430	2	97.215	187.558	.000
	Within Groups	231.689	447	.518		
	Total	426.120	449			
FixationNumber	Between Groups	2381.258	2	1190.629	163.883	.000
	Within Groups	3247.500	447	7.265		
	Total	5628.758	449			
RevisitsNumber	Between Groups	101.333	2	50.667	16.734	.000
	Within Groups	1353.387	447	3.028		
	Total	1454.720	449			

A one-way ANOVA revealed that there was a statistically significant effect of defined areas of interest on time viewed at the $p<0.05$ level for the three conditions [$F(2,447) = 187.558$, $p = 0.000$]. One-way ANOVA also revealed that there was a statistically significant effect of defined areas of interest on fixation number at the $p<0.05$ level for the three conditions [$F(2,447) = 163.883$, $p = 0.000$]. Finally, one-way ANOVA revealed that there was a statistically significant effect of defined areas of interest on revisits number at the $p<0.05$ level for the three conditions [$F(2,447) = 16.734$, $p = 0.000$]. Post hoc comparisons using the Tukey HSD test indicated that the illustration ($M = 1.789$, $SD = 1.017$) was significantly ($p = 0.000$) longer gazed upon than the logo ($M = 0.332$, $SD = 0.365$), and the title ($M = 0.466$, $SD = 0.620$) (Graphic 1). Post hoc comparisons using the Tukey HSD test also indicated that the illustration ($M = 7.13$, $SD = 3.675$) had a significantly ($p = 0.000$) higher number of fixations than the logo ($M = 2.05$, $SD = 1.633$) and the title ($M = 2.47$, $SD = 2.371$). Finally, Post hoc comparisons using the Tukey HSD test indicated that the illustration ($M = 2.39$, $SD = 1.771$) had a significantly ($p = 0.000$) higher number of revisits than the logo ($M = 1.32$, $SD = 1.481$) and the title ($M = 1.45$, $SD = 1.937$).



Graphic 1: A statistically significant difference between graphic elements in gaze duration was observed in all samples

On the other hand, one-way ANOVA was performed to compare the effect of each position of graphic elements on gaze duration, fixation number, and the number of revisits (Table 2).

Table 2: One-way ANOVA results for defined positions of graphic elements

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
TimeViewed	**Between Groups**	.614	2	.307	.323	.724
	Within Groups	425.505	447	.952		
	Total	426.120	449			
FixationNumber	**Between Groups**	31.591	2	15.796	1.261	.284
	Within Groups	5597.167	447	5.811		
	Total	5628.758	449			
RevisitsNumber	**Between Groups**	20.520	2	12.596	3.198	.042
	Within Groups	1434.200	447	2.682		
	Total	1454.720	449			

A one-way ANOVA revealed that there was a statistically significant effect of the defined position on the revisits number at the $p<0.05$ level for the three conditions [$F(2,447) = 3.198$, $p = 0.042$]. Post hoc comparisons using the Tukey HSD test, on the other hand, indicated that there were no statistically significant ($p = 0.054$, $p>0.05$) differences between positions top ($M = 1.54$, $SD = 1.685$) and position middle ($M = 2.02$, $SD = 1.797$) in case of revisits number.

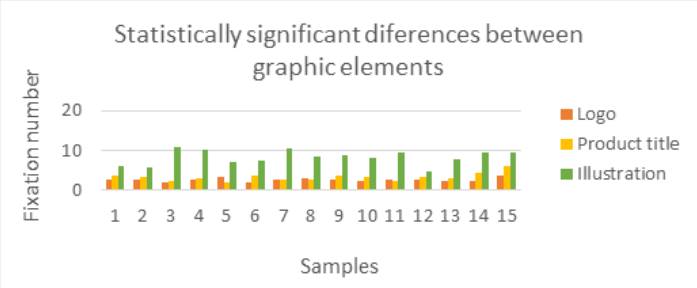
3.2 Color variations of the graphic elements

A one-way ANOVA was performed to compare the effect of each area of interest, including logo, product title, and illustration, on time viewed, fixation number, and revisits number (Table 3), this time for the different groups of samples.

Table 3: One-way ANOVA results for defined areas of interest that represent each graphic element

ANOVA						
		Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
TimeViewed	**Between Groups**	309.731	2	154.866	282.799	.000
	Within Groups	244.785	447	.548		
	Total	554.516	449			
FixationNumber	**Between Groups**	3003.693	2	1501.847	258.432	.000
	Within Groups	2597.687	447	5.811		
	Total	5601.380	449			
RevisitsNumber	**Between Groups**	25.191	2	12.596	4.696	.010
	Within Groups	1198.933	447	2.682		
	Total	1224.124	449			

A one-way ANOVA revealed that there was a statistically significant effect of defined areas of interest on time viewed at the $p<0.05$ level for the three conditions [$F(2,447) = 282.799$, $p = 0.000$]. One-way ANOVA also revealed that there was a statistically significant effect of defined areas of interest on fixation number at the $p<0.05$ level for the three conditions [$F(2,447) = 258.432$, $p = 0.000$]. Finally, one-way ANOVA revealed that there was a statistically significant effect of defined areas of interest on revisits number at the $p<0.05$ level for the three conditions [$F(2,447) = 4.696$, $p = 0.010$]. Post hoc comparisons using the Tukey HSD test indicated that the illustration ($M = 2.162$, $SD = 1.119$) was significantly ($p = 0.000$) longer gazed upon than the logo ($M = 0.320$, $SD = 0.327$), and the title ($M = 0.498$, $SD = 0.532$). Post hoc comparisons using the Tukey HSD test also indicated that the illustration ($M = 7.71$, $SD = 3.284$) had a significantly ($p = 0.000$) higher number of fixations than the logo ($M = 2.04$, $SD = 1.465$) and the title ($M = 2.43$, $SD = 2.122$) (Graphic 2). Finally, Post hoc comparisons using the Tukey HSD test indicated that the illustration ($M = 1.84$, $SD = 1.443$) had a significantly ($p = 0.000$) higher number of revisits than the logo ($M = 1.27$, $SD = 1.389$), but there were no significant differences ($p = 0.139$, $p>0.05$) in comparison to the title ($M = 1.48$, $SD = 2.009$).



Graphic 2: A statistically significant difference between graphic elements in the number of fixations was observed in all samples

On the other hand, one-way ANOVA was performed to compare the effect of each color of graphic elements, including primary, secondary, and tertiary colors, on gaze duration, fixation number, and the number of revisits. A one-way ANOVA revealed that there was no statistically significant effect of defined color variations of interest on time viewed at the $p<0.05$ level for the three conditions [$F(2,447) = 0.16$, $p = 0.984$], no statistically significant effect on a number of fixations [$F(2,447) = 0.28$, $p = 0.989$], and statistically significant effect on a number of revisits [$F(2,447) = 1.991$, $p = 0.695$].

4. CONCLUSIONS

The results of this preliminary research showed that the respondents spent the most time looking at the illustration, which further confirms the theory of the dominance of the image to the textual content shown on the packaging (Lemke, 1998, Bateman, 2014). This phenomenon is best visible in the relationship between illustrations and the logo. The logo, which consisted exclusively of typography, has a significantly shorter gaze duration compared to the illustration. This research also showed that a significant role in consumer perception is played by the type of information (element) that is displayed, while the position of the element itself does not have a statistically significant effect on gaze duration. After this research, we also came to the conclusion that the color variations of the graphic elements of the packaging do not significantly affect the gaze duration, number of fixations, and number of revisits. This preliminary research provides a foundation for subsequent research and enhancements. Conducting the same survey on a larger sample size and exploring modifications to the configuration of graphic elements, such as incorporating a multiplication of images and text within the logo, would be intriguing avenues for further inquiry.

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DESIGN AND TYPOGRAPHY

ILLUSTRATION AND DESIGN OF CHILDREN'S BOOK FOR DYSLEXIC CHILDREN

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Abstract: *The aim of our study was to write, illustrate and design a children's book for children with dyslexia and to measure the outcome on a small group of subjects. Based on the most frequently recurring guidelines for text preparation for dyslexic readers, we created two different text designs for a children's book. In one case, we considered the suggested text alterations, while in the other, we tried to emulate the text design available in a school library. We expected that both reading speed and reading accuracy would improve in the book that incorporated the guidelines both for children with and without dyslexia. The results showed that adjusting the type size, additional white space between letters and lines of text, and lower contrast between the text and background colour had a positive impact on the reading speed, reading accuracy and reading comprehension of children with and without dyslexia.*

Keywords: *children's illustration, dyslexia, reading, text adjustments, text comprehension*

1. INTRODUCTION

Reading is a cognitive process used to discern the meaning of a text. It is a skill used to acquire knowledge, a form of communication, and a way to spread information and ideas (Thompson, 2009).

Dyslexia is a condition that affects the ability to recognise and differentiate between letters and other symbols. It is most likely a hereditary condition that affects phonetic processing, reading, writing, spelling and handwriting (Pavlin, 2014; Rello, 2017; Riddick, 2003).

An important factor of typeface quality is its legibility, as well as the ability to easily recognise different symbols. The key part of typeface design is the relationship between characters, which have to retain their own characteristics, and, at the same time, work as a cohesive unit (Sanocki, 2012). Oftentimes, an inverted process occurs, where we use a higher-level unit (in this case a word) to identify single letters. During fluent reading, we frequently guess the word we are reading, before even having read it till the end (Sanocki, 2012).

Serifs are supposedly helpful while reading, as they keep the horizontal arrangement of the line and aid focus (Beier, 2012). Even so, studies have shown that sans-serif typefaces are easier to read for dyslexics (Pavlin, 2014; Potočnik, 2010; Bigelow, 2023). Typefaces made specifically for dyslexics exist as well and have more diversely shaped letters. It has been shown that dyslexics benefit from typefaces with longer ascenders and descenders, which reduce the impact that crowding has on reading (Sanocki, 2012). A 30% increase in type size is recommended for dyslexics compared to the type size used for average readers in the same conditions (Bigelow, 2023). An increased space between characters has been shown to be beneficial for both dyslexics and people without dyslexia (Sanocki, 2012). The relationship between the spacing of words and the spacing of characters is important for the readers with dyslexia; hence, the choice of a justified text is not recommended (Beier, 2012; Bigelow, 2023). Moreover, very short lines, i.e. between 16 and 18 characters, are helpful for dyslexic readers (Schneps, 2013). According to some research, legibility is increased, when the background has less contrast (Krivec, 2016).

The aim of this study was to test a children's book designed with adjustments for children with dyslexia in comparison to a book without such adjustments.

2. EXPERIMENTAL

2.1 Story

The title of the children's book that was tested is "Vesoljček Pip – ali kako veš, da nisi sam". The text was co-authored in collaboration with the Faculty of Education of the University of Primorska and is suitable for children aged between eight and eleven.

2.2 Illustration and design

We prepared two different layouts of the same text. With the first, non-adjusted layout, we followed standard design recommendations. We designed a children's book akin to those children could find in a school library. With the second, adjusted layout, we used the recommendations dedicated to reading and dyslexia. Table 1 contains all the variables that were used. The length of the lines was susceptible to the design and not part of the measurements.

The book consists of eleven illustrations, some of which were adapted based on the layout (Figure 1).

Table 1: Text variables according to proposed layout

Text variable	Non-adjusted layout		Adjusted layout	
Typeface	Playfair Display (medium and semi bold)		Lato (bold)	
Type size	13 pt		18 pt	
Character spacing	+0.13 pt		+0.72 pt	
Line spacing	+20%		+40%	
Line length	Not measured		Not measured	
Alignment	Justified		Left aligned	
Colour of typeface and background	100% white on dark background	100% black on light background	10% black on dark	90% black on light background

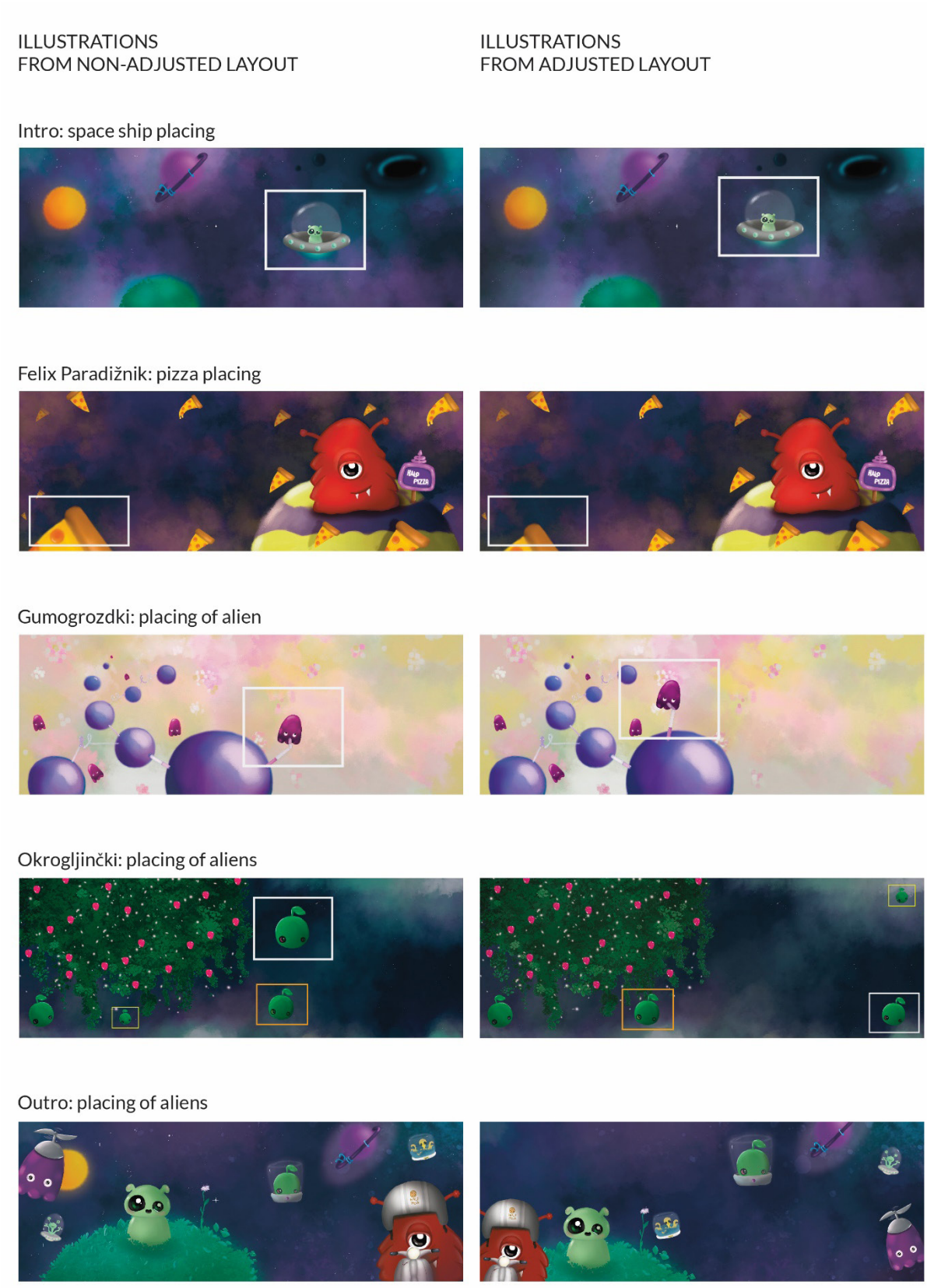

Figure 1: Changes in illustration between non-adjusted (left) and adjusted (right) layouts

2.3 Preparation and execution of testing

The test used in this study was prepared in cooperation with the Faculty of Education of the University of Primorska and comprises three parts, which aim to test the child's reading speed, reading accuracy and reading comprehension. The test was based on a reading test by Pečjak et al. (2011).

The testing was performed in a control group of four children without dyslexia and a test group of four children with a dyslexia diagnosis. The children of both groups were aged between eight and eleven. The test subjects were divided into two mixed groups, each containing two children with dyslexia. The testing was performed in two separate steps with a 14-day break between them. The testing of each subject lasted approximately ten minutes.

3. RESULTS

The study examined three aspects of reading, i.e. reading speed (measured in seconds), reading accuracy (measured according to the number of mistakes made while reading aloud) and reading comprehension (measured by the number of correct answers in a questionnaire).

3.1 Reading speed

The reading speed was tested by measuring the time in which the participants read aloud part of the text.

Table 2 shows the average reading speed according to the layout and the difference between reading times according to the layout. It can be seen from the results (Table 2) that both groups needed on average less time to read the adjusted layout. We also compared the difference in the reading speed between the test group and control group according to the layout (Table 3).

Table 2: Comparison of reading speed of both groups according to layout

Group	Average reading time (non-adjusted layout) [s]	Average reading time (adjusted layout) [s]	Time difference according to layout [s]	Time difference according to layout [%]
Control group	105.8	89.9	–16.0	–15.1
Test group	182.5	146.5	–36.0	–19.7

Table 3: Comparison of reading speed of test group with control group according to layout

Layout	Extra time, used by test group compared to control group [%]
Non-adjusted layout	+172.5
Adjusted layout	+163.1

3.2 Reading accuracy

We measured reading accuracy based on the number of mistakes made when reading aloud. A higher number of mistakes indicated poor reading accuracy.

Table 4 shows a comparison between the number of mistakes made by each group according to the layout. Both groups made on average fewer mistakes when reading in the adjusted layout.

The number of all types of measured mistakes decreased with the adjusted layout; hence, none of the variables had a negative impact on reading.

Table 4: Comparison of average number of mistakes made by each group according to layout

Group	Average number of mistakes (non-adjusted layout)	Average number of mistakes (adjusted layout)	Difference in average number of mistakes	Difference in average number of mistakes [%]
Control group	6	2.8	–3.2	–46.7
Test group	16	7.8	–8.2	–46.8

3.3 Reading comprehension

Reading comprehension was measured using a questionnaire. Table 5 contains a comparison of the average number of correct answers each group gave according to the layout. To account for the impact of memory on this test, one half of the test subjects read from the adjusted layout in the first testing step, and the other half read from the adjusted layout in the second. The number of correct answers was higher with the adjusted layout in both cases.

All test participants gave more correct answers after reading the text in the adjusted layout version. None of the participants gave all correct answers after reading the text in the non-adjusted layout (i.e. 7/7). Two test subjects from the control group and one from the test group gave all correct answers while reading in the adjusted layout.

Table 5: Comparison of average number of correct answers for both groups according to layout

Group	Average number of correct answers (non-adjusted layout)	Average number of correct answers (adjusted layout)	Comparison of average number of correct answers	Comparison of average number of correct answers [%]
Control group	4.3	6	1.7	39.5
Test group	4.0	6	2.0	50.0

4. CONCLUSIONS

The study has shown that a relatively small number of adjustments made during the design of a text can significantly and positively impact the reading speed, reading accuracy and reading comprehension of test subjects with dyslexia. Given the fact that the variables were not tested separately in this study, we cannot discern which variable had the most positive effect. However, none of the observed reading aspects was impaired by the adjustments, which shows all variables had either a neutral or a positive impact. Moreover, none of the observed aspects worsened in the control group readers. On the contrary, all observed aspects improved. The adjustments significantly reduced the difference between the reading accuracy of the test and control group. These small adjustments could reduce the difference in the reading advancement of children with dyslexia compared to the children without dyslexia. Due to the nature of variables, these changes could be easily applied by teachers themselves, while preparing, for example, reading materials. Extensive research is needed in order to discover which variables have the most positive impact with the smallest adjustment.

In conclusion, we have found that the adjustments (i.e. increased type size, increased character spacing, increased line spacing and lowered background contrast) had a positive impact on the reading speed, reading accuracy and reading comprehension of children with dyslexia, while also having a positive impact on children without dyslexia.

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DESIGN OF ECO-FRIENDLY LABELS

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Abstract: *In our research packaging labels were designed using eco-design approach based on the existing corporate visual identity of the Tr'glav brand. Two different pressure-sensitive adhesive labels were used, both recyclable. In one case, the adhesive is declared as compostable, making label completely biodegradable. The goal of the research was to determine if biodegradable label could replace frequently used commercial label. Peel adhesion test was performed to measure the adhesive strength between label and packaging. With the value over 1.5 N / 15 mm a good adhesion was confirmed for both tested labels. A comparative analysis of the durability of prints showed that the selected biodegradable label has excellent resistance to mechanical rubbing. Light fastness ensures that there will be no major changes in durability of print during use. With an on-line survey and interview with two focus groups an insight into what the respondents like the most and how they evaluate differently designed labels was gained. The label C was rated as the highest quality, most expensive and visually most attractive.*

Keywords: *pressure-sensitive adhesive label, eco-design, peel adhesion, print durability, survey*

1. INTRODUCTION

Labels play a key role in product identification and provide important information about the characteristics of the product. Label is defined as a small piece of paper or other material attached to an object and giving information about it (Cambridge Dictionary, 2024). The use of labels can be traced back to the early 1700s, though the product labelling, as we know it, evolved at the end of the 19th century, when cost-effective colorful paper labels printed with lithography were produced (Fairley, 2005). At that time, labels were used mainly to identify products. Nowadays, labeling has surpassed its basic function of describing the product and by contributing significantly to the design of a product or its packaging, has become a vital sales and marketing tool (Werblow and Noah, 2010). Initially labels were printed onto plain paper and cut to a rectangular size by guillotine before being applied with a wet-glue or gum. Self-adhesive labels, invented in the mid-1930s, started to make an impact on the product labelling market in the late 1960s, and since then have been gaining widespread acceptance and usage (Fairley, 2005). Today, pressure-sensitive adhesive labels (PSA labels) , also called self-adhesive labels make up over 50% of all label usage (Kaushal, 2021). They offer the package-labelling market a wider range of face materials and adhesives than any other method of labelling, as well as the greatest range of in-line printing and converting options (Fairley, 2005). PSA labels, composed from facestock, adhesive and liner, can be applied to different surfaces, shapes, and textures due to their flexibility and lightweight nature. (Dani, 2023).

The label must be precisely positioned and firmly attached to a specific surface of product or packaging. It must remain secure throughout the life of the product and must be resistant to various environmental conditions. In our research we investigated the adhesion of PSA labels and packaging and determine the CMYK printed label durability. Print durability can be defined as the change in initial print quality over time and/or in response to a specific factor (light, heat, humidity, air quality, fluids and/or mechanical rubbing). In several studies durability of printed labels made with conventional and/or digital printing techniques was evaluated (Zala et. al., 2005; Heilman and Rusko, 2011; Malenica et al., 2023; Pogačar et al., 2024; Beiner, 2020). The findings indicate that digital prints can have similar durability than conventional prints and that the printing substrate can significantly affect print durability. Using sustainable plant-based materials, re-design to use fewer materials and less print is the way to design more eco-friendly labels. The goal of this study was to implement eco-design at PSA labels for product and packaging.

2. EXPERIMENTAL

2.1 Materials

The labels tested in our research are commercial PSA labels produced by Avery Dennison and UPM Raflatac. They are made from FSC-certified paper with a basis weight of 80 g/m^2, an acrylic-based adhesive, and paper liner of different basis weight and typ. The face stock of Avery Dennison label, marked as Lable 1 is one-side-coated, woodfree paper, and that of UPM Raflatac label, marked as Label 2 is one-side-coated art paper. The latter is recyclable but not fully biodegradable, whereas Label 1 has been declared as a biodegradable, compostable PSA label.

2.2 Methods

2.2.1 Peel testing

A peel resistance of PSA was investigated visually and by determine the peel strength. Peel strength is the average load per unit width of bond line required to separate bonded materials. A modified ASTM D903 peel strength testing was performed at 180° peeling angle. The rigid substrate, a corrugated cardboard, was clamped in a fixed vertical position in the testing machine Instron 5567 (Instron, Norwood, MA, ZDA), and adhesively bonded PSA label was peeled off at the rate of 250 mm/min. The load versus displacement was recorded. The curve is given as the average of six measurements.

2.2.2 Color fastness testing

CMYK (cyan, magenta, yellow, black) color patches with 100% coverage were printed on both samples using electrophotography. The light fastness of the prints was determined after aging using a xenon lamp in a Xenotest Alpha (Atlas, Germany) apparatus based on the ISO 12040 standard. Testing conditions were: chamber temperature of 35 °C, black standard temperature of 50°C, 35% relative humidity, and 42 W/m^2 irradiation intensity. The time of exposure was 144 hours. The dry rub fastness test was performed according to the ASTM D5264-98 standard with 2 kg mass of weights and speed of 106 cpm using a rubbing device, Param RT-01 (Labthink Instruments Co., Medford, MA, USA) The CMYK prints were rubbed against the unprinted paper in 1000 strokes. The color change was determined using spectrophotometric measurements. Ink transfer or bleeding from the printed test piece to the receptor surface (unprinted paper) was evaluated visually. Spectrophotometric measurements were performed using an X-Rite Eye-One i1Pro (X-Rite, Grand Rapits, MI, USA) spectrophotometer where measurement geometry was 45/0, observation angle 10°, and light source D65. Each CMYK print was measured three times at three different positions on the printed area. Altogether, nine measurements were made on each tested area for each CMYK color. The color differences, ΔE*ab between the prints before and after the conducted treatments, were calculated using the equation 1 and the hue difference was calculated using the equation 2.

2.2.3 Survey

In the survey, we focused on consumers and collected their opinions on various graphic label designs. Quality, price range and visual appeal were evaluated. An online questionnaire entitled „Sustainable packaging“ was used as a data collection tool. The questionnaire was divided into two parts: the first part investigated the socio-economic situation of the respondents, the second part focused on the design of labels. The questionnaire was constructed with multiple-choice questions and a 5-point Likert scale from 1 (poor quality/cheap/less attractive) to 5 (high quality/most expensive/most attractive). The target population were citizens of Slovenia over the age of 18. The invitation to participate in the on-line survey was distributed via e-mail, social networks and various communities. We received and analyzed a total of 207 valid questionnaires, in which we got answers to all questions.

The same questionnaire was used in conversation with both focus groups. The focus group 1 consisted of five employees from company Tourism Bled; the meeting took place live at the headquarters of the company, with prior agreement and a brief presentation of the content. Five incubates from the start-up business accelerator Katapult participated in focus group 2; the meeting took place at the headquarters of the company, with prior agreement

with the accelerator‘s management and a brief presentation of the content. Respondents of on-line survey and participants in focus groups remained anonymous, no personal data or identifiers were collected in accordance with the GDPR.

3. RESULTS WITH DISCUSSION

3.1 Label design

Using the Adobe Illustrator CC software four different graphic images of bottle labels (Figure 1) and three different graphic images of packaging labels (Figure 2) were made. The design was based on the existing graphic image of the Tr’glav brand and following eco-design principles. The elements arranged on the bottle labels are the logo, the illustration, the lines of different thicknesses and 18th Century font. The number of graphic elements was increased from the label A, where only the logo and font are included to label B, where illustration was added and label C with a special cutout. Label D has all elements, but without colored part in illustration. The graphic layout is divided into two parts: the upper one for basic product information, and the lower colored rectangular part for mandatory product information. Labels are designed monochromatically.

Figure 1: Graphic image of bottle labels A, B, C and D.

Figure 2 shows packaging labels in three versions. The elements arranged on labels are the logo, the lines and product information written in 18th Century font. The graphic layout is divided into two parts: the part with the cut-out logo and the printed part. The 18th Century font is placed in left-aligned columns written in font sizes of 11 pt, 10 pt and 28 pt. Labels are designed monochromatically.

Figure 2: Graphic image of package labels.

3.2 Characteristics of PSA labels

One of the requirements for self-adhesive label is that label is precisely positioned and firmly attached to the product or its packaging. A peel resistance of PSA label attached to bottle and packaging was investigated visually. The visual assessment of peel adhesion is presented in Figure 3. Both labels adhere good to the glass surface and to the corrugated cardboard. Label 1 has a slightly better grip, the label feels more compact, when we tore it from the bottle, it also came off more easily in one piece. Also when labels were attached to the packaging Label 1 has a slightly better grip, the label feels more compact. When torn from the surface, it feels like the glue is less elastic. Both PSA labels separated from the corrugated cardboard very easily, and did not damage the surface of the corrugated cardboard and did not tear.

Figure 3: Testing the adhesion of PSA labels to the bottle and packaging.

Peel adhesion test was performed in order to measure the adhesive strength between label and packaging. The peel strength test involves adhesively bonding the flexible adherent to a substrate, peeling it back at the specified rate by a 180° angle, and measuring the average peel strength. In Figure 4 graph showing delamination/peel strength is presented. Both PSA labels show similar delamination behavior, with average load of 1,54 N /15 mm for Label 1 and 1,61 N/15 mm for Label 2.

The durability of CMYK printed labels was determined with the color fastness testing. This test was employed as an accelerated aging method for assessing identical areas of the individual CMYK prints following exposure to light. The changes in colorimetric values relative to those measured for an untreated sample were calculated and are presented in Table 1. More information about color fastness of labels is given in survey of Pogačar et al., 2024. The cyan print (C), with ΔE^*ab over 5,2 showed an obvious difference in color after exposure to the light on both printed labels, resulting mainly from the change in value a* in the red direction. A clearly visible change was also seen at yellow print (Y) on the Label 1, where also the change in chroma was the highest, resulting in darker and

duller color. Visible, but acceptable tolerance for printing industry was obtained for the magenta print (M), which showed a medium-level difference, whereas no visible difference was seen for the black print (K). The CMY prints on Label 2 are lighter, brighter and the K print is darker and duller than the print on Label 1. After exposure to light prints are a bit darker, greater change in color was seen on printed Label 1.

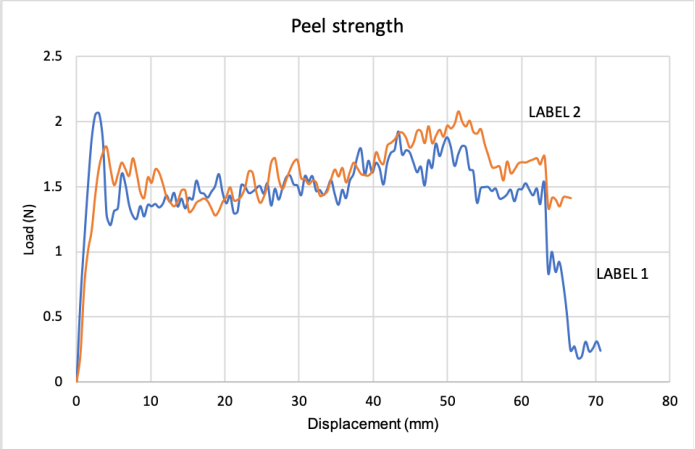

Figure 4: Load vs. displacement of delamination of PSA labels

Table 1: Color differences of the CMYK printed PSA labels after exposure to light.

		ΔL*	Δa*	Δb*	ΔC*	ΔE*ab	ΔH*ab
CMYK printed Label 1	C	-1.63	4.49	-2.12	0.17	5.22	4.96
	M	-0.92	-0.84	-2.67	-0.26	2.95	2.79
	Y	-2.89	-1.98	-4.07	-3.76	5.37	2.52
	K	0.13	0.14	-0.23	0.20	0.29	0.16
CMYK printed Label 2	C	0.07	4.00	-3.44	1.00	5.28	5.09
	M	-0.43	1.64	-2.24	2.15	2.81	1.76
	Y	-1.33	-0.81	-0.90	-0.78	1.80	0.93
	K	-0.29	-0.01	0.40	-0.38	0.49	0.11

Visual evaluation of color transfer from the printed label to the unprinted paper revealed no bleeding, as shown in Figure 5. The color differences of the CMYK printed labels after 1000 rubbing strokes is small. The most values are lower than 3, indicating the acceptable color change (Liu et al., 2013; Schewe, 2014) and good rub resistance of the printed labels. The minimum ΔE*ab for seeing a difference is about 2. Prints on Label 1 showed slightly higher color difference after rubbing than prints on Label 2, especially in magenta (M) and yellow (Y) prints, where a medium-level difference was obtained.

Table 2: Color differences of the CMYK printed PSA labels after dry rubbing.

		DL*	Da*	Db*	DC*	DE*ab	DH*ab
CMYK printed Label 1	C	-1.04	0.75	1.16	-1.35	1.72	0.23
	M	-0.49	-2.18	-1.99	-1.68	3.00	2.44
	Y	-1.90	-0.24	-2.16	-2.11	2.89	0.54
	K	0.39	0.07	-0.16	0.14	0.42	0.07
CMYK printed Label 2	C	-0.28	0.04	0.12	-0.12	0.30	0.00
	M	-0.37	-0.90	0.24	-0.93	1.01	0,14
	Y	-0.79	0.55	-0.63	-0.71	1.15	0.44
	K	-0.13	-0.10	0.25	-0.22	0.30	0.16

Figure 5: Rubbed CMYK prints and unprinted paper after 1000 rubbing strokes

3.3 Results of survey

In survey respondents evaluated the structural design of labels, shown in Figure 1. The average score obtained in on-line survey according to socio-economic factors is presented in Table 3. The lowest score for quality and price range was 2.8 and for visual attraction 2.4. The highest score for quality and visual attraction was 4.4, for price range 4.6. The standard deviation and coefficient of variation were determined. Coefficient of variation for quality assessment was between 4 and 8%, price range 4.5 and 9% and visuall atraction between 5.6 and 9.5%. On average label C was rated as the highest quality, followed by Labels A and B. In terms of socio-economic factors, Label C was rated as the highest quality by generation Z, respondents with elementary school, unemployed, students and respondents with lower income. Label C was rated as the most expensive and the most visually appealing, socio-economic factors had no effect on perception. Label D was rated as the low quality label and least attractive, and at the same time expensive. Socio-economic factors had no effect on rating in this case also.

Table 3: Average score for label design according to socio-economic factors from on-line survey

	Quality				Price range				Visual attraction			
	A	B	C	D	A	B	C	D	A	B	C	D
Age												
Generation Z	3.6	3.5	3.9	3.2	3.4	3.3	3.8	3.3	3.4	3.4	3.9	2.8
Generation Y	3.5	3.5	3.5	3.0	2.8	3.0	3.5	3.2	3.2	3.2	3.5	2.9
Generation X	3.3	3.4	3.4	3.0	2.9	2.9	3.6	3.3	3.1	3.2	3.6	2.8
Baby boom	3.0	3.2	3.4	3.0	2.9	3.2	3.6	3.5	2.8	3.3	3.5	3.1
Level of education												
Elementary school	3.6	3.6	4.3	3.4	3.1	3.3	3.7	3.3	3.0	3.7	4.4	3.1
High school	3.2	3.4	3.6	3.0	2.9	3.2	3.8	3.4	3.1	3.3	3.8	2.9
University	3.4	3.4	3.6	3.1	3.1	3.0	3.6	3.2	3.2	3.3	3.6	2.8
Master‘s or doctoral degree	3.9	3.5	3.3	3.2	3.2	3.1	3.3	3.3	3.3	3.3	3.4	2.9
Employment status												
Unemployed	3.2	3.8	4.4	2.8	3.6	3.6	4.6	3.6	3.0	3.8	4.4	3.2
Students	3.5	3.5	3.8	3.2	3.3	3.2	3.7	3.4	3.4	3.4	3.8	2.8
Employed	3.4	3.4	3.5	3.0	2.9	3.0	3.6	3.2	3.2	3.2	3.5	2.8
Retired	2.9	3.2	3.6	3.4	2.8	3.1	3.6	3.5	2.4	3.2	3.7	3.5
Average monthly income (net)												
up to 800 €	3.5	3.4	3.6	3.0	3.6	3.3	3.6	3.3	3.6	3.5	3.7	2.7
801 – 1.300 €	3.3	3.4	3.7	3.3	2.8	3.0	3.8	3.7	2.7	3.0	3.7	3.1
1.301 – 1.800 €	3.2	3.2	3.4	3.0	2.7	2.7	3.5	3.2	3.0	3.1	3.5	3.0
from 1.801 €	3.5	3.6	3.6	3.1	3.0	3.2	3.5	3.1	3.4	3.5	3.5	2.8

Labels were evaluated in two focus groups having five participants each. A focus group is a small group of demographically diverse people (by age, gender, profession) who participate as part of a market research group. The highest score by the participants of the focus groups gained Label C, followed by Label D. Label C again stands out in the focus group assessments, particularly in Focus Group 1, where it achieved remarkable scores for quality (4.8) and visual attraction (4.6). This suggests that when individuals have an opportunity to discuss and reflect on their preferences, the appeal of Label C is very pronounced. Label D shows lower scores, especially in the online survey portion for visual attraction (2.9), indicating a consistent lack of appeal across different evaluative settings.

Table 4: Average score for label design obtained from on-line survey and focus groups.

Label	Quality				Price range				Visual attraction			
	A	B	C	D	A	B	C	D	A	B	C	D
On-line survey	3.4	3.4	3.6	3.1	3.0	3.1	3.6	3.3	3.2	3.3	3.6	2.9
Focus group 1	3.4	3.6	4.8	4.4	2.6	3.6	4.2	4.0	2.8	3.4	4.6	3.8
Focus group 2	3.6	3.0	4.2	3.6	3.0	2.6	4.0	3.8	3.2	3.2	4.2	3.4

According to the results of the online survey and both focus groups, the Label C was rated as the highest quality, most expensive and visually most attractive (Table 4).

4. CONCLUSIONS

Corrugated cardboard packaging which is recyclable and biodegradable must be equipped with labels that do not limit its recyclability and/or biodegradability. Even for labels attached to a product such as a bottle, it is recommended to use labels that are recyclable and/or biodegradable. PSA labels with biodegradable adhesive meet the conditions of recyclability and/or biodegradability. In addition to the material of the labels themselves, it is important to design the labels sustainably. In our case labels were designed in one color in a way to avoid a lot of graphic elements and print, but still standing out with their graphic image. The opinions of the survey respondents confirmed that designed labels are visually attractive and of high quality. The label must be firmly attached to a specific surface of the product or packaging. The peel strength for both labels is high, showing good adhesion between PSA label and packaging. A comparative analysis of the durability of printed labels showed that the selected biodegradable PSA label has excellent durability against mechanical rubbing and good lightfastness, which will ensure durability of printed information.

PSA label, which is also recyclable and biodegradable, with a graphic design that uses cutouts instead of printing, adds value to the gift packaging. Good print quality and excellent resistance to rubbing, along with good adhesion when applied to the product, ensure its suitability for use on packaging and bottles.

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THE EFFECT OF LOGO REDESIGN ON THE PERCEPTION OF A PET SHELTER

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Abstract: *Animal shelters put a lot of effort in helping homeless and injured animals, which require financial support. Most animal shelters raise funds through online stores by selling items with their own eye-catching print designs. Shelters in Croatia generally do not have a consistent visual identity, which can weaken the impression of the shelters and its marketing strategy. Thus, the purpose of this study was to propose a redesign of the logo for the most popular Croatian animal shelter and to investigate its effect on the perception of the shelter and the people's willingness to donate. 156 people participated in the study in which they were presented with the redesigned logo and online store items with print designs based on the redesigned logo. The results showed that the redesigned logo influenced the perception of the shelter. The participants who may be considered as potential donors were sensitive to variations in t-shirt designs from the shelter's online store. The findings could be used in the animal shelter's marketing strategy, since they suggest that visual identity influences people's evaluation of the shelter and that the perceived attractiveness of the logo redesign can have a notable impact on the perception of the shelter's qualities.*

Keywords: *animal shelter, logo, redesign, visual identity, willingness to donate*

1. INTRODUCTION

There have always been abandoned animals in Croatia but after the coronavirus pandemic and the earthquake in the Sisak-Moslavina County, their number has increased significantly. A lack of knowledge about the method of the Coronavirus disease (COVID-19) transmission and false information have sparked panic that has led some people to abandon their pets in the fear of spreading the disease. People and property were terribly damaged in devastating earthquakes. The earthquakes left many people homeless, along with their pets. The aftermath of the earthquake revealed a number of irregularities in pet care. The animals were found on leashes in unacceptable conditions. For those which were lost, it was difficult to find the owner because a large number of pets were not microchipped despite current legislation on the pet identification system in Croatia NN 72/2010 (Ministry of Agriculture Fisheries and Rural Development, 2010). Animal protection societies and shelters have taken care of a large number of abandoned animals that primarily needed accommodation and food, and some of them also needed surgery. All these activities required financial support. In most cases, it is very challenging to gather a sufficient amount of donations due to the unpredictability of the costs.

The existence of the non-profit organizations and survival of the animals they care for depend on the number of donations. Donations can be collected in several different ways. There are permanent sponsors who donate throughout the year, and occasional charity events where funding assistance is provided by larger companies. Websites have the option of directly donating money to a bank account. Furthermore, there is an option of purchasing a specific product in the accompanying web store as a sign of support. Given that larger charity events are often organized only once a year, non-profit organizations mostly rely on direct donations from companies and individuals or on the sale of promotional items in their web stores.

From the perspective of visual communication, there is a problem of inconsistent visual appearance of the societies' branding. Most societies for animal protection in Croatia, even the larger ones, do not have a consistent visual identity. Their logos are different on individual social networks and websites, which can reduce the perceived legitimacy and make it difficult to find a society in social media. The most common items in the web stores are t-shirts with the association's logo, but in many cases they do not meet the criteria of professional graphic design.

To increase the number of donations, it is necessary to attract people who are not already familiar with or interested in helping abandoned animals, that is, it is necessary to encourage the general population to donate. Chances of donation are higher if a person wants to have a product they perceive as visually attractive. The starting point for

this paper is the assumption that the redesign of the logo and the attractive design of the logo on the products in the web store can positively affect the perception of the animal shelter and can attract more donations.

1.2 Problem statement

The design of visual content is an important aspect of effective communication. Good visual content design is innovative, memorable and communicates exactly what the product or organization wants to convey. Sometimes it is necessary to redesign the visual identity to keep the company or organization up to date and to refresh its visual content (Phillips, McQuarrie, & Griffin, 2014). Redesign is the process of changing the appearance, function or content. Sometimes the redesign may result in high costs (Chen & Bei, 2020) and detrimental effects in people's responses (Kim & Lim, 2019). Therefore, it is not done out of whim but out of need for a better communication with the target group. A successful redesign starts with a detailed analysis of the problem and the context. It is essential to consider whether a redesign is truly necessary and to recognize the most prominent reasons for it. A redesign can be carried out for several different reasons. For example, if the current visual identity is not consistent and does not communicate a clear message, if it wants to expand the scope or the current position does not allow addressing a new goal (Todor, 2014). When the reasons for changing the visual identity are identified, the next step is determining the values which want to be communicated and an appropriate analysis of the target group.

When considering the potential donations, people make their decisions based on economic indicators, such as patent ownership, the amount of money needed, the education of the entrepreneur and the degree of networking (Ahlers, Cumming, Günther, & Schweizer, 2015). In addition to economic indicators, the likelihood of donating is also affected by visual signs such as logos, images and illustrations. The digital environment, especially social media such as Facebook and Instagram, is based on visual content. Thus, the visual indicators are viewed as dominant. People are more likely to click on content if they see an interesting image than if they have to read a longer text. Therefore, it can be concluded that visual content such as a logo can encourage a person to donate. A large audience can be reached online. There are lots of people who do not have the necessary experience and financial knowledge which would help them to make a deliberate donation decision, so they rely on visual indicators in order to shorten the decision-making process (Ahlers et al., 2015).

The logo is the predominant visual indicator as it represents the values and reputation of the organization (Foroudi, Foroudi, Nguyen, & Gupta, 2019). It conveys significant signals to consumers on the basis of design features such as colour (Séraphin, Ambaye, Gowreesunkar, & Bonnardel, 2016), shape and typeface. It belongs to the category of inexplicit indicators because it does not provide direct information about the quality and profitability of the organization. Nevertheless, it influences the way in which people perceive the image of the organization and identify it (Grobert, Cuny, & Fornerino, 2016). Therefore, in this paper we presented the redesign of the existing logo of the largest Croatian animal shelter named Dumovec and investigated how potential users and donors responded to it.

2. EXPERIMENTAL

2.1 Current logo

Dumovec's logo consists of letters and an image (Figure 1). A red handwritten font is used for the shelter's name. The picture shows a highly structured dog house in orange and brown. These two elements of the combination mark are significantly different. The house depiction has a high degree of structure, while the name is made without any effect of three-dimensionality. The main issue of the current logo is the limited possibilities of its various applications. Due to its complex structure, the logo is not applicable on small-scale formats such as a pen and small promotional items. In addition, the current logo cannot retain its clear distinctiveness in a black-and-white version, which is often required for application to a variety of substrates or printing techniques.

Figure 1: The current logo for the Dumovec animal shelter

2.2 Redesigned logo

Figure 2 presents the proposed redesigned logo (Železić, 2021). Aim of the redesign was to create a meaningful visual form with positive connotations (Henderson & Cote, 1998) which arouses curiosity (Peterson, AlShebil, & Bishop, 2015). It was developed according to Gernsheimer's guidelines for successful logo design (Gernsheimer, 2008). The redesigned logo has a stronger concept than the current logo. It conveys a multi-layered message by presenting three major concepts. The first concept is love, presented by the symbol of the heart. The second concept is the animal character indicated by the depiction of a dog and a cat with a negative space (Sharma & Varki, 2018), and also the bird in the upper part of the logo. The third concept is the protection presented by a shield in the centre. The logo has a simple cohesive structure and good visibility when downsized. The composition is well-balanced, without using a mirroring effect, which makes the logo more dynamic compared to the composition based on duplication of the mirrored elements. Special effort was put in the appropriate selection of the colour, since a professionally developed colour identity can serve as a cue for the target audience to engage in the brand experience (Jin, Yoon, & Lee, 2019). Still, the logo also retains great recognition in its black-and-white version. The logo contains both icon and name, since this combination is considered as an attractive design solution (Bresciani & Del Ponte, 2017).

Figure 2: The redesigned logo for Dumovec animal shelter

2.3 Survey

To examine how potential users perceive the redesign of the logo, an online survey was used. The study involved 156 people, 80% of whom were women. The majority of respondents were between 18 and 35 years old (64%), followed by persons up to 45 years of age (21%), and respondents who were older than 45 (15%).

3. RESULTS AND DISCUSSION

The survey consisted of four blocks. The first block of questions referred to demographic data and experience with donations. 63.46% of the participants made donations to the animal shelters in the past. Most of them made the donations by purchasing an item in the web store (48.48%).

In the second block the participants were presented with five different logos. The logos were: the current logo for Dumovec (Figure 1), its redesigned version (Figure 2) and three current logos for other popular animal shelters in Croatia. Their task was to select the one they think represents the most legitimate animal shelter. Additionally,

they were asked to select the one which they prefer the most according to willingness to donate. The results of the McNemar's tests showed statistically significant differences between the current logo and the proposed redesigned logo. In particular, when asked about the shelter's legitimacy, the proposed redesigned logo was selected more frequently (26.92%) than the current logo (7.05%), $p < 0.001$. When asked about the willingness to donate, the participants also preferred the proposed redesigned logo (17.95%) over the current logo (4.49%), $p < 0.01$. This indicates that the redesigned logo improved the transmission of the message regarding the legitimacy of the shelter and improved people's willingness to donate. Consequently, these positive effects could contribute to the shelter's reputation and financial support donated for animal protection. This is in line with previous research on the factors influencing charitable giving which showed that the reputation of a non-profit association plays one of the most important roles in people's willingness to donate (Sarstedt & Schloderer, 2010; Snipes & Oswald, 2010).

In the third block of questions, the participants were asked to use a 5-point scale to evaluate the current Dumovec logo and the proposed redesigned logo according to three parameters: perceived legitimacy of the shelter, visual attractiveness of the logo, and professionalism of the shelter. The results are presented in Figure 3. The paired t-tests showed significant differences between the current and the redesigned logo across all the parameters. The shelter's legitimacy was evaluated better for the redesigned logo ($M = 3.60$, $SD = 1.14$) than the current logo ($M = 2.99$, $SD = 1.05$), $p < 0.001$. Furthermore, the redesigned logo was evaluated as more visually attractive ($M = 3.59$, $SD = 1.17$) than the current logo ($M = 2.62$, $SD = 1.10$), $p < 0.05$. The professionalism was evaluated better for the redesigned logo ($M = 3.51$, $SD = 1.12$) than the current logo ($M = 2.33$, $SD = 1.09$), $p < 0.05$. Taken together, these results suggest that the redesigned logo efficiently transmits the message about the shelter's attractiveness, professionalism and legitimacy. This may help to attract potential funders, but also to stimulate the adoption of pets.

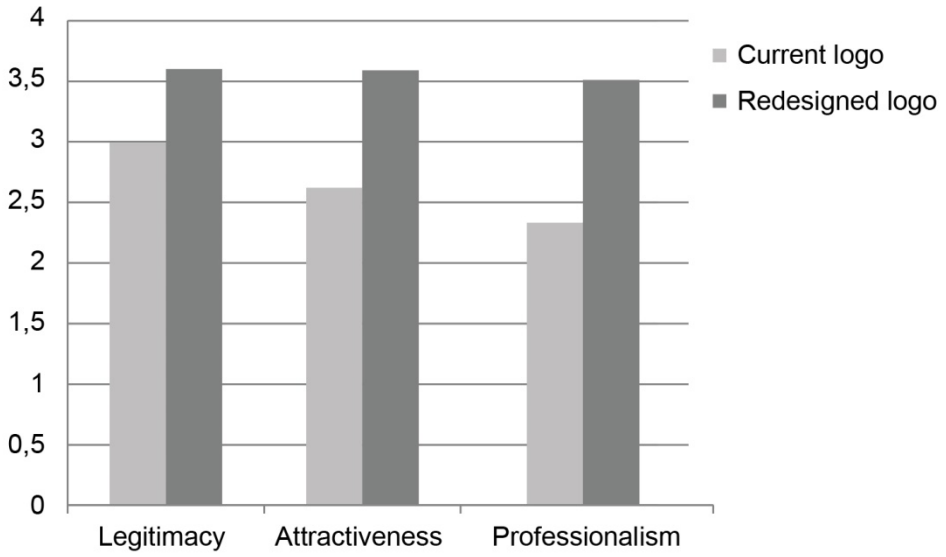

Figure 3: Results of the participants' evaluation of the current and the redesigned logo

In the fourth block of questions, the participants were presented with the web store items (namely, t-shirts) printed with different designs based on the redesigned logo. The t-shirt designs were: the redesign logo in colour, the redesigned logo in black, a one-colour line illustration, a colour illustration, and a realistic illustration (Figure 4). The redesigned logo and the illustrations were based on the same concept. For each t-shirt design, the participants were asked to evaluate the quality of the design and the willingness to purchase using a 5-point scale. A repeated measures analysis of variance (ANOVA) was used to test the effect of the t-shirt design on the participants' responses. The results showed a significant effect of t-shirt design on both variables. Particularly, the results showed differences in the participants' evaluations of the design across variations in designs, $F(4, 620) = 21.58$, $p < 0.001$, as well as in the participants' willingness to purchase, $F(4, 620) = 29.67$, $p < 0.001$. Post hoc

analyses were done with the Bonferroni correction with the 0.013 level of significance. The analyses revealed that variations in t-shirt design affected dependent variables differently. When comparing the redesigned logo in colour with the redesigned logo in black, the participants' evaluations of design quality did not differ significantly ($p > 0.013$). On the other hand, their willingness to purchase was significantly higher for the logo in black ($M = 2.92$, $SD = 1.36$) than the logo in colour ($M = 2.69$, $SD = 1.26$), $p < 0.001$. Furthermore, the participants rated the colour illustration ($M = 4.04$, $SD = 1.06$) better than the realistic illustration ($M = 3.82$, $SD = 1.14$), $p < 0.01$, whereas there was no difference in the willingness to purchase between the two designs, $p > 0.013$. There were no significant differences between the one-colour line illustration and the colour illustration for both dependent variables (both $ps > 0.013$). In contrast, t-shirt design with the one-colour line illustration was significantly better evaluated ($M = 4.02$, $SD = 1.08$ for the quality of design, $M = 3.64$, $SD = 1.24$ for the willingness to purchase) than t-shirt design with the logo in black ($M = 3.46$, $SD = 1.20$ for the quality of design, $M = 2.92$, $SD = 1.36$ for the willingness to purchase), both $ps < 0.001$. From these results, it can be concluded that the one-colour line illustration may be used in the shelter's marketing strategy as the most appropriate graphic for the t-shirt design. Since t-shirts are the most popular items in the shelters' web stores, it is reasonable to expect that the shelter's income would benefit from the improvement in t-shirts designs.

Figure 4: T-shirts printed with different designs based on the redesigned logo

To summarize, the results suggest three major findings. First, in the selection tasks, the proposed redesigned version of the logo was preferred over the current logo. Second, the positive effects of the redesign were confirmed by the participants' subjective evaluations of attractiveness, professionalism and legitimacy. This implies that a sophisticated logo can influence the perception of the animal shelter and increase the likelihood of being noticed by potential donors. Third, our results demonstrated that people are sensitive to variations in t-shirt design which could be used in the shelter's web store, suggesting that the one-colour line illustration would be more appreciated by potential donors than other designs used in our study.

When considering the logo design, some practical conclusions can be drawn from our results. The redesigned logo used in our study was a visually balanced symbol which conveyed a strong concept with several layers of information (i.e. love, community, protection, animal variety). Its new, improved visual appearance can be used

as an added value to the shelter's identity and may lead to greater interest from potential donors and adopters. The study showed that visual identity does influence people's evaluation of the shelter and that the attractiveness of the logo redesign can have an impact on the perception of the shelter's qualities. Still, relying on professional appearance of the shelter's visual symbols is not the only aspect of a successful strategy. In order to increase the likelihood of donations, shelter managers should also communicate additional relevant information in a more explicit form, such as progress toward meeting the shelter's goals (Lord, Olynk Widmar, & Litster, 2014).

4. CONCLUSIONS

Societies that help and protect animals should plan carefully how they present themselves, because it influences the amount of financial aid they receive. Nowadays, the logo is the first thing a person sees given that most communication takes place over the Internet. Thus, visual communication should be prudent and in line with the visual identity of the animal shelter. Logos with too complex structures can evoke an unprofessional impression about the shelter, and therefore potentially result in fewer donations. This paper demonstrates how the redesign of the logo for the animal shelter and the creation of attractive graphics for web store items have a great potential for attracting more donations. The redesign evaluation was conducted by a survey oriented toward the target group and its goal was to examine which logo version was the most attractive and whether the attractiveness of the product with the logo print affected the willingness to donate. The results indicated that the current logo does not look attractive enough for most of the respondents and does not seem professional enough. The new, redesigned version of the logo had significantly better ratings according to all investigated criteria (attractiveness, legitimacy, professionalism). It was perceived as more attractive and professional, and consequently encouraged potential donors to be more willing to support the work of one of the most prominent animal shelters in Croatia.

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PACKAGING

COLORIMETRIC PROPERTIES OF STARCH-BASED FILMS WITH ANTHOCYANINS FROM AGRO WASTE FOR SMART PACKAGING APPLICATIONS

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Abstract: *In this research, the colorimetric properties of bio-based pH sensitive sensors for smart packaging applications such as detection of the food freshness inside the packaging were analysed. Anthocyanins were extracted from agro waste peels of red onions. The extraction of anthocyanins was performed with and without the ultrasound pretreatment. They were immobilized in biodegradable composite films based on potato and maize starch. Optical and colorimetric properties of the produced films as well as their changes after immersion in chemical agents with different pH values were evaluated. Results have shown that maize starch-based films generally have higher transmittance and lower diffuse transmission density than potato starch-based films. Ultrasound pretreatment during anthocyanin extraction did not significantly influence the optical properties of the films, while all components in film compositions had a noticeable effect on all changes related to the colour of the films. A significant color change of the films was observed in various buffer solutions.*

Keywords: *anthocyanins, biodegradable composite films, pH-responsive smart packaging*

1. INTRODUCTION

In recent years, the smart packaging industry, which combines traditional packaging systems for food containment and protection with advanced technologies, has developed rapidly. Its role is to provide additional information to consumers by displaying various alerts about changes in the packaging environment that could affect food safety and quality (Gregor Svetec, 2018; Vasuki, 2023). The technologies commonly used to warn of various food quality issues in packaging are different types of sensors/indicators. They are used to display potential food quality issues and quickly inform the consumer about the contamination or spoilage of the packaged product. Smart packaging materials can contain various sensors to monitor different aspects of the product such as temperature, humidity and freshness and/or contain indicators such as colour-changing labels or electronic displays that provide real-time information about the condition of the packaged product (Brockgreitens, 2016; Halonen, 2020).

The use of natural compounds to produce packaging films that can serve as indicators requires the use of bio-based materials in combination with a sensing element. To function as a pH indicator, the produced film must be placed in the headspace of the food container, close enough but without direct contact with the food to detect a pH change in the packaging environment (Rodrigues, 2021).

The use of bio-based materials for different packaging applications is being intensively researched, and among the various materials, starch-based polymer films have been the most widely used. Their main advantages lie in the high availability of different types of starch, inherent biodegradability, and annual renewability (Niu, 2021; Jiang, 2020; Żołek-Tryznowska, 2021). The starch sources used in packaging applications come from various agricultural crops such as potatoes, rice, corn, tapioca and others (Niu, 2021; Żołek-Tryznowska, 2021; Jiménez, 2012). Their different formulations, mixed with other ingredients such as glycerol, sorbitol and polyethylene glycol, are most commonly used for the production of bio-based films (Zhang, 2020; Peralta, 2019; Zhang, 2019). As Croatia and Slovenia has traditional farming of maize and potato, and also factories which produce starch from these industrial crops the two were chosen as a locally sourced raw ingredient.

For production of pH sensors/materials in this research, the bio-based films were prepared by forming a polymer matrix with starch, glycerol and pH sensing element. As the aim was to produce a pH indicator, it was important to

use a material that was sensitive to changes in acidity or alkalinity, as it must contain substances that undergo a visible color change in response to changes in the pH (acidity or alkalinity) of the environment. For this research, anthocyanins extracted from also locally available agro waste were used as sensing elements. Anthocyanin extracts are rich in pigmented compounds and are interesting for the production of pH indicators, as they change their color in response to pH fluctuations caused by microbial growth on the food surface. Anthocyanin can be found in red onions, blueberries, raspberries, grapes and red cabbage, among others, and can be used to produce pH-sensitive indicators as they have the ability to change color depending on the degree of food spoilage and the presence of microbial metabolites (Halonen, 2020; Kurek, 2019; Hogan, 2008). They are used for the safety and quality assessment of food products that are mainly composed of proteins, where the decomposing proteins generate alkaline volatile nitrogen compounds that lead to pH changes on the food surface. Their use makes it possible to detect the change in food quality with the naked eye, which helps to raise consumer awareness as they can visually assess the condition of the packaged product.

The aim of this paper was to evaluate the colorimetric differences between the novel bio-based pH-sensitive indicators for real-time monitoring of food freshness which resulted from differences in their compositions. Furthermore, the changes of the indicators' colours after the changed pH of the surroundings were analysed.

2. EXPERIMENTAL PART

2.1 Materials

Maize starch (extra pure, CAS: 9005-25-8), potato starch (extra pure, CAS: 9005-25-8) (Carl Roth, Germany), distilled water, glycerol (purity 99.5%, CAS: 56-81-5) and glacial acetic acid (CAS: 64-19-7) were used to prepare the films.

The anthocyanins were extracted from agro waste peels of red onions. The different colors of onions are primarily due to the presence of two types of flavonoids in onions, namely anthocyanin and flavonols, which are used as pH sensing elements as they change color with pH fluctuations (Samota, 2022). Extraction of anthocyanins was performed at 60 °C for 120 min, with a 96 % (Pharmachem, Ljubljana, Slovenia) ethanol solvent extraction method with and without ultrasonic pretreatment. The ultrasonic (pre)treatment was carried out using an ultrasonic probe (Sonics Vibracell VCX 750) at a power of 350 W for 10 minutes. Following one minute of probe operation, a one-minute pause was performed. This approach, combined with a cold-water bath, prevented excessive heating of the suspension.

Commercially available pH buffers (Gram-Mol d.o.o., Zagreb, Croatia) (pH2 [C6H8O7 (1-hydrate), NaOH, HCl], pH7 [H2KO4P, HNa2O4P] and pH10 [H3BO3, KCl and NaOH]) were used for the detection of color changes.

2.2 Methods

Diffuse transmission density and transmittance of the films produced were measured with the Macbeth TD-102 QuantaLog densitometer (Macbeth, New York, USA). The diffuse transmission density (density D_T) is usually measured on translucent images and films, whereby the optical density corresponds to the negative common logarithm of the transmittance (T) of an image area (D_T = –log T) (Zarobila, 2022).

The colorimetric properties of the produced films were measured with the spectrophotometer CM-3600d from Konica Minolta (Tokyo, Japan). Based on the reflectance and transmittance values, the CIE coordinates L*a*b of the CIELAB colour space were measured. L* stands for the lightness of the colour, a* for the position between green and red and b* for the position between yellow and blue (ICC.1:2004-10, n.d.; Fairchild, 2013). The illumination area was set to 25.4 mm to measure the samples in reflectance and transmittance mode with a geometry of d/8° and d/0°, respectively, according to the CIE No. 15, ASTME1164 and DIN5033 Part7 standards. Photographs of films immersed in different pH buffers were taken to observe the visual change in the films produced.

2.3 Film preparation

The starch films were prepared by mixing starch with other components in different concentrations. 15% (w/v) potato starch and 10% (w/v) maize starch (MS) were dissolved in distilled water under stirring using the DLS Digital Overhead Stirrer (Velp Scientifica Srl, Usmate, Italy). Aqueous glacial acetic acid (1% (v/v)) and glycerol were added to the film-forming solution. Glycerol was added at concentrations of 10 % (w/w) and 15 % (w/w). Untreated and treated anthocyanins extracted from red onion peel (ROP) were added at concentrations of 15 % (w/w). Potato starch (PS) films containing 10% (w/w) glycerol and untreated anthocyanins were designated PS-G10-ROP, and potato starch films containing 15% (w/w) glycerol and treated anthocyanins were designated PS_G15_ROPt. Films made from maize starch (MS) were designated MS_G10_ROP, films containing 10 % (w/w) glycerol and untreated anthocyanins and films containing 15 % (w/w) glycerol and treated anthocyanins were designated MS_G15_ROPt. Preparation of each film lasted approximately 30 minutes. After the homogenization process, the film-forming solutions were poured into glass Petri dishes and dried in a room temperature at 25 °C and 50 % relative humidity for 10 days.

3. RESULTS AND DISCUSSION

Figure 1 presents the results of diffuse transmission density and transmittance of the film samples. It is visible that the type of starch significantly affected the diffuse transmission density of the prepared films. Generally, films based on potato starch displayed higher diffuse transmission density and lower transmittance than the films based on maize starch. One exception was the sample MS_G10_ ROP, whose values were closer to those obtained on maize starch-based films, which is probably due to the occurrence of isolated air bubbles in the film layer. Maximal diffuse transmission density of 0.32 was obtained on the sample PS_G15_ROP, and minimal value of 0.17 on the sample MS_G10_ROPt. Glycerol concentration influenced the diffuse transmission density and transmittance of the samples, as well. Increased amount of glycerol in the film generally resulted with the increase of the diffuse transmission density and decrease of the transmittance. The ultrasound pretreatment during the anthocyanin extraction did not have a significant influence on the measured optical properties of the films.

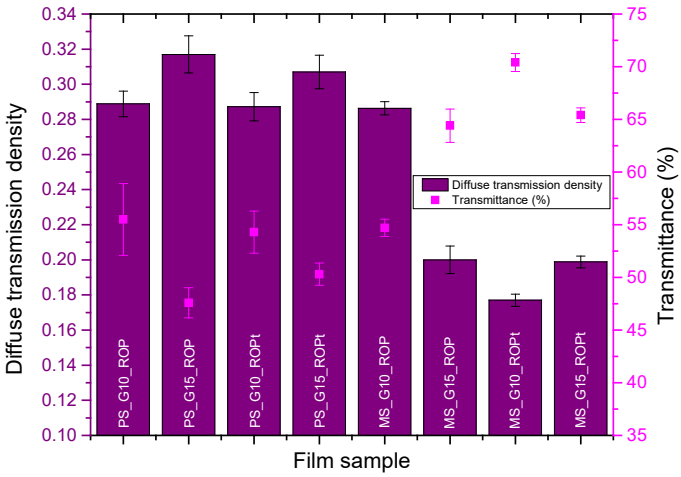

Figure 1: Diffuse transmission density and transmittance of the starch-based films with anthocyanins

In Figure 2, CIE L*a*b* values of the starch-based films with anthocyanins, obtained using transmitting light, are presented. Figure 2.a shows the lightness (L*) of the films, while Figure 2.b shows the a*/b* diagram of the starch-based films with different compositions. It can be seen in Figure 2.a that the potato starch-based films with ultrasound pretreated anthocyanins had higher lightness than the films with anthocyanins without the pretreatment. The highest average lightness was measured on the film PS_G15_ROPt (36.87). The difference in the procedures of anthocyanin extraction did not result with significant changes of lightness of maize starch-based films with 15% (w/w) glycerol, while the film with 10% (w/w) glycerol and pretreated anthocyanin displayed lowered lightness than the same film with untreated anthocyanin. Lowest lightness in general was obtained on MS_G10_ROPt film (31.21). Changes of lightness related to the glycerol concentration were opposite for the films

with pretreated and untreated anthocyanins: increased concentration of glycerol resulted with small decrease of lightness for the samples with untreated anthocyanins, and a noticeable increase of lightness of the samples with pretreated anthocyanins.
Figure 2.b presents the CIE a*/b* diagram for the film samples. It is visible that all maize starch-based films have lower a* and b* values than potato starch-based films. Furthermore, higher glycerol concentration resulted in lower a* and b* values on maize starch-based films.
Presented changes of the CIE L*a*b* values suggest that all three components in the film (starch, glycerol, and anthocyanins) affect its colorimetric values. Therefore, precise characterization of the specific influence of each component which can be performed using the wider range of samples with different compositions, is needed.

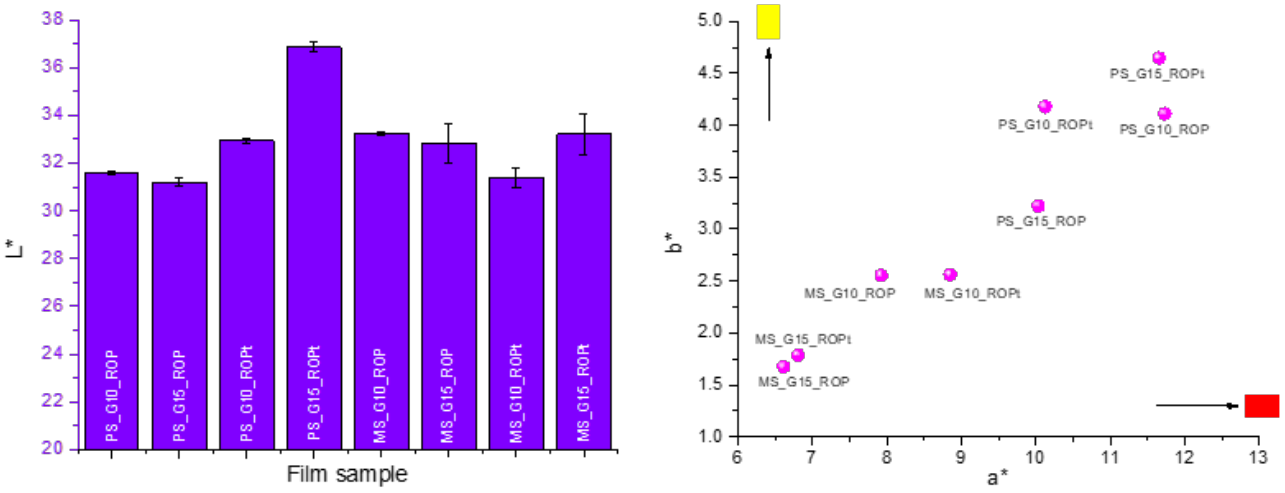

Figure 2: Lightness (L*) (a) and CIE a*/b* (b) values of the starch-based films with anthocyanins (transmittance)

Since anthocyanin films are translucent, their change of colour or colour differences among the samples with varied composition could sometimes be observed and visually better compared when they are placed on a white substrate. For this reason, CIE L*a*b* values on films were obtained using the reflecting light for measurements, as well. After the calibration, samples were measured while placed on a white paper serving as a substrate. Relative colorimetric values (with paper as a white point) are displayed in Figure 3. The relations between the obtained CIE L*, a* and b* values are similar to the relations between the values obtained using the transmitting light.

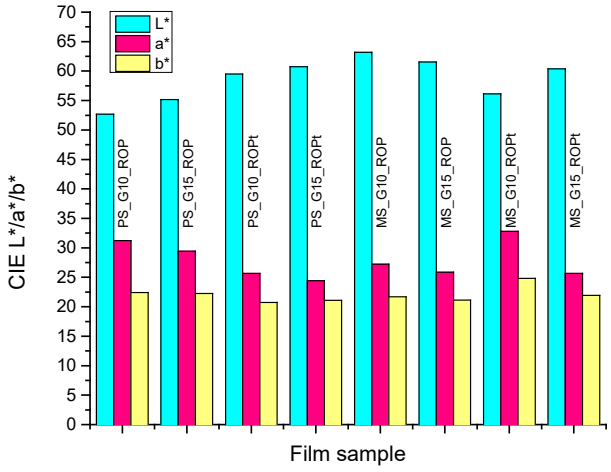

Figure 3: Relative CIE L*a*b* values of the starch-based films with anthocyanins (reflectance)

The images of the prepared films observed after immersion in different buffer solutions are shown in Figure 4.

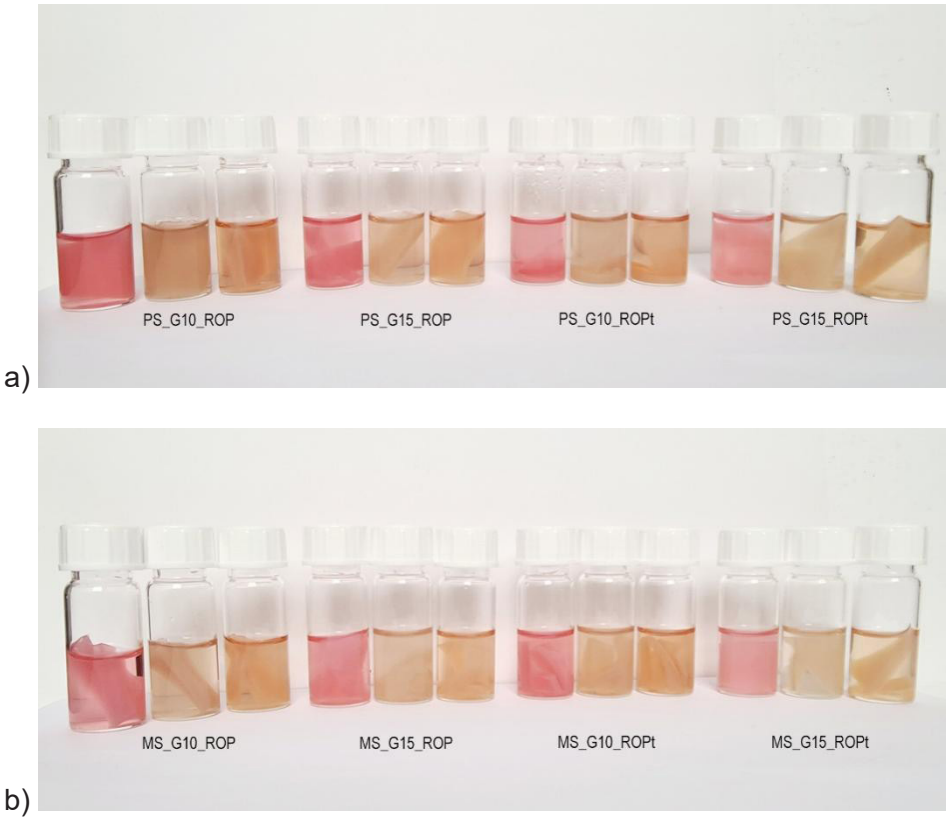

Figure 4: Images of the films immersed in different buffer solutions: potato-starch-films (a), maize-starch-films (b) (from left: pH 2, pH 7, pH 10)

The images show immersed films in solutions with pH 2, pH 7 and pH 10, from left to right. It can be seen that the samples exhibit considerable color variation at different pH values, which is visible to the naked eye. The color of the starch films changed from pink (pH 2) to light pink (pH 7) and light pinkish-yellowish at pH 10. Detailed influence of each component of the film on the colorimetric change as a result of the changed pH, as well as the influence of the anthocyanin pretreatment, need to be analyzed in future research.

4. CONCLUSIONS

In this paper, pH-sensing bio-based films were prepared by forming a polymer matrix with starch, glycerol, and a pH sensing element: anthocyanins obtained from waste red onion peels. Optical and colorimetric properties of the produced films as well as their changes after immersion in chemical agents with different pH values were evaluated, with the aim of characterizing the effect of the components on the optical and colorimetric properties of the prepared films.

Results have shown that maize starch-based films generally have higher transmittance and lower diffuse transmission density than potato starch-based films. Ultrasound pretreatment during anthocyanin extraction did not significantly influence the transmittance and diffuse transmission density of the films. Both main components in film compositions (type of the starch, share of glycerol) had a noticeable effect on all changes related to the colour of the films. The images of the prepared films viewed after immersion in different buffer solutions showed considerable color variations at different pH values. These results show the great potential of using starch films with anthocyanins as bio-based pH-sensitive sensors for the visual detection of changes in food freshness in packaging.

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ECOCHIC ELEGANCE: SUSTAINABLE COSMETIC PACKAGING SOLUTIONS FOR A GREENER TOMORROW

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Abstract: *This study presents a comprehensive global evaluation of sustainable packaging options for the cosmetics sector, with a specific focus on the urgent necessity for sustainable practices in the baby cosmetics segment. Addressing the undeniable environmental impact of the industry, the research underscores the importance of balancing safety, hygiene, and consumer preferences with environmentally friendly packaging solutions. Employing a systematic approach involving Python programming, data mining, and analysis, the study scrutinized packaging claims of 2050 brands, including 76 specializing in baby cosmetics. Results reveal that nearly 40% of delicate-baby cosmetic brands lack specified packaging materials, while the remaining 60% embrace recyclable, refillable, or bio-based alternatives. This shift highlights the industry's increasing inclination towards sustainability, though transparency gaps necessitate stronger regulations. The cosmetics industry faces challenges and opportunities in sustainable packaging, with successful case studies indicating positive strides. The study calls for consumer education, industry collaboration, and shared responsibility among cosmetics companies to shape a sustainable future for baby cosmetics packaging.*

Keywords: *eco-friendly solutions, packaging design, transparency, certification standards*

1. INTRODUCTION

In recent years, the cosmetics industry has increasingly prioritised sustainable packaging, driven by a global market that is expected to reach USD 412.8 billion by 2027, with the cosmetics sector playing a key role (Packaging Industry Report, 2023). A significant trend is the demand for biodegradable materials, which is expected to grow at a CAGR of 15.3% from 2023 to 2028, driven in part by the cosmetics industry (Packaging Industry Report, 2023). Companies are shifting to paper-based materials such as paperboard or moulded pulp, which is in line with the expected growth of 5.5% CAGR in the global paper packaging market from 2021 to 2026. Recycling is an important aspect, and as companies focus on making packaging materials more recyclable, the global recyclable packaging market is expected to reach USD 265.6 billion by 2028 (Packaging Industry Report, 2023). Leading global brands are committed to sustainability and are exploring various approaches such as refillable or reusable packaging, biodegradable or recyclable materials, waste reduction initiatives and in-store recycling programmes (Gatt & Refalo, 2022; Jestratijevic et. al., 2022; De et al., 2023; Swain et. al, 2023). While conventional packaging materials can be harmful to the environment, especially in the sensitive area of baby cosmetics, the introduction of sustainable packaging is crucial to mitigating the environmental impact. Brands that are committed to sustainability can strengthen brand loyalty among customers who value environmentally friendly practises (Adomako, S., & Nguyen, 2022; Bharti et al., 2023). This study looks specifically at the urgent need for sustainable packaging in the baby cosmetics industry. It examines the current sustainable packaging solutions, identifies the materials used and analyses their actual application. By providing insights to improve sustainability practises, the study contributes to a positive impact on the environment and ensures competitiveness in the market. The study includes a systematic protocol to ensure the credibility and validity of the findings and outlines the benefits, limitations and potential legal issues. Collaboration between stakeholders is emphasised, highlighting the study's practical findings for a more sustainable future for the baby brand cosmetics industry. This study addresses the urgent need for sustainable practises in the cosmetics industry, sheds light on the environmental impact and provides a shared roadmap for a sustainable future.

2. EXPERIMENTAL

In 2022, a systematic study focussed on international cosmetics brands that presented their efforts towards sustainable packaging. Applying a rigorous methodology, the data analysis used only information from primary sources such as official websites and sustainability reports, excluding secondary sources such as social media and third-party websites. Initially, 2050 all cosmetic brands, after excluding non-English websites and irrelevant sources, the final sample consisted of 76 baby cosmetic brands. These brands represented a wide range of baby cosmetic products and were present in Europe, America, Australia and Asia. Thematic content clustering guided the iterative data analysis through five research phases: planning the search, conducting the search, reviewing the datasets for relevance, data management and summarising the results.

Firstly, a research protocol was created with clear study objectives and methods, including the development of a Python 3.6 web scraper for automated data collection. In the second phase, the web scraper accessed the World Wide Web via HTTP and identified 2050 cosmetic brands promoting sustainable cosmetics packaging. The next phase involved manual review of the websites, screening of the datasets for data management and quality assessment to include only primary sources. This process resulted in a final sample of 76 baby cosmetic brands and 1974 other cosmetic brands (woman, man, teenagers) for the systematic review. The fourth phase utilised thematic clustering, a qualitative method of analysis. Thematic coding by two researchers identified emerging themes and resolved any inconsistencies through discussion. In the final phase, the results were summarised and reported to create a comprehensive overview of sustainable practises in cosmetics packaging.

3. RESULTS WITH DISCUSSION

It is important to recognise the significant differences in the types of packaging chosen by cosmetics brands, which are influenced by product characteristics and brand preferences.

The following results show a differentiated view of the introduction of standards and materials for sustainable packaging in the cosmetic industry around the world (Figure 1-3). This research highlights positive trends, identifies challenges and offers insights into a more environmentally conscious future for cosmetics packaging.

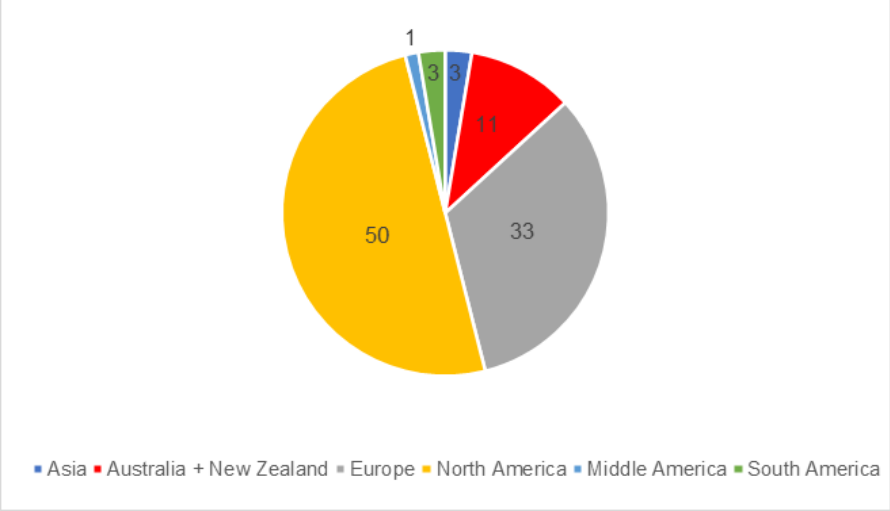

Figure 1: Percentage of brands using sustainable packaging solutions around the world

This study firstly presents the distribution of cosmetic brands across different continents based on sustainable packaging practices. The analysis reveals a diverse distribution, with North America leading at 50%, followed by Europe at 33%, and Australia + New Zealand contributing 11%. Asia, South America, and Middle America exhibit lower percentages at 3%, 3%, and 1%, respectively. This geographical distribution provides valuable insights into the varying degrees of adoption and emphasis on sustainable packaging practices within the global cosmetics industry. Further exploration of regional trends and factors influencing these percentages can contribute to a more comprehensive understanding of sustainable packaging initiatives in the cosmetics sector.

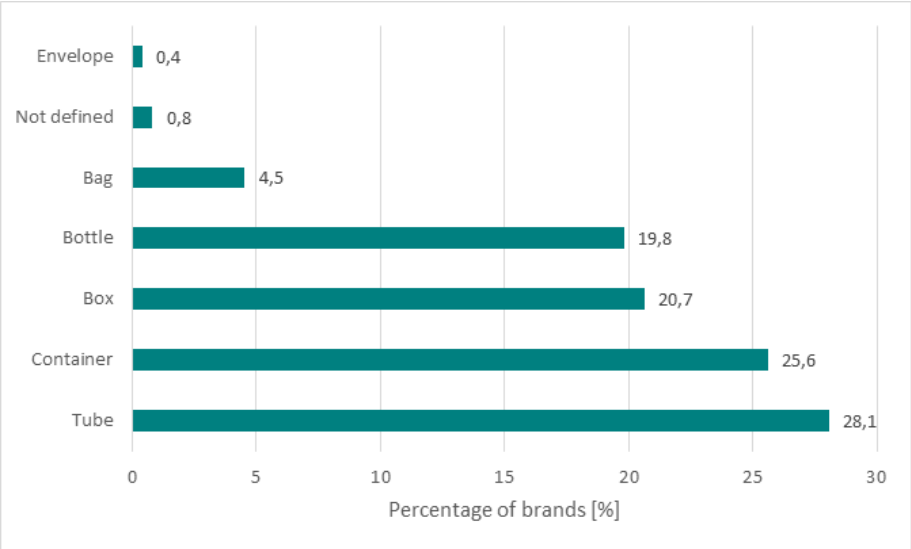

Figure 2: Most frequently used types of packaging for cosmetics brands

The analysis (Figure 2) shows that among the cosmetic packaging types indicated, tubes are the most common types and are used by 28,1 % brands. Containers are in second place with 25.6 %, followed by cartons with 20.7 % of brands. Bottles are the fourth most frequently used with 20% of brands, while bags are the least frequently used with 4.5 %. Only 0.4 % opts for envelopes and less than 1 % among envelopes, do not specify their packaging type. In the analysis, emphasis was placed on defining the type of sustainable packaging material used.

Analysis in the cosmetics industry shows how high the proportion of sustainable packaging standards and certificates is and provides a differentiated insight into the industry's commitment to environmentally friendly practises (Figure 3).

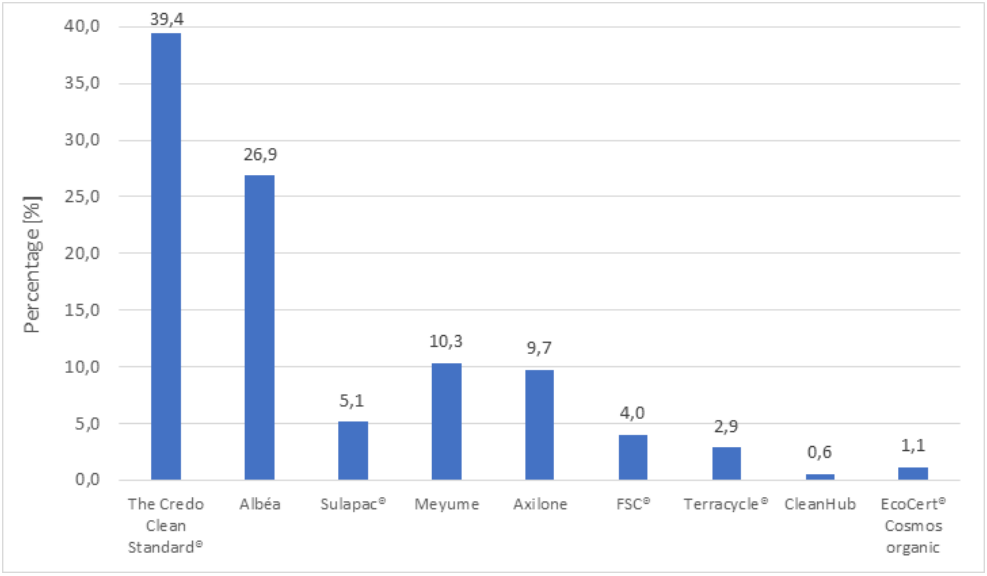

Figure 3: Standards and certificates used for sustainable packaging solutions

The Credo Clean Standard® is the most widely used standard with 39.4% of brands using it. Albéa follows closely behind with 26.9% and is a sustainable packaging option. Sulapac®, an alternative to conventional plastics, was chosen by 5.1%, while Meyume and Axilone were chosen by 10.3% and 9.7% respectively. The Forest Stewardship Council (FSC®), which promotes sustainable packaging, is chosen by 4.0%, and Terracycle®, which

specialises in dealing with materials that are difficult to recycle, is used by 2.9%. CleanHub and EcoCert® Cosmos organic is used by 0.6% and 1.1% of brands respectively. Comparing the results of the overall cosmetic packaging analysis with the specific analysis focused on baby cosmetic packaging, some notable differences and similarities emerge. In both analyses, the incorporation of certifications and standards is recognized as a pivotal strategy for ensuring the adoption of sustainable packaging materials and practices.

In the specific realm of baby cosmetic packaging, out of the 76 brands analyzed, only 4 incorporate various certifications and standards. TÜV, OEKO TEX, and EcoCert® Cosmos organic certifications further contribute to environmentally friendly practices in manufacturing. Several brands within the baby cosmetic packaging sector utilize sustainable packaging solutions provided by companies like Albéa, Sulapac®, Axilone, Meyume, and Terracycle®. Each company offers unique sustainable alternatives, from tubes and containers to biodegradable and compostable materials. Noteworthy is the focus on mono-material designs, recycled components, and adherence to prominent environmental guidelines, indicating a commitment to sustainability and responsibility in both the broader cosmetic and baby cosmetic packaging segments. These percentages show the diversity of sustainable packaging choices in the cosmetics industry and emphasise the industry's gradual shift towards environmentally friendly practises. The results highlight areas where brands can further strengthen their commitment to sustainability to encourage a concerted effort towards a more environmentally conscious future for cosmetics packaging.

The data presented shows that the issue of sustainability is interpreted differently in the packaging industry. Although there are encouraging developments towards the use of renewable, biodegradable and recyclable materials, there is still a notable lack of transparency as some brands continue to use unsustainable materials. Raising consumer awareness is crucial in this context as it will enable them to make informed choices about the materials used in the packaging of the products they buy and emphasise the importance of sustainability considerations.

The findings present a comprehensive overview of primary packaging materials used by cosmetic brands, emphasizing their sustainability percentages:

1. Paper and Cardboard: Commendably, 25% of brands prioritize the use of paper and cardboard as their primary packaging material, showcasing a commitment to sustainability. The renewable and biodegradable nature of these materials makes them both recyclable and reusable.
2. Aluminium: Notably, 17% of brands opt for aluminium as their primary packaging material. While aluminium offers durability and lightweight properties, its non-biodegradable nature and significant energy requirements for production underscore important considerations.
3. Biodegradable, Compostable Plastic: A positive trend is evident, with 6% of brands selecting biodegradable and compostable plastic as their primary packaging material. This choice aligns with eco-friendly practices, as these materials are designed to break down harmlessly in the environment.
4. Recyclable Plastic: A significant 31% of brands choose recyclable plastic as their primary packaging material, reflecting a positive step towards sustainability. However, it's crucial to note that challenges such as contamination and inadequate infrastructure can hinder the effective recycling of all types of recyclable plastics.
5. Combination of Packaging Materials (Paper, Cardboard, Recycled Plastic): Encouragingly, 15% of brands adopt a combination of paper, cardboard, and recycled plastic as primary packaging materials. This trend signifies a positive direction towards enhancing overall sustainability.
6. Combination of Packaging Materials (Paper, Cardboard, Biodegradable or Compostable Materials): Another positive trend is observed, with 5% of brands incorporating a combination of paper, cardboard, and biodegradable or compostable materials in their primary packaging.
7. Not Defined: Transparency concerns arise as 30% of brands do not specify their primary packaging material. This lack of clarity raises questions about the sustainability of the materials used by these brands.

This approach reflects efforts to reduce the environmental impact associated with packaging materials.

8. CONCLUSIONS

Although commendable progress has been made and a significant percentage have opted for renewable and environmentally friendly materials, challenges remain. The analysis data shows a diverse landscape and emphasises the need for greater transparency in material specifications. Consumer awareness remains crucial in guiding purchasing decisions towards sustainability.

Several challenges emerge from the analysis. The notable lack of transparency, with 30% of brands not defining their primary packaging material, is a barrier to assessing and ensuring sustainability. In addition, while recyclable plastics are widely used (31%), the effectiveness of recycling processes is hampered by issues such as contamination and inadequate infrastructure, revealing critical areas for improvement.

The future of sustainable packaging in the cosmetics industry requires collaborative efforts. Solving transparency issues, introducing standardised reporting procedures and improving recycling infrastructure are crucial steps. Industry stakeholders, including brands, regulators and consumers, have a key role to play in promoting a more sustainable and transparent ecosystem. Continued research and innovation in packaging materials, combined with consumer education, will contribute to a more environmentally conscious and responsible future for cosmetics packaging.

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2D AND 3D PRINTING

THE POSSIBILITY OF DIAGNOSING THE PERFORMANCE OF HIGHLY PRODUCTIVE ELECTROPHOTOGRAPHIC MACHINES USING COLOURIMETRY AND IQC SOFTWARE

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Abstract: *(Installation and adjustment of brand-new EP printing machines are crucial for the quality of future half-tone colour prints. Print quality is a parameter that defines several parameters. The most important are: quality of CMYK colour tone, reproduction of fine details, range of tonal values, a precision register and surface properties of the printed image or entire page/sheet. Recently, the number of highly productive electrophotographic machines has increased on the market of printing machines, Therefore, the printing speed becomes higher than 120 pages/min of A4 format. This characteristic is primarily made possible by increasing the dimensions of the basic components in the electrophotographic printing unit (photoreceptors, developing rollers, toner housing). The changes are also accompanied by colours (powder toners) that contain new formulations of developer particles. The aim of this paper is to establish a method of indirectly monitoring the success of the adjustment of EP machines by testing the quality of the new highly productive Konica Minolta AccurioPress C12000 electrophotographic machine, whose printing speed is 120 A4 colour pages per minute. The printing substrate used in the experiment was Fedrigoni Splendorgel Extra White offset paper, weight 160 g/m2. The size of the printed edition was 60 copies, of which 12 were randomly selected. Fogra 52 (Ugra/Fogra MediaWedge wedge of 74 fields) was taken as target reference. The uniformity of the printed edition was tested, while the test interval within 60 seconds was monitored in detail (1, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55 and 60 prints). The achieved colour oscillations over a period of 60 seconds are significantly larger in the second test interval, i.e. from 35 to 60 seconds. The new black toner fails to achieve the target values immediately due to the high proportion of initial starter particles.*

Keywords: *highly productive electrophotography, diagnostics of EP machines, colourimetry*

1. INTRODUCTION

The most modern electrophotographic machines (EP) have realised the possibility of printing at speeds higher than 120 pages/min. Due to the increase in speed and the application of a complex method of printing machines, a more significant oscillation of the tonal value of the produced prints is expected (especially at the end of the printing run). Additionally, new modern development units that use customised EA toners (EA = Emulsion Aggregation) have been adapted, enabling easier achievement of colour reproductions that are per the desired printed standard. This paper aims to analyse CMYK imprints on a brand-new Konica Minolta AccurioPress C12000 machine (first installation) and determine its possible deviations at the beginning of machine production. Thus, the colourimetric measuring method can be applied to diagnose machine operation and serve EP machine technical services to check the operation of individual EP components (diagnostic tool).

Quality of electrophotographic printing

The quality of four digital EP prints depends on many parameters. The following are crucial: file preparation, selected printing technology, construction of the EP machine, and consumables used (papers and toners). Finishing processes and equipment affect the quality of the final printed product itself. Therefore, the quality of printing can be defined by monitoring the quality of full-tone surface, the reproduction of delicate line structures, the range of realization of halftoned values, the precision of the register, and the surface properties of the printed image or the entire (solid) page/sheet. (Majnaric,2015) Special measuring tapes, also used for visual assessment, are defined for this purpose. For CMYK colour reproduction, the current Fogra/Ugra MediaWedge 3.0 wedge with 72 fields is adapted to evaluate test and production prints. (Kipphan, 2001.) Visual verification, although subjective, must also meet certain conditions, such as lighting and viewing angle. These are also the minimum requirements according to the ISO 3664 standard. (Kraushaar, 2016)

The fundamental principle of operation in electrophotographic machines

Electrophotography is characterised by the physical appearance of the photoelectric effect, which is specific to electrically non-conductive or weakly conductive crystal structures. The photoreceptor is the basis of the entire EP process, and its function is to create a latent image from a digital or analog image. The latent image is then transferred into a visible toner image during development. Each photoreceptor must contain at least two layers (substrate and photoconductive) for controlled electron movement to take temporal place. The underlying layer consists of aluminium, which retains a uniform charge over the entire photoreceptor spectrum and controls the strength of the electrostatic field. Also, the underlying layer enables the electronic grounding of the photoreceptor. The photoconductive layer enables the transfer of charges created by the action of light. The most common materials for producing the photoconductive layer are selenium alloys, cadmium sulfide, arsenic triselenide, amorphous silicon, and organic compounds. Organic receptors consist of two photoconductive layers, i.e., a layer in which the charge is generated and a layer in which the charge is transported. Organic layers also contain a barrier layer whose function prevents the easy flow of electrons between the carrier and upper photoreceptor layer. Modern organic photoreceptors also have protective layers with phthalocyanide pigment, which increases light fastness. Phthalocyanides can be found in two colours (green and blue). However, modern receptors are characterised by their blue colour because the particles of blue phthalocyanine pigment successfully reflect the UV-C region of the spectrum and prevent the passage of this light into the photoreceptor structure. (Schein, 1996) The formation of electrophotographic imprints is usually carried out in six primary phases. These are charging the photoconductor drum, illuminating the photoconductor drum, developing the photoconductor drum, transferring the toner from the photoconductor to the printing substrate, fixing the toner on the printing substrate, and cleaning the photoconductor surface from toner residue. (Johnson,1998)

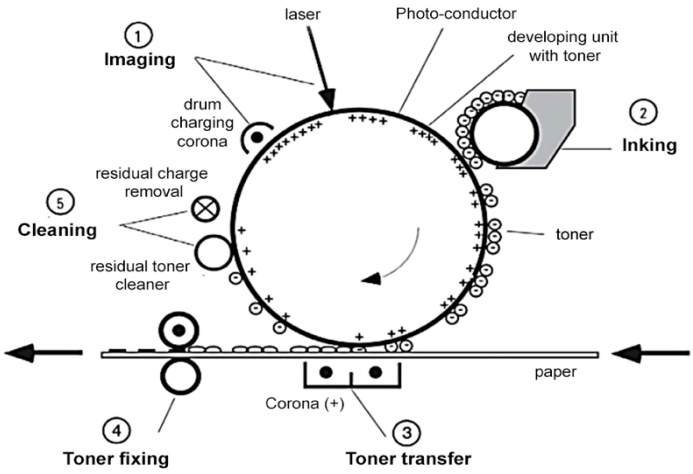

Figure 1: Basic principle of electrophotography

The first phase in printing with the electrophotographic process is charging. That will create a controlled charge on the surface of the photoreceptor. To create a layer of charged air molecules, charging units are used as corotrons or skorotrons. The corotron emits positively charged ions, while the skorotron emits electrons (negative ion charging). (Lee, 2003.)

The generation of the desired image information (imaging) is realised by LED laser illumination of the photoreceptor surface. By neutralizing photoreceptors with light, we achieve either negative CAD (CAD = Charged Area Development) or positive DAD (DAD = Discharged Area Development) images. Thus, the type of laser radiation or the spectrum of light illumination will determine the future appearance of the virtual printing form (positive or negative image). [10] The creation of a toner image on the surface of the photoreceptor (developing) by applying powder toner (developing). This will make the latent image optically visible. After that, the toner selectively moves toward the latent printing form (it needs to be pre-charged). After charging, the process of distributing the coloured toner to the pre-illuminated photoreceptor zone follows. Depending on the type and composition of the toner,

two developing systems are most often used. These are the one-component development system and the two-component development system. (Thompson, 1999)

The process of transferring the generated toner image to paper is called electrophotographic transfer. During this process, the printing substrate (paper) is brought into direct contact with the developed image of the photoreceptor (direct EP printing). However, indirect EP printing is performed if the toner is applied to the transfer intermediate blanket. For a more successful toner transfer to the paper (transfer media), a transfer corona works under the paper or intermediate blanket). Since the powder toner is not firmly fixed, melting and pressuring the powder toner into the paper follows. This procedure, known as fusing, is performed with hot rollers using high thermal radiation. The principle of application of the process depends on the type of applied toner and the speed of printing in electrophotographic machines. [12,13]

The final stage of generating an EP print is cleaning the photoreceptor from toner residues. And it prepares the photoreceptors for new printing. The cleaning process is performed in two steps. The first is erasing the remnants of the previously generated image, removing toner particles remaining on the photoreceptor, and finally neutralizing the photoreceptor surface with light. (Garaedts, 1997)

Innovations in the construction of EP machines

Many renowned global manufacturers produce highly productive EP machines (HP, Xerox, Kodak, Canon, Ricoh, Konica Minolta, and Kyocera). In addition to different technical characteristics, a significant difference is visible in the machine construction itself. High-productivity EP machines use vacuum trays, the minimum number of which is three. The bottom one is usually used for loading all types of printed materials and is the only one that can load 450 g/m2 paper with dimensions of 330x487 mm. For the paper to not change its properties, a heating unit can be installed in the tray, which can also be used to condition the paper. (Pauler, 2012)
This construction enables highly productive machines to print envelopes and long banner formats. In this case, one-sided printing will achieve a print length of 1300 mm on the paper substrate or 900 mm in double-sided printing. At the beginning of the paper transport path, sensors are installed that can recognise the characteristics of the printing substrate. The sensor recognises the paper's thickness, weight, and dimensions, determined by the exact paper profiles. Registration of two-sided printing is automated, and each sheet of paper is aligned before entering the EP printing unit. (Konica Minolta, 2021) In addition to the basic printing unit, installing an additional transport unit with a mechanical straightening of the paper sheets is possible. Due to the fusing heat, the lightweight papers unfortunately become stiff and uneven. This unit cools the paper with water, removing unevenness and eliminating formed electrostatics. At the end of the printing process, it is possible to install a unit to measure the printed content's quality. The unit contains two scanners (analyse the upper and lower sides of the sheet) and a spectrophotometer that automatically calculates the colourimetric values on the print. In addition, it is possible to perform automatic linearization, calibration, and profiling of prints. (x-Rite 2021)
High-capacity toner cartridges can now print up to 200,000 prints and can be changed during printing. Thanks to the new fusing units (now weighing 43 kilograms), the melting temperature of the new toners has been reduced, and a large amount of heat is not required to accept the toner to the paper. Compared to previous generations of toners, the electrostatic behaviour has been improved, and the particle size has been reduced. Thus, with the ROS print head of 16 laser sources, a maximum print resolution of 2400x3600 dpi, a matte print structure, and the possibility of printing on structured or embossed papers are enabled. The productivity of such EP machines based on powder toners achieved a speed of more than 120 pp/min, corresponding to a productivity of 80 A3 pp/min. (Konica Minolta, 2021)

2. EXPERIMENTAL PART

To verify the success of the installation of the new EP printing machine, Konica Minolta AccurioPress C12000, CMYK printing was applied in a printing run of 120 sheets. Testing was performed on June 3. 2020 at the Konica Minolta Demo Centre in Ljubljana. For the target values, the ISO 12647-2 standard is defined. That means that during printing, the Fiery IC-318 RIP settings are applied following FOGRA 52 with the application of the PSOcoated_v3 profile and the measurement mode M1. Fogra/Ugra MediaWedge 3.0 CMYK wedge with permitted tolerances $\Delta E < 3.0$ was used to measure test and production samples. [18,19] During the experiment, 100 lpi line amplitude rasters were used, and the printing substrate was uncoated Fedrigoni Splendorgel EV offset paper

with a grammage of 160 g/m2. The obtained CMYK prints were analysed using the colourimetric method (X-Rite eXact Advanced) to determine colour changes in CIELAB, ΔE, ΔL, ΔC. In addition, the uniformity of the printed edition was tested, while the test interval of 60 seconds was monitored in detail. The Origin Pro 8.5 program was used for other graphical representations of the results. The X-Rite iQC Control application was used along with its iQC graphic displays.(x-Rite 2021)

3. RESULTS AND DISCUSSION

The standard configuration of EP machines allows printing with only four process inks. The EP prints were created sequentially: yellow, magenta, cyan, and black. Process shades measured in the experimental part are located on the Ugra/Fogra MediaWedge wedge, which for cyan separation are defined at positions a1 to a5, magenta from 6a to 10a, yellow from a11 to a15, and black from a16 to a23. Other halftones and spot tones are created by overprinting and the screening process. The most demanding tones to print are solid tone (100% TV) and a halftoned field of 40% TV. For this reason, these two tonal areas were analysed in 60 seconds. Figures 2, 3, 4, and 5 show the dynamics of colour changes from 12 CMYK prints (measured every 5th print).

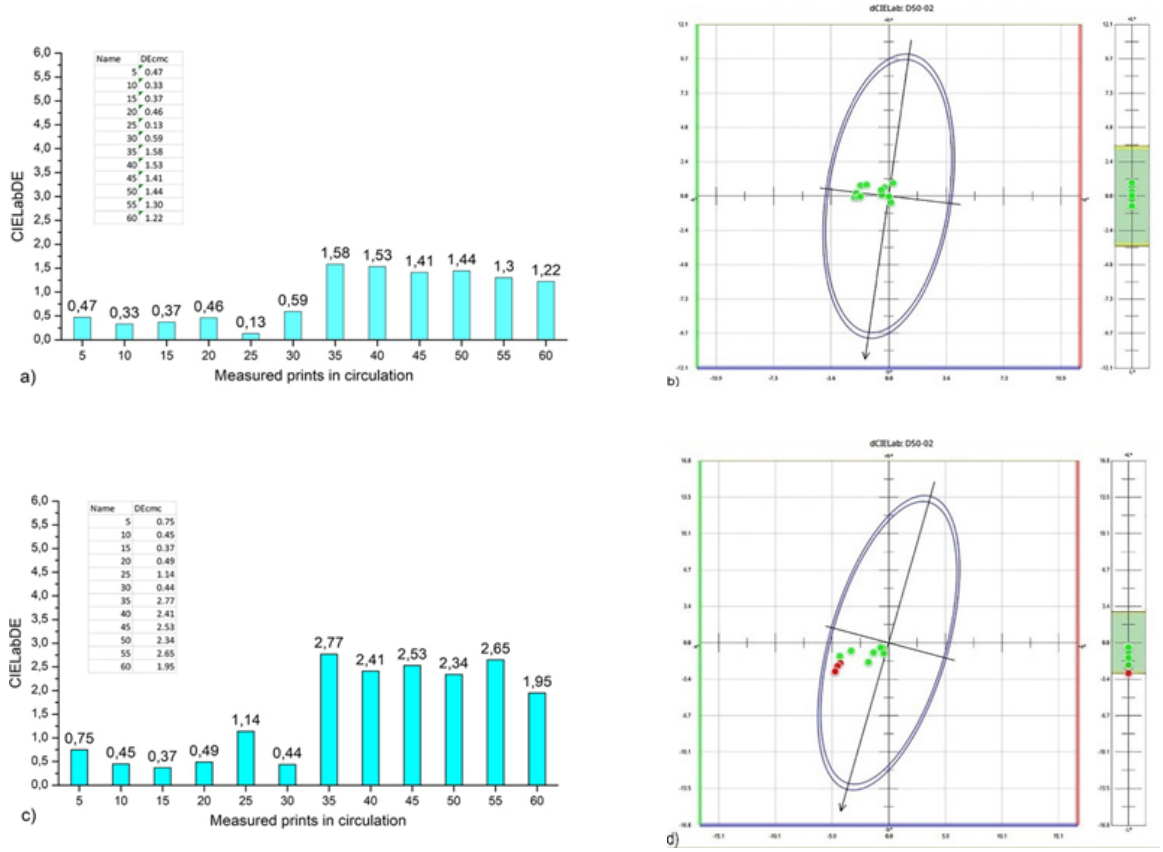

Figure 2: Accomplished of colour oscillation on prints for cyan colour over 60 seconds: a) Histogram of changes in 40% TV; b) CIELab colour deviations about the standard for 40% TV, c) Histogram of changes for 100% TV; d) CIELab colour deviations about the standard for 100% TV

Analysing the cyan separation histogram of 40% TV (Figure 2a), we observe that the initial print run period of the machine has no significant deviations, after which there is a sudden increase in the value of the colour change when the print is printed in the 35th second. After the aforementioned sharp increase in colour change after the sixth print, the stability of the print is re-established, and no significant deviations occur.

For the initial print run period, we obtained results that are invisible to the human eye in mid tones (40% TV cyan separation) and amount to $\Delta E_{5s\text{-}30s}$=0.61. The mean value for the second period has a large amount of

$\Delta E_{35s\text{-}60s}$=2.44. The maximum value was recorded on the 35th print and is ΔE_{35s}=1.58, while the minimum value is present on the 25th print $\Delta E_{C40\%\_25s}$=0.13. The calculation of mean values for the entire period of 60 seconds amounts to $\Delta E_{0s\text{-}60s}$=1.53, which is within the tolerance limits.

The 2D CIEL*a*b* diagram (Figure 2b) created in the iQC program shows that all 12 measurements are within the ellipse of permitted deviations. This alone confirmed the stability and precision of the printing press at a print run of 60 copies. Oscillations of some tones in terms of chromaticity are read in this, creating more greenish prints. The brightness remains stable. We observe the same sequence of results by analysing the cyan print with 100% TV. The histogram in the first 30 seconds has relatively continuous deviations (except the 25th print, which records a deviation of ΔE_{25s}=1.14). After the first 30 seconds, the cyan prints form a sudden jump (in the 35th second), continues with stable movements. By calculating the colour deviations of the cyan solid tone, we concluded that in the first part of the histogram, we have exceptional stability $\Delta EC100\%\_5\text{-}30s$=0.39. However, it is followed by deviations of cyan tones $\Delta E_{C100\%\_35\text{-}60s}$=1.41 in the second part of the histogram. The recorded maximum is analogous to Figure 4a with $\Delta E_{C100\%\_35s}$=2.77, while the minimum was recorded in the 30th second with $\Delta E_{C100\%\_30s}$=0.44. The arithmetic average of all deviations for 60 seconds amounts to $\Delta E_{0s\text{-}60s}$=0.9.

Realised solid tone measurements (Figure 2d) are also precise and do not exceed the elliptical tolerance limit. However, unlike 40% TV, at a solid patch, the three points are at the upper tolerance limit. Such tones are significantly greener and darker than the default Fogra 52 reference. From the above, a short period of cancellation of operation of the fuser unit (due to possible overheating) and, thus, a more significant deviation in the cyan colouring of all tested fields can be seen.

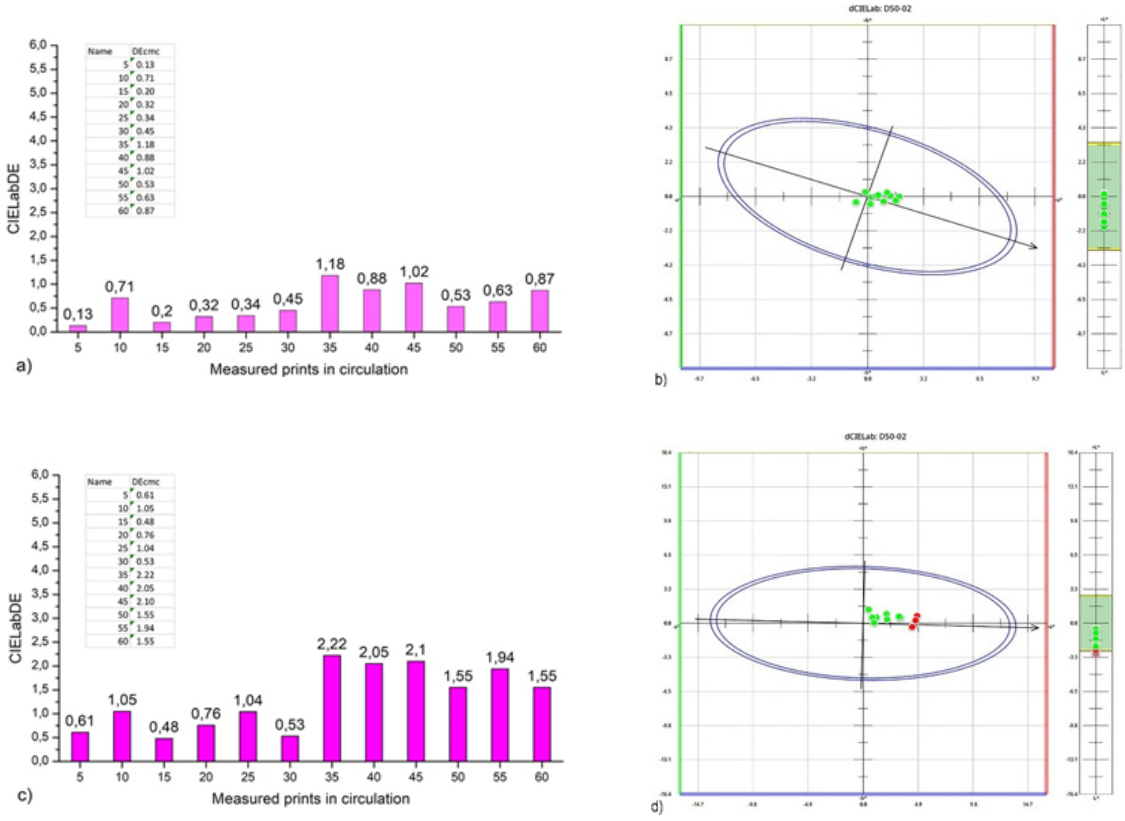

Figure 3: Accomplished of colour oscillation on prints for magenta colour over a period of 60 seconds: a) Histogram of changes of 40% TV; b) CIELab colour deviations about the standard for 40% TV, c) Histogram of changes for 100% TV; d) CIELab colour deviations about the standard for 100% TV

By interpreting the histogram (Figure 3a) obtained for magenta separations of 40% TV, an increase in the value of the colour change in the print printed in the 35th second is recorded. As with cyan separation, the mentioned change occurs in the same period and continues until the end. In the first half of the measurement, the mean

value was ΔE_{5s-30s}=0.36, after which there was an increase of $\Delta E_{35s-60s}$=0.85. The maximum colour change was also recorded in the 35th second (ΔE_{35s}=1.18), while the minimum was achieved in the 5th second (ΔE_{5s}=0.13). Overall, the average oscillation of magenta in a field of 40% TV amounts to ΔE_{5s-60s}=0.6. The specified deviation is within the tolerance limits.

Figure 2b shows confirmed deviations within the tolerance limits, and the prints do not record significant deviations in tone or brightness. A slight deviation is noticeable in the direction of the red tone. That is, the specified print is slightly redder than the default standard.

Figure 3c shows the magenta separation values at solid tone. The same trend as in Figure 3a is maintained here. The print with the slightest deviation is present in the 15th second with ΔE_{15s}=0.48. In the first 30 seconds, the stated deviations are also insignificant, and their mean value is ΔE_{5s-30s}=0.75.

The histogram again shows a sudden jump in the 35th second, representing the maximum measured value, ΔE_{35s}=2.22. In the second part of the measurement, consolidation occurs with a mean value of $\Delta E_{35s-60s}$=1.9. The mean value of all deviations for 60 seconds is ΔE=1.32, which is within the tolerance limits.

The 2D CIEL*a*b* graphs show deviations in tone and brightness that indicate that the specified print at solid tone is slightly redder than the default standard. However, all the points are inside the ellipse. Three points record deviations in brightness that are at the tolerance limit. As in the case of cyan, the adjustment and operation of the EP machine were well executed while maintaining the trend created by the interruption of the operation of the fuser unit, which ultimately gives a slightly larger deviation in the magenta colouring of the tested fields.

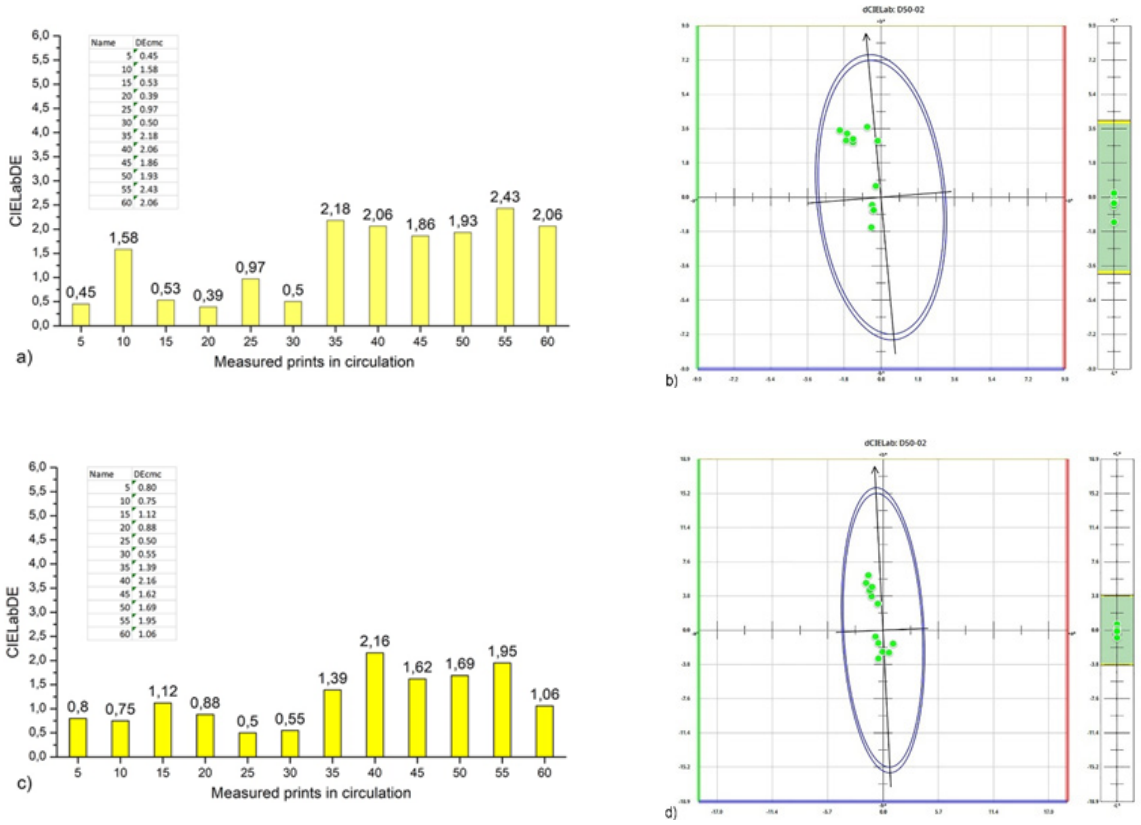

Figure 4: Accomplished of colour oscillation on prints for yellow colour over 60 seconds: a) Histogram of changes of 40% TV; b) CIELab colour deviations about the standard for 40% TV, c) Histogram of changes for 100% TV; d) CIELab colour deviations about the standard for 100% TV

Two atypical deviations are noted in the case of yellow prints with a surface coverage of 40% TV. They were measured in the first half of the graph, i.e., the peaks were detected in the 10th and 25th seconds. The minimum deviation value was achieved in the 20th second (ΔE_{20s}=0.39), followed by the growth of the yellow colour change (except for the print printed in the 30th second). Unlike the previously analysed separations, the mentioned change is not at the same time maximal for the mentioned test period. The mean value of realised deviations for the period before the sudden growth in the 35th second is $\Delta E_{5s\text{-}30s}$=0.74.

In the second half of the measurement (the period from the 35th to the 60th second), a deviation in the amount of $\Delta E_{35s\text{-}60s}$=2.09 is realised. The maximum recorded on the 55th print with ΔE_{55s}=2.43. Overall, the mean value of all deviations for the yellow separation of 40% TV in 60 seconds is ΔE=1.41. The resulting deviations are within the permitted tolerance limits.

The oscillations are within the elliptical tolerance limits, and the diagram in Figure 4b shows slightly more significant deviations in the yellow tone. The mentioned EP prints with Simitri toner are bluish and greener than the default standard. The change in brightness does not record significant deviations.

The yellow separation value with 100% TV coverage shows no identical trend. Figure 4c shows a sudden increase at the 40th print. The trend of yellow deviations is not continuous, so the minimum was recorded in the 25th second (ΔE_{25s}=0.5), while the maximum was recorded in the 40th second (ΔE_{40s}=2.16). Within the starting interval, the realised difference in colouring is ΔE_{5s_35s} = 0.86, while the final interval will be $\Delta E_{40s\text{-}60s}$=1.7.

Within 60 seconds, a deviation variation of ΔE=0.7 is realised within the tolerance limits. At the solid tone of the yellow print, CIEL*a*b* shows no additional deviations in brightness. In the case of yellow separation, no significant change in yellow tones was achieved at the end of the print run. This can be attributed to the print order where the yellow toner is first printed (transferred) to the photoreceptor and transfer belt. Therefore, there is no possible contamination from other applied toners.

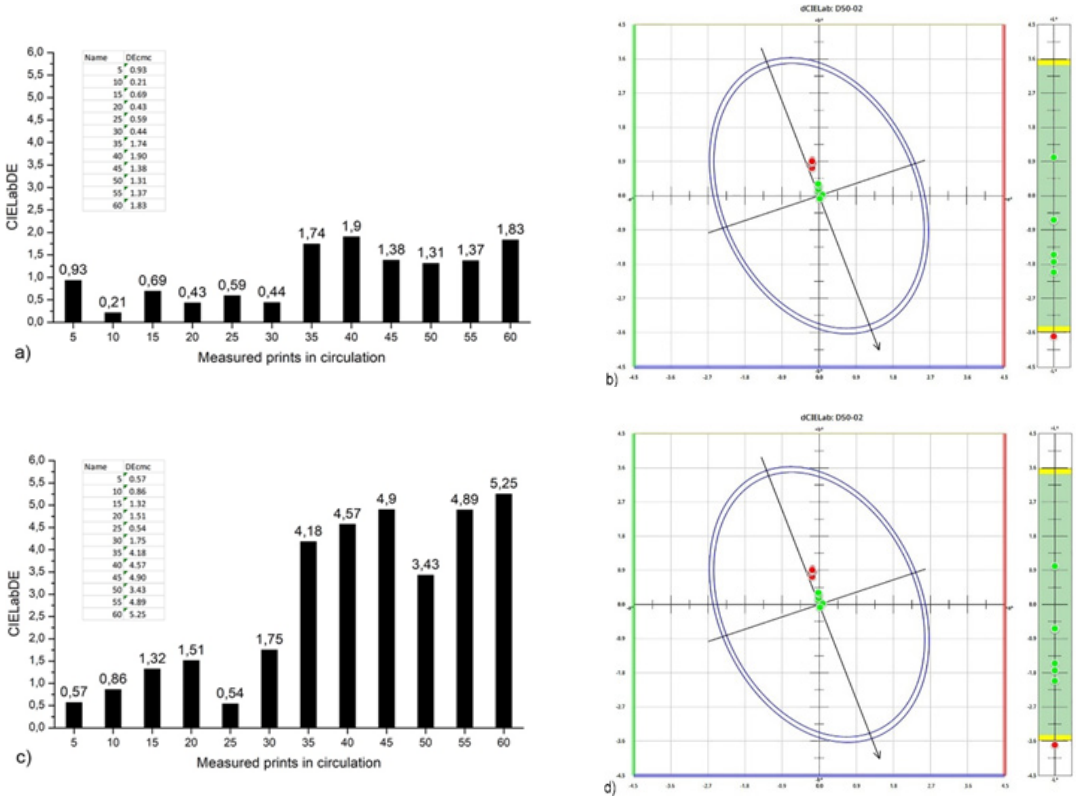

Figure 5: Accomplished of colour oscillation on prints for black colour over 60 seconds: a) Histogram of changes of 40% TV; b) CIELab colour deviations about the standard for 40% TV, c) Histogram of changes for 100% TV; d) CIELab colour deviations about the standard for 100% of TV

Black prints of 40% TV also suddenly change colour after the 35th second (Figure 5a). So, the trend continued, as with other colour separations. In the first printing cycle, the minimum deviation was recorded in the 10th second ΔE_{10s}=0.21, while the maximum was achieved in the 40th second (ΔE_{40s}=1.9).

The mean value for the first period was recorded up to the 35th second and amounts to $\Delta E_{5s\text{-}30s}$=0.55, while the mean value for the second period (after the 35th print) is $\Delta E_{avg(35\text{-}60s}$)=1.59. The overall deviation of rasterised black in 60 seconds is ΔE=1.07, within the tolerance limits.

The CIEL*a*b* diagram records deviations in brightness, and the print is significantly darker than the default standard. Since it is a black separation, it does not necessarily represent a low-quality print, as would be the case with other separations.

Figure 5c shows the deviation of black in a solid tone. By calculating the mean deviations for the initial period, a value of $\Delta E_{5\text{-}35s}$=1.09 was obtained. At the same time, the lowest ΔE value was achieved on the 25th impression and amounted to ΔE_{25s}=0.54. An extreme increase of $\Delta E_{40s\text{-}60s}$=4.54 characterises the second period. The numerically highest value was obtained at the end of the circulation and is ΔE_{60s}=5.25. Overall, the solid tone black separation achieved an average deviation of ΔE=2.81, outside the permitted tolerance limits.

The possibility of such oscillations lies in the composition of the black Simitri V toner, which has a specific ferrite concentration for better application. As there are entirely new carrier particles (starter) in the developer box, toner transfer is maximal and will decrease over time due to tribological wear. In the starting period, it is therefore required to reduce the voltage of the magnetic roller, which can additionally regulate the final application.

4. CONCLUSION

From all the results presented, we conclude that of the process colours, yellow separation showed the highest quality reproduction. Black separation is initially the worst and has the most significant deviations among all tested tones. Halftoned fields are precisely reproduced (ΔE10%-80%=1.36), while the solid tone is printed uncontrollably and deviates from the standard (ΔE>6).

Within a print run of 60 copies (60 seconds) in most of the printed tones (CMYK colours), there was a sudden jump in the colour change value when the print was created at the 35th second, which is attributed to the action of the components of the machine itself.

Within the analysed interval, the most constant colour separation is magenta, with a surface coverage of 40% (ΔE40%TV=0.61), while black has a significant oscillation in solid tone (ΔE100%TV=2.81).
It would be good to extend this test over a much longer period, during which the IQ unit would be activated. However, this paper informs service technicians and users about the possible causes of print discrepancies for shorter runs and machines without an IQ unit

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INTERDISCIPLINARY APPROACH IN STUDYING AN EXCEPTIONAL ARCHAEOLOGICAL DISCOVERY

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Abstract: *The Negova helmet from Podzemelj, held by the Bela Krajina Museum in Metlika, was studied by students from various fields, including archaeology, conservation, restoration, metallurgy, materials, and graphics. The research focused on the manufacturing technology of a bronze helmet dating back to the 4th century BCE. The cultural-historical aspects were explored by archaeology, conservation, and restoration students, who also contributed to determining the manufacturing technology. The chemical composition and microstructure of the helmet were analysed by materials and metallurgy students. They also conducted compression tests on cast plates. The helmet was dimensionally captured in 3D by graphics students, who used 3D printing to create the basis for a casting model. The research demonstrates the significance of interdisciplinary approaches in archaeological investigations and other fields. The collaboration among students from different disciplines provided a holistic approach.*

Keywords: *interdisciplinary approach, archaeological find, manufacturing technology, 3D capture, 3D printing*

1. INTRODUCTION

Bronze helmets represent some of the most prestigious objects of material culture from the Early Iron Age or Hallstatt period as we name the time between the 9th and 4th centuries BCE. The helmet from Pezdirčeva njiva is defined as a Negova type due to its characteristics (Grahek, Kovač 2020). The latter were named after the Negova site near Ženjak in the Slovenske gorice (Egg 2012).

Generally, this type of helmet was widespread in a vast area between the Alps, the Danube, the Adriatic and the Apennine Peninsula in the 5th and 4th centuries BCE. Each region had its own directions of development and production centers. In Slovenia out of 49 examples, most of them are known from the area of the Dolenjska Hallstatt group where their workshops are also located. Because of this, they are valued as a distinct Slovenian type named the so-called Negova horizon of the late Hallstatt period of this region (Dular 1999; 2003, 143-150; Teržan 2010, 321–323; Tecco Hvala 2012, 147–149). Mostly they were discovered in graves and to a lesser extent in hoards. Graves with Negova helmets represent the burials of elite warriors of that time. The helmet was deliberately and violently destroyed on both sides with blows from a battle axe as a part of the ritual before the burial. It was a ritual characteristic of the Dolenjska community, which was directly related to social representations of power, rank and the prestige of individuals (Blečić Kavur 2018).

The importance of Negova helmets in the society of that time is reflected primarily in their numerous representations in depictions of the warrior class in Situla art, as shown by the battle scene on the prestigious rectangular belt buckle from Vače (Dular 1999, 146) as well as in small bronze sculptures with an exceptional example being a figurine from Idrija near Bača (Božič 1999, 179). The status symbol of Negova helmets is further confirmed by various impressed decorations as well as engraved symbols and inscriptions. The inscriptions on helmets from Ženjak and Vače represent the first “writings” in the Slovenian territory, thus affirming their place in the historical narrative. (Tecco Hvala 2012, 154).

Before commencing with conservation-restoration interventions we examined the helmet using non-invasive X-ray radiography (RTG), revealing extensive corrosion damage of the bronze sheet. Subsequent invasive investigations delved into corrosion mechanisms interpreted based on the stratigraphic arrangement of corrosion products using scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS). Both corrosion types I (noble patina) and type II (vile patina) were present on the helmet. The types of corrosion products (malachite and cassiterite) were determined using X-ray diffraction (XRD) technique.

The conservation-restoration intervention involved removing soil, cleaning with distilled water and eliminating corrosion products with scalpels. Due to the extremely poor condition of the bronze sheet, damaged areas were reinforced promptly with a solution of Paraloid B-72 and Japanese paper. After the initial cleaning phase, the helmet was repeatedly reinforced with a solution of BTA inhibitor in a vacuum oven. The success of the inhibitor penetrating unstable and brittle corrosion layers was confirmed by Raman spectroscopy. This was followed by additional reinforcement with acrylic resin Paraloid B-44 also in a vacuum oven. With the stabilized helmet we could proceed to remove corrosion products using mechanical methods (ultrasonic hammering). The main challenge was supplementing missing parts in the lower section of the helmet, for which epoxy resin was used. Damages on the helmet crest were supplemented with colored epoxy resin. The retouching through which we harmonized the color tones with the surroundings was elegantly executed using acrylic paints. Since the crest damages were not static these supplements were made to be easily removable. Finally, the helmet was reinforced again with BTA inhibitor, lacquered, and waxed with Renaissance wax.

Within the scope of the research project, our attention was directed towards exploring the cultural-historical dimensions and uncovering the manufacturing techniques behind the helmet. We elucidated and detailed the processes involved in analyzing the chemical composition and microstructure of the helmet along with conducting compression tests on cast plates.

This article primarily showcases the final phase of the project's results, where based on precise 3D scanning and printing of the helmet prototype we initially created a silicone mould for a wax model into which the helmet was cast. Finally, after conducting tests on various patination methods we also applied the patina.

2. EXPERIMENTAL

2.1 3D capture and printing of the helmet prototype

The capture of the restored Negova helmet (Figure 1) was performed in two ways namely photogrammetry and scanning. For photogrammetry a digital camera - Nikon D780 with a Nikkor 24-70mm 2.8 lens was used. Photos were captured with maximum depth of field. For photogrammetry capture the helmet was placed on a white surface and illuminated with two diffuse light sources. It was manually rotated to achieve a 360-degree capture. In the next step the scanning was done with a handheld scanner, Shining 3D Einscan HX (Figure 1) using structured light. The acquired digital model needed to be cleaned and prepared for printing.

The digital model obtained from the scanner was used for printing. Printing was done with white PLA thermoplastic filament, applied layer by layer using 3D printing with fused deposition modeling (FDM) and the Artillery Sidewinder X2 3D Printer.

2.2 Creation of a silicone mould for the wax model and casting the helmet

Based on the 3D printed prototype of the helmet we smoothed out the visible layers that occurred during printing and created a two-part flexible silicone mould (Figure 2). Initially, we made the mould for one half and then for the other. Next, we created a two-part plaster cap to maintain the shape of the flexible mould, followed by a plaster "container" where we placed the entire flexible mould to stand independently during our work.

Wax was applied with a brush onto the prepared silicone mould to create a layer that was approximately 4 mm thick. An ingating system also made of wax was attached to the wax layer. Polymer filaments were then shaped into vents. The entire structure was coated with a ceramic suspension and sprinkled with sand. This process was repeated 9 times to obtain a ceramic shell. The wax was melted out of the shell to create an empty cavity, which

was subsequently sintered at a temperature of 1100 °C. The bronze alloy with 10 wt.% tin was melted to form a melt, which was poured into the shell. After cooling and solidification, the shell was broken to retrieve the casting from which the ingate system was removed, and the casting was chiseled and prepared for further processing with patination to achieve the desired final appearance.

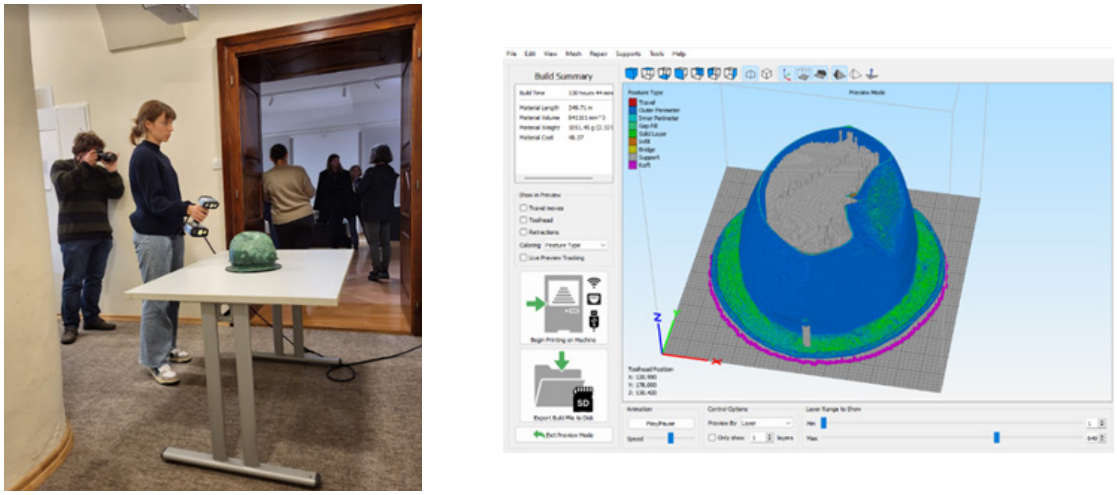

Figure 1: The restored helmet and the process of 3D scanning the helmet (left), showing the layered construction of the digital model with internal supports included (right).

2.3 Creating samples for testing the patination process and patinating the helmet

The production of test pieces began with the creation of models for casting tiles which had thicknesses of 4, 8, and 12 mm. Two tiles were made for each test with each mould. Using these models a mould was created consisting of a wooden frame and a bentonite sand mixture into which the tile model with an embedded gating system was pressed.

Subsequently, the melt preparation took place in an induction furnace. The melt consisted mostly of copper with 10 wt.% tin. Before casting a sample of the melt was taken for chemical composition analysis. The sample underwent XRF analysis to determine the composition which revealed an insufficient amount of tin. To achieve the correct proportion of tin, 1 wt.% of pure tin was added.

Once the melt composition was appropriate, it was poured into the moulds. The moulds were additionally weighted during the casting process to prevent spillage or mould lift. After cooling, the castings were removed from the moluds as well as the gating system.

Test pieces were then fabricated from the obtained tiles for further analysis such as metallurgical tests for material formability and testing the patination process. Prior to this, patina samples were created on the test pieces using liver of sulfur and a mixture of ammonium chloride and copper sulfate aiming to mimic the original patina. By replicating the tested artificial patination process the patina on the helmet was created. Finally, the helmet received a final protection layer with a solution of beeswax in gasoline and polishing.

3. RESULTS WITH DISCUSSION

3.1 Results of printing the helmet prototype

For 3D printing a digital model obtained from the scanner was used. Printing was performed using white PLA thermoplastic filament which was applied layer by layer using fused deposition modeling (FDM) technique with the Artillery Sidewinder X2 3D Printer. This printer has a working volume of 300 mm × 300 mm × 400 mm, allowing us to print the model at a 1:1 scale. The filament layer thickness used during printing was 200 µm and the diameter

of the nozzle on the extrusion print head was 400 µm. The infill density was set to 50%. The final printed helmet is visible in Figure 2. The printing of the helmet took 130 hours and 44 minutes, consuming a total of 1051.45 grams of material. Some of the material was used for printing the model layers, while the rest was used for printing supports, mainly required in the internal part of the helmet (Figure 1). Stepped transitions were noticeable on the surface of the printed model, varying in visibility across different parts.

3.2 Result of making the silicone mould for the wax model and casting the helmet

The silicone elastic mould (Figure 2) is two-parted with a logical parting plane along the crest and across the net of the helmet. It features zigzag patterns and enough catches to ensure consistent and precise assembly and placement within the plaster cap each time. This method allows for a greater number of copies in wax, or any other material applied to the inner side of the elastic mould. Wax is applied in multiple layers controlling the thickness of the deposits, which also determines the thickness of the cast (minus 5% shrinkage). If precise interior detailing were desired an additional internal volume would need to be created and printed with wax poured between them which is nearly impossible and entirely cost-prohibitive for this technique.

After the completion of the silicone rubber mould with the plaster cap a harder blue wax was applied in layers with a brush, capturing the surface of the prototype model very accurately. Since this type of wax is fragile and expands when heated and posing a risk of cracking the ceramic shell during further production, subsequent layers up to a thickness of 4 mm were made using a softer yellow wax to prevent shell cracking. Similarly channels for constructing the gating system were created using a similar method and attached to the wax model itself. Once the entire wax model was completed it was removed from the silicone rubber and chiseled to prepare it for building the ceramic shell. This shell was constructed by pouring with a ceramic suspension and sprinkling with quartz sand in nine layers (Figure 3). After the shell was constructed and dried the wax was melted out in an oven at 400 °C and the hollow shell was further sintered at 1100 °C. Meanwhile, in an induction furnace a bronze alloy with 10 wt.% tin was prepared and reaching the temperature of 1250 °C it was poured into the hot shell. After solidification and cooling of the alloy the shell was broken followed by the removal of the gating system and preparation of the helmet for patination (Figure 4).

Figure 2: Printed helmet (left), smoothing of the 3D printed model (middle) and silicone rubber applied to the prototype – printed helmet (right).

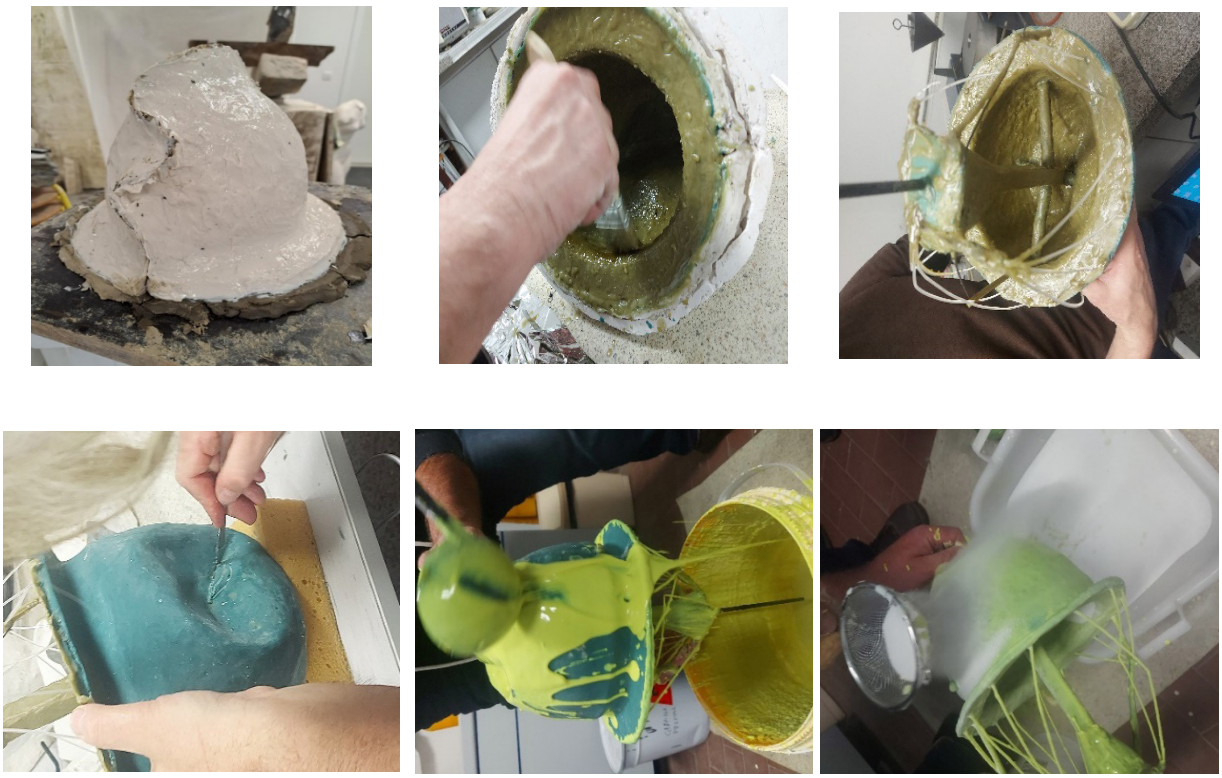

Figure 3: Silicone mould (top left), applying layers of wax to the silicone mould (top middle), constructed gating system with vents (top right), chiseling of wax (bottom left), immersion and covering of the wax model with ceramic suspension (bottom middle) and sprinkling with quartz sand (bottom right).

3.3 Testing results of the patination process and patination of the helmet

After chiseling the helmet was degreased to enable it to accept the patina. The first coating applied was an underlayer - a dark patina made from liver of sulfur (potassium sulfide), followed by 15 coatings of a mixture of ammonium chloride and copper sulfate with water which at regular intervals provided a noble malachite patina. Over three weeks of coating the patina stabilized and firmly adhered to the helmet. Protection for the patinated helmet was made from beeswax which was applied to the surface of the patinated helmet in a 5% solution in gasoline and later polished.

Figure 4: Pouring the leftover melt after casting the helmet (left), the helmet after casting (middle), patinated helmet (right).

4. CONCLUSIONS

The interdisciplinary approach used to study the Negova helmet from Podzemelj, which we named 'Splendor and Misery of Prehistoric Bronze', was highly successful from several perspectives. Archaeometric analyses and mechanical tests on specimens cast from the same bronze alloy as the original provided precise insight into the methods and techniques of production used in the 4th century BCE. Due to the rapid deterioration of archaeological finds, it is crucial to have a thorough understanding of conservation and restoration procedures. Therefore, the main objective of the project was to devise the most suitable approach for replicating the item. However, due to time and financial constraints, only a cast replica could be produced. The most suitable mould for this purpose was a ceramic shell. The production was based on creating an accurate 3D model of the original find. We explored the utility of two common methods: photogrammetry and 3D laser scanning. The mould was then modeled in several steps, and the replica was cast into it. With only minor adjustments and a final patination, we achieved an authentic approximation of the original piece. Archaeological finds made from bronze are usually heavily corroded and no longer have their gleaming shine as during their use. Preserving such objects necessitates conservation and restoration interventions with expertise in metallurgy, graphic modeling, and design making significant contributions.

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APPLICATIONS IN LARGE-SCALE 3D PRINTING

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Abstract: *Additive manufacturing technologies are rapidly increasing their share in various areas, including art, design and construction. Currently, 3D printing of large items is progressing from academic and laboratory-based research to transferring knowledge to the public. Nevertheless, many questions are still debated in an ongoing discussion about the applicability of 3D printing technology for the fabrication of large elements. At the Slovenian National Building and Civil Engineering Institute (ZAG) we have implemented two technologies suitable for printing larger items, namely particle-bed binding and the extrusion method. The paper first outlines the printer capabilities and materials we use for printing. Next, methods used to create a digital model, namely, 3D modelling, parametric design and 3D scanning, are presented. Finally, the items printed on three different printers are presented and the pros and cons of each method are discussed.*

Keywords: *composite 3D printing, large-scale 3D printing, particle-bed binding, extrusion method*

1. INTRODUCTION

The graphic design has been significantly changed with the accessibility of computers. Computer-aided design (CAD), in particular parametric design, enables shaping 3D objects using analytical functions which shifts the design process from implementing artistic skills towards mathematical and computational modelling. Since the majority of the designs are nowadays produced in a digital format the next step is to transform the design into a physical object by digital means.

Digital fabrication becomes indispensable as design increases in complexity and precision requirements. Well-established digital fabrication technology is Computer Numerical Machining (CNC) which is a form of subtractive machining using either milling or turning. Other examples of subtractive digital fabrication means comprise water jet cutters, routers and laser-cutting machines. Contrary to subtractive are additive technologies colloquially known as 3D printing. The term encompasses a myriad of methods such as extrusion, particle-bed binding, vat polymerization and sheet lamination to name a few (Lowke, 2022).

Furthermore, transforming the physical objects into their digital replicas is also possible through three-dimensional (3D) scanning, for example, with computed tomography, structured-light 3D scanners or LiDAR. These techniques enable us to study object structure as well as geometry on a scale which is too small or too large to perceived with the naked eye (Tissen, 2022).

Digital technology that enables transformations from the physical to the digital world and vice versa is already commercially available and has established its value in bio-inspired design, rapid prototyping and fabrication of customized items. Over recent years size of the items fabricated by digital means has increased to the point where full-size buildings can already be 3D printed (Olawumi, 2023).

Contemporary design, either graphical, interior, urban or industrial, is inherently digital and it often presupposes digital fabrication. The latter, however, challenges the way we approach the design in general and in particular it requires a paradigm shift in how we think and fabricate large-scale elements that enrich the urban environment.

This paper aims to inspire the graphic design community by outlining the activities carried out in the field of large-scale 3D printing at the *Slovenian National Building and Civil Engineering Institute* (ZAG) and how it is complemented by 3D scanning and a parametric design approach.

2. MATERIALS AND METHODS

For 3D printing of large-scale items, two methods have emerged as most suitable, namely (i) particle-bed binding method, and (ii) extrusion process. In the first instance, the particle-bed consists of either a precursor or inert granular material while the liquid component is either an activator, in the case of precursor bed, or a mixture of activator and precursor in the case of inert bed material. In the extrusion process, the filament is formed by pressing a paste-like material through the nozzle and stacking layers on top of each other. The filament then solidifies either due to chemical reactions or drying.

At ZAG, both of these two methods are implemented for printing with gypsum, cement and clay-based materials.

2.1 Particle bed-binding method

The printer used for particle bed-binding (Lowke, 2022; Talke, 2023) is a commercial printer *ZPrinter 310* (Fig. 1a) where gypsum is used as a precursor in the particle-bed and is activated by water containing dissolved admixtures necessary to control the process. The printing chamber dimensions are 200 × 250 × 200 mm^3 (width × depth × height). The powder layer thickness is 0.1-0.2 mm and the resolution is 300 × 450 dpi which enables printing of fine details.

The research in this field is focused on the exploitation of synthetic gypsum which is a waste stream or by-product in a range of industrial processes. It is a fine-grained white or lightly coloured powder with grain sizes ranging between 20-100 µm (Fig. 1b). Its suitability for 3D printing depends on the morphology of the gypsum crystals, their particle size distribution and reactivity (Zalar Serjun, Korat, 2021). Usually, heat treatment and optimization of particle size distribution are needed to render synthetic gypsum suitable for particle-bed printers (Zalar Serjun, Korat, 2021).

(a)

(b)

Figure 1: Particle-bed 3D printing at ZAG showing (a) gypsum powder being fed into the *ZPrinter 310*, and (b) synthetic gypsum collected from waste streams in various industrial processes.

2.2 Extrusion method

Extrusion 3D printing (Wolfs, 2021) at ZAG is carried out either with a medium-scale Delta WASP 40100 printer (Fig. 1a) or with the Robotic station for digital fabrication (Fig. 1b). The former is a commercial printer with a triple-arm mechanism providing three degrees of freedom. It comprises a gravity-driven print head suitable for cementitious materials with up to 1 mm grain size, and a pressure-driven head suitable for clay-based materials.

The Robotic station is a custom-made printer whose central unit is an articulated robotic arm with six degrees of freedom, a payload of 240 kg and a reach of 2.7 m. It is complemented with a MAI 2PUMP Pictor 3D pump with a capacity of 9 L/min and the ability to handle cement and clay-based materials with nominal aggregates size 0/2 mm.

(a) (b) (c)

Figure 2: Extrusion printers at ZAG, namely (a) *Delta WASP 40100*, and the *Robotic station for digital fabrication* where (b) is the articulated robotic arm and (c) is the *MAI 2PUMP Pictor 3D* pump.

In terms of cement-based materials, three mixes were developed, namely (i) the benchmark mix, (ii) the waste powder mix and (iii) a decorative mix. Important considerations in the mix design process were the particle size distribution of powders and the volumetric fraction of excess paste. The benchmark mix is based on cement type CEM II, silica fume and limestone.

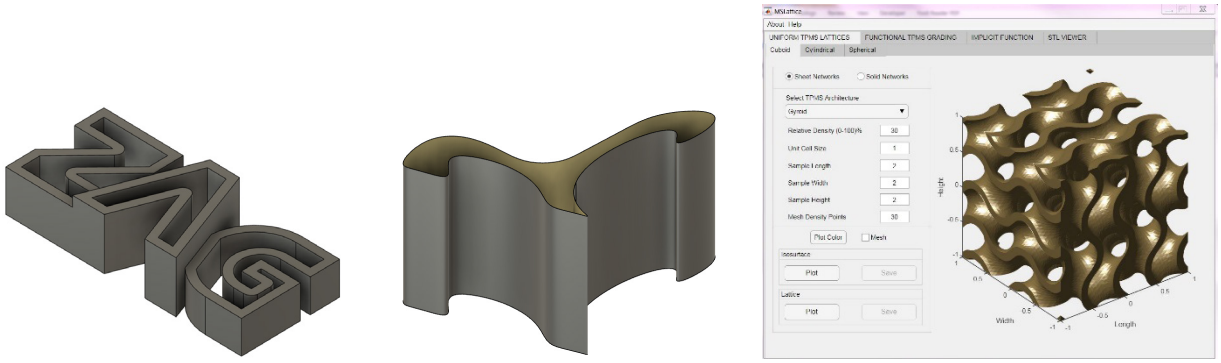
To improve the environmental footprint, the second mix was developed. It contains less cement and no silica fume. They were supplemented by waste powders from aluminium and stone production. The former renders a brick-red colour to the mix. The decorative mix is formulated with white cement and limestone. The powder composition along with the excess paste is crucial for the cohesiveness of the mix which translates into filament extrudability and buildability.

In addition, a clay-based formulation was also developed. It consisted of clay, silt and sand. The water was added to the extent to yield a medium-soft paste. The consistency was improved by the addition of alginate. This natural product, an extract from seaweeds, has many applications in industry, amongst other reasons, due to its thickening effect.

2.3 Geometrical design

For 3D printing, it is necessary to create a geometrical model of the item in a digital environment. This can be achieved in either of two ways, namely using (i) CAD software, or (ii) 3D scanning. Tools for 3D design such as Rhinoceros 3D, Fusion and Creo are well-received in the engineering community while graphic designers prefer to work with Maya, Zbrush or similar. Parametric tools, on the other hand, enable the creation of organic, fluid and harmonic configurations. These tools use mathematical functions shaped by their parameters. The most popular parametric design tool is Grasshopper.

Fig. 3 shows three examples of CAD modelling used in 3D printing at ZAG. The 3D design where the two-dimensional shape was extended in the third dimension was utilized in Fig. 3a-b. The difference between the two models is that the first one is presented as a body with actual volume, while the second is represented with a curved surface. Both models were used with particle-bed and extrusion printers. Fig. 3c, on the other hand, is an example of parametric modelling. In this case, an open-source modelling tool using a triply periodic minimal surface (TPMS) method was adopted to shape acoustic panels and print them on a particle-bed printer.

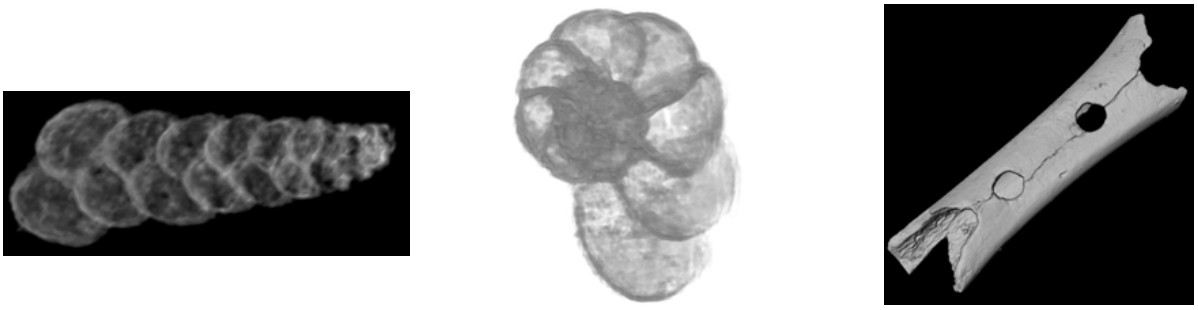


(a) (b) (c)

Figure 3: Geometry for 3D printing developed by 3D modelling where (a) the object is modelled as a body whose walls have a specified thickness, while in (b) the object is modelled as a curved surface without specified thickness. Geometrical design with parametric modelling in (c) shows the triply periodic minimal surface (TPMS) method.

Geometrical design using 3D scanning at ZAG is carried out by computed tomography (CT) using Xradia MicroXCT-400 tomograph that is suitable for inorganic and biological samples. The system operates with 40 to 150 kV X-ray source with a power of up to 10 W. The maximum sample size is about 15 cm. The resolution depends, amongst other factors, on the lens used, however with the macro lens a resolution of 20-50 µm can be obtained.

Two examples of obtaining the geometry for 3D printing with tomography are shown in Fig. 4. An example of foraminifera (Fig. 4a, b) is selected for its complexity and size. Namely, complex formations found in biological samples may inspire highly functional and profoundly intricate designs, however, these formations are not accessible to human vision. The example of the flute found in the Divje babe cave I (Fig. 4c) is interesting for its archaeological value and fragility. Creating a digital twin of the item provides information without damaging the original and serves for the production of replicas.



(a) (b) (c)

Figure 4: Geometry acquired by tomography, where (a-b) are scans of foraminiferas which are 1 mm in size, and (c) is the scan of a 50-60 thousand year old flute found in the *Divje babe* cave I.

3. RESULTS WITH DISCUSSION

The geometry shown in Fig. 3a, that is ZAG logo, was realized with the extrusion printers Delta WASP 40100 and the Robotic station as well as with the particle bed printer ZPrinter 310. Logos printed with the extrusion method are shown in Fig. 5a as a small and large grey item, printed with Delta WASP and the Robotic station, respectively. They were printed with the benchmark mix. The three white items are logos printed with ZPrinter 310.

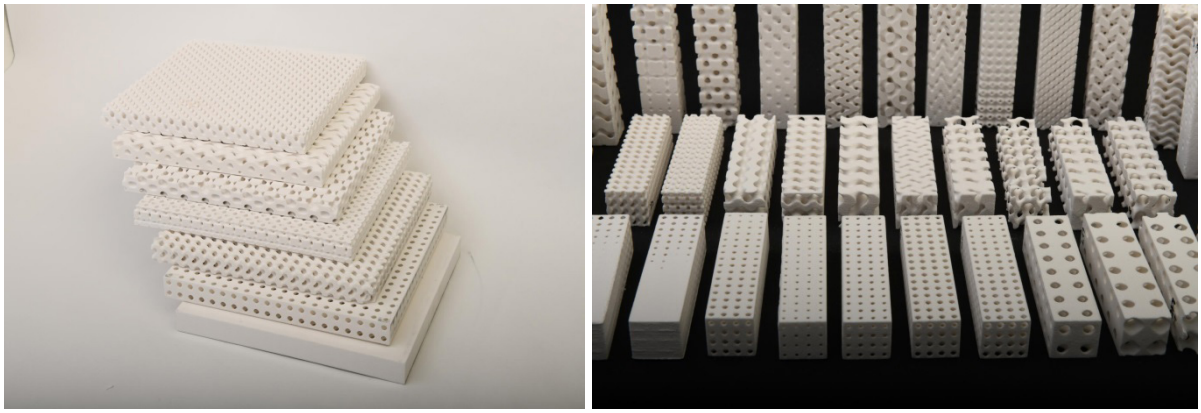
The geometry presented in Fig. 3b, which is a chair suitable for use as urban furniture, was fabricated on the Robotic station using the waste powder mix. This gives it a brick-red colour. The chair immediately after fabrication

is shown in Fig. 5b, while Fig. 5c shows the chair flipped into the position ready for use (possible to sit on). On top of it is a smaller version of the chair printed with the particle-bed method.

(a) (b) (c)

Figure 5: Items fabricated by printing the 3D models shown in Fig. 3a-b, where (a) shows different versions of ZAG logo printed with the *ZPrinter 310* (white items), *Delta WASP 40100* (small grey item) and with the *Robotic station for digital fabrication* (large grey item), (b) shows a full-scale concrete chair immediately after being printed on the *Robotic station*, and (c) shows the full-scale chair printed with the extrusion method and a small-scale version printed with the particle-bed method.

Geometries created with the parametric modelling, the example of which is presented in Fig. 3c, were materialized with the particle-bed method on ZPrinter 310. Some of the printed items are shown in Fig. 6a and 6b. The main purpose of fabricating panels with various sizes and shapes of holes was to design acoustic panels which absorb the selected frequencies (sound).



(a) (b)

Figure 6: Items fabricated by particle-bed printing of 3D models created with parametric modelling shown in Fig. 3c. (a) large plates with dimensions of 20 × 20 × 2 cm^3 and (b) sample sizes of 2 × 2 × 8 mm^3 cm^3 with different cell structures.

Finally, the geometries acquired by tomography were also executed with the particle-bed method. They are shown in Fig. 7. Different foraminifera were printed on an enlarged scale with their cross-section exposed (Fig. 7a). The replica of the flute from the Divje babe cave I was printed on a 1:1 scale. Such replicas can serve educational purposes on one hand, but even more importantly as a valuable tool in the preservation of cultural heritage.

In terms of lessons learned, the importance of material design needs to be emphasised. For both methods, the particle size distribution is of paramount importance. In extrusion printing, it directly affects the cohesiveness of the extruded filament, which in turn determines how the material is pumped and extruded, how it can be pressed

to bind with the previous layer and to some extent how it behaves under the load of subsequent layers. For the particle-bed printing, the particle size distribution must be such to allow the liquid component to penetrate through the layer and create a sufficiently dense material after setting.

(a) (b)

Figure 7: Items fabricated by particle-bed printing of geometry acquired by tomographic scanning shown in Fig. 4, namely (a) various foraminifera printed on an enlarged scale with exposed cross-section, and (b) a replica of the flute from the *Divje babe* cave.

4. CONCLUSION

Digital fabrication methods provide an unprecedented range of opportunities to a number of professionals, graphical designers included. Printers utilizing polymeric materials are already commercially available at an affordable price and are thus being used for rapid prototyping. Printing large-scale items, however, dictates also the use of inorganic materials. Suitable techniques for printing with ceramic materials are particle-bed binding and the extrusion method. Both of them are being successfully implemented at ZAG. The robotic arm system for extrusion printing was so far used to print street furniture elements using cement-based material. The next step is going to be the fabrication of load-bearing elements. Additionally, we are experimenting with clay-based materials which have a near-zero environmental footprint. The particle-bed method is suitable for intricate, bio-inspired patterns and in combination with 3D scanning is of great value in cultural heritage operations. Designing the materials suitable for printing is, however, a task which requires specialised knowledge.

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PHOTOGRAPHY AND COLORIMETRY

EFFECT OF FOCAL LENGTH ON REPRESENTATION OF MOTIFS IN DIFFERENT PHOTOGRAPHIC GENRES

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Abstract: *The aim of the research was to establish correlations between different technical options within the possibilities of photographic equipment, focussing on the lens. Looking at each piece of photographic equipment led us to the lenses that offer the greatest possibilities for manipulation, mainly due to their focal lengths. We sought to define or measure the influence of focal length on a particular genre and on that basis explain how it affects the result. We approached this task with a range of genres, within which we shot wireframe models and specific genre scenes at different focal lengths for comparison. Through research we explored the purpose of different lenses and their focal lengths. Based on experiments, we came to the conclusion that the different focal lengths work better in certain genres. However, these conclusions are not set in stone, because despite the chosen genre, the photographer can go beyond it if he wants to convey a message in a different, imaginative way.*

Keywords: *photographic genres, lens types, focal length, distortion, quality*

1. INTRODUCTION

A photographer's tool bag consists of many elements, such as the camera body, a selection of lenses, batteries, hard drives, light sources and more. In this study, we focus on the variety of lenses, especially the focal length of a lens, as it is one of the most crucial factors that visibly influences the photographic result (Dolenc, 1979; Jacobson, 2000).

Lens types:
We know many types of lenses. Prime lenses which have a set focal length and zoom lenses which have a variable focal length. In general, prime lenses will offer a higher quality but lack the practicality of a zoom lens. Lenses have a variety of effects on photographs. They influence the depth of field and perspective via the aperture, focal length, and the distance from the object. Once a photographer master's those they can pick and choose lenses based on their desired effect (Hedgecoe, 2003; Jacobson, 2000; Stepanoff, 2023).

Optical distortions:
There are a variety of distortions that can occur depending on the lens. Most distortions can be removed in postproduction but in extreme cases they are permanent. We recognise three types of distortion. Barrel, pincushion and mustache distortion (Ikeda, 2023). If you take a low-quality fixed focal length lens and a high-quality zoom lens, the results will be better with the high-quality lens, although the fixed focal length lens should be better because it has fewer moving parts and tends to give higher quality end results (Peres, 2007). When choosing a lens, the focal length is often the deciding factor. Especially in situations where distortion is either desirable or not. Specialised lenses such as fisheye, macro and tilt-shift lenses are often used in such situations (Dolenc, 1979).

The aim of our research was to confirm or deny these hypotheses:
H1: Each genre has a lens that is indisputably best suited to it.
H2: Lenses with a longer focal length are better suited to portrait and people photography.
H3: Lenses with a short focal length are better suited for indoor or interior photography.
H4: Lenses with a short focal length are best suited for landscape photography.
H5: Lenses with a focal length similar to the angle of view of the human eye are the most favourable.
H6: The image quality depends on the focal length.

2. EXPERIMENTAL

The primary goal of the research was to define the most appropriate lens for a certain photographic genre. We applied two approaches to the analysis – quantitative and qualitative. In both parts of the study, we have used a *Nikon D750* fullframe camera body in combination with four lenses: a fish-eye lens *Opteka 6.5 mm*, a wide-angle lens *Nikkor AF S 14-24/2.8 ED*, a prime natural lens *Nikkor 50 mm 1.4G*, a zoom lens with lower zoom range *Nikkor AF S 24-120 4G*, and a zoom lens with a higher zoom range *Sigma 50-500 mm* (for Nikon). The lenses were chosen with the aim to include in the research as big of a spectrum of the focal lengths.

2.1 Quantitative and qualitative analysis of wire models

To quantify the effect each lens at different focal length, we set up an experiment in studio environment. The goal of these was to show the effect focal length has on photograph purely from a technical standpoint. A white paper was used as background, while we individually placed three wire models (cube, pyramid, and cone) in the centre of the scene. The entire scene has been uniformly lit with *Elinchrom ELC Pro HD 500* flash unit with attached *Elinchrom LiteMotiv Octa 190cm softbo*x.

The three wire models were photographed at nine different focal lengths (14, 24, 50, 85, 120, 195, 420, 480 and 500 mm), while the distance from the wire model had to be enlarged regarding the higher focal length to maintain the identical size of the wire model representation in the photograph. *Figure 1* shows a scheme of wire model and camera placement at applied focal lengths. A set of 36 images was created, 9 per wire model from the frontal perspective and an additional set of 9 for the cube under an angle.

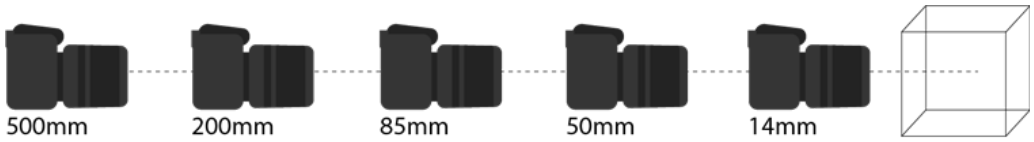

Figure 1: Scheme of camera and wire model positioning at tested focal lengths.

To determine the influence of focal length on perspective distortions, we have compared the 9 images taken per wire model and described the differences in distortion, which can be observed visually. In addition, we have measured the area of frontal plane of the cube wire model in frontal orientation and the area of the lateral plane. We used *ImageJ* software (ImageJ, 2023) to manually trace the edges of each plane and with the command *Analyze – Measure* measured the area of traced plane in pixels. With comparison of frontal and lateral plane we have acquired the plane ratio, illustrating the distortion level produced by the focal length variation.

2.2 Qualitative analysis of photographic genres

To evaluate the influence of focal length on the representation of motifs in different genres we conducted this part of the experiment in the photographic studio and in natural environments. We chose to analyse seven genres: interior, urban – detail, urban – city, landscape, product, fashion, and portrait photography.

First four genres were photographed in a natural environment, while the sets of photographs for the latter three were taken in the studio environment. In this case the studio setup was identical to the setup in section 2.1, while additional LED panel *Lupo Superpanel Dual-Color* was added to fill in the shadows created by the flash unit.

For each of the genres we have made a set of four images, differentiating in focal length, while the distance between the camera and the motif was fixed to the same value. The scheme of the setup is shown in *Figure 2*. Sets of four images per genre were visually analysed.

Figure 2: Scheme of camera and motif positioning at tested focal lengths.

3. RESULTS AND DISCUSSION

Obtained results from the experimental part are presented and commented in this section. They are divided by the contents and methodology approach to illustrate the correlations between both.

3.1 Results of the qualitative analysis of wire models

Figure 3 shows the front view of the wireframe model of the cube. The first noticeable change is the drastic difference in size in the plane furthest away from the camera. It becomes smaller and smaller the shorter the focal length is. In *Figure 3* you can see how it gradually increases in size until it is practically the same size as the frontal plane. The longer the focal length, the smaller the difference between the planes and the smaller the distortion.

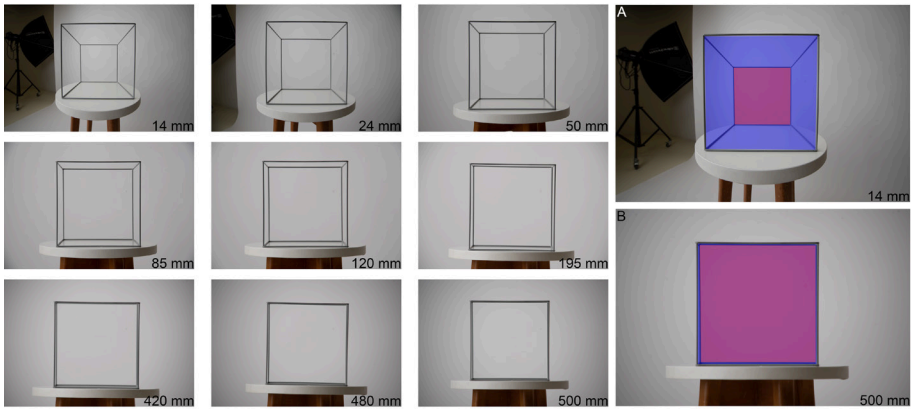

Figure 3: Wire model of the cube from the front view.

Figure 4 shows a side view of the wireframe of the cube. Here we see the same concept as in the previous example. It simply gives us a better spatial example of how these deformations work and how they affect the object we are photographing. Another notable effect of longer focal lengths is the slight vignetting that becomes visible at longer focal lengths. Dark corners are also visible at shorter focal lengths, but this is due to the white background not being large enough to cover all the wider angles that are present at short focal lengths. The effect of the lens is visible from about 50 mm.

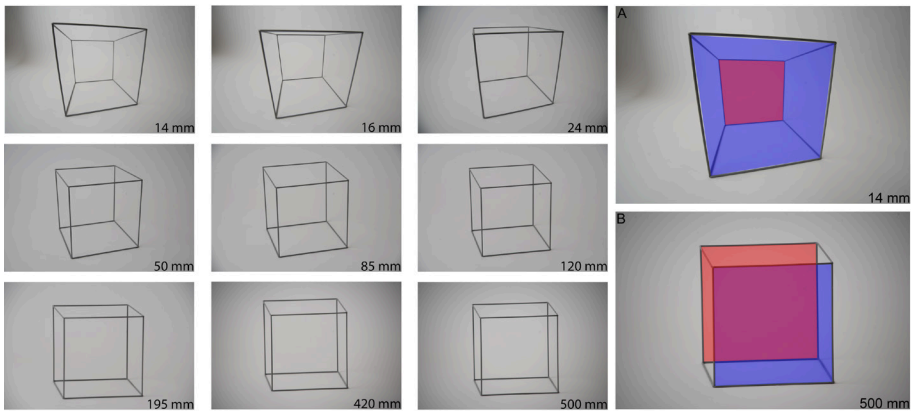

Figure 4: Wire model of the cube from the lateral view.

Figure 5 shows the front view of the pyramidal wireframe. From this example we can see the tendency of how the focal length affects the object. One thing we notice in all the examples except the last one is that the lines of the wireframe models appear curved. If we look at the example at 500 mm focal length, the coloured triangles have straight edges, whereas the wireframe models at shorter focal lengths are not perfectly aligned. This is due to the distortion that stretches the image equally in all directions from the centre.

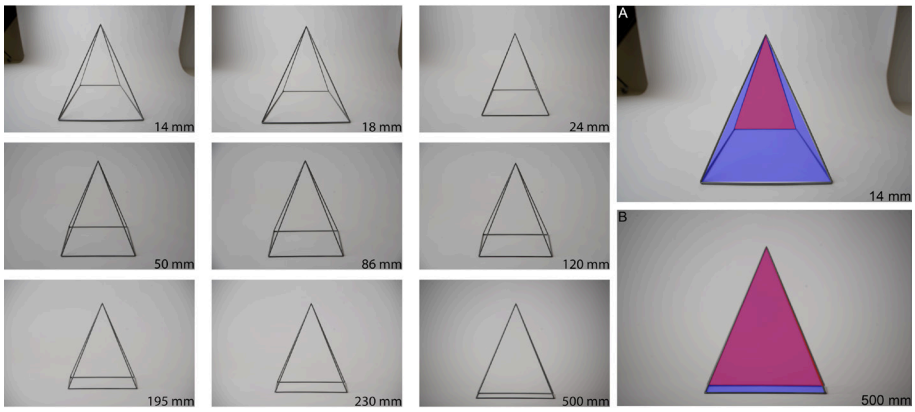

Figure 5: Wire model of the pyramid.

Figure 6 shows the wireframe of a cone. The photographed object is cone-shaped, with the larger circle closer to the camera and the smaller one furthest away. In contrast to the previous examples, we can see in image no. that the coloured circles are perfectly aligned with the object. This is due to the distortion. If the round object was not in the centre of the image, it would be distorted in the same way.

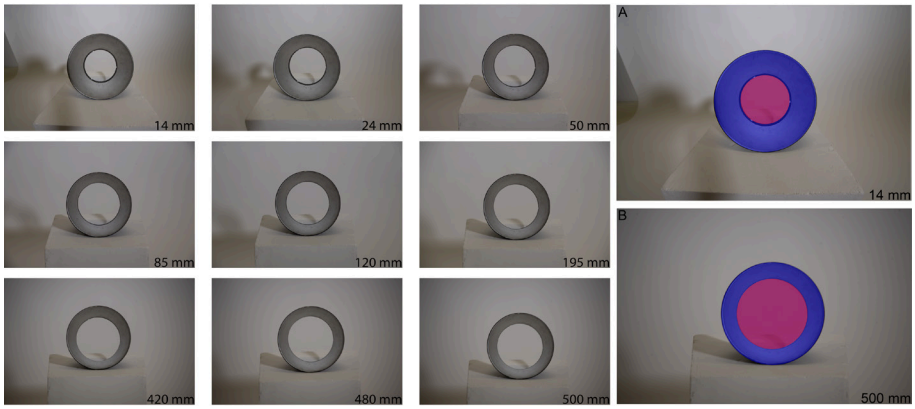

Figure 6: Wire model of the cone.

3.2 Results of the quantitative analysis of wire models

Based on the measurements of frontal and lateral plane areas we wanted to define the relation between the focal length and the normalised surface areas. The results are shown in Table 1. As the focal length increases the distortion becomes exponentially less apparent. The apparent fall off starts stagnating at around 120 to 195 mm. That is when the distortion becomes unnoticeable in practice.

Table 1: the relation between the focal length and the normalised surface areas.

Focal Length (mm)	Frontal plane area (px)	Lateral plane area (px)	Ratio
14	5 266 864	1 316 263	4.00
24	6 413 654	2 382 314	2.69
50	7 266 494	4 050 912	1.79
85	6 766 116	4 710 774	1.44
120	6 874 091	52 31 763	1.31
195	6 997 822	6 009 736	1.16
420	6 917 737	6 436 212	1.07
480	6 266 968	5 873 957	1.07
500	5 891 788	5 564 653	1.06

3.3 Results of the qualitative analysis of photographic genres

Interior and urban – detail:
In interior photography, the choice of lens depends on the purpose of the images. If we want to show an architectural detail, we will choose a longer focal length, while if the goal is to show the openness of a space, we will choose a shorter focal length.
In urban and detail photography, we can see how changing the focal length can shift the focus of the viewer. With a shorter focal length, we can recognise not only the details, but also the background such as streets and houses. As the focal length increases, the perspective narrows, and the focus shifts not only to the detail, effectively making it stand out from the background, but also because it is sharper.

Urban – city and landscape:
The choice of lens for urban photography also depends on the purpose. Depicting the entire city requires shorter focal lengths, while depicting details requires the opposite. In most cases, focal lengths that are closest to the viewer's field of vision prove to be advantageous. The same applies to landscape photography.

Product:
This type of photography is usually used to sell a product. It is important to represent the product as realistically as possible, so the customer knows what they are getting. This takes us back to the natural look of the 50 mm lens, but if we consider that a shorter focal length means more distortion, we can go higher.

Fashion and portrait:
When the subject being photographed is a person, it is often important to maintain the natural proportions of the face and body. As already mentioned, this is achieved with focal lengths around 50 mm, as can be seen in image example B. It should also be noted that shorter focal lengths give the image a more dynamic look, while longer focal lengths make it appear more static. Another advantage of longer focal lengths is the reduced distortion, which leads to the usually desirable results.

4. CONCLUSIONS

H1: To summarise, our study aimed to determine whether there is an optimal combination of lens and focal length for each photographic genre. The most important determinant in this choice seems to be the purpose of the photographs. A more precise definition of the genre leads to a clearer choice, but experienced photographers show the ability to adapt different focal lengths to different genres.

H2: Our results support the hypothesis that longer focal lengths are well suited to portrait and people photography and produce conventionally desirable results. However, we emphasise that this should not discourage photographers from experimenting with shorter focal lengths to enhance their creative concepts.

H3: In interior photography, shorter focal lengths prove effective in capturing more space and creating an open atmosphere. However, our research also shows that longer focal lengths have the potential to emphasise intricate details that might otherwise be overlooked, highlighting the nuanced nature of lens selection.

H4: For landscape photography, our study confirms the appropriateness of shorter focal lengths, with the caveat that longer focal lengths remain a viable option depending on the photographer's proximity to the landscape. This emphasises the dynamic relationship between focal length and the position of the photographer.

H5: The versatility of focal lengths closest to the human eye's field of view is confirmed, with the 50mm lens featuring prominently in many photographers' kits. An essential piece of equipment, the 50mm lens consistently delivers excellent results in a variety of situations, emphasising its golden middle ground.

H6: Finally, our research proves the correlation between lens quality and focal length. A thorough examination of the lens tests shows significant variations in quality at different focal lengths. This emphasises the importance of considering both factors together when aiming for optimal photographic results. To summarise, our comprehensive analysis highlights the nuanced interplay of genre, purpose, and focal length when it comes to achieving outstanding photographic results.

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ASSESSMENT OF COLORIMETRIC ACCURACY OF VARIOUS TYPES OF DIGITAL CAMERAS

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Abstract: *The study was focused on the colorimetric accuracy of conventional digital cameras that differ from one another based on the type and size of sensor and the number of pixels the built-in sensor is capable of capture. The ColorChecker SG test chart was captured to determine the colorimetric accuracy of several 3-channel digital cameras. Using color profiling software, camera profiles were generated. ArgyllCMS program was utilized to compute volume of profiles, facilitating a more accessible three-dimensional comparison and the identification of correlations between CIEDE2000 color differences, ICC profile 3D volumes, sensor resolution, and bit depth When comparing the average CIEDE2000 color differences and camera sensor sizes, it was found significant differences between profiles and average errors in the ArgylCMS and i1Profiler profiles. This comparison also revealed correlations between sensor resolution and CIEDE2000 color differences: cameras with higher sensor resolutions provide lower CIEDE2000 color difference values, and vice versa.*

Keywords: *digital camera, colorimetric accuracy, camera profile, ColorChecker SG test chart*

1. INTRODUCTION

For the capture and reproduction of artistic works, it is crucial to have controlled conditions, quality lighting, and a camera with a sensor that ensures colorimetric accuracy and the widest dynamic range of color capture (Green, 2020, ICC, 2002, Argyl, 2024, Sharma, 1998). Therefore, our research aimed to investigate the volume of sensor color spaces in cameras based on price range, size and type of sensor, sensor manufacturer and the number of pixels the sensor is capable of capturing. In our research various amateur, semi-professional, and professional cameras were analyzed.
The procedures for creating profiles for each individual device involved in the color management workflow are generally very similar and always include the following sequence of steps:

- selection of target values,
- device calibration and
- device characterization (Giorgianni, 2008).

The selection of target values enables the determination of the quality of the final capture, in our case, the capture setup and scene lighting (Homann, 2010).

When comparing the calculated volumes of profiles, it should be emphasized that the calculated volumes do not reflect the absolute color gamuts of the cameras but serve as a basis and primarily for relative comparison between the color gamuts of different cameras. The colorimetric evaluation was not performed from real interpretations and displays on screens, where a human observer would give an opinion about color differences, but only at the level of volume profile calculations and calculations of CIEDE2000 color differences. For the creation of profiles, based on which further analyses were conducted, ICC Version 2 specification was purposefully defined and selected, as ArgyllCMS version 2.3.1 does not support the latest Version 4 profiles, therefore, comparison based on profile volumes would not have been possible. It should also be noted that captures of both ColorChecker DC and ColorChecker SG charts were made for the calculation of camera color gamuts, but only the profiles created for the ColorChecker SG chart were analyzed for objective comparison, as the i1Profiler program does not support profile creation with the ColorChecker DC chart.

2. EXPERIMENTAL

To determine the colorimetric accuracy of capturing 3-channel digital cameras, the capture of the ColorChecker SG test chart was done in controlled conditions in a studio using various amateur, semi-professional, and professional cameras. Using color profiling software (ArgyllCMS and i1Profiler), camera profiles were created according to

ICC version 2 specifications. This was followed by the assessment of colorimetric accuracy based on calculated color differences (CIEDE2000) between captured and reference values of the chart patches. For all created profiles, volume calculation was performed using the ArgyllCMS program for easier 3-dimensional comparison and identification of correlations between color differences (CIEDE2000), 3-D volumes of ICC profiles, resolution, and sensor bit depth. Colorimetric evaluation was based on comparison of different cameras by calculating color differences (CIEDE2000) between captured RGB and measured reference CIELAB values of the ColorCheckerSG chart patches. The second method involved comparison in terms of volume calculation in the ArgyllCMS program.

The scene was set up in the studio as shown in Figure 1. A neutral gray background was used and Xrite ColorChecker DC with 240 color patches and ColorChecker SG with 140 color patches (Figure 1) were captured with all cameras. The scene was evenly illuminated with LED lights from the manufacturer Rotolight Anova. The lights were covered with white diffusers to soften hard shadows and reflections on the chart. The color temperature of the lights was set to 5000 kelvins, which was also measured with the i1 Pro2 spectrophotometer.

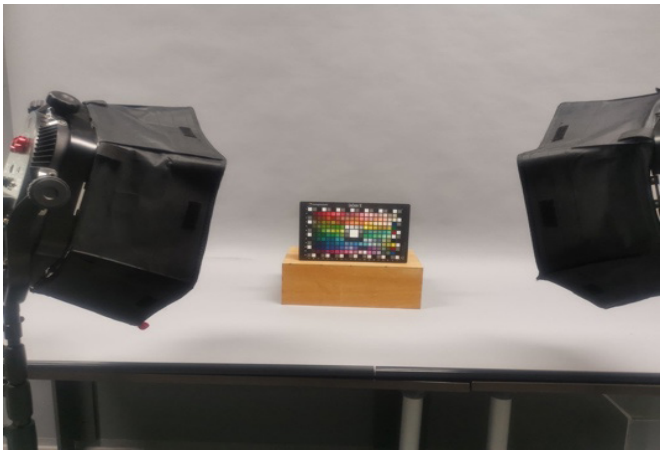

Figure 1: Scene in the studio for camera analysis

2.1 Camera settings and capture of the test chart

Device calibration involves adjusting the device to achieve repeatability and optimal color gamut. It is an important process carried out before the characterization process. In our case, the conditions for shooting with digital cameras were set (shutter speed, aperture, ISO sensitivity) and the scene was captured in RAW mode (Sharma, 2003).
All cameras had the ISO value set to the lowest available, ensuring the lowest possible noise level. This also allowed us to regulate the light intensity, ensuring that it did not affect the over- or underexposure of captured photographs. The shutter speed was adjusted in accordance with the aperture setting. These two parameters are closely related, and our starting point for setting up the cameras was to capture photographs with an “ideal” exposure value of 0, ensuring that the captured image was neither under- nor overexposed.
We aimed to capture the color chart with lenses with a focal length of 50 mm to simulate human eye perception. For the Nikon D300, D700, D850, and D3X cameras, the fixed focal length AF-S NIKKOR 50 mm f/1.4G lens was used. For other lenses with variable focal lengths, the frame was adjusted to achieve a focal length of 50 mm, as there was the possibility of zooming in. The white balance was set to 5000 K on all cameras, except for the Nikon D300, which does not have this option. In the latter case, a white balance shot was taken, and the above described method was used to set the white point.
The cameras were set to capture images in RAW mode, allowing for further editing of the photographs without data loss and the highest possible dynamic range of color capture. The bit depth was set to 14 bits on all cameras except for the Nikon D3200, Sony Nex-5N, and Panasonic Lumix DMC GX80, where it was set to 12 bits.

2.2 The process of creating a camera profile

Camera color characterisation means precise colorimetric description of the device and includes color mapping between the color space of the calibrated device and a device-independent color space (CIELAB or CIEXYZ).

Often, instead of the term “device characterization,” the term “device profiling” is used. The characterization process was carried out by capturing a large number of color samples (240 patches of the ColorChecker DC chart) with digital cameras, measuring them spectrophotometrically, and finally comparing the value of each color patch with its corresponding recorded value from the text reference file.

Each individual image of the chart was captured in RAW mode and converted using Adobe Camera Raw version 15.3 to a 16-bit TIFF format without color profiles to enable further use in programs such as ArgyllCMS and i1Profiler. The set color temperature of the LED light during capture was 5000 kelvins and was considered for each camera, so white balance adjustment in Adobe Camera Raw was not additionally set.

The next step was to create profiles for each camera using ArgyllCMS and i1Profiler (Argyll). Before creating profiles, it was necessary to properly prepare (crop) the converted input images of the chart, which the programs compared with the reference (measured Lab values with i1Pro2) for all 140 values of ColorCheckerSG chart patches and create color profiles according to ICC V2 specification. ICC V2 specification was chosen because Argyll in version 2.3.1 does not support the latest V4 profile version. The obtained device description may vary in quality, depending on the noise generated during camera capture, known as the occurrence of random pixel values in the image. This phenomenon mainly depends on the conditions during photography, camera settings, the algorithm used in data digitization, and the type of sensor.

3. RESULTS WITH DISCUSSION

To evaluate color profiles of a digital camera, first a color profile for each device has to be created. Initially, appropriate color charts were captured to obtain an RGB image. Each color patch of the captured chart includes average RGB values. To create a profile, a reference file is needed with CIELAB values for each color patch (measured with the i1Pro 2 spectrophotometer). During profile creation, the captured RGB values and reference CIELAB values are inserted into a file that includes conversion from RGB to CIELAB. This file is saved in the form of a lookup table (LUT) and is the main functional component of the input profile.

CIEDE2000 color differences between the processed CIELAB values for color patches and those of the reference file are a measure of the accuracy of the camera profile. Small color differences indicate a high-quality profile, and vice versa. Profile accuracy can be presented as the result of measuring color differences of individual patches or as the average color difference of all patches. It’s also useful to monitor the maximum differences. A high-quality profile has a small average color difference and also a small maximum color difference for all included color patches.

It should be emphasized that color differences in neutral grayscale tones are less noticeable than errors or color differences in darker tones and saturated colors. Additionally, it must be considered that the described objective test only shows accuracy for reproducing colors included in the color chart, not for colors that the chart does not cover.

To analyze or assess the quality of color profiles, we adopted Adobe Photoshop to manually calculate the CIEDE2000 color difference for each of the 140 color patches of the chart. Since multiple cameras were selected, the process had to be automated – CIEDE2000 color difference calculation was performed automatically during camera profile creation in ArgyllCMS and i1Profiler programs. In addition to calculating CIEDE2000 color differences, the volumes of color profiles calculated with the ArgyllCMS 2.3.1 program were compared.

3.1 CIEDE2000

As a metric for the colorimetric accuracy of cameras, the CIEDE2000 color differences between the RGB input data of the captured chart and the measured reference data of the chart were calculated. The ArgyllCMS program, when creating a camera profile using the COLPROF function, provides average CIEDE2000 values for all 240 patches of the chart. Similarly, i1Profiler also provides average color differences between the input RGB data of the captured chart and the measured reference data during profile creation (Sharma, 2004).

3.2 Camera profile volume

In the research color profile volumes were calculated for each camera using the ICCGAMUT function, part of the Argyll program, obtained with both ArgyllCMS and i1Profiler programs. Volumes are expressed in color space units [CSU]. The calculated volumes do not reflect the absolute color gamuts of the cameras but serve as a good starting point and primarily for relative comparison between the color gamuts of different cameras.

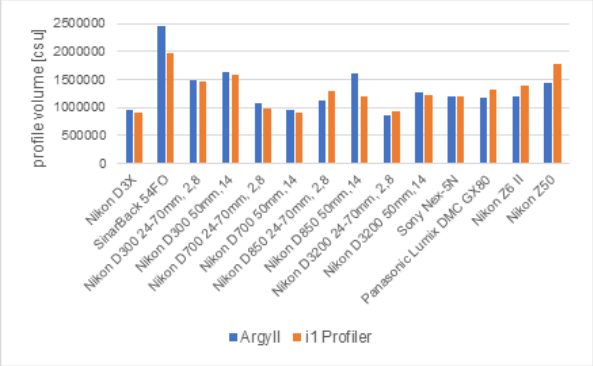

Figure 2: Comparison of profile volumes calculated with ArgyllCMS and i1Profiler

Figure 2 shows a comparison of profile volumes for each camera between ArgyllCMS and i1Profiler. Despite identical input data (the same captured chart image was used in both cases), there are noticeable discrepancies in three cases. The largest difference occurs with the Nikon D850 camera using a fixed focal length 50mm lens, where the difference in volumes is 406,653 units, i.e. 25.2%. Similarly, with the SinarBack54FO camera, the difference in volume is 475,523 units, representing a 19.4% increase in volume size. In addition, for the Nikon Z50 camera, the difference in volumes is 327,169 units, representing an 18.5% increase in volume size. For other camera profiles significant deviations are not observed. It can be observed that the Sinarback 54FO medium format camera has the largest color gamut of all tested cameras, or the largest calculated profile volume with 2,455,806 units, while the Nikon D3200 camera has the smallest color gamut with a volume of only 858,079 units. The Sinarback 54FO has the largest image sensor with dimensions of 50.8 mm x 59.61 mm, while the Nikon D3200 has dimensions of 15.4 mm x 23.2 mm.

For a more illustrative representation of the dependency of the average CIEDE2000 for each camera profile on resolution, Figure 3 is available, where a trend can be observed that as the number of pixels on the camera's image sensor increases, the CIEDE2000 value decreases.

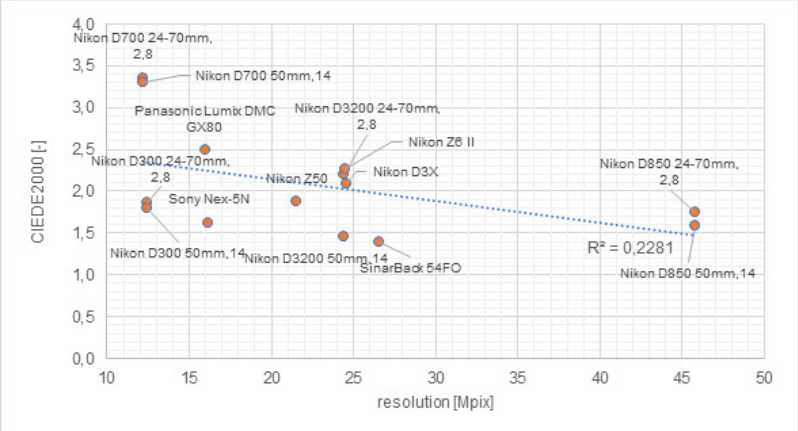

Figure 3: Display of the dependence of average CIEDE2000 for each camera profile, calculated with ArgyllCMS, on camera resolution

In the research, we were interested in whether the choice of test chart has an effect on the volume of the camera's color gamut. From the calculated profile values of the SinarBack 54FO camera, we found the following: when capturing the ColorChecker SG test chart, the volume size of the profile was 2,455,806 units, while when using the ColorChecker DC chart, it was 1,955,770 units, representing a difference of 20.4% in color gamut of the same camera under identical lighting conditions. Interestingly, the ColorChecker SG test chart has 100 fewer patches than the ColorChecker DC, but evidently, the patches on the ColorChecker SG test chart are selected to represent a broader spectrum of colors, resulting in a larger dynamic range of the camera. Based on yhese results it can be concluded that the choice of the test chart definitely affects the color gamut of the camera.

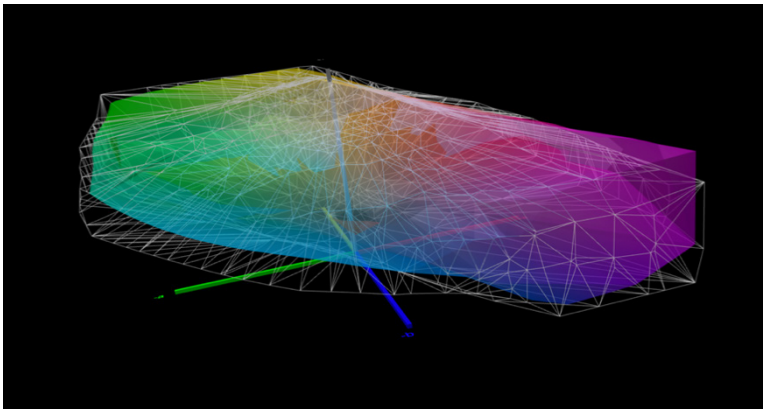

Figure 4: Comparison of volumes of two profiles using different charts - ColorChecker SG (gray grid) and ColorCheckerDC (color grid)

4. CONCLUSIONS

When comparing the volume size of profiles calculated for the same camera under the same capture conditions (distance, camera settings, and lighting), it was found that the deviation between profiles created with ArgyllCMS and i1Profiler was significant in five cases (Nikon D850 50: 25.4%, SinarBack54FO: 19.4%, Nikon Z50: 18.5%, Nikon Z6 II: 13.7%, and Nikon D850: 24–70 mm). For the remaining cameras, profile volumes were quite similar, with deviations less than 10%.

Comparison of the average color difference (CIEDE2000) between cameras and profile volumes, revealed a trend that cameras with larger profile volume (color gamuts) provide lower CIEDE2000 color difference values and vice versa. When comparing average CIEDE2000 color differences and camera sensor sizes, we noticed significant differences between profiles and average errors in ArgylCMS and i1Profiler profiles. When comparing sensor resolution (Mpix) and average CIEDE2000 differences, it was noticed that when using the Argyll program significantly higher CIEDE2000 values were obtained for the same camera and identical input data in most cases. Based on these results we also identified correlations between sensor resolution and CIEDE2000 color differences (cameras with higher sensor resolutions (Mpix) provide lower CIEDE2000 color difference values and vice versa). During the capture and analysis of patches of the ColorChecker DC and ColorChecker SG charts, it was shown that despite the smaller number of patches (100 less) on the ColorChecker SG test chart, the color spectrum is larger. Using the ColorChecker SG chart under the same lighting conditions and with the same camera, a 20.37% larger color gamut was achieved. We conclude that the choice of the test chart consequently affects the "relative" color gamut of the camera.

For more colorimetrically accurate and larger color gamuts of cameras, an increase in the number and diversity of patches for capture is recommended. It might be reasonable to capture the Munsel Color Atlas, which includes many more patches, as this would cover a wider range of colors and likely increase the color gamut.

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THE APPLICABILITY OF LIGHTING TECHNIQUES IN PORTRAIT PHOTOGRAPHY FOR SPECIFIC PURPOSES

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Abstract: *The aim was to analyse and observe the influence of facial features on the appearance of a subject in a photograph taken with different lighting techniques and to determine the best use of these techniques depending on the purpose of the photograph. The experimental part is divided into four main steps: analysis of the influence of the light characteristics on the appearance of the face in the photograph, photographing eight different lighting techniques taken with one light source, then again with three more side lights added to the main light and a final online survey. The authors have identified the four most common uses for portrait photography which are presented next. The results suggest that loop lighting is most suitable for corporate portraits. Short lighting appears to be best for social media photos. Butterfly and background lighting are best for personal documents photographs. Short lighting is best for magazine covers.*

Keywords: *portrait photography, portrait lighting techniques, studio photography, light, purpose of the photograph*

1. INTRODUCTION

One of the most important fields of digital photography is portrait photography, of which studio photography is an important part. Its main advantage is the ability to control the lighting. There are different lighting techniques for portraits that affect the appearance of the person's face in the photograph.

This research aims to analyse and observe the effects of facial features on the appearance of a portrait photograph taken with different lighting techniques. We also aim to determine the applicability of these techniques depending on the purpose of the photograph. Before starting, we made six hypotheses. We hypothesised that the portrait lighting techniques would visually alter the shape and facial features of the subjects. Photographs of different subjects captured with the same portrait lighting technique will differ from each other due to their different facial features. For a corporate portrait, the best lighting technique is Rembrandt or loop portrait lighting. For a personal document, the best lighting technique is butterfly lighting. For a personal photo on social media, the best lighting technique is short lighting. For a magazine cover, the best lighting technique is rim lighting.

Photographic portraits come in different styles, which are selected depending on the intended use. Lighting is a crucial aspect that often draws on techniques from commercial and editorial photography and is applied to consumer portraits (Kroninger, 2011). In portrait photography, the subject and main light are usually positioned to emphasise one side of the face while minimising excessive shadows for a pleasing effect (Smith, 2011). Light ratios measure the difference in power between primary (main light) and secondary (fill light) light sources and influence the balance between highlights and shadows (Zhang, 2020). The midtones that lie between the brightest highlights and the darkest shadows add depth and realism to the image (Smith, 2011).

The classic lighting styles in portrait photography include split lighting, loop lighting, Rembrandt lighting, butterfly lighting, broad lighting, short lighting, rim lighting, and background lighting. With split lighting, the face is divided into an illuminated half and a shaded half. This is achieved by positioning the light source at a 90-degree angle to the subject, resulting in a dramatic effect (Chen, 2015). In loop lighting, facial features are softly defined with the light source placed at a 45-degree angle above eye level (Chen, 2015). Rembrandt's lighting, reminiscent of the painter's high-contrast portraits, creates a distinctive triangle of light on the cheek by positioning the light source at an angle of 30-40 degrees above head level (Chen, 2015). Butterfly lighting casts a soft, even light with a shadow under the subject's nose, achieved by positioning the light source slightly above and behind the camera (Chen, 2015). Broad lighting widens the face by illuminating a larger portion, while short lighting narrows the face by emphasising the darker side. Both are achieved by adjusting the position of the subject relative to the light source (Wedio, 2021). With rim lighting, the subject is illuminated from behind, creating a bright outline and

making it stand out from the background. The light source is positioned behind and above the subject (Wedio, 2021). Background lighting brightens the area behind the subject, enhancing contrast and possibly creating a silhouette, with the light directed towards the background (Smith, 2011).

2. EXPERIMENTAL

We created two sets of 32 photographs – 8 lighting settings for each of the 4 subjects, using the first set to customise the lighting settings. The photographs were taken in a studio environment using a tripod with a mounted Canon EOS 5D Mark III camera and EF24-106mm f/4L IS USM lens, with the following settings: ISO 100, focal length 65 mm, aperture f/6.3, shutter speed 1/200 sec. Two studio lights (both LED Rotolight Anova Pro Eco Flood), four studio flashes (two Elinchrom ELC Pro HD 500 and two Elinchrom BRX 500), four light diffusers (three softboxes, one beauty dish attachment) and a light reflector were used to illuminate four test subjects (models). Images were processed in Adobe Lightroom software (version 6.2) and HP ProBook 450 G8 laptop.

The experimental part was carried out in multiple phases. First, we photographed the test subjects, changing the characteristics of the light between each photograph. We varied the hardness and intensity of the light, the contrast and the direction of the light source depending on the subject. We photographed the subject in front of a white background using eight different lighting techniques using one light source (split lighting, loop lighting, Rembrandt lighting, butterfly lighting, broad lighting, short lighting, rim lighting, and background lighting). This helped us to understand how to place the main light for each of the lighting techniques, giving us some additional information how to set up lighting for the final experiment. Additionally, in most of the portraits we noticed a subtle but noticeable brightening from behind, as the white background reflected the light. Therefore, we changed the background to grey to achieve the best results with minimal light reflection or absorption. We also removed the glasses from model no. 3 to consistently compare the shadows and highlights of the faces.

After these adjustments, we captured the final set of 32 photographs, while this time we added a fill light, a hair light and a background light to each scene setting. Finally, we conducted a survey where we showed all 8 photographs of each subject to randomly selected people who decided in a two-choice system which of the 8 photographs is best for a personal document, a corporate portrait, a personal photo for social media and a magazine cover. Based on the results, we determined which lighting technique is most useful for the specific purpose of the photograph and which lighting characteristics are best suited for each use.

3. RESULTS WITH DISCUSSION

We have analysed all the elements in the photographs from the subject's perspective, so the discussion is written as if we were looking through the subject's eyes. The left side of the face refers to the left side of the face from the subject's perspective, not from the perspective of the person looking at the photograph.

Figure 1 shows portraits with split lighting. Subject 1 was a challenge due to his reddish complexion. All subjects have shadows on the right side of the face and slight shadows on the other side of the face caused by the bulging of the eyes and cheeks. Subject 1 has the darkest shadow in the left eye, while the shadow of the cheekbone is lighter and smaller. This subject has noticeable shadows near the mouth and under the chin. Subject 2 has intense shadows on the left eye and cheek, which are elongated due to a longer jaw. Subject 3 has less intense shadows on the eye, but a more pronounced shadow on the cheek that extends to the chin. Subject 4 has shadows along the eye and cheekbone, with the shadow on the cheekbone being the strongest due to the pronounced cheekbones. The shadow on the chin is faint but clearly separates the face from the neck. In all four subjects, only the left side is well lit, resulting in a less pronounced face shape. Both the left eye and the left cheek stand out in each portrait. The shadowed half of the face creates the optical illusion of a narrower face compared to other lighting styles and contributes to a mysterious and dramatic effect in the portraits.

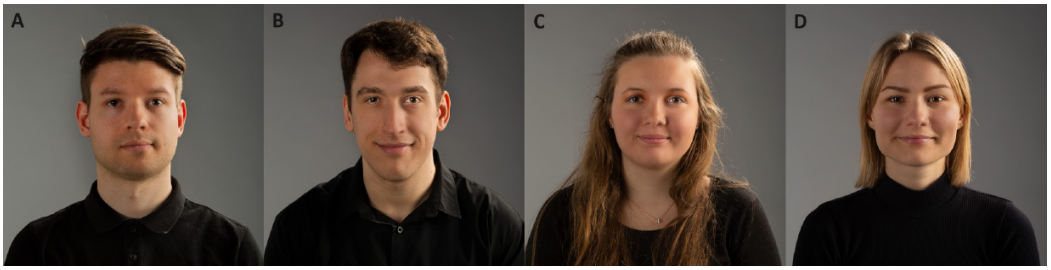

Figure 1: Split lighting: A - subject 1, B - subject 2, C - subject 3, D - subject 4

In Figure 2, the loop lighting in the portraits is evident in all four subjects. In each portrait, a distinct circular shadow appears under the right side of the nose. Subject 1 shows a less intense circular shadow under the nose that extends towards the eye. In subject 2, on the other hand, the shadow is larger due to the shape of the nose and extends to the eyebrows. Due to their smaller noses, subjects 3 and 4 have smaller shadows under the nose, with subject 4's shadow extending almost to the eyebrow and subject 3's ending slightly earlier. The transition between light and dark areas is softer in subjects 1 and 3 due to their softer facial features, while the transition is quicker in subjects 2 and 4 with stronger facial features. In addition, the shadow under the chin is more intense and smaller in subjects 2 and 4, creating a clearer separation between the face and neck than in subjects 1 and 3. The facial features are very well defined overall despite the shadow covering almost half of the faces, especially in subjects 2 and 4. This lighting style produces a more three-dimensional appearance compared to split lighting, as part of the right side of the face is also illuminated. Both eyes are clearly visible and the nose plays an important role in casting shadows. The bright areas create a formal and three-dimensional effect.

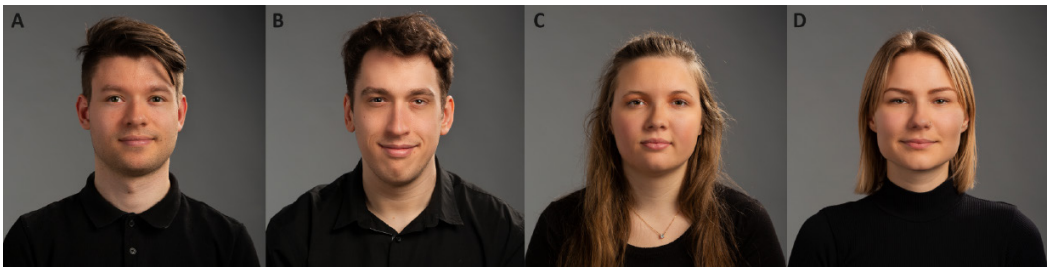

Figure 2: Loop lighting: A - subject 1, B - subject 2, C - subject 3, D - subject 4

In Rembrandt's lighting portraits (Figure 3), all four subjects show a triangular illuminated area on the right cheek, as a result of the nose and cheekbone shadows coming together. In subject 1, the triangle is less visible due to the reddish complexion. Subjects 3 and 4 have the most pronounced triangles due to their strongly convex cheeks. The contrast is strongest in subject 3. Subject 2 has an elongated triangle due to his longer face. The eyes are well highlighted in all subjects, whereby the right eye of subject 1 is particularly emphasised by the light. The high-contrast effect of the small, intense light area of the Rembrandt triangle attracts attention and creates a dramatic, three-dimensional atmosphere in the photographs.

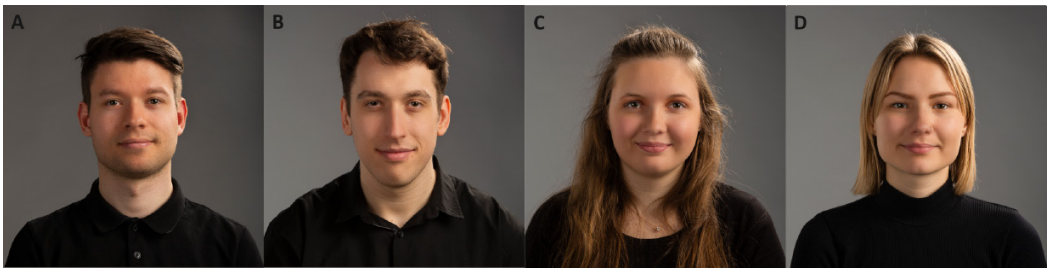

Figure 3: Rembrandt lighting: A - subject 1, B - subject 2, C - subject 3, D - subject 4

In the portraits with butterfly lighting (Figure 4), the faces of the subjects are evenly illuminated. Subject 3 only has shadows under the nose and chin, while the others have additional hair shadows. The butterfly shadow under the nose is visible in all portraits. Subjects 1, 3 and 4 have similar shadow size and intensity, although they appear slightly lighter on the right side due to complementary light positioning. Subject 2 has a larger, more intense shadow due to a more convex nose. The shadows under the chin and the eyes vary, although they are particularly pronounced in subject 4 and extend into the hair. The lack of dominant shadows creates a visually wider face with soft features, well-lit eyes, a light-coloured face separated from the neck and an attractive, positive and professional atmosphere in the photographs.

Figure 4: Butterfly lighting: A - Subject 1, B - Subject 2, C - Subject 3, D - Subject 4

Figure 5 shows broadly lit portraits in which the left side of the face is light and the right side is dark. In all subjects, there are subtle shadows near the inner part of the left eye and under the chin. The intensity of the shadow varies. Subject 4 has a slightly more prominent shadow under both cheeks, while the other shadows are less intense. Under the chin, the shadows range from thin and intense (subjects 1 and 4) to larger and less intense (subjects 2 and 3). The test subjects look away from the light so that the facial features are somewhat more difficult to recognise due to the darkened side of the face and the face appears narrower. Attention is initially focused on the illuminated left side, particularly the left eye and cheekbones. This creates a relaxed and engaging look when the face is turned away from the camera.

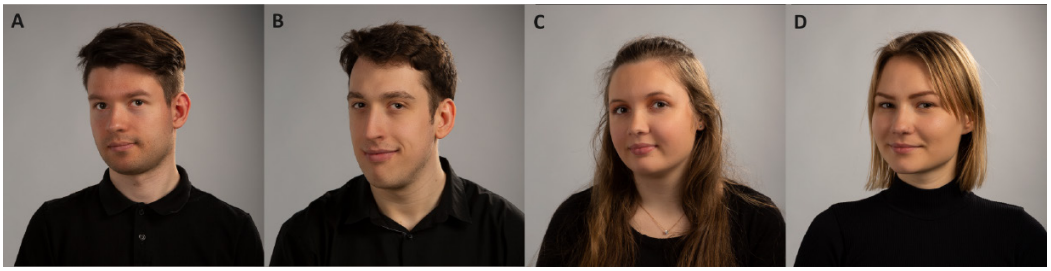

Figure 5: Broad lighting: A - Subject 1, B - Subject 2, C - Subject 3, D - Subject 4

Figure 6 shows portraits with short lighting, in which a focussed light illuminates most of the faces but casts a shadow on the other side, especially under the nose and chin. The intensity of the shadow differs between subjects, with subject 1 showing a darker and larger shadow than the others. Subject 3 has the lightest shadow due to the softer facial features. While the shadows of the first three subjects look similar, subject 2, who has a more elongated face, has a narrower and longer shadow. Subject 4 has a clear shadow with sharper transitions that emphasise his sharp facial features. These portraits, where the subjects are looking to the side and the faces are well lit, make the face appear wider and give an interesting and informal feel, similar to broad lighting.

Figure 6: Short lighting: A - Subject 1, B - Subject 2, C - Subject 3, D - Subject 4

Figure 7 shows portraits with rim lighting that emphasise different areas of the four subjects due to their different hairstyles and head shapes. In subjects 1 and 2, the ears and the edges of the face are well lit, while in subjects 3 and 4 the hair is emphasised more strongly. The rim lighting technique casts a slight shadow over a large part of the faces and draws attention to the edges of the scalp or neck. This special lighting makes for fascinating portraits, as it focuses on normally unexposed parts of the face and makes the faces appear darker.

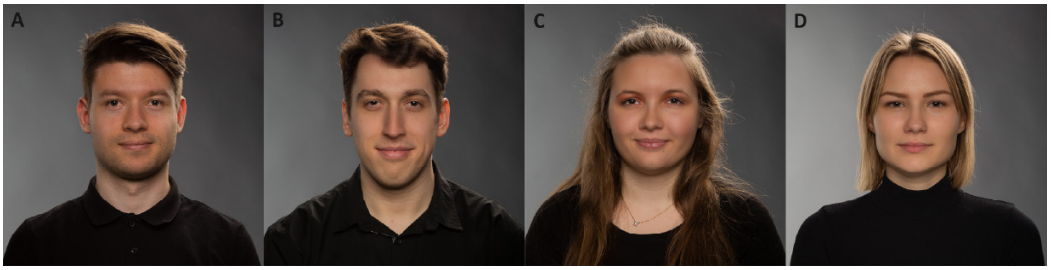

Figure 7: Rim Lighting: A - subject 1, B - subject 2, C - subject 3, D - subject 4

Figure 8 shows portraits with backlighting that emphasise the background, which appears brighter compared to other lighting techniques. This style creates the illusion of a white background and makes the photo brighter and more vibrant overall. The subjects appear to be backlit, which is reminiscent of butterfly lighting due to the additional light source. The result is intriguing and informal portraits where the subjects do not draw as much attention to themselves as with other lighting techniques.

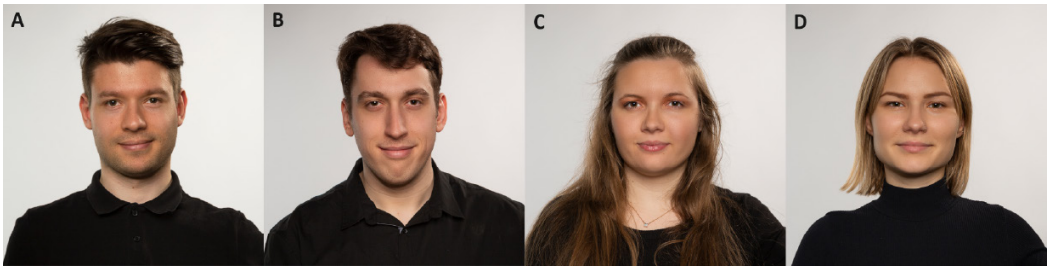

Figure 8: Background lighting: A - Subject 1, B - Subject 2, C - Subject 3, D - Subject 4

The final questionnaire was completed by 50 people, 10 men and 40 women. The age of the participants ranged from 21 to 54 years, with 21 of the respondents being 22 years old. All participants were from Slovenia. The total number of clicks or selections between two photos within the survey was 3200.

For a corporate portrait, the loop lighting was selected as the most suitable photograph (123 clicks), followed by the Rembrandt lighting (120 clicks). Split lighting (60 clicks) and broad lighting (69 clicks) were chosen the least often. For the photograph on the personal document, the butterfly lighting and the background lighting were chosen most frequently, with 153 clicks. The broad lighting was by far the least frequently selected with 24 clicks, followed by the short lighting with 42 clicks. For the social media photograph, the most frequently selected lighting

technique was short lighting with 129 clicks, followed by Rembrandt lighting with 125 clicks. The least frequently chosen lighting technique was rim lighting with 71 clicks, followed by background lighting. For the cover of the magazine, short lighting was chosen most frequently with 131 clicks. This was followed by loop lighting with 128 clicks. Split lighting was chosen the least frequently with 58 clicks.

4. CONCLUSIONS

One of the most important applications of the photographic medium is portraiture, where light plays a crucial role as it directly influences the appearance and mood of the photograph. By understanding how light affects the subject, you can create high-quality portrait photographs for a variety of purposes. In this article, we have analysed lighting techniques for portraits and observed the influence of facial features on the appearance of a photograph of a subject taken with different lighting techniques. We have also determined the usefulness of these techniques depending on the purpose of the photograph.

We confirmed the first hypothesis, as the lighting techniques significantly changed the shape and features of the subjects' faces visually. We confirmed the second hypothesis, as the photographs of different subjects with the same portrait lighting technique differed from each other due to the different facial features of the subjects. We confirmed the third hypothesis, as the Rembrandt and loop portrait lighting techniques were chosen most frequently for the corporate portrait. The fourth hypothesis was only partially confirmed, as for the personal document photo, the two most frequently chosen lighting techniques with the same number of clicks were butterfly lighting, which confirms the hypothesis, and background lighting, which disproves it. The fifth hypothesis was confirmed as the short lighting was most frequently chosen for personal photo on social media. The sixth hypothesis was disconfirmed, as the short lighting was most frequently chosen for the magazine cover photo rather than the rim lighting. Each of the portrait lighting techniques offers a unique way to emphasise the subject's features and create a look that is useful for many different purposes.

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SUBSTRATES AND STANDARDIZATION

INFLUENCE OF TEXTILE SUBSTRATE PARAMETERS ON PRINT QUALITY

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Abstract: *Digital printing technologies enable the printing of textiles that surpass the diversity of paper substrates, not only in terms of the variety of materials, but also in terms of the structure (woven, knitted or non-woven), the weight and thickness of the textiles, the type of yarn (twists and winding direction) and thread thickness, the type of weaving and knitting, the use of possible finishes and coatings, the open area of the surface, etc. As various parameters have a significant impact on printability, in this study we investigated the differences in printing results on paper and textile substrates to gain insight into the influence of textile parameters on quality in terms of colour and image resolution as well as the ability to reproduce lines and typographic elements. The results obtained showed significant differences in the printability of paper and textile substrate and provided information on the influence of individual structural elements of textiles on the quality of the prints. In the study we came to the conclusion that the construction of the fabric and the printing technique used have a significant influence on the print quality.*

Keywords: *ink-jet printing, printing on textiles, textile structure properties, quality of prints, colour management*

1. INTRODUCTION

Textiles are present in all areas of daily life. Today, they are slowly replacing some areas where paper substrates used to dominate. With aesthetics taking centre stage and the importance of information, textiles are often printed in one way or another. Studies show that up to 95% of all printed textiles are still predominantly printed using conventional techniques and only around 5% using digital processes (inkjet printing). (Romano, 2016)

The latest research from Smithers highlights inkjet textile printing as a key growth segment in the printing industry. Advances in printhead technology, ink formulations and media handling systems are driving productivity gains and expanding the scope of digital textile printing. (Smithers, 2024)

Inkjet printing is a digital printing process in which ink droplets are ejected onto various substrates such as paper or textiles. The printing process is a non-contact printing process, so the substrate does not need to be held aggressively, as is the case with conventional screen printing, for example. Most inkjet inks have a low viscosity and low surface tension, which places high demands on the porosity and absorbency of the coating. To achieve better print quality on textile substrates with inkjet printing, the surface must be pre-treated to prevent excessive ink penetration. It is important to keep the textile substrate flat during the printing process and ensure that the warp and weft threads are aligned at right angles to each other; the print head moves perpendicular to the warp thread. It has proven crucial to determine the fabric properties of the textile substrates to determine the impact on the quality of the inkjet print. (Svanholm, 2007; Li, 2017)

Textiles are therefore printed for decorative or promotional purposes, which makes printing a major challenge. Broadly speaking, printed textiles can be divided into two groups: (1) decorative textiles, which include fashion products and sportswear, underwear and swimwear, footwear and other fashion accessories, home and household textiles, decorative and technical textiles, and (2) promotional textiles, which include so-called "*soft signage*" or "*sign and display*", on which mainly advertising content is printed. As an additional group we could mention a hybrid group to which we add sportswear and direct-to-garment (DTG). (Tschudi, 2020; Romano, 2016)

The main problem with printing on textiles is the colour gamut that can be printed. In many cases it varies greatly in size – it can be too small or too large in certain areas of the colour gamut, with spot colours presenting a further challenge. As already mentioned, there are a variety of possible interpretations due to the different profiling engines. We should not forget that we can use different colour spaces when defining colours: CMYK, LAB or

RGB. CMYK consists of only four process colours, while more colours can be used when printing on textiles. With LAB, however, a completely different problem arises due to the applications of design programmes and with RGB the question arises as to which RGB colour space we should use. Experts have therefore developed Fogra58 for printing on textiles, an ICC RGB working profile space that is compatible with design programmes (Adobe Photoshop, Illustrator, etc.). It is slightly larger than Pantone TCX and typical DTP colour gamuts and enables realistic colours on screens (soft proof) and paper (hard proof) when calibrated and the rendering intent is set to absolute colorimetric. It is LUT-based and shows appealing out-of-gamut mapping features (from sRGB, aRGB) and is designed for “classic” textile applications (D65/10°). (Tschudi, 2020)

The roughness and unevenness of the substrate surface affects the print quality in inkjet printing. Increased roughness (unevenness) leads to a higher mottle value, lower line quality, dot roundness, print sharpness and colour reproduction. Roughness also influences the colour gamut of the profiles created, with rougher substrates having a smaller colour gamut, which affects the colour reproduction. (Novaković, 2013)

2. EXPERIMENTAL

2.1 Printing substrates

To evaluate the effects of textile parameters on print quality, which include colour, uniformity of prints and the reproduction of graphical elements (lines, circles and text), we created prints on textile and paper substrates. For the study, we selected print substrates that are available on the market for large format printing – Blackout VI DirectTex textile substrate (Pongs, Germany) and the Microporous Satin Photo Paper paper substrate (Papergraphics, UK). This comparative approach enabled us to analyse and compare the print results on both substrates and thus make a comprehensive assessment of the influence of the textile parameters on the print quality.

Selected textile substrate Blackout VI DirectTex (Pongs, Germany) belongs to the group of so-called »promotional soft signage« (Tschudi, J. 2020). For this category, the measuring device uses standardised lighting conditions D50 and a 2° observer, as does the i1Pro 3 spectrophotometer we used. We wanted to investigate the extent to which we could reproduce an RGB colour space, Fogra 58, with a conventional inkjet printer for printing on paper. According to the manufacturer, the textile substrate is a PVC-free fabric made of 100% polyester (PES) with a grammage of 330 g/m^2. It is a fabric with a bright white front side and a dark grey back side that prevents light from shining through. It has an inkjet coating that enables printing with UV, latex and dye-sub ink systems with minimal shrinkage (Pongs, 2021). Since the parameters of the textile substrate were of interest to us, we carried out a more detailed investigation. We found that the yarns used were multifilament yarns. The fabric consists of a construction with two weft yarns with the sequences 1 : 1, consisting of a 7-end reinforced satin on the front and a 14-end weft satin on the back side. The thread density on the front (print) side is 597 picks per 10 cm in the warp and 275 ends per 10 cm in the weft direction. The average warp thread diameter is 170 µm and the weft diameter 340 µm. A higher thread density reduces the open area and thus increases the density of the surface structure. The pronounced influence of the floating threads of the satin weave, which is emphasised on the surface, implies the direction of the threads. This effect can significantly influence the bleeding and the wicking of the ink in this direction, resulting in smudged or blurred prints and therefore poor print quality. The type and properties of the »inkjet« coating applied to the surface were not specified by the manufacturer. Its purpose was to smooth the surface, increase the surface energy and enable a higher print quality. The CIE whiteness of the textile substrate, measured according to ISO 11475, was 118, with a tint value of 25.

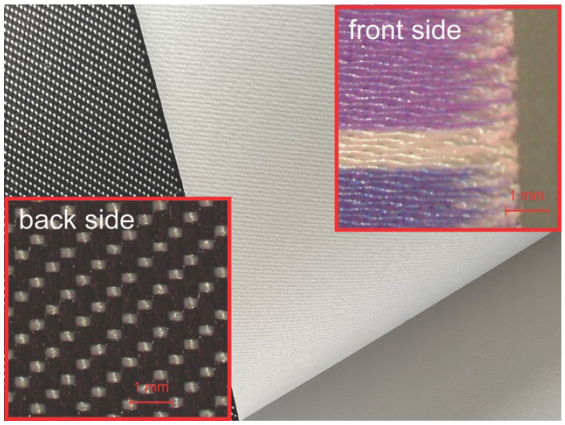


Figure 1: Surface of the selected textile substrate (in the background) with enlarged images of the front* and back side of the fabric

**As the front is white, the weave was not clearly recognisable, therefore the image was taken on a printed section*

The paper substrate Microporous Satin Photo Paper (Papergraphics, UK) was chosen as a reference as it has been proven to produce high quality prints on wide format printers that can print on a variety of substrates. The substrate is a one-side coated, semi-gloss paper with a grammage of 195 g/m^2. The CIE whiteness was 98, measured according to ISO 11475, with a tint value of 7.

2.2 Printing process

The imagePROGRAF PRO-4000S printer with its 8-colour system and a width of 44 inches is designed for the poster and signage industry. It is characterised by its speed and consistent colour reproduction in large format printing. Equipped with a new integrated 12-channel compact print head with a width of 1.28 inches, the LUCIA PRO water-based full-pigment ink set, a precise mechanical platform and the L-COA PRO high-speed image processing engine, this printer strikes a harmonious balance between fast printing and exceptional print quality (maximum print resolution of 2400 × 1200 dpi), according to the manufacturer. The inks are resistant to external influences, UV light, ozone and moisture and are also said to provide long-lasting prints with minimal fading. (Canon, 2024)

The printer optimisation for each print substrate, before calibration and profiling, was carried out with the Media Configuration Tool. Although the printer uses 8 colours, it was calibrated and profiled as a 4-colour CMYK printer. The selection of input values, linearisation and determination of total ink limit (TIL) were carried out using the Fiery XF RIP (EFI, USA). The best RIP print quality (600 × 600 dpi) was selected for both substrates.

The linearisation of the printer was performed by printing the linearisation chart (without colour management). The programme offered areas with optimal ink limit per channel based on the measured values. We specified the exact values. In the next step, the TIL value was determined by measuring the TIL test chart. The TIL value was taken into account when creating colour charts and colour profiles in the i1Profiler programme. We chose 2033 patches, although the colour gamut of inkjet printers is already well defined with 500 patches (Đorđevič, D., 2007). Two colour profiles were created for the textile substrate, one with a low TIL value (CP1) and one with a high TIL value (CP2) (Table 1). The TIL values were lower than we had expected in the first steps of the research. Nevertheless, high ink application resulted in ink bleeding and wicking, which was also demonstrated in the next steps of the research. The results also showed that high ink coverage on this substrate is not recommended when printing text and image details. Only one colour profile with a high TIL (CP3) was defined for the paper substrate (Table 1).

We have linked the colour profiles on the Fiery XF RIP to the calibration measurements and completed the printer calibration and profiling process. The colour management and colour profile settings were used when printing the test form.

Table 1: Values of the highest ink limits for textile and paper substrate depending on the colour profile (CP) settings

Ink colour	Ink limits of printing substrate according to colour profile (CP)		
	Textile		Paper
	CP1	CP2	CP3
C	80	99	99
M	78	99	99
Y	81	99	99
K	84	99	99
TIL	**206**	250	302

2.3 Test form

We designed a test form for the evaluation of final prints. It consisted of lines in different weights (from 0.25 to 2 pt, with increments of 0.25 pt) and short text in Helvetica in different sizes (from 3 to 20 pt), printed both as positive and negative in vertical and horizontal direction, control elements for the halftone value (from 10 to 100%, in increments of 10%) for CMYK, K and CY, a 100 × 100 mm 100% K square, the colour chart ColorChecker Classic (X-Rite), a PDI test image (Image science) and test images from the ISO 12640-4:2011 standard.
We created our own colour chart with 128 colour patches in Adobe Illustrator from the specified reference values of the Textile MediaWedge RGB V1.0 Fogra58 and used it to evaluate prints on textile printing substrate.

2.4 Measurements of colour values and calculation of colour differences

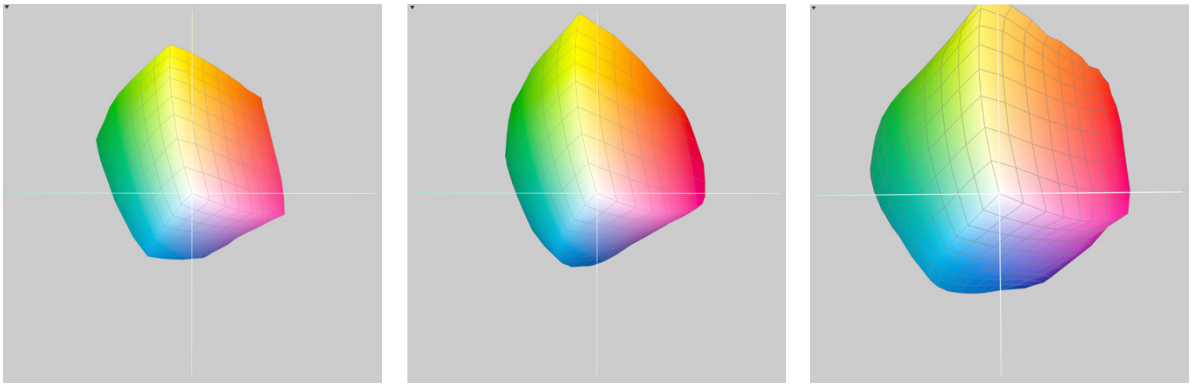
Colour values were measured with ArgyllCMS system and i1Pro 3 (X-Rite, USA). Colour differences were calculated with CIEDE2000 equation (Luo,. M. R., 2001). Three measurements were taken for each colour patch and the average calculated.

3. RESULTS WITH DISCUSSION

3.1 Visual comparison of the colour gamuts of the defined colour profiles

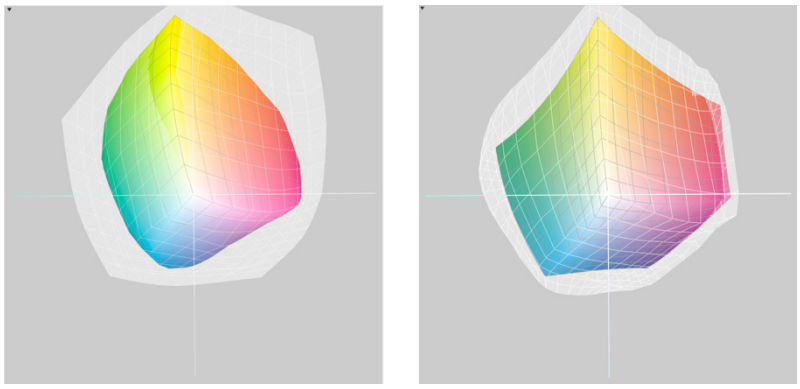
We compared all the colour profiles with ColorSync Utility to get an insight into their colour gamuts (Figure 2). The results showed that the largest colour gamut was obtained for CP3 on paper, while the colour profiles for textiles were significantly smaller, with CP1 being so small that it was excluded from further research.

A comparison of the colour gamut of the created colour profiles CP2 and CP3 with the standard colour gamut of Fogra58 (textile) and Fogra39 (paper) showed that the colour gamut of CP3 is much larger and more comparable with the corresponding standard (Figure 3).



CP1 *CP2* *CP3*

Figure 2: Visual representation of the colour profiles for textile (CP1 and CP2) and paper substrate (CP3)



CP2 – colored space
Fogra58 – gray space

CP3 – gray space
Fogra39 – colored space

Figure 3: Visual representation of the colour profiles for textile (CP2) with Fogra58 and paper substrate (CP3) with Fogra39

The big difference between CP2 and Fogra58 is due to the fact that Fogra58 is an RGB-based colour gamut, while CP2 is CMYK-based. It is generally known that CMYK colour gamuts are smaller than RGB colour gamuts. Finally, the colour gamut is also influenced by the type of printing material and the printing technology (printing device and ink). The results show that a textile substrate with defined print settings on a selected inkjet printer printing with water-based inks with CP2 is not suitable to describe the full colour gamut of the Fogra58 colour profile. This led us to the assumption that high colour differences are to be expected. As the CP3 colour gamut was larger than the Fogra39 standard, the results showed the opposite of what was the case with textile substrates. Due to the larger colour gamut, it could be assumed that the selected paper substrate was suitable for the simulation of offset printing on coated paper (hard proof), which was verified with i1Profiler. The measurements were carried out by printing Ugra Fogra media wedge on paper substrate and measuring the colour values. The colour difference (ΔE_{00}) of the paper whiteness was lower (1.30) than the standard tolerance according to ISO 12647-8:2021 (3.00). The average ΔE_{00} value of all patches was also lower (1.88) than the tolerance specified in the standard (2.5), with the highest ΔE_{00} value being quite high (6.03) and the lowest ΔE_{00} value being very low (0.33).

3.2 Colour differences

The results of the calculated ΔL* values for colour patches on textile substrate show that the ΔL* values were mostly negative, leading to the conclusion that printed colours on textile substrate were lighter than the referenced

colour patches. Colour patches with a high ΔE_{00} value also had the highest ΔL^* values. The highest average ΔE_{00} values occurred in the 4th quadrant (+a* and –b*), in violet hues, which was also observed when comparing the colour gamuts of CP2 and Fogra 58, where it was found that the 4th quadrant was smaller in CP2. The lowest ΔE_{00} values were measured in the 2nd quadrant (–a* and +b*), in green-blue hues (Figure 4 left).
However, slightly different results were achieved with prints on paper substrate. Here the ΔL^* values were really small (around 1 or even less), except for two patches – B3 and F4. Similar results were observed when calculating ΔE_{00}. The average ΔE_{00} value of all 24 colour patches was 1.57, with two patches standing out with the highest ΔE_{00} of 4.15 (B3) and 3.85 (F4) as indicated by the higher ΔL^*. White, grey and black patches had higher ΔE_{00}, with the lightest and darkest patches showing the greatest variation. The colour differences were much smaller on the paper substrate than on the textile, as can be seen in the diagram of colour values (Figure 4 right).

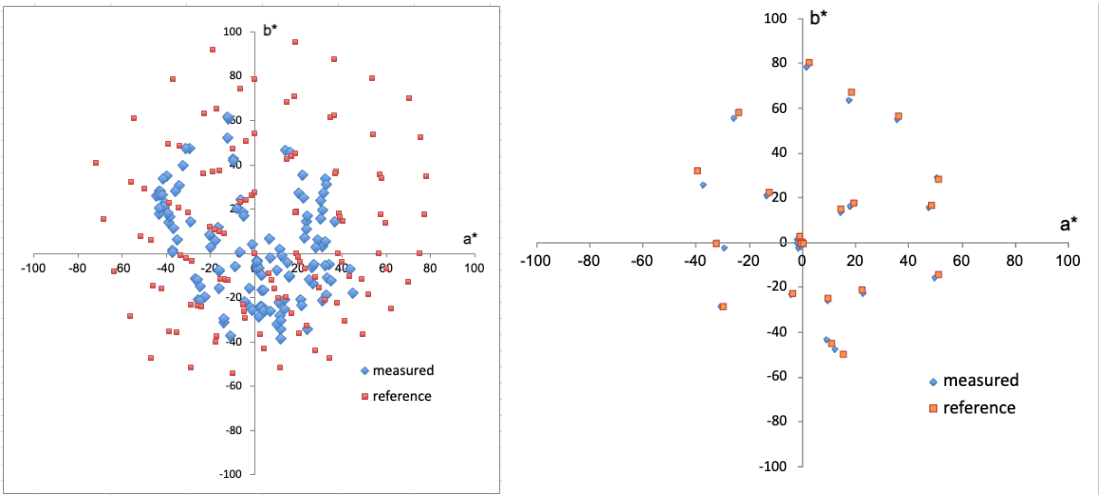


Figure 4: Diagram of the colour values (a*b*) of measured and reference Fogra58 patches for textile (left) and measured and reference Fogra39 patches for paper (right)

3.3 Halftone values for black ink and print non-uniformity

The halftone values (RTV, A) for black (K) printed control elements for the halftone value showed that the printed colours of both substrates were significantly higher than digitally specified (Figure 5), showing a higher dot gain. Higher A values were obtained for the textile substrate, which we attribute to the greater unevenness of the textile surface, its higher roughness and the bleeding and wicking of the ink. The A values increase evenly for both substrates.

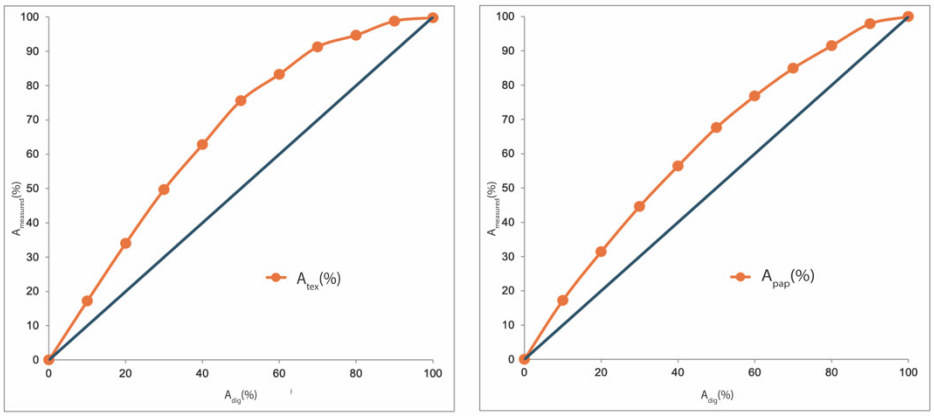


Figure 5: Diagram of the digitally specified and measured values of the control elements for the halftone value for K prints on textile (left) and paper substrate (right)

Since we printed on two different substrates with different surface and structural properties, we also wanted to analyse the non-uniformity of the print (NU). The image analysis showed that the NU for textile substrates was quite high (24.22), while the NU for paper was significantly lower (3.79). The high NU for textile was not only expected due to the higher surface roughness of the textile substrate, but also due to the different coating. Figure 6 shows histograms of scans of K-patches printed with 100% A.

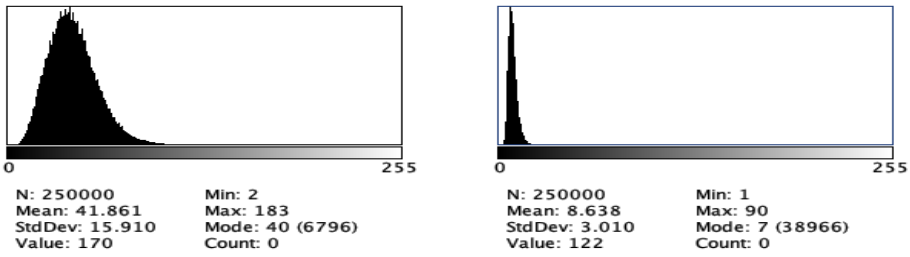


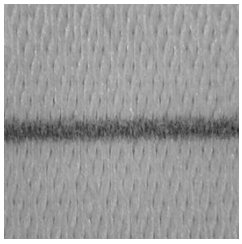
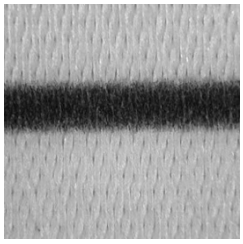
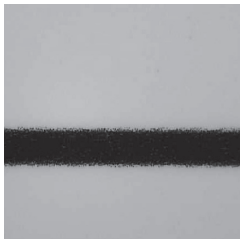
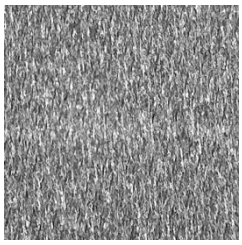
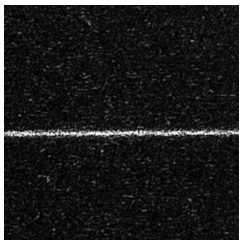
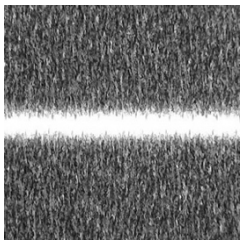
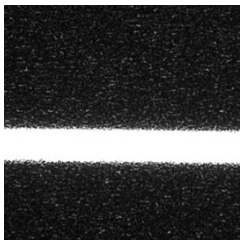
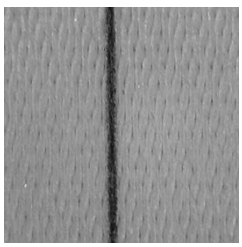
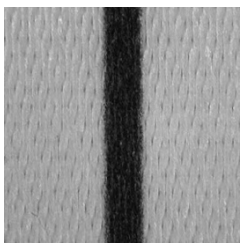
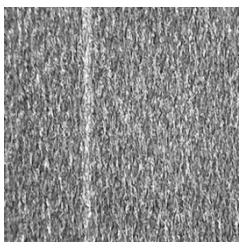
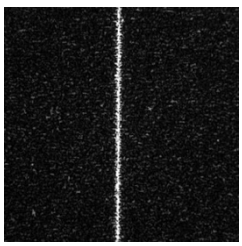
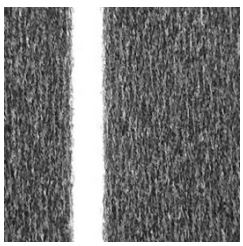
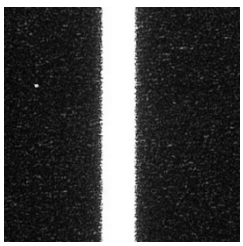
Figure 6: Histograms of the scans of K patches for NU analysis for textile (left) and paper (right)

3.4 Geometrical deformations of graphical elements

We also wanted to investigate the effects of printing different elements (lines, circles and text) when they are printed on both substrates as positive and negative. Using image analysis, we compared and measured the differences between digitally defined and printed elements in terms of area and perimeter (with a tracing tolerance of 70 in ImageJ).

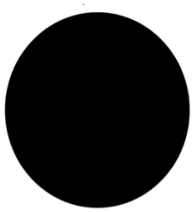
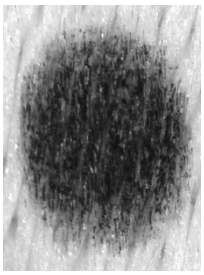
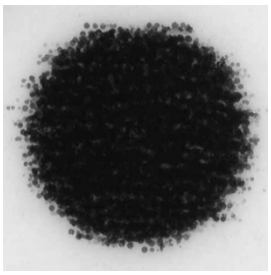
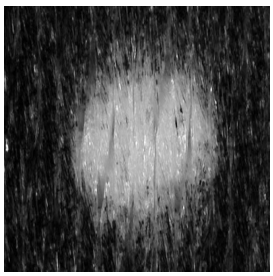
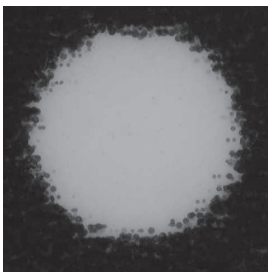
The analysis of the results showed that there were large deviations in the line widths of both the positive and negative prints on textile and paper (Table 2), whereby the print edges were rough (in all cases). On both substrates, the lines were wider in the positive prints and narrower in the negative prints. On the textile, the deviations were significantly greater, which was to be expected due to the structure of the substrate as well as the wicking and bleeding of the ink. When printing on paper substrates, the image analysis showed the characteristic imprint and visibility of individual ink droplets that occur when printing with an inkjet printer. This resulted in a larger printed area and unevenly printed edges of lines. Both positive and negative horizontal line prints on textile substrate were wider or thinner, respectively, than the vertical line prints. We attributed this difference to the weft direction of the fabric, where thread flotation is more pronounced and thread density is lower. This contributed to wicking and bleeding of the ink transferring to individual threads rather than from one thread to another in the direction of the weft line. As can be clearly seen in Table 2, negative print lines with a thickness of 0.25 pt are barely visible when printed vertically (in the direction of the weft threads), while rotating the lines by 90° results in such heavy bleeding and wicking of the ink that the lines are not visible. This shows how important the direction of the weft thread is when printing and that, of course, the arrangement and fineness of the elements in the design must also be taken into account.

Table 2: Images of horizontally and vertically printed positive and negative lines of two thicknesses (0.25 and 2.00 pt)

	Printing material			
	textile	paper	textile	paper
	line thickness 0.25 pt		line thickness 2.00 pt	
Digitally defined				
Horizontall positive and negative prints				
				
Verticall positive and negative prints				
				

We further analysed the circle, measured its area, circumference and roundness (with a tracing tolerance of 70 in ImageJ) and compared all values with the values of the digitally designed circle. Table 3 shows images of positively and negatively printed circles on textile and paper substrates. From the image analysis, we could conclude that the prints of the circle in both negative and positive on the textile substrate differed greatly from the digitally defined circle, while the prints on paper varied less. The circle deviated not only in its dimensions, but also considerably in its shape/roundness, which had become an ellipse. In the direction of the weft, where there are more floating threads on the surface due to the structure of the fabric, more bleeding and wicking occurred. The area was therefore larger in the positive prints and smaller in the negative prints than the digitally defined circle. The circumference of the circles was significantly larger in the positive textile prints than in the negative prints. A comparison of the circumference of the printed circles on both substrates showed that the circumference of the prints on textile substrates was more than twice as large as the circumference measured on paper. The differences between the circumferences of the circles printed on the substrates and the digitally determined circumferences can certainly be attributed to the direction of the weft on the textile substrate and the characteristic imprint of dispersed individual ink droplets on the paper substrate.

Table 3: Images of positively and negatively printed circles

	Printing material	
	textile	**paper**
Digitally defined		
Positive		
Negative		

A similar analysis was carried out for text (Figure 7), with similar results as for lines and circles. For individual letters formed from straight and rounded strokes, more pronounced effects were observed at certain points – straight lines were fairly well defined when printed vertically, while rounded parts of letters were more deformed due to ink bleeding and wicking.

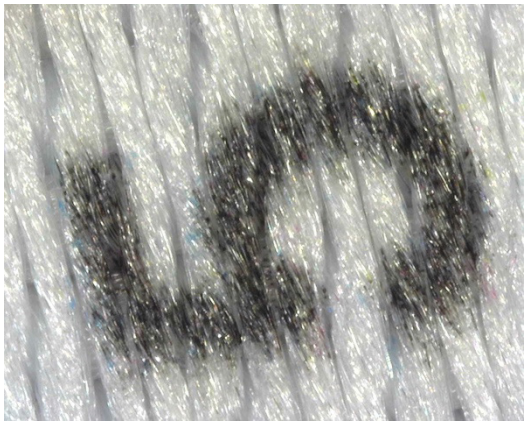


Figure 7: Effect of the printed ink in the form of a number on the surface of the textile substrate

4. CONCLUSION

In this study we wanted to investigate the effects of the textile substrate on the quality of the inkjet printing compared to the paper substrate. As expected, the differences between prints made on textile and paper substrates were significant. We emphasised the importance of calibration and profiling the inkjet printer for different materials, with the TIL being of great importance when creating the colour profile. The detailed analysis showed that the colour gamut of the colour profile for the textile substrate was significantly smaller than for the paper substrate. The colour differences were barely perceptible to the naked eye on the paper substrate, whereas they were considerable on the textile substrate. Due to the structural and surface properties of the textile substrate, the surface of which had to be treated accordingly for inkjet printing, it was to be expected that the same print quality could not be achieved as on paper. Due to the thread weave and the alignment of the threads, wicking and bleeding occurs in the prints, which significantly impairs the print quality and the reproduction of graphic elements. The bleeding and wicking of the ink, which is particularly pronounced in the weft direction of the textile substrate, contributes to variations in line widths, circle dimensions and text clarity. However, it is certainly true that by respecting the minimum dimensions of the printed elements (either the thickness of the lines or the size of the letters) and the appropriate layout, taking into account the weave characteristics of the textile substrate, we can guarantee satisfactory prints. With our study, we wanted to investigate the effects of fabric construction in combination with different printing technologies, limited to one textile substrate and one printer. For future studies on ink bleeding and wicking related to fabric construction, we suggest testing more textile substrates with different constructions. We should include different textiles and printing technologies in the future studies to gain a comprehensive understanding of the relationship between fabric construction and printing technologies.

5. REFERENCES

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CRACKING PHENOMENON OF COATED PAPERS

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Abstract: *The phenomenon of cracking in paper coatings was investigated. Coating mixtures were compared according to their composition, the effects of cracking in the coating were determined, and certain combinations of the components of the base paper and the paper coating showed the lowest tendency to cracking. It was shown that the appropriate selection of pigments (calcium carbonate, kaolin) and binders (starch, latex), whose elastic properties influence the deformation of the paper under physical and mechanical stress, is of central importance. An important role is played by the choice of base paper, which should contain as many cellulose fibres as possible and be as long as possible in order to avoid fibre breaks and their interconnections. The content of inorganic substances has a demonstrably negative effect by worsening the physical-mechanical properties of the paper and leading to the deposition of inorganic substances at the joints between the cellulose fibres and reducing their bonding.*

Keywords: *paper, coating, coating cracking, paper folding*

1. INTRODUCTION

High demands on print quality often lead to the choice of coated paper, which offers a better surface quality and can reproduce a wider range of colours than uncoated paper. Coating paper is a finishing process that improves the optical and printing properties and deteriorates the physical-mechanical properties, which also includes folding the paper. The aim of folding is to bring the printed product into a form that can be directly processed or reproduced in order to carry out a further finishing process(1–5). To avoid line cracks when folding the paper, the paper must have the properties of layering and even distribution of forces on the outside (6). The defect at the crease appears as a line that usually runs parallel to the fold line, but it can also be orientated differently (7). Cracks in the paper coating appear in a fibrous layer of paper in which the bonds between the fibres are broken, and in some cases even the cellulose fibres are broken, resulting in a loss of tensile strength of the paper. The negative effect is also reflected in the appearance of the end product, as it leads to a number of complaints that manufacturers want to avoid (8,9).

Coated papers must have the ability of an elastic body, which is largely influenced by the choice of coating components. The choice of pigments affects the degree of paper deformation. Calcium carbonate is the more suitable choice for higher loads as $CaCO_3$ particles tend to have a round, isometric shape and therefore no fibre damage occurs, whereas kaolin particles have a flat shape which damages the fibres more quickly but offers better resistance to cracking during bending when the particles are loaded axially. Starch is more commonly used due to its low price, which is important for the production process. However, due to the low elastic properties of the binder, this leads more often to damage to the coating, i.e. cracking. When folding the paper, other parameters must be taken into account to prevent damage to the coating, such as the surface mass of the base paper, the amount of coating, the stiffness and thickness, and environmental factors such as temperature and humidity (9–12).

2. EXPERIMENTAL

2.1 Materials

Five different samples of special graphic papers were tested, namely PackPro 7.1 (S1; G = 71.0 g/m^2), NiklaPack (S2; G = 79.0 g/m^2), NiklaSelect 8.0 (S3; G = 70.0 g/m^2), NiklaPET 7.0 (S4; G = 70.0 g/m^2) and PackPro 7.5 (S5; G = 71.2 g/m^2). The selection of papers was based on the tendency towards higher quality of the final product and the reduction of complaints due to paper crack coatings from the paper mill Papirnica Vevče, d.o.o. The samples of coated graphic papers considered were selected in order to treat different papers according to the raw material

composition and to coat them with different coating mixtures. The analysed paper samples all have a one-sided surface coating in common and are suitable for the lamination process. They are intended for the production of flexible packaging (S1, S2 and S5) and label paper (S3 and S4). The base paper of S1 and S5 is wood-free and the raw material composition of S2, S3 and S4 consists of groundwood pulp. The papers are suitable for flexo, offset, rotogravure and digital printing processes (13–17).

2.2 Methods

The test methods were divided into two groups. In the first, the basic, surface and structural properties were analysed (grammage, density, specific volume, moisture and ash content, roughness/porosity, contact measurement of roughness with a profilometer, tensile strength and elongation as well as anisotropy). In the second series, we analysed the composition of the coating mixtures and the base paper of the samples to determine the tendency for cracking in the paper coating. Selected paper samples were offset printed with black ink and folded under a load of 1 kg for 1 minute. An image analysis of the printed and folded samples was then carried out. The images were captured with an optical microscope and pre-processed and analysed in Adobe Photoshop.

3. RESULTS WITH DISCUSSION

3.1 Microscopy and image analysis

Fig. 1 shows the area of the unfolded samples of the coated papers analysed, which were taken for the purpose of investigating the cracking problem. The samples are coated with different amounts of coating, defined as the sum of the pre-coatings and the pressure coatings according to the specifications of the paper mill. The smallest amount (14.0 g/m^2) is applied to S5 and the largest to S2 (20.7 g/m^2).

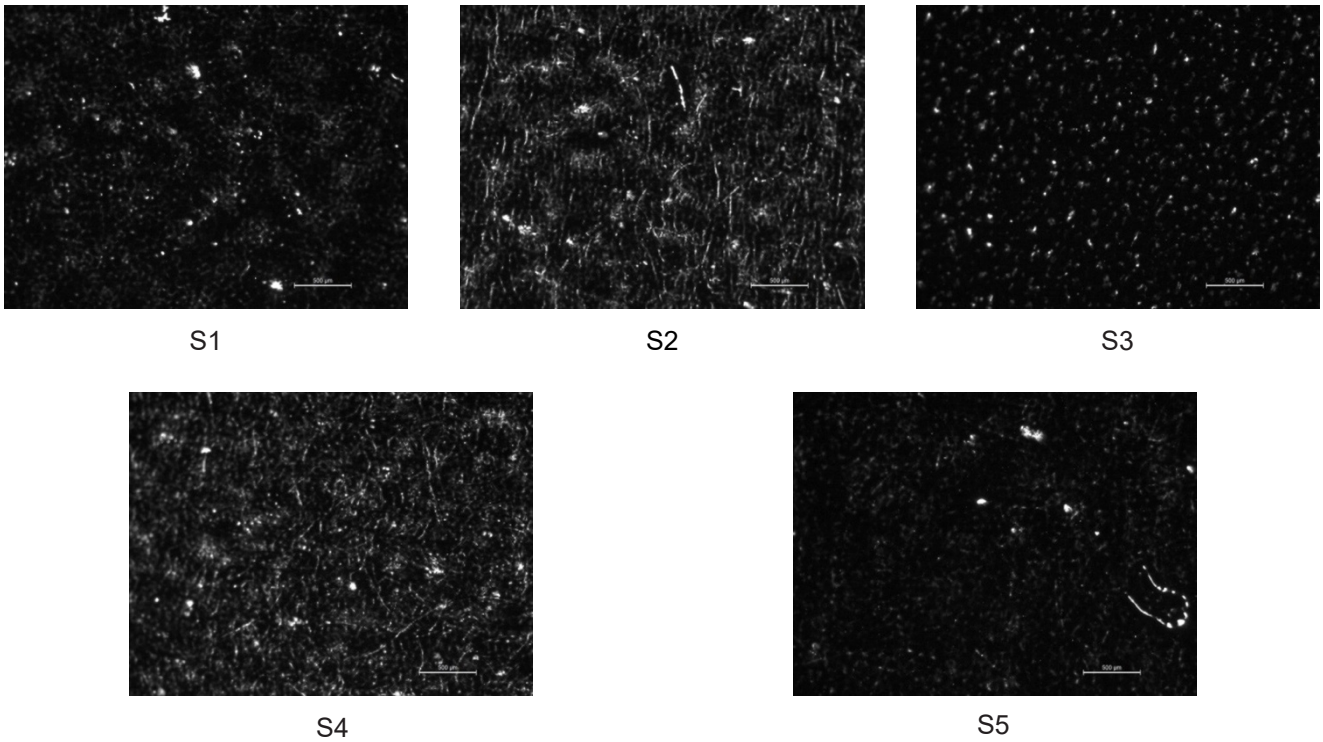

Figure 1: Unfolded offset printed samples

Fig. 2–6 shows examples of cracks in the coating when bending in MD or CD. Overall, cracking is more pronounced in the MD in all the samples analysed. The most pronounced cracking in both directions of the fibre flow during folding can be seen in Fig. 4 for S3 and the least for S2 (Fig. 2). S5 (Fig. 6) shows the greatest contrast between the cracking on the surface between MD and CD compared to the recorded images, as the cracks in the paper coating on the CD are almost invisible, which is the opposite of the image showing the folding on the MD.

Figure 2: S1 – coating cracking when bending in MD and CD

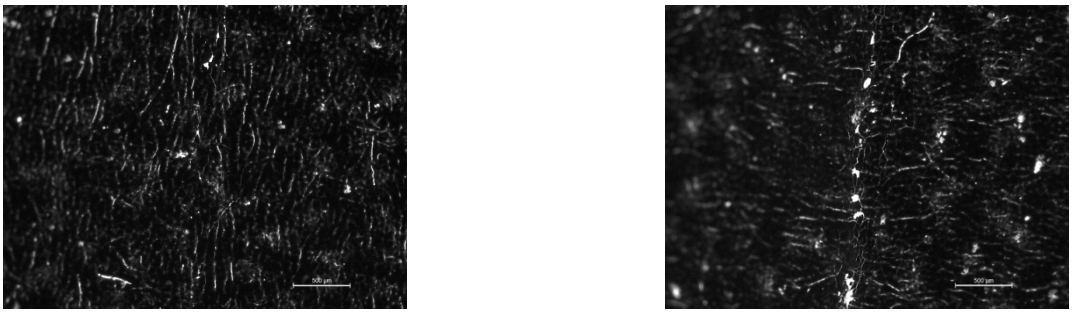

Figure 3: S2 – coating cracking when bending in MD and CD

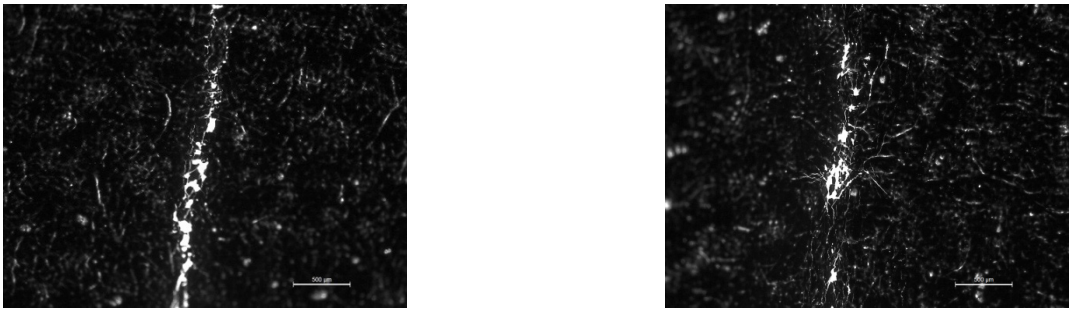

Figure 4: S3 – coating cracking when bending in MD and CD

Figure 5: S4 – coating cracking when bending in MD and CD

Figure 6: S5 – coating cracking when bending in MD and CD

The results of the extent of the cracks in the paper coating were calculated on the basis of the quantity of the black and white pixels in a black and white pictures between the unfolded and folded paper samples (Table 1). When analysing the relationship between the cracking in the coating and the paper properties (basic, structural and surface properties), we compared the results of the basic, surface and structural properties with the results of the cracking of the tested samples and plotted the comparison of the most important data in order to determine the effects on the cracking in the coating.

Table 1: Extent of paper coating cracking

	Area of crack – AC [%]				
	S1	**S2**	**S3**	**S4**	**S5**
CD	6.07	6.74	7.17	6.03	2.44
MD	5.55	4.61	8.08	8.18	8.17
AC	5.81	5.68	7.62	7.10	5.30

A comparison of the values from Table 1 shows us that S3 has the highest crack area in the paper coating at 7.62% and S4 is slightly lower at 7.10%. The sample with the lowest crack area in the paper coating is S5 with a total of 5.30%. If we compare the amount of cracking in the sample with the highest and lowest value, we get a difference of 30.5%. The ratio of cracks to fibres is 17.75%, which tells us that the tendency for cracking in the paper coating is lower in CD (crack area – ACCD = 5.69%) than in MD (ACMD = 6.91%). The result of this difference is the influence of a pronounced anisotropy, which is reflected in the mechanical properties as a function of the measurement direction, since the folding of the paper in MD leads to cracks perpendicular to the direction of the fibre course and parallel to the bending direction (18). Despite the overall higher proportion of crack area (CV) in MD, this observation does not apply to all individual samples.

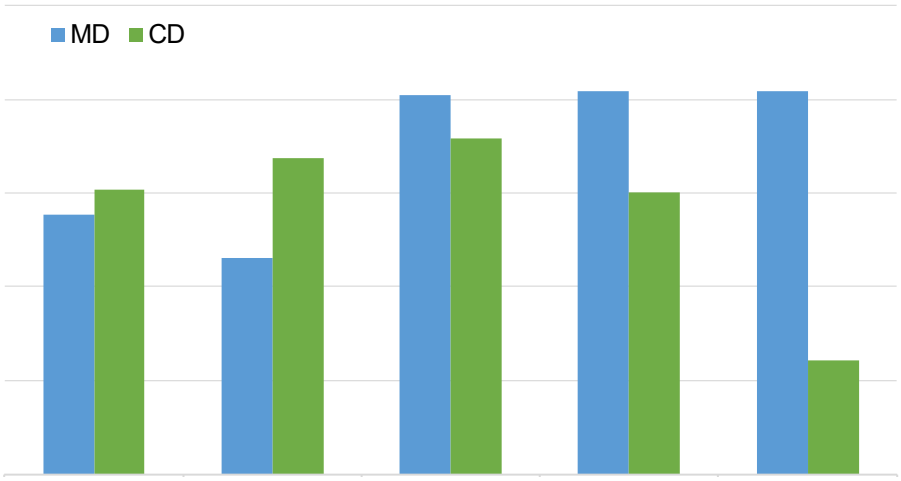

Figure 7: Area of paper surface coating cracking

Fig. 7 shows the results graphically, with the average being higher for CD in the case of S1 and S2 (ΔACV1[CD-MD] = 0.52%; ΔACV2[CD-MD] = 2.13%). The clearest difference in the cracking of the paper coating in the individual samples depending on the orientation of the cellulose fibres can be observed in S3, where the difference is as much as 70.1% (Fig. 7). A comparison of the thickness value with the paper coating cracking data proves that the thinnest sample is the least susceptible to paper coating cracking, as the thickness of the paper is also influenced by the amount of coating applied to the surface. The influence of the amount of coating on the tendency of the paper coating to crack is the basis for the assumption that the amount of coating is proportional to the extent of cracking. The amount of coating was defined on the basis of the sum of primer (PC primer) and print coating (second coating–SC). V5 is again a paper that correlates with the order of the amount of coating, as this sample has the least amount of coating.

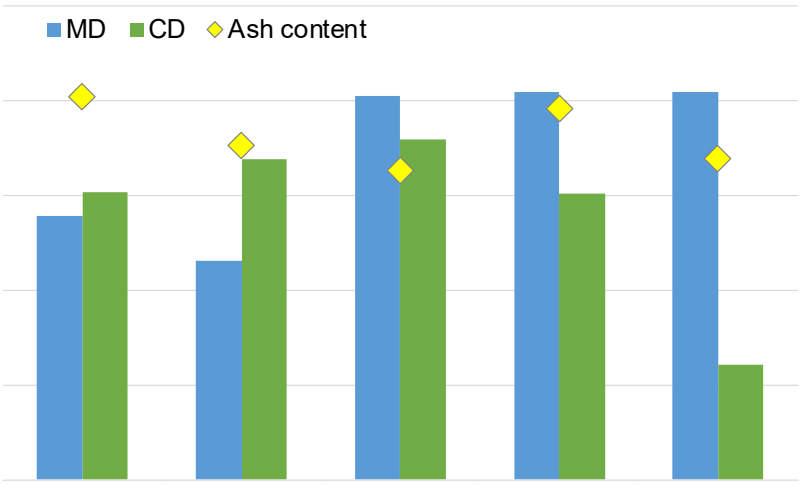

Figure 8: Area of crack and ash content

The ash content determines the proportion of inorganic substances in the paper, which can be up to 40% for graphic papers. Inorganic fillers attach themselves to the cellulose fibres and reduce the potential connections between the fibres and the interlacing, as they act as a physical barrier. Weaker bonds between the fibres lead to faster and stronger cracking, especially in papers that are less resilient because their cellulose fibres are shorter and fewer in number. This causes the fibres to break more quickly and the joints between the fibres to tear. The

manufacturer‘s data, i.e. Papirnica Vevče, shows that the content of calcium carbonate H60 in the primer layer of all samples (with the exception of S4 and the presence of calcium carbonate H90) is present in all printing varnishes. As a pigment, coarse and fine kaolin is also present in the coating mixtures S1-S5, namely in S1 and S2 in both PC and SC. Only coarsely ground kaolin is used in SC for S2 and S5 and finely ground kaolin for S1, S4 and S5. Calcium carbonate and kaolin are used as a combination in the composition of the coating mix to fill the gaps between the fibres. The result is a reduction in the naturally embossed surface of the paper. The ash content in terms of quantity is as follows: S3 (19.58%) < S5 (20.31%) < S2 (21.17%) < S4 (23.46%) < S1 (24.24%) and is shown graphically in Fig.8, from which it can be seen that the sample with the least cracking in the paper coating is the one where the least amount of inorganic matter was detected. Depending on the distribution, S4 confirms the assumption that the amount of inorganic substances in the coating mixture influences the extent of cracking, while for S1–S3 the correlation between the measured values cannot be confirmed. In particular, S3 stands out, in which we found one of the lowest ash contents compared to the average; at the same time, it shows the greatest extent of cracking, which is due to the composition of the coating mixture S3, which has the highest proportion of H60 in the primer (100 pph) and coarse kaolin in the printing coating (40 pph). A higher content of calcium carbonate H60 means a greater number of large carbonate particles, which affects the extent of cracking in the paper coating. To reduce the extent of cracking in the paper coating, a higher content of H90 is optimal as it contains smaller and finer CaCO3 particles. Kaolin is a pigment with flat shaped particles and is a favourable choice in case of deformation, i.e. bending in axial direction, to avoid cracking in the paper coating. A higher proportion of coarse kaolin (larger flat particles) in the coating mixture S3 indicates an increased risk of bending perpendicular to the axis of the particles (19–23). Both natural binders and synthetic binders are used in the coating mixtures of the analysed papers. The aim of the study was to determine the influence of binders on the occurrence of cracks in the paper coating and to establish whether the combination of finely ground pigment (H90) and binders with elastic properties (latex) influences the degree of cracking in the paper coating.

In Table 2, the samples are presented values of the content of the analysed binders (latex and starch) and pigments (H60 and H90). In the coatings of the analysed samples of special graphic papers, starch is used in all mixtures, but in varying amounts in the primer.

Table 2: Amount of the content of pigments and binders

	Filmpress			Blade coater		
	H60 [%]	**Kaolin [%]**	**Starch [%]**	**H90 [%]**	**Kaolin [%]**	**Latex [%]**
S1	50.05	33,37	6,67	25,72	60,02	9,00
S2	49.24	32,83	7,39	30,05	55,81	9,02
S3	83.85	32,83	7,34	29,05	58,11	8,35
S4	0.00	0,00	100,00	69,80	17,45	8,73
S5	69.68	0,00	17,42	26,00	60,67	11,26

The highest value of the primer coating contains S4 (100% in precoating), which also shows a high degree of cracking in the paper coating, which could be due to the large amount of said binder, i.e. starch. Starch is a binder with a hard, film-forming character that has low elasticity and is more susceptible to cracking than latex, which, due to its viscoelastic properties, improves the stiffness and responsiveness of the paper to physical and mechanical loads (24–26). The low starch content leads to the low cracking tendency measured for S1 and S2. The starch content of coatings S1–S3 and S5 is 80–92% lower than that of S4. Therefore, a major effect on cracking of the paper coating in these samples cannot be confirmed with certainty, especially since S3 has a very low starch content (9 pph) and the highest cracking volume (7.62%). Coated papers containing a higher percentage of latex as a binder are more flexible and stiffer, which is confirmed by the correspondence between the crack area of the coating in Table 2 and the latex content in the case of S2–S4. S5 is the sample with the lowest latex content, but also the one with the highest crack resistance (5.30%), while S3 has the highest latex content (21 pph) and the lowest crack resistance (7.62%) among the analysed paper samples. Coated paper is a composite material and each of the components of the composite contributes to the overall behaviour of the material subjected to physical and mechanical stresses. In the case of S3, despite the high content of highly elastic latex, cracking in the paper coating is more influenced by the high levels of calcium carbonate with larger particles (H60) and coarse kaolin

present in the coating compound in the largest amount of coated paper samples analysed (S3; H60 [PC] = 100 pph and coarse kaolin [SC] = 40 pph).

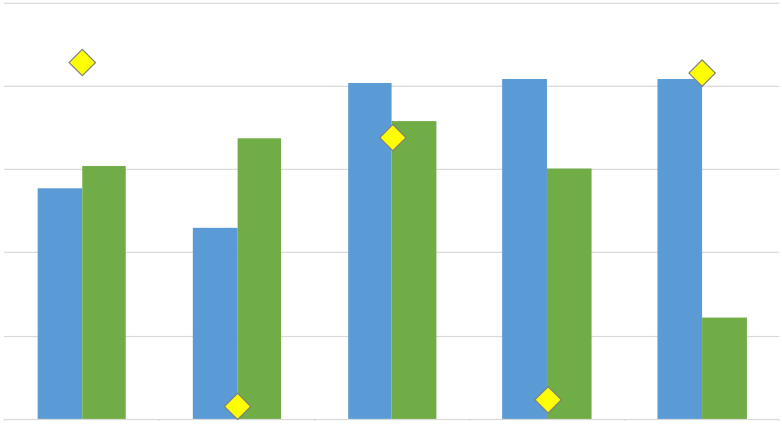

Figure 1: Area of crack and degree of anisotropy

Fig. 9 shows the relationship between the degree of anisotropy and the extent of cracking in the paper coating. Anisotropy is a change in physical properties as a result of the different orientation of the fibres in the paper structure. Anisotropic properties have a direct influence on the shrinkage and elongation of the paper (27,28). As shown in Fig. 9, S1 (85.71%) and S5 (83.04%) have the highest degree of anisotropy. S2 (3.17%) and S4 (4.65%) have significantly lower anisotropic properties. The high degree of anisotropy means that the orientation of the fibres is greater in the MD direction, which has an effect on the bending capacity due to the different fibre orientation (29). In the analysed samples, we can see the influence of anisotropy in S2, which has a low degree of cracking and anisotropy. S3 has a relatively high degree of anisotropy and also the highest tendency to cracking in the paper coating (7.62%) among all the papers analysed.

Table 3: Raw material composition of the underlying papers of the studied samples

	Individual proportions of raw materials [%]				
	Eucalyptus	**Deciduous woods**	**Conifers**	**BCTMP**	**Fresh filler**
S1	32	/	36	/	0.0
S2	25	/	25	/	0.0
S3	37	/	23	5	1.0
S4	20	19	22	/	0.6
S5	37	40	23	/	0.0

When comparing the raw material composition of the base paper (Table 3) and the extent of cracking in the coating (Table 1), the influence of individual raw material components on the tendency of the paper coating to crack was determined. The paper industry mainly uses hardwoods (eucalyptus, birch, poplar and beech) and conifers (spruce, pine and fir). In order to guarantee quality, the right ratio between short (hardwood) and long (softwood) fibres, their fibrillation as well as the regrinds and fillers are particularly important. The reaction of the paper to loads depends on the quality of the cellulose fibres, and the parameters of the paper machine must also be taken into account (30–32). All paper samples tested contain deciduous fibres (only S1–S3 eucalyptus fibres) and conifers. S5 is the most optimal with regard to the appearance of the paper coating and at the same time contains the highest total content of deciduous cellulose fibres (∑ (deciduous + eucalyptus) = 77%). The interweaving of the cellulose fibres is higher in hardwood, which leads to a higher elastic reaction to external physical and mechanical loads, i.e. also to a higher folding strength. The higher density of hardwood and the greater wall thickness of the cellulose fibres ensure a strong structure and a better response to loads (33,34).

The results of the measurements are also consistent with the theoretical starting points in other cases, as the S1 and S3 samples, which achieve a high degree of paper coating, also have a low content of hardwood cellulose fibres, which affects the low resistance to mechanical loads. Bleached chemical pulp is only present in S3, i.e. 5%, the sample with the highest measured cracking volume (AC = 7.62%). The effect on cracking in the paper coating compared to the raw material composition was most evident when comparing the use of fresh filler in the paper composition of the analysed paper samples, where the correspondence between cracking and fresh filler was identical in order (S3 > S4 > S1, S2 and S5). Samples S3 and S4 are the only ones containing fresh fillers (S3 = 1.0% and S4 = 0.6%) and at the same time the samples where the paper coating cracked the most (AC; S3 = 7.62% and S4 = 7.10%), which is due to the fact that the higher content of fillers worsens the bending strength after coating.

4. CONCLUSIONS

A higher resistance of coated papers to cracking in coatings is achieved by the appropriate selection of base paper and a coating with high flexibility. When selecting coatings, it is crucial that they have a high absorption capacity for the paper, as this reduces the risk of cracking in the paper coating on the surface. It is also important to minimise the amount of coating used, as well as the pigments and binders used. The choice of binders and pigments in the composition of the coating mix is critical to the behaviour of the coating when folded and should be based on the ability to deform without physical damage, i.e. high elastic properties.

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SLOVENIAN STANDARDS AND WORK OF SIST/TC GRT GRAPHIC TECHNOLOGY

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Abstract: *The presentation will focus on working activities of SIST – Slovenian Institute for Standardization, Ljubljana, Slovenia – EU, where several various active technical committees are established, among many others as well technical committee SIST/TC GRT Graphic technology. In the presentation I am briefly presenting some basic rules in the field of standardization that are important for the experts working procedures, pointing out the general importance of standards, why they are needed in modern world, where are their main advantages of use in business environment (companies), that is on different levels, and in various (specific) areas. I am also identifying certain most relevant and important principles of standardization, the process of creating standardization documents, ways of adopting standards (by adoption, with translation) and specifying the types of standardization documents. In conclusion I am referring to the work of technical committee SIST/TC GRT Graphic technology.*

Keywords: *SIST, rules, standards, SIST/TC GRT graphic technology*

1. BASIC INFORMATION ABOUT THE SLOVENIAN INSTITUTE FOR STANDARDIZATION (SIST)

The Slovenian Institute for Standardization (SIST) is the Slovenian national body responsible for the preparation and issuance of SIST Slovenian standards. It represents Slovenia's interests in international standards organizations such as ISO and IEC, as well as European ones such as CEN, CENELEC, ETSI. Members of the Slovenian technical committees (SIST/TC) have the opportunity to equally participate in all standardization activities, in Slovenia, Europe and the world and can collaborate to create European and international standards.

2. AREAS OF SIST ACTIVITIES

The core activities of SIST are:

- standardization,
- contact points available for notification of/information about technical regulations, standards and requirements for services, products and construction,
- providing assistance to small and medium-sized enterprises,
- education and seminar-related activities,
- the sale of standards and other standardization documents,
- publishing.

3. THE SIGNIFICANCE OF STANDARDS OR IN OTHER WORDS THE BENEFITS OF HAVING STANDARDS

A standard is a document created by consensus and approved by a recognized authority which defines rules, guidelines or characteristics for activities and their results and is intended for general and repeated use and aimed at achieving an optimal level of regulation in a given field.

Figure 1: Things work with European Standards

4. ADVANTAGES COMPANIES CAN GAIN FROM USING STANDARDS

- better efficiency, fewer costs, and less waste,
- ensure the high quality and safety of products,
- the compatibility between products or services,
- he access to the EU internal market and the reputation of companies; the use of the EN standard in European countries has a potential internal market of more than 500 million (potential) consumers

5. ADVANTAGES OF PARTICIPATING IN THE STANDARDIZATION PROCESS

- co-creation of national standards in Slovenia,
- the possibility of impacting the content of European and international standards,
- accessible experts information about the most up-to-date (recent) techniques,
- achieving access to draft standards and working materials that are not freely accessible,
- establishing and developing business connections in meetings,
- harmonized terminology.

6. SIST ORGANIZATION

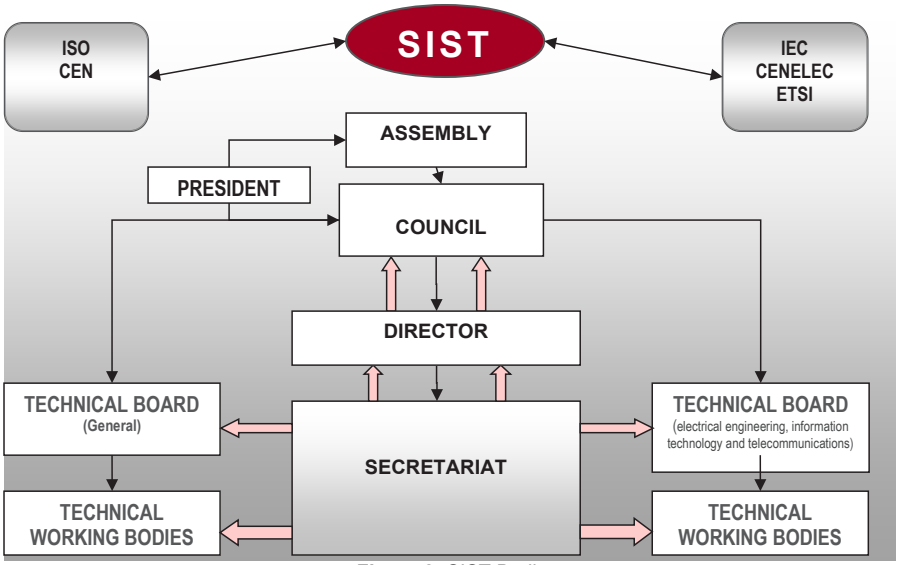

Figure 2: SIST Bodies

Work in SIST/TC is classified under:
- Rules of Procedure regarding the establishment and working methods of technical working bodies of the Slovenian Institute for Standardization and
- Instructions on the procedure for adopting Slovenian national standards and other documents in the field of Slovenian national standardization.

7. PRESENTATION OF THE BASIC RULES OF THE SIST

Standardization principles:
- participation by all interested parties is voluntary;
- the content of the Slovenian national standards has consensus – agreement in principle of a significant part of interested parties;
- preventing the dominance of individual interests over the common interest of interested parties;
- Slovenian national standards transparency require work transparency and accessibility for the public;
- taking into account the techniques and rules that have been achieved through international and European standardization.

Professional technical work is carried out within the framework of SIST in technical working bodies (TDT), i.e.:
- technical committees (SIST/TC),
- sub-committees (SIST/SC) and
- working groups (SIST/WG).

The professional technical work in SIST supervises:
- members of the technical education board that specializes in electrical engineering and
- members of the board of technical experts in the general field.

Members of the board technic are responsible for the following tasks:
- establish, reform and dissolve TDT to determine the rules for professional work,
- decide in case there is a misunderstanding between the SIST technical committees or within the technical committees,
- they take care of standards in the field, where there are no active SIST technical committees.

Participation in technical working bodies means the possibility of:
- expert's representing the interests of the institution from which she/he comes to participate in the preparation of international, European and original national standards,
- expert's, based on the application, participation in the working groups of international or European organizations for standardization,
- expert's participation in voting decisions on the content of international, European and original national standards,
- receiving working material of draft standards (prEN, FprEN),
- tracking technical progress, reflected in standards,
- knowledge and experience exchange at meetings etc.

The basic rules on the establishment and working method of technical working documents are:
- quorum at the meeting,
- consensus on essential issues,
- when approving standardization documents, 75% votes of the members present are required,
- resolutions are adopted by the majority of votes of the members present,
- meetings with presence/correspondence/hybrid.

8. STANDARDS PREPARATION

- In the Slovenian national standardization sistem there are app. 35,000 valid standards,
- professional standardization work takes place in technical committees (SIST/TC),
- currently 81 SIST/TC are active (47 among them in the general field of standardization),
- the preparation time of the standard is approximately 2 years, the revision of the standard is in principle every 5 years,
- during the public enquiry there is the possibility of free access to draft standards.

9. TYPES OF STANDARDIZATION DOCUMENTS

- International ISO,
- European EN,
- National SIST (SIST EN, SIST ISO),
- Technical specifications TS,
- Reports TR,
- Guide (Guide - V).

10. STANDARDS ADOPTION METHODS

Members of CEN, CENELEC and ETSI must adopt all European standards within 6 months.
International standards and other national standards are adopted by initiative.

The methods of adoption of standards are the same in all cases;
- method of adoption,
- translation method,
- original Slovenian standard.

11. TECHNICAL COMMITTEE SIST/TC GRT GRAPHIC TECHNOLOGY

In the committee there are currently 4 experts involved in a standardization work.

At the European level, they monitor the work of:
CEN/SS F14 - Graphical Technology, Sign-boards and Nameplates
CEN/SS F18 - Micrographics
CEN/TC 198 - Printing and paper machinery - Safety
CEN/TC 198/WG 1 - Printing and paper converting machines - Drafting of safety standards
CEN/TC 198/WG 2 - Paper Machinery
CEN/TC 198/WG 3 - Paper making machines - Noise

At the international level, they monitor the work of:
ISO/TC 130 - Graphic technology
ISO/TC 42 – Photography.

European technical committees also cooperate with international technical committees and therefore European standards are in the field of graphic technology as well adopted as international standards.
SIST/TC GRT adopts European and International standards as Slovenian national standards. Experts also participate in public enquiry of draft standards and formal voting of European and international final draft standards.

All interested parties can join the technical committee with a written application and a signed access declaration.

Members of the technical committee have the following rights and benefits:
- they participate in the technical committee,
- ability to influence the content of Slovenian national, European and international standards,
- ability to represent national interests in European and international standardization,
- they have access to information that is otherwise not freely available (intellectual property).

By 1 March 2024 in the field of graphic technology, there will have been issued 166 Slovenian standards.

For the year 2024, the members of SIST/TC GRT Graphic technology plan to translate following standards:
SIST ISO 12637-1:2010 Graphic technology - Vocabulary - Part 1: Fundamental terms
SIST ISO 12637-2:2010 Graphic technology - Vocabulary - Part 2: Prepress terms
SIST ISO 12637-3:2010 Graphic technology - Vocabulary - Part 3: Printing terms
SIST ISO 12637-4:2010 Graphic technology - Vocabulary - Part 4: Postpress terms.

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POSTER PRESENTATIONS

EYE TRACKING ANALYSIS OF FRONTAL AND PROFILE FACIAL IMAGES

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Abstract: *In our study, we compared the recognition of the two most common representations of facial images (frontal and in profile). We determined the correct recognition and the incorrect recognition. We then checked these results with the eye-tracking system, with which we obtained the results of fixation duration and saccade length. Both groups of images were tested with the standard yes/no test, which consists of an observation test and a recognition test. To make the results of our test as meaningful as possible, we used four different times for displaying the facial images in the observation test (1, 2, 4 and 8 seconds). The results are presented for each group of facial images with different display times.*

Keywords: *face recognition, facial images, eye tracking, fixation, saccades*

1. INTRODUCTION

Recognising faces is something we deal with every day. The conditions for observing faces are usually very different. The most important parameters of different face presentation are the display angle of face and the representation of facial emotions. Mostly facial images are shown in a frontal or profile view (Gao, 2002). In addition, we know the term “caninocal view” is used for faces that are shown at a certain angle. Among those, most research has been conducted for the ¾-view, which is between the frontal and profile views at an angle of 45º (mid profile view). The set of basic facial emotions varies somewhat among researchers (Schurgin, 2014, Humitell, 2010), but the most widely used set has definitely been proposed by Ekman and Friesen (Ekman, 2003). This set is known as 7AFC (seven alternative forced-choice) and is based six emotions to which a neutral expression has been added.

In our research, we limit ourselves to neutral facial expressions of emotions and to the two extreme positions regarding the angle of facial images, i. e. frontal view and profile view respectively.

2. EXPERIMENTAL

2.1 Participants

We recruited 48 participants among our students (24 for testing of frontal facial images and 24 for testing profile facial images). This means that each time test (1s, 2s, 4s, and 8s) was completed by 6 participants. Average age was 21,2 years (SD = 0,89). All participants volunteered and had normal vision.

2.2 Stimuli

Facial images were obtained from the Minear & Park database (Minear, 2000). We wanted to simulate the natural observation conditions, i.e. viewing a face at natural size at a distance of 1 m. The test recommendation for our eye-tracking system is observation at a distance of 60 cm. From this data and the screen resolution information, we calculated the dimensions of the facial images used in the test, which were 640 × 480 px. For each test, we prepared 20 facial images (10 male and 10 female) for the observation test and added 20 more for recognition test. A example of frontal and profile facial image is shown in Figure 1.

Figure 1: Frontal and profile facial images

2.3 Aparatus

All tests were performed in the Laboratory of Visual Perception and Colorimetry at the Department of Textile, Graphic and Design of the Faculty of Natural Sciences and Engineering at the University of Ljubljana. Setting up the environmental and testing system was based on the standards and recommendations (Pernice, 2009)

We performed the test with the Tobii X-120 eye tracking system. As mentioned before, the distance between the participants and the screen with the facial images was 60 cm. Analysis were done in Tobii Studio 3.4.8 software. The defaults setting for definition of fixation was 100 ms for 30 px area. That means if eyes stayed in the area 30 pixel for at least 100 ms it was concerned as one fixation (Tobii Technology, 2000).

2.4 Procedure

As already mentioned, we used a standardised yes/no test. The test therefore consisted of two tests, an observation test and a recognition test. The procedure observation test is shown in Figure 2.

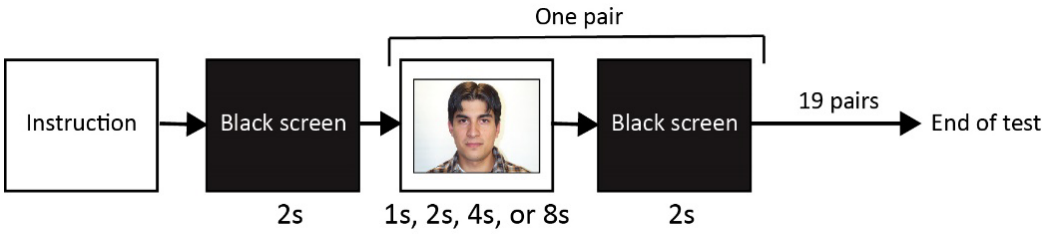

Figure 2: Procedure of the observation test

The observation test included 20 facial images (10 male and 10 female). After the initial instructions, a two-second dark screen was displayed. Facial images appeared automatically with a pause of two seconds to neutralize the gaze position before the presentation of the next facial image. The order of facial images was evenly distributed by gender. The observation test was followed by the recognition test (Figure 3).

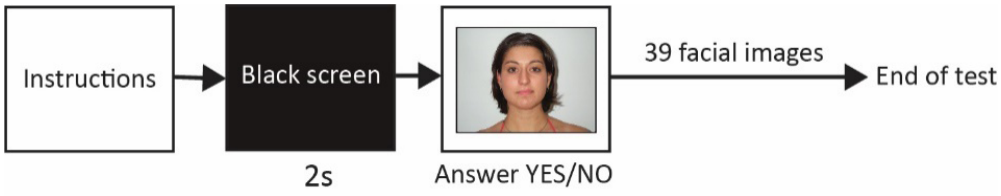

Figure 3: Procedure of the recognition test

In the recognition test we have added 20 new facial images to the original 20 facial images of the observation test. For each facial image displayed on the screen, participants were asked to answer whether they had seen it in the observation test. We recorded their responses as correct or incorrect. Correct responses were those in which the participant answered correctly that the face image was included in the observation test or answered correctly that it was not included in the observation test. Incorrect responses were those in which the facial image was not present in the observation test but in recognition test, participant said it was, and vice versa (the facial image was present in the observation test, but the participant did not confirm this in the recognition test). We have carried out an identical test for profile face images with the difference of profile facial images as stimuli.

2.5 Analysis of results

The first part of the study provided us with the results correct recognition and incorrect recognition for each of the 8 tests (two types of facial images and four different displayed times). We compared these results with each other. The results of fixation duration and saccade length were obtained directly with Tobii Studio. These values were taken from observation tests which were controlled.

3. RESULTS

Figure 4 shows a comparison of the correct recognition for frontal and profile facial images.

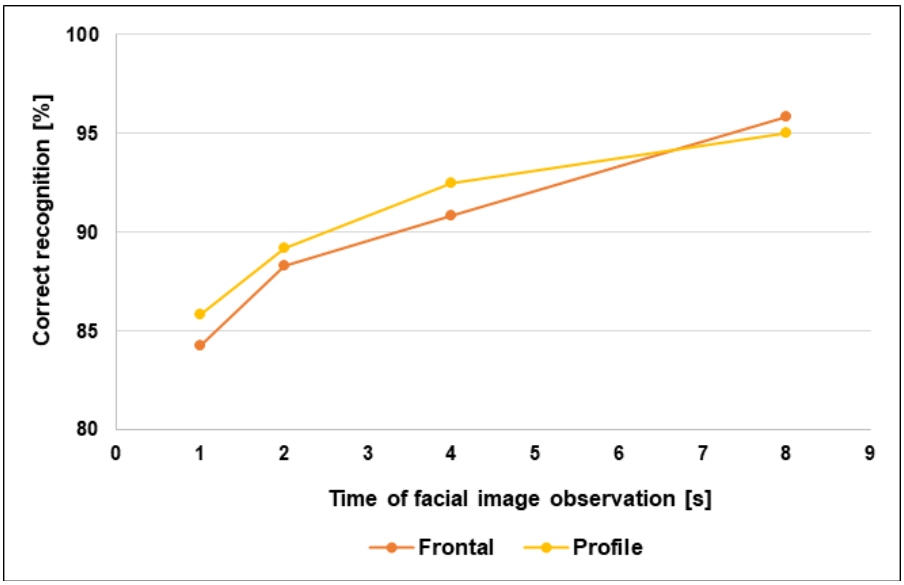

Figure 4: Correct recognition for frontal and profile facial images

Figure 5 shows a comparison of the incorrect (false) recognition for frontal and profile facial images.

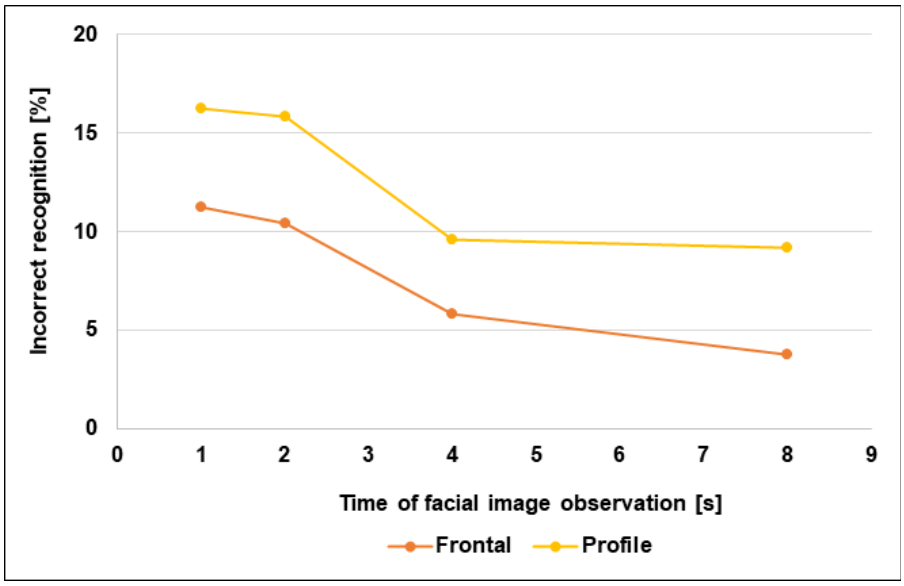

Figure 5: Incorrect recognition for frontal and profile facial images

Figure 6 shows a comparison of the fixation duration for frontal and profile facial images.

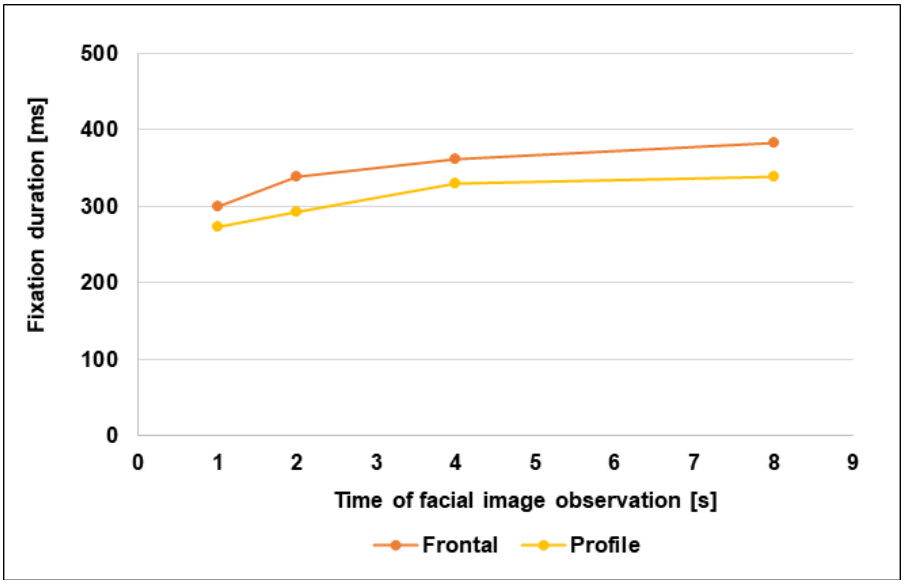

Figure 6: Fixation duration for frontal and profile facial images

Figure 7 shows a comparison of the saccade length for frontal and profile facial images.

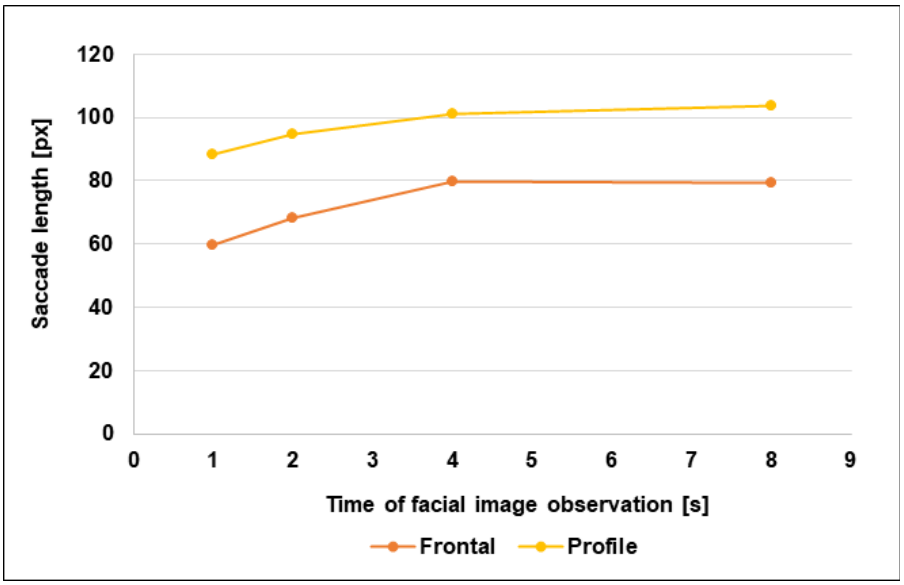

Figure 7: Saccade length for frontal and profile facial images

4. DISCUSSION

As can be seen from Figure 4, the correct recognition is very similar for both groups of facial images. For both groups of facial images, correct recognition increases with increasing display time of the facial images in the observation test, which makes sense because the longer the facial image is displayed, the better it can be memorised.

Comparing these two groups of facial images, the correct recognition of profile facial images is slightly better for shorter viewing times (1s, 2s and 4s) and slightly worse for longer times (8s). On average, the correct recognition of profile facial images is slightly better than the correct recognition of frontal facial images (90.6% vs. 89.8%). However, this difference is so small that one can speak of equally good and correct recognition of facial images, regardless of the display method. This is also confirmed in study (Liu, 2002) where it was found that correct recognition is almost the same regardless of the angle of the face image (the tests were performed for frontal, profile facial images and facial images at an angle of 45°). The results of correct recognition at a display duration of four seconds were between 90% and 92% in their studies.

The difference between the two groups of facial images can be seen in incorrect recognition (Figure 5), where incorrect recognition was significantly higher for the profile facial images. (on average 8.2% for the frontal facial images and 12.7% for the profile facial images.

The main difference between frontal and profile face images is the number of facial features that are important for memorizing faces. These are the eyes, the mouth, and the nose. In frontal facial images, all these facial features are clearly visible in the centre of the face. In profile facial images, on the other hand, we only see one eye, half of the mouth and the nose from the profile view. The number of visible facial features is important for the memorization process. However, this can only be seen in the false recognition results.

Regarding the fixation duration (Figure 6), the longer the facial images are displayed in the observation test, the longer are fixations duration. The reason for this is that the eye adapts to a faster pace when the facial images are displayed for a shorter time and the gaze therefore move more quickly over the facial image (more fixations of shorter duration), while the eye calms down when the facial images are displayed for a longer time and the gaze stay longer on the facial features (longer fixation duration). However, the fixation duration for frontal facial images

is shorter than for profile facial images in all time tests because more facial features are visible and the gaze jumps back and forth between them more frequently (i.e. more fixations of shorter duration).

The length of saccades (Figure 7) also increases with increasing display time of facial images, as participants look at a larger part of the facial image with longer viewing times. With shorter durations, the eye moves less.

When comparing the two groups of face images, we can summarize from the results of saccade lengths that fewer main facial features are visible in profile face images, so participants' gaze was also directed to the ear, hair, neck and other parts. As these are far apart, the eye movements are also longer. In frontal facial images, the main facial features are closer together and the gaze remains on them, and saccades only mean a shift of the gaze from one facial features to another.

5. CONCLUSION

Considering all results of false recognition, duration of fixations and length of saccades, the smallest changes between tests are observed at 4 and 8 seconds. This indicates that the display duration of the facial image of 4 seconds is sufficient for good memorization (false recognition decreases to a constant value) and that this is also a "turning point" when we speak of calming the eye and relaxed viewing of facial images (almost no increase in fixation duration and saccade length).

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SERIES OF POSTERS TO PROMOTE SLOVENIAN DETAIL IN TYPOGRAPHY

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Abstract: *Choosing the right typeface for a particular purpose is crucial to understanding of information. The aim of our study was to design a series of typographic posters to promote details in typography. The designed posters point out the correct use of typographic elements in the Slovenian language (ellipsis, quotation marks, hyphens and dashes, date and time), as incorrect entries are often found in the Slovenian language. A series of five typographic posters was designed to draw attention to the correct use of typographic elements and to encourage especially younger generations to use detailed typographic elements correctly. We tested the effectiveness of the poster design with an online survey. The designed posters could be put on display in educational institutions or in their surroundings to inform general public and encourage reflection on the correct use of detailed typographic elements in the Slovenian language.*

Keywords: *detail in typography, typography, typographic poster, visual communication*

1. INTRODUCTION

In the Slovenian territory, posters began to appear at the turn of the 19th to the 20th century when the national awakening led to the establishment of many societies that advertised their events with various posters, mostly typographic. In the first half of the 20th century, modern design was introduced by painters and architects who, after their education in Vienna, brought the characteristics of the Art Nouveau movement to the Slovenian territory (Možina 2003; Požar, 2015). A further development of design was concurrently influenced by the progressive achievements of Bauhaus, transferring modernist influences into everyday use. Modernists emphasised the importance of legibility, utility, simple and sans-serif typeface, an economical style, appropriate colour contrast (black and red), the use of photography and photomontage (Možina, 2003; Ambroise, 2006; Požar, 2015). Slovenian designers, under the influence of Modernism, emphasised a refined image of posters. In their design, they abandoned framing, illustration and unnecessary ornamentation, creating a lively edge. They positioned letters as the primary means of expression, placing them diagonally, vertically and asymmetrically. Sans-serif typefaces on Slovenian posters can be observed since the first half of the 20th century, remaining one of the most commonly used typeface styles on posters today (Kordiš, 2005; Požar, 2015). For a poster to address the viewer and convey a message as quickly as possible, it must be designed with simple, yet psychologically grounded elements, meaning that a poster is far from merely a mechanical drawing (Požar, 2015). We perceive posters at two levels (Samara, 2006). In the first level, typography is the main element of communication, which captivates and stimulates the viewer. This is further accentuated if the main element of the poster is just one letter. The second level of perception is informative, where the viewer acquires and understands the information and purpose of the poster. The arrangement of information by importance or typographic hierarchy is crucial (Henderson, 2012). A poster is effective if viewers gain new information, insights, or if the message changes their perception (Samara, 2006). The aim of our study was to design a series of five typographic posters to promote details in typography. The designed posters point out the correct use of typographic elements in the Slovenian language (ellipsis, quotation marks, hyphens and dashes, date and time (Možina, 2009; The Chicago Manual of Style, 2017), as incorrect entries are often found in the Slovenian language.

2. EXPERIMENTAL

Firstly, a geometric sans serif typeface suitable for younger generations was designed. We initiated the content of posters by preparing short and simple texts that draw attention to the easy and playful correct usage of punctuation in the Slovenian language. Across all posters, we used a text where an imaginary “Minister of Spelling” emphasises the correct usage of punctuation or a proper way to write dates and times. The central content element of the posters is the headlines, selected for their emphasis on a particular detail in typography. The headlines on all

posters are complemented by a concluding text where we communicate that we, the “Minister of Spelling”, correctly employ details in typography. Simultaneously, we directly address the observer with the question, “What about you?” At first glance, the posters do not explicitly display the correct usage of details in typography, as we wanted to encourage the observer to further explore the field on their own, since we have presented only one of possible correct spellings on the posters. The design of posters commenced with sketching on paper and correctly placing a prepared text. In Adobe Illustrator, we initially determined an upright B2 format, with 500 mm in width and 707 mm in height, then proceeded to lay out the text and other graphic elements within the format. We opted for a minimalist approach to design, utilising simple compositions and colours. We crafted a series of five posters that are thematically and visually interconnected.

2.1 Online survey

The respondents’ attitude towards the visual appearance of the posters and their understanding of the content was evaluated using the online survey tool 1ka.si. We invited predominantly young individuals who are either in the process of education or have recently completed their education to participate in the survey. By means of five questions, we gathered data on the appropriate selection of colours, typefaces and composition, clarity of the message, and to what extent the poster prompted respondents to contemplate.

3. RESULTS WITH DISCUSSION

3.1 Poster design

The result of the design is a series of five typographic posters that are thematically and visually connected (Figure 1). Through appropriate composition and established hierarchy, we emphasised essential information in the design process. In the upper part, we placed a lowercase text at a size of 80 pt (points), where the “Minister of Spelling” highlights the correct spelling. For this text box, we opted for left or centre alignment. The central elements of the posters are headlines in uppercase letters, positioned in the lower halves of the formats and presented in the largest type size (215 pt). Below the headlines, texts in lowercase letters at the smallest type size of 50 pt are added, directly addressing the observers. Based on each poster’s composition, we aligned the texts to the left, right or centre. Larger punctuation marks (quotation marks, ellipsis, hyphens and dashes) and lowercase text (date and time, hyphens and dashes) were placed on individual posters, emphasising the themes. In selecting colours for the posters, we followed modernist recommendations (Požar, 2015). The primary colour of the poster series is black, creating a strong contrast with the white background, ensuring good visibility. We added contrasting red (CMYK [0, 100, 93, 17]) to the black text, highlighting the title or theme of the poster. For other text in the background, we used two shades of grey (CMYK [0, 0, 0, 20] and CMYK [0, 0, 0, 10]). With the chosen colours, we wanted to maintain a simple and minimalist design while preserving the seriousness of the theme and creating contrast with a more playful text at the top of the poster.

(Poster 1) (Poster 2) (Poster 3) (Poster (Poster 5)

Figure 1: Series of designed typographic posters.

With Poster 1 (Figure 1), we highlighted the correct use of the Slovenian double lower-upper quotation marks („...“), as we often notice incorrect usage of quotation marks, such as the Anglo-Saxon style of using the upper quotation mark (“...”) or even the mathematical symbol for seconds (“...”). We visually displayed their usage by placing the quotation marks, the left-bottom and the right-top sections, reminding the observer of the correct use of quotation marks in Slovenian. Poster 2 (Figure 1) shows that we can use double middle quotation marks

(»...«). It is important to use them correctly, right-oriented at the beginning and left-oriented at the end of a word or sentence, without spaces. We placed enlarged quotation marks diagonally, top-left and bottom-right, illustrating their placement at the beginning and end of a word or sentence. Poster 3 (Figure 1) shows the difference between a hyphen and a dash, highlighted in red and supplemented with the words hyphen and dash. We added the phrase “Can you differentiate between them?” directly addressing the observer and encouraging contemplation about distinguishing and correctly using these punctuation marks. The composition of this poster differs from the others. We left-aligned the top and bottom text and right-aligned the central text, reducing the white space in the upper half of the format. The title “Space and ellipsis ...” on Poster 4 (Figure 1) alerts to the correct usage of non-connective ellipsis. In the representation of ellipsis, indicating an unfinished thought, we often forget the space or continue the thought with any number of dots, which is incorrect usage. Unlike other posters, the supplementary text reveals the correct use of ellipsis and prompts the observer to contemplate with a question. The larger empty space in the upper half of the format creates balance and hierarchy, guiding the observer’s focus to the essential. Poster 5 (Figure 1) shows the correct writing of date and time. It is important to remember to use spaces between the numerical representation of the day, month and year, and not to write ohs before single-digit dates or hours, which is often observed incorrectly in public. The primary purpose of the poster is to demonstrate the most common correct format for dates and times. Symbolically, we used the date of 21 February, marking the International Mother Language Day, which promotes respect for our own languages.

3.2. Results of online survey

A total of 153 people responded to the online survey regarding their perception of the visual appearance of the posters, with 84% identifying as female and 16% as male. They were categorised into five age groups, i.e. 15.8% of all respondents were in the age group up to 14 years, 22% from 14 to 19 years, 52% from 20 to 26 years, 12% from 27 to 30 years, and 6% of individuals aged 31 and above. Figures 2–7 demonstrate the results of legibility research. In the main part of the survey, the respondents indicated their level of agreement (strongly disagree, disagree, somewhat agree, agree, strongly agree).

The majority of respondents strongly agreed with all statements (Figure 2, Poster 1). Larger differences were noted in the statements regarding the choice of colours, composition and encouragement for correct usage. The results confirm the appropriateness of all statements while also indicating room for improvement, primarily in composition. The highest percentage of agreement regarding appropriate colour selection came from the respondents aged up to 14 years, while the respondents older than 30 years marked them as the least suitable. The selection of suitable fonts was confirmed by the majority of young respondents aged between 15 and 19 years, while those up to 14 years found the selected typeface least suitable. All respondents above 31 years confirmed that the typeface is easily legible, with the respondents aged between 27 and 30 marked it as the least legible. The respondents aged between 15 and 19 years rated the composition as appropriate, while those up to 14 years old found it the least appropriate. Regarding understanding the message, the statement was most positively evaluated by those up to 14 years old, while the most difficulty in understanding the message was confirmed by the respondents older than 31 years. The poster most encouraged young respondents up to 14 years to correctly use quotation marks, while the respondents older than 31 years were most divided on the last statement, with almost half of them disagreeing or partially agreeing with the statement.

The most positively evaluated statements were about the appropriate typeface choice and its legibility (Figure 3, Poster 2). The most divided opinions were about the appropriateness of the composition and encouragement for correct usage of quotation marks. The highest percentage of young respondents aged between 15 and 19 years confirmed the appropriate colour selection on the poster, while the most disagreement was among the respondents aged between 27 and 31. The appropriate typeface selection was confirmed by the majority of young respondents aged from 15 to 19, while those above 31 found the typeface the least suitable. Nearly 95% of the respondents aged between 20 and 26 agreed that the typeface on the poster was easily legible, while the most disagreement came from the respondents aged from 27 to 30, marking it as illegible. Young respondents aged between 15 and 19 confirmed the appropriateness of the composition, while those aged from 27 to 30 found it inappropriate. Understanding the poster’s message was the best among the group aged between 15 and 19 years, while the worst understanding was observed among those aged 31 or more. Young respondents up to 14 years old unanimously agreed that the poster encouraged them to correctly use quotation marks, while those aged 31 or above the least agreed with the statement.

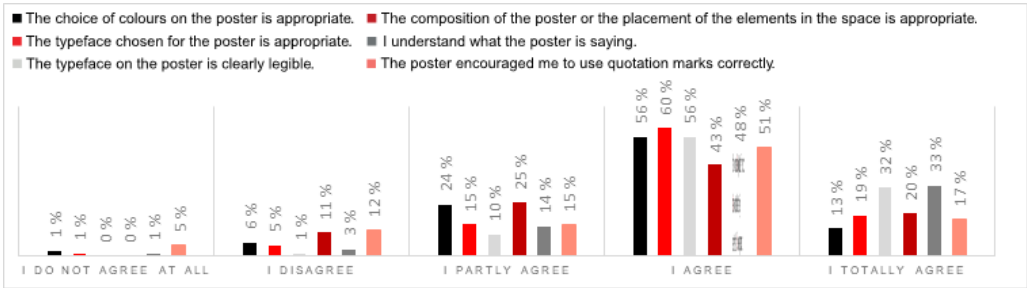

Figure 2: Claims referring to poster with double bottom-up quotation marks.

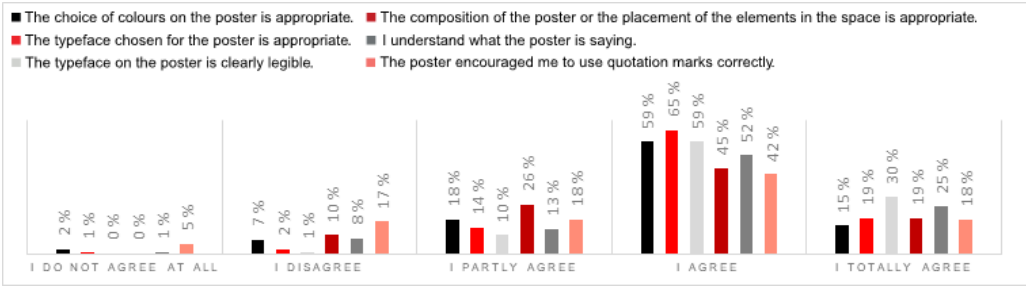

Figure 3: Claims referring to poster with double middle quotation marks.

The results (Figure 4, Poster 3) show majority agreement regarding the appropriateness and usefulness of the poster. The appropriate colour and typeface selection on the poster were confirmed by the majority of young respondents aged from 15 to 19, while the least agreement came from those aged 31 or more. 94% agreement about good typeface legibility was reached among the group aged between 15 and 19 years, with the most disagreement among young respondents aged between 27 and 30. The highest percentage of respondents deemed the composition appropriate in the age group up to 14, while the most disagreement about appropriate composition was expressed by those older than 31. Understanding the poster's message was the best among young respondents aged from 15 to 19, while the worst was among those aged 31 or more. The poster encouraged correct usage of dashes and hyphens among the youngest respondents up to 14 years old, while the least agreement with the statement was among the respondents aged from 20 to 26 and 31 or older.

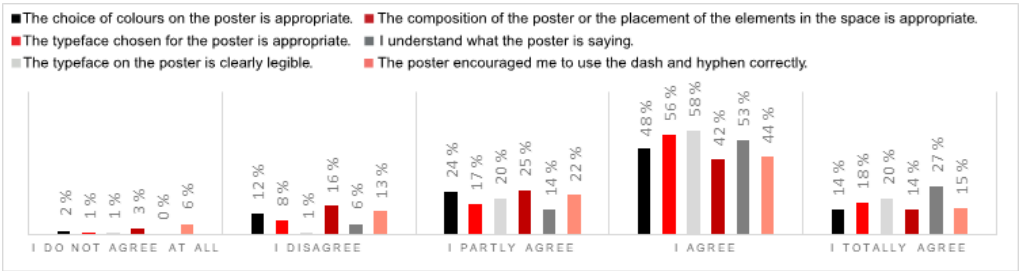

Figure 4: Claims relating to poster with dash and hyphen.

Poster 4 is shown in Figure 5, where the results for the ellipsis poster are represented. The majority of the respondents aged 31 or more confirmed the appropriateness of colour selection on the poster, while the least agreement about suitable colours was among the respondents aged between 20 and 26. Similar proportions confirmed the appropriately chosen typeface on the posters in the age groups up to 14, from 15 to 19, and 27 to 30. A small disagreement was observed in the age groups up to 14, from 20 to 26, and 27 to 30. The typeface chosen as the most legible was designated by young respondents aged between 15 and 19, while those aged 31 or more found it the least legible. The highest percentage of respondents confirmed appropriate composition in the age group from 27 to 30, while those aged 31 or older rated it the least appropriate. Young respondents aged between 15 and 19 understood the poster's message the best, while the most misunderstanding was observed

in the age group of 31 or more. All respondents up to 14 years old agreed that the poster encouraged them to correctly use ellipsis. The highest disagreement with the statement was marked in the age group from 20 to 26.

Figure 6, Poster 5 shows that the claims on composition and encouragement to correct use were rated with the most divided votes. The appropriate colour selection on the poster was most positively evaluated by young respondents up to 14 years old, while the least agreement was among those aged 31 or more. Those aged from 27 to 30 achieved the highest agreement percentage regarding appropriately chosen typeface, with the least agreement among young respondents aged up to 14. Almost all respondents aged between 15 and 19 confirmed good legibility of the typeface, while it was marked as less legible in the age group from 20 to 26. Almost equal agreement percentages were reached in considering the appropriateness of composition among those aged between 15 and 19. Those aged from 20 to 26 marked it as the least appropriate. Understanding the message of the poster was 100% among young respondents aged up to 14, with less understanding present in the age group from 20 to 26. The poster encouraged correct date and time formatting mostly among the respondents aged up to 14 and from 27 to 30, and the least among those aged between 20 and 26.

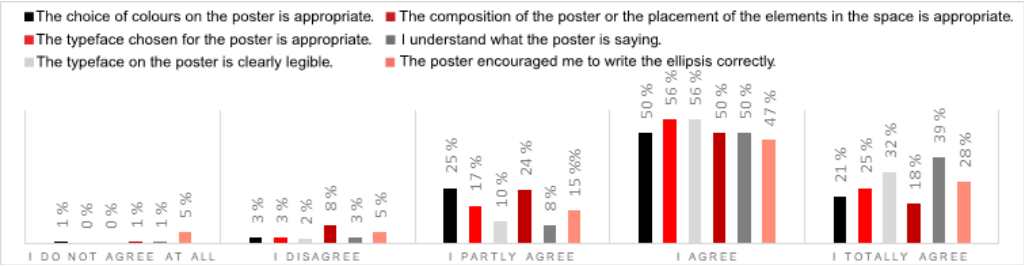

Figure 5: Claims relating to ellipsis poster.

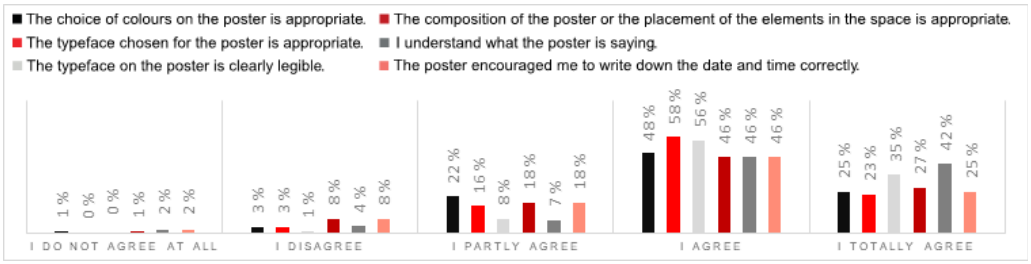

Figure 6: Claims relating to poster with date and time.

The majority of respondents agreed that the posters are visually connected and that the typeface style on the posters is appropriate. Opinions about the content's interesting nature and encouraging young people towards correct details and typography writing are mostly in agreement, with one third partially agreeing or disagreeing. 100% of respondents aged up to 14, from 14 to 19, and from 27 to 30 fully agreed with the statement about the design cohesion of the posters. In the age groups from 20 to 26 and 31 or older, 4% of respondents partially agreed. The appropriateness of the chosen font was most positively evaluated by young respondents aged from 15 to 19, with the greatest disagreement among those aged 31 or more. The content of the posters was most interesting to young respondents aged between 15 and 19, while the respondents aged up to 14 and those aged 31 or more did not find the content interesting. Overall, the posters encouraged correct formatting of dates, times and punctuation marks the most among the respondents in the age groups up to 14 and those from 15 to 19. They the least encouraged those aged between 20 and 26.

4. CONCLUSIONS

In a study with a specific demographic distribution, we designed a series of typographic posters that address and highlight the correct usage of punctuation marks, which are often incorrectly written. We emphasised the use of quotation marks, hyphens, dashes, ellipsis, and the representation of date and time. Posters complement each other both in content and design, as confirmed by the results of the online survey. The results affirmed our assumptions

that a typographic poster on detail in typography encourages young people to use detail in typography correctly, that the typeface style influences better information comprehension, and that proper composition on typographic posters affects the perception and understanding of information. Very good understanding of information on the posters is attributed to the appropriate choice of typeface, composition and minimalist design. We achieved the study's objectives and the expected results. The designed posters could be printed and displayed in educational institutions or their surroundings, alerting and engaging a broader audience to contemplate the correct usage and representation of detail in typographic elements in Slovenian. Additionally, the posters could be further developed both in content and design, expanding the range of correct punctuation usage.

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3D AUTOMOTIVE DESIGN

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Abstract: *3D computer modelling is one of the most important fields in the industrial design today. There are several different ways in which we can represent 3D geometry. Two most common are polygon modelling and NURBS (Non-Uniform Rational B-splines) modelling. NURBS can represent precise shapes such as circles, arcs and other geometries without loss of quality because they are based on mathematical equations. CAD programs use NURBS in industrial design where the quality of the final product is extremely important, e.g. in the automotive industry. In this paper we took an in-depth look at creating a 3D model of a car from NURBS in Autodesk Alias Autostudio software. In the end, we created a few renderings and an animation. This was a new area for us to explore.*

Keywords: *3D car model, visualisation, NURBS modelling, animation*

1. INTRODUCTION

In this paper, we dive deep into the world of automotive design, which is part of a larger branch called industrial design. Automotive design is a unique field where designers can express their creativity with a pencil and a piece of paper. However, this is only the beginning of a larger workflow. These sketches are digitally retouched and later converted into CAS 3D models. Although changes can still be made to the design, the designers must make compromises with the 3D modelers. The virtual model is converted into a physical 3D clay model using a CNC machine. The model is further retouched and covered with a thin, glossy film that allows for better surface analysis and overall visualization. The clay model is scanned back to the computer where the Class A modelling process begins. During Class A modelling, the modeler has time to produce the surfaces to the highest quality standards and prepare them for production (Spinetti, 2023). In the production phase, people from different fields come together to build a functional, unique prototype that is presented to the public in auto saloons (Turpen, 2016). Before mass-production the prototype is put through a series of tests. This is important because it allows car companies to test their designs before they are mass-produced. This ensures that the cars meet all safety standards and perform well in different driving conditions (JH May, 2024).

2. EXPERIMENTAL

The software we used is Adobe Photoshop, Autodesk Alias Autostudio, VRED and Adobe Premiere Pro. The whole process was done on a desktop computer with two monitors. The hardware components were an Intel Core i5 6500 processor, an MSI B150M PRO-VD motherboard, Crucial DDR4 8GB RAM, an NVIDEA GeForce GTX 1060 6GB graphics card and a 1TB SSD hard disk.

First, we opened Adobe Photoshop and started sketching our car with the brush tool. We made three drawings of the car (side view, front quarter view and rear quarter view). These are the three basic views that provide all the information about how the car should look. The sketches were imported into Autodesk Alias Autostudio, where the modelling process began. We started by adding simple curves around the model in the 2D side view, as seen in Figure 1. It is important to know that the curves will not match the sketch 100% because car designers like to overdo it with the size of the wheels and the stance of the car. It is also good practise to start with lower degree curves to begin with and slowly add to them as needed. The degree of the curve simply indicates how many control points (CV) a curve has. Curves with fewer degrees are easier to control and result in better reflections. A poor CV network can lead to holes and continuity brakes between two surfaces (Autodesk Inc, 2022).
Continuity indicates how the surfaces meet at the edges. Higher continuities require more aligned CVs at the edges of the surface, resulting in smooth reflections. There are four types of continuities in Alias (G0 – position continuity, G1 – tangent continuity, G2 – curvature, G3 – curvature with constant rate of change). Once we had created the outline of a car, we moved on to modelling the fenders (Autodesk Inc, 2024).

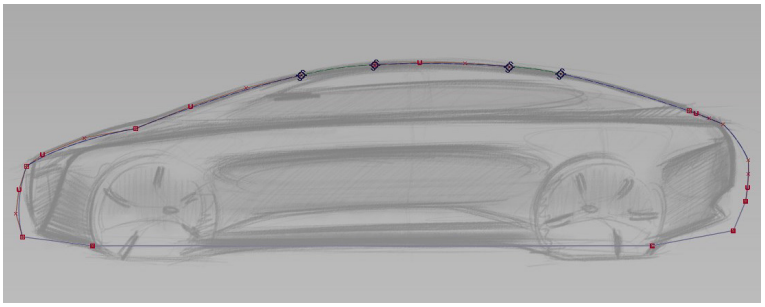

Figure 1: Building wireframe from curves

2.1 Fenders

Figure 2 shows a finished fender. We have grouped the elements into one object and moved it from the centre. We activated the Symmetry option in the Layers panel and got the other fender on the other side. This gave us the total width of the car. From here, we proceeded to expand our wireframe. A good wireframe helped us to get a spatial representation of our model.

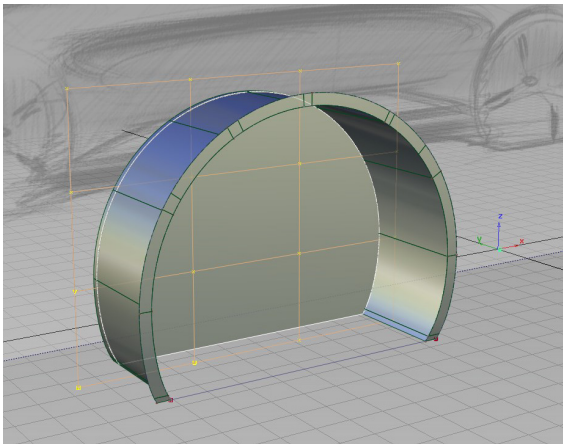

Figure 2: Finished fender

2.2 Cabin

We added another set of curves into the scene and shaped them according to our sketch. We used a different tool that offered much more control over the surface. As it was a large surface of a car, we wanted to get the best reflections. That meant greater continuity. In this case, we choose for a G2 continuity. We could also go for a G3 continuity, but this would require more CVs would have to be aligned. We had to consider the smoothness across the centre. Figure 3 shows the alignment of the CVs in the centre. If this were not the case, we would get a dip or a peak in the middle.

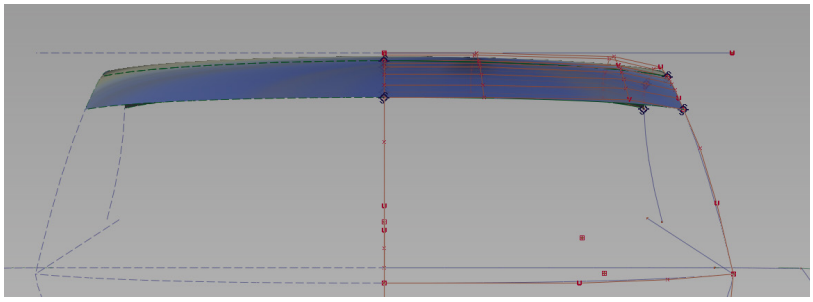

Figure 3: Smooth rooftop

2.3 Body

For the body modelling, we used different tools to connect surfaces. Before we started adding surfaces, we needed additional cross-section curves. Cross-section curves are normal NURBS curves that are used to divide a larger part into smaller parts. NURBS surfaces are 4-sided by default, which gives the best quality. A 3, 5 or n-sided surface is not recommended as it can cause artefacts and refraction. In the early stages of design this is not so important, but later in the Class A modelling process it is. Section curves make it easier to visualise the volume of a vehicle. Some parts required a lot of curve projection, surface trimming and realignment of these surfaces. Often, we needed a different approach to achieve continuity. This meant we had to rebuild the entire surface, manually move the CVs and check for errors. Figure 4 shows a poor CV flow along the surfaces. This resulted in poor reflections.

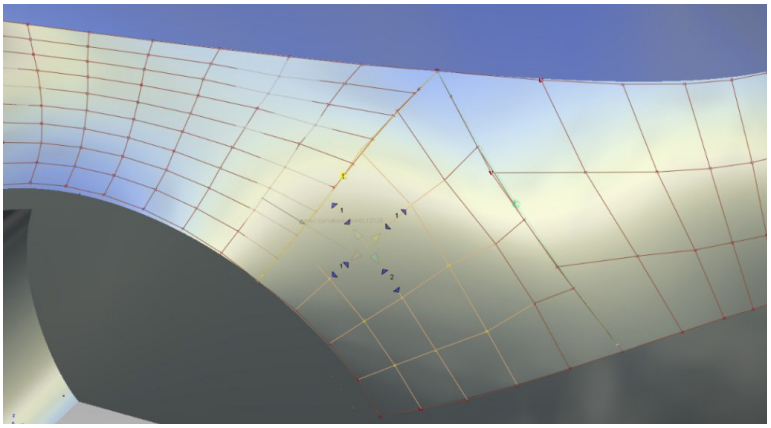

Figure 4: Poor CV flow along the surfaces

2.4 Face design and details

We modelled a simple AUDI-like front side. We added many small fillets to achieve nice reflections during modelling. Then we modelled an AUDI badge, which can be seen in Figure 5. We grouped the entire badge and copied it to the rear side. We also added additional details to our model, such as headlights, taillights and side mirrors.

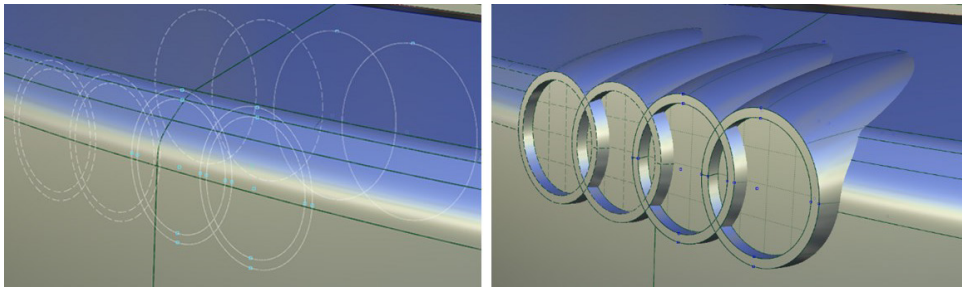

Figure 5: Modelling AUDI badge

2.5 Tires and rims

The tyres were quickly modelled by connecting circles with surfaces and adding large fillets. We wanted to make a nice 5-spoke rim, so we spent some time modelling and rebuilding it. In the end we made one spoke and copied it four times around the pivot point. We wanted more detail, so we also modelled discs for our model. Figure 6 shows the rim modelling process. The final model was then checked with different diagnostic shaders and was ready to be exported to VRED for visualisation.

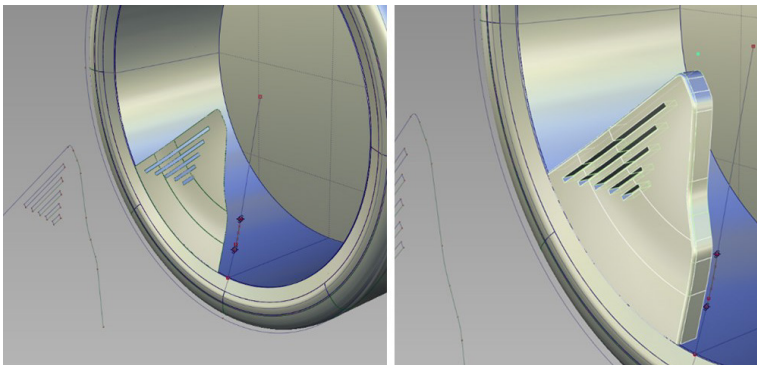

Figure 6: Rim modelling process

2.6 VRED

We have imported the finished alias file into the VRED software. VRED is a professional software for visualizing models in different environments and creating high-quality renderings in real time. We started by creating different materials for different parts of our model. After applying all the materials, we added a 2D background image to our scene. The perspective of the car did not match the perspective of the background image, which we corrected using perspective lines. We also had to adjust the shadow position of the car to match the background image when we activated the ray tracing. As we wanted to create a sense of movement, we blurred the background image in Photoshop. It was also necessary to add a motion effect to the wheels of the car. This was done by animating the wheels around their pivot points and adjusting the shutter speed of the camera. The result can be seen in Figure 7.

Figure 7: Final result

We also created another set of renders and animations in a different environment. We added multiple cameras around the scene and animated each one. In the animation export settings, we had to reduce the render quality as it would take days to render. However, the images were rendered at the highest settings available. The animation was later opened in Adobe Premiere Pro, where it was enhanced with music and text.

3. RESULTS

The final animation can be viewed via this link on YouTube: https://www.youtube.com/watch?v=2uWJHUI19TM. We have taken some interesting shots that capture details of our model. These can be seen in Figure 8. In Figure 8, example A, we see a detailed close-up of a rim with a disk behind it, which is an additional level of detail. Many different materials were required to create the rims due to the many small parts. Example B shows the front part of our model. We can see small fillets that create nice reflections on the front mask and hood. These small details are important to achieve realistic results. Example C shows the rear part of our model. We have created a simple design for the rear lights that is connected to the AUDI logo and added a strong glowing red material. In example D, we see a whole model from the top view, showing nice surface highlights across the cabin. Poorly constructed hips and transitions can be seen in the reflections, which break in some places and give the impression of damaged sheet metal.

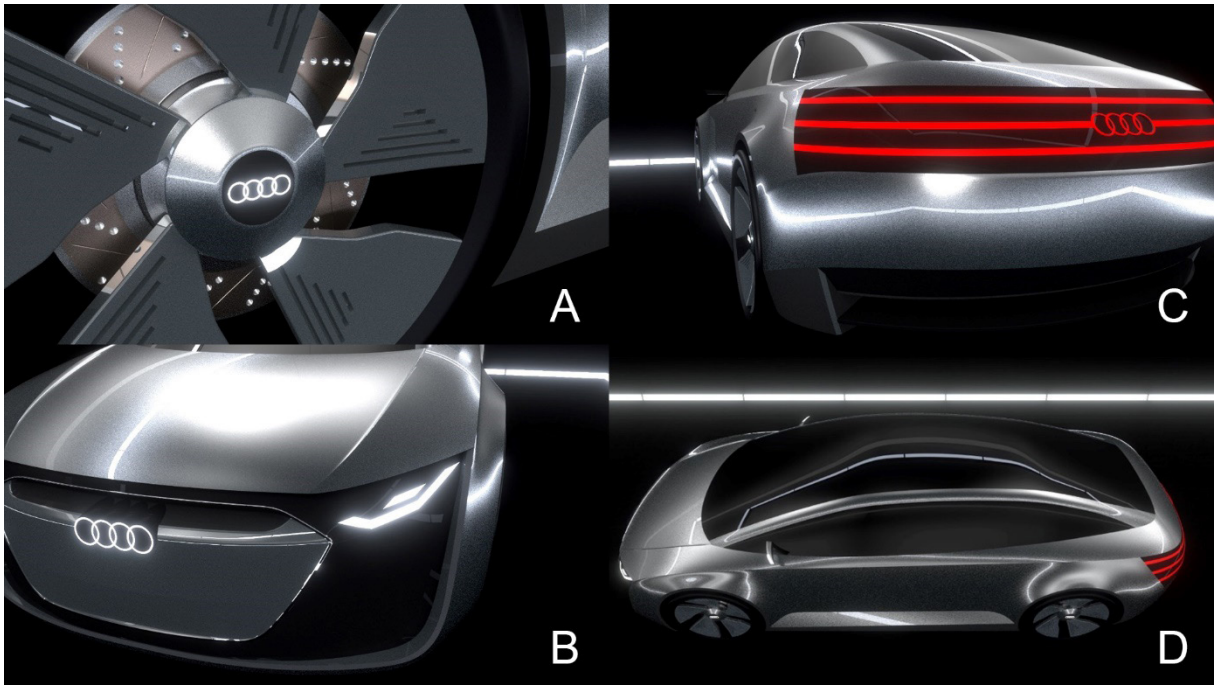

Figure 8: Final renderings

4. CONCLUSION

Through the modelling process, we learned about many factors that contribute to better surface quality. Creating a good wireframe with 4-sided NURBS surface topology with good CV network and resolving errors with various diagnostic tools are all challenges for a good alias modeller. A good wireframe helped us to visualize the model and to place the surfaces. Some parts required a lot of experimentation with different tools, so we spent a lot of time exploring different tool settings and parameters. Despite all the difficulties, we managed to build a model with the right proportions that matched the sketches. VRED required delving into the creation of materials, model visualization, scene setup, camera settings and animation. With more experience and time, the entire model could be enhanced with additional details, such as a more complex sculpt of the car, parametrically designed patterns on the front mask, details in the interior and the creation of an interesting animation in VRED where the car would move in the scene.

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INTEGRATING THERMOCHROMIC INKS WITH CONVENTIONAL OFFSET INKS TO ENRICH THE COLOR PALETTE FOR SELF-ADHESIVE LABEL PRINTING

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Abstract: This research explores the integration of thermochromic inks into graphic design, enhancing product appeal and functionality by leveraging dynamic colour changes and additional information presentation. Despite their advantages, their limited market presence is attributed to higher costs. The study investigates blending one thermochromic ink with two conventional offset inks to broaden the colour spectrum. Modern label printing, facilitated by advanced technologies, aids product identification and provides tracking capabilities during transit. Thermochromic inks, serving as label indicators, are especially suitable for printing substrates. The research employs pressure-activated self-adhesive labels, including eco-friendly options made from recycled fibers and a bio-based polymer label. The study demonstrates that combining thermochromic and conventional inks creates prints with novel tones and desired characteristics, thereby broadening the dynamic color spectrum. The thermochromic effect is influenced by varying label materials. In general, the functional and dynamic attributes of blended inks do not significantly differ from those of single thermochromic inks.

Keywords: *thermochromic inks, self-adhesive labels, activation temperature, dynamic colour palette*

1. INTRODUCTION

Regarding packaging, colour is one of the most crucial components for attracting customers (Tan, 2011). The choice of colour has a great impact on the effectiveness of the message we want to convey. (Stephenson, 2016). Attractive and meaningful packaging colours leave a strong impression on consumers. Visually appealing packaging can encourage a consumer to purchase a more expensive product.

Thermochromic (TC) inks belong to the group of chromogenic printing inks and change their colouration due to temperature variations. This change adds additional functional value to the product itself. Activation temperatures for TC printing inks range from 15°C to 65°C; however, most applications are limited to three temperature ranges - cold, body temperature (31°C), and hot (Seeboth, 2008). TC inks that combine leuco dyes and process printing inks enable a change from one colour to another. TC materials have applications in many industries and are a functional part of products. For example, in the food industry, they serve as indicators of freshness and product temperature, while on the packaging of beer and wine, they indicate the ideal drinking temperature (Thamrin, 2022). They are also used in the dairy industry as evidence that milk has been stored appropriately (Luo, 2022). For commercial purposes, they are applied as decorative cups, wallpapers, jewellery, promotional flyers, etc. In the field of security documents, they are used to quickly and easily verify identity and conceal information (Ma, 2021).

A crucial factor for printing TC inks is the choice of printing substrate to achieve the best visual effect of the colour change. Label printing, with its continuous development, has become a highly sophisticated branch of production comprised of modern printing technologies. Labels also offer the opportunity to track transportation, logistics, and storage, not only in terms of quantity but also in terms of the quality of the product, which is crucial for the use of, for example, food labels (Robertson, 2005).
This study aimed to demonstrate how combining TC inks with conventional ones can produce prints with new tones that exhibit good characteristics, thereby expanding the colour palette with dynamic features. The objective was also to determine the influence of the substrate on the dynamics of colour change, for which purpose three environmentally friendly labels with different characteristics were used.

2. EXPERIMENTAL

2.1 Selection of printing substrate

For this research, three different types of labels were used, two of which are eco-friendly and made from recycled fibers, while one is a bio-based polymer. The eco-friendly labels used are citrus and grape-based. The production of the top layer of the labels reduced CO2 emissions by 20%. The top layer of the labels is constructed from fibers made from 15% agro-industrial bio-products, specifically citrus and grapes, containing 40% recycled paper and 45% virgin wood pulp to obtain high-quality natural paper. Grape fibers are obtained from residues of grapes used in winemaking, and citrus fibers are derived from fruit residues and juice processing by-products. The bio-based polymer used, polyethylene white (PEW), is primarily made from ethanol derived from sugarcane, with a gum-based adhesive. The top layer of the label is thermally coated, and underneath it is a black thermo-sensitive layer that provides good resistance to fats, moisture, oils, and alcohol. The spectral reflections of all three labels are shown in Figure 1, and the specification of pressure-sensitive labels is given in Table 1.

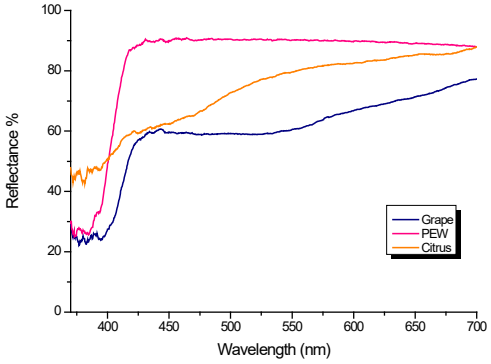

Figure 1: Spectral reflection curves of all examined unprinted labels

Table 1: Specification of pressure-sensitive labels

		Facestock	Liner		Total Laminate	
Substrate		**Basic Weight ISO 536, g/m²**	**Caliper ISO 534, µm**	**Basic Weight ISO 536, g/m²**	**Caliper ISO 534, µm**	**Caliper ISO 534, µm**
Fasson®rCrush Grape	Grape	90	114	70	61	192 ± 10%
Fasson®rCrush Citrus	Citrus	100	130	70	61	210 ± 10%
Fasson®PE85-BIOB White	PEW	82	82	59	53	152 ± 10%

2.2 Selection of Thermochromic and Conventional inks

The TC ink chosen for this study is a commercially available offset printing ink formulated with leuco dyes. This particular ink is reversible, triggered at an activation temperature of 29°C. Before reaching the activation temperature, the TC ink exhibits a blue colour. Upon heating to and reaching this temperature, it transitions to a colourless state. This transformation reveals solely the underlying conventional colour with which it is blended. The conventional offset inks employed in this study include yellow (Y) and warm red (WR). Each label is printed with TC ink alone, as well as with combinations of TC ink and one conventional offset ink (yellow and warm red).

2.3 Printing Technique of Thermochromic Ink

All samples were printed at the printing house using a commercial dry offset machine specifically designed for label printing under real conditions. The prints were dried using a UV drying unit integrated into the offset printing machine.

2.4 Determination of Colorimetric Characteristics of Printed Samples

The calculation of colourimetric parameters and measurement of spectral reflections were achieved using the Ocean Optics USB 2000+ spectrophotometer. To display the measured results, the OceanView software was used. The light source utilized was the Ocean Optics LS-1 tungsten, emitting in the wavelength range of 360 – 860 nm. For the measurement of samples in this study, the wavelength range of the visible spectrum (400 – 700 nm) was employed. The measurement geometry used in the study is 8°:di, indicating that the sample was illuminated at an angle of 8° relative to the perpendicular (8 ± 5 degrees) and collects light that is reflected in all directions.

2.5 Heating and Cooling System

For measuring the TC ink of the samples, an electrostatic circulator was used, providing the capability to heat and cool samples to a predetermined and pre-set temperature. The samples used in this study were heated to temperatures ranging from 15°C to 45°C, with recorded temperatures within this range being: 15°C, 20°C, 25°C, 27°C, 29°C, 30°C, 31°C, 33°C, 35°C, 40°C, 45°C. After heating, cooling followed in the same temperature intervals until reaching the temperature of 15°C again. Data for each measured temperature were recorded. The even temperature distribution on the label during measurement is facilitated by the plate to which the label is affixed. The plate itself, where the measurement samples are placed, is made of copper and nickel. The device's heating occurs with the help of a heater that warms the liquid, which then circulates through the system.

3. RESULTS WITH DISCUSSION

Figures 2 to 4 illustrate how the lightness (L*) changes depending on the temperature (T) of the TC ink on Citrus, Grape, and PEW labels. These are characteristic hysteresis curves of TC inks. From the graphs, it is evident that an increase in temperature leads to an increase in the lightness of the sample itself, attributed to the change of the TC ink from blue to colourless, leaving only the conventional colour visible. The increase in lightness continues until the activation temperature, which in this case is 29°C, after which the change gradually ceases, and the graph becomes continuous. This is the trajectory of TC colour change that is common and documented in our other similar studies (Kulčar 2011, 2022; Malenica 2023).

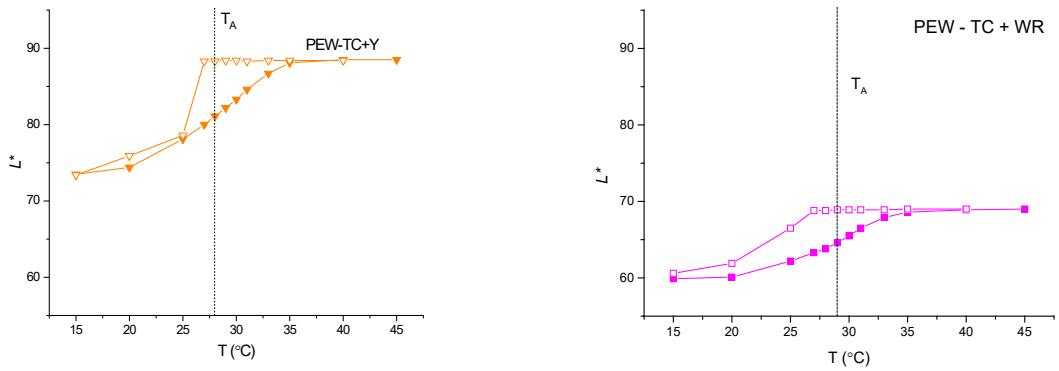

Figure 2: Colour hysteresis of TC samples PEW–TC+Y and PEW–TC+WR labels, at heating (full signs) and cooling (open signs).

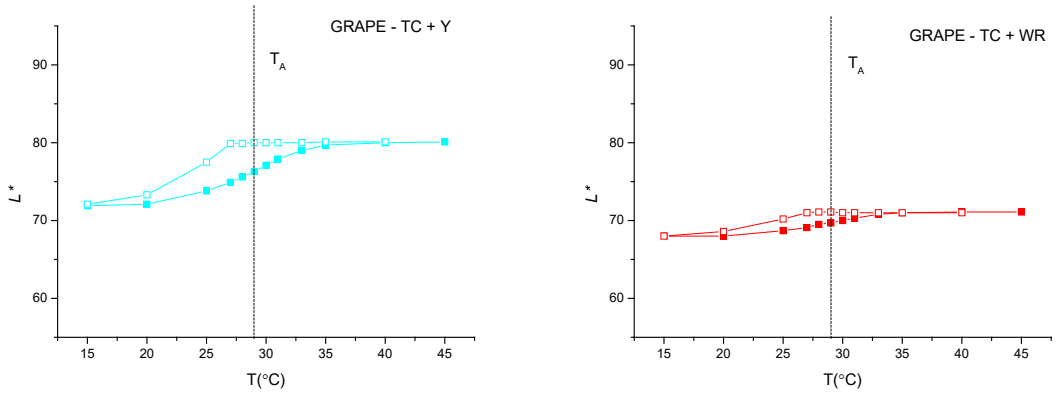

Figure 3: Colour hysteresis of TC samples Grape–TC+Y and Grape–TC+WR labels, at heating (full signs) and cooling (open signs).

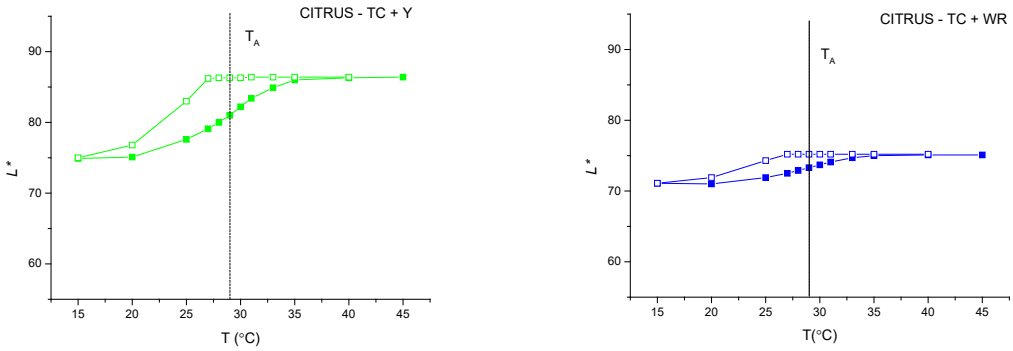

Figure 4: Colour hysteresis of TC samples Citrus– TC+Y and Citrus – TC+WR labels, at heating (full signs) and cooling (open signs).

During the cooling process of Citrus-TC+Y, Grape-TC+Y, and PEW-TC+Y samples, the change is more pronounced. After passing the activation temperature, a sudden change occurs, whereas in other samples, this change is less noticeable. A greater change indicates that the thermochromic effect, i.e., the dynamics of colour change, is more clearly visible. It is also noticeable that the colour coverage of the label itself on which the printing was applied has a significant impact. Furthermore, the Grape-TC+WR sample exhibits the slightest, almost imperceptible modification during the heating and cooling processes. In contrast, the PEW-TC+Y sample displays the most notable change in lightness. This discrepancy can be ascribed to the fact that the PEW label, relative to the other two, boasts a smooth and highly reflective surface. The Grape label exhibits a faint purple tint, whereas the citrus label leans towards a yellowish hue. These analyses suggest that the substrate itself plays a pivotal role in influencing colour alterations, with the most pronounced dynamics observed in prints on PEW labels. Consequently, the changes in lightness during the heating and cooling phases are not uniform across all tested TC inks, indicating that the reversible process is suboptimal, and the hysteresis shape varies among the different substrates under examination.

In Figure 5, the chromatic change on all three examined substrates and the alteration of the TC ink colour throughout the entire heating and cooling cycle are evident. In the PEW-TC+Y sample, during heating, starting from the minimum temperature of 15°C, the colour shifts from green to the yellow part of the spectrum. Conversely, during cooling, where the maximum temperature is 45°C, it moves in the opposite direction, from the yellow to the green part of the spectrum. A similar colour change is observable in the Citrus-TC+Y sample, but in comparison to PEW-TC+Y, this sample has lower saturation. The Grape-TC+Y sample exhibits the lowest saturation. The colour printed on the PEW label is the most saturated due to its smooth surface, which is non-absorbent. In absorbent

substrates, the pigment penetrates the fibers, as is the case with the Grape and Citrus substrates, whereas, in non-absorbent substrates, the pigment remains on the surface. This graph vividly illustrates the significant impact of the substrate (its structure and colour) on the shade of the TC ink, especially when printed using offset printing, which, compared to screen printing, has much lower colour coverage. Another observation from this graph is that the reversible process is not ideal, as the heating and cooling curves do not align perfectly.

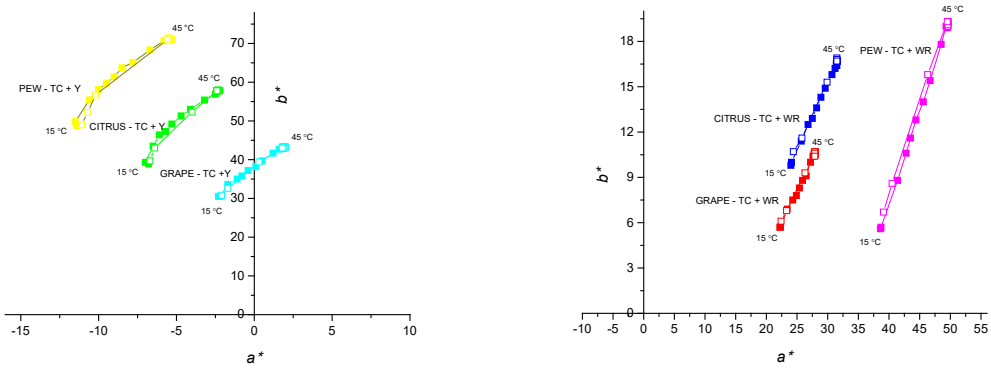

Figure 5: Colour trajectories in the (*a*b**) plane of CIELAB colour space for the TC+Y and TC+WR mixtures printed on all three tested substrates during both the heating (full signs) and cooling (open signs) process

In Figure 5, the *a*b** graph illustrates the chromaticity on all three examined substrates and the colour change of the TC ink. The Citrus substrate inherently has a yellowish tone, Grape a purplish one, and PEW an extremely white tone. In the print on the PEW label, it is evident that the printed colour, during heating, starting from the minimum temperature of 15°C, shifts from pink to the red part of the spectrum. During cooling, where the maximum temperature is 45°C, it moves in the opposite direction, from red to the pink part of the CIELAB colour space. The change is also noticeable in the remaining two substrates, Citrus and Grape, which are significantly less saturated compared to the PEW substrate. This graph demonstrates that the substrate influences the shade of the TC ink and that the reversible process is not ideal, as the heating and cooling curves do not align perfectly. Similar to the previous case, greater chromaticity of the printed TC ink is observed on the smooth PEW label than on the other two labels.

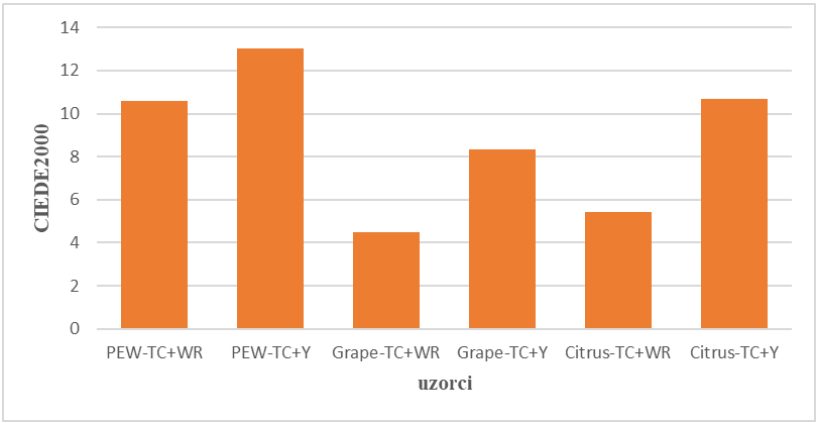

Figure 6: CIEDE2000 difference of all samples during the heating process at 15°C and 45°C

Figure 6 shows the CIEDE2000 colour difference among all samples at two temperatures, 15°C and 45°C, achieved during the heating process. This is the so-called overall colour contrast, indicating the extent of the TC colour change effect. The graph reveals a noticeable difference among the samples during heating. For instance, the PEW–TC+Y sample achieves the greatest colour difference, while the Grape-TC+WR sample achieves a significantly smaller colour difference compared to the others. The actual numerical values for the PEW-TC+WR

sample are 10.57, for the PEW-TC+Y sample 13.01, for Grape-TC+WR 4.49, for Grape-TC+Y 8.32, for Citrus-TC+WR 5.41, and for Citrus-TC+Y 10.69. Based on these results, the conclusions from previous graphs can be confirmed, indicating that the structures of the top layer of the label and its colour influence the colour impression and the TC effect. Moreover, the dynamic colour change is observable, satisfying the functional role of colour.

4. CONCLUSIONS

Based on the conducted research and analysis of the results, it has been determined that TC inks mixed with conventional offset inks can produce prints with new tones of good characteristics, thereby expanding the dynamic colour palette. One of the motivating factors for this research was the high cost of TC inks, and this study aimed to explore possibilities for expanding printing capabilities in combination with conventional inks. It has been proven that the substrate significantly influences the visual appearance, hue, saturation, and dynamic change of TC ink, especially when using offset printing, which has less colour coverage compared to screen-printing. Environmentally friendly labels had a weaker TC effect compared to polymer-based bio labels, but they remained visible. The reason for the weaker TC effect on environmentally friendly substrates is their rough and absorbent surface, allowing the pigment to penetrate the fibers. On smooth surfaces, the TC effect is much more noticeable because the pigment remains on the surface, and smooth surfaces are more saturated than rough ones. Calculating the CIEDE2000 colour differences yielded results showing that the polymer-based bio label with a mixed TC blue ink with an activation temperature of 29°C and conventional yellow ink exhibited the highest TC effect. Furthermore, it has been demonstrated that the structure of the top layer of the label and its colour significantly affect the print colour and TC effect. In future research, there are plans to integrate additional conventional inks blended with TC inks, aiming to broaden the dynamic colour palette. Furthermore, the investigation will encompass labels with diverse surface characteristics.

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3D DESIGN AND ANIMATION IN CULTURAL HERITAGE PRESERVATION

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Abstract: *Preserving cultural heritage has become an increasingly vital facet of contemporary life. With constant technological and social change, we face challenges in preserving and presenting cultural heritage in innovative ways. This article aims to explore creative approaches to the preservation and presentation of cultural heritage, utilizing 3D modeling, animation, and video editing. Our objective was to showcase active contributions to cultural heritage preservation and enhance the appreciation of historical chess content in the Balkan region through modern technologies. Focusing on interconnected events, individuals, and moments in chess history that hold significance for the Balkan geographical area, the article leverages advanced 3D technologies to document, recover, and present both tangible and intangible aspects of our cultural heritage, ensuring its conservation for future generations.*

Keywords: *chess, 3D technologies, cultural heritage, preservation, promotion*

1. INTRODUCTION

Over the last decade, technological advances have revolutionized our approach to cultural heritage preservation, with 3D modelling and animation playing a pivotal role. The integration of digital archiving, virtual reality and advanced techniques like 3D scanning, photogrammetry and modelling has reshaped the way we engage with and safeguard our cultural legacy. This article explores the intersection of technology and cultural heritage preservation, with a focus on 3D modeling and animation techniques (Ocón, 2021).

The evolution of 3D technology has enabled the preservation of both tangible and intangible cultural heritage in various sectors, including crafts, storytelling, dance, game-based education, sports, settlements and more. Interactive digital storytelling employs various methods such as VR, AR, 3D modeling and 3D visualization to highlight historical items, places, events, myths and artworks (SkublewskaPaszkowska, 2022). Chess as a timeless strategy game is a significant element of global cultural heritage and storytelling, especially in the context of historical games and famous matches, fostering connections among people and reflecting the intellectual richness of different civilizations (Tasdelen, 2023).

In our research, attempts to digitize the Dubrovnik chess set using advanced scanners and photogrammetry proved unsatisfactory, so we opted for the technique of 3D modeling. This approach involved using specialized software like Blender and AutoCAD to create accurate digital representations of objects in three dimensions. Our objective was to contribute to the preservation of cultural heritage and promote the recognition of historical content in the Balkan region through modern technologies, focusing on chess events that hold significance for this area. By drawing attention to the region's often overlooked influence on global chess development, we aimed to raise awareness of lesser-known events and individuals who made notable contributions to chess heritage.

Our project delved deeply into the historical aspects of chess, exploring the games, competitions, and players, with a specific emphasis on significant events and chess figures in the Balkans. The focal point was the extensive research into the seventeenth game of the 1972 World Chess Championship in Reykjavik between Spassky and Fischer. Fischer, who favored the Dubrovnik chess set, introduced Pirc's defense for the first time in a World Championship. This defense was named after Vasja Pirc, a Slovenian grandmaster who won the Chess Olympiad in Dubrovnik in 1950. The Dubrovnik chess set, crafted for this occasion, holds profound historical significance in the chess heritage of the Balkans (Noj d.o.o., 2023, Zaletel, 2020).

2. MATERIALS AND METHODS

In our pursuit of preserving this heritage, we adopted an experimental approach with the goal of transforming the original Dubrovnik chess set from 1950 into digital 3D models. Through our research, we found out that the original Dubrovnik chess pieces from 1950 were kept by a collector (Noj d.o.o.), who allowed us to borrow an original set. This collaboration contributed to our goal of converting the chess set into a digital format through reverse engineering processes in order to integrate the chess set into the animation.

The conversion processes involved 3D scanning, photogrammetry and modelling, utilizing tools such as the DAVID SLS-2 and the Shining 3D EinScan scanners. We employed the Agisoft Metashape program for photogrammetry, while AutoCAD and Blender programs were used for 3D modeling. The optimal transformation results were achieved with Blender, enabling the creation of a digital representation of the chess set. Subsequently, we animated the chess set using Blender and made further edits to create a video using Adobe Premiere Pro.Top of FormBottom of Form

2.1 3D MODELING

3D modelling is the process of creating three-dimensional (3D) digital models of objects or spaces within a computer environment. This enables the visualization and simulation of three-dimensional objects and environments in digital form. 3D modelling found applications across various industries, including film production, video games, architecture, product design, animation and others. (FutureLearn, 2022)

In our case, the conversion of physical figures into 3D models was carried out with the Blender software, a powerful open-source program for creating 3D computer graphics. Utilizing a reference image (Figure 1) and precise measurements of the physical figures, we successfully generated digital 3D models of the chess pieces (Community, 2018).

Figure 1: The original 1950 Dubrovnik chess set

Blender's versatile techniques, including digital sculpting and mesh modeling, were used in our project to recreate chess pieces. Initiating with the default cube mesh, we adapted it to create polygonal models like the king piece, ensuring accurate dimensions. The process involved selecting cylinder meshes, aligning reference images and adjusting sizes in the "Layout" workspace (Figure 2).

Figure 2: Mesh modelling

Using tools like “Shade Smooth” in “Object Mode,” we smoothed the edges to achieve a polished look. Similar techniques, including “Bevel” and “Modifiers,” were applied to model various chess pieces to ensure intricate details.

For the game board, a mesh cube was manipulated to form squares using the “Loop Cut” tool, resulting in a 60 mm × 60 mm grid. The final step involved modeling the original table used in the 1972 Reykjavik tournament, following the dimensions of Icelandic designer Gunner Magnusson’s iconic creation.

2.2 ANIMATION

Animation in Blender refers to the process of making objects dynamic through the arrangement of keyframes created to represent key moments in the animation timeline. Each keyframe dictates the position and rotation of the objects, and Blender seamlessly generates transitions between them, in our case the animation of both the pieces and the camera (Community, 2018).

Initially, we strategically positioned the modelled chess pieces on the chessboard as they would be in the game. Keyframes were introduced by positioning our indicator at specific frames on the timeline and adjusting object properties. The “Insert Keyframe” button recorded these changes and served as a marker for significant animation moments.

Blender’s automatic interpolation between keyframes facilitated fluid motion, sparing us from manually specifying each step. To improve the result, we fine-tuned the transitions using the “Graph Editor.”

Once the animation was complete, we reviewed it in real-time using Blender’s playback option. Exporting the project offered flexibility, and our animation, enriched with materials and lighting was exported frame by frame in .png format. The image size was set to 1920 px × 1080 px, with a frame rate of 25 fps.

2.3 POST-PRODUCTION

Post-production is a crucial phase in the creation of audiovisual content, where the raw material is refined and enhanced for distribution. Using Adobe’s Premiere Pro, a leading video editing software, we handled tasks such as content editing, color correction, sound editing and adding effects.

Our project involved creating a video from image sequences exported from Blender, consisting of 12,750 frames in .png format. After configuring parameters for a new sequence based on the image specifications of the exported images (1920 × 1080 pixels at 25 frames per second), we arranged the images in the timeline. By adjusting the default image length, we achieved the desired playback length of two hundredths of a second for each image.

Text, symbols and captions were added to illustrate chess moves, titles and key phrases from Bobby Fischer’s interview. The text was animated for a set amount of time and contributed to the end credits. We also included an

interview with Bobby Fischer from June 27, 1999 in the Philippines, which was notable for Fischer's anti-Semitic remarks. This interview, conducted over the phone for various radio stations, added depth to the narrative.

The animation was complemented with the soundtrack "Waltz No. 2" by Dmitri Shostakovich, a Russian composer and enthusiastic chess lover. The music piece formed a fitting background and merged with the chess atmosphere. The music from the movie "Pawn Sacrifice" titled "Boris Spassky" by James Newton Howard heightened the tension in the decisive moments.

After completing the montage and editing, we checked the settings before exporting the video. Selecting H.264 format with the "High Quality 1080p HD" preset, commonly used for online platforms, we set time interpolation to "Optical Flow" for improved video motion.

In summary, during post-production, we carried out detailed work using Premiere Pro, contributing to the creation of a visually compelling video. Organizing image sequences, incorporating text and interviews, and integrating music enhanced the storytelling of Bobby Fischer's life and the historic chess match against Boris Spassky in 1972. The outcome is a refined and captivating animation suitable for distribution across various platforms.

3. RESULTS WITH DISCUSSION

Our efforts resulted in a 5-minute and 27-second video in .mp4 format with captions, an interview and musical accompaniment, with move notations in the lower right corner (Figure 3).

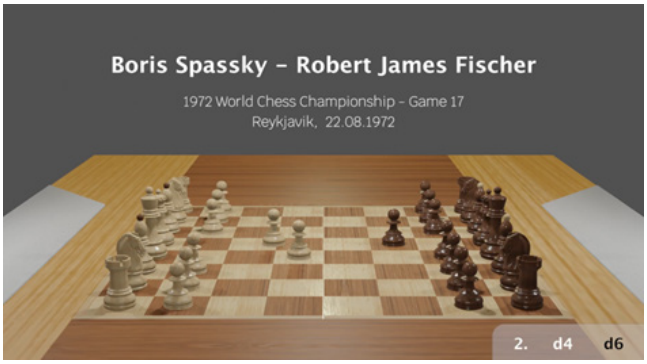

Figure 3: Animated video

The Dubrovnik chess set is showcased on a replica of the table used at the 1972 World Championship in Reykjavik. Our initial attempt to recreate the realistic appearance of the pieces by scanning encountered difficulties due to their symmetrical, glossy and dark-coloured nature (of half of them). Photogrammetry proved insufficient due to data volume and minimal differences between images. Despite using fewer pieces, the processing time for accurate point cloud manipulation was excessive. However, relying on reference images and precise measurements, we were able to successfully create 3D models in Blender. Blender's modeling capabilities allowed us to accurately track the dimensions of physical pieces, while animation was achieved through the keyframe placement. Adding materials from BlenderKit enhanced the realistic appearance of the chess pieces and board.

The video shows the 17th match of the 1972 World Chess Championship, in which Bobby Fischer used the Pirc's Defense for the first time in the history of world championships. Also included is an interview with Fischer in which he expresses his admiration for the Dubrovnik chess set.

Lighting and framing played a crucial role in enhancing the overall aesthetics of the project, achieved through the proper positioning of point lights for even board illumination and the adjustment of the frames for key animation moments. Camera movement in space facilitated various shots, from detailed close-ups to distant angles. Blender's flexibility allowed adjustments in depth of field, crucial for varying shot distances. Animated text was added to provide important information to better understand the video content

The entire process enabled the creation of a lifelike 3D animation of a chess game, bringing the physical pieces and board to life. Blender proved to be a powerful tool that contributed to the successful transformation of physical pieces into digital replicas. Its diverse features provided a high degree of flexibility and creative freedom.

To further improve the results, more time could have spent on setting up the frames, ensuring smoother animation transitions with precise parameters and additional graphics curves for enhanced realism. Processor limitations were overcome by accessing more powerful computers. To achieve smoother animation, considerations such as increasing the frames per second (fps) or shortening the frame duration were considered. Ultimately, a compromise was reached with a frame rate of 25 fps and slight time stretch in Premiere Pro to achieve a more realistic effect.

Post-production, specifically using Adobe Premiere Pro, played a crucial role in refining the raw material. Properly configured parameters ensured high-quality and fluid motion in the final video. Optical flow for temporal interpolation improved object motion tracking and overall visual quality.

The addition of a carefully selected soundtrack contributed to the thematic atmosphere and text elements were integrated to emphasize the project's significance. Thoughtful editing tried to ensure a cohesive narrative without overwhelming the audience.

4. CONCLUSIONS

Chess, as a significant part of global cultural heritage, connects people and reflects the intellectual wealth of diverse civilizations. With chess in the Balkans playing a crucial role in the development of the game and chess competitions, we witness a rich history in this region, even though it is often overlooked. Chess in the Balkans has had a profound impact on the entire history of the game and modern chess competitions. However, it is little known that so many important events and individuals have emerged in our region.

Modern developments, especially in the context of computer and 3D technology, have been significant in interpreting and preserving this cultural heritage. They have enabled us to recreate historical events and present them in digital form through 3D modeling, animation and computer video editing.

The final product is an animated video depicting a historically important chess game. It serves educational purposes, raises awareness of the chess history in our region and contributes to preserving cultural heritage through digital technologies. With ongoing technical advances, there is the potential to further improve the preservation and interpretation of history. Future research into various technologies within the field of graphic design could open new avenues for the conservation of cultural heritage.

The intended use is to employ the animation in a VR environment, depicting a room for a chess tournament, with exhibition panels hanging on the virtual walls playing our video. Additionally, it could be utilized in a museum, lecture hall or for casual online viewing.

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ASSESSING THE IMPACT OF CINEMAGRAPHS ON MESSAGE TRANSMISSION EFFECTIVENESS IN ADVERTISING

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Abstract: *The aim of the study was to analyse cinemagraphs, a unique blend of static photography and dynamic videography, with a focus on creating effective advertisements for various products. Utilizing both static and animated formats based on lifestyle photography was used to communicate benefits and appeal. The study explored the role of commercial photography, traced the evolution of cinemagraphs, and conducted an in-depth analysis of existing examples across fields. Customised animated photo series were developed using a Nikon D750 camera and Adobe Photoshop CC. Eye-tracking technology was used to assess viewer engagement and message transmission effectiveness in both ad formats. The results suggest that incorporating animated elements into static images significantly increases viewer engagement, highlighting the potential of cinemagraphs as an effective tool in commercial advertising to attract and retain consumer attention more effectively than traditional static images.*

Keywords: *cinemagraph, commercial photography, lifestyle photography, advertising, eye-tracking*

1. INTRODUCTION

Nowadays we are surrounded by advertising at every step, as we are confronted daily with thousands of images and other forms of adverts that inform us about new products and tempt us to buy them. Advertisers endeavour to get users to notice their product and give it at least a few seconds of attention. (Admin, 2016) Although static photographs have a great impact and contain a strong message, extensive advertising has shown that the attention and memorability of the content quickly diminishes. (Lendvai, 2017) In addition, video footage is becoming increasingly popular and serves not only to advertise and inform, but also as a constant source of entertainment. (Lendvai, 2017, Niewland, 2012) However, visual content that builds visual communication has a hard time making a real impact without the right creative design. In the vast sea of advertising, it can be easy to overlook photographs, and deliberately ignore videos because they seem too long and take up too much time. (Adler, 2021, King, 2013, Rose, 2018)

Advanced technology and the rapid development in photography offer a wealth of creative possibilities that have also enabled the development of one of the most well-known and popular photographic styles – animated photography or cinemagraph. This photographic style with a sophisticated interplay of static photography and moving image (video) tells a unique story and gives the viewer the feeling of seeing a live photograph. The animated details are captured in a flawless loop that allows us to experience and preserve the depicted moment indefinitely. (Adler, 2021, Mevorah, 2017, Perez, 2012, Declan, 2018)

The aim of the research was to create a series of static and animated commercials that use lifestyle photography to illustrate the purpose and use of different products. In addition, we wanted to investigate the effectiveness of messaging in both forms of adverts created, as we were interested in what the viewer notices first in static and animated adverts and which element receives the most attention.

2. EXPERIMENTAL

In the first part of the experimental section, we focussed on planning, recording and editing an animated photographic series. Firstly, we planned the necessary photographic equipment, which mainly consisted of the Nikon D750 camera and the AF-S Nikkor 24–70 mm f/2.8 ED VR lens. Using a zoom lens allowed us to adjust the focal length, which made it easier to capture the entire intended frame.

Next, we selected the shooting location and designed the frames and placement of the light sources. As we wanted to represent the selected products through authentic everyday situations of the users, we opted for indoor shots with plenty of natural light. We chose the kitchen, the living room and the bedroom. To make the work and

organisation easier, we also prepared a photographic plan showing the planned arrangement of the elements and light sources in the form of a floor plan. Figure 1 shows an example of the arrangement of the light sources for most of the scenes.

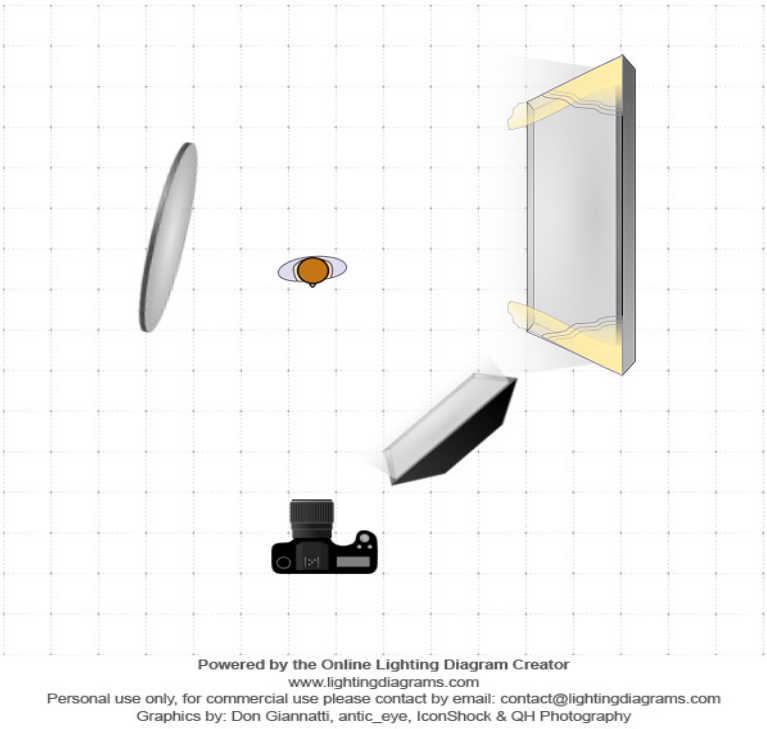

Figure 1: An example of a photographic scene

As a primary light source, we mainly used the natural daylight coming in through the window. When the natural light was weak, we also used the Lempa LENSSO lamp, on which we mounted a 50 × 70 cm softbox. To complement the main light source, we mounted a silver Godox reflector on the opposite side, which also served to fill in shadows and reduce contrast. During the planning phase, we also defined static and animated elements for each frame.

2.1 Recording

We then proceeded with shooting, or capturing the planned motifs. We used a tripod to prevent the device from moving and to facilitate the subsequent creation of cinemagraphs. We recorded each planned scene multiple times to ensure that we had enough good seconds for further processing. We paid attention to the smooth movement of the subject and made sure that the start and end points of the movement were as similar as possible. This ensured the perfection of the animated loop, which made it easier for us to later process the video footage into an cinemagraph. To streamline and speed up the recording process, we also had an assistant to help us set up the light sources and, in particular, to help us manage the animated parts of the frame.

2.2 Editing

In the processing phase, we combined the created video material with a static image. First, we determined the static part of the final cinemagraph for the selected frame, and then we used a technique called layer masking to determine the animated parts of the frame. Using an appropriate motion loop, we connected these animated parts into a seamless motion with flawless transitions. Before the final export, we further refined the resulting cinemagraph by adjusting basic settings such as brightness, contrast and colour temperature. Where necessary, we retouched to remove any distracting elements that were created during shooting. The final animated photographs were exported in GIF format, while the static ones were exported in JPEG format.

2.3 Testing

The next step was testing, where we used eye-tracking technology to evaluate the effectiveness of messages in the animated and static adverts we created. We were interested in what the viewer notices first in static and animated advertisements and which element receives the most attention. The entire testing process was compiled and conducted using Tobii Studio software, where we created a meaningful sequence of tests by arranging individual slides. Each advertisement was displayed for 5 seconds, followed by a simple question with pre-set short answers. The participant could only select one answer for each question. As the tests took place at the Faculty of Natural Sciences and Engineering, we mainly tested students between the ages of 20 and 27, with some professionals or faculty staff also taking part. All participants were randomly invited to the tests and tested individually under the same conditions. Each test performed was recorded using the integrated Tobii Eye Tracker software, which tracked the participant's eye movements and recorded their path. To avoid a vast and unnecessary amount of data, we limited the recorded eye movements and fixations to designated areas of interest, which were subsequently marked for each advertisement. Primarily, we were interested in the areas of packaging, beverage and user or person (Figure 2).

Figure 2: Selected areas of interested on static and anymated forms of advertisements

Once we had created the segmentation of all tested advertisements, we defined the export parameters, with the most important being the time to first fixation and total gaze duration. We exported the data extracted with these selected parameters and then organised it more comprehensively in the Microsoft Excel programme for ease of use. In addition to the above parameters, we also exported the results of the responses, which we later used to verify the effectiveness of the messages conveyed in the created advertisements.

3. RESULTS WITH DISCUSSION

The initial result of the study is a series of eight animated advertisements, which are shown in Figure 3 in three sequences (initial, intermediate and final sequences).

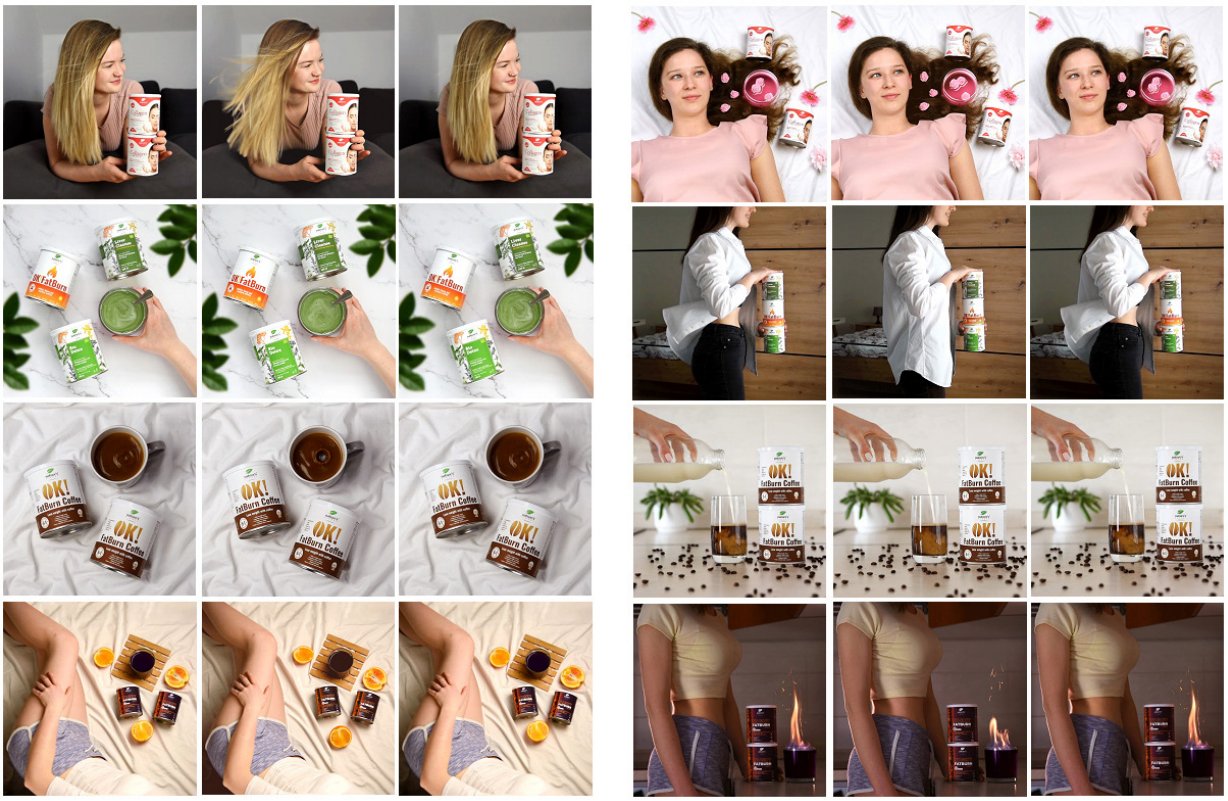

Figure 3: The series of eight created animated advertisements, presented with initial, intermediate, and final sequences

Based on the results of the test conducted, we can summarise that both forms of advertisments successfully attracted the attention of the participants. In both the static and animated forms of the advertisement, participants focused most of their attention on the designated areas of interest within five seconds, which also contributed to optimal final results and insights.

The test results showed that both forms of adverts effectively captured participants‘ attention. In both the static and animated forms of adverts, participants‘ interest was predominantly focused on the designated areas of interest. However, the measurements indicated that the animated form of the advertisement did not significantly influence faster perception by the participants compared to the static form. Most participants actually perceived a person, their posture or another static element that takes up a larger part of the frame more quickly in the animated form of the advertisement. Table 1 shows the average time it took participants to perceive one of the designated areas of interest in all static and animated forms of the advertisement. For static forms, participants took an average of 1.13 s, while for animated forms of advertisements, the time to first fixation was slightly longer. On average, participants needed 1.17 s before they focussed on one of the designated areas of interest.

Table 1: The average value, standard deviation, and coefficient of variation of the time taken by participants to the first fixation on designated areas of interest in static and animated forms of advertisements.

			Selected areas of interest [s]
Time to first fixation	**Static** advertising formats	$\bar{x}$	1.13
		S_x	0.51
		CV [%]	44.88
	Animated advertising formats	$\bar{x}$	1.17
		S_x	0.71
		CV [%]	60.18

Although animated details did not initially capture the viewer‘s attention, it turned out that the animation held the participants‘ attention for a longer period, without overshadowing the promoted products. Table 2 shows the average length of total observation of designated areas of interest that participants spent observing static and animated forms of advertisements. The total observation length of designated areas of interest was longer in animated advertisements, averaging 3.47 s, while participants observed designated areas of interest in static advertisements for only 2.93 s.

Table 2: The average value, standard deviation, and coefficient of variation of the total observation length spent by participants on designated areas of interest in static and animated forms of advertisements.

			Selected areas of interest [s]
Total visit duration	**Static** advertising formats	$\bar{x}$	2.93
		S_x	0.34
		CV [%]	11.78
	Animated advertising formats	$\bar{x}$	3.47
		S_x	0.55
		CV [%]	15.77

The longer observation time of designated areas of interest in animated advertisements also successfully influenced the final effectiveness of the messaging. With the help of answers to questions displayed after each advertisement, it was revealed that the percentage of correct answers in animated advertisements was higher than in static advertisements (Figure 4). Consequently, from the obtained results, we can infer that animation successfully contributed to better and longer perception of promoted products, even though it did not directly occur within their area.

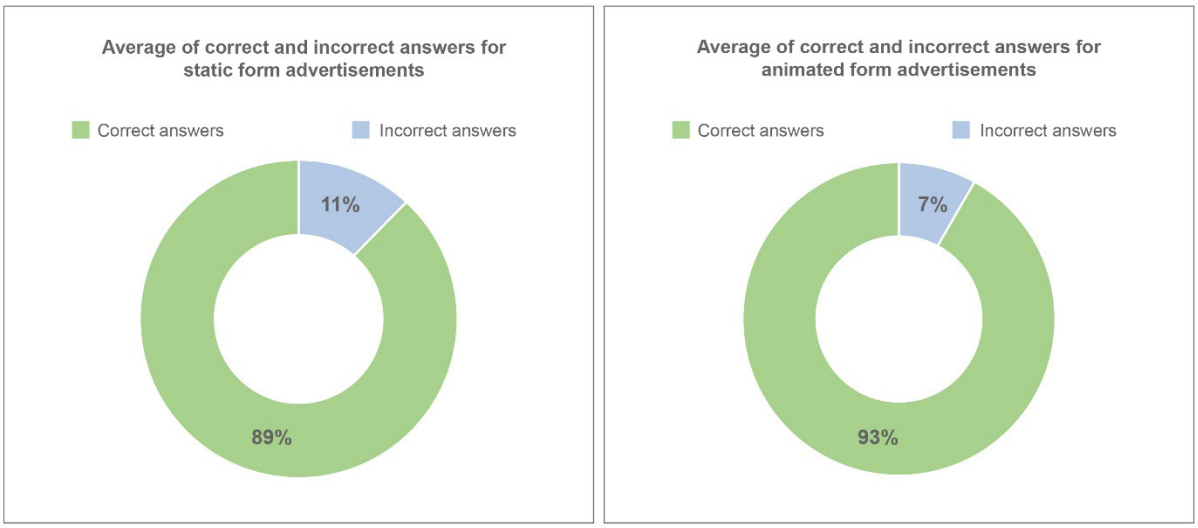

Figure 4: Display of the average of correct and incorrect answers to final questions in static (a) and animated (b) forms of advertisements.

4. CONCLUSIONS

Based on the conducted analysis, we find that the animated form of advertisement (cinemagraph), compared to the static form, had a more effective impact on the test subjects and their perception. The animated advertisement presented the promoted products to viewers in a more creative and consequently more interesting manner. The promoted products felt closer to them as they were depicted in a natural or everyday environment familiar to the users of the products. Consequently, they could more easily identify with the captured scenes, and due to animated details, they better understood the purpose and use of the promoted products. Although the animated details did not immediately capture the viewers‘ attention, it turned out that the gaze and attention of the test subjects were directed to the designated areas of interest for a longer period. This also successfully influenced the final understanding of the content of each advertisement, as the value of correct answers in animated advertisements was proportionally higher than in static advertisements. Commercial photography with animated details continues to evolve actively today and, as an important factor in modern messaging media, increasingly influences digital marketing. It offers the viewer a new dimension of observation while effectively influencing their attention and purchase decision.

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INFLUENCE OF ILLUMINATION AND OBSERVER ON PERCEPTION OF ELEMENTARY RED COLOUR

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Abstract. *The aim of the present study was to find out how an individual perceives and experiences the red colour. By relying merely on their long-term colour memory, observers selected a sample from a set of red hues that they believed represented the elementary red. The experiment was performed under controlled lighting conditions and the phenomenon of colour constancy was evaluated. In addition, the observation was repeated after a certain time delay to study the colour memory of the observers. Numerical evaluation of the colour constancy and colour memory was performed using the CIEDE2000 equation for colour differences. The results show that the most uniform response was observed under the daylight and the biggest differences were established under incandescent light, where observers on average tended to choose darker and less saturated colours. The analysis of short-term colour memory under daylight conditions showed considerable differences among the observers.*

Keywords: *colour, CIELAB, colour memory, colour constancy*

1. INTRODUCTION

Colour perception is a highly subjective process that depends on the characteristics of the individual's visual system as well as on his experiences and various environmental influences. Colour is an extremely powerful means of communication, which is used to advantage in the fields of art, science, technology, marketing, fashion and elsewhere. From the point of view of human evolution, the ability to perceive colour was developed with the aim of making it easier and faster to recognize objects and the environment and thus to assure better chances for survival.

In connection with this, scientists also explain the development of the ability of adaptation, i. e., the ability to recognize colour under different lighting conditions. Some characteristics of the human visual system can be modified in such a way that the colour is recognized despite smaller changes in the intensity or spectral composition of the light in which we are observing.

One of the consequences of the adaptation process is colour constancy. We speak of colour constancy if the apparent colour of the object does not change, even though the spectral composition of the light in which it is observed changes (Kuehni, 1997). From the perspective of the vision science, colour constancy is an example of perceptual constancy. It allows maintaining a stable mental representation of the colour of the object, despite the changes that occur on the retina due to change in light reflected from the object at the expense of changes in the illumination spectrum (Hurlibert, 2019). In this way, the ability to adapt and the phenomenon of colour constancy support our colour memory and memory in general.

In everyday life, we often deal with a situation where we want to compare two or more colours which are not observed simultaneously, but we have to help ourselves with an impression from the memory. Based on the experience, we store colour impressions in our long-term memory and thus build our own library of colour shades (Car, 2011). Comparison with the image from our long-term memory happens completely automatically and can be performed for objects of natural or artificial origin (Lewis, 2013). According to Pérez-Carpinell (1998), colour memory represents a sequential colour match that occurs when a certain amount of time elapses between observation and recall of a colour from memory. However, it may happen that when the colour of a certain object, i. e., the memory colour, is compared with a colour observed in the past, a change in colour appearance occurs and the two colours do not match (Seliger, 2002; Ratner, 1990). Obviously, our colour memory is not always reliable. Previous research on colour memory has shown that the results of testing depend on the choice of colours and the conditions of observation (Bynum, 2006). In addition, it turns out that colour memory research in which colours are

presented independently and without context is very rare (Pérez-Carpinell, 2006; Bynum, 2006; Pérez-Carpinell, 2008). The aim of our study was to find out how an individual perceives and experiences the colour red, which, in addition to green, yellow and blue, represents one of the four basic colours. Observers were asked to select a sample from a set of red hues that they believed represented the elementary red. The experiment was performed under different exactly defined lighting conditions and the phenomenon of colour constancy was analysed. In addition, the observation was repeated after a certain time delay in order to evaluate the colour memory of the observers. Numerical evaluation of colour constancy and colour memory was performed using the parameters of CIELAB colour space and the CIEDE2000 equation for colour differences.

2. MATERIALS AND METHODS

Using Illustrator and its colour swatch library, twenty red colour swatches were chosen for the experimental part. The swatches were printed as squares (3 cm × 3 cm) on paper (Microporous Satin 195 g/m^2, Papergraphics) using an ink-jet printer (Canon imagePROGRAF PRO-4000S). Four colour charts with the same twenty swatches were prepared. The position of the swatches changed with each chart, so the observers never observed the red swatches in the same position.

39 observers, students of the 4th semester Graphic and media interactions programme, took part in the study. The room where the observation took place was adapted, with neutral grey walls and no secondary light source. To reduce the influence of the surroundings on the visual assessment, a light booth (Judge QC, USA), which allows observation under well-defined illumination conditions (D65 (T_C = 6500 K), A (T_C = 2856 K) and FL2 (T_C = 4225 K)), was used. Furthermore, the colour charts in the light booth were positioned at a 45° angle to prevent glare during the visual assessment (Figure 1).

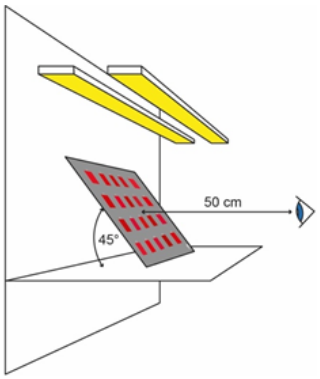

Figure 1: Schematic representation of the visual assessment.

2.1 Influence of illumination on perception of red colour and colour constancy

Observers were asked to select a sample from a set of 20 red hues that they believed represented the elementary red. The experiment was performed under defined lighting conditions with standard light source D65 (T_C = 6500 K), followed by the test light sources A (T_C = 2865 K) and FL2 (T_C = 4225 K). Numerical evaluation of colour constancy was performed on the basis of CIELAB colour space and the CIEDE2000 equation for colour differences (Hunt, 2011).
Colour was measured in accordance with ISO 13655 using a reflectance spectrophotometer i1 Pro (X-Rite, USA) on a white backing, with the CIE illuminant D65, A or FL2, respectively, standard 10° observer and 45°:a:0° measurement geometry. The most frequently selected sample at D65 was chosen as a standard. The results of colour constancy analysis are presented in Table 1.

2.2 Colour memory analysis

Observers were asked to select a sample from a set of 20 red hues that they believed represented the elementary red. The experiment was performed under standard light source D65 (6500 K) and
the observation was repeated after a certain time delay (9 - 10 min). Numerical evaluation of short-term colour memory was performed on the basis of CIELAB colour space and the CIEDE2000 equation for colour differences (Hunt, 2011). The results of colour memory analysis are presented in Table 2.

3. RESULTS AND DISCUSSION

3.1 Influence of illumination on perception of red colour and colour constancy

Observers selected a sample from a set of 20 red hues that they believed represented the elementary red, relying on the representation of the colour stored in their long-term memory. The experiment was repeated under different lighting conditions: under average daylight (D65), under incandescent light (A) and under fluorescent light (FL2). The analysis was made on the basis of measurements of CIELAB parameters (cf. Figure 2) and the assumption that the most frequently selected red sample at D65 illumination was considered as the standard.

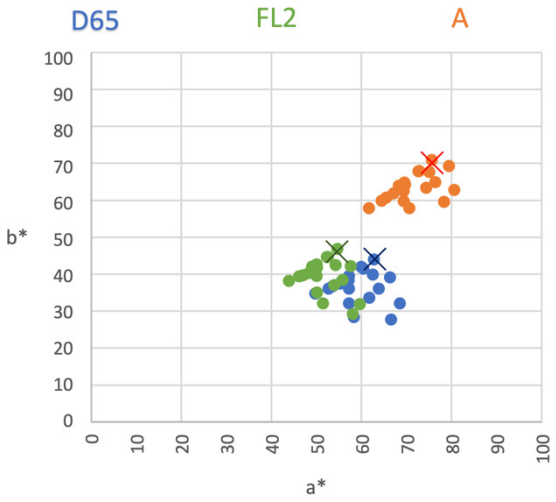

Figure 2: CIELAB parameters for all observers under average daylight D65, incandescent light A and fluorescent light FL2. (– the most frequently selected sample)

The results (Table 1) showed that the smallest deviations occur under the daylight as the average value of total colour difference was only slightly above the limit of detection ($\Delta E^*_{00} = 1.14$). The differences were mainly reflected as deviations in lightness and chroma; observers tended to choose slightly darker ($\Delta L^*_{00} < 0$) and less saturated samples ($\Delta C^*_{00} < 0$). The largest deviations appeared under illuminant A and they were mainly manifested as difference in lightness. The average differences were $\Delta L^*_{00} = -2.64$ and $\Delta C^*_{00} = -1.15$, meaning that observers chose darker and less saturated samples than the standard was. When observing under fluorescent light (FL2), the deviations were relatively small, and the average colour difference was $\Delta E^*_{00} = 1.97$. The contributions of all three parameters were very similar, with the difference in the hue slightly higher and negative ($\Delta H^*_{00} = -0.69$), which means that the observers chose samples that were, on average, more intensely red than the selected standard.

Table 1: Average total colour difference, ΔE^*_{00}, and differences in lightness (ΔL^*_{00}), chroma (ΔC^*_{00}) and hue (ΔH^*_{00}) at different conditions of illumination.

Illumination	ΔE^*_{00}	ΔL^*_{00}	ΔC^*_{00}	ΔH^*_{00}
D65	1.14	–0.78	–0.57	–0.22
A	3.58	–2.64	–1.15	–0.56
FL2	1.97	–0.53	–0.53	–0.69
D65 repeated	1.31	–0.78	–0.57	–0.24

3.2 Colour memory analysis

The observers' task was to choose from 20 samples the one they believed represented the basic red colour, relying on an image of the colour stored in their long-term memory. The procedure was repeated after a shorter time delay (9 - 10 min). Observation took place under controlled constant conditions using standard illuminant D65.

The results (Table 2) showed that 10 observers chose exactly the same colour in both cases ($\Delta E^*_{00} = 0$). Eight observers chose a colour that deviated only slightly from the originally chosen one ($\Delta E^*_{00} < 1$) and 19 chose a colour that considerably differed from the originally chosen one ($\Delta E^*_{00} = 1–5$). Two observers chose significantly different samples ($\Delta E^*_{00} > 5$) in the repeated observation. The average colour difference was 1.43 CIEDE2000 units.

According to results (Table 2), the differences were mainly manifested as a difference in chroma, which is true for 22 out of 39 cases. This shows that saturation is the property of colour that we remember the least accurate. The observers remembered the colour either as more saturated ($\Delta C^*_{00} > 0$ in 16 cases) or as less saturated ($\Delta C^*_{00} < 0$ in 13 cases). The smallest deviations occurred in hue recall. The difference in hue (ΔH^*_{00}) was below 1 unit in as many as 36 out of 39 cases, which means that the differences were minimal or undetectable. The deviations ranged from –3.21 to 1.73 units. Most of the values (18 out of 39) (cf. Table 2) were positive ($\Delta H^*_{00} > 0$), which means that the observers remembered the red samples as slightly more yellowish or orange. The differences in lightness ranged from $\Delta L^*_{00} = –4.39$ to 6.25 units, but only in five cases did it turn out that the difference in lightness was prevailing, i.e. greater than the difference in chroma or hue. Most of the observers (20 out of 39) remembered the sample as slightly darker ($\Delta L^*_{00} < 0$).

Table 2: Number of observers detecting total colour difference, ΔE*00, and colour differences in lightness, ΔL*00, chroma, ΔC*00, and hue, ΔH*00; Total number of observers: 39.

Colour difference	Number of observers
ΔE*00 = 0	10
0 < ΔE*00 < 1	8
1 < ΔE*00 < 5	19
ΔE*00 > 5	2
ΔL*00 = 0	10
ΔL*00 > 0	9
ΔL*00 < 0	20
ΔC*00 = 0	10
ΔC*00 > 0	16
ΔC*00 < 0	13
ΔH*00 = 0	10
ΔH*00 > 0	18
ΔH*00 < 0	11

4. CONCLUSIONS

The aim of the study was to establish how an individual perceives and experiences the colour red, which represents one of the four basic colours. Observers were asked to select a sample from a set of red hues that they believed represented the elementary red, relying on their long-term colour memory. The results showed that the perception of colour is influenced by subjective differences among the observers as well as by lighting conditions. The most uniform response was observed under the daylight (illuminant D65) as the colour differences were the smallest in this case. The biggest differences were established under incandescent light (illuminant A), where the observers on average tend to choose much darker and less saturated colours. In the case of fluorescent light (FL2), however, the deviations were only slightly larger than in daylight and much smaller in comparison to incandescent light, which can probably be attributed to the fact that the D65 and FL2 light spectra are more similar, thus the colour constancy is more likely.

Analysis of the short-term colour memory under the daylight conditions showed considerable differences among the observers. Approximately one quarter of a test group chose exactly the same colour on repeated trials ($\Delta E^*_{00} = 0$), on the other hand, approximately one half chose a colour that differed moderately or even strongly from the original (ΔE^*_{00} above 1). It turns out that we remember colour hue the best and the saturation the least accurate.

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DESIGNING CORPORATE IDENTITY FOR ABECEDNE URICE

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Abstract: *In today's world, a corporate identity is of great importance. This study describes the development of integrated graphic identity for the company Abecedne urice. The company deals with proofreading and learning assistance in Slovenian. First, we defined the target group and analysed corporate identities of similar companies. We presented the process of designing a corporate identity from an idea to the final product, which we supported with a survey among 45 potential customers of the company. In the survey, we tested six different design solutions for the logo, their meaning and associations, as well as different colour combinations. Based on the results of the survey, we shortlisted suitable symbols and elements for the logo design as well as colours that would match the company's activities. The products are a logo, business card, letterhead, envelope, folder, email signature and a Facebook profile picture thumbnail.*

Keywords: *company Abecedne urice, corporate identity, designing, logo*

1. INTRODUCTION

Corporate identity is a comprehensive graphic solution for a company or a brand, representing it to the public. It expresses the identity of a company and, on a symbolic level, communicates its values, goals and activities. A consistent use of corporate identity builds trust with customers and facilitates recognition among competitors. The main components of corporate identity are a symbol or logo, typography and colour scheme (Repovš, 1995; McAdam, 2018; Celostna grafična podoba, 2023; Corporate identity, 2023). Manuals with guidelines on individual corporate identity describe the use of graphic elements and their possible variations, including colour, element size, chosen typography, iconography, patterns and textures related to the brand. The purpose of such manuals is to ensure the consistency and recognisability of the brand and facilitate the creation of visual materials (Corporate identity, 2023). A logo is a visual element or graphic symbol that represents a brand or a company. It is a crucial part of corporate identity as it enables the first interaction with potential customers (Grove, 1997). There are seven main types of logos, i.e. emblems, symbolic or pictorial logos, wordmarks, monograms or lettermarks, abstract logos, mascot logos and combination logos (Mollerup, 1999; Barnhart, 2021; Morr, 2023). Additional types could include logos with letters inside shapes, negative space logos, dynamic logos, 3D logos and animated logos (Velarde, 2023). The colour scheme represents the selection of colours used for the visual representation of a company or a brand, including the choice of primary colours, their shades, the relationship between them and their application on different materials (Wheeler, 2013). Typefaces are an important design element that can influence the message and recognisability of a brand or a logo. The choice of typefaces can create different impressions; hence, it is essential to select the right typeface for a specific purpose and target audience (Ditrih, 2010).

The aim of the study was to create a corporate identity to increase brand recognition of the company *Abecedne urice*, which was founded in 2022.

2. EXPERIMENTAL

The company *Abecedne urice* deals with proofreading and learning assistance in Slovenian, and needs corporate identity. Initially, we discussed with the founder the preferences for the company's corporate identity. We analysed eight companies in a similar field and identified the target users of the services offered by the company, i.e. parents of elementary school pupils, secondary school students and university students. During the development of the corporate identity, we performed a survey to assess the suitability of conceptual and design solutions. The survey was conducted by means of the online survey application 1KA. Through this platform, we sought information on which logo sketch respondents preferred. We specifically asked whether the version selected by the client effectively conveyed the core message of the company, i.e. learning hours or reading hours. We wanted to create several variations, taking into account the opinions and suggestions of survey participants.

The survey comprised 17 questions, including eight related to design, three on the use of the Facebook social network, two questions regarding the demand for company services and four general questions about the respondents.

3. RESULTS WITH DISCUSSION

3.1 Online survey

Survey responses were received from 45 respondents. The majority of participants, i.e. 34 (76%), were aged between 16 and 30 years. Among them, 14 (32%) were secondary school students and 15 (34%) were university students. Unfortunately, not all respondents (45) answered all questions. Some provided responses to most questions, but not all.

The first design-related question was: “What symbols, things, or images come to mind when you think of the word proofreading?” Various responses were received, including book or text, letter, pen, correction or proofreading mark, punctuation, glasses or eyes, red pen, teacher or proofreader, computer or keyboard. Most respondents, i.e. 19 (28%), associated proofreading with books and different texts (e.g. essays, theses, notes, documents).

The second question was: “What symbols, things, or images come to mind when you think of the term learning assistance?” Again, the most common response was a “book” (Table 1). Based on the responses to the first two questions, it can be inferred that the chosen symbol for the logo is appropriate.

Table 1: Common responses to question two: “What symbols, things, or images come to mind when you think of the term learning assistance?”

Book, textbook	**Teacher, instructor**	**Note-book, note**	**Pupil**	**Pen**	**Instruction**	**Mathematics**	**Hand**	***Together***
12 (30%)	7 (18%)	5 (13%)	4 (10%)	3 (8%)	3 (8%)	3 (8%)	2 (5%)	39 (100%)

The third question was: “What does the symbol in the picture remind you of? Write three associations you have with this image.” Alongside the question, a picture of the initial version of the colour logo was provided (Figure 1). There were numerous responses. We compiled the recurring ones in Table 2. We ignored those that appeared only once if they did not fit into any category. The majority of respondents understood the clock symbol as representing time, often mentioned in various word combinations or standalone (17 times). The most common associations were learning, followed by a battle with time (time pressure, lack of time), school or lesson, and in the fourth place by frequency of mentions, the phrase “lesson hour” or “reading hour,” representing the intended meaning.

Figure 1: Attached image for third and sixth question in survey regarding representation of symbol

Table 2: Common responses to question three: "What does the symbol in the picture remind you of? Write three associations you have with this image."

Learning	Battle with time	School, lesson	Lesson or reading hour	Reading	Hour	Exam	Writing	*Together*
24 (33%)	13 (18%)	10 (14%)	9 (13%)	6 (8%)	5 (7%)	3 (4%)	2 (3%)	72 (100%)

The fourth question included a rating scale (from 1 (inappropriate) to 5 (appropriate)) in which respondents evaluated the suitability of the initial sketches (Figure 2) for the company's logo. With this question, we wanted to assess whether the client's preferences aligned with the opinions of customers and potential clients. Sketch number 1 was mostly rated as "more appropriate than inappropriate," sketch 2 received lower ratings, with 12 (28%) respondents giving it an "inappropriate" rating, and 13 (30%) respondents being neutral. Among all the sketches, sketch 3 received the most votes for being "appropriate," with 15 (35%) respondents giving it this rating. Sketch 4 was also considered "appropriate" by 12 (27%) respondents, "more appropriate than inappropriate" by 21 (48%) respondents and 10 (23%) respondents remaining "neutral"; one (2%) marked it as "inappropriate". Sketch 5 received lower ratings regarding suitability, with 13 (30%) respondents rating it as "more inappropriate than appropriate" and 8 (19%) as "inappropriate." Sketch 6 was deemed "appropriate", with 13 (30%) votes for "appropriate" and 15 (35%) for "more appropriate than inappropriate." In terms of the number of votes for "appropriate," the sketches ranked in the following order: sketch 3, sketch 1, sketch 6, sketch 4, sketch 5 and sketch 2. The sketch chosen by the client, i.e. sketch 4, appeared more suitable than inappropriate to the respondents. 33 (75%) out of 44 (100%) participants gave it a positive rating, only 1 (2%) rated it negatively, and the remaining 10 (23%) were neutral.

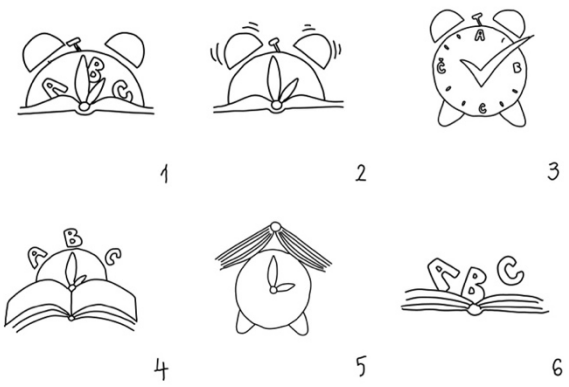

Figure 2: Initial sketches attached to fourth question of survey

With the fifth question, we checked whether the initial colour symbol is according to the respondents suitable for the company's logo. In response to the question accompanying the symbol: "Do you find the combination of the book and clock symbol appropriate for the logo of the company *Abecedne urice*, which deals with proofreading and provides educational assistance?" we received the following answers: 31 (70%) respondents marked the image as "appropriate," 1 (2%) as "inappropriate," 10 (22%) were undecided, and 3 (7%) added a comment or remark. The fifth question was answered by 45 (100%) participants.

The sixth question involved a rating scale that further examined how respondents interpreted the symbolism of the sign. In response to the question "How much does the symbol shown remind you of written words? For each, indicate the strength with which the image in the picture reminds you of the chosen word," Figure 1 was again provided. The evaluation results are shown in Table 3. From the results, we can infer that the initial symbol does not represent the alphabet or the Slovenian language, as most respondents do not associate it with these concepts. According to the ratings, the symbol effectively represents learning, an alarm clock and hour, a book, reading and a lesson.

Table 3: Ratings for question six: "How much does the symbol shown remind you of written words?"

Word or phrase	The least	A little	**Neutral**	**Very**	**The most**	***Together***
Alphabet	**24 (53%)**	16 (36%)	2 (4%)	1 (2%)	2 (4%)	45 (100%)
Hour	1 (2%)	2 (4%)	7 (16%)	**19 (42%)**	16 (36%)	45 (100%)
Lesson support	6 (13%)	7 (16%)	**16 (36%)**	13 (29%)	3 (7%)	45 (100%)
Proofreading	13 (29%)	12 (27%)	**16 (36%)**	2 (4%)	2 (4%)	45 (100%)
Lesson	1 (2%)	1 (2%)	10 (22%)	**20 (44%)**	13 (29%)	45 (100%)
Learning	0 (0%)	3 (7%)	1 (2%)	18 (40%)	**23 (51%)**	45 (100%)
Wakening	7 (16%)	**13 (30%)**	8 (18%)	11 (25%)	5 (11%)	45 (100%)
Alarm clock	8 (18%)	6 (13%)	6 (13%)	11 (24%)	**14 (31%)**	45 (100%)
Slovenian language	**12 (29%)**	11 (24%)	11 (24%)	8 (18%)	2 (4%)	45 (100%)
Book	0 (0%)	3 (7%)	7 (16%)	**23 (51%)**	12 (27%)	45 (100%)
Reading	0 (0%)	5 (11%)	7 (16%)	**20 (44%)**	13 (29%)	45 (100%)

The seventh question was also an open-ended one, focusing on colours. The question was: "What colours do you associate with companies that are engaged in education and proofreading? Why?" Table 4 shows how many times each colour was mentioned in responses. Blue was mentioned by 19 respondents, associating it with wisdom and learning. Yellow was linked to positivity. Based on the answers to the fifth and seventh question, we selected suitable colours for the logo.

Table 4: Number of answers about colours at question seven

Blue	**Yellow**	**Red**	**Green**	**White**	**Black**	**Vivid colour**	**Gray**	**Orange**	***Together***
19 (30%)	13 (20%)	12	7 (11%)	4 (6%)	3 (5%)	3 (5%)	1 (2%)	1 (2%)	63 (100%)

The eighth question was a closed-ended one with an option for comments, assessing the appropriateness of the colours in the initial version of the symbol. To the question "Do you find the choice of colours suitable for the logo of the company *Abecedne urice*?" we attached a colour scheme (Figure 3) of the symbol at that time. 41 (91%) respondents marked the colours as appropriate, 1 (2%) as inappropriate, 1 (2%) was undecided, and 1 (2%) provided comments, suggesting that the colours could be more vibrant and fewer in number.

Figure 3: Attached colour scheme to eighth question

With the analysis of the survey results, we found that the initial version of the logo represents lesson or reading hours well in the eyes of the respondents. However, it does not evoke impressions related to the Slovenian language and the alphabet. More than half of the respondents found the symbol (clock and book) suitable for the logo of the company *Abecedne urice*.

Based on the results of questions related to the Facebook network, we can conclude that despite a large number of registered users, the platform may not be the most effective one for expanding brand awareness. It would make sense to include other media channels in the company's advertising strategy.

3.2 Design results

Based on the survey results, we made some changes to the logo design (Figure 4) as the client preferred. We adjusted the final colour scheme by eliminating yellow tones and cyan colour. We retained red, white and blue; however, with modified tones. The colour scheme (Figure 4) consists of red (C0 M100 Y100 K0), light blue (C32 M17 Y0 K0), dark blue (C100 M90 Y0 K0) and additional white (C0 M0 Y0 K0). Blue represents wisdom and trust, while red is a vibrant colour that attracts attention. Blue, being a cool colour, could appear too calm on its own; therefore, the warm red adds a lively touch. Both red and dark blue are saturated colours, while light blue is less saturated, closer to pastel shades.

We used the Montserrat typeface in both bold and regular styles for all business materials (Figure 4). Montserrat is a geometric sans serif typeface with angular terminals. With 18 variations, it is suitable for both large and small formats, ensuring good legibility. When combined with basic colours, it conveys a sense of regularity. The primary typeface can be paired with a secondary one, i.e. Source Serif Pro. This typeface belongs to the transitional type style, offering excellent legibility, especially for longer texts. Its bold version is used for titles and emphasis, while the regular version is employed for longer text passages.

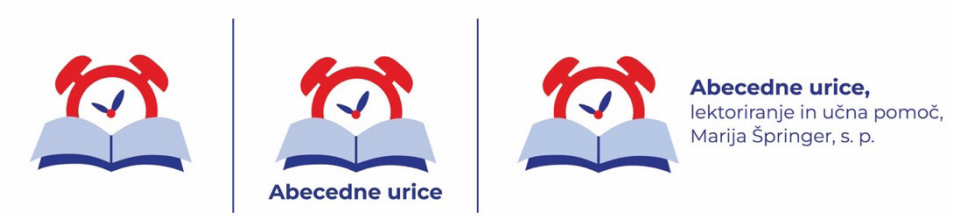

Figure 4: Logo sign with and without typeface

Additionally, we created a black-and-white version of the logo, both in positive and inverse variations. The graphic identity products (Figure 5) include a logo, business card, letterhead, envelope, folder, email signature and a Facebook profile picture thumbnail. We also prepared a corporate identity manual.

Figure 5: Some products of corporate identity

4. CONCLUSION

This study describes the development of an integrated graphic identity for *Abecedne urice*, a company founded in 2022. The company deals with proofreading and learning assistance in Slovenian. The aim of the study was to create a corporate identity to increase the company's visibility. First, we defined the target group and analysed corporate identities of similar companies. In the survey of 45 potential customers, we tested six different sketched draft solutions of a logo, their meaning and associations, as well as different colour combinations. Based on the results of the survey, we shortlisted suitable symbols and elements for the logo design as well as colours that would match the company's activities. The products of graphic identity are a logo, business card, letterhead, envelope, folder, email signature and a Facebook profile picture thumbnail. The client was satisfied with the design solutions for various products.

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CHARACTER DESIGN AS A MEANS OF EXPRESSION FOR SUCCESSFUL ANIMATION

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Abstract: *This paper investigates the creation of suitable characters for animations and provides guidelines for successful design. Through a five-phase research process: categorization of character features, illustration of a representative character, character likability testing on viewers (self-assessment questionnaire regarding the suitability of the utilized features of the character for subsequent animation), AI-based eye tracking analysis and interpretation of the results, the paper categorizes the important attributes for character design, illustrates a representative character, and analyses likability. Within the attributes important for designing the character, namely face, body, posture/pose, and style, we examined the use of features such as proportion, geometric figure, emotion, action line, symmetry, and weight distribution (in the pose) and their variations in the illustration work. The results suggest that proportions, geometric figures, and emotion are important to a character's face, while when evaluating character's body, the respondents prefer asymmetric poses and dynamic action lines.*

Keywords: *character design, animation, design features, self-assessment questionnaire, AI-based eye-tracking*

1. INTRODUCTION

Animations are a communication tool for emotional involvement and responsiveness, especially when they are based on a character and their story. Creating a suitable character that convinces and attracts the audience is crucial for successful further animation or desired communication. This is achieved by carefully considering the character's personality, based on which a convincing and believable visual image of the character is created through a sophisticated design. To ensure the character is appealing and charming, it is best to follow specific recommendations regarding the character's design, including facial and figure proportions, silhouette, geometry, emotional expressiveness, plot development, symmetry, etc.

The most important emotional expressions and micro-movements of the emotional state are in the face of the character. The study (Stres, 2022) examines how animated facial expressions are perceived for six basic emotions: happiness, sadness, anger, surprise, fear, and disgust. Using micro-animation techniques, three levels of intensity were generated for each emotion and participants were asked to identify the emotions in the animations. The results show that the perception of emotions varies according to intensity and emotion type. The study of authors Chen (2020) analyses the importance and influence of the design of facial features in animated characters. Facial features are the key to creating realistic and believable characters that can attract and hold the viewer‘s attention. The paper examines various aspects of character facial design, focusing on elements like facial proportions, eye, nose, and lip shape and size, and their interrelation, influencing expressions and emotions. When designing an animated character, we consider the target audience and intended use of it is also crucial. This is shown in the research of the author Pintarič (2017), which explores the development of a digital animated character for a mobile educational application targeting children. The study details the design process, including analyzing interactive story and character, illustrating, and animating the environment and character. The research findings provide insights into the development of effective mobile educational applications for children. The researchers also propose advanced techniques that include the analysis and classification of characters and their characteristics using neural network technologies (Islam, 2011) and when the characters are implemented in mixed realities environments (Piankarnka, 2023). These methodologies involve annotating character images, generating silhouettes, developing an online game for user feedback, analyzing data in stereotype label and character shape spaces, training a neural network classifier, and mining Bayesian graphs. The results suggest valuable interventions in drawing design and show that mixed reality can also be an effective tool for developing practical skills in drawing design for animation.

The aim of the research was to review and summarize character design guidelines to further animate and categorize important design features of both the face and body of the character. We only included illustrations in the study as an illustrative plan for animations. The goal was to illustrate the author's character based on the feature categories studied. A series of character illustrations were created by drawing changes to the character's face and body to test likeability and suitability for animation. The study focused on mastering character illustration skills based on specific traits and assessed appropriateness and effectiveness through participant tests.

2. EXPERIMENTAL

The experimental framework comprised 5 phases.

A. Determining the key features for the design of the illustrated faces and bodies of the characters
Based on the reviewed literature, we identified key elements crucial for designing the illustrations of characters' faces and bodies. These were geometric shapes, proportions, and emotions. Additionally, we depicted various poses applying principles such as symmetry, action line, and considerations of weight and balance.

B. Drawing, illustrating the faces and bodies of the characters
The illustrations were made utilizing the Procreate application on a 3rd generation iPad Pro featuring an 11-inch display in conjunction with the second-generation Apple Pencil. Illustrations were made in accordance with the analyzed elements, including geometric shapes, proportions, emotions, symmetry, action line, and consideration of weight and balance distribution. These illustrations were executed in alignment with author's personal style.

C. Testing the character illustrations on the participants in the form of questionnaires
a.) semantic differential (including sections 1-5 regarding face and body geometry, proportions and facial expressions) and b.) personal evaluation or viewpoint regarding the appeal of the character's facial features, satisfaction with the character overall, and its appropriateness for use in animation (including all 8 test sections, in addition to the aforementioned sections (1-5) the study explored various poses related to symmetry, action line, and weight distribution).

The questionnaires displayed illustrations of faces and bodies, organized by geometric shapes, facial proportions, emotions, and diverse poses. Faces included shapes like square, triangle, and ellipse (Figure 1a, while bodies featured geometric forms (square, triangle, circle, hourglass), varied proportions (small, normal, tall) – Figure 1b, and poses categorized by symmetry, action line, and weight distribution – Figure 1c. The testing took place on 46 graphic arts students who volunteered to participate in the study based on informed consent. Dates of the testing were the 14th and 15th of January 2024. We conducted self-assessments of our character illustrations through participant feedback obtained via two distinct questionnaires. The test protocol was: explanation of the test procedure, passing and signing of the informed consent form, 20 minutes of testing in two groups (2 street students). The first group of 30 students selected the most suitable character based on provided information (Figure 1a), while the second group of 16 students utilized a semantic differential, rating facial features on a Likert scale from 1 to 5 (Figure 1b). The semantic differential test was slightly shorter as it only involved analyzing the faces and bodies of the characters and not their poses. The illustrations of the characters were shown to the participants via a projector in the classrooms and structured in 8 assemblies: face geometry, face proportions, face emotions, body geometry, body proportions, pose symmetry, pose action line, and pose weight and balance. The questionnaires were in printed form.

D. Analysis of the character illustrations with AI-based eye tracking
We used an artificial neural network-powered solution expoze.io (https://www.expoze.io/) to investigate whether differences in facial geometry and proportion can influence a user's visual attention (Zuza, 2022). Heatmaps were generated using the normal preset and standard jet colormap.

E. Analyzing and interpreting the results in Excel.

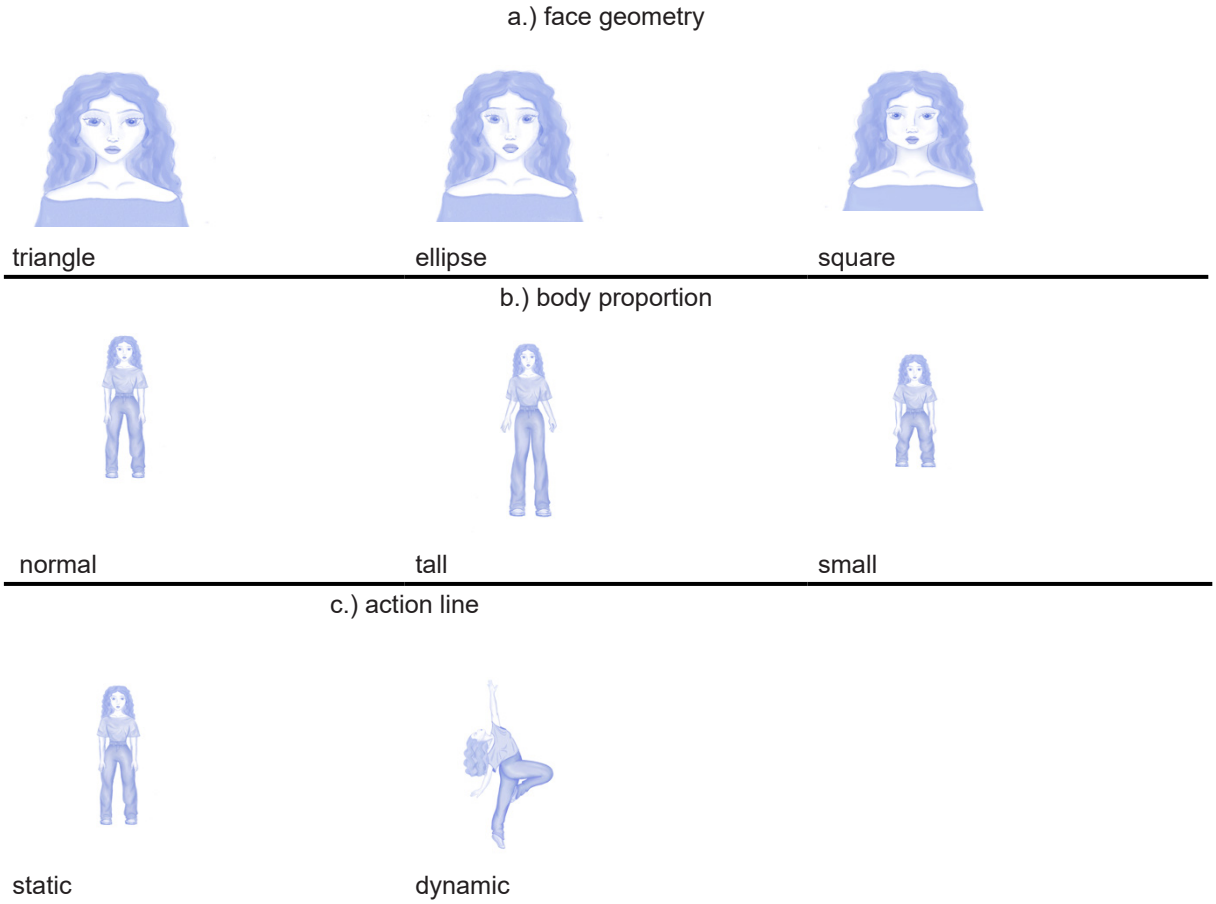
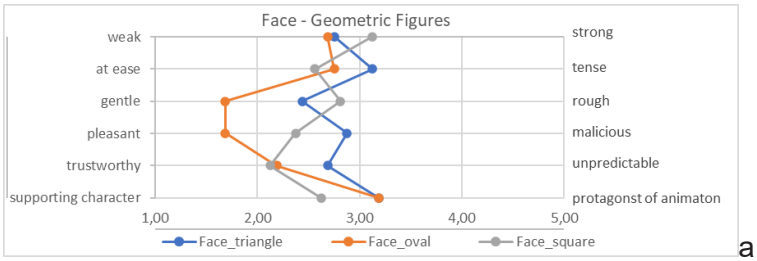


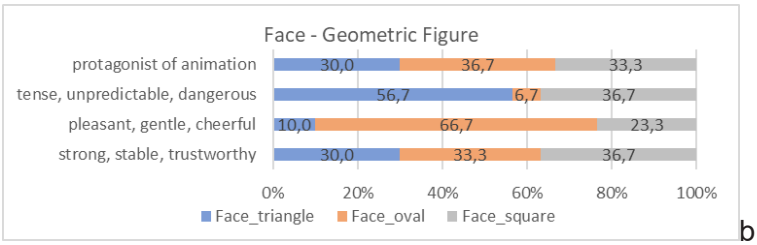
Figure 1: Examples of illustrations of character faces with variations in geometry features (a), body proportions (b.) and body action line (c).

3. RESULTS AND DISCUSSION

In Figure 2 the results of semantic differential (a.) and self-assessment based on participants' opinion (b.) about the appearance, likability, and possible use for animation of the character faces with variations in geometry features are presented.



a.)



b.)

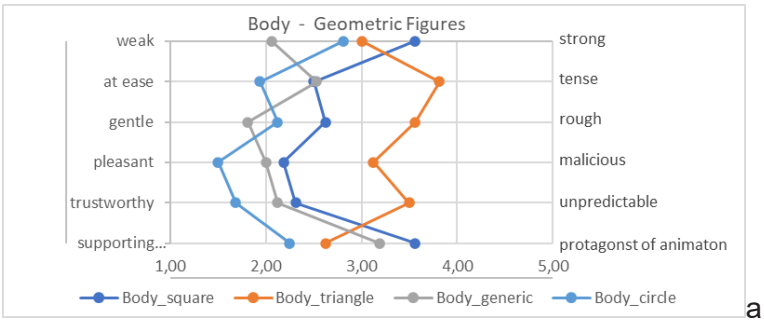
Figure 2: Results of semantic differential (a) and participant self-assessment (b) on character faces with varying geometric features.

36.7% of participants exhibited a subtle tendency towards the notion that a square-faced character evokes sentiments of strength, stability, and trustworthiness (Figure 2a). Nevertheless, the deviation is insufficient to derive meaningful conclusions, thereby precluding the confirmation of our thesis. The outcomes pertaining to a character with an oval face were anticipated and aligned with our expectations. 66.7% of participants agreed that the character exhibited qualities of gentleness, pleasantness, and cheerfulness. Consequently, we can confirm our thesis that suggests that characters with soft facial features are typically perceived as described above. The findings from our two questionnaires diverged in their evaluation of a character with a triangular face. The semantic differential analysis failed to provide definitive insights for triangle-shaped faces, as responses did not manifest distinct extremes, making it difficult to draw definite conclusions. Conversely, our alternative questionnaire yielded valuable information, indicating that 56.7 % of respondents perceived the character with triangle-shaped face as tense, unpredictable, and dangerous. While these results align with our initial thesis, it is noteworthy that they lack consistency with the outcomes of our other survey. The participants expressed varied viewpoints regarding the most appropriate facial features for a protagonist. Anticipating a preference for the character with an oval-shaped face, commonly associated with lead roles (Chen, Chen, and Hsieh, 2020), we found that participants did not consistently favor this choice (only 36.7% agreed). Traditionally, triangular faces are more prevalent among villains due to their sharper features. However, our research suggests that the geometric configuration of a face may not significantly impact the selection of a protagonist's appearance.

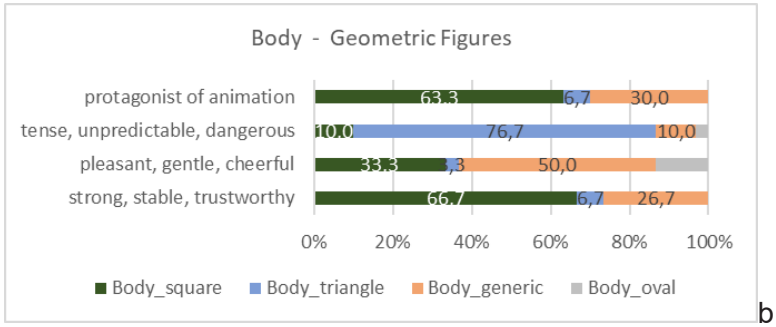
The analysis of the face proportions showed that 66.7% of participants consistently preferred the generic face in line with industry norms for young female characters. The characters with exaggerated proportions, while intriguing, ranked lower. The majority (63.3%) deemed a standard face most suitable for a protagonist, confirming expectations. Despite interest in exaggerated features, the trend aligns with the idea that standard faces are most suitable for a protagonist in this demographic.

In the part about facial expressions, participants uniformly identified angry and cheerful facial expressions as the most expressive ones, with a slightly lesser degree of expressiveness attributed to the fearful face. Despite this, the character is expressive and proficient in conveying diverse emotions, as confirmed by the respondents (100% of respondents agreed).

In Figure 3 the results of semantic differential and self-assessment based on participants' opinion about the appearance, likability, and possible use for animation of the character body with variations in geometry features are presented.



a.)



b.)

Figure 3: Results of semantic differential (a) and self-assessment based on participants' opinions about the appearance, likability, and possible use for animation (b) of the character bodies with variations in geometry features.

Answers about the influence of geometry features on a character's body indicate that participants perceived a character with a square-shaped body as powerful, evoking stability and being suitable for a protagonist role in both surveys. Hence, in accordance with our anticipated outcomes, we can infer that the square-shaped body is perceived as indicative of strength and stability. Moreover, the majority (63.3 %) deemed this body shape as the most suitable for a protagonist. This body type has been increasingly prevalent in the industry over recent years, leading individuals to potentially exhibit a greater familiarity with it and, consequently, favor its selection (Rowe, 2019). Triangular body shape consistently conveyed malevolence, especially tension, while generic body type was perceived as gentle, pleasant and to some extent trustworthy. The results for triangle-shaped body were expected, thus confirming our thesis. The circular body was associated with friendliness and calmness while being judged on its own, but interestingly being overlooked while being considered with other body types. This may lead us to believe that its soft shape makes it seem like a gentle, friendly, and calm character, as our thesis suggests. However, the form appears to be overshadowed by other body types in the questionnaire.

Lastly, we examined the influence of proportions, symmetry, action line and weight and balance on body appearance, likability, and the possible use for animation. Combined findings of both questionnaires indicate that participants perceived low-stature and high-stature characters (Figure 1b) as unsuitable for a protagonist, appearing somewhat clumsy, while a character with standard body proportions was consistently regarded as the most likable, elegant, and suitable for a leading role (as much as 80% participants agreed that it would be best suited for a starring role). Findings also revealed that 96.7% of respondents preferred asymmetric poses, confirming increased pose dynamics, and all respondents (100%) preferred dynamic action lines, emphasizing the potential for enhanced viewer engagement and animated appeal (Kosmos, 2022). The study suggests that uneven balance distribution in drawings does not yield a more natural outcome than uniform distribution, emphasizing the potential influence of drawing quality on observed results.

After analyzing the heatmaps generated by AI, it was found that there were no significant differences between them, despite using different facial geometries and proportions. Even though the shapes of the hotspots varied slightly (as shown in Figure 4), the heatmaps were too uniform to be considered valid, particularly when compared to previous studies that utilized actual eye-tracking devices (Iskra, 2019).

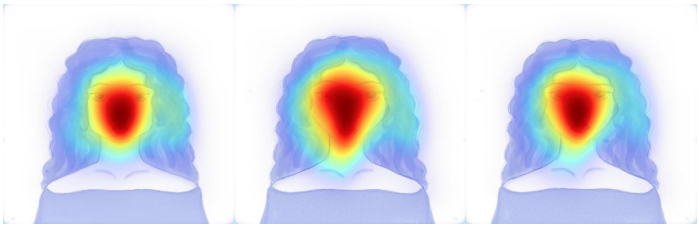


Figure 4: Heatmaps generated by AI for characters with different facial geometries and proportions

4. CONCLUSIONS

Our research emphasizes the ongoing significance of thoughtful and strategic character design in the ever-expanding field of animation. The objective of this study was to explore geometric figures, proportions, emotions in relation to face and body, and poses based on distinct attributes. Notably, participant feedback revealed a preference for characters with standard face and body proportions, emphasizing their appeal and suitability for leading roles. Additionally, our research presented connections between geometric shapes and distinctive character attributes. However, the face shape of the character does not impede its capability to take on the role of the protagonist. Whether applied in educational applications, digital learning, or entertainment, adept character design emerges as a pivotal force in communication and engagement. Essentially, character design surpasses animation step; it is a vital link connecting creators with viewers, influencing the success of projects. The study is subjected to certain limitations, notably a singular character focus, potentially influencing perceived results. Broader character inclusion would enhance findings' significance and relevance. Furthermore, increasing participant numbers could address the limited participant pool, strengthening result importance and reliability. Additionally, the quality of drawings may also impact outcomes.

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THE USE OF ANIMATION AS A TEACHING TOOL TO LEARN ABOUT THE MEANING AND FUNCTION OF OZONE

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Abstract: *This study explores animations as a teaching tool for understanding ozone, focusing on memory and comprehension. After reviewing existing research, a technical text about ozone was transformed into an animation. Two test groups learned about ozone: one through the animation, the other by reading the text. Afterwards, both groups were tested on memory and comprehension. Results showed the animation group performed better, supporting the hypothesis that animation enhances learning in natural sciences. The discussion interprets these findings and highlights the potential of animation as a valuable educational tool.*

Keywords: *didactic animation, memory, comprehension, ozone, comparative analysis*

1. INTRODUCTION

Memorization and comprehension are an essential part of the learning process and is achieved in traditional teaching through the use of printed material (textbooks), which has been increasingly supplemented in recent decades by the inclusion of ICT, multimedia content and also animation (Huk, 2003). Theoretically, the use of animations suggests two basic assumptions about their role in learning. Many animations are used to fulfil an affective function, i.e. to attract attention, engage the student emotionally in the learning process and maintain motivation. However, animations can also fulfil a cognitive function and thus facilitate learning, as they can help the learner build a more accurate mental model of how the system works than static graphics and images alone (Malamed, 2016).

Memorization is the retention of ideas, thoughts, data in consciousness, in memory and is defined as the storage of information in long-term memory in such a way that this information can be easily retrieved (Seel, 2012). Comprehension is a psychological process that relates to an abstract or physical object, such as a person, situation, or message, and in which a person is able to use concepts to form and understand that object (Beireiter, 2002).

Researchers have studied academic achievement and found that the most common factors that can be used to explain individual differences in students' learning performance are psychological characteristics and family factors, as well as broader social factors (Mullis, 2004). Animations that stimulate cognitive processes - the cognitive role can facilitate learning because they provide more information than static graphics. They have the potential to help the learner build a more accurate mental model of system behaviour compared to static graphics and static images (Hegarty, 2002). There are many functions that animations can serve, such as (Perovšek, 2018): explaining a dynamic process, visualizing things that cannot be seen with the naked eye, simulating a system, representing abstract concepts, telling a story, etc.

Researchers' opinions on the impact of animation on memorization, comprehension and learning are divided (Perovšek, 2018). Researches show that the effectiveness of using animation as a teaching tool depends on the area of application, the presentation techniques used and the combination of moving images with other visual and acoustic elements. More research has been done in engineering and natural sciences, as predictions about the effectiveness of animations for memorization and comprehension are higher in these areas (Zaman, 2010). Educational animations have a positive effect on learning, the animated version of the learning material is clearer as it provides more motion information and constantly shows all aspects of changes (Mayer, 2009), animations are also more successful in showing abstract concepts (Hari Narayanan, 2002) and phenomena and processes that cannot be observed by human eye (Starbek, 2010).

The purpose of the research was:
- to investigate animation and its use in education and the factors that influence memorization and comprehension;
- to create an educational animation on the topic of the ozone layer and
- to analyse the learning performance of the animation and test memorization and comprehension.

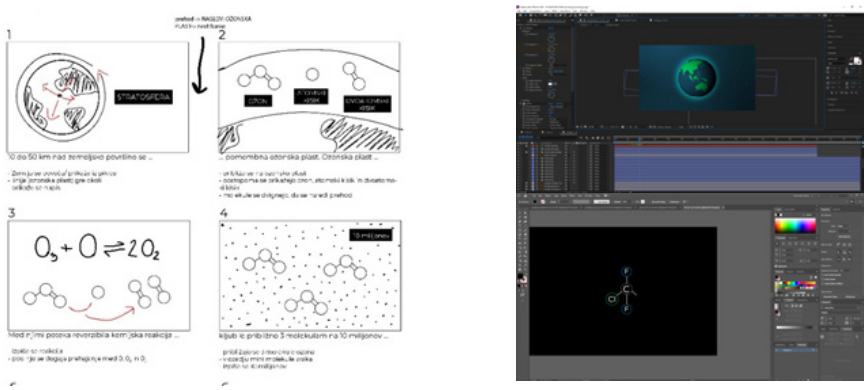
Before we begin with the research work, we hypothesized the following:

H1: The use of animation improves memorization and comprehension of the topic of ozone compared to a static text approach (text-based educational material).

2. EXPERIMENTAL

The research work began with the choice of topic, we wrote a text for reading tests and animation narratives (Farman, 1985, US EPA, 2017; reviewed by an expert in the field). We created the animation storyboard, in which we considered the meaningfulness and professionalism of the content, Mayer's principles, the dynamics of the scene, movement design and composition. This was followed by the sketching and design of graphic elements and the recording of the audio narration. Then we imported the designed graphic elements into the animation program and animated them. When we finished with the animation, we added background music and sound effects and created a questionnaire to test memorization and comprehension, which we combined with animation and text to create a survey and conducted an online test.

Software and tools for creating animations and recording narration were Adobe After Effects, Adobe Illustrator and Audacity; Wacom Intuos CTL-6100WL graphics tablet. Figure 1 shows an excerpt from the story outline.



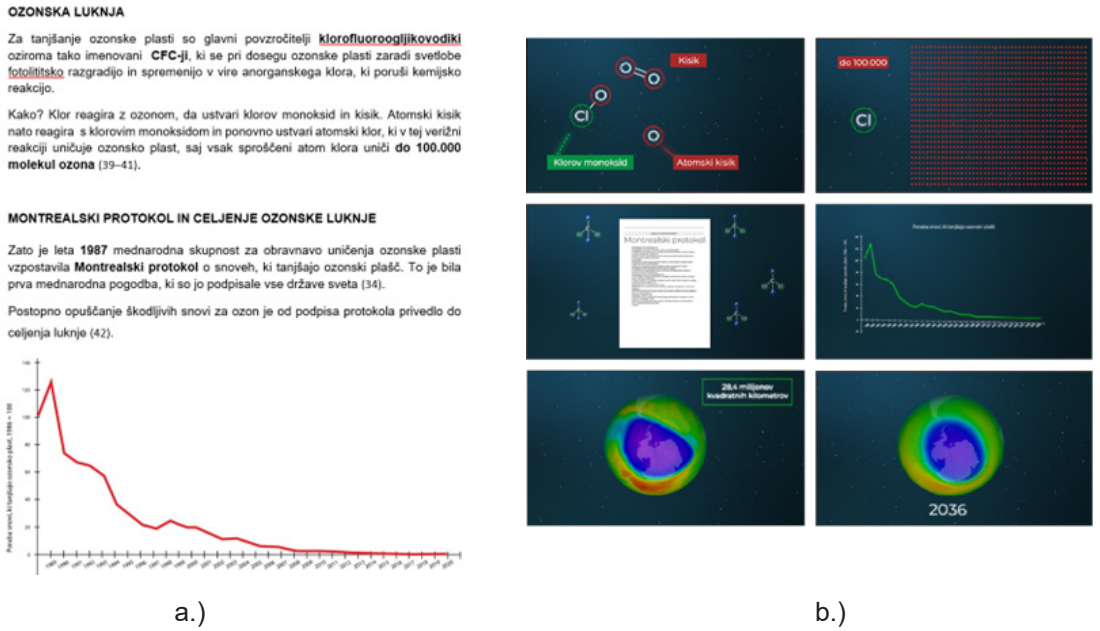
a.) b.)

Figure 1: Excerpt from the storyboard a.) and production of two animated sequences b.)

2.1 Testing

After the production of the animation and text learning material, an analysis of the learning success of the animation and the memorization and comprehension test was carried out using an online questionnaire on the 1ka.si platform. The respondents participated in the research voluntarily. Two versions of the questionnaire containing the same questions were prepared for the test, with one group of respondents reading the written text before answering the questions, while the other group watched the animation (Karo, 2022). To ensure that the choice of questionnaire was random, respondents first chose a number from 1 to 4, with numbers 1 and 3 representing a survey with animation and numbers 2 and 4 representing a survey with text. In this way, we obtained a control and an experimental group of respondents. Questions 1 to 4 were optional, such as "What are the names of the substances that are the main cause of ozone layer depletion? a.) chlorofluorocarbons, b.) hydrocarbons and c.) chlorine compounds", and questions 5 to 10 required answers from the respondents, such as "Name a natural chemical reaction that occurs in the ozone layer."

The control group materials included text with words highlighted in bold and three diagrams, as shown in Figure 2a. Instead of the written text, the experimental group watched an animation (Figure 2b) that contained the same information about the ozone, except that it was converted into a graphic and animated.



a.) b.)

Figure 2: Text and graphic teaching material a) and animated learning material with narration b.)

In the first part of the questionnaire, participants filled in demographic information and selected a number, then either read the text or watched an animation, depending on their number choice. This was followed by 10 questions, four of which were multiple-choice questions where only one answer was correct, while the other six were open-ended questions where respondents had to enter their own answer. The online questionnaire was active from 10/05/2022 to 14/05/2022 (Karo, 2022).

The content questions of the survey were: 1. What are the main substances that make up the ozone layer?; 2. What is the name of the substances that are the main cause of the thinning of the ozone layer?; 3. What is the name of the official document that restricts the use of substances that thin the ozone layer?; 4. What was the largest expansion of the ozone hole?; 5. What is the role of the ozone layer?; 6. Name a natural chemical reaction that takes place in the ozone layer.; 7. Why has the ozone layer been depleted?; 8. Describe in your own words the chemical reaction of chlorine with ozone.; 9. Using the diagram, explain the consumption of pollutants for ozone.; 10. Explain how the size of the ozone hole has changed over time.

3. RESULTS AND DISCUSSION

The number of respondents who successfully completed the entire survey was 123. There were significantly more female than male respondents participated in the tests, namely 95 women and 28 men. Most of the respondents were between 19 and 25 years old, which means that mainly students took part in the survey. None of the respondents were under the age of 19. 57 respondents represented the control group (2 and 4) and 66 respondents represented the experimental group (1 and 3).
The success rate of correct answers to closed questions is shown in the graph (Figure 3).

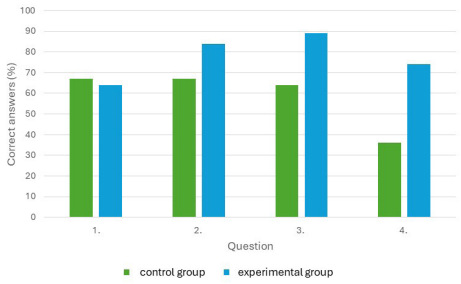


Figure 3: Proportion of correct answers to closed type questions (number of respondents = 123).

Open-ended questions followed, where respondents had to write their own answers. The proportions of correct answers to open-ended questions for each group are presented in Figure 4.

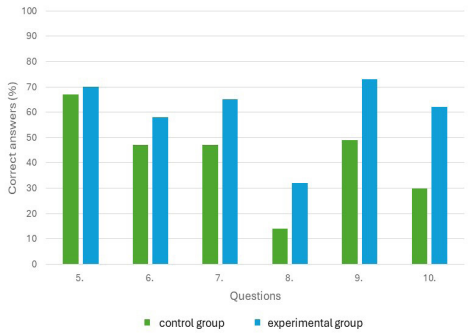


Figure 4: Proportion of correct answers to open questions (number of respondents = 123).

For all open-ended questions, the experimental group that watched the animation was more successful in answering the questions. On average the experimental group answered 60% of the open questions correctly. The control group answered the open-ended questions correctly on average 42% of the time, which is 18% worse than the experimental group. From the test results, it can be concluded that the animation improved memorization and understanding, because throughout the survey, participants in the experimental group answered the questions asked more successfully and answered 67% of all questions correctly, which is 21% better than the control group, which is one Had a success rate of 46%.

If the answers to the individual questions are compared between the groups, it can be seen that the success rate for answering the individual questions correctly differs by an average of 17%. The greatest differences occurred in the 3rd, 4th, 9th and 10th questions, where the difference between the two groups in the proportion of correct answers was over 20%, and even 32% for the last question. These differences are due to the fact that the answers to these questions were less revealed in the text version than in the animated version, in which viewers could even see the Montreal Protocol (Figure 5), which was the correct answer to the third question. For the explanations of questions 9 and 10, viewers of the animation saw an animated sequence of changes and an accompanying audio explanation, which led to better understanding and a higher number of correct answers. The smallest differences between the groups occurred on question 1, where the control group performed 3% better, and on question 5, where there was also a 3% difference, but in this case the experimental group had a better result.

a.) b.)

Figure 5: Scenes from the animation -a.) images of the Earth and layers of the atmosphere and b.) text with infographic.

4. CONCLUSIONS

The results of the research showed that the animated version was clearer and conveyed information about ozone at more perceptible levels. For example, when describing a movement or change, the animated learning material shows all aspects of the movement or change, allowing users to perceive and understand the meaning of the content through the movement of the visualized information. This could be one of the reasons why respondents who saw the animation answered the questions better when describing chemical reactions. When reading the text, respondents had to explain and interpret concepts themselves, which were animated through movement or graphic representation. Animations also require less reading because they contain narration and only isolated representations of concepts. The possibility of content being misread is therefore low.

Through testing, we confirmed our hypothesis that animation improves memorization and comprehension. 123 people of different ages took part in the test, with the 19- to 25-year-old age group prevailing. Respondents who watched the animation were more successful at answering the questions posed than those who read the text, answering 67% of all questions correctly, 21% better than the control group, which had a 46% success rate.

During the tests, we did not capture respondents' prior knowledge of climatology, climate change, and environmental issues that could influence the results. Opportunities for further research include testing long-term memory when using animated learning materials.

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SPECTRAL CHARACTERIZATION OF FLASHLIGHTS ON SMARTPHONES

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Abstract: *The widespread use of smartphones, integral in various aspects of daily life, highlights their importance in capturing moments, facilitating information transfer, and emphasizing the significance of factors like smartphone model choice, software impact, and the role of built-in features like LED flashes in low-light conditions. The research examines the impact of battery charge level on the intensity of the flash spectral radiance. Additionally, the spectral radiance density curves of two smartphone models from different manufacturers most represented in the market are compared. The results show that the spectral radiance density curves of two different manufacturers and models differ, indicating distinct dominant wavelengths of emitted radiation. The conclusive finding suggests that a fully charged battery results in minimal variations in flashlight intensity.*

Keywords: *spectral radiance, smartphone, flashlight characteristics, light intensity*

1. INTRODUCTION

With the increasing prevalence of smartphones, their implementation in everyday use is growing. Smartphone photography is present in all aspects of individual's activities, in capturing everyday moments, traveling, various manifestations, creative projects, education, documentation, scientific research, etc. The speed of information transfer is a key indicator of presence in various professions, making it increasingly necessary to directly capture a moment with a smartphone and publish it on social media and/or public communication networks. In this context, the choice of a smartphone model becomes crucial. Although the software embedded in smartphones significantly influences the appearance of the final image, impact of the smartphone light source and battery charge level cannot be eliminated especially when dealing with low-visibility conditions.

Smartphones are equipped with built-in LED flashes that serve as a light source for low-light photography or as a flashlight for illumination. The spectral characteristics of a smartphone flashlight, particularly the LED flash, can impact the quality of photos in various ways. Research on the spectral characterization of flashlights on smartphones has revealed significant variations in their performance. Vu (2022) found that the intensity and duration of smartphone flash emissions vary with phone state and model, with potential implications for point-of-care diagnostics (Vu et al. 2022). Kimme (2013) identified a discrepancy between the spectral parts of flash LEDs and the color reproduction of smartphone cameras, proposing optimized flash LED spectra to improve color reproduction (Kimme et al. 2013). Solyman (2022) investigated the safety of smartphone LED flashlights for indirect retinal photography, finding them to be within safe limits but noting a potential concern with the high composition of short wavelength blue light (Solyman et al. 2022). Holz (2018) proposed using the smartphone display as a selective light source for camera oximetry, demonstrating that this approach can double the signal quality compared to flash illumination (Holz and Ofek 2018).

In the context of photography, the spectral characteristics of the flashlight can influence color rendering, white balance, and overall image quality. The presence of specific wavelengths in the flashlight's spectrum can affect how colors are represented in photos, potentially impacting the accuracy and tone of the captured images. Additionally, the color temperature of the flashlight, which is related to its spectral characteristics, can influence the overall warmth or coolness of the light, thereby affecting the mood and color balance of the photos. Furthermore, the spectral characteristics of the flashlight can also have implications for specialized photographic applications. In such cases, the safety and spectral composition of the flashlight's emissions are of particular importance, as they directly impact the potential phototoxic hazards and the suitability of the light source for ocular examination and imaging.

Smartphone flashlights generally provide about 40-50 lumens with a diffused beam, suitable for illuminating small, nearby areas. The spectral composition of the light emitted by smartphone flashlights, particularly the presence of specific wavelengths, can influence color rendering and the overall quality of photos, as well as the safety and suitability of the light source for specialized photographic applications.

2. MATERIALS AND METHODS

The measurements were made using the Ocean optics USB4000 spectrometer. The USB4000 model is a compact fiber optical spectrometer with an enhanced detector and powerful electronic components. Furthermore, it is compatible with operating systems such as Linux, Macintosh and Windows and sensitive to stimuli in the range 350-1100 nm. In addition to the mentioned spectrometer, a transmittance optical probe was used, in charge of receiving stimuli and sending them via the spectrometer to the computer. The software used to perform measurements and collect results is Ocean view. Ocean view is a fully modular, Java-based software platform, compatible with the same operating systems as the spectrometer. Smartphone flashlight was placed perpendicular to the optical fiber on a constant distance (50 cm). Throughout the measurements, the blinds were lowered to minimize the impact of external radiation, and standard room lighting was excluded as part of the calibration procedure.The measurements were performed individually for each smartphone, iPhone SE and Samsung A 53. Smartphone characteristics are given in Table 1.

Table 1: Characteristics of the smartphones used in the study

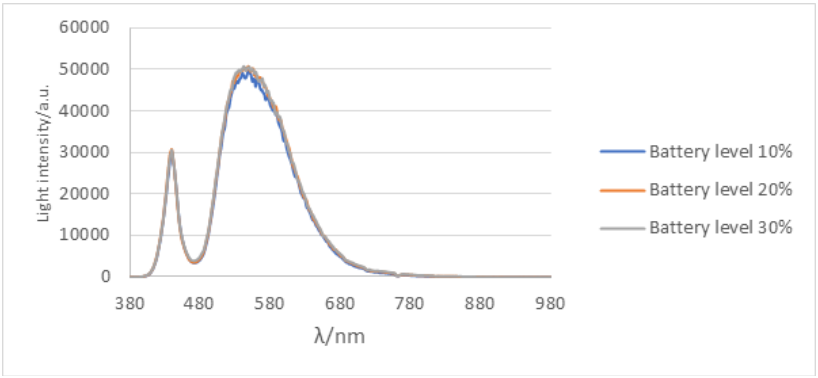
Manufacturer	Model	Manufacturing year	Flashlight
Apple	SE	2020	LED
Samsung	A53	2022	LED

The iPhone SE 2020 (Apple iPhone SE (2020) n.d.) is equipped with a rear LED flashlight that can be activated through the Control Center. The flashlight does not have an adjustable brightness setting and operates at a default brightness level when activated. The Samsung A53 2022 (Samsung A53 n.d.) features a flashlight that can be accessed through the Quick settings panel. The flashlight uses the phone‘s camera LED as a bright light that can illuminate the area.

For each smartphone, the light intensity emitted by the smartphone flashlight is measured at 10% battery charge, 20%, 30%, etc., up to the fully charged battery. It is important to emphasise that the smartphone was charged between measurements, but it was not connected to the charger at the time of measurement.

3. RESULTS AND DISCUSSION

The graphs show the intensity of light emitted by the smartphone flashlight from 370 to 980 nm, depending on the percentage of battery on the smartphone. For better visibility measurements were grouped so that the light intensities for 10%, 20%, 30%, specifically for 40%, 50%, and 60%, furthermore, 70%, 80%, 90%, and ultimately that for 100% battery charge are displayed together. Apple’s iPhone shows the maximum light intensity for the wavelength of 560-580 nm corresponding to yellow/green colour. The emitted light intensity from the smartphone lamp shows a notable difference. When the percentage of battery is 10%, the intensity of the light emitted is 2% lower than when the battery is charged 20% - 30% (Fig. 1a).


60000
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Light intensity/a.u.
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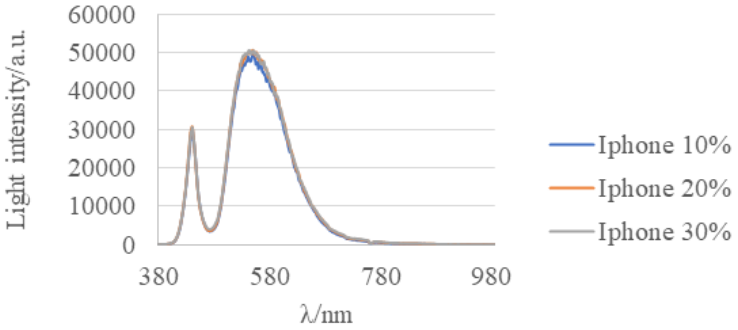
λ/nm
Battery level 10%
Battery level 20%
Battery level 30%

a)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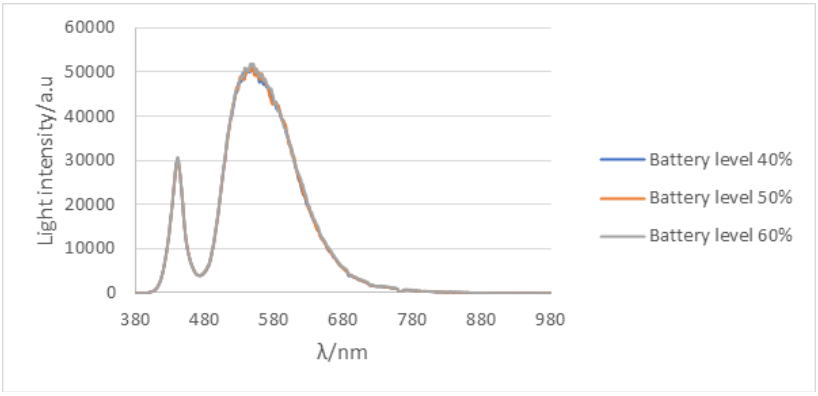
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Light intensity/a.u
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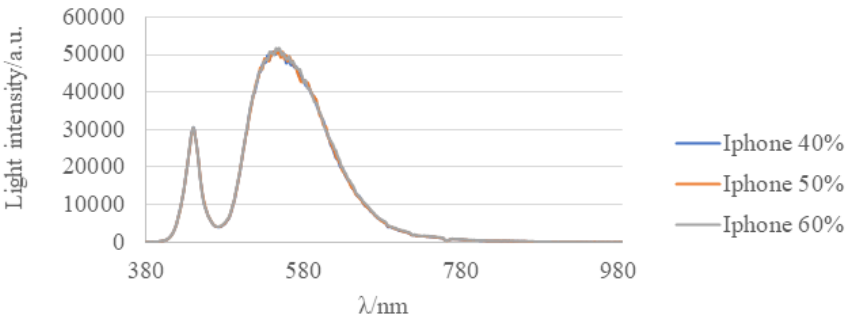
Battery level 40%
Battery level 50%
Battery level 60%

b)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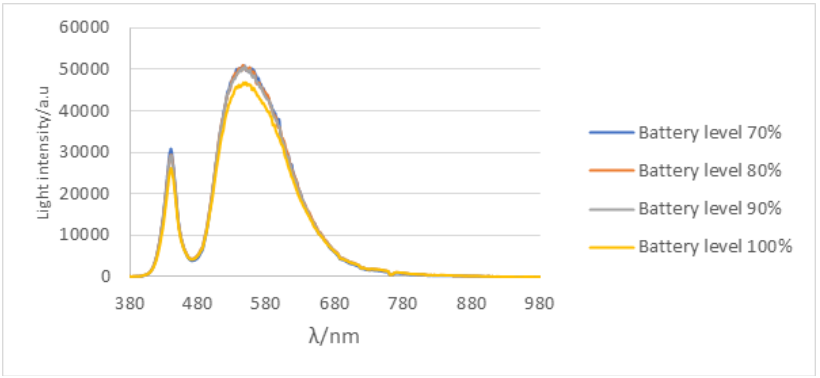
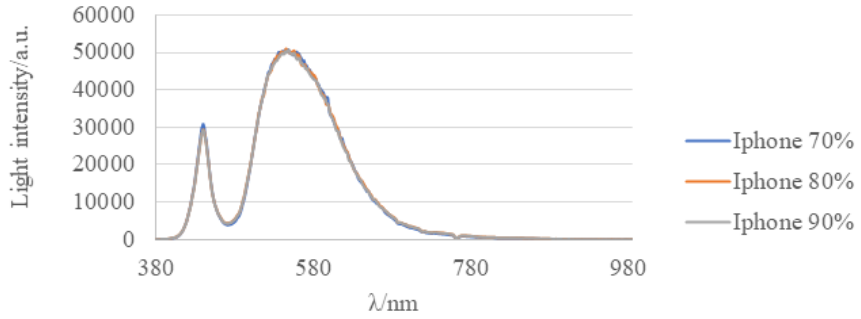
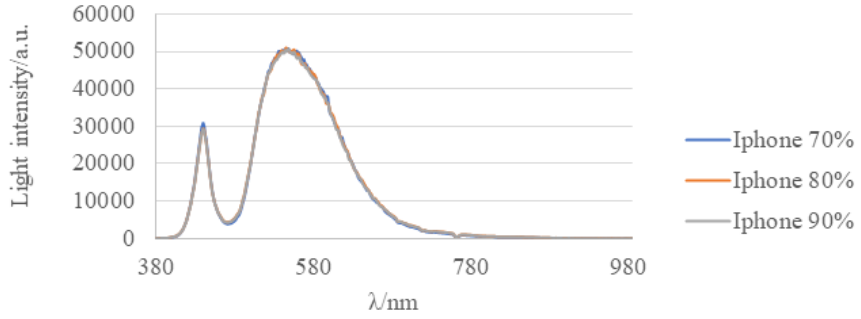


c)





d)

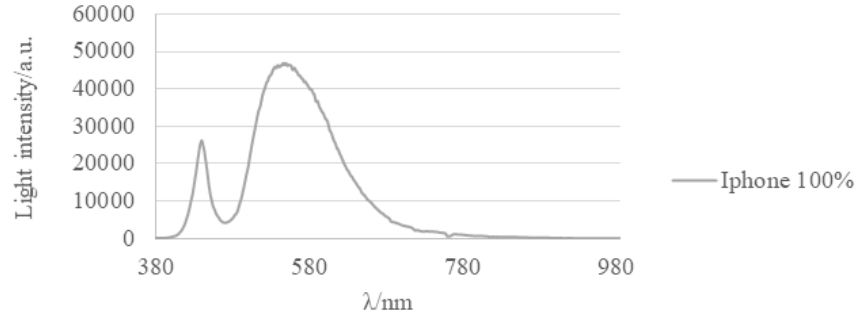


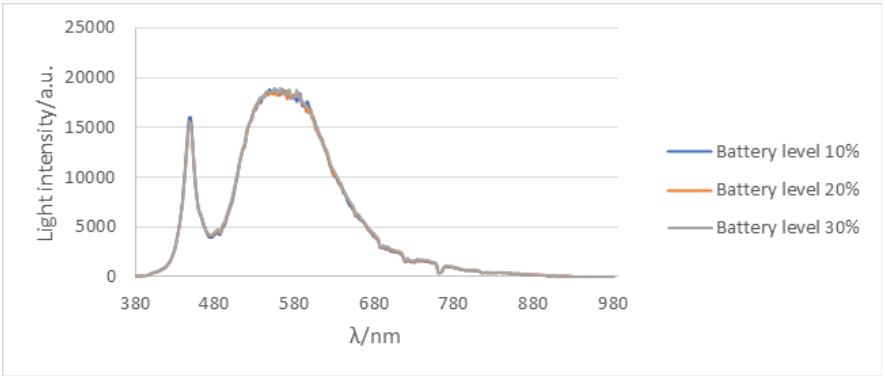
Figure 1: Iphone model at a) 10%, 20%, 30%; b) 40%, 50%, 60%; c) 70%, 80%, 90%,100% battery level

At the battery values of 40%-60% on Apple‘s smartphone (Fig. 1b), the difference in the intensity of the emitted light is less noticeable than it was at the lower percentages of the battery. Maximum light intensity is observed for the wavelength of 560-580 nm indicating yellow/green colour.

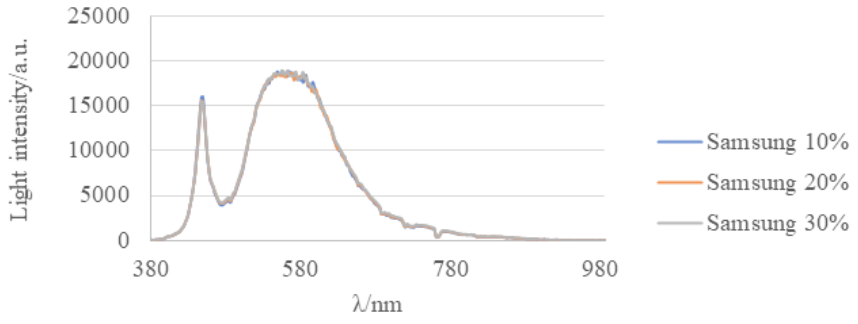
It evident that as the battery level, the variation in the intensity of the emitted light diminishes.At the percentage of the battery, 70% - 90% (Fig. 1c) is the maximum light intensity at a wavelength with a value of approximately 500 nm - 550 nm corresponding to cyan/green colour. It is observed that the lamp emits colder coloured light as the battery of the smartphone has higher battery level. It is noted that the maximum light intensity in the case of the fully charged battery (Fig. 1c) for iPhone model is placed for the wavelength between 500 nm and 550 nm indicating a shade of cyan and green. It is evident that the intensity of the emitted light has decreased compared to the results shown in the previous graphs (Fig. 1 a-c).

Samsung‘s smartphone shows the maximum light intensity for the wavelength between 550 nm and 600 nm (Fig. 2a) corresponding to the green/orange colour. It is noted that the light emitted by the flashlight of Samsung‘s device is a warmer shade than the light emitted by Apple‘s device.

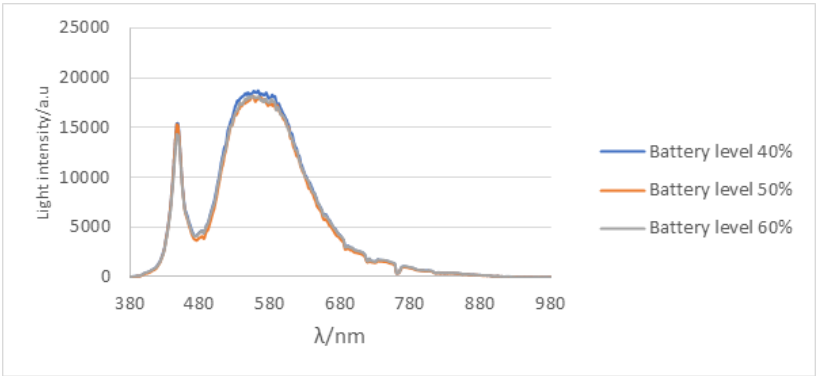
Figure 2b) shows a similar situation to Apple‘s smartphone, which is that at the 40% - 60% of battery the variation in the maximum intensity of the emitted light depends on the percentage of the battery. A very interesting phenomenon is that at 40% of the battery, flashlight emits light with a higher intensity than at 50% or 60% of the battery. The highest light intensity occurs at a wavelength ranging from 550 nm to 600 nm, suggesting a green-orange appearance.



a)



a)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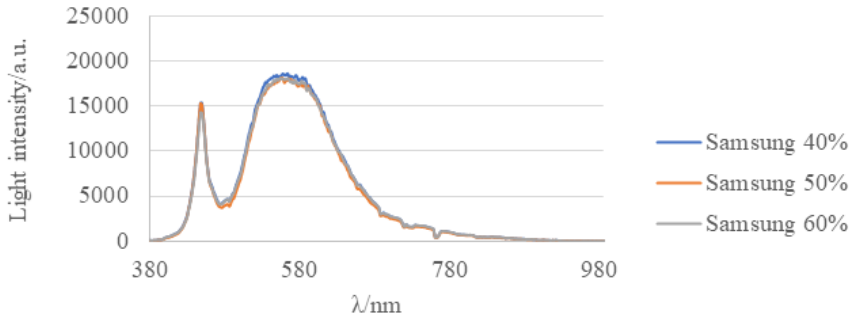
λ/nm
Battery level 40%
Battery level 50%
Battery level 60%

b)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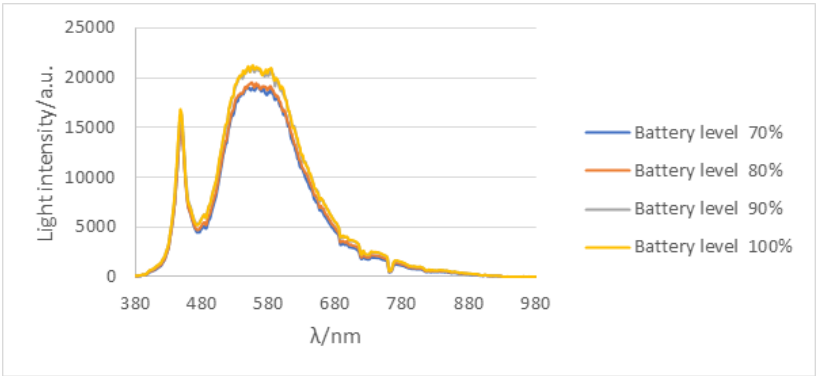
Samsung 40%
Samsung 50%
Samsung 60%

b)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Light intensity/a.u.
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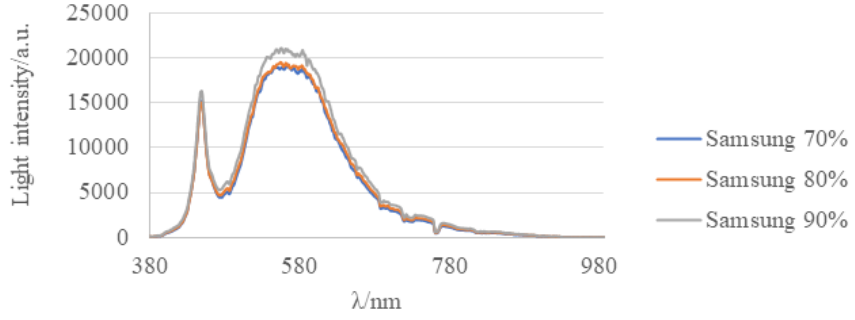
Battery level 70%
Battery level 80%
Battery level 90%
Battery level 100%

c)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Light intensity/a.u.
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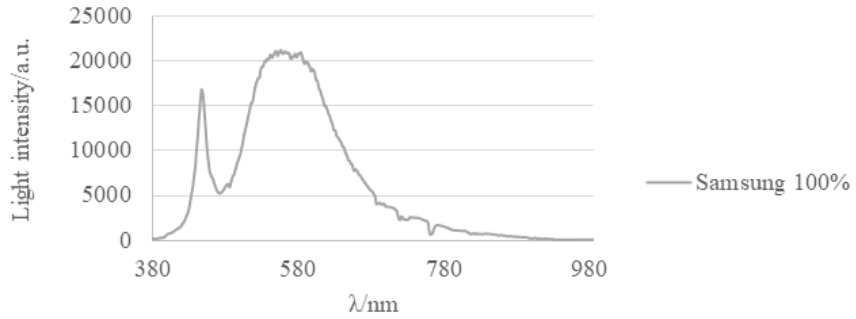
λ/nm
Samsung 70%
Samsung 80%
Samsung 90%

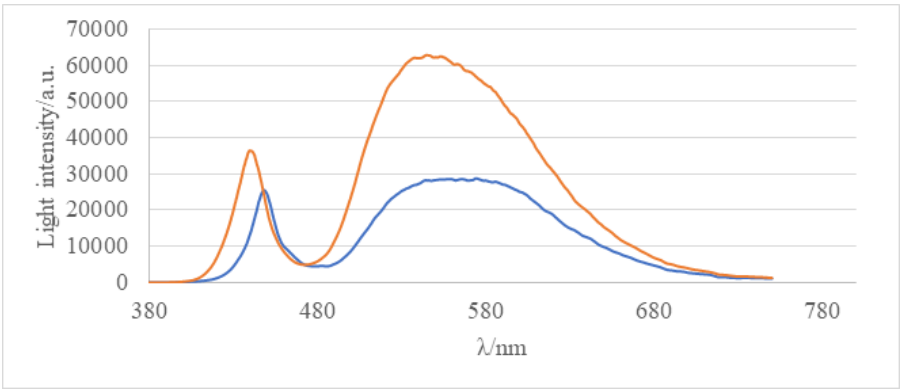
c)



d)

Figure 2: Samsung smartphone model at a) 10%, 20%, 30%; b) 40%, 50%, 60%; c) 70%, 80%, 90%;100% battery level

Highest differences among intensity levels of emitted light for Samsung model can be observed in Fig. 2c for 70%-90% battery levels. The peak light intensity is found in the wavelength range of 550 nm to 600 nm, signifying a green-orange hue.. There is no decrease in light intensity on the fully charged battery for Samsung model as was the case with Apple smartphone flash (Fig. 2c).



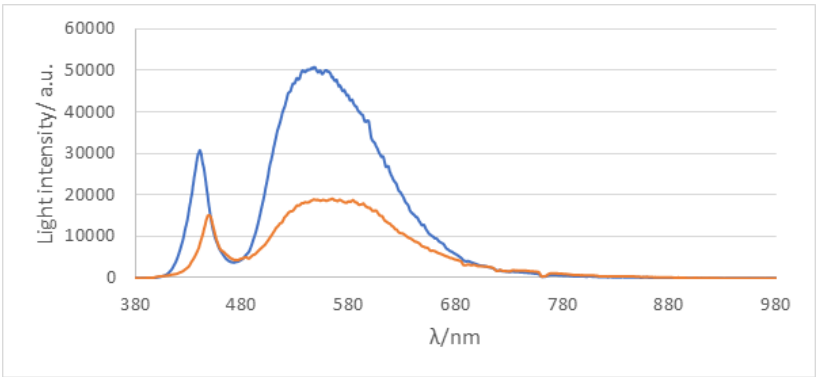


Figure 3: Comparison of Samsung (orangeline) and Iphone (blue line) light intensities for the 70% battery level

Comparison of Samsung's and Iphone's light intensity emitted by the smartphone flashlight when it is constantly lit for the same battery level (Fig. 3) clearly confirms large difference in the intensity of the light emitted by the tested devices. The maximum intensity for both devices is at a wavelength between 500 nm and 600 nm, which means that the light emitted is blue/green colour.

4. CONCLUSION

The study analysed how the level of battery charge influences the flash spectral radiance intensity by comparing spectral radiance intensity curves associated with two prominent smartphone models manufactured by different companies, both highly prevalent in the market. In the case of the first manufacturee, Apple, it was observed that the intensity of the emitted light remains consistent when the battery is 10-90% charged, but when the battery is fully charged, the light intensity is lower. Given the range in the visible part of the spectrum in which this device emits a majority of light (500-580 nm), it can be concluded that the flash of this smartphone emits light in a slightly cold shade of cyan/green colour. As for Samsung's smartphone model, the intensity of the emitted light can be said to be consistent up to 40% of battery charge, followed by slight variations. From the above it can be concluded that the flash of Samsung's smartphone emits a slightly warmer shade of light (550-600 nm), compared to Apple's device, in green/orange. In relation to the results for Apple smartphone model, a difference in the intensity of the emitted light between the two tested devices is evident. Given that the study exclusively focused on a singular device of a specific model, produced by a sole manufacturer, we cannot definitively conclude that any disparities observed stem from damage or wear specific to that particular device.

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ANALYSIS OF THE PROCESS OF TRANSFORMING A WEB APPLICATION INTO MOBILE APPLICATION

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Abstract: *As the usage of mobile devices continues to dominate the digital landscape, the demand for mobile applications has surged exponentially. In response, developers are frequently tasked with transforming existing web applications into mobile-friendly counterparts to meet the evolving needs of users. This scientific paper explores the intricate process of this transformation, delving into the key challenges, methodologies, and best practices associated with the conversion of web applications to mobile applications. The research investigates various strategies employed in the adaptation of user interfaces, navigation structures, and functionality to ensure optimal performance and user experience. The aim is to offer a comprehensive resource for developers, researchers, and industry professionals engaged in the dynamic field of application development. By understanding the nuances of transforming web applications into mobile applications, stakeholders can make informed decisions, mitigate challenges, and ultimately deliver enhanced mobile experiences to a diverse user base.*

Keywords: *mobile applications, user interface, user experience, adaptation*

1. INTRODUCTION

The rapid development of mobile technology has changed the way people access information. The increased prevalence of smartphones and tablets has led to a significant shift in user behavior, with individuals increasingly relying on mobile applications for their daily needs. This change has also brought unique challenges and opportunities for businesses and organizations that already have web applications and want to adapt them to the mobile ecosystem. Due to the limitations of mobile devices, some elements of the user interface (UI) require adaptation to mobile ecosystems.

1.1 Navigation

Navigation is an integral part of every website and application, often presented as a series of vertical or horizontal links. Several methods are applied when converting menus.

The hamburger menu has become a standard in web design and application design. Clicking on the icon opens a menu on the side, often identical to the web version. This type of navigation is suitable for applications where a large number of functionalities are used in both the mobile and web versions. The advantage of such a menu is that users have adopted a mental model of this type of navigation. However, this menu is not suitable for applications where users frequently need to switch between pages. Additionally, this menu is positioned in the area that is most challenging for users who hold their devices with their right hand or with both hands, and touching this menu requires extra effort (Ingram, 2016).

Bottom navigation is common in mobile applications and typically contains between 3 and 5 links. It is recommended for applications with fewer functionalities, as it requires less effort from users and can be controlled using just the thumb. On the other hand, options are limited, and if an application has more main functionalities, the hamburger menu may be a better option.

Top navigation combines elements such as links, hamburger menus, and tabs. It provides a greater number of options but may cause strain on the hand. This is useful for displaying more elements compared to bottom navigation.

1.2 Tables

Displaying tables with a large amount of data is not a problem on desktop devices, but when transitioning to mobile devices, it is impossible to retain them in their original form, considering the limited screen width. There are several methods to address this issue.

Shortening is the simplest way to solve this problem. Shortening involves displaying only the key columns in the table and hiding the rest.

Scrollable tables are the most common way to address the issue of displaying tables on mobile devices. Users navigate through the table with finger gestures, and horizontal scrolling is enabled. It is crucial to clearly indicate that the table can be navigated through this method.

The term “transformed tables” refers to converting them into distinct cards. This solution is suitable for web applications, as a large amount of information can be displayed immediately without requiring additional user actions. It is also possible to create an option where specific parts can be hidden as needed, filtered, or sorted.

1.3 Buttons

A button is one of the key elements of the user interface. Pressing a button typically triggers an action, serves for navigation, or changes a state. In web applications, a single page often has multiple buttons, so it is important to establish a visual hierarchy for the buttons. Visual hierarchy involves arranging elements based on their importance (Interaction Design Foundation, 2016). Some button properties that dictate visual hierarchy include size, color, and shape. Unlike color and shape, size plays a significant role in transforming a web application into a mobile one.

In mobile design, when placing buttons, it is crucial to create buttons whose size is optimized for touch. Microsoft recommends a minimum button size of 34x26 pixels, while Apple suggests a size of 44x44 pixels (Design, 2019). Research has shown that the smallest accuracy is achieved when the button is less than 42 pixels, while a button larger than 72 pixels also yields imprecise results (Jin, Plocher and Kiff, 2007). In addition to the button size itself, the spacing between them is also an important factor.

A common occurrence in web applications is the existence of a primary button on the page, representing the main action to be performed. Considering the significance of this button and the limited space on mobile devices, it is essential to find a way to make this button always accessible. One solution to this problem is the Floating Action Button (FAB). The FAB represents the main action on the screen and is always available to users.

1.4 Forms

Forms are encountered in various applications, from registration to complex tasks. The Baymard Institute conducted research examining the reasons users abandon online purchases. According to the results of their study, the number of fields in a purchase form is a more significant factor than the length of the process itself (Holst, 2021).

During user registration, it is desirable to expedite the process, which can be achieved by offering the option of “one-click registration.” This term refers to registration through the user’s account with services such as Google, Facebook, or Apple. This method is the best way to streamline the account creation process in any application, as it requires no additional effort from the user.

1.5 Notifications

In-app notifications aim to guide and inform users and are displayed while using the application itself. Push notifications are often sent when users are not within the application, and they appear as external notifications from the operating system. It is important to use push notifications cautiously due to their potential negative impact on the user experience. According to research, even 78% of millennials have deleted an app at some point in their lives because notifications bothered them. It has also been shown that this is the least preferred form of communication among users, with many preferring communication via email (Wilson, 2019).

1.6 Modals

Modals are elements that appear in front of content and are useful when it is necessary to interrupt the user flow to make a decision, confirm an action, focus on specific content, or expand content. When creating modals, it is recommended to adhere to several practices, including scrolling, appropriate button sizes, positioning the most important button within the thumb zone, adding an option to close the modal and interrupt the process, as well as using animations to indicate where the modal is coming from.

2. EXPERIMENTAL

In the process of transforming a web into a mobile application, several factors should be taken into account, such as user experience, functionality, and device technological constraints. This process involves adapting and optimizing the functionality of web applications to suit the mobile environment.

Before the actual transformation, a group of participants was selected to test the web version of the application, provide answers to questions about the desired outcomes of the transformation, and evaluate the final version of the mobile application. The participant group consisted of 20 individuals aged 25-40. Ten participants regularly use desktop applications for business management, while the other 10 participants are involved daily in UI/UX design for desktop and mobile applications. Both groups were composed of 5 female and 5 male participants.

The participants were introduced to a simplified web application for business management and were given 30 minutes to familiarize themselves with its features and operation. Afterward, the participants provided responses to survey questions aimed at gathering information about the desired appearance, functionalities, and operation of the mobile application.

The web version of the application consists of multiple modules, of which the following 3 are made available to survey participants:

- Dashboard: The main screen of the application, where users see a visual presentation of data about their business presented in graphs.
- Clients: In this module, users have an overview of all their clients and their finances, and they can also add new clients.

At its core, the application consists of a navigation menu on the left side, a header at the top, and the main content. While the menu and header mostly remain unchanged, the main content always varies depending on the page the user is on.

During the transformation, concepts explored and presented in the theoretical part of the work will be applied. These concepts were chosen as desired solutions by the survey participants, and additional explanations on why certain practices and steps used in the transformation process are considered good solutions will be given. Considering that the mobile application aims to have a simplified workflow, the mobile version of the application will have a similar structure with the simplification or relocation of certain options and functionalities.

In the end, after reacquainting themselves with the web application, participants were presented with the final version of the mobile application and given 30 minutes for testing. Following the testing, participants evaluated the success of transforming the web application into a mobile one by filling out a survey.

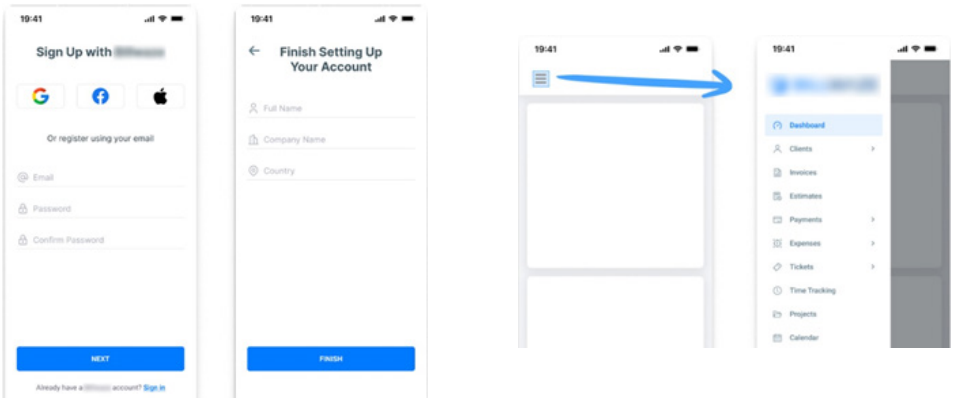
3. RESULTS AND DISCUSSION

Figure 1 shows an overview of participants responses to survey questions aimed at gathering information about the desired appearance, functionalities, and operation of the mobile application.

Figure 1: Responses to survey about the desired appearance and operation of the mobile application

The registration process for the application consists of several steps. The first involves entering an email address and a desired password on the initial screen. Afterward, the user receives an email with a verification link. By clicking on that link, the user proceeds to a step where they enter information necessary to create their account, including some details used for research and marketing purposes. Following this, the user‘s account is created, and they are logged into the application.

This registration process is deemed impractical for mobile devices due to the number of steps and the input of a significant amount of data, particularly when entered via a digital keyboard. Therefore, this process is simplified for mobile devices, requiring only the absolutely necessary information, while additional data may or may not be entered on the next screen, as depicted in Figure 2a.



a) b)

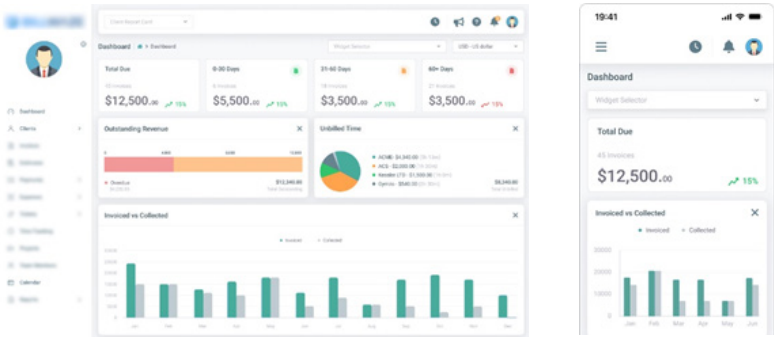
Figure 2: a) Screens for registration on a mobile device; b) Navigation menu

Another advantage is an option of registering through Google, Facebook, or Apple accounts is that the information entered in the name and country fields can be directly retrieved from those accounts, leaving users with only the task of entering the company name on the second screen. The login process follows a similar flow to the registration process.
Taking into account that this mobile application, despite removing certain functionalities, still has a large number of available modules, the best option for the navigation menu is to retain a similar structure and display it by pressing the hamburger icon. It will be located in the header and will open the navigation menu with an animation from the left side of the screen, as shown in Figure 2b.

Users access notifications by tapping the bell icon. The number of unread notifications is inside a circle in the upper right corner of the icon. In-app notifications are available on both the web and mobile applications, therefore their display practically remains unchanged.

The Command Dashboard, or Dashboard, is one of the most common concepts in web application design. Users can view crucial information about their business and clients in graphical form on this screen. In the analyzed application, it consists of a series of cards containing various information. Part of the web version's control table is shown in Figure 3a.

A notable feature for converting these types of cards for mobile applications is the fact that, despite large graphics that may seem overwhelming, phones have the ability to zoom in using two fingers. Users can also be presented with a smaller number of horizontal columns to enable horizontal scrolling for a better view of data. Unlike the web version, all cards must be converted into a single column for mobile devices. By default, the number of displayed cards should be minimized, and users can use the Widget selector dropdown menu to choose which cards they want to see and which ones they want to hide. An example of several cards is given in Figure 3b.



a) b)

Figure 3: Display of Dashboard on the a) web version; b) mobile version of the application

In the Clients module, users can see an overview of their clients in a table and add new clients. The client management screen is shown in Figure 4.

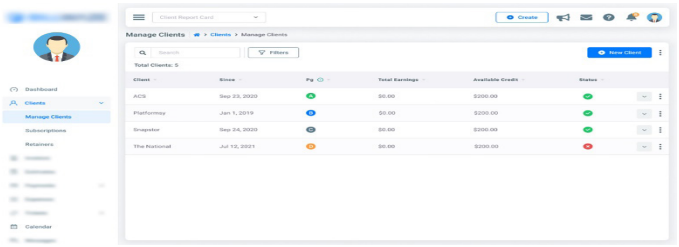
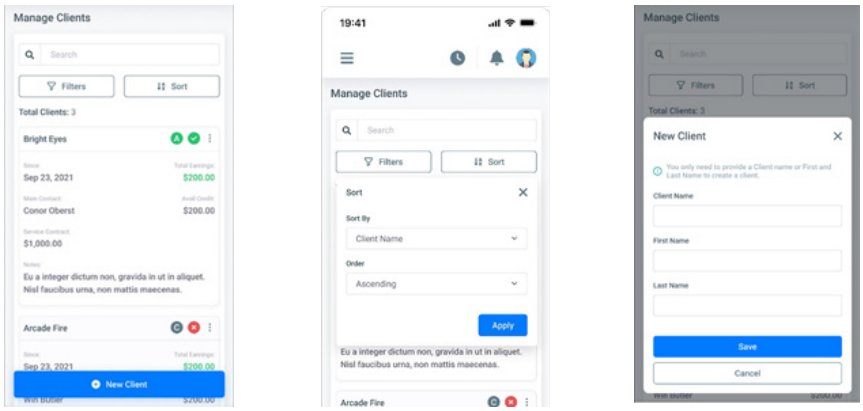


Figure 4: Client management screen on the web application

Clients module includes search and filter fields, a primary action button (New Client in this case), and a table. Since tables in the application have a large number of columns, the chosen approach for mobile devices is table transformation. All table rows are transformed into separate cards, as shown in Figure 5a. Since columns on the

web application can be easily sorted by clicking on their names in the table header, a sorting button is added to the mobile version. Pressing this button reveals an additional section where users can choose the property by which they want to sort the results and whether they want to do it in ascending or descending order, as shown in Figure 5b.



a) b) c)

Figure 5: Display of the a) Clients screen; b) sorting results; c) New Client modal on the mobile application

The main action button on this screen is the button for adding a new client. On the web version, this button opens a modal with a large number of input and selection fields. Since the main action button (in this case, the button for adding a new client) is crucial for this screen, leaving the button at the top would be problematic. If a user is at the bottom of the screen and wants to add a new client, they would have to scroll to the top of the page to access the button. For this reason, it was decided that the main action buttons become FAB (Floating Action Button) buttons on mobile devices. Figure 5a shows this method using the example of the button for adding a new client.

The main action button is fixed to the bottom edge of the screen, and while the entire screen content scrolls, it does not change its position. Each main action button of the initial screens of the modules will behave similarly in the mobile version of the application.

Considering that adding a new client requires filling in either the client‘s name or the name and surname of the contact person, it is unnecessary to display all input fields in the modal on the mobile version. Instead, these can be added later, either by modifying the client on the web application or directly on the mobile application. The modal for adding a new client in the mobile version is shown in Figure 5c.

Positive ratings on the mobile application evaluation survey (Figure 6) indicate that the chosen solution for the transformation process is successful. Additionally, participants exhibit similar habits in using mobile applications for business management, significantly simplifying the transformation process of such applications. Adhering to the principles covered in the paper and adapting the survey questions to the purpose and content of the application greatly facilitates the transformation process.

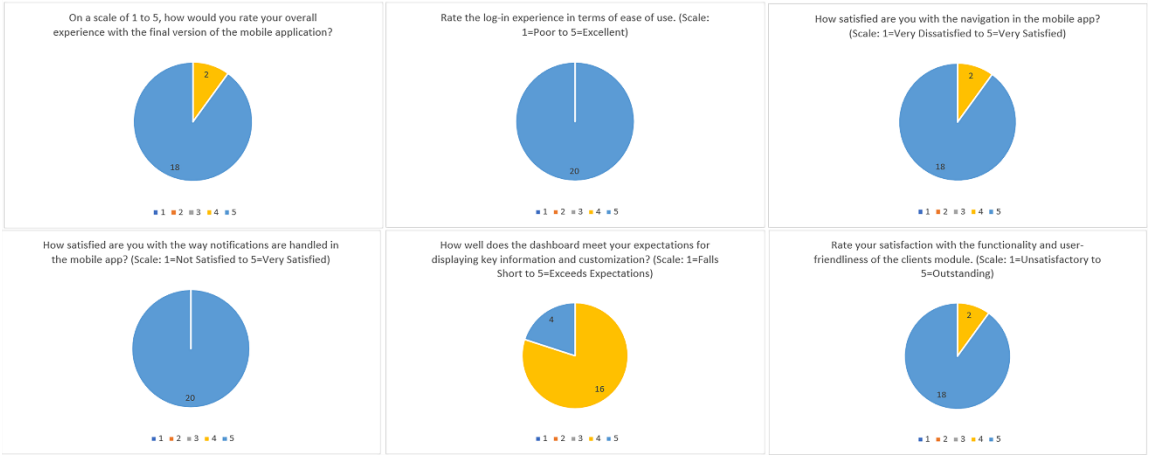


Figure 6: Mobile application evaluation survey results

4. CONCLUSION

The mobile industry is taking an increasingly significant share of the electronic devices market, and rapid growth and dominance of mobile devices over tablets, desktops, and laptops are expected. For companies that aim to remain competitive in the market, it has become imperative to have not only a web application but also its mobile version, adequately adapted to such an environment. All types of mobile applications have their advantages and disadvantages, but with the accelerated development of web technologies and Google's support, progressive web applications are expected to take the lead.

There are various methods to address specific user experience issues when adapting UI elements to the mobile environment. Most of these solutions find application today, and the decision to choose an appropriate solution is made by considering multiple factors, such as the application's purpose, technical capabilities depending on the application type, and priorities when selecting solutions for displaying specific elements. For a quick and successful final transformation process, it is essential to investigate existing solutions and methods for converting individual segments of the application, explore the desires and needs of future application users, conduct an evaluation of the final solution, and, if necessary, redesign parts of the application that did not receive a positive response from users.

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ACKNOWLEDGEMENTS

This paper has been supported by the Ministry of Education, Science and Technological Development through the project: “Innovative scientific and artistic research from the FTS (activity) domain”

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CREATIVITY THROUGH INTERACTIVE STORYTELLING

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Abstract: *Numerous movable or more known pop-up books are currently available on the market, also in Slovenia, and show a spectrum of complexity ranging from simple to complicated. The main goal of this work was to gain insight into the production process of movable books and to find optimal solutions for a seamless end product. The goal of this work was to produce an unconventional toy, a pop-up and play book entitled "Jelko the Elf and his Forest House"," with a minimal ecological footprint during production. The use of interactive mechanisms is intended to offer children in the first years of school an appealing opportunity for imaginative play. Educational elements are woven into the narrative to promote understanding and knowledge of meadow flowers, animals, forest trees and their fruits. Accompanied by characters and other interactive elements, the book encourages children to act out familiar everyday routines, making learning an enjoyable and immersive experience.*

Keywords: *pop-up book, play book, graphic finishing, interactive elements*

1. INTRODUCTION

The first example of movable books dates back to the 13th century, when rotating discs were used in literature to prove various theories (Akhiraningrum & Bektiningsih, 2023). In the 14th century, so-called hinged books appeared in literature, although the books were intended for a different type of literature, e.g. anatomy, and such books were not suitable, especially not for children (Davis et al., 2015). Thus, it was not until the 19th century that there was a noticeable increase in movable books in children's literature. This was quickly followed by a commercial explosion in the growth of children's book production, which took place in 1929 (Komari et al., 2022). Today there are many movable books on the market, also in Slovenia. Their complexity ranges from the simplest to the most complicated. This form of children's literature, in which paper mechanisms are raised in a book, helps children to understand and theorise in a different way (Liu, 2019). Movable books develop a child's creativity and imagination while stimulating an interest in reading (Rahmawati & Rukiyati, 2018). They also help to visualise the shapes created by the mechanisms more easily. The child can explore and add to their knowledge using the book and the help of an older person. Movable books can therefore be an alternative learning medium (Zaeni et al., 2018). The aim of this research was analysing the process of making a movable book and to find out what are the best solutions and approaches for the proper functioning of this type of product, which is also graphically designed according to the given theme. The focus is on the material and the construction of the mechanisms that work properly, an important approach in the manufacturing process. The ultimate goal was to create an unconventional, movable toy book stacker with as little material waste as possible. With interactive elements and characters and a graphic image, the playbook would provide children of the first triad with an interesting play opportunity where they can use their imagination. The educational elements included are designed to teach understanding and knowledge about meadow flowers, animals and forest trees and their fruits. With the help of the main character, the children will be encouraged to act out the daily routine they already know (brushing teeth, showering, having breakfast, washing up, tidying up...).

2. EXPERIMENTAL

2.1 Materials

The quality of the finished book depends on the properties of the paper used. As it is exposed to constant bending and rubbing, it must be as durable and long-lasting as possible. For the production of the test models, white paperboard coated on one side with a grammage of 320 g/m^2 and thickness of 0.5 mm was used. For the inside of the book and the movable elements, MB Prime FBB Bright cardboard coated on one side with a grammage of 330 g/m^2 and a thickness of 0.6 mm was used for the final product. Papyrus Premium tissue paper, of grammage 300 g/m^2 and thickness of 0.5 mm, was chosen for the production of the attached props and the main character.

2.2 Methods

Adobe Illustrator (Adobe, USA) was used to prepare the design of the book. For the printing procedure UV digital printer Apex Flatbed (Apex Microtec Technology Co., Ltd, China) was used. Since the detailed production of the movable parts of the pop-up book was needed, the cutting machine Kongsberg X20 (Esko Kongsberg, Belgium) was used.

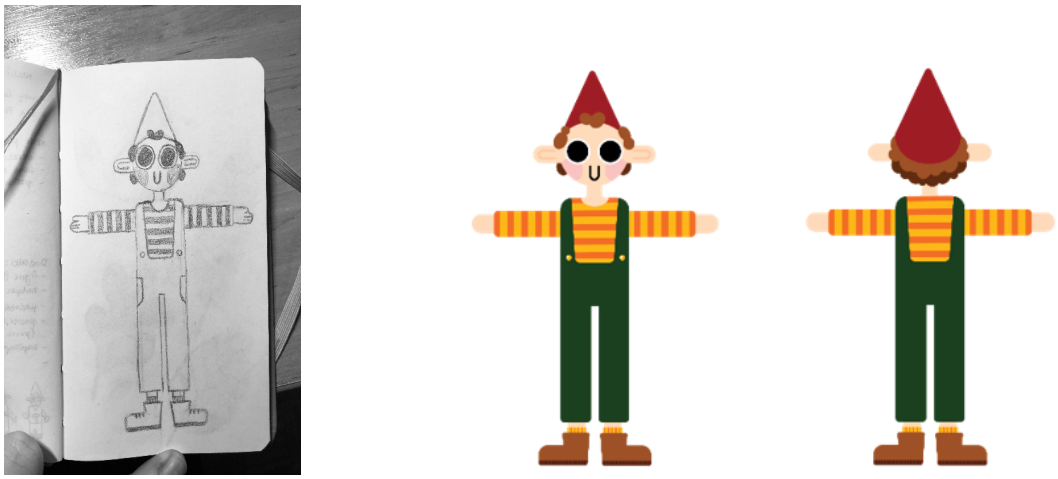
2.3 Theme of the book and first prototypes

With the book, we wanted to incorporate some educational content and opportunities for the child to learn or reinforce new content. The three main ideas were:

- Learning about and finding hidden animals: beetle, butterfly, ant, ladybird, snail, worm, spider and bee
- Learning about and connecting the leaves of trees and their fruits. Beech, oak, chestnut and acorn, acorn and chestnut were used
- Sowing and identifying meadow flowers. These are a daisy, a trumpet and a souvenir.

In addition to the educational activities mentioned above, with the concept of a house where daily activities such as brushing teeth, eating breakfast, tidying up, etc. normally take place, the child encounters a routine that is already familiar to him and thus projects his habits into the game itself, consolidating his cognition at the same time.

The idea for the main character of the pop-up book, who is represented by a dwarf, arose from the idea of the forest theme and from the first sketch shown in Figure 1. As dwarves are depicted in existing fairy tales and books as small, bearded creatures, the aim of the image of the first character was to transform the stereotypical appearance of a small and stocky fairy tale hero into something more modern and attractive.



a) b)

Figure 1: The main dwarf character of the pop-up book a) idea and b) design

The design and the first prototype of the book construction are presented in figure 2.

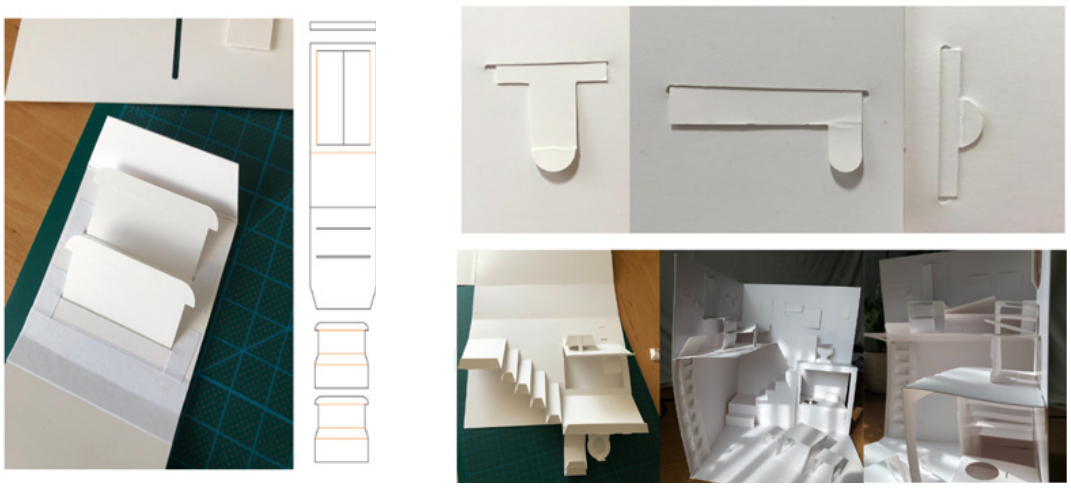
a) b)

Figure 2: The a) idea and b) construction details of the pop-up book

The design and first impression of the book construction was drawn by hand and certain details inside the book were defined (Figure 2a). When deciding how the construction would function, the prototype was done from the cardboard, especially the details regarding stairs, openings, closet and sink were carefully studied by many attempts (Figure 2b).

3. RESULTS WITH DISCUSSION

Pop-up books require movable and specific details that should be carefully prepared and produced. In figure 3 certain details for the moving particles are presented.



a) b)

Figure 3: Construction details of the pop-up book a) the closet, b) different types of moving mechanisms, stairs, etc.

Figure 3a presents the opening of the closet. Figure 3b shows construction details and different types of openings that were hid by the back of the book cover. The most important detail regarding different types of opening was to hide these details and to be at the same time functional, could be moved, slided etc.

When all details for the openings have been prepared and construction of the book, the design was prepared according to the story. Figure 4 presents the final construction and design of the pop-up book.

a) b)

Figure 4: Final a) construction for the cutting procedure and b) the interior design of the pop-up book

Certain parts at the design (Figure 4b) were added due to additional parts, props for the play. The pop-up book also included the cover, which was separately prepared (Figure 5).

Figure 5: The cover of the pop-up book

The result of the research was a complex graphic product that interactively encourages the user to play an imaginary game. The advantage of the book is that after its use, it can be folded and appears as usual book (Figure 6).

The production of a pop-up book called Jelko the Dwarf and his Forest House, required precision and many attempts. The book therefore consists of interactive and moving mechanisms, which required the most attention from a production point of view, and the production itself would have taken longer without the test models.

a) b)

Figure 6: The final a) opened and b) closed pop-up book

4. CONSLUSIONS

The process of producing a pop-up book, which requires a high degree of accuracy, is undoubtedly complex and lengthy. The number of test models has helped to facilitate the understanding of movable and interactive mechanisms. As these mechanisms are in constant use and susceptible to breakage and wear, they must be designed to function flawlessly. An important factor that enables and contributes to the functioning of these mechanisms is paper and cardboard, because the higher the degree of coating, the better coated paper improves the movement of the mechanisms, the more smoothly the mechanisms' function. Choosing the right material for this type of graphic product is crucial, but a compromise must be found between the most ideal paper and the printing process that will visualise the desired graphic image. Many problems were already solved on the test models on site, so that the production of the final product went as smoothly as possible. The visual content was designed according to the final test model, trying to maintain a consistent graphic image in terms of colours and patterns, which provides variety. After the finished game, the product is converted into a smaller format that takes up little space on the shelves.

The production of the book set fulfilled all the expected objectives resulting from the educational content about the forest and nature, as well as the purpose itself, which was based on learning about the production processes and finding the best solutions. The final product thus represents an unconventional toy book set that stimulates the imagination and creativity through interactivity.

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COLORFUL CODING FOR CONSCIOUS CONSUMPTION: INTEGRATING SUGAR AWARENESS AND SUSTAINABILITY IN DAIRY PRODUCT PACKAGING DESIGN

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Abstract: *Food packaging in Slovenia is being revolutionized by research, with a color-coded system being introduced to raise awareness of sugar content in dairy products and promote sustainability. The focus of the analysis was on hidden sugars and the associated health risks, resulting in packaging with uniform labelling that complies with sustainability principles. Market analysis, sampling, visual analysis of information on the dairy products and definition of color-coding system on the products was proceeded. The goal was to create effective labeling aligned with sustainable practices. By applying the system to a fictional brand, codes were seamlessly integrated, ensuring ease of use. The results of the analysis are integration of multi and single color-coding systems and designs into 3D models for dairy categories such as yogurt, attention-grabbing labels were created, that provided important information. Our commitment to sustainability extends from production to disposal, aligning with our aim to promote environmental responsibility in the packaging process. In anticipation of a paradigm shift towards informed choices, a more sustainable future for food packaging is promised by our innovative system.*

Keywords: *food packaging, sustainability, sugar content, packaging design*

1. INTRODUCTION

The consumption of sugar is pervasive in everyday life and can be found in almost all packaged foods. The distinction between natural and added sugar is crucial due to the different health effects. While sugar adds beneficial properties to foods, excessive addition can lead to health problems. The increase in hidden sugar products, especially in seemingly healthy foods, poses a challenge as they often go unnoticed by consumers. Existing labelling systems around the world are inconsistent and have limited effectiveness. Various studies (Roberto et. al., 2014; Feteira-Santos et al., 2020; Vandevijvereet al., 2020; Gupta et al., 2021; Song et al., 2021) have investigated different labelling formats to improve consumer understanding and promote healthier choices. Interpretation formats that combine the sugar content in grammes with colors, information on high sugar content or the percentage of the daily value proved to be the most effective (Franco-Arellano et al., 2020; Meijer et al., 2021; Roberto et al., 2021). In Slovenia, a standardized labelling system is still unexplored and in the European Union there is no standardized model for nutrient profiling due to different data. The lack of a clear distinction between free and added sugars leads to confusion, which is exacerbated by different terminology. The problems with labelling also extend to the measurement methods used, as gas chromatography and liquid chromatography are unable to distinguish naturally occurring sugars from added sugars. The complex terminology makes it difficult for consumers to rely on ingredient lists for sugar content. To address these challenges, this study aims to raise awareness of sugar content in dairy products, especially in yogurt through innovative packaging design. The overall goal is to formulate a uniform labelling system applicable to different products to promote informed consumer choices and contribute to a healthier food environment.

2. EXPERIMENTAL

This study followed a systematic methodology that included specific steps to analyze the sugar content in dairy products such as yogurts. The results obtained were then integrated into 3D packaging layouts. In addition, a novel color labelling system was developed to improve the visual presentation. The 3 steps of this research were:

1. Sampling in the Slovenian Market
This stage included a investigation, i.e. a market analysis and then a visual information analysis of 49 yogurt product samples from 10 different producers available in Slovenian shops (Ljubljanske mlekarne, Mlekarna Celea, Proteini.si, Bohinjska sirarna, Vindija, Mercator, Milfina, Pomurkse mlekarne, Planika and Spar).

2. Analysis of Sugar Content
For natural, fruit, and protein yoghurts, statistical functions, specifically frequency distribution, were utilized. This facilitated the classification of sugar amounts into color-coded classes. For instance, the lowest sugar content class was assigned the color blue. Sugar content in the product range varied from 3.8 g to 14.0 g.

3. Preparation of color coding and positioning of information to the yogurt products.

3. RESULTS WITH DISCUSSION

This study systematically examines the sugar content in a diverse array of yogurt types from 10 different producers, available in the Slovenian market. Understanding the sugar composition in yogurt is crucial for consumers seeking to make informed dietary choices.

1. Ljubljanske mlekarne: Brand MU from Ljubljanske mlekarne offers a range of yogurt types - brands Bio yogurts and EGO, with notable differences in sugar content. The Bio yogurt has a relatively low sugar content of 4.5 g, while the Bio strawberry yogurt exhibits a substantially higher sugar content of 13.8 g. Brand EGO from Ljubljanske mlekarne introduces distinctions in sugar content among its yogurt offerings. The regular yogurt has 4.7 g of sugar, while the strawberry yogurt exhibits a higher sugar content of 12.6 g. Additionally, yogurts enriched with proteins demonstrate varying sugar levels, with the EGO regular yogurt with proteins containing 6.4 g and the EGO fruit yogurt with proteins containing 9.4 g of sugar.

2. Mlekarna Celea: brand Zelene doline showcases diverse sugar levels and brands (LCA, Oki Doki and Mythos) across its regular yogurts. The 3.2% variant has 4.1 g of sugar, the 3.1% variant has 5.1 g, and the 3.2% variant has 4.3 g. Notably, strawberry yogurt by Zelene doline has a higher sugar content of 14 g, while the Super strawberry yogurt contains 11.5 g. Brand LCA introduces a unique category with its LCA raspberry yogurt, no added sugar, having a minimal sugar content of 3.8 g. Comparatively, LCA Strawberry yogurt has a higher sugar content of 14 g, and LCA protein Strawberry yogurt contains 4.8 g. Brand Oki Doki presents its strawberry yogurt with 8.2 g of sugar. There is also Greek yogurt from brand Mythos, which provides Greek yogurt with 4.3 g of sugar, while the Strawberry Greek yogurt demonstrates a higher sugar content of 12.3 g.

3. Proteini.si: it contributes to the study with LCA raspberry protein yogurt, certified with no added sugar, and containing 4.8 g of sugar.

4. Bohinjska sirarna: its regular yogurt has a sugar content of 4.3 g.

5. Vindija: its brand Z bregov introduces variations in sugar content across its yogurt offerings. The regular yogurt has 5.1 g of sugar, while the protein yogurt contains 4 g, and the strawberry protein yogurt exhibits a higher sugar content of 8.5 g.

6. Mercator: it presents distinctions in sugar content among its yogurt variants. The regular yogurt 3.2% has 4.8 g of sugar, the regular yogurt 1.3% has 5.1 g, and the fruit yogurt demonstrates a higher sugar content of 12.6 g. The greek yogurt variant contains 4.1 g of sugar.

7. Milfina: Milfina’s regular yogurt 3.2% has 4.1 g of sugar.

8. Pomurske mlekarne: its regular yogurt has 4.5 g of sugar, while the fruit yogurt exhibits 10.1 g, and the strawberry yogurt contains 11.7 g of sugar.

9. Planika: it introduces bio regular yogurt with 4.3 g of sugar, yogurt with honey with 10.1 g, and another regular yogurt with 4.3 g of sugar.

10. Spar: it presents variations in sugar content across its yogurt offerings. The regular yogurt 3.2% has 4.3 g of sugar, the regular yogurt 1.3% has 5.1 g, and the Greek yogurt 10% contains 4.0 g of sugar. Additionally, the premium fruit yogurt demonstrates a higher sugar content of 13.5 g, while the Greek yogurt vanilla 0% contains 10.5 g, and the Greek yogurt with strawberries and no lactose has 8.0 g of sugar.

Table 1 illustrates the distribution of products across five consecutive classes, each with a 2.5 g sugar interval, depicting the range and frequency of sugar content in grams. There were also classes determined according to sugar amount, as presented in previous research (Žnidaršič, Vrabič Brodnjak 2023).

Table 1: Classes and frequency of sugar content in analyzed yogurts and ascending classes

Sugar content in one yogurt [g]	Frequency of yogurts with the amount of sugar
3.0 – 5.4	28
5.5 – 7.4	1
8.0 – 10.4	7
10.5 – 12.9	9
13.0 – 15.4	4

Determined ascending classes of amount of sugar	Amount of sugar in grams [g]
Very low	< 0.3
Low	1.5 – 7.9
Medium	8.0 – 10.4
High	10.5 – 12.9
Very high	> 15.4

According to sugar content in yogurts, sugar cubes have been used to create different versions of symbols (Figure 1a and 1b) and multi-color version have been prepared (Figure 1c and 1d). The use of sugar cubes makes it easier to recognize the ingredient clearly and quickly. The cube symbol was compared with the possibility of using the sweet symbol.

Figure 1: Two versions of single colored symbols according to sugar content a) white shaped cubes and b) filled cube shapes and two versions of color-coding c) with words and d) with lettering.

The symbols were designed to be clear, simple and minimalist and to ensure quick and direct communication of information (Figure 1a,1b). The shapes were rounded to create a friendly and welcoming environment for the customer and avoid unnecessary severity and harshness (Antúnez et al., 2015; Li et. al; 2015). The sole aim was to provide information about the content without imposing an opinion on the buyer. In the option shown in Figure 1a, the increase in sugar content is visually conveyed by the weight and direction of the arrow and the increasing number of sugar cubes. The lowest value is represented by a single cube accompanied by a thickened downward arrow conveying the concepts of ‘quite’ and ‘low’ The upward symbols increase accordingly with the amount of sugar, indicated by a greater number of cubes and a thickening of the upward pointing arrow. This subtle hint encourages the buyer to consider increasing the quantity (Antúnez et al., 2015; Li et. al; 2015; Dunford et. al.,

2020). At color coding (Figure 1c, 1d), when selecting the font for the text of the scales, particular attention was given to the legibility of the font in small sizes or letter heights. A font with features facilitating ease of reading, including a high central letter belt (x-height), moderately wide letterforms to avoid compressed and narrowed typefaces, and a relatively low contrast between bold strokes, was deliberately chosen. Additionally, assurance was taken that the chosen font had recognizable counterforms of the letters, as these are more easily discernible at smaller sizes.

In Figure 2 final positions of single colored and multi color-coding symbols are presented in the yogurt designs for the bottle.

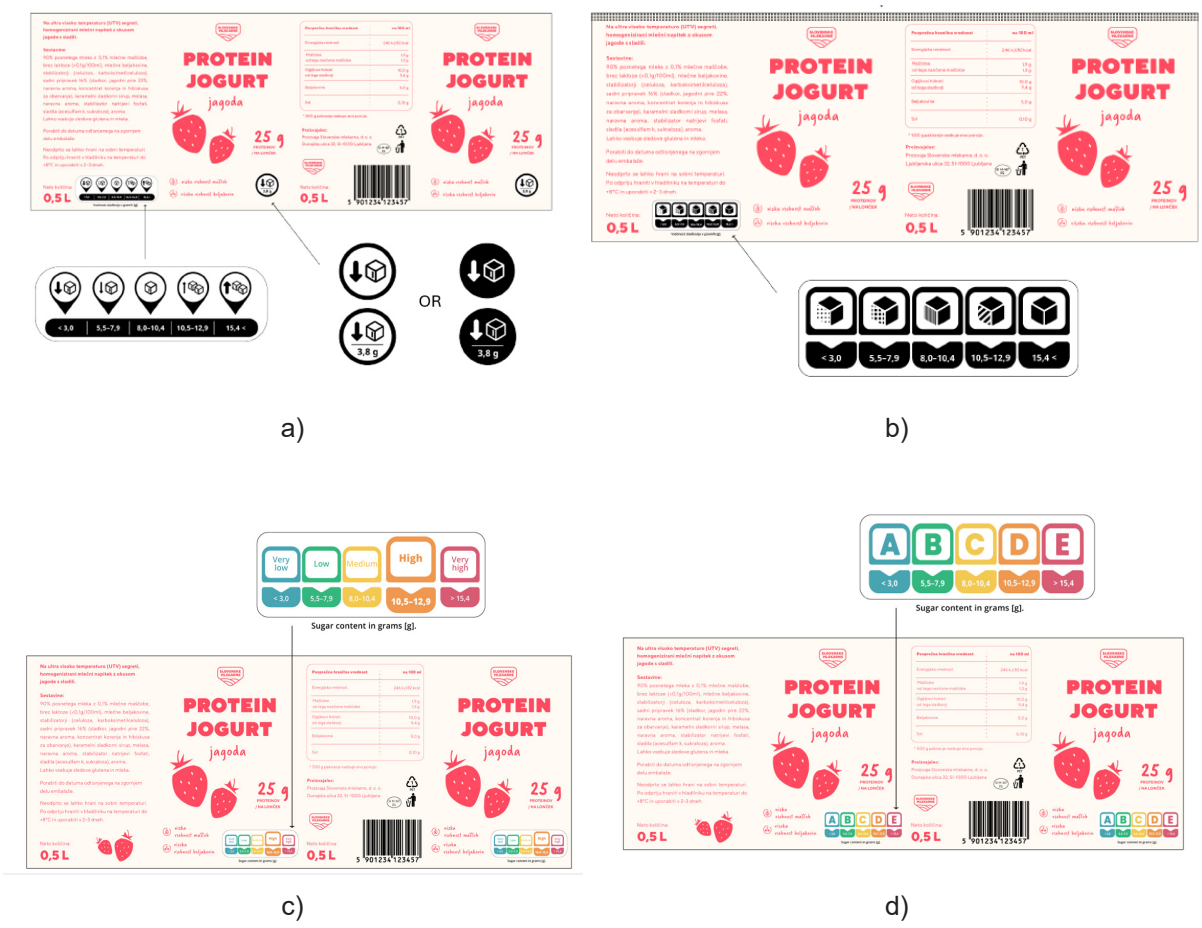

Figure 2: Final 4 color coding positions on yogurt products a) with shaped sugar cubes, b) with filled sugar cubes, c) with words and d) with lettering.

The four versions were chosen due to the repetition of the primary page, allowing the pots to be swiftly identified, and the primary information to be made visible on the shelves, which are frequently oriented or rotated in random directions (Figure 2). The recognizability of the brand enables the logo to be replicated on several pages. Sugar content and coding positions were placed in 2 different lower positions. In the design of the yogurt in the cup packaging, it was constructed on the basis of an analysis that included black-white sugar cubes and color coding with lettering (Figure 3).

a) b)

Figure 3: Two different scale placements on the cup of the yogurt packaging a) single-colored sugar cubes and b) with multi-colored coding lettering.

As seen in the figure 3, the primary side can only be seen once on the packaging, but is also reproduced on the lid, whereby the layout has been adapted to better match the round shape. The placement of the multicolored and single colored, as shown, ensures that the arrangement of the data (except for the scales) remains consistent. The lactic acid content, which could be defined as more important than the nutritional information, appears in a less conspicuous place, but is enlarged and emphasised more strongly. In addition, the deviation is on the right-hand side, as the scale is on the left-hand side (third zone) and the barcode on the right-hand side (fourth zone), which in principle attracts more attention. In this case, we have placed the scale on the left side as it is in close proximity to the sign that explains it and is more noticeable when looking at the cover from the primary (front) side. The logo is repeated for better recognition and the nutritional information icons provide quicker visibility.

Final placements of the color-coded sugar content designs on the yogurt bottle and pot are presented in Figure 4.

a) b)

Figure 4: Final 3D model and design of the multicolor coded sugar content scales on a) the yoghurt bottle and b) the yoghurt cup

4. CONCLUSIONS

When the existing methods of nutritional labeling were analyzed, it was concluded that there is still no uniform labeling system for sugar content in the Slovenian market. Consequently, different design solutions were designed and compared, varying in format, colors, and interpretability (graphic visualizations). Two types of scales were decided upon, differing in the presentation of the main information. A multi-colored scale with a word or letter representation of the primary information and a single-colored scale with symbols or a pattern instead of the primary information were designed. Consideration was given to the optimal placement of the scales on the packaging, ensuring that information about the amount of sugar is the first thing that catches the customer's eye while not being destructive in relation to the existing graphic image. The graphic image of the packaging was inspired by the analyzed samples, conveying a refined, natural, and slightly playful impression. The packaging layout for each food group was created, presenting two options. The first option features a multi-colored scale on the primary side, while the second option incorporates a single-colored scale on the reverse side and a sign on the primary side. In the subsequent phase, research activities such as surveys and questionnaires will be conducted to enable more informed decisions regarding the presentation of information and aesthetics in our designed packaging. Through these research efforts, we aim to gather valuable insights that will guide us in making constructive choices for optimizing the visual appeal and informative quality of our product packaging.

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RESISTANCE OF FUNCTIONAL LABELS TO CHEMICAL AGENTS

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Abstract: *Labels play a key role in product protection and information, and in the marketing aspect of the product. Therefore, it is crucial to ensure high quality and aesthetics of labels in order to attract customers and achieve sales success. The stability and functionality of labels is often a challenge, especially when exposed to high temperatures, humidity, and chemicals. The paper analyses the influence of different chemicals on the stability of labels to predict their durability in real conditions. In this study, one blue thermochromic ink (TC) and two conventional offset inks (red (R) and yellow (Y)) were used for printing of substrates made from residues from agricultural production (citrus -C). The results of the chemical stability test showed that the greatest changes in the shape of the spectral reflectance curve occur in the sample C-TC and C-TC-Y when it is exposed to the influence of ethanol, which indicates a change in coloration.*

Keywords: *thermochromic inks, stability, chemical resistance, colour*

1. INTRODUCTION

Thermochromic inks (TC) as wonders of modern technology and design, open doors to innovations and interactivity across various industries. These special inks are revolutionary due to their ability to change color according to temperature variations, creating dynamic visual effects that capture attention (Liu et al., 2022)creating a thermochromic painting requires knowledge of electrical engineering and computer science, which is a barrier for artists and enthusiasts with non-technology backgrounds. Existing toolkits only support limited design space and fail to provide usable solutions for independent creation and for meeting the needs of the artists. We present ViviPaint, a toolkit that assists artists and enthusiasts in creating thermochromic paintings easily and conveniently. We summarized the pain points and challenges by observing a professional artist's entire thermochromic painting creation process. We then designed ViviPaint consisting of a design tool and a set of hardware components. The design tool provides a GUI animation choreography interface, hardware assembly guidance, and assistance in assembly process. The hardware components comprise an augmented picture frame with a detachable structure and 24 temperature-changing units using Peltier elements. The results of our evaluation study (N = 8. They find application in a wide range of industries, from graphic design and packaging to textiles, toys, and electronics. With the help of thermochromic inks, ordinary surfaces become interactive and lively, responding to changes in ambient temperature. This effect is achieved thanks to special pigments that react to thermal variations, altering their molecular structure and hence the color they reflect. Thermochromic inks can be divided into two basic categories: reversible and irreversible. Depending on their chemical composition, thermochromic inks are further divided into leuko dye-based TC inks and liquid crystal-based TC inks. Leuko dye-based inks change color in response to oxidation, and the color change in them can be reversible or irreversible, while inks based on liquid crystals change color due to changes in their molecular structure, and the color change can only be reversible - meaning that after the cessation of the cause, the color returns to its original state, and the process can be repeated (Bamfield, 2010; Seeboth et al., 2013; Seeboth and Lotzsch, 2008).

The most common application of thermochromic inks is in packaging, such as bottles or boxes, where the thermal reactivity of the ink can indicate changes in the temperature of the product. They are also used as indicators in thermal printed circuits, toys that change color when heated by hand or with other heat sources, and in the fashion industry for creating effective patterns and designs on fabrics. Despite their innovative and creative possibilities, thermochromic inks also have their challenges. Sensitivity to UV radiation and chemicals can limit their durability and stability (Friškovec et al., 2010; Jamnicki Hanzer et al., 2023; Kulčar et al., 2023; Malenica et al., 2023). However, further advances in research and development of thermochromic ink technology pave the way for addressing these challenges and expanding their application in the future. As is the case with other materials, colors undergo changes in shade due to certain external influences, including exposure to chemicals and liquids. The purpose of this research was to conduct an analysis of the chemical resistance of thermochromic inks cured using UV radiation and applied to self-adhesive labels. To investigate their resistance to various chemicals and

liquids, prints were subjected to treatment with two different liquid agents. The chemical stability of the prints was assessed by analyzing changes in their optical appearance after treatment with the liquid agents, comparing them to prints that had not been treated.

2. MATERIALS AND METHODS

All inks were printed on a self-adhesive label, whose printing surface is fiber-based, composed of 15% agro-industrial by-products (citrus), 40% recycled post-consumer paper, and 45% pure wood pulp to obtain high-quality natural paper (AveryDennison, 2021).
In printing, one thermochromic (TC) offset ink was used alongside two conventional offset inks. The TC offset ink is based on leuco dyes. The activation temperature (TA) of this ink is 29°C. Before reaching the activation temperature, the ink has a blue coloration but as the temperature rises and reaches its activation value, the ink becomes completely colorless. Additionally, the standard offset inks used include warm red (WR) and yellow (Y). The prints were created using a printing press under standard working conditions and were later dried using a UV dryer on the offset printing press.

In this study, chemical testing of samples was conducted with alcohol and water. The purpose of this study are to provide a more realistic and faithful representation of labels, i.e., their reaction to various products, in this case, liquids such as alcoholic beverages and water. The assessment of the durability of prints to different liquids was conducted according to the standard method ISO 2836:2021 (ISO 2836, 2021) and conditions presented in Table 1.

Table 1: Testing conditions of chemical stability (ISO 2836, 2021)

Substance	Surface receptor	Temperature (°C)	Duration of testing	Contact conditions
Water (distilled)	Filter paper	23 ± 2	24 h	1kg/54 cm2
Ethanol (96%)	Test tube	23 ± 2	5 min	1kg/54 cm2

The assessment of chemical degradation of prints was conducted through spectrophotometric measurements. Colorimetric measurements were performed using the Ocean Optics USB2000+ spectrophotometer using an integrating sphere with a width of 30 mm in accordance with the (8◦: di) measurement geometry. An Ocean Optics LS-1 tungsten halogen light source with a radiation range from 360 to 2000 nm was used. The samples were mea- sured at room temperature and heated to 20 ◦C, 29 ◦C, and 40 ◦C. The samples were heated using a temperature-changing device (EK Water Blocks, EKWB d.o.o., Komenda Slovenia. The spectral reflectance was measured in the visible range of the electromagnetic spectrum (400 to 750 nm) with a step size of 1 nm. Samples were measured before and after exposure to chemicals or to the accelerated aging process. In addition to the spectral reflection curves, the colorimetric parameters C*, h*, L*, a*, and b* were measured, which were used to calculate the CIEDE2000 colorimetric difference according to Equation (1) (CIE Central Bureau, 2004) chromaticity coordinates, colour spaces and colour differences; and various other colorimetric practices and formulae. This publication is consistent with the fundamental data and procedures described in the CIE Standards on Colorimetry. This publication, which replaces CIE 15.2 (and is not to be known as 15.3!.

$$\Delta E_{00}^{*} = \sqrt{\left(\frac{\Delta L'}{k_L S_L}\right)^2 + \left(\frac{\Delta C'}{k_C S_C}\right)^2 + \left(\frac{\Delta H'}{k_H S_H}\right)^2 + R_T \frac{\Delta C'}{k_C S_C}\frac{\Delta H'}{k_H S_H}} \quad (1)$$

3. RESULTS AND DISSCUSSION

The spectral reflection curves (Figures 1 - 4) are presented in the range from 400 nm to 800 nm, at a temperature of 20°C for prints obtained using conventional offset inks, red (WR), and yellow (Y) (Figure 1). The displayed curves show the characteristic curves of the prints before and after treatment with water and ethanol. From Figure 1, it is evident that water and ethanol do not significantly affect the shape of the spectral reflection curve, except for a slight decrease in the reflection value. Figure 2 presents the spectral reflection characteristic curves of prints made with thermochromic ink (C-TC), as well as treated samples with water and ethanol, measured at different

temperaatures. From Figure 2, it is evident that the print at a temperature below the activation temperature (TA) has a blue coloration, and as the temperature increases, this color gradually fades, assuming the color of the printing substrate. It is evident that water and ethanol do not significantly affect the shape of the spectral reflection curve of the thermochromic print. The greatest impact of ethanol is noticeable at a temperature of 40°C. Figure 3 presents the spectral reflection characteristic curves of prints made from mixtures of thermochromic and conventional red (C-TC-WR) inks as well as treated samples with water and ethanol, measured at different temperaatures. The spectral reflection curves show the characteristic curves of prints made from mixtures of thermochromic and conventional red ink (C-TC-WR). From the presented figures, a significant influence of ethanol is visible at all temperatures, suggesting that there is degradation of the color, both of the thermochromic and conventional pigment.

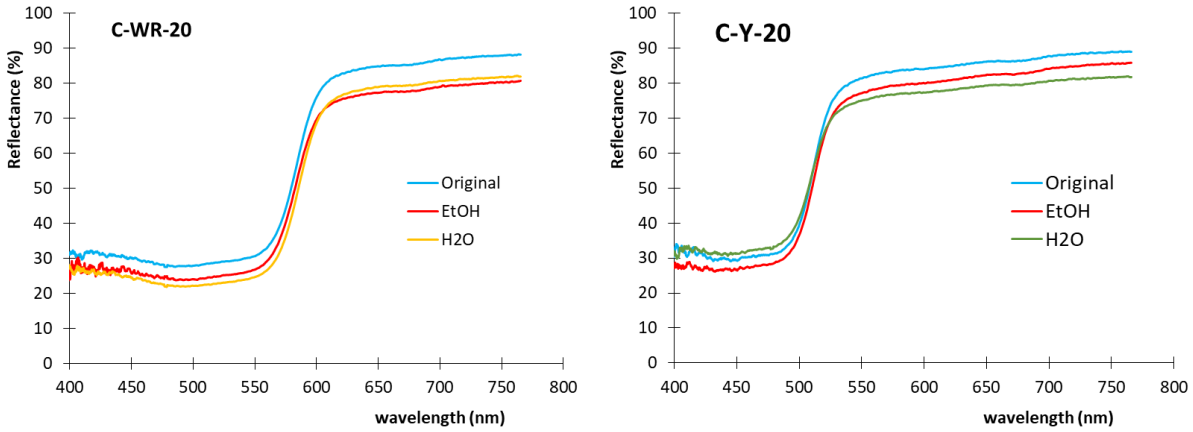

Figure 1: Spectral reflection curves of prints made from conventional inks before and after chemical stability to ethanol and water

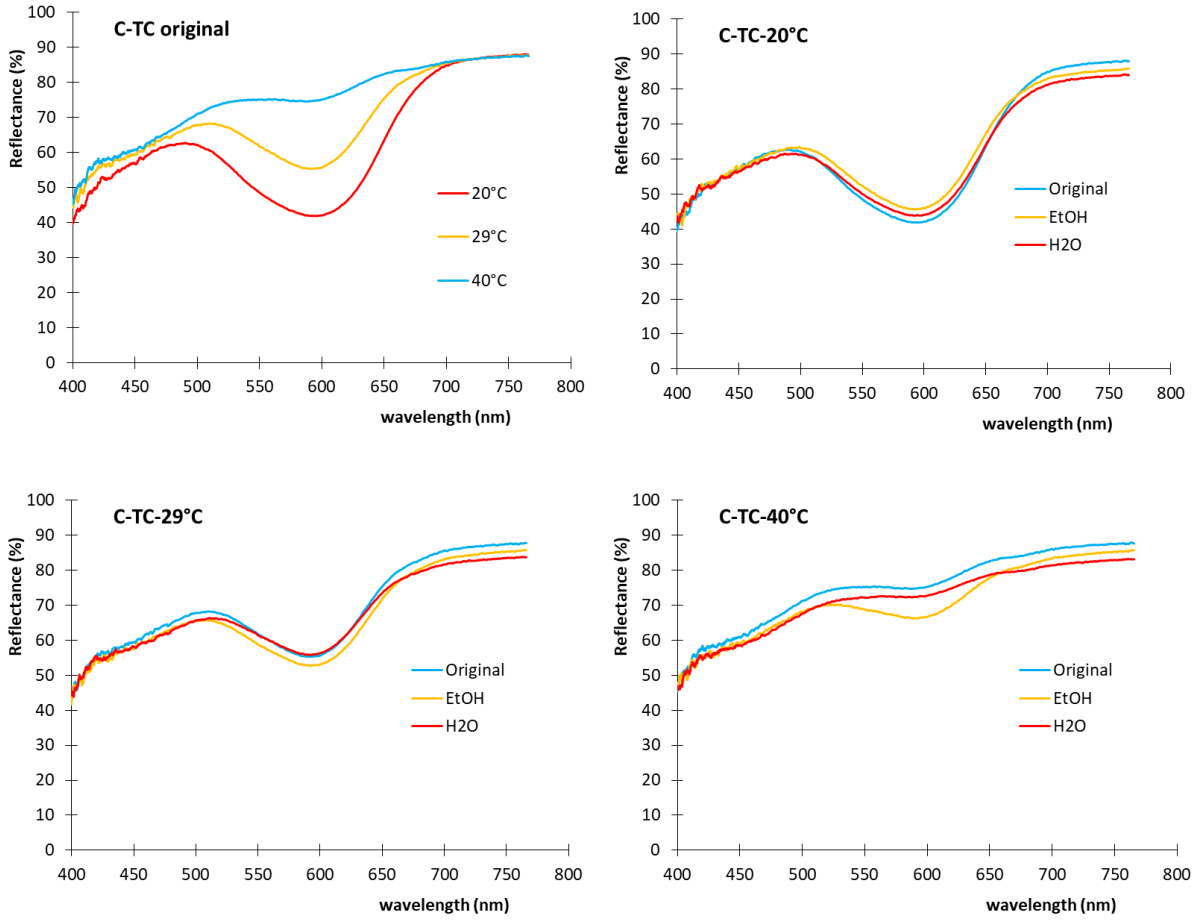

Figure 2: Spectral reflection curves of prints made from thermochromic inks before and after chemical stability to ethanol and water, measured at different temperatures

Figure 4 presents the spectral reflection characteristic curves of prints made from mixtures of thermochromic and conventional yellow (C-Y-WR) inks as well as treated samples with water and ethanol, measured at different temperatures. The spectral reflection curves show the characteristic curves of prints made from mixtures of thermochromic and conventional red ink (C-Y-WR). From the presented figures, it is evident that both water and ethanol affect the reflection value, suggesting an impact on both the thermochromic and conventional pigment.

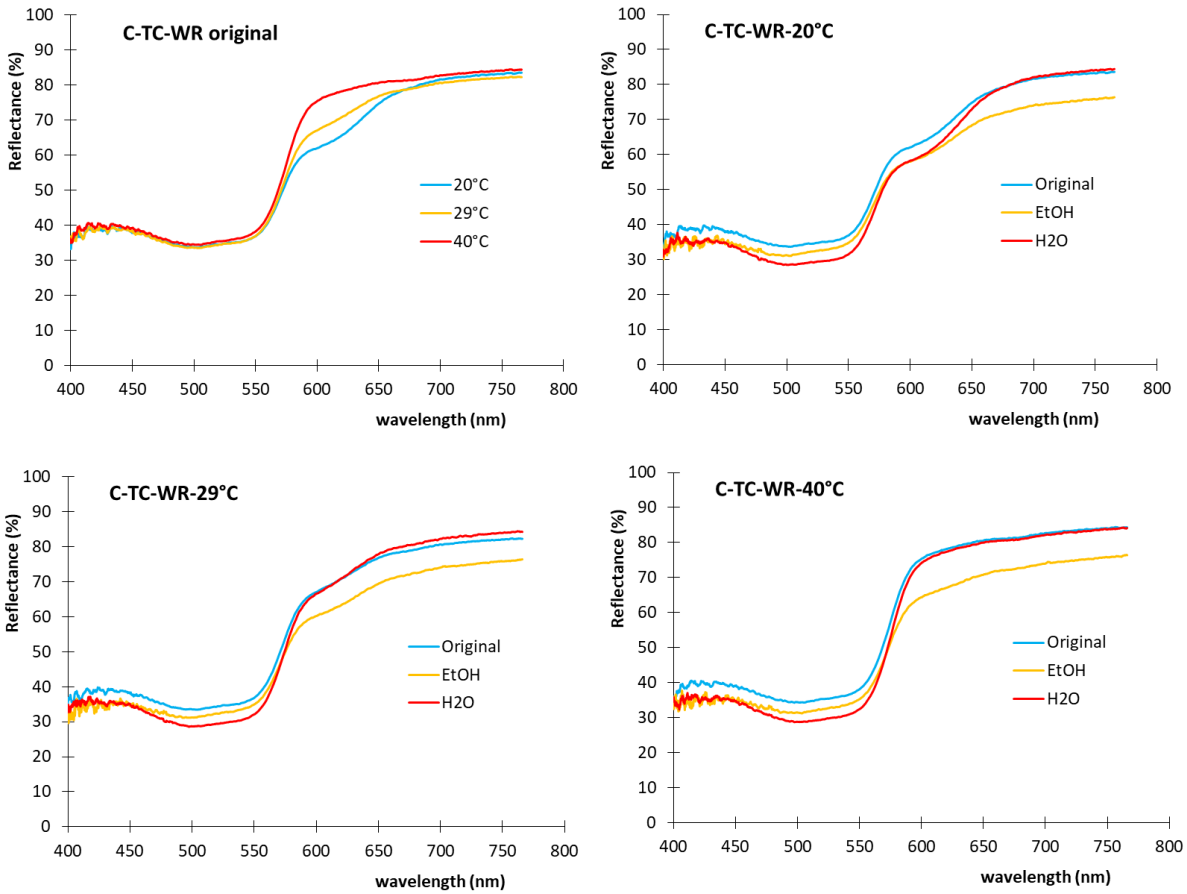

Figure 3: Spectral reflection curves of prints made from mixture of thermochromic ink (TC) and conventional warm red (WR) ink, before and after chemical stability to ethanol and water, measured at different temperatures

Observing CIEDE2000 values for print samples obtained with conventional WR and Y colors (Figure 5 and 6), a greater influence of water than ethanol is evident, i.e., CIDE2000 values are higher and exceed the value of 3. It can also be seen that the WR print, in both cases, exhibits greater instability towards the mentioned chemicals. In the case of thermochromic ink and its mixtures with conventional ink, a greater influence of ethanol on stability is noticeable, especially at 20°C when the TC microcapsules are active and impart color to the print. At higher temperatures, higher CIEDE2000 values are observed after exposure to water (Figure 6), especially in the case of mixtures, confirming their greater instability to water. When ethanol acts on TC mixtures, CIDE2000 values are slightly lower (Figure 5).

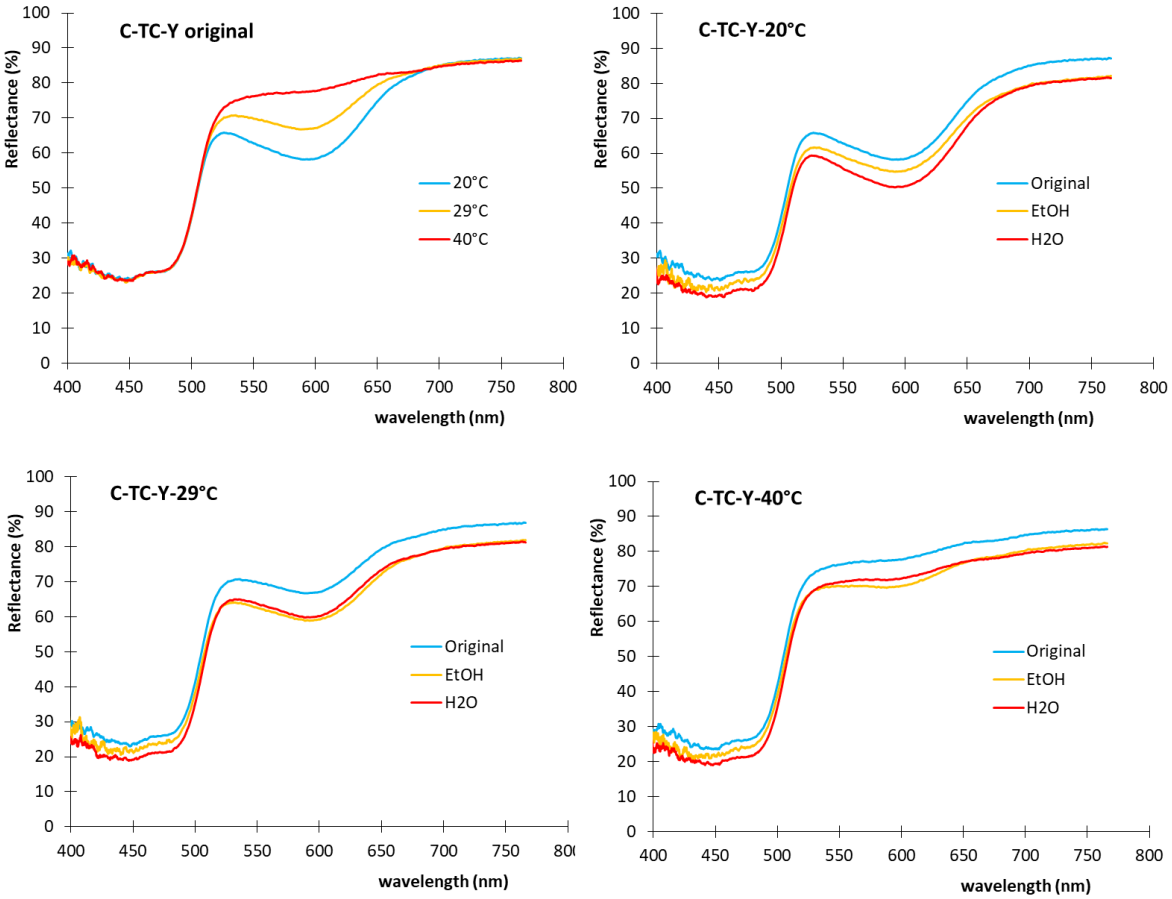

Figure 4: Spectral reflection curves of prints made from mixture of thermochromic ink (TC) and conventional yellow (y) ink, before and after chemical stability to ethanol and water, measured at different temperatures

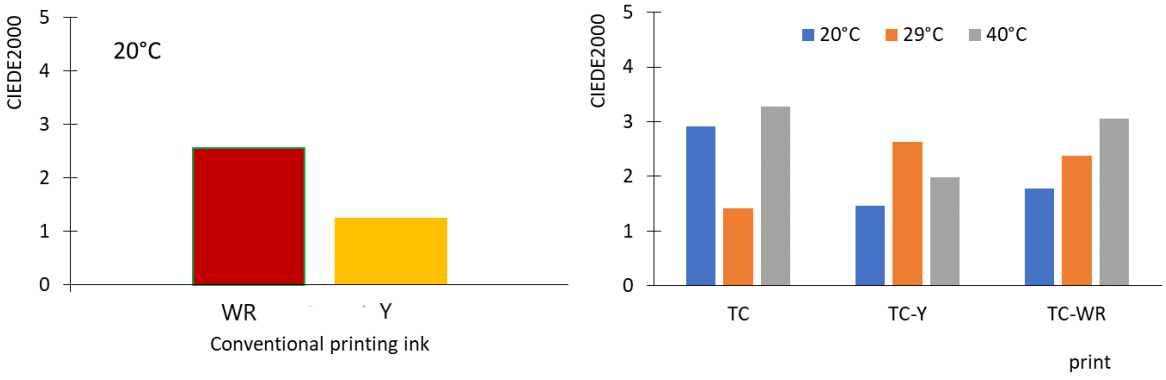

Figure 5: CIEDE2000 values of prints - stability towards ethanol at different temperatures

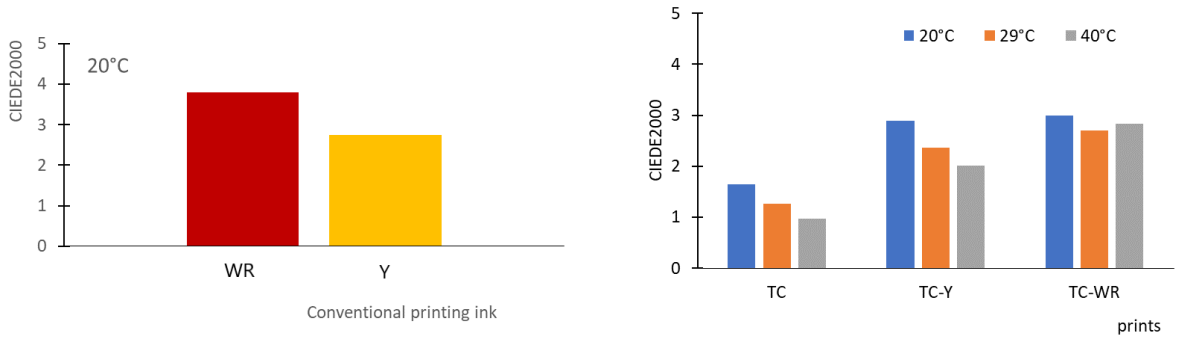

Figure 6: CIEDE2000 values of prints - stability towards water at different temperatures

4. CONCLUSIONS

The aim of this research was to analyze thermochromic offset ink and its impact on the stability of prints under different environmental conditions. Additionally, the study aimed to investigate whether the stability of prints could be improved by mixing thermochromic ink with conventional printing inks. For this purpose, chemical stability studies were conducted. Blue thermochromic ink and two conventional offset inks (red and yellow) were used in experiments for prints on substrates made from agricultural production residues (citrus). The results of the chemical stability test showed that the most significant changes in the spectral reflection curve occurred in samples C-TC and C-TC-Y when exposed to ethanol, indicating a change in color. Similarly, in the color difference test, almost none of the samples showed resistance to the tested substances within acceptable limits. From this, we can conclude that thermochromic inks demonstrate greater sensitivity to water and ethanol. In all samples, the thermochromic effect remains present, but after exposure to water and alcohol, changes in the saturation and brightness of the sample colors are observed, with changes in saturation being more pronounced. Although both types of inks used are intended for labeling, based on the results of this research, it is recommended to apply protective coatings over the prints to preserve the color and aesthetic appearance of the product when the label comes into contact with the product content.

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ENHANCING ART ACCESSIBILITY FOR THE VISUALLY IMPAIRED THROUGH 3D TECHNOLOGIES

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Abstract: *Museums and galleries worldwide are increasingly focusing on making art accessible to vulnerable groups, including the blind and visually impaired. Moving beyond traditional methods like ultraviolet inkjet printing that added textures for tactile experiences, the use of 3D printing technology has become more prevalent. This approach allows for the creation of detailed relief reproductions of artworks, providing a richer tactile experience from two-dimensional pieces. Our study demonstrates the process of transforming artworks into 3D tactile reproductions, particularly focusing on portraits. We present examples of converting two notable works by renowned Slovenian artists—Anton Ažbe's „Zamorka" and Ivana Kobilca's „Kofetarica"—into 3D forms. This showcases the advancement from traditional texture-based relief reproductions to the innovative application of 3D printing for creating tactile versions of original 2D artworks, enhancing accessibility and interaction for visually impaired audiences.*

Keywords: *accessibility, 3D technologies, visual impairments, digital modelling*

1. INTRODUCTION

Today we encounter an increasing number of artworks in museums and galleries all around the world that are reproduced, sometimes even reinterpreted, with the aim of enriching their meaning and bringing art closer to vulnerable groups of people. Below are presented some examples.

Figure 1: 3D printed reproduction of Michelangelo's sculpture of David, (University in Florence, 2020)

The famous artistic creation the statue of David crafted by Michelangelo has been reproduced using various techniques including 3D printing (Figure 1). By employing this advanced technology, they managed to meticulously capture the intricate details of the original artist's work. For a complete digitization of the statue, they had to create a special stand and perform hundreds of scans, as the statue measures five meters in height. The reproduction, printed from acrylic resin, was divided into fourteen parts and then assembled (University in Florence, 2020, Madeline, 2021).

Figure 2: Relief reproduction, portrait of Luiza Pesjak, painter Mihael Stroj,(National galery, 2014)

In December 2014 a relief painting was exhibited at the National Gallery selected from the permanent collection – the renowned portrait of Luiza Pesjak by the painter Mihael Stroj. A tactile diagram was placed in front of the original artwork accessible even to individuals in wheelchairs as it was attached to a reachable stand. Tjaša Krivec the author of the tactile adaptation successfully emphasized the key elements of the portrait using six different relief textures and an elevated contour. For an even better approximation and understanding of the work the adaptation was equipped with an audio recording of the portrait, a larger font transcription and a Braille transcription. The legend with tactile elements (reliefs) is also added on the painting adaptation (National galery, 2014).

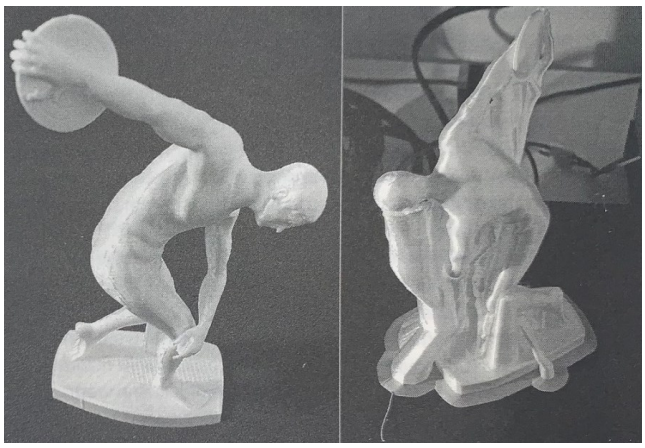

Figure 3: 3D printed reproduction of the Discus Thrower (Herzog, 2022)

In the photograph (Figure 3) an example of reproduction using 3D printing is presented, employing the technology of extruding thermoplastic materials. Polymer material is highly suitable for tactile reproduction, as it can be touched without any concern. The printed reproduction must not be too fragile or excessively large; therefore, larger objects are usually replicated on a smaller scale. The material from which the replica is made is also adjusted, as it is often not possible to use the same material in the process of 3D printing as the artist used in the original creation. Thus, with the increasingly accessible technology of 3D printing, works made from stone or metal can be produced and reproduced with plaster or polymer material (Herzog, 2022).

The curator of the exhibition titled 3D Printed Tactography For Blind People to Explore Photography, Gabriel Bonfim, is one of the pioneers who has merged photography with 3D printing technology, creating relief reproductions of photographs with the aim of allowing blind and visually impaired individuals to “see” them. The author’s so-called tactography uses 3D technology named stereolithography to create precise 3D reproductions of original photographs (Watkin, 2017, Bonfim, 2019).

Figure 4: Demonstration of the tactile experience of 3D printed tactography (Bonfim, 2019)

2. EXPERIMENTAL

For the conversion of artworks into 3D tactile reproductions we selected works from two renowned Slovenian painters namely Anton Ažbe ("*Zamorka*," 1889, oil on wood, 55.2 × 39.4 cm) and Ivana Kobilca ("*Kofetarica*," 1888, oil on canvas, 100 × 70 cm), whose works are included in the permanent exhibition and collection of the National Gallery in Ljubljana (National gallery, 2024).

Figure 5: Photographs of the original artworks; "Zamorka" (left) and "Kofetarica" (right) (National gallery, 2024)

2.1 Modeling Procedures for Tactile Reproductions

In the conversion of the photographs of the artworks "*Kofetarica*" and "*Zamorka*" into 3D tactile reproductions using Blender, 3D modeling program, we focused on the careful planning and step-by-step execution of several key steps. We began by importing the photographs into the program, where we defined reference points to preserve the proportions and details of the original images. Initially, we used primitives such as spheres, cones, and cubes to place them in a virtual space and create the basic structure of the figures from the artworks, which could then be further refined. So we used a sphere for the head, a cylinder for the neck, arms, hands and fingers

and multiple spheres to shape the torso. We then combined all individual primitives into one object and further proceeded with more detailed modelling.

Reference points were placed on key points or lines, such as the edges of the cup, clothing edges, facial features, and so on. We employed digital sculpting, enabling us to gradually shape the relief surfaces. Throughout the process we closely followed facial features, clothing, and other details, adjusting their shapes to align with the original photograph placed in the background. Various brush strokes were used to create a 3D effect. Special attention was given to maintaining the natural flow of the lines from the original image and proportions which were crucial for achieving a realistic result. Simultaneously improvisation was necessary for shaping the objects in the background of the original artwork as we had limited information to rely on for accurate design. One such challenge was presented by the chair on which "*Kofetarica*" is seated. Since only a small part of the chair is visible in the original artwork, we had to invent the shape of the chair mostly based on different references to similar wooden chairs found online, with characteristics of the time period in which the artwork was created.
Once we successfully established the basic form of the digital representations of the portraits of "*Kofetarica*" and "*Zamorka*," we focused on adding details. This involved refining facial expressions, clothing texture, and other specific features.

2.2 Printing Tactile Reproductions

The tactile reproductions were created using the Artillery Sidewinder X2 3D printer, which operates with the technology of extruding thermoplastic materials and utilizes white thermoplastic filament, PLA. This printer has a working volume of 300 × 300 × 400 mm allowing us to print the model in a 1:1 scale. The printing process used a layer thickness of 200 microns and the nozzle diameter on the extrusion print head was set to 400 µm. The infill density was 50% and the number of walls was 3.

3. RESULTS WITH DISCUSSION

3.1 Printed Tactile Reproductions

The 3D printing of tactile reproductions proved to be an intricate and time-intensive endeavour. The printing of "*Zamorka*" took 98 hours and 21 minutes, while the printing of "*Kofetarica*" took 131 hours and 24 minutes. During the transformation from a digital model to a physical model the use of supports was necessary (Figure 6). During the printing of the 3D tactile reproduction of "*Zamorka*" supports had to be positioned primarily in the facial area. For the printing of "*Kofetarica*" the quantity of supports was much greater as it was necessary to support all overhanging structures, from outstretched arms to the neck and head, since the latter is slightly tilted forward.

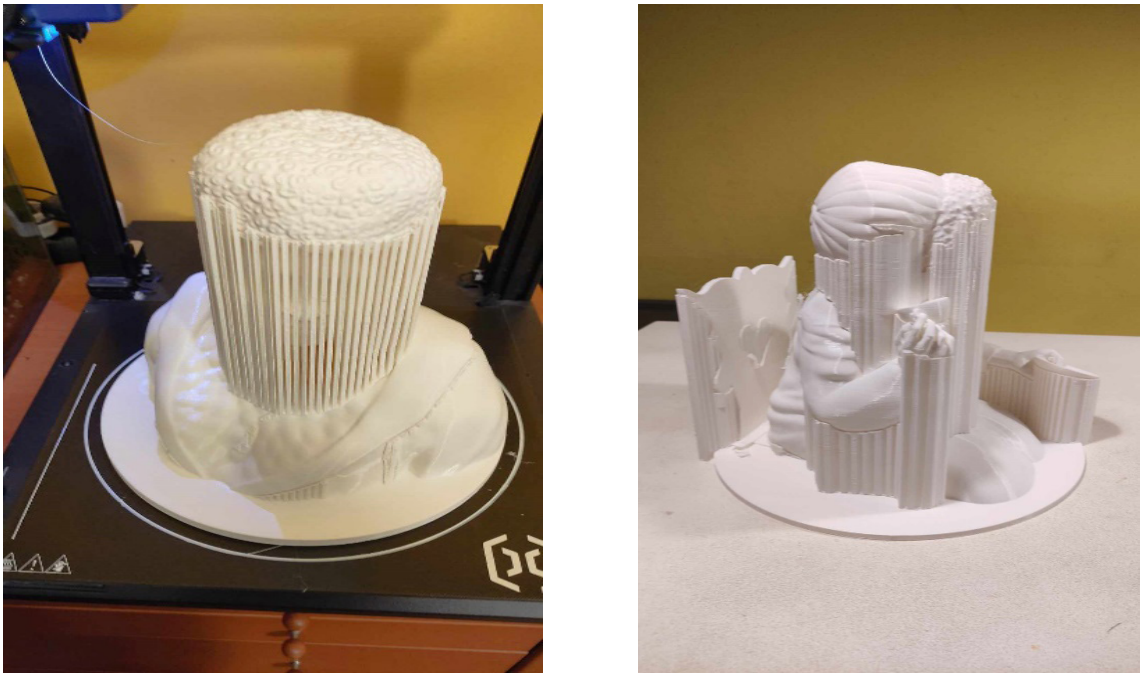

Figure 6: Printed tactile reproductions before the removal of supports; “Zamorka” (left) and “Kofetarica” (right)

After the removal of supports we were highly pleased with the printing results. The facial features are clearly visible and tactile, distinct from the other parts of the body and various pieces of clothing. Even the nails on “Kofetarica” and the iris in the eyes of both “Zamorka” and “Kofetarica” are easily noticeable.

Figure 7: Printed tactile reproductions in the National Gallery; “Zamorka” (left) and “Kofetarica“ (right)

3.2 Artistic Analysis of the Printed Tactile Reproduction

Exploring the works of artists Kobilca and Ažbe prompts us to contemplate whether 3D reproductions truly depict what the painters saw or rather reflect the creative interpretation of the person creating the reproduction. For instance, the imagined appearance of the chair on which "*Kofetarica*" was seated is a product of imagination. The author offers their perspective derived from one painting, one viewpoint. The transformation allows us to explore different directions and views even those not depicted by Kobilca.

It is primarily about perception and possibilities of creation for people with visual impairments, as well as for us, who observe the printed reproductions, contemplate them and seek our own solutions. This process not only satisfies museum requirements but also contributes to creativity that enriches our visually constructed world.
In the process of painting "*Zamorka*" Ažbe faced different challenges particularly in portraying light and shadow in the depicted interior. While a realistic depiction brings pride to the painter the challenge of tactile reproduction introduces complete light and material whiteness, vividly displaying Ažbe's portrait. Racial differences are evident in the anatomy and form of the bust portrait, emphasizing the shapes and textures on the surface, accessible to tactile perception. The relationships between skin, fabric and hair are clearly defined and differently treated in the context of tactile perception.

4. CONCLUSIONS

In the creation of relief or 3D printed tactile reproductions of artworks the author must invest their creative effort to show us what the original creator could not capture on the canvas. The challenge in transforming artworks into relief or 3D forms is that most of this is done by technically skilled individuals without sufficient artistic sensibility, knowledge of anatomy or other visual elements. This can lead to distortions that may go unnoticed by the blind while we as evaluators seek deviations.

Nevertheless, with the professional assistance of a sculptor, the author successfully transformed the artworks into 3D tactile reproductions. The tactile nature of both reproductions was also tested directly by blind individuals at the National Gallery. Following the testing we received feedback indicating that the 3D printed tactile reproductions of artworks especially those featuring portrait depictions provide a wealth of information in the three-dimensional space making additional texturing unnecessary.

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ADDING QUERCETIN WATER BASED COATING TO DIMINISH UV DEGRADATION OF THERMOCHROMIC PRINTS

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Abstract: *To enhance the communication process, packaging often includes dynamic elements. Among others, thermochromic inks enable dynamicity of printed motive by changing their appearance when the surrounding temperature changes. Due to their sensitivity to the irradiation, thermochromic prints should be protected. The aim of this paper is to investigate applicability of water-based coating with added quercetin to diminish UV degradation. A set of coatings were prepared by altering quercetin amount in a coating and applied onto the thermochromic prints. The samples were exposed to the UV accelerated ageing and evaluated by determining their colour values in CIE LAB system before and after ageing process. The results showed …It is expected that the results of this research will enable evaluation of quercetin applicability in coating for protection of prints against UV radiation.*

Keywords: *thermochromic print, UV ageing, water-based coating, quercetin*

1. INTRODUCTION

The demand for printed packaging is growing on the world market, with cardboard packaging having the biggest share (Smyth; S., 2017). The primary role of packaging is the protection of goods, but with the industrial development, the packaging's role significantly developed improving stability of the goods in transport and storage and increase of the marketing and sales of the packed goods (Grundey, 2010). Besides cardboard boxes, a significant rise is present in the labeling. Labels are widely used to give enable product tracking, give important information to consumers (Giró-Candanedo et al., 2022), and play similar role to boxes – promoting it on a shelf (Fripp, n.d.). Development of the printing industry led to the use of various effects to enhance packaging attractiveness. There are many methods present as application of coatings, enhancing gloss, cold and hot foil, etc. In addition to these static visual elements, in recent years a lot of materials used in packaging introduce dynamicity to print to enhance communication with a customer. This is usually achieved by application of materials which are sensitive to change in their surroundings. One of those inks, which change their appearance due to the change of the surrounding temperature are thermochromic inks (Kerry & Butler, 2008). Although being able to communicate with the customers by giving them information about temperature change, the thermochromic inks are unstable when exposed to high temperatures and UV radiation (Friškovec et al., 2013) or to various chemical agents (Hanzer et al., 2023).This fact stresses the need for protection of the thermochromic prints if they will be exposed to such influences. One of the possible solutions is to apply coating on the printed surface. These coatings act as a barrier and can diminish negative influences (Vukoje et al., 2023). For the protection against the UV light one can enhance coating's properties by adding particles with ability to adsorb UV radiation (Cigula et al., 2021). One of the substances which can absorb UV light is flavonoid quercetin (Golonka et al., 2020). Compared to other flavonoids, the quercetin has the highest antiradical property (Casagrande et al., 2006) enabling it to act as an antioxidant in an ink degradation.

Having these facts in mind, the aim of this paper is to investigate applicability of water-based coating with added quercetin to diminish UV degradation of thermochromic prints.

2. EXPERIMENTAL

The printing substrates used in this research are commercial self-adhesive labels composed of 45% virgin cellulose fibres, 40% of recycled cellulose fibres and 15% of barley (B) or grape (G) waste (AveryDennison, USA). The added barley or grapes waste indicates their proposed use for craft beer or wine bottles. These labels are applicable in lithographic or flexographic printing.

The prints were made in lithography using commercial reversible thermochromic ink based on leuco dye. The ink has the activation temperature of 29 degrees Celsius. After reaching the activation temperature, the ink changes from blue to transparent. The coatings were prepared by dissolving quercetin granules (Q) in a commercial water dispersive varnish. The mixtures were prepared by alternating mass of the added quercetin granules, without quercetin (WD), 0.25% (Q0.25), 0.5% (Q0.50) and 1% (Q1.00) w/w. After adding the quercetin granules, the coatings were mixed with a magnetic stirrer at 1000 rpm for 10 minutes. The prepared coatings were applied to the prints using K202 Control Coater (RK Print, Litlington, UK) and a coating rod Nr. 2 (wet film thickness of 12 µm). The prepared prints were exposed to the accelerated ageing in a CO.FO.ME.GRA Solarbox 1500e chamber under temperature of 50 degrees Celsius and irradiation of 550 Wm-2 for 4 hours.

In order to determine the influence of the applied coatings, the prints were characterized by measuring the reflectance curves in visible part of the spectrum (400 – 750 nm) by using the Ocean Optics USB2000+. The spectra of the prints were measured at 20 (bellow the activation temperature), 29 (at the activation temperature) and 40 (above the activation temperature) degrees Celsius. The temperature of the samples was set and controlled by using EK Water Blocks (EKWB d.o.o., Slovenia). From the measured spectra and CIE L*a*b*values, calculation of colour difference CIE ΔE2000 (Mokrzycki & Tatol, 2011) between the samples was performed.

3. RESULTS AND DISCUSSION

The reflection curves in visible spectrum below the activation temperature (20 °C) at the activation temeprature (29 °C) and above the activation temperature (40 °C) on grape label is shown Figure 1.

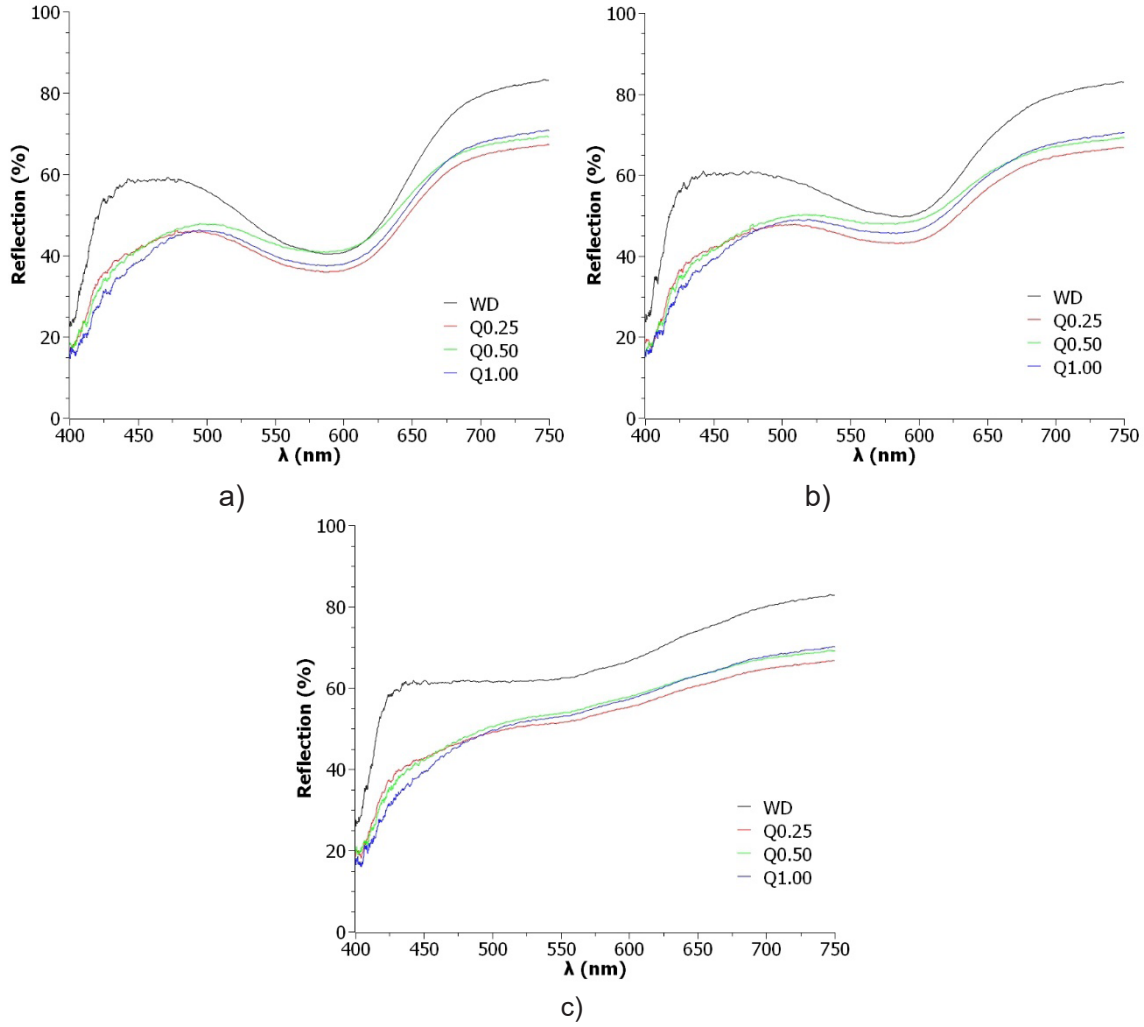

Figure 1: Reflection curves in visible spectrum of print on grape at a) 20 °C, b) 29 °C and c) 40 °C

It can be seen that there is a significant difference in the reflectance between the WD and the samples coated with quercetin containing coatings, regardless on the temperature of the sample. The samples coated with quercetin containing coatings show a lower reflectance across the visible spectrum, resulting in a darker appearance.

The reflectance at 20 and 29 °C shows a similar curve, the highest reflectance is in the red part of the spectrum and the lowest in the green part of the spectrum. An increase in temperature leads to an increase of the reflectance in the green part of the spectrum.

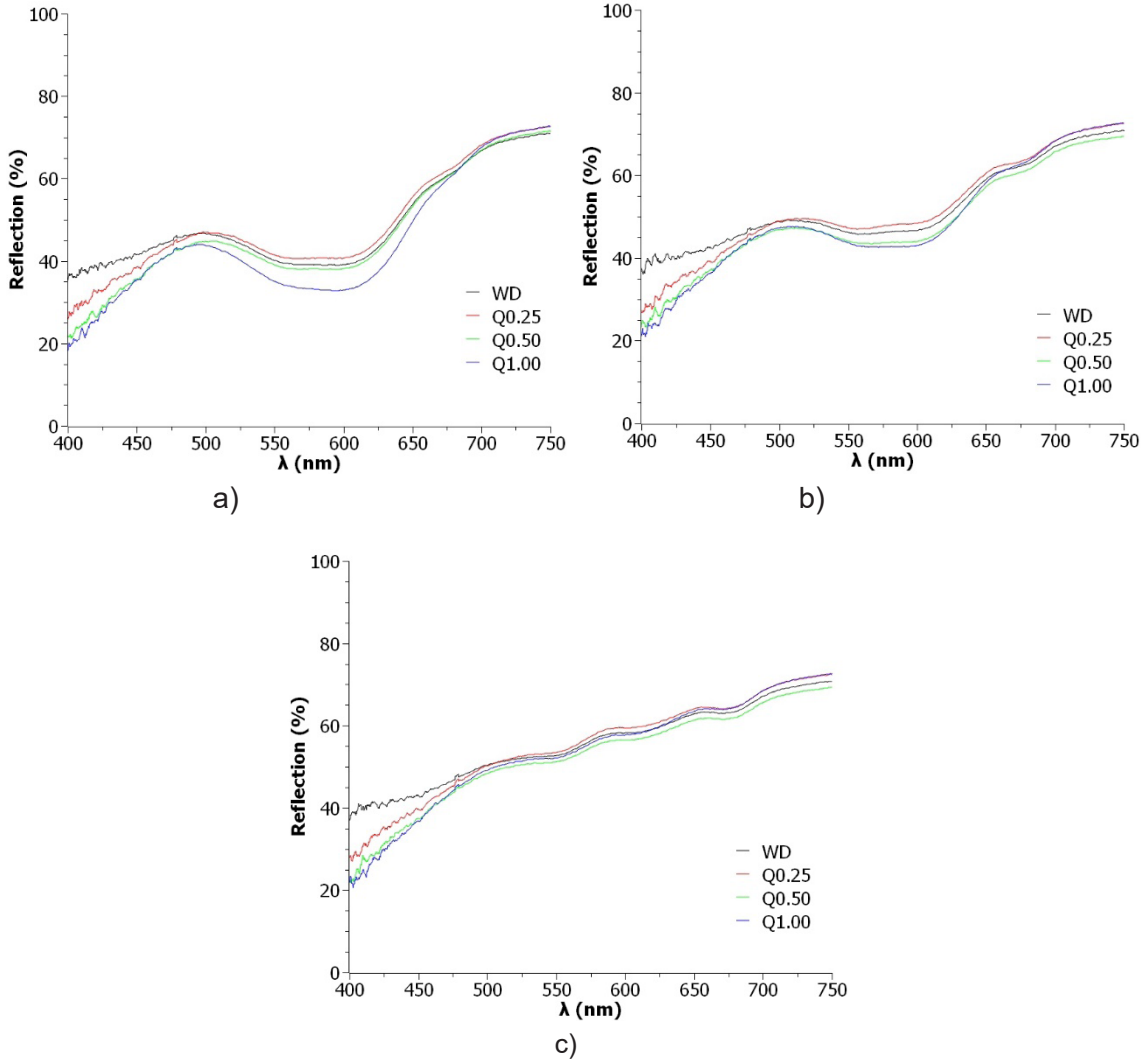

Figure 2: Reflection curves in visible spectgrum of print on barley at a) 20 °C, b) 29 °C and c) 40 °C

The reflectance curves of the prints on the barley labels differ significantly from those on the grape labels (Figure 2). The reflectance at wavelengths up to 475 nm is different, with WD having the highest value and an increase in the amount of quercetin in a coating lead to the decrease in reflectance. The reflectance at wavelengths above 475 nm is almost the same for all samples at 40 °C, while at 20 °C and 29 °C the samples differ in the green part of the spectrum, with Q1.00 having the lowest reflectance.

The results in Figures 1 and 2 prove that the application of coatings will not affect the function of the thermochromic ink, i.e. the ink changes from its original colour to transparent when the sample is heated. These results are not unexpected as quercetin does not change at temperature below 100 °C (Borghetti et al., 2012).

To better assess the colour change due to the addition of quercetin to the coating Table 1 shows the colour difference CIE ΔE2000 between WD and samples coated with a quercetin containing coating. The results presented in Table 1 show that the colour difference on the grape label is very high even with the lowest amount of added quercetin (Q0.25). On the other hand, the colour difference on the barley labels is much smaller. On both labels, the colour difference is smallest at 40 oC.

Table 1: Colour difference CIE ΔE2000 between WD and samples coated with quercetin containing coating

Sample	Grape			Barley		
Temperature	20 °C	29 °C	40 °C	20 °C	29 °C	40 °C
Q0.25	7.83	9.13	7.91	4.59	3.87	3.06
Q0.50	12.02	12.03	9.15	5.25	3.81	3.69
Q1.00	12.24	12.68	10.60	4.41	4.26	4.45

The results of the colour difference are consistent with the appearance of the labels and the print on them. The measured CIE L*a*b* values for WD on the grape and the barley labels at 20 °C are 73.73, 1.23, -10.87 and 70.77, 0.10, -0.71, respectively. The quercetin is yellowish (Victor et al., 2016), and therefore has less influence on the colour of the less chromatic barley label print.

To evaluate the influence of the accelerated ageing induced by UV light, the colour difference between aged and unaged samples was calculated (Table 2).

Table 2: Colour difference CIE ΔE2000 between aged and unaged samples

Sample	Grape			Barley		
Temperature	20 °C	29 °C	40 °C	20 °C	29 °C	40 °C
WD	5.85	3.31	4.70	6.41	2.43	2.19
Q0.25	10.06	6.94	5.24	5.95	2.39	3.18
Q0.50	6.04	4.18	4.43	7.52	4.70	2.38
Q1.00	34.82	37.83	39.79	11.13	4.67	2.16

The results show that on the grape labels the quercetin containing coating does not help to preserve colour appearance, moreover the colour difference is larger than on the WD. On the barley labels, however, the smallest amount of quercetin leads to a slight reduction in colour change at lower temperatures, compared to the plain water dispersive varnish.

These results indicate the degradation of the thermochromic ink, but the quercetin as well, as quercetin changes its absorbance by exposure to irradiation (Golonka et al., 2020).

4. CONCLUSIONS

This research was conducted to evaluate coatings with added quercetin at different weight ratios when applied to the thermochromic offset prints on two types of self-adhesive labels. For the purpose of the research a series of coatings were prepared by mixing quercetin in commercial water dispersive varnish and applied in a 12 µm thick wet film over the dry offset print.

The evaluation of the colour of the prints showed that the applied coatings did not affect the function of the thermochromic ink (colour change due to temperature change) but caused a significant colour change. In addition, the colour change of the print was highly dependent on the printing substrate, i.e. on the barley label the colour change was small compared to the grape label. The accelerated ageing process induced by UV light caused a significant colour change on the grape. For barley labels, the lowest quercetin weight ratio tested resulted in less colour change, but increasing the quercetin amount led to the higher colour change.

In summary, the addition of quercetin to the water dispersive varnish does not provide protection for the print when exposed to UV light, while it causes a significant colour change on the label without yellowish appearance.

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GLOBAL MARKET AND FORECAST OF EDIBLE PACKAGING – A REVIEW

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Abstract: *The global plastics industry is changing. Growing environmental awareness and the need to reduce plastic waste and non-biodegradable packaging materials are the main drivers for edible packaging. Companies and manufacturers are innovating and adopting materials and practices that are in line with environmental goals. The concept of edible packaging material is a stimulating way to develop new packaging materials. Edible packaging is designed to reduce waste, reduce carbon footprint and improve overall sustainability while providing safe and effective packaging for a variety of foods. Increasing consumption of ready-to-eat and processed products, changing preferences for hygienic products and growing populations are contributing greatly to the growth of the edible packaging market. Rapid growth and urbanization in developing countries and increasing population across the globe are also boosting the market growth. This overview study covers the market analysis, market share, growth factors, and global future forecast for edible packaging.*

Keywords: *edible packaging, environment, pollution, market analysis, CAGR*

1. INTRODUCTION

Food packaging plays an imperative role in society, protecting food and food products from potential damage and degradation while ensuring safety and hygiene, and actively reducing food waste (Trajkovska Petkoska et al., 2021). There are number of food packaging materials such as glass, paper and cardboard, metals and plastic are available. However, the plastic is a mostly used non-biodegradable packaging material which causes environmental pollution. Globally, factories produce 400 MT of plastic per year approximately. About 12.7 metric tons of plastic waste enters the ocean every year which affects the life of marine lives. From total plastic waste about 79% is dumped in land, 12% incinerated and 9% is recycled (Meshram et al., 2023).

There is a trend towards ecologically sustainable and edible forms of packaging. Edible packaging, i.e. edible coatings and films, have attracted a lot of attention in recent years. They offer a sustainable and environmentally friendly alternative to conventional packaging materials such as plastics, which often contribute to environmental pollution. As conventional plastic packaging generates waste that harms the environment, edible packaging is already on the market. Leading companies are now focusing on edible packaging solutions that serve as an oxygen barrier for food and are equipped with milk proteins, vitamins and probiotics (Edible Packaging Market Outlook, 2023). It is considered a sustainable and biodegradable alternative in the field of active food packaging and offers an optimization of food quality compared to conventional packaging. Edible packaging typically uses sustainable, biodegradable material that is placed around the food as a consumable wrapper or coating and does not generate waste (Pooja et al., 2019; Trajkovska Petkoska et al., 2021). They can be made from various natural sources, including algae, starch, proteins and other plant-based materials. These materials are biodegradable, compostable and can even provide additional nutritional benefits (Edible Packaging Market Size, 2023).

The main advantage of edible packaging over synthetic packaging is that it can be safely consumed as part of food, reducing packaging waste and pollution. Edible packaging is categorised into films, coatings, bags and sheets. Edible packaging can be used in the form of both films and coatings. The edible coating (EC) is applied directly to the food, whereas edible films (EF) and layers with a thickness of 10 mm or less than 254 µm or more than 254 µm are produced separately and then the food is packaged in them, in the form of pouches or between the food layers. The packaging material contains various additives (flavourings, colorings, sweeteners). Lipids, carbohydrates, proteins (casein) and tomato skin are used to produce edible packaging. Some examples of edible films (packaging) are based on starch, collagen, zein, gluten, etc. (Meshram et al., 2023)

The materials used for edible packaging (polysaccharides, lipids and proteins and their composites) have obvious advantages over synthetic films. They could contribute to reducing environmental pollution. By acting as barriers,

edible films can reduce complexity and thus improve the recyclability of packaging materials compared to the conventional, non-environmentally friendly packaging materials, and they have the potential to replace synthetic polymer films (Pooja et al., 2019).

The development and characterization of edible films and coatings has increasingly attracted the attention of biochemists, biotechnologists and physicists, mainly because of the wide variety of applications that bio-based polymers offer (Prakash et al., 2023).

2. METHODS

2.1 Market analysis

Market analysis is a comprehensive and analytical study of a particular market within an industry, including an examination of its various components, such as market size, key success factors, distribution channels, target audience, profitability and growth rate, and market trends. It provides an overview of the characteristics of the market and emerging future trends. The aim of market analysis is to evaluate and understand market conditions, trends and competition in order to make informed business decisions (Team, 2023). The analysis in this review is based on freely available market reports from 2022 to 2033

3. RESULTS WITH DISCUSSION

3.1 Market growth

Edible packaging is rapidly becoming more accepted as an eco-friendly and efficient alternative to traditional methods. Consumers now have a wide range of options that can improve the stability, quality, safety and variety of products and make life easier for customers as they reap the benefits of this packaging (Jones, 2023).

The edible packaging market is predicted to develop from USD 1.10 billion in 2023 to USD 4.18 billion by 2033, mounting at a prominent CAGR (Compound Annual Growth Rate) of 14.31% over the forecast period (Figure 1). The growing demand for biodegradable packaging along with a surge in packaging innovations is pushing this fast development globally, owing to its capacity to deliver secure and sanitary transportation of edible packaged food.

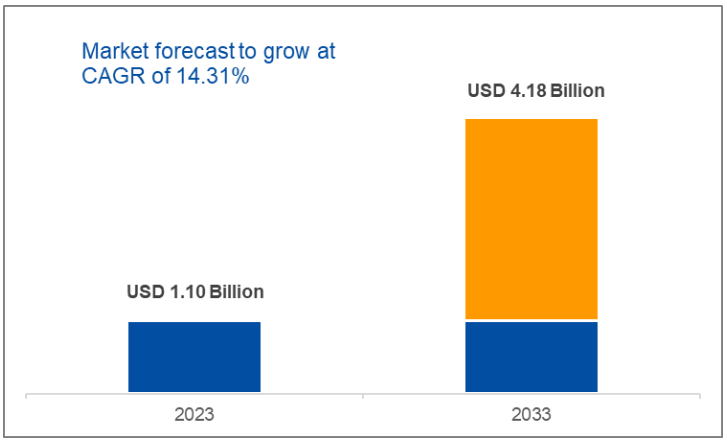

Figure 1: Global edible packaging market.

Figure 2 shows the global production of edible films and coating market. The global market is estimated to grow at a CAGR of 9.20% over the forecast period from 2023 to 2030.

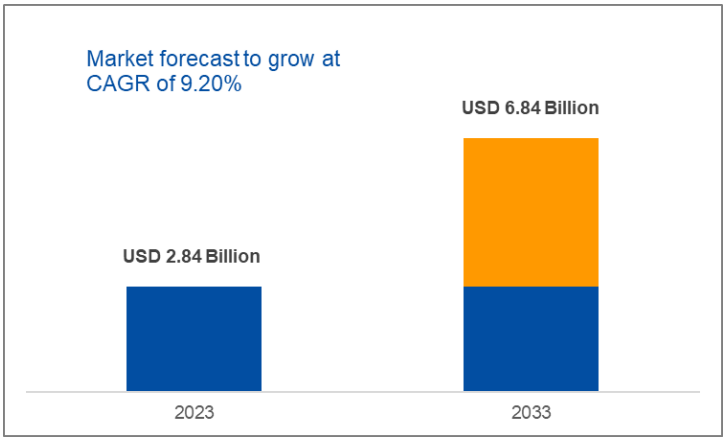

Figure 2: Global edible films and coating market.

Choosing the most appropriate direction for the growth of the edible packaging industry is crucial since consumers and food processors are becoming more interested in environmentally packaging options as a result of increased awareness of plastic waste. The global edible packaging market is anticipated to increase as a results of increased investment in research and development in the industry. The market is anticipated to evolve gradually depending on several factors:

- Short Term (2023 to 2026): The fast-paced contemporary lifestyle and rising economic status of individuals have increased the consumption of processed food items, which is expected to drive the demand for edible packaging as a substitute for harmful plastics.
- Medium Term (2026 to 2029): Quick-service food and beverage suppliers are likely to determine that edible packaging is the optimum packaging for their products since these allow customers to order their meals in eatable boxes at restaurants.
- Long Term (2029 to 2033): As more individuals become conscious of their carbon footprint and waste contribution, there is an emphasis being placed on developing new innovative bio-products. These factors are anticipated to continue to create lucrative business opportunities for both established players and new entrants in the global market (Edible Packaging Market Outlook, 2023).

The changed post Covid-19 business landscape, the global market for plastic packaging estimated at US$ 702.4 billion in the year 2022, is projected to reach a revised size of US$ 944.3 billion by 2030, growing at a CAGR (Compound Annual Growth Rate) of 3.8% over the analysis period 2022-2030.

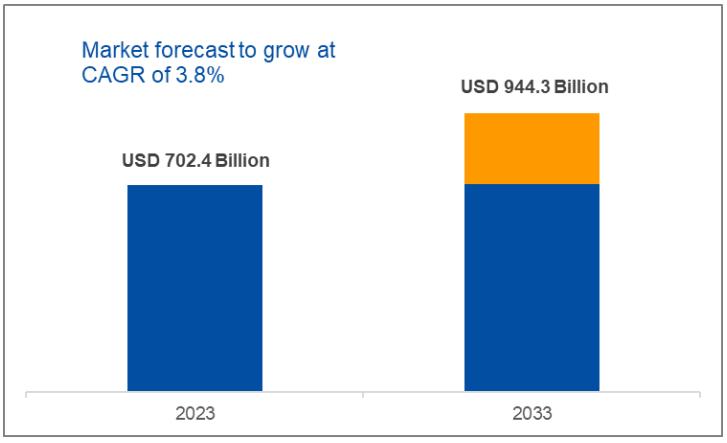

Figure 3: Global plastic packaging market.

The plastic packaging market in the U.S. is estimated at USD 191.4 Billion in the year 2022. China, the world's second largest economy, is forecast to reach a projected market size of USD 192.7 Billion by the year 2030

trailing a CAGR of 6.3% over the analysis period 2022 to 2030. Among the other noteworthy geographic markets are Japan and Canada, each forecast to grow at 2% and 3.1% respectively over the 2022-2030 period. Within Europe, Germany is forecast to grow at approximately 2.5% CAGR. Led by countries such as Australia, India, and South Korea, the market in Asia-Pacific is forecast to reach USD 124.6 Billion by the year 2030 (Plastic Packaging, 2024).

3.2 Market size and share

The edible packaging market has experienced significant growth in recent years, driven by increasing demand for sustainable packaging solutions and growing environmental awareness. Consumers are becoming increasingly aware of the negative impact of conventional packaging materials, such as plastic, on the environment, leading to a growing preference for eco-friendly alternatives. Furthermore, the expansion of edible packaging beyond the food and beverage industry offers additional growth opportunities. Industries such as cosmetics, pharmaceuticals and personal care are exploring the use of edible packaging in their products (Edible Packaging Market Size, 2023).

The potential use of edible materials is significantly influenced by consumer acceptance issues, including sensory properties, safety, marketing, and cultural and religious restrictions on the use of new materials and applications. Commercialization of edible packaging also depends on marketing factors, including price, consumer reluctance to use new materials, and adherence to special instructions required for opening, cooking, consuming packaged/coated food, or disposing of the packaging (Prakash et al., 2023).

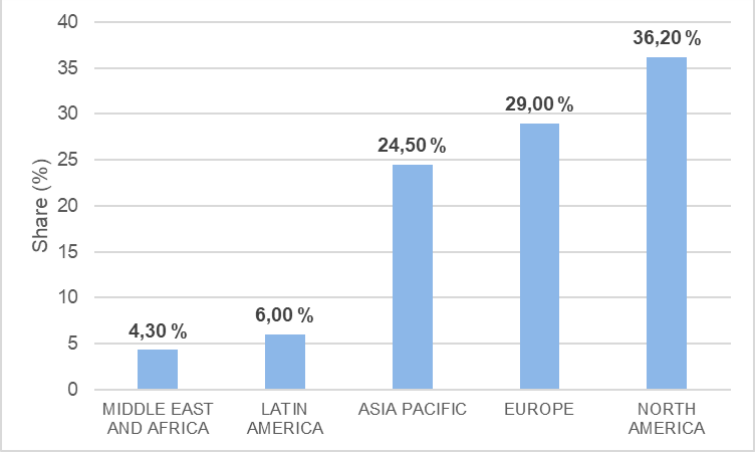

Figure 4: Edible packaging market share, by region, 2022 (%).

In 2022, North America accounted for the greatest portion of the worldwide market. Its dominant position in the worldwide market is attributed to the existence of sizable processed food and pharmaceutical sectors, as well as a sizable number of edible packaging makers. Furthermore, during the course of the forecast period, the market is expected to be driven by rising innovation in the edible packaging arena, notably in the United States.

From 2023 to 2032, the Asia Pacific market is anticipated to develop at the fastest rate. The main element driving the exceptional demand for the product in the region is rising consumer awareness of the negative effects of excessive plastic use for food packaging together with expanding plastics bans. Over the next years, rising food and beverage and pharmaceutical sectors are also anticipated to boost product demand. However, it is anticipated that high production costs and hygienic problems with product transportation may impede market expansion in the area (Edible Packaging Market Size, 2022).

4. CONCLUSIONS

Nowadays, there are many new innovative packaging products on the market, including edible packaging. Edible packaging plays an important role in reducing landfill disposal. Research development in the area of edible/ biodegradable films/coatings is an important and unique area of research in food packaging that has enormous economic and environmental potential. As more and more consumers pay attention to their carbon footprint and their contribution to waste disposal, there could be a shift towards edible food packaging as an alternative to harmful plastics. On the other hand, edible food packaging is a relatively new technology that still needs time to be adopted globally.

Acknowledgement: The authors would like to acknowledge the financial support of Horizon Europe projects REMEDIES (GA 101093964), UPSTREAM (GA 101112877) and Interreg Central Europe project CE0100433 - TeBiCE.

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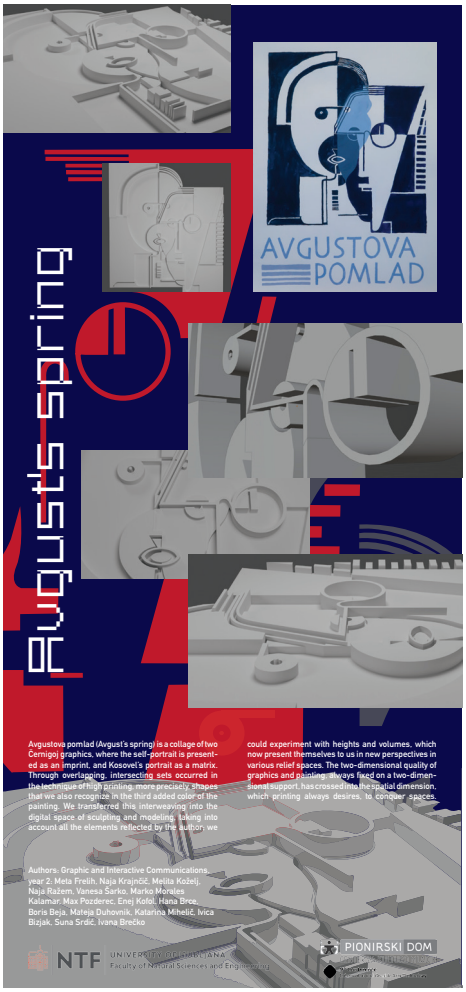
EXHIBITION

AVGUST'S SPRING

Ivica Bizjak, Hana Brce, Ivana Brečko, Boris Beja, Mateja Duhovnik, Meta Frelih, Enej Kofol, Melita Koželj, Naja Krajnčič, Katarina Mihelič, Marko Morales Kalamar, Max Pozderec, Naja Ražem, Suna Srdić, Vanesa Šarko.

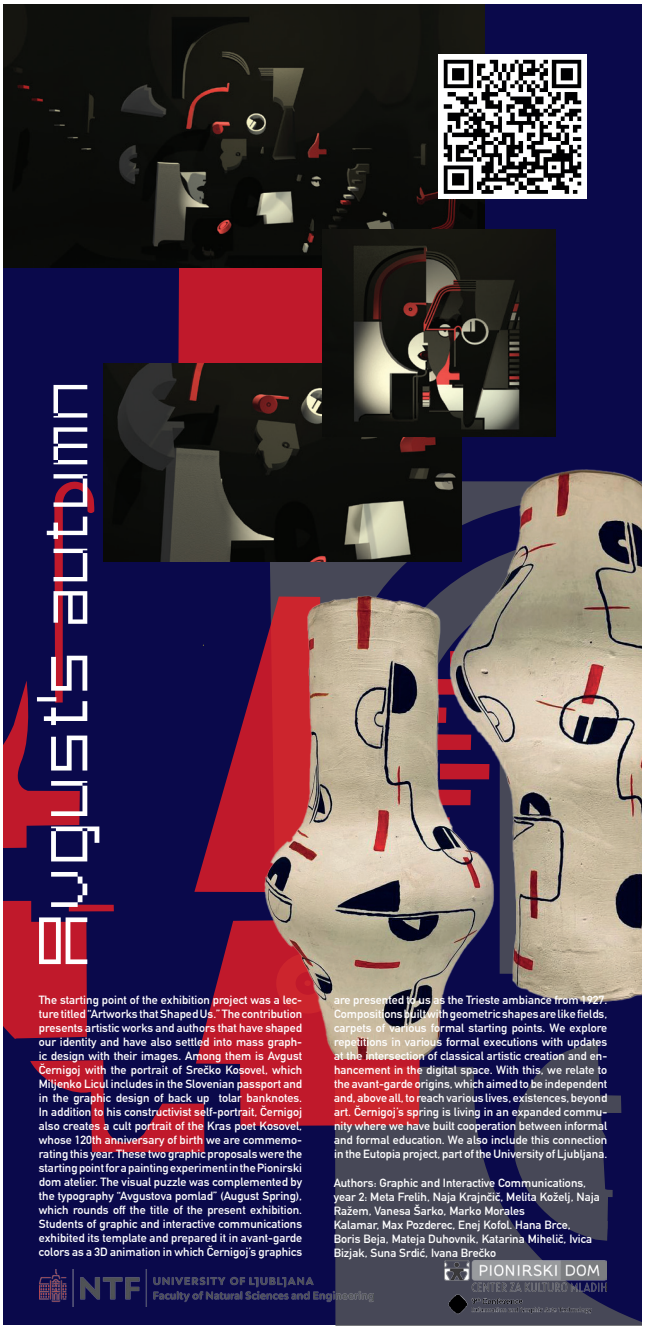
The starting point of the exhibition project was a lecture titled "Works of Art That Have Shaped Us." The article presents artworks and authors that have influenced our identity and have also made their way into mass graphic design with their images. Among them is Avgust Černigoj with his portrait of Srečko Kosovel, which Miljenko Licul included in the Slovenian passport and the graphic design of the reserve tolar banknotes.



Surrealism heralded the avant-garde in art history, to which Černigoj also belonged, bringing the Bauhaus experience into our cultural space. Although avant-gardes are mostly brief, immediate responses to societal events, they are extremely powerful if we consider them from the view point of their programmes and ideology or their content and form. . On the centenary of the birth of Avgust Černigoj (1998), an extensive study exhibition entitled TANK – Slovenian Historical Avant-garde was organized at the Modern Gallery. The title was taken from the magazine of the same name, which was published in 1927 by director Ferdo Delak in collaboration with the artist Černigoj, which rounds off the content that students of graphic and interactive communications encounter during their studies. Alongside visual artists, the exhibition also dedicated space to the poets Anton Podbevšek and Srečko Kosovel. In addition to his constructivist self-portrait, Černigoj created with lines and primary forms a cult portrait of the Karst poet Kosovel, whose 120th anniversary of his birth is being commemorated this year. These two graphic templates were the basis for a painting experiment at the Pionirski Dom studio. At the bottom of the visual puzzle is the inscription "Avgustova pomlad", which we borrowed for the title of the exhibition. Students of graphic and interactive communications took apart its template and prepared it in the colours of the avant-garde as a 3D animation, in which Černigoj's graphics are presented to us as the Trieste ambient from 1927. Painterly forms, cut into planes, gained volume in the animation and, in the course of the animation, assemble and exhibit themselves as if the artist had cut and composed them with a craft knife. The compositions in the exhibition, built with geometric shapes, are like a field, a carpet of various formal starting points. We research repetitions in various formal executions with updates at the intersection of classical artistic creation with enhancements in the digital space. In graphic design, alongside Kosovel's legacy, we also referred to the square field of Brumen, which inspired us to design a new typeface with a square. We moved from the plane to space using digital technology and 3D printing, thus translating images into experiences for the blind and visually impaired. In painterly details, we sought opportunities for building a textile pattern, which we also considered in the context of packaging, vase painting, and classical collage. This connects us to the origins of the avant-gardes, which aimed to be independent and above all to reach different lives, existences, beyond art. Černigoj's spring is a living experience in an expanded community where we have built collaboration between informal and formal education. This bond is also included in the Eutopia project, part of the University of Ljubljana.

The project was created in collaboration with the public institute Pionirski dom – Centre for Youth Culture and the Faculty of Natural Sciences and Engineering, Department of Textiles, Graphics, and Design, University of Ljubljana, in collaboration with the project leader Assoc. Prof. Boris Beja and colleagues: Dr. Gregor Franko, Jon Brceta, Mag. Tanja Medved.


August's summer
Vase painting was among the first to engage in some form of narrative, also dealing with the design of packaging. Art moved from wall surfaces to the surface of useful objects. Transferring Kosovel's portrait onto ceramics served as inspiration for us, a matrix for spatial modeling, and new occasional impressions. The superficiality of the painting, depicted as part of a keyboard with geometry, is complemented by curves that we used to transfer them into the field of 3D modeling through vectorization. Flatness was complemented by experimenting with various deviations in height, relative to the floor, printable surface. In the print, on the white object, strong contrasts were replaced by contrasts in formative aspects, juxtapositions of forms that, in modal tonality, play a constructivist narrative in dialogue with the Ďurovian painting contribution.
Authors: Graphic and Interactive Communications, year 2: Meta Frelih, Naja Krajnčič, Melita Koželj, Naja Ražem, Vanesa Šarko, Marko Morales Kalamar, Max Pozderec, Enej Kofol, Hana Brce, Boris Beja, Mateja Duhovnik, Katarina Mihelič, Ivica Bizjak, Suna Srdić, Ivana Brečko
NTF UNIVERSITY OF LJUBLJANA Faculty of Natural Sciences and Engineering
PIONIRSKI DOM CENTER ZA KULTURO MLADIH


August's autumn
The starting point of the exhibition project was a lecture titled "Artworks that Shaped Us." The contribution presents artistic works and authors that have shaped our identity and have also settled into mass graphic design with their images. Among them is Avgust Černigoj with the portrait of Srečko Kosovel, which Miljenko Licul includes in the Slovenian passport and in the graphic design of back up tolar banknotes. In addition to his constructivist self-portrait, Černigoj also creates a cult portrait of the Kras poet Kosovel, whose 120th anniversary of birth we are commemorating this year. These two graphic proposals were the starting point for a painting experiment in the Pionirski dom atelier. The visual puzzle was complemented by the typography "Avgustova pomlad" (August Spring), which rounds off the title of the present exhibition. Students of graphic and interactive communications exhibited its template and prepared it in avant-garde colors as a 3D animation in which Černigoj's graphics are presented to us as the Trieste ambiance from 1927. Compositions built with geometric shapes are like fields, carpets of various formal starting points. We explore repetitions in various formal executions with updates at the intersection of classical artistic creation and enhancement in the digital space. With this, we relate to the avant-garde origins, which aimed to be independent and, above all, to reach various lives, existences, beyond art. Černigoj's spring is living in an expanded community where we have built cooperation between informal and formal education. We also include this connection in the Eutopia project, part of the University of Ljubljana.
Authors: Graphic and Interactive Communications, year 2: Meta Frelih, Naja Krajnčič, Melita Koželj, Naja Ražem, Vanesa Šarko, Marko Morales Kalamar, Max Pozderec, Enej Kofol, Hana Brce, Boris Beja, Mateja Duhovnik, Katarina Mihelič, Ivica Bizjak, Suna Srdić, Ivana Brečko
NTF UNIVERSITY OF LJUBLJANA Faculty of Natural Sciences and Engineering
PIONIRSKI DOM CENTER ZA KULTURO MLADIH

NTF · BRUMEN · 2024

Razstava študentskih izdelkov Katedre za informacijsko in grafično tehnologijo, Naravoslovnotehniške fakultete, Univerze v Ljubljani, ki so bili prijavljeni na 11. bienale slovenskega oblikovanja Brumen, 2024.

Exhibition of student projects from the Chair of Information and Graphic Arts Technology at the Faculty of Natural Sciences and Engineering, University of Ljubljana, submitted to the 11th Biennial of Slovenian Design Brumen, 2024.

Avtorji razstave/*Exhibition authors:*
asist. mag. Tanja Medved
Ana Mendizza (tehniška sodelavka/technical assistant)
prof. dr. Klementina Možina
doc. dr. Jure Ahtik
asist. dr. Gregor Franken

DOTIK.OBJEM.POLJUB/ *TOUCH. HUG. KISS*

Promocijski plakat za modno revijo/
Promotional poster for a fashion show

Naročnik/*Client:*

Katedra za oblikovanje tekstilij in oblačil, Oddelek za tekstilstvo, grafiko in oblikovanje, NTF UL

Avtorji plakata/*Poster Authors:*

Nik Hrovat, Nik Valenta, Žan Kreft, Ana Berwanger, Neja Skornšek

Avtorji logotipa/*Logo Authors:*

Lovro Frece, Janja Benedik, Tara Fošner, Kaja Dolgov, Teja Kolar

Mentorji/*Menthors:*

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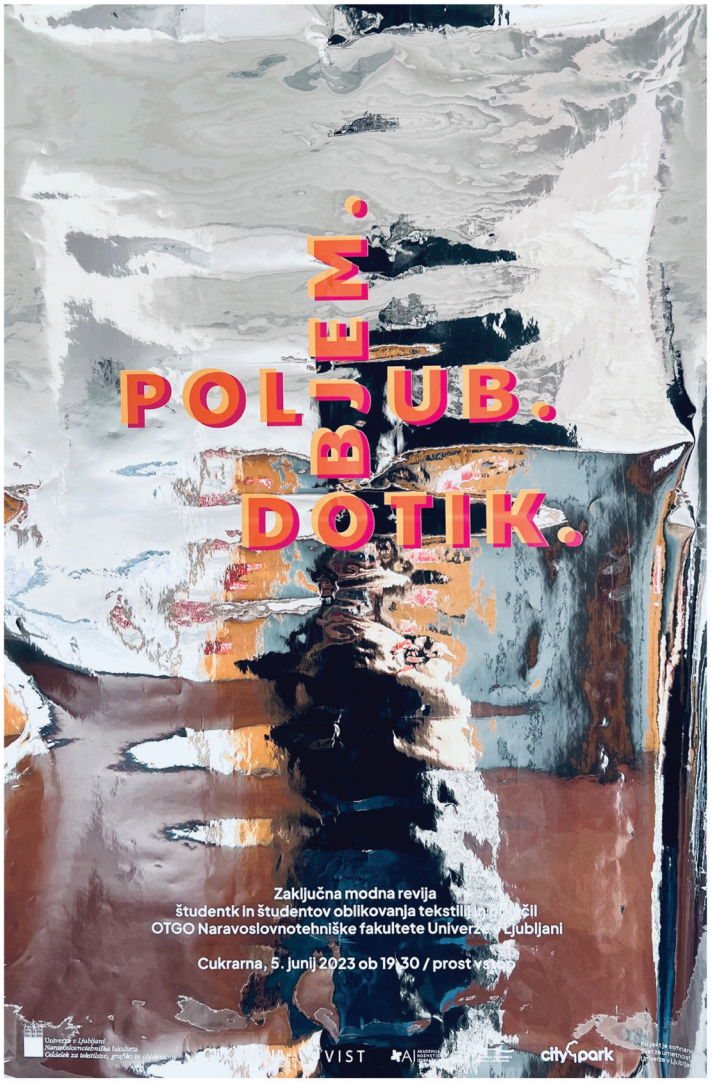
asist. Veronika Štampfl,
prof. Elena Fajt, doc. Petja Zorec



OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Za modno revijo „DOTIK.OBJEM.POLJUB“ smo ustvarili inovativni plakat kot ogledalo, ki vabi mimoidoče k refleksiji. Namen projekta ni bil le pritegniti pozornost, temveč globoko spodbuditi k razmišljanju o osebnih spremembah v času izolacije. Nepopolni odsevi na plakatu močno simbolizirajo, da je naša samopodoba kompleksna, nejasna, kar odraža našo prilagodljivost in odpornost na življenjske izzive. Cilj je bil vzpodbuditi introspekcijo in povezovanje, poudarjajoč vlogo mode kot orodja za izražanje skupnih izkušenj, čustev in skupno premagovanje izzivov, krepi skupnostni duh.

For the fashion show “TOUCH.HUG.KISS” we designed a mirror-like poster to inspire reflection among passers-by. It aimed not just to catch the eye but to provoke thought on personal changes during isolation. The poster’s imperfect reflections symbolize our complex and ambiguous self-image, showing our adaptability and resilience. The goal was to foster introspection and connection, emphasizing fashion’s power to convey shared experiences and emotions, thus strengthening the sense of community.

POSTOPEK PRENOSA ZNANJA NA UNIVERZI V LJUBLJANI/ *THE KNOWLEDGE TRANSFER PROCESS AT THE UNIVERSITY OF LJUBLJANA*

Informacijske ilustracije in grafike/
Informational illustrations and graphics

Naročnik/*Client:*

Pisarna za prenos znanja, UL/
Knowledge Transfer Office, UL

Avtorica/*Author:*

Lara Vukelić

Mentorja/*Menthors:*

doc. Boris Beja,
asist. mag. Tanja Medved

OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Projekt predstavlja oblikovno rešitev vodnika „Po poti inovacij do uspeha na trgu“ za Pisarno za prenos znanja, Univerza v Ljubljani, v obliki enajstih ilustracij in treh postopkovnih infografik, ki omogočajo jasno komunikacijo kompleksnih vsebin. Minimalistične ilustracije vizualizirajo ključne informacije na estetsko privlačen način, medtem ko postopkovne infografike podrobno razčlenjujejo zapletene procese. Oblikovane so zgolj tiste strani vodnika, na katere izdelane ilustracije in infografike se najbolje prilegajo.

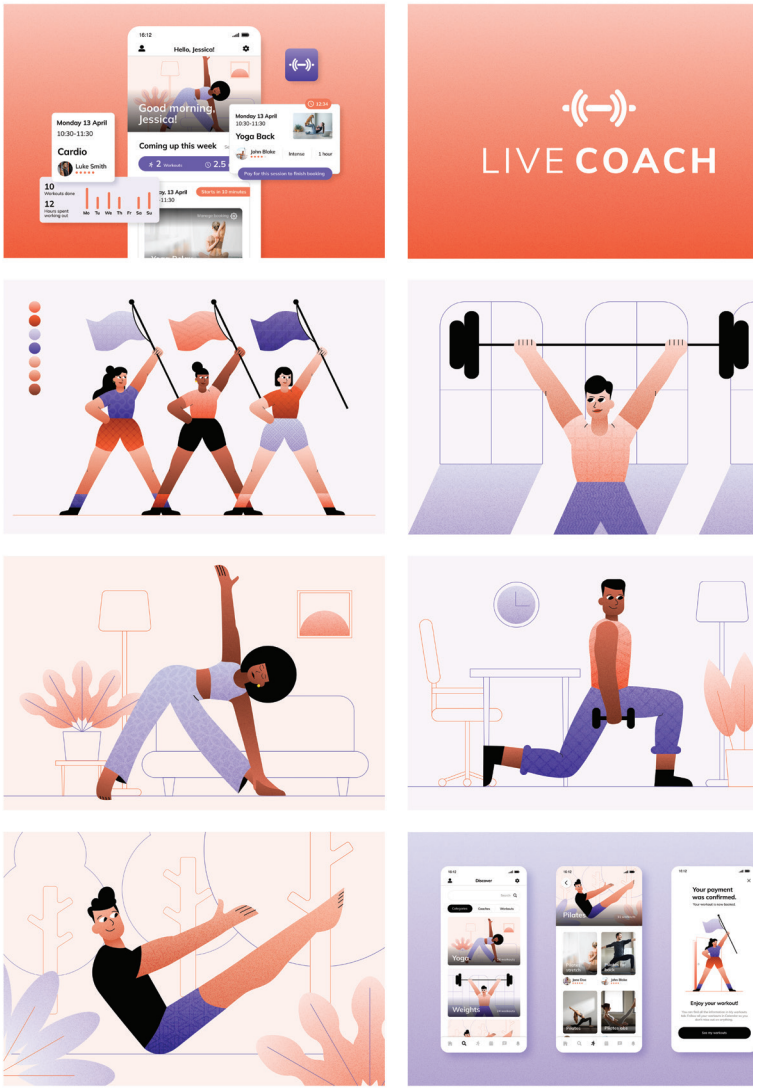
The project presents a design solution for the guide “On the path of innovation to market success” for the Knowledge Transfer Office, University of Ljubljana, in the form of eleven illustrations and three procedural infographics, which enable clear communication of complex content. The minimalist illustrations visualise key information in an aesthetically appealing way, while the procedural infographics detail complex processes. Only those pages of the guide are designed on which the elaborate illustrations and infographics fit best.

LIVE COACH

Aplikacija namenjena individualnim treningom s trenerji na daljavo/
Application designed for individual training sessions with remote coaches

Avtorica/*Author:*
Sara Krašovec

Mentor/*Menthor:*
doc. dr. Jure Ahtik



OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Aplikacija Live Coach je namenjena individualnim treningom s trenerji na daljavo in omogoča sledenje gibanju telesa za natančno preverjanje izvedbe vaj. Za njen prototip je bilo oblikovanih več kot 80 zaslonov pogleda uporabnika in trenerjev. Bistveni del vizualne identitete aplikacije Live Coach je sistem ilustracij, ki se ga uporablja čez celoten uporabniški vmesnik. V sistem ilustracij so vključena pravila za oblikovanje, ilustracije in njihove komponente, ki jih lahko med seboj kombiniramo. Tako znotraj sistema ohranimo enotnost, hkrati pa na preprost način dosežemo raznolikost ilustracij.

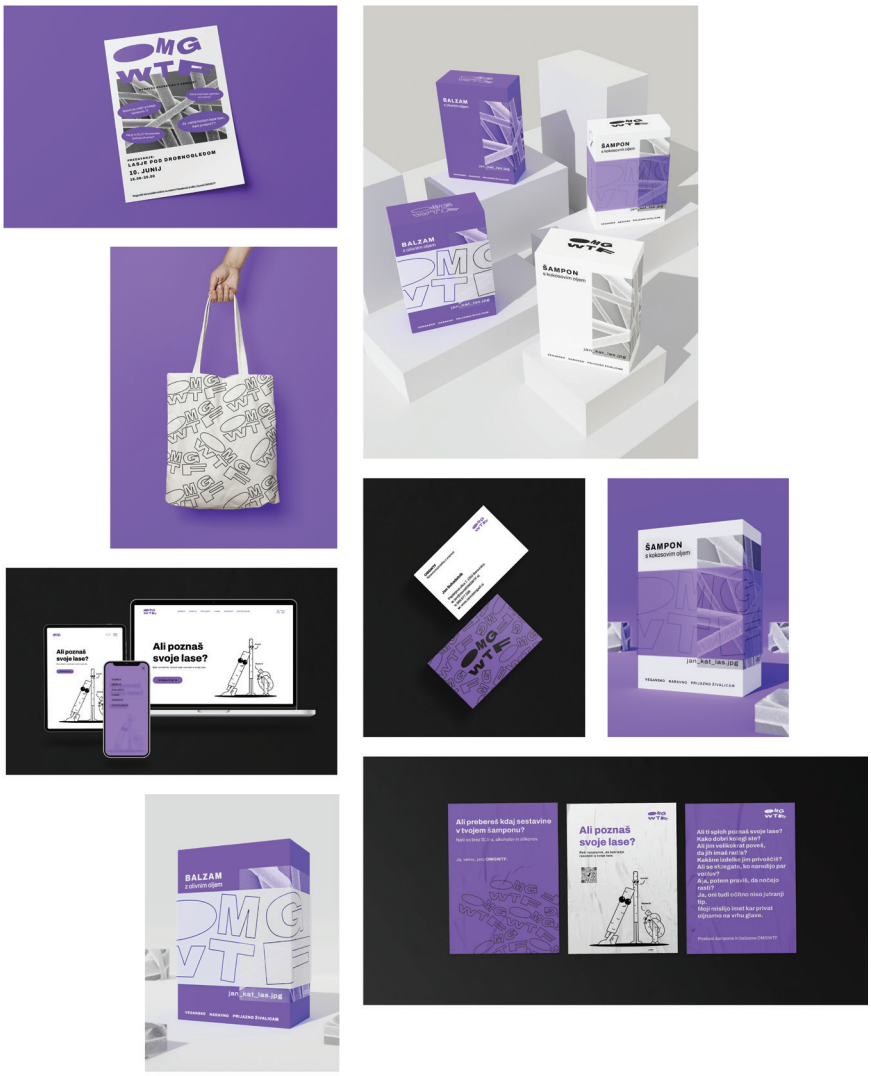
The Live Coach application is designed for individual training sessions with remote coaches and enables tracking of body movement for precise exercise execution assessment. More than 80 user interface screens were designed for its prototype. A vital part of the visual identity of the Live Coach application is the illustration system, which is utilized throughout the entire user interface. The illustration system includes design rules, Ilustrations, and their components, which can be combined with each other. This ensures consistency within the system while also achieving a diverse range of illustrations in a straightforward manner.

OMGWTF

Podoba blagovne znamke/
Brand image

Avtorica/*Author:*
Urška Klenovšek

Mentor/*Menthor:*
doc. dr. Jure Ahtik



OPIS PROJEKTA/*PROJECT DESCRIPTION:*

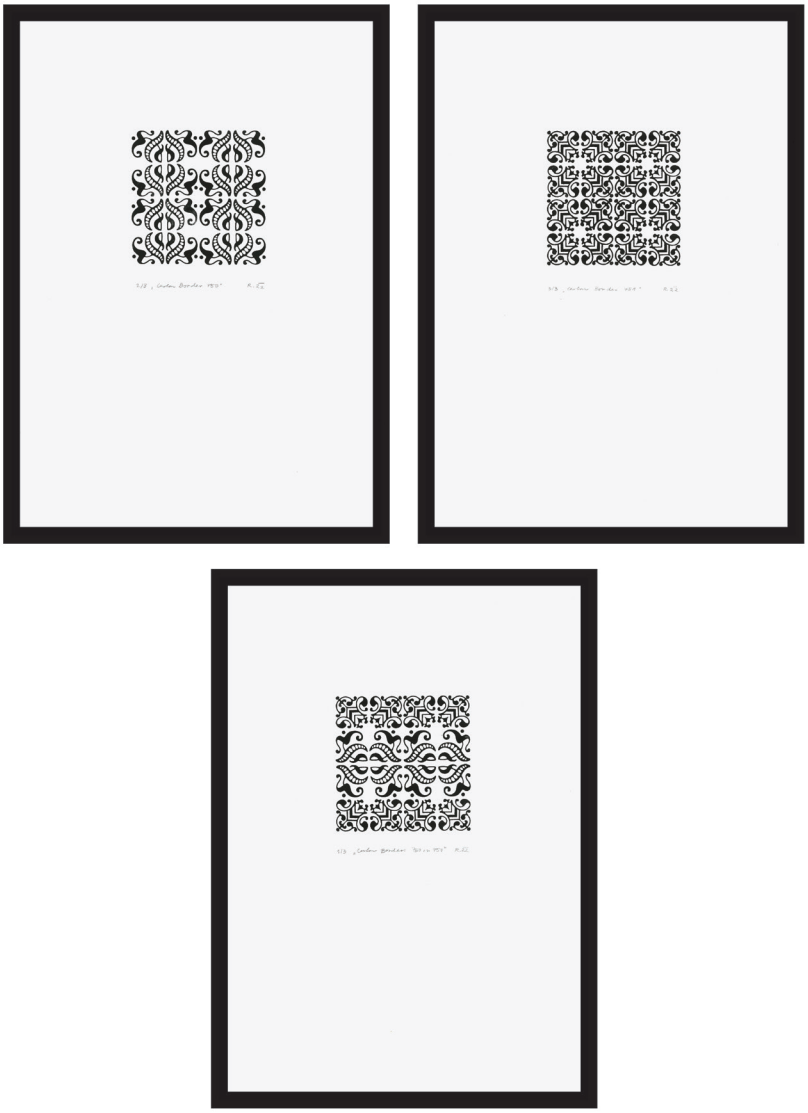
Podoba blagovne znamke OMGWTF je študijski projekt, ki je luč sveta ugledal leta 2022 v obliki diplomske naloge. Projekt je sprva nastajal v sodelovanju z realnim naročnikom, a na koncu ni bil uresničen. OMGWTF je podjetje, ki se primarno ukvarja s proizvodnjo naravne kozmetike, skozi svoje poslanstvo pa ozaveščа in spodbuja k aktivnemu udejstvovanju v družbi, širi dobrodelnost in skrbi za okolje. Lahko bi rekli, da je sinonim za predrznost in upanje. Predrznost, da v času, ko naše vrednote oblikujejo tudi znamke, ki nas spodbujajo k nepremišljenemu nakupovanju materialnih dobrin, oni na prvo mesto postavljajo ljudi in naravo. In upanje v družbo, ki bo svoje vrednote prilagodila blagostanju posameznika in narave, ne kapitala. Zelo omgwtf, ja.

The OMGWTF brand image is a study project that saw the light of day in 2022 in the form of a bachelor thesis. The project was initially developed in collaboration with a real client, but ultimately did not materialise. OMGWTF is a company primarily engaged in the production of natural cosmetics, but through its mission it raises awareness and encourages active participation in society, spreads charity and cares for the environment. It could be said to be synonymous with audacity and hope. The audacity to put people and nature first at a time when our values are also shaped by brands that encourage us to shop recklessly for material goods. And hope

OBOGATITEV TIPOGRAFSKE KULTURNE DEDIŠČINE ORNAMENTNIH VZORCEV/ *ENRICHING TYPOGRAPHIC CULTURAL HERITAGE* OF ORNAMENTAL PATTERNS

Avtorica/*Author:*
Maja Račič

Mentorica/*Menthor:*
prof. dr. Klementina Možina



OPIS PROJEKTA/*PROJECT DESCRII*

Delo oblikuje nov pogled na estetsko dekorativno vlogo ornamentnih vzorcev, predstavi tehnične zakonitosti in spodbudi razmislek o tendenci vrednotenja zgolj z vizualnega vidika estetike. Delo k stroki prispeva z vidika ohranjanja tipografske in tiskarske kulturne dediščine, oživlja in bogati tradicionalne pristope ter vzpostavlja jasno povezavo digitalnega in analognega sveta. Dotakne se nasprotujočih se pogledov na dekoriranje tudi v kontekstu psihologije ornamentalne umetnosti. Izbrane tri tipografske ornamente Williama Caslona smo prenesli v vektorski zapis in tvorili nabor modularnih vzorcev. Sledila je laserska gravura lesenih pečatnikov in v končnem visoki tisk grafik.

The study opens a new perspective on the aesthetic perception of ornamental patterns. It highlights technical requirements and encourages reflection, given the tendency to percieve based solely on visual aspects. It contributes to preserving typographic and printing heritage, revitalizing traditional methods, and bridging digital-analog worlds. It delves into divergent views on decoration, merging art theory with ornamental psychology, focusing on William Caslon's typographic ornaments. Three ornaments were closely observed and converted into vector curves. A series of modular patterns has been crafted, followed by engraving of wooden modules and letterpress printing of the graphics.

PLAKTIVATOVA DELAVNICA/ *THE PLAKTIVAT WORKSHOP*

Oglasni plakat/*Advertising poster*

Naročnik/*Client:*
TAM-TAM mestni plakati

Avtorice/*Authors:*
Tina Černetič, Nika Trnovec,
Ana Stevanovski, Lara Vukelić

Mentorja/*Menthors:*
doc. dr. Jure Ahtik,
asist. Veronika Štampfl

OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Projekt predstavlja oglasni plakat v namen promocije Plaktivatove delavnice. Na plakatu prevladuje beseda „Plaktivat“, ki izstopa s svojo edinstveno obliko, sestavljeno iz raznolikih barvnih likov. Ta osrednji element plakata takoj pritegne pozornost in komunicira ime in bistvo dogodka. Beseda „Plaktivat“ je oblikovana tako, da združuje kreativne pristope in raznolikost, ki ju spodbuja delavnica. Vsak lik, ki sestavlja besedo, je unikaten in doprinaša k celotni podobi besede. Barvna paleta, polna živahnih in svetlih odtenkov, dodatno privablja pozornost ter odraža dinamičnost in energijo dogodka. Kljub svoji izvirni obliki ostaja beseda „Plaktivat“ jasno berljiva in prepoznavna. To zagotavlja, da bo ciljna publika brez težav prepoznala ime dogodka ter ga povezala z njegovim namenom.

The project presents an advertising poster for Plaktivats workshop. The posters are dominated by the word “Plaktivat”, which stands out with its unique design consisting of various colored characters. This central element of the poster immediately draws attention and communicates the name and essence of the event. The word “Plaktivat” is coined to combine the creative approaches and diversity that the workshop encourages. Each character that makes up a word is unique and contributes to the overall image of the word. The color palette, full of lively and bright shades, additionally attracts attention andreflects the dynamism and energy of the event. Despite its original form, the word “Plaktivat” remains clearly legible and recognizable. This ensures that the target audience will easily recognize the name of the event and associate it with its purpose.

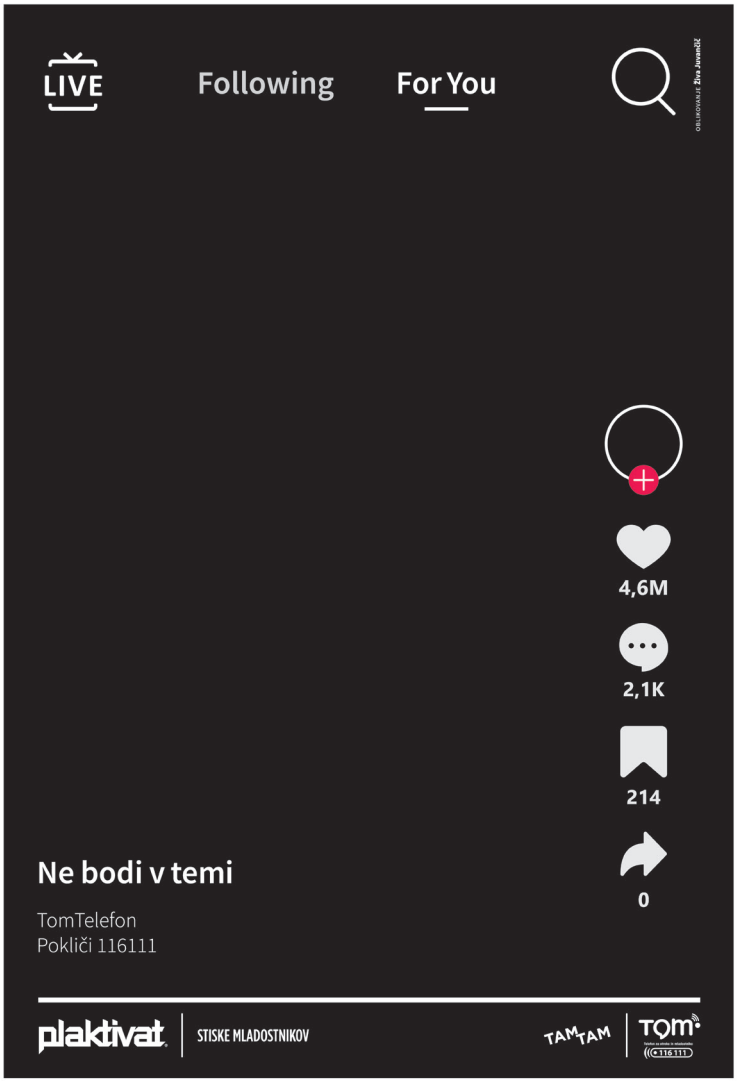
TIK-TAK

Plakat/*Poster*

Naročnik/*Client:*
TAM-TAM mestni plakati

Avtorica/*Author:*
Živa Juvančič

Mentorica/*Menthor:*
asist. mag. Tanja Medved



OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Plakat z naslovom „Tik-Tak“ je bil ustvarjen v okviru projekta Plaktivat 16 – Osveščanje o stiskah mladostnikov. Ta plakat je bil izbran med finaliste tekmovanja v kategoriji Sveža kri in je bil razstavljen v plakatni galeriji BTC. „Tik-Tak“ je bil oblikovan s ciljem, da opozori današnjo mladino na pomembnost ozaveščanja o stiskah. Preprosta podoba črnega ekrana na socialnem omrežju TikTok je bila namenjena temu, da gledalce spodbudi k razmišljanju o resničnosti v ozadju sicer zabavne vsebine. Sporočilo plakata je jasno: če se znajdejo v težavah, mladi niso sami, saj imajo na voljo pomoč v obliki Tom Telefona.

The poster aims to remind young people about the importance of being aware of difficulties. It shows a simple black screen from the TikTok app, encouraging viewers to think about reallife problems behind the fun content. The poster's message is clear: young people have support available through Tom Telephone if they ever face problems. The "Tik-Tak" poster was made for the Plaktivat 16 project, focusing on raising awareness about teenage struggles. It was chosen as a finalist and displayed at the BTC Poster Gallery.

TRANZICIJA

Črkovna vrsta/*Typeface*

Avtor/*Author:*
Nik Leban

Mentorici/*Menthors:*
prof. dr. Klementina Možina,
asist. mag. Tanja Medved

OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Črkovna vrsta Tranzicija je eksperimentalna spremenljiva pisava, ki odpira nove poti za ta način tipografskega ustvarjanja. Njena interpolacija namreč poteka med znaki latinice in cirilice z ročno narejeno vmesno verzijo, ki služi dvema namenoma: poskrbi za lepšo interpolacijo med znaki in je nova pisava, katere ideja je, da jo lahko berejo tako bralci latinice kot bralci cirilice. Poleg majuskul vseh črk, ki jih najdemo v slovenski, hrvaški, srbski in bosanski abecedi črkovna vrsta vsebuje še številke in osnovna ločila ter simbole. Tranzicija je nastala v sklopu diplomskega dela, katerega glavni namen je bil raziskovanje področja spremenljive tipografije kot sredstva za eksperimentiranje, ki prej ni bilo mogoče.

The Tranzicija typeface is an experimental variable font that opens new paths for this method of typographic creation. Its interpolation occurs between Latin and Cyrillic characters with a hand-made intermediate version, serving two purposes: to ensure smoother interpolation between characters and to create a new font that can be read by both Latin and Cyrillic readers. In addition to uppercase letters found in the Slovenian, Croatian, Serbian, and Bosnian alphabets, the typeface also includes numbers, basic punctuation, and symbols. Tranzicija was created as part of a diploma thesis, the main purpose of which was to explore the field of variable typography as a means of experimentation that was not previously possible.

MLEKARNA PLANIKA

Posodobitev grafične identitete/
Updated visual identity

Avtorica/*Author:*
Tija Šadl Praprotnik

Mentorja/*Menthors:*
izr. prof. dr. Urška Vrabič Brodnjak,
asist. dr. Gregor Franken

OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Osnovo prenovljene grafične podobe predstavljajo valoviti hribi, ki svojo obliko in barvo prilagajajo glede na produkt. Grafična podoba ohranja motive, ki so uporabljenih na dosedanjih embalažah mlekarne Planika. Kot del posodobljene grafične podobe so bile ustvarjene nove etikete za tekoče mlečne izdelke in sire, ki prinašajo svež pristop in hkrati ohranjajo zvestobo tradiciji. Dodatno je bila oblikovana tudi črtna koda, ki se elegantno vklaplja v koncept podobe, saj je oblikovana v obliki gorskih vrhov.

The basis of the renewed graphic identity is represented by undulating hills, which adjust their shape and colour depending on the product. The graphic design includes the motifs used on the previous packaging of the Planika dairy. As part of the updated graphic image, new labels for liquid dairy products and cheeses have been created, bringing a fresh approach while maintaining loyalty to tradition. In addition, a barcode was also designed, which elegantly fits into the concept of the graphic identity, as it is designed in the form of mountain peaks.

MLEKARNA PLANIKA

Posodobitev grafične identitete/
Updated visual identity

Avtorica/*Author:*
Ana Kušar

Mentorja/*Menthors:*
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OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Grafična podoba je nastala v okviru projekta Preoblikovanje embalaže za izdelke slovenske Mlekarne Planika. Podoba ohranja motiv lija, ki je uporabljen že na dosedanji embalaži in prestavlja tradicijo mlekarstva. V preoblikovani podobi pa ga gradijo stilizirane rože planike različnih velikosti, ki s svojo razgibanostjo naredijo izdelek privlačen, hkrati pa poudarjajo identiteto mlekarne. Za vsak posamezen izdelek je uporabljena svoja barva planik, zaradi česar se izdelki med seboj z lahkoto ločijo, pri čemer pa enoten videz celotne serije ni ogrožen. Silhueta Krna – najznačilnejše gore Posočja – pa je upodobljena na črtni kodi.

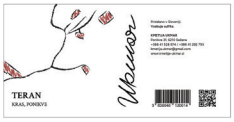
The graphic design was created as part of the project Redesigning the packaging for the products of the Slovenian dairy Planika. The image retains the funnel motif already used on the existing packaging and represents the tradition of dairy farming. In the redesigned image, it is built up by stylised edelweiss flowers of different sizes, which make the product attractive and emphasise the dairy's identity. Each individual product is given its own colour, making the products easily distinguishable from each other, without compromising the uniform appearance of the whole series. The silhouette of Krn mountain – the most famous mountain in Posočje – is depicted on the barcode.

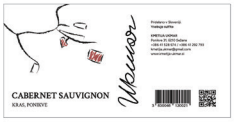
KMETIJA UKMAR

Vinske etikete/
Wine labels

Avtorji/*Authors:*
Mara Bibin, Tina Fornazarič,
Jure Jelenc

Mentorja/*Menthors:*
doc. dr. Nace Pušnik,
asist. dr. Gregor Franken





OPIS PROJEKTA/*PROJECT DESCRIPTION:*

Napis Ukmar, natisnjen v slepem tisku, je digitaliziran podpis ustanovitelja Kmetije Ukmar in osrednji element grafične podobe kmetije. Izrisana podoba na etiketah predstavlja tloris vinogradov kmetije ter poti do njih. Na posamezni etiketi so obarvani le vinogradi z grozdjem, iz katerega izvira tudi vrsta vina v steklenici. Barvna paleta simbolizira barve krasa in starih dokumentov. Naročniki so želeli, da se na etiketi pusti določen prostor za nalepko s podatki, ki se spreminjajo iz leta v leto. Projekt je bil zasnovan v sklopu fakultete, realiziran pa iz strani avtorjev.

The digitized and embossed signature Ukmar is the focal point of the brand's identity, and was originally created by the farm's founder. The wine labels feature illustrations depicting the layout of Ukmar's vineyards and surrounding roads. Each label indicates the specific vineyard from which the wine type originates. The color scheme was inspired by the color of the karst landscape and historic documents. At the employees' insistence space was left on the label for a yearly changing data sticker. The project began as a university endeavor, but was completed by the authors at a later stage.

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