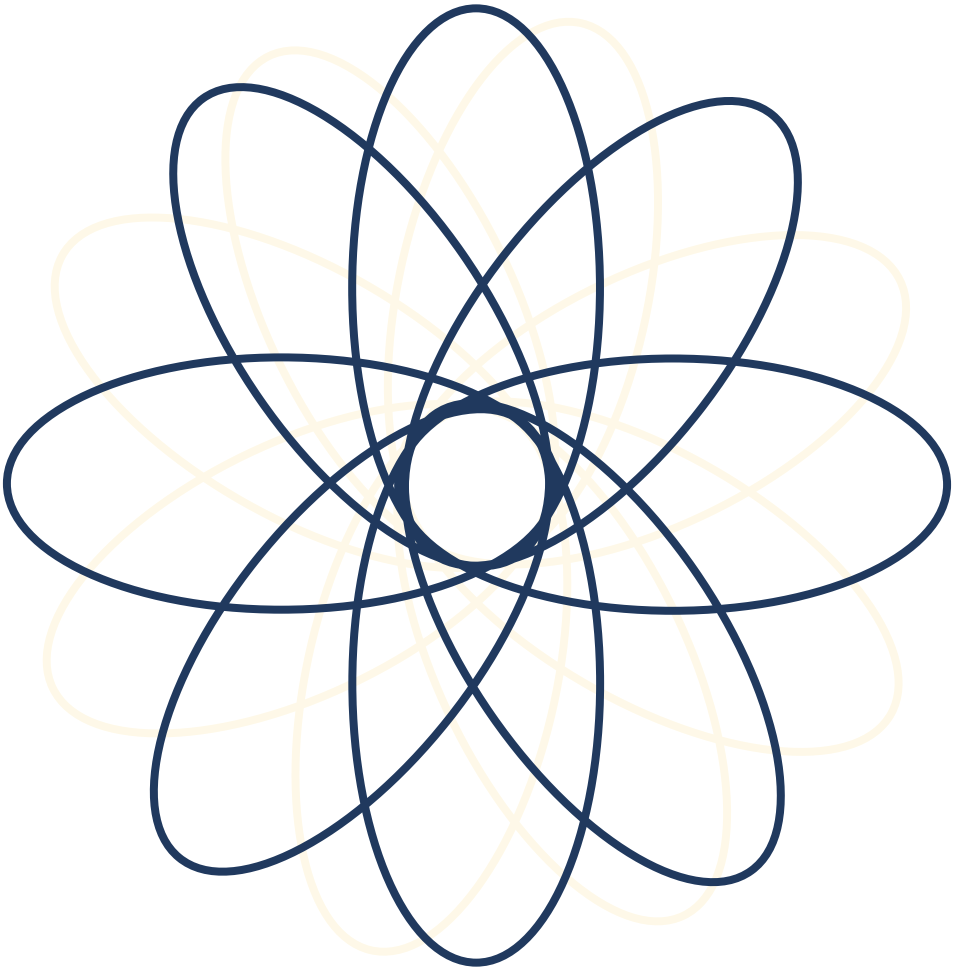
CLEMSON TAGA



TWO THOUSAND & TWENTY FIVE

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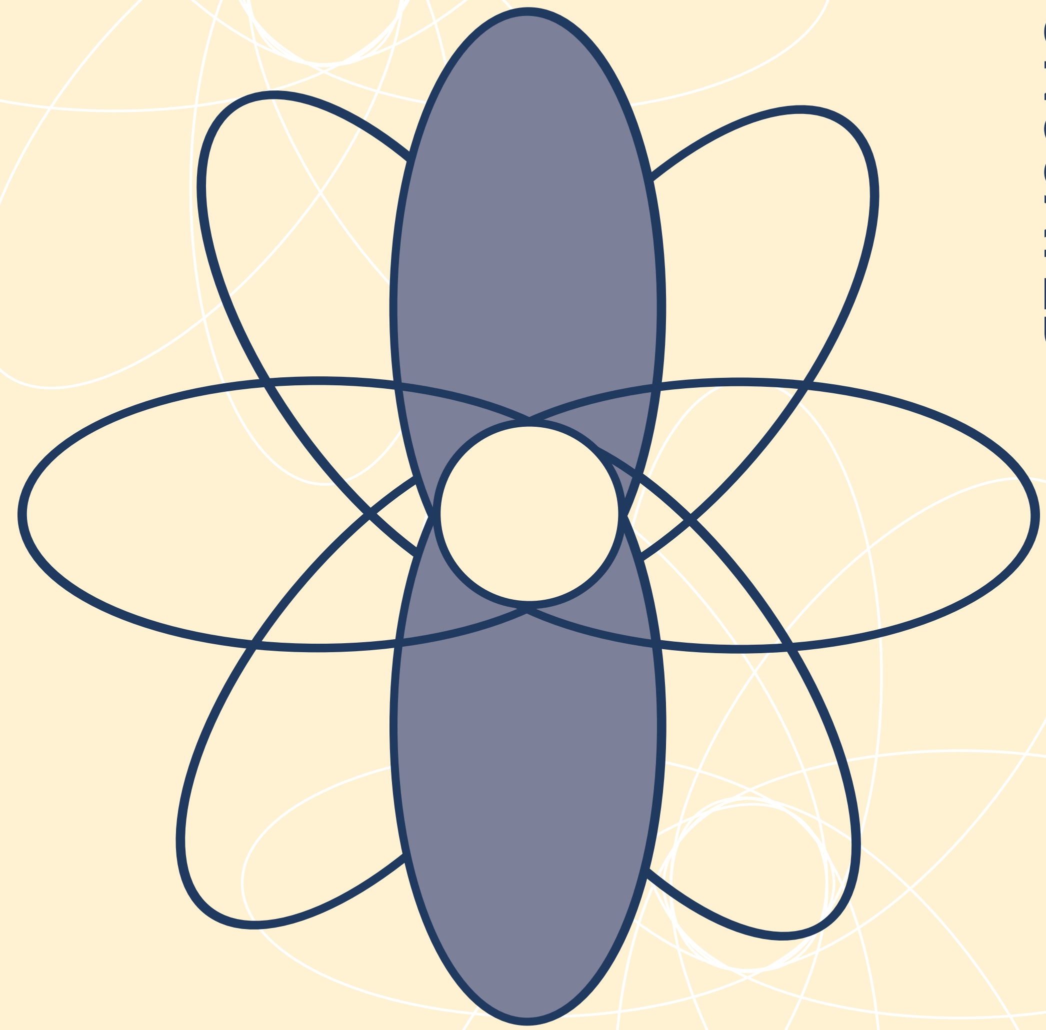

COATED & UNCOATED

WHY USE UNCOATED PAPER?

Writable Surface

Because it absorbs ink more readily, uncoated paper is better suited for handwriting or writing with pens, which is why it is often used for forms, letterheads, and resumes.

Better Absorption

The porous surface allows ink or toner to be absorbed into the fibers of the paper, which can give printed text a softer, more organic look. The lack of coating gives a more tactile texture.

Sustainable

Uncoated papers are sometimes seen as more environmentally friendly, as they require fewer chemicals in production and may be more readily recyclable.

- LESS DURABLE - PRONE TO WEAR & MOISTURE DAMAGE
- LESS VIBRANT COLOR - DUE TO INK ABSORBTION
- SMALL DETAILS CAN GET LOST IN PRINT
- SLOW PRODUCTION PROCESS

Generally less expensive.

Since coated paper does not require adding additional fibers, machines can operate quicker and continually.

1 PULPING

Raw materials, like wood chips, are collected by a paper mill. The fibers are broken down using chemical or mechanical processes, which turns the pulp into a paste.

2 REFINING

The pulp is further processed, where additives and/or chemicals are added to modify the paper properties and help bond the fibers. This impacts the paper's final strength and texture.

3 FORMING

More water is added to the pulp to form a thick liquid. It is applied to wire mesh via high-pressure sprayers and becomes a thin mat, or a web. The web is then squeezed between rollers, which dries out the sheet.

4 DRYING

The paper is sent through a final drying process before beginning any finishing. It is wound onto large reels and is ether sheeted for packaging (uncoated) or sent further into the finishing process (coated).

Costly to Produce.

The production of coated paper is an expensive process due to the composition of fibers and raw materials.

Durability

The coating provides some level of water resistance, which can make the print more durable in certain conditions.

Better Image Quality

The smooth surface of coated paper helps ink sit on top of the paper, resulting in sharper, more vibrant colors and finer detail. It's ideal for high-quality printing, such as photos and marketing materials.

Professional Apperance

The glossy or matte finish gives the printed material a more polished and professional look, which is important in advertising and other formal documents.

- SHEEN - REFLECTS LIGHT - COULD BE HARD TO READ
- DIFFICULT TO RECYCLE - NOT BIODEGRADABLE
- NOT ABLE TO BE WRITTEN ON EASILY
- DOES NOT ABSORB INK WELL

WHY USE COATED PAPER?

UNCOATED & COATED

1

CHAPTER ONE

"Optimizing Sublimation Transfer Printing"

By Ramya Potnis

ABSTRACT

Various techniques are employed to create images on textile fabrics. This study utilized a dye sublimation transfer process to print onto synthetic textile fabrics. Sublimation transfer printing is a widely used method for applying designs onto fabrics. However, achieving consistent and accurate color reproduction remains a significant challenge. Factors such as temperature and dwell time can heavily influence the color accuracy and overall quality of the prints, making it essential to study their effects.

The study focuses on the influence of temperature and dwell time to evaluate the color quality of the sublimation transfer prints across different synthetic fabrics. The study comprised 11 fabric samples, consisting of 5 Aberdeen fabrics and 6 Fisher fabrics. The Aberdeen fabrics are categorized as coated, white and backlit and printed on an EPSON Surecolor F9470 printer. The Fisher fabrics are classified as blockout, heavy, and soft knit and printed on the MUTOH Xper Jet 1624WR Pro printer. These 11 fabrics were printed at three different temperatures, 380°F, 390°F and 400°F, with a dwell time of 35 seconds, 45 seconds, and 55 seconds. A cyan, magenta, yellow and black test target was printed on each fabric sample. These color patches served as the basis for evaluating the print's accuracy and consistency.

This study measures and evaluates color metrics such as LAB values, dot gain, and Delta E values to assess the color accuracy of the printed colors. These color metric values were measured using an X-Rite i1 Pro 3 Plus spectrophotometer. The spectrophotometer allowed for precise and reproducible data collection, ensuring the results were reliable and could be used to draw meaningful conclusions.

This research aims to identify the optimal temperature and time setting to achieve the highest color accuracy by analyzing the color quality parameters. The study found that a temperature of 380°F with a dwell time of 55 seconds consistently shows the lowest Delta E values, suggesting the optimal sublimation condition for color accuracy and stability across most fabrics. The fabric properties, such as opacity, OBA Index, texture and fiber composition, and LAB values of the fabrics, were examined to understand the interaction with the sublimation printing process, which

may influence the color outcomes. For instance, fabrics with higher opacity or certain fiber compositions showed different levels of color accuracy compared to others.

This research not only provides a deeper understanding of the relationship between temperature and dwell time but also offers practical insights that can be applied to improve the color accuracy and consistency of sublimation printing. By identifying the conditions that minimize Delta E values and enhance color stability, this study contributes to the optimization of printing practices. The findings provide valuable insights to enhance the color accuracy, improved color reproduction and consistency of the sublimation prints across the synthetic fabrics used as samples in this research, which is practically valuable and benefits the textile printing industry. This study provides a foundation for future research to explore additional variables, such as humidity and pressure, which may further refine the sublimation printing process and its outcomes.

Keywords: Dye Sublimation printing, Temperature, dwell time, Textile printing, CIELAB values, Delta E Evaluation, Color reproduction, Color management, Color Accuracy, Synthetic fabrics

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Finally, to my family, in-laws, and friends, thank you for your constant encouragement, understanding, and belief in me. Your love and support have been my most significant source of strength and motivation.
Thank you all for your support.

This research study investigates the influence of temperature and dwell time to evaluate color quality, consistency and overall print quality in dye sublimation printing. The research will also assess the application differences depending on temperature and dwell time, which influence the intensity of color and color values. In addition, this research will study the optimal temperature and dwell time combination that yields the most accurate color reproduction in terms of LAB values (CIE - International Commission on Illumination recognized L* (Lightness), a* and b*(hue and chroma) values) and Delta E values across different synthetic fabrics.

In this study, different types of synthetic fabrics were examined. The cyan, magenta, yellow and black test target was printed on each fabric at three different temperatures – 380°F, 390°F and 400°F and three dwell times – 35 seconds, 45 seconds, and 55 seconds. After printing, the CMYK test target on each fabric was measured using an X-Rite i1 Pro 3 Plus Spectrophotometer. The CIELAB values were recorded in the Chroma checker application. This study's observations, findings and outcomes are anticipated to improve color management techniques, ensuring efficiency and visual quality.

The temperature and dwell time during the transfer process significantly impact the accuracy of color reproduction in dye sublimation printing. The influence of these variables affects the intensity of the color as well as the overall consistency and quality of the print. Excessive heat during the dye sublimation process can cause color shifts, inaccurate colors, fabric damage or print distortion because the dye oversaturates or bleeds into the fabric (Print Chomp, 2024). Conversely, insufficient heat can lead to inadequate dye transfer and better print quality. It is essential to ensure proper dye bonding with the fibers of the fabric (Troy Corbin, 2024).

Achieving the ideal balance between temperature and dwell time is crucial, especially when working with synthetic fabrics, to reduce color inconsistencies and improve print durability (Troy Corbin, 2024). This balance between these parameters is essential for improving visual quality and production efficiency in textile printing.

LITERATURE REVIEW

Fabrics have been an integral part of human life for providing clothing and shelter throughout history. For many years, natural fabrics like cotton, silk, wool and linen were the only options. However, with the help of growing and advanced technology, new options were studied, and attempts were made to create synthetic fabrics. These fabrics could address the limitations of natural fibers and reduce manufacturing costs. (Twombly, 2023)

Today, synthetic fibers have replaced cotton and other natural fibers in many cases. Due to their flexibility, high durability, dimensional stability, resistance to various chemicals and low moisture absorption, these fibers are accepted globally. Synthetic fibers are produced using the compounds derived from fossil fuels, including petroleum-based chemicals and petrochemicals. Unlike natural fibers, synthetics offer properties such as more excellent stretchability, stain resistance and water resistance, making them highly appealing to consumers. In 2021, synthetic fibers comprised 64% of the global fiber market. (Textile Exchange, n.d.)

There are various printing methods to transfer designs and images onto fabrics, such as screen printing, Dye sublimation, Direct-to-Garment (DTG), heat transfer printing etc. Each technique offers distinctive advantages depending on the type of material and desired outcome. Out of these methods, the dye sublimation process stands out for its ability to produce vibrant, long-lasting prints on synthetic fabrics. (Belinda, n.d.)

This method is used to transfer decorative designs onto the surfaces of plastic, coated metal, and ceramic items(Hong & Nguyen, 2021). The sublimation printing process comprises various elements like printer, ink formulation, sublimation transfer paper, textile material, printing parameters, and color management platform. Each component is essential to determine production speed, color quality and cost efficiency. The ideal print includes clarity, color accuracy and durability(Toshikj & Prangoski, 2023).

Dye sublimation is a printing process using a specially designed ribbon that holds solid inks. The printer heats the ink and transitions directly into a gaseous form, skipping the liquid form. Once the ink hits the media, it transitions from gas back to solid, which results in a printed image of the product. The ink is applied with intense pressure and heat to print. The dye sublimation ink is longer-lasting and waterproof than traditional ink, so the printed image does not wash off or peel off the printed item. Due to high heat and coating, it eliminates the possibility of smudging. (DTG, 2021)

Transfer paper plays a crucial role in this process. It serves as a medium that carries the dye(image) before transferring it to the fabric(substrate). The key to the dye sublimation process is the transfer paper's ability to hold the ink and release it only under specific heat and pressure conditions. The transfer paper has a unique composition, which includes a coating that optimizes the hold of the ink until the heat is applied. At this point, the dye transforms into a gas. The paper is lightweight but robust enough to handle the high temperatures required for the sublimation process, typically between 350-400 degrees Fahrenheit. (DTG, 2021)

The printed transfer paper is placed on the fabric's surface, and then heat and pressure are applied using a heat press. This causes the dye on the paper to vaporize and bond with the fabric's fibers. The

heat and pressure should be controlled to ensure even sublimation. The temperature must be high enough to sublimate the dye without damaging the substrate. Pressure is essential to maintain close contact between the transfer paper and the substrate. (DTG, 2021)

The substrate material (fabric) plays a critical role. For an effective sublimation process, the substrate must contain polymers with open molecular structures capable of trapping the dye gas when heated. The heated gas expands and penetrates the substrate's open polymer structure during the sublimation. Once the substrate cools, the dye becomes permanently trapped within the fibers. This gives durable, colorfast images that resist washing, wear and friction. This technology is ineffective with cotton or other natural fabrics. Unlike synthetic fabrics, gaseous ink passes through natural fabrics rather than bonding with fibers. (Troy Corbin, 2024)

Color management in dye sublimation printing is crucial to ensure accurate and consistent color reproduction on various substrates. The goal is to control and optimize the printing process. This involves factors such as substrate, ink, temperature, dwell time, printer calibration, CIELAB values, DELTA E values, and ICC profiles. The interaction between sublimation inks and substrates varies depending on the type of material. It is critical to understand how different fabrics react to the same ink. Some fabrics absorb more ink, which affects color accuracy and saturation. High-quality (and compatible) inks and substrates must be used to achieve accurate color reproduction.

Earlier, it was stated that temperature and dwell time directly impact the color's quality, consistency and accuracy. The correct combination of these parameters ensures the complete dye(color) transfer from paper to substrate without color shifts. Along with these factors, printer calibration is essential to maintain and deliver consistent color output over time.

Furthermore, ICC profiles are used as a standard method to translate the colors displayed on the monitor to the fabrics on which printing will happen, ensuring accurate color reproduction. These profiles help to maintain consistent color quality regardless of the materials or equipment used. The CIELAB and DELTA E values are the quantifiable way to ensure the consistency and accuracy of the color. DELTA E is essential, as it allows printers to evaluate if the printing meets the necessary color quality standards or if adjustments need to be made to improve the color quality.

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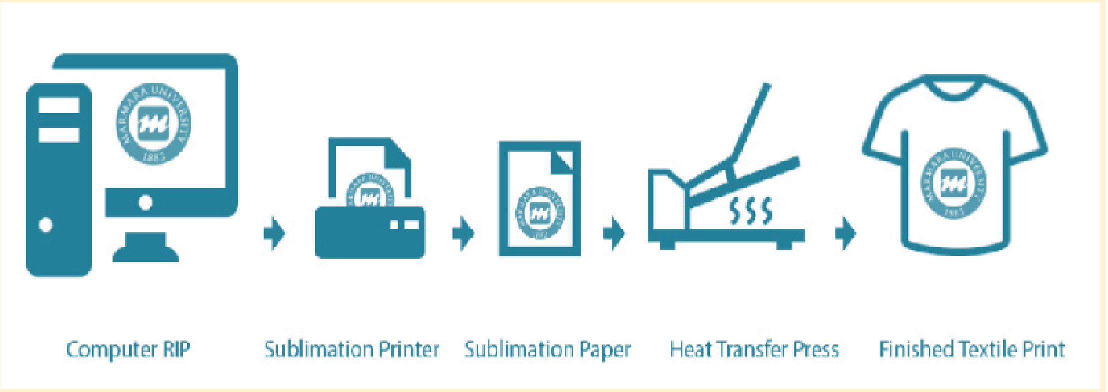

Image 1 Sublimation Printing Overview (ÖZOMAY & ÖZOMAY, 2021)

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RESEARCH DESIGN

This research is intended to evaluate the influence of temperature and dwell time to obtain the required color quality in dye sublimation printing. By determining the optimal combination of these two parameters, the purpose of the study is to improve the accuracy of color reproduction. The findings will provide valuable insights and address the industry demands for color accuracy, improved color reproduction and consistency of the sublimation prints across synthetic fabrics, which is beneficial for the textile printing industry.

For this research, the experimental design is based on collecting and analyzing quantitative data. Eleven synthetic fabrics were utilized – consisting of 5 Aberdeen fabrics and 6 Fisher fabrics. The Aberdeen fabrics are categorized as coated, white and backlit and printed on an EPSON Surecolor F9470 printer. The Fisher fabrics are classified as blockout, heavy, and soft knit and printed on the MUTOH Xper Jet 1624WR Pro printer. The characteristics of these fabrics differ significantly and play an essential role in dye sublimation printing. These fabrics' texture, surface, opacity and composition impact color reproduction.

The fabrics supplied by PCC Textile Trade Group were printed at temperatures ranging from 380°F to 400°F. The reason is that the molecules of the dye sublimation ink begin to sublimate at a temperature of 367°F, which is unsuitable for production as it would take longer dwell time. The most effective temperature range is 385°F up to 410°F with a shorter dwell time.

These specific temperature (380°F, 390°F, and 400°F) and dwell time (35 seconds, 45 seconds, and 55 seconds) ranges were selected because it is intended to bracket the typical sublimation temperature and dwell time.

The printed fabrics were supplied by PCC Textile Trade Group, each with a CMYK test target. Nine samples were provided for each fabric, each printed at three different temperatures - 380°F, 390°F, and 400°F and with three dwell times - 35 seconds, 45 seconds, and 55 seconds. Measurements were taken one fabric at a time using the X-Rite i1 Pro 3 Plus spectrophotometer. The color values were measured and recorded via the ChromaChecker application. From the ChromaChecker, CIELAB values and dot gain (TVI) values were collected and used for further calculations and analysis.

MATERIALS AND METHODS

This section outlines the materials, tools and procedures used in this study. It includes details about the substrates (fabric types), such as category, opacity, OBA Index and LAB values. In addition, it covers information on transfer paper, heat press, printers, measurement devices and software.

Substrate (Fabrics):

The fabric properties are listed in the table below.

OBA - Optical Brightening Agent:

The optical brightening agents (OBAs) are chemical additives. These are applied during the bleaching and finishing processes to enhance the whiteness and brightness of the fabric. However, due to their variability across brands, concentrations and reflective properties, the color accuracy is affected. OBAs can influence the color space, impacting the final print by distorting color accuracy and consistency. (FESPA, 2019)

Opacity:

The opacity of the fabric plays a significant role when printing with the dye sublimation process. It impacts the visual quality and functionality of the fabric. Opacity is measured in terms of the percentage of light it blocks and prevents show-through from the background. High-opacity fabrics produce vibrant and consistent colors, while low-opacity fabrics can produce dull and muted colors. (Chad Twombly, 2023).

Printer:

EPSON Surecolor F9470

The SureColor F9470 64-inch printer is a reliable solution for dye-sublimation applications in high-volume factory environments. It features dual precision core printheads and delivers high-quality prints. The printer uses UltraChrome® DS technology with High-Density Black ink, providing excellent color saturation and contrast for professional-quality apparel, soft signage, and décor. This printer is compatible only with Epson HDK Inkset. (EPSON, n.d.)

MUTOH Xper Jet 1624WR Pro

The XpertJet 1642WR Pro 64" is a high-speed dye-sublimation inkjet printer with a new platform that inherits the properties of the XpertJet series. It features new extra-wide MUTOH AccuFine print heads with best-in-class dot placement accuracy, enabling high print speeds and quality. MUTOH's original DH21 dye-sublimation transfer ink provides optimum media transfer, high-density colors, less ink consumption, and fast ink-drying times for thinner and lighter transfer papers. The printer delivers high-quality graphics onto various materials. (MUTOH, n.d.)

Transfer Paper:

Colden hove HTR 3500

The paper used is a high-quality paper specifically designed for dye sublimation printing. The unique composition includes a coating that is recognized for its outstanding release properties, ensuring efficient transfer of sublimation ink to the fabric and producing crisp and vibrant images(Troy Corbin, 2024). It is crafted to optimize the release of sublimation ink, reducing ink waste and producing brighter and more accurate colors. The paper dries quickly, preventing smudging and allowing fast handling, which is essential for high-volume printing (NEENAH COLDENHOVE & BDF Graphics, n.d.). It can manage heavy ink loads, which makes it ideal to produce rich, dense colors without compromising print quality. (NEENAH COLDENHOVE & BDF Graphics, n.d.).High temperatures between 350F and 400°F are required for the sublimation process. The HTR 3500 is designed to withstand high temperatures and ensure reliable and effective transfer. Due to its consistent performance, high-quality results and ability to meet the demands, this paper is widely used in professional dye sublimation printing.

MUTOH Xper Jet 1624WR Pro:

It is a high-quality and versatile heat press. The design of the machine is easy to access, making it ideal for applications that require accuracy and durability in heat transfer printing. As the name suggests, the upper platen rotates completely, reducing the risk of accidental burns. This machine is equipped with a digital display of time and temperature, providing accurate control overheat and pressing time, which varies based on the substrates. The pressure can also be adjusted, which allows to customize the variables for varying thicknesses of the materials. (GEO Knight & CO, INC, n.d.)

X-Rite i1 Pro 3 Plus Spectrophotometer:

This measurement device is designed for accurate color analysis, print quality and color measurement (X Rite PANTONE, n.d.). It has built-in quality assurance tools that can easily capture and manage colors and a large aperture that supports high brightness levels, improves emissive measurement, and produces the best possible calibration(X Rite PANTONE, n.d.).

Software:

ChromaChecker

ChromaChecker is the industry's first Color Conformance Platform that allows a printer to determine a production standard that meets the customer's expectations(ChromaChecker, n.d.). It helps the user establish desired color standards and evaluate if the printer can produce those color conformance requirements that maintain and track it over time (ChromaChecker, n.d.). It offers an inclusive suite of color measurement and analysis tools, workflow automation and efficiency improvement (ChromaChecker, n.d.). The platform enables color consistency across different devices and substrates, optimizes workflows, reduces waste, and saves money.

RESEARCH METHOD

For this research, eleven different synthetic fabrics were utilized. These fabrics were pre-printed through the dye sublimation process. Each fabric sample has a corresponding settings specification sheet detailing printing conditions, temperature, and dwell time.

Aberdeen fabrics were printed on an Epson Surecolor F9470 printer using an Epson HDK Inkset. The pressure was 45psi, and the resolution was 720X720. Fisher fabrics were printed on Mutoh Xper Jet 1624WR Pro printer using Mutoh DH 21 inks. The pressure was 45psi, and the resolution was 600X600. Geo Knight Digital Swinger 16x20 Clamshell heat press was used.

A CMYK test target was printed on each fabric at three different temperatures – 380° F, 390° F and 400° F, with a dwell time of 35 seconds, 45 seconds, and 55 seconds. A test target included 16 tint patches of CMYK – 25%, 50%, 75% and 100%, respectively.

The light source was D65 under an observation angle of 10 degrees angle. Color measurements were carried out using an X-Rite i1 Pro 3 Plus spectrophotometer and recorded through the ChromaChecker application software. The CIELAB values and dot gain (TVI) values were extracted from ChromaChecker software for further calculations and analysis to evaluate color quality parameters.

RESULTS

This section evaluates color measurements – CIELAB values, Delta E (color accuracy) and dot gain (TVI) of the pre-printed samples at different temperatures and dwell times across all fabrics.

The changes in temperature and dwell time impacted lightness (L*) and color saturation (a* and b*). The analysis also focuses on the fabric performance and how their categories affect color metrics.

CIELAB Values Analysis:

LAB values analysis for Aberdeen 5384-63:

The CIELAB values for Aberdeen 5384-63 coated fabric across different percentages- 25%, 50%, 75% and 100% at three temperatures – 380°F, 390°F and 400°F and three dwell times – 35seconds, 45seconds and 55seconds are presented in the following tables. Table 5.1.1 shows the CIELAB values for Cyan tints, Table 5.1.2 for Magenta tints, Table 5.1.3 for Yellow tints and Table 5.1.4 for Black tints.

Abderdeen 5384-63		Cyan 25%			Cyan 50%			Cyan 75%			Cyan 100%		
Temp. (°F)	Time (sec)	L	a	b	L	a	b	L	a	b	L	a	b
380	35	65.83	-15.20	-40.60	52.68	-10.08	-50.97	38.93	0.96	-54.60	31.55	7.01	-50.82
380	45	65.64	-15.28	-40.84	52.07	-10.17	-52.32	41.42	-0.51	-54.66	38.55	1.93	-51.64
380	55	65.72	-15.05	-41.19	51.97	-9.93	-51.85	38.65	1.31	-54.65	31.89	6.84	-49.45
390	35	65.54	-15.49	-40.61	52.34	-10.19	-51.40	39.23	1.20	-54.84	34.38	5.43	-50.27
390	45	65.84	-14.68	-40.10	51.33	-9.96	-52.01	39.07	1.16	-53.84	30.13	7.81	-51.04
390	55	65.64	-14.93	-41.37	51.89	-9.70	-52.04	38.02	1.45	-55.24	30.78	7.51	-49.08
400	35	65.99	-14.97	-40.65	52.25	-10.01	-51.20	38.60	1.05	-54.46	31.05	7.50	-48.18
400	45	65.50	-15.59	-40.59	51.64	-10.72	-50.25	37.73	0.27	-52.72	29.06	7.54	-44.75
400	55	65.89	-14.54	-39.92	51.90	-10.19	-49.60	39.04	-1.09	-51.06	30.05	4.92	-43.70

Table 5.1.1 Cyan LAB values for Aberdeen 5384-63

Aberdeen 5384-63		Magenta 25%			Magenta 50%			Magenta 75%			Magenta 100%		
Temp (°F)	Time (sec)	L	a	b	L	a	b	L	a	b	L	a	b
380	35	63.81	63.03	-1.67	55.99	71.55	9.94	50.14	71.84	19.92	47.04	69.82	22.14
380	45	63.95	62.25	-2.51	55.90	71.06	8.25	52.13	70.64	14.80	50.07	69.89	15.98
380	55	63.94	62.92	-1.73	56.34	71.06	9.91	49.96	71.98	20.50	47.07	70.08	22.56
390	35	63.83	62.49	-2.01	56.08	71.25	9.29	51.34	71.47	16.51	48.72	69.95	19.28
390	45	62.99	62.58	-1.99	55.22	71.88	10.14	48.89	72.82	21.39	45.51	70.67	24.01
390	55	63.30	63.67	-1.68	56.18	71.14	10.15	49.39	72.36	21.37	46.85	68.98	22.85
400	35	63.34	63.49	-1.83	55.87	71.34	9.79	49.72	71.71	20.37	46.75	69.42	22.03
400	45	62.61	62.26	-1.40	55.41	72.73	11.17	48.97	72.56	22.91	44.34	68.99	27.60
400	55	63.64	62.25	-0.95	55.68	71.69	10.73	49.44	72.00	21.62	45.07	69.18	25.83

Table 5.1.2 Magenta LAB values for Aberdeen 5384-63

At the highest temperature(400°F) and longer dwell time (55 seconds), the lightness L* values tend to decrease, indicating darker shades as the tints increase from 25% to 100%. The a* values are predominantly negative (which indicates a greenish hue) and shift toward neutrality at higher cyan percentages and temperatures. The b* values are strongly negative, which means a blue hue. Increased temperature produces the most significant shift between 25% and 50% tints and a decrease in a* and b* values.

Like cyan, the magenta lightness L* values tend to decrease as the tint percentage increases (25% to 100%). The a* values are consistently positive, which indicates a solid red hue. The b* values are slightly negative to positive, which suggests a shift from green to yellow. With the higher temperatures and longer dwell times, magenta shifts towards more intense red saturation at higher percentages.

The yellow lightness L* values tend to remain high as the tint percentage increases, indicating lighter tones. The a* values are predominantly negative, which suggests a shift toward green. The b* values are strongly positive, indicating yellow tones at higher tint percentages. This data shows that yellow shows very few shifts in a* and b* values across all tints and temperatures.

Aberdeen 5384-63		Yellow 25%			Yellow 50%			Yellow 75%			Yellow 100%		
Temp (°F)	Time (sec)	L	a	b	L	a	b	L	a	b	L	a	b
380	35	90.45	-10.97	60.29	89.36	-8.65	75.49	87.64	-3.63	85.66	86.08	1.22	90.67
380	45	90.09	-10.69	58.79	89.37	-8.91	74.24	87.98	-5.46	81.90	87.67	-3.89	83.49
380	55	90.57	-11.02	59.94	89.49	-8.68	75.06	87.63	-3.03	85.98	86.51	0.57	89.60
390	35	90.27	-10.50	59.31	89.06	-9.05	73.04	87.61	-3.74	85.04	87.86	-5.47	80.20
390	45	89.78	-10.44	59.39	88.87	-8.61	75.63	87.14	-2.87	86.39	85.54	1.75	90.33
390	55	90.51	-11.00	59.53	89.34	-8.63	74.99	87.50	-2.80	86.14	85.87	1.97	89.77
400	35	90.30	-10.73	59.83	89.06	-8.72	75.80	87.49	-2.91	85.70	85.20	2.44	92.07
400	45	90.56	-10.93	60.67	89.51	-8.61	76.31	87.54	-2.53	87.82	85.17	4.66	94.03
400	55	90.23	-10.93	59.42	88.94	-8.55	74.54	87.29	-2.74	85.76	84.73	4.10	93.87

Table 5.1.3 Yellow LAB values for Aberdeen 5384-63

Aberdeen 5384-63		Black 25%			Black 50%			Black 75%			Black 100%		
Temp (°F)	Time (see)	L	a	b	L	a	b	L	a	b	L	a	b
380	35	40.14	2.42	-2.60	29.12	3.05	-1.57	21.66	2.44	-1.67	21.54	1.42	-0.91
380	45	40.52	2.16	-4.10	29.00	2.71	-3.53	22.60	2.03	-2.75	23.18	1.53	-0.77
380	55	40.08	2.33	-3.10	27.71	3.31	-1.67	21.91	2.24	-1.46	22.64	1.39	-1.12
390	35	41.82	1.90	-4.23	28.63	3.03	-2.40	22.44	2.29	-2.43	22.46	1.58	-1.11
390	45	39.63	2.51	-2.78	27.02	3.51	-1.78	22.91	2.07	-2.43	19.67	1.68	-1.16
390	55	41.12	2.51	-2.28	28.18	3.45	-1.53	20.77	2.59	-1.33	21.16	1.49	-1.32
400	35	39.65	2.60	-2.72	27.28	3.46	-1.94	20.73	2.56	-1.34	22.02	1.29	-1.40
400	45	39.74	2.64	-1.55	27.80	3.91	-0.43	21.05	2.69	-0.61	21.23	1.30	-0.78
400	55	40.98	2.54	-1.68	27.22	3.68	-0.99	23.06	2.29	-0.95	18.59	1.61	-0.92

Table 5.1.4 Black LAB values for Aberdeen 5384-63

As the tint percentage increases, the black lightness L* values show significant changes with darker black. The a* and b* values indicate a minimal color shift. Black shows less color shift than cyan, magenta, and yellow, particularly at higher percentage tints. Overall, higher temperatures and longer dwell times produce more pronounced shifts, especially for cyan and magenta. Yellow and black show more stable shifts. The middle tint percentages (50% - 75%) of cyan and magenta show the widest LAB shifts, indicating these colors are more sensitive to changes in temperature and dwell time.

The detailed data (CIELAB values) tables across all colors of different tint percentages- 25%, 50%, 75% and 100% at three temperatures – 380°F, 390°F and 400°F and three dwell times – 35seconds, 45seconds and 55seconds for fabrics except Aberdeen 5384-63, including Aberdeen 6243L-63, Aberdeen 2100-63, Aberdeen 4200 RS-63, Aberdeen 5384-63, Aberdeen QUAD 7-63, Fisher GF 1707, Fisher GF 1708, Fisher GF 4019, Fisher GF 4020, Fisher GF 6050 and Fisher GF 8880 are provided in the Appendix A.

The analysis of these data (CIELAB) for each fabric is as follows:

The CIELAB values for Aberdeen 6243L-63 are provided in Appendix A. Table A.1 shows the CIELAB values for Cyan tints, Table A.2 for Magenta tints, Table A.3 for Yellow tints and Table A.4 for Black tints.

As the tint percentage increases (25% to 100%), the lightness L* values of cyan tend to decrease (indicating darker shades), and the highest shifts are at higher temperatures and longer dwell times. The a* values shift from predominantly negative to less negative, indicating a less greenish hue. The b* values remain consistently negative, marking a shift towards a blue hue at higher temperatures and longer dwell times.

The L* values of magenta decrease as the tint percentage increases (25% to 100%), indicating a more intense color. The a* values are strongly positive, which suggests a shift towards red at higher tint percentages. The b* values remain close to neutral. This shows that increasing magenta levels enhances the red hue without impacting the blue-yellow axis as much (390°F and 400°F and 45-55 seconds). The increased saturation and deeper colors are noticeable with higher tint percentages at higher temperatures (400°F) and longer dwell time (55 seconds).

With higher tint percentages, L* values of yellow decrease, indicating a more intense yellow color. The a* values remain close to neutral, and the b* values are 21 strongly positive, indicating significant changes across tints moving towards yellow and showing intense yellow saturation at 100%. This trend suggests that yellow tones maintain a high brightness level on the fabric at lower tint percentages. Higher temperature(400°F) and longer dwell time (55 seconds) lead to more dramatic shifts in brightness and saturation for other colors. In contrast, the yellow color shows

intense saturation with higher tint percentages at higher temperatures and longer dwell time.

As the tint percentage increases, the L* values of black decrease steadily, indicating deep and dark black tones. The a* and b* values remain neutral, indicating a balanced grayscale and less pronounced shifts towards other hues compared to different colors. The darkest shades are noticeable at higher temperatures (400°F) and dwell times (45-55 seconds) at higher tint percentages.

The analysis for Aberdeen 6243L-63 fabric shows that the temperature and dwell time settings influence the color shift and intensity across all colors.

LAB values Analysis for Aberdeen 2100-63:

The CIELAB values for Aberdeen 2100-63 are provided in Appendix A. Table A.5 shows the CIELAB values for Cyan tints, Table A.6 for Magenta tints, Table A.7 for Yellow tints and Table A.8 for Black tints.

The L* values of cyan increase slightly with temperature and dwell time. The impact of temperature and dwell time is noticeable at mid-range tints (50%,75%). The a* values are negative, indicating a shift toward green with the increased temperature at lower tint percentages (25%). The b* values are strongly negative, marking a shift 22 towards blue. The higher temperatures (390°F and 400°F) produce more pronounced shifts at higher tint percentages (75% to 100%).

The L* values of magenta remain consistent. Other changes are noticeable, especially with the increase in dwell time (35 to 55 seconds) at 25% and 75% tint percentages. The a* values are positive, indicating a shift towards red, and the b* values are negative, marking a shift towards blue at higher temperatures. As the temperature and dwell time increase, the hue becomes more saturated across all tint percentages.

The L* values of yellow are stable. However, changes are noticeable with increased temperature and dwell time at mid-range tint percentages (50%,75%).

The a* values are mostly negative, indicating a shift towards green. The b* values are predominantly positive, indicating intense yellow reproduction. The largest and most significant color shifts are seen at higher tint percentages (100%) at temperatures between 380°F and 400°F.

The black L* values are consistent but increase steadily at higher temperatures (390°F and 400°F), producing pronounced shifts at 50% and 100% tint percentages. The a* and b* values are neutral, indicating less variation across all tints and temperatures. The changes in shifts are noticeable at a high tint percentage (100%) with longer dwell times (45-55 seconds).

The Aberdeen 2100-63 fabrics analysis shows that cyan has the most significant shifts, magenta shows moderate changes, and yellow and black remain more stable.

LAB Values Analysis for Aberdeen 4200 RS-63:

The CIELAB values for Aberdeen 4200 RS-63 are provided in Appendix A. Table A.9 shows the CIELAB values for Cyan tints, Table A.10 for Magenta tints, Table A.11 for Yellow tints and Table A.12 for Black tints.

With temperature and dwell time, the cyan L* values increase. The most pronounced shifts are produced at a high tint percentage (100%) at temperatures between 380°F and 400°F and longer dwell time (55 seconds). At higher temperatures, the a* values are mostly negative, indicating a shift toward green, and the b* values become less negative, indicating a slight reduction in the blue.

For magenta, the L* values increase with temperature and dwell time, showing brighter colors at high tint percentages. The a* values are mostly positive, indicating a shift toward red. However, as temperature increases, the magenta tones slightly reduce. The b* values are moving from negative to positive as the tint percentage increases with an increase in temperature and dwell time, shifting towards more yellow hues.

The L* values of yellow are stable across temperatures. The a* values change from negative to positive, shifting from green to red at higher temperatures. The b* values are strongly positive, shifting towards yellow. There is an increase in a* and b* values with an increase in the temperatures and tint percentages. However, the values are higher at lower dwell times.

As the tint percentage increases (25% to 100%), the black L* values decrease. At higher temperatures and dwell times, the L* values increase significantly. This indicates the lighter tones of black. The a* values are mostly positive, indicating a slight shift 24 toward red. The b* values are positive to negative, indicating a yellowish-blue tint. However, these values show very few changes.

The Aberdeen 4200 RS-63 fabrics analysis shows that cyan has the most significant shifts, magenta shows moderate changes, and yellow and black remain more stable.

LAB values Analysis for Aberdeen QUAD 7-63:

The CIELAB values for Aberdeen QUAD 7-63 are provided in Appendix A. Table A.13 shows the CIELAB values for Cyan tints, Table A.14 for Magenta tints, Table A.15 for Yellow tints and Table A.16 for Black tints.

As the tint percentage increases, the L* values tend to decrease. The L* values increase at longer dwell times across temperatures and tint percentages. The a* values shift from negative to positive, shifting from green to red at higher tint percentages and temperatures, especially at 400°F. The b* values are strongly negative, indicating a solid shift toward blue at lower tint percentages.

At higher temperatures (400°F) and longer dwell time (55 seconds), the L* values increase, especially for 25%, 50% and 75% tint percentages. At a higher tint percentage (100%), the L* values increase at lower temperatures (380°F) and dwell time (35 seconds).

The a* values are predominantly positive and stable with minor shifts, indicating a shift towards red. The b* values change from negative to positive with major shifts at 75% and 100% tint, shifting towards yellow.

The L* values decrease as the tint percentage increases (25% to 100%). This indicates less saturation at higher tint percentages (100%). The a* values change from negative to positive, shifting from green to red. The b* values are predominantly positive and increase as the tint percentage increases (25% to 100%), indicating a solid yellow reproduction.

With an increase in temperature and dwell time, the L* values increase. As the tint percentage increases (25% to 100%), the L* values decrease, indicating fading of black tones. The a* and b* values remain stable with very few shifts.

The analysis for Aberdeen QUAD 7-63 fabric shows that all colors have substantial color shifts, especially at lower tint percentages, and the changes are noticeable with changes in temperature and dwell times.

LAB values Analysis for Fisher GF 1708:

The CIELAB values for Fisher GF 1708 are provided in Appendix A. Table A.17 shows the CIELAB values for Cyan tints, Table A.18 for Magenta tints, Table A.19 for Yellow tints and Table A.20 for Black tints.

The L* values of cyan decrease as the tint percentage increases (25% to 100%). The a* values are mostly negative, indicating a shift toward green. The b* values are negative, marking a shift toward blue. The cyan has moderate color shifts at lower tint percentages.

As the tint percentage increases, the L* values of magenta decrease. The a* values are strongly positive and increase as the tint percentage increases (25% to 100%), indicating a solid red hue. The values are high at lower temperatures (380°F) and all dwell times. The b* values are positive and relatively increase as the tint percentage increases, indicating a yellowish tone.

The L* values of yellow are very high and stable, slightly decreasing as the tint percentage increases (25% to 100%). Also, the L* values are relatively high at lower temperatures (380°F) and shorter dwell times (35 seconds). This indicates high consistency with minor variations. The a* values are strongly negative, marking a shift toward green. The b* values are strongly positive and increase as the tint percentage, temperature and dwell time increase. This indicates a saturated yellow reproduction.

As the tint percentage increases, the L* values slightly decrease. Across temperatures and dwell times, the L* values are relatively stable. The a* values are strongly positive and consistent across all tints, indicating a slight red tone. The b* values are negative, indicating a slight bluish tone. The a* and b* values show minor color shifts.

The Fisher GF 1708 fabric analysis shows that cyan and magenta demonstrate moderate color shifts at different temperatures and dwell times. Yellow and black exhibit higher stability and consistent color accuracy.

LAB values Analysis for Fisher GF 1707:

The CIELAB values for Fisher GF 1707 are provided in Appendix A. Table A.21 shows the CIELAB values for Cyan tints, Table A.22 for Magenta tints, Table A.23 for Yellow tints and Table A.24 for Black tints.

The L* values decrease as the tint percentages increase (25% to 100%) and the temperature and dwell time increase. The a* values are primarily negative and change to positive at the higher tint percentage (100%), indicating a shift toward green than red. The b* values are significantly negative, indicating a strong blue shift.

The L* values are consistent and relatively high across all tints. However, as the tint percentage increases (25% to 100%), the L*values decrease. The L* values are high across all temperatures and at lower dwell time (35 seconds). The a* values are strongly positive and keep increasing as the tint percentage increases, indicating a solid red hue. Similarly, the b* values are positive and increase with tint percentage, displaying a yellow hue.

The L* values of yellow are very high, indicating significant lightness across all tint percentages. The a* values are negative, indicating a slight shift toward green. The b* values are positive, high and increase with tint percentage, indicating a solid yellow hue across all tints, temperature and dwell time.

The L* values are lower than other colors and decrease as the tint percentage increases (25% to 100%). This represents low lightness and indicates dark shades. The a* values are positive, indicating a mild red tone shift. The b* values are negative, indicating a bluish tone. The a* and b* values show minor shifts.

The Fisher GF 1707 fabric analysis shows that cyan shows the most noticeable color shifts at higher temperatures and longer dwell times. Yellow maintains high lightness and consistent yellow tones. Magenta demonstrates moderate variations. Black shows minimal shifts, maintaining dark tones.

LAB values Analysis for Fisher GF 4019:

The CIELAB values for Fisher GF 4019 are provided in Appendix A. Table A.25 shows the CIELAB values for Cyan tints, Table A.26 for Magenta tints, Table A.27 for Yellow tints and Table A.28 for Black tints.

The L* values of cyan are relatively stable across all tint percentages,

temperatures and dwell times. There is a slight decrease in L* values with an increase in tint percentages (25% to 100%). The a* values are negative, indicating a shift toward green. The b* values are negative, indicating a shift toward blue. The shift changes are most noticeable in a* and b* values with an increase in temperature and dwell time.

The magenta L* values are moderate and consistent across all temperatures and dwell times, with a slight decrease as the tint percentage increases (25% to 100%). The a* values are strongly positive and increase as the tint percentage increases, indicating a saturated red reproduction. Similarly, the b* values are positive and increase with an increase in tint percentage, indicating a yellow tone.

The L* values of yellow are higher than other colors, with a slight decrease as the tint percentage increases. The a* values are negative, indicating a shift toward green. The b* values are positive, higher, and increase with an increase in tint percentage (25% to 100%), indicating a saturated yellow reproduction.

As the tint percentage increases, the L* values of black decrease. The a* values are positive, indicating a slight shift toward red. The b* values are negative, indicating a slight shift toward blue. The L*, a* and b* values are consistent across all tints at all temperatures and dwell times with the least change.

LAB values Analysis for Fisher GF 4020:

The CIELAB values for Fisher GF 4020 are provided in Appendix A. Table A.29 shows the CIELAB values for Cyan tints, Table A.30 for Magenta tints, Table A.31 for Yellow tints and Table A.32 for Black tints.

With an increase in tint percentages (255 to 100%), the L* values of cyan decrease. The a* values are negative, indicating a shift toward green. The b* values are also negative, indicating a shift toward blue. The L*, a* and b* values are consistent across all tints at all temperatures and dwell times.

The magenta L* values decrease as the tint percentage increases (25% to 100%). The L* values are consistent across all tints at all temperatures and dwell times. The a* values are positive and increase as the tint percentage increases, indicating a solid red tone reproduction. The b* values are positive and increase as the tint percentage increases, indicating a yellow shift. As the temperature and dwell times increase, the a* values show consistency while the b* values increase and exhibit significant color shifts across all tints.

The L* values of yellow are high and consistent across tint percentages, temperatures and dwell times, with a slight decrease as the tint percentage increases (25% to 100%). The a* values are negative, indicating a shift toward green. The b* values are positive, higher and increase as the tint percentage increase, indicating a saturated yellow reproduction at the highest tint. The L*, a* and b* values are relatively stable and consistent with minor variations.

With an increase in tint percentage, the L* values of black decrease. The a* values are positive and stable, indicating a slight red shift. The b* values are negative and stable, indicating a slight blue shift. The L*, a* and b* values are consistent with minor color shifts.

The Fisher GF 4020 fabric analysis shows that cyan exhibits the most pronounced color shifts, indicating less stability. Magenta shows moderate variations. Yellow and black remain stable, with minor changes across all parameters.

LAB values Analysis for Fisher GF 6050:

The CIELAB values for Fisher GF 6050 are provided in Appendix A. Table A.33 shows the CIELAB values for Cyan tints, Table A.34 for Magenta tints, Table A.35 for Yellow tints and Table A.36 for Black tints.

The L* values of cyan decrease as the tint percentage increases (25% to 100%). Within the tint percentage, the L* values increase as the temperature and dwell time increase. The a* values are negative, indicating a shift toward green. The b* values are negative, indicating a shift toward blue. The a* and b* values are consistent at all temperatures and dwell times across all tint percentages.

Like cyan, the L* values of magenta decrease with the increase in tint percentage (25% to 100%) and are consistent at all temperatures and dwell times across all tint percentages. The a* values are strongly positive, indicating a shift toward red. The b* values are positive, indicating a shift toward yellow. The a* and b* values are stable and increase as the tint percentage increases. The magenta values exhibit moderate changes.

The L* values of yellow are high, with a slight decrease as the tint percentage increases. The L* values are relatively high at all temperatures with shorter dwell time (35 seconds) across all tints. The a* values are negative, indicating a slight shift toward green. The b* values are positive and increase as the tint percentage increases, indicating a saturated yellow tone. The yellow values maintain consistency and show higher stability across all parameters.

As the tint percentage increases, the L* values of black decreases. The L* values are relatively high at all temperatures with longer dwell time (55 seconds). The a* values are positive, indicating a slight shift toward red. The b* values are negative, indicating a slight shift toward blue. The a* and b* values are consistent across all tints at all temperatures and dwell times. The black values show the least color shifts with stronger stability across all parameters.

The Fisher GF 6050 fabric analysis shows that cyan is the most significant color shift. Magenta shows moderate variations. Yellow and black are stable with minimal changes.

LAB values Analysis for Fisher GF 8880:

The CIELAB values for Fisher GF 8880 are provided in Appendix A. Table A.37 shows the CIELAB values for Cyan tints, Table A.38 for Magenta tints, Table A.39 for Yellow tints and Table A.40 for Black tints.

The L* values of cyan increase with the increase in temperature (380°F to 400°F) and dwell time (35 to 55 seconds) across all tints. The highest L* values are at a temperature of 400°F and a dwell time of 55 seconds across all tints. As the tint percentages increase (25% to 100%), the L* values decrease. The a* values are primarily negative and change to positive at a high tint percentage, indicating a greenish-red hue. The b* values are negative, indicating a saturated blue reproduction at temperatures between 380°F and 390°F. The b* values decrease at higher temperatures, shifting towards less blue.

As the tint percentage increases, the L* values of magenta decrease. However, the L* values increase consistently with higher temperatures and dwell times, especially at 75% and 100% tints. The a* values are strongly positive, indicating a saturated red hue. Similarly, the b* values are positive, indicating a shift toward yellow. The a* and b* values increase with the increase in the tint percentages. Also, at higher temperatures (400°F) and all dwell times, the a* and b* values decrease relatively across all tints.

The L* values of yellow are stable and consistent at all temperatures and dwell times, with a very slight decrease as the tint percentage increases (25% to 100%). The a* values are negative, indicating a shift toward green. The b* values are strongly positive and increase significantly with increasing tint percentages. Also, the b* values are decreased across all tints at the highest temperatures. This indicates that the intensity of yellow varies slightly.

The L* values of black increase at higher temperatures, 400°F, with a longer dwell time of 55 seconds. As the tint percentage increases (25% to 100%), the L* values decrease. The a* values are positive, indicating a shift toward red. The b* values are negative, marking a shift toward blue. The a* and b* values are consistent across all tints at all temperatures and dwell times.

The Fisher GF 8880 fabric analysis shows that the most considerable color shifts can be seen in cyan. Magenta shows moderate variations. Yellow and black remain stable, indicating better consistency across varying parameters.

Delta E Evaluation:

This section will report on the evaluation of the quantification of color accuracy in Delta E. The samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric for calculating the color differences in the samples. Because it offers a baseline representing a moderate and typical dwell time in dye sublimation printing. Also, it provides consistent LAB value readings compared to 45 seconds and 55 seconds, which makes it easier to observe variations in Delta E. Additionally, it allows for a controlled comparison to assess the

impact of the increasing dwell times. The CMC (2:1) formula was used to calculate the Delta E. The fabrics (textiles) have different textures and are not uniform in color if looked them closely. This formula is designed to align with the human eye's perception of color differences in textiles. The tolerance for variations in lightness compared to chroma is more important when matching colors across different fabric types and dyeing processes. The "2:1" ratio means that a color can deviate twice as much in lightness as it can in chroma. The acceptable range of Delta E is 3 for dye sublimation printing; Delta E values less than 3 shows high-quality results and meet the expected print outcome.
The analysis is divided into two parts. The first part includes Delta E of Cyan, Magenta, yellow and black for each fabric at various temperature and dwell time settings. The second part comprises Delta E of individual colors – Cyan, Magenta, yellow and black across temperature, dwell time and fabrics. The evaluations and analyses are critical to understanding color accuracy and reproduction in sublimation transfer printing.

At 380˚F and 45 seconds:

The Delta E values of cyan, magenta, yellow and black are calculated across temperature 380°F and a dwell time of 45 seconds for each fabric. According to the data in the table and figure below, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. Table 5.2.1.1 below shows the Delta E values for CMYK across all fabrics at 380°F and 45 seconds.

Figure 5.2.1.1 shows that the Aberdeen 5384-63 fabric shows the highest Delta E across all colors, with Delta E values for cyan, magenta and yellow significantly high and above the acceptable range. The Aberdeen QUAD 7-63 fabric also shows a little high Delta E for cyan. However, it is lower than Aberdeen 5384-63 fabric. The fabrics Aberdeen 6342L-63 and Aberdeen 2100-63 show lower Delta E values across all colors, with a noticeable low deviation in black.

The Aberdeen 4200 RS-63 shows moderate Delta E values across all colors, although Aberdeen QUAD 7-63 shows moderate Delta E values, apart from cyan. The Fisher fabrics exhibit moderate to low Delta E across all colors, except for Fisher GF 8880, which exhibits the lowest Delta E.

The color deviation is considerably significant for coated fabrics. Due to their surface treatment, the absorption of the dye can be affected, leading to increased perceptual color differences. As for the white and backlit fabrics, the translucent nature of the fabric and higher OBA might impact light absorption and color accuracy.

The heavy and soft knit fabrics show a stable color response, possibly due to their opacity and fabric density. The blockout fabrics have high opacity, and due to their low OBA index, the color difference is lowest and more consistent. The LAB values of the fabrics before the printing also influence the color fidelity. The white, heavy knit, soft

Temp (°F)	Time (see)	Fabric Types	C	M	Y	K
380	45	A-5384-63	5.44	4.12	3.37	1.18
		A-6243L-63	1.74	0.91	1.87	0.59
		A-2100-63	1.77	1.80	1.72	0.83
		A-4200 RS-63	2.58	1.90	2.30	1.92
		A-QUAD 7-63	3.55	2.32	2.41	0.50
		F-GF 1708	1.24	0.86	1.25	1.32
		F-GF 1707	1.77	2.07	1.35	1.85
		F-GF 4019	1.28	1.18	2	1.81
		F-GF 4020	1.49	1.57	2.26	1.78
		F-GF 6050	1.21	0.45	0.60	1.30
		F-GF 8880	0.50	0.22	0.15	0.44

Table 5.2.1.1 Delta E values for CMYK across fabrics at 380°F 45 seconds

knit, and blockout fabrics have near-neutral LAB values, indicating moderate to low Delta E. However, the coated and backlit fabrics have pre-existing color characteristics, indicating more deviation.

This temperature setting of 380°F and dwell time of 45 seconds shows minimal color shifts for most fabrics except the coated fabric. This suggests that this temperature and dwell time combination provides sufficient color transfer on the synthetic fabrics. However, the exception-coated fabrics might need further temperature or dwell time changes for precise color-matching applications.

At 380˚F and 55 seconds:

The Delta E values of cyan, magenta, yellow and black are calculated across a temperature of 380°F and a dwell time of 55 seconds for each fabric.According to the table and figure below, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. Table 5.2.1.2 on the following page shows the Delta E values for CMYK across all fabrics at 380°F and 55 seconds.

Figure 5.2.1.2 shows all fabrics have Delta E values within the acceptable range. However, the trend is seen where some fabrics show the lowest, and some show moderate Delta E values. The Aberdeen 5384-63 and Aberdeen QUAD 7-63 fabrics show the lowest Delta E across all colors.

Temp. (°F)	Time(sec)	Fabric Types	C	M	Y	K
380	55	A-5384-63	0.57	0.17	0.49	0.8
		A-6243L-63	0.6	1.2	0.21	0.35
		A-2100-63	2.06	1.31	1.62	0.88
		A-4200 RS-63	2.4	1.64	2.13	1.83
		A-QUAD 7-63	0.78	0.23	0.42	0.18
		F-GF 1708	0.89	0.67	1.37	1.4
		F-GF 1707	1.84	2.44	1.62	2.41
		F-GF 4019	1.23	1.43	2.21	2.02
		F-GF 4020	1.42	1.7	2.35	1.95
		F-GF 6050	2.24	0.82	0.68	2.01
		F-GF 8880	1.5	0.93	0.34	1.33

Table 5.2.1.2 Delta E values for CMYK across fabrics at 380°F 55 seconds

This suggests that the coated and backlit fabrics show better color stability at the longer dwell time of 55 seconds. The other Aberdeen white fabrics – Aberdeen 6243L-63, Aberdeen 2100-63 and Aberdeen 4200 RS-63 show low to moderate Delta E values. The fabric Aberdeen 4200 RS-63 exhibits slightly higher Delta E values, particularly cyan and yellow.

The Fisher GF 1707 soft knit fabric, especially magenta and black, shows higher Delta E values. This could be due to the structure and thickness of the fabric; suggesting a shorter dwell time or a different temperature setting may help to reduce the Delta values, as a longer dwell time can lead to over-dye absorption. The rest of the Fisher fabrics show moderate to low Delta E values. The blockout fabric, Fisher GF 8880, shows lower Delta E values. These fabrics have high opacity and low permeability, which leads to stable color performance.

The fabrics with higher opacity, like block out and heavy knit, show lower Delta E values. In contrast, the fabrics with high OBA show low to moderate Delta E values, as the brighteners can vary the color perception under specific temperatures and dwell times. The LAB values of fabric do not show the influence at 55 seconds of dwell time.

The longer dwell time of 55 seconds influences the coated and backlit fabrics, showing the lowest Delta E values and improved color stability for Aberdeen 5384-63 and Aberdeen QUAD 7-63 fabrics. However, the Delta E values are increased for white and knit fabrics. This suggests that dwell time adjustments need to be considered for different fabrics for optimal color accuracy.

At 390˚F and 45 seconds:

The Delta E values of cyan, magenta, yellow and black are calculated across a temperature of 390°F and a dwell time of 45 seconds for each fabric. According to the table and figure on the following page, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. Table 5.2.1.3 below shows the Delta E values for CMYK across all fabrics at 390°F and 45 seconds.

As shown in Figure 5.2.1.3, the Aberdeen 5384-63 fabric shows high Delta E values across all colors compared to other fabrics, especially for magenta and yellow. Both the colors exceed the acceptable range of Delta E. This indicates that as the temperature increases from 380°F to 390°F, the coated fabric shows noticeable and significant color deviations. This could be due to its reflection characteristics and coating, which varies the dye absorption. Also, this temperature of 390°F and the dwell time of 45 seconds might not be an ideal combination for coated fabrics, affecting the color fidelity.

The white fabrics- Aberdeen 6243L-63, Aberdeen 2100-63, and Aberdeen 4200 RS-63 show the lowest Delta E values for most colors. This indicates stable color performance for these fabrics at this temperature and dwell time. The OBA index is high for white fabrics, which influences the color stability in lighter shades. The backlit fabric- Aberdeen Quad 7-63, shows moderate Delta E values, with a slight increase in cyan. The knit fabrics Fisher GF 1708, Fisher GF 1707, and Fisher GF 6050 show low to moderate Delta E values. The blockout fabrics- Fisher GF 4019 and Fisher GF 4020 show the lowest Delta E values as compared to other fabrics. The Fisher GF 8880 slightly increases Delta E values than other blockout fabrics.

Temp. (°F)	Time(sec)	Fabric Types	C	M	Y	K
390	45	A-5384-63	2.88	3.77	4.85	1.95
		A-6243L-63	1.65	1.33	0.1	0.2
		A-2100-63	1.7	0.18	0.51	0.18
		A-4200 RS-63	1.46	0.27	0.2	0.49
		A-QUAD 7-63	1.89	0.65	0.99	0.33
		F-GF 1708	0.92	0.31	0.28	0.6
		F-GF 1707	0.63	0.88	1.36	1.12
		F-GF 4019	0.34	0.22	0.29	0.35
		F-GF 4020	0.7	0.09	0.27	0.45
		F-GF 6050	1.84	0.81	0.34	1.57
		F-GF 8880	1.31	0.84	0.32	1.01

Table 5.2.1.3 Delta E values for CMYK across fabrics at 390°F 45 seconds

The opacity of the blockout fabrics is on the higher side, which helps minimal color bleed and more consistent dye transfer. These fabrics show more stable color performance at this temperature, maintaining color accuracy. White fabrics have a high OBA index, showing lower DELTA E values. This indicates that optical brighteners may help to reduce color deviation under these temperature and dwell time conditions. The LAB values of white, heavy knit, and blockout fabrics influence the color stability, showing lower Delta E values across these fabrics.

The increasing temperature from 380°F to 390°F with a shorter dwell time of 45 seconds influences most fabrics, especially white, backlit, knit and blockout. These fabrics show stable color performance. However, coated fabrics show increased Delta E values, suggesting higher temperatures might lead to over-saturation of colors or spreading of the dye.

At 390˚F and 55 seconds:

The delta E values of cyan, magenta, yellow and black are calculated across temperature 390°F and a dwell time of 55 seconds for each fabric. According to the table and figure below, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. Table 5.2.1.4 below shows the Delta E values for CMYK across all fabrics at 390°F and 55 seconds.

All the Fisher fabrics have Delta E values within the acceptable range, and the trend shows low to moderate Delta E values. The Aberdeen 5384-63 fabrics show high Delta E values, particularly for yellow. This indicates that coated fabrics are sensitive to longer dwell times, leading to color deviation. The white fabrics- Aberdeen 2100-63 and Aberdeen 4200 RS-63 show significantly high Delta E values for cyan; other colors are moderate. This could be due to a higher temperature and longer dwell time, causing over-dye penetration or color bleeding.

The Aberdeen 6243L-63 shows lower Delta E values, predominantly yellow and black. This indicates that this fabric type has more stable colors under this temperature and dwell time conditions. The Aberdeen QUAD 7-63 backlit fabric shows moderate Delta E values, suggesting better color stability.

The knit fabrics – Fisher GF 1708, Fisher 1707 and Fisher GF 6050 Exhibit low to moderate Delta E values. The black Delta E values slightly increased in all three fabrics compared to other colors. This suggests that dark shades may have color shifts in thick knit fabrics as they have longer dwell time. The blockout fabrics- Fisher GF 4019, Fisher GF 4020, and Fisher 8880 show low to moderate Delta E values. There is a slight increase in Delta E values of cyan for Fisher GF 8880 fabric.

The high-opacity fabrics, like blockout and coated, show moderate Delta E values, except for yellow for Aberdeen 5384-63 fabric. Due to their nontranslucent nature, color variability and color bleeding are minimized. High OBA Index fabrics,

Temp. (°F)	Time(sec)	Fabric Types	C	M	Y	K
390	55	A-5384-63	2.55	2.54	4.84	0.94
		A-6243L-63	2.8	0.73	0.19	0.15
		A-2100-63	5.65	1.19	0.84	0.5
		A-4200 RS-63	5.3	0.87	0.6	0.38
		A-QUAD 7-63	2.09	0.96	1.02	0.53
		F-GF 1708	1.65	0.71	0.37	1.58
		F-GF 1707	0.55	1.02	0.95	1.45
		F-GF 4019	1.01	0.2	0.32	0.79
		F-GF 4020	1.43	0.15	0.22	0.94
		F-GF 6050	2.64	1.49	0.57	2.36
		F-GF 8880	2.11	1.25	0.46	1.11

Table 5.2.1.4 Delta E values for CMYK across fabrics at 390°F 55 seconds

such as white fabrics, have lower Delta E values, except the color cyan for Aberdeen 2100-63 and Aberdeen 4200 RS-63 fabrics. The OBA helps to minimize the color shifts and control color consistency. The white fabrics with neutral LAB values show stable color, particularly in yellow and black, under these temperature and time conditions. Thesefabrics show higher cyan LAB values, suggesting more color deviation for this color. This could be due to high dye sensitivity to the increased temperature.

The longer dwell time of 55 seconds influences blockout and some white fabrics and helps to stabilize the color deviation. However, some white fabrics with higher cyan LAB values show more color variation. This temperature and dwell time combination might be too intense for some fabrics, which show higher color deviation with high Delta E values.

At 400˚F and 45 seconds:

The Delta E values of cyan, magenta, yellow and black are calculated across a temperature of 400°F and a dwell time of 45 seconds for each fabric. According to the table and figure below, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. The table following shows the Delta E values for CMYK across all fabrics at 400°F and 45 seconds.

As shown in Figure 5.2.1.5, all the fabrics have Delta E values within the acceptable range. However, the trend is seen where some fabrics show the lowest, moderate and highest Delta E

Temp. (°F)	Time(sec)	Fabric Types	C	M	Y	K
400	45	A-5384-63	1.84	3.5	1.22	0.8
		A-6243L-63	1.64	0.57	0.2	0.56
		A-2100-63	1.76	0.72	0.36	0.41
		A-4200 RS-63	2.71	0.69	0.25	0.65
		A-QUAD 7-63	3.19	0.09	0.56	0.56
		F-GF 1708	0.92	0.58	0.19	0.97
		F-GF 1707	0.75	0.16	0.43	1.01
		F-GF 4019	0.57	0.16	0.19	0.44
		F-GF 4020	0.86	0.32	0.1	0.39
		F-GF 6050	1.94	0.94	0.53	1.59
		F-GF 8880	1.22	0.77	0.5	1.07

Table 5.2.1.5 Delta E values for CMYK across fabrics at 400°F 45 seconds

values within the acceptable range. However, the trend is seen where some fabrics show the lowest, moderate and highest Delta E values across colors. The Aberdeen 5384-63 fabric exhibits relatively highest Delta E values among all fabrics, particularly for magenta. This indicates considerable color deviation in this color. This temperature of 400°F is more prone to coated surfaces. However, the rest of the colors have moderate Delta E values.

The white fabrics – Aberdeen 6243L-63, Aberdeen 2100-63 and Aberdeen 4200 RS-63 show low to moderate Delta E values. The Delta E values of cyan are slightly increased for Aberdeen 4200 RS-63 fabric, suggesting higher temperatures affect cyan color stability in white fabrics. The backlit fabric- Aberdeen QUAD 7-63, shows high Delta E values, particularly for cyan. This could be due to higher temperature settings, leading to significant color deviation for backlit fabrics.

The knit fabrics- Fisher GF 1708, Fisher GF 1707, and Fisher GF 6050 show low Delta E values. Due to the dense structure of these fabrics, colors are stable. The blockout fabrics -Fisher GF 4019, Fisher GF 4020 and Fisher GF 8880 also show low Delta E values. Due to the high opacity and light-blocking properties in white and knit fabrics, colors are stable with the least color shifts under heat. OBA helps in reducing color shifts under high-temperature settings. The fabrics with high OBA, such as white fabrics, show stable color performance. The fabrics, such as white and blockout with neutral LAB values, tend to show color stability at high temperatures, as their properties interact well with the heat with minimal to no color deviation.

This temperature of 400°F and shorter dwell time of 45 seconds seems intense to show high Delta E values in fabrics like coated and backlit, which are sensitive to high temperatures. The white and knit fabrics show acceptable color stability. This combination of temperature and dwell time can be utilized where bold color retention is needed, with further adjustments for coated and backlit fabrics.

The knit fabrics- Fisher GF 1708, Fisher GF 1707, and Fisher GF 6050 show low Delta E values. Due to the dense structure of these fabrics, colors are stable. The blockout fabrics -Fisher GF 4019, Fisher GF 4020 and Fisher GF 8880 also show low Delta E values. Due to the high opacity and light-blocking properties in white and knit fabrics, colors are stable with the least color shifts under heat. OBA helps in reducing color shifts under high-temperature settings. The fabrics with high OBA, such as white fabrics, show stable color performance. The fabrics, such as white and blockout with neutral LAB values, tend to show color stability at high temperatures, as their properties interact well with the heat with minimal to no color deviation.

This temperature of 400°F and shorter dwell time of 45 seconds seems intense to show high Delta E values in fabrics like coated and backlit, which are sensitive to high temperatures. The white and knit fabrics show acceptable color stability. This combination of temperature and dwell time can be utilized where bold color retention is needed, with further adjustments for coated and backlit fabrics.

At 400°F and 55 seconds:

The Delta E values of cyan, magenta, yellow and black are calculated across a temperature of 400°F and a dwell time of 55 seconds for each fabric. According to the table and figure below, while calculating the color differences in the samples, the samples printed at a dwell time of 35 seconds across all temperatures were taken as a reference for each fabric. The table below shows the Delta E values for CMYK across all fabrics at 400°F and 55 seconds.

The Delta E values for Fisher fabrics are within the acceptable range. The Aberdeen 5384-63 fabric shows moderate Delta E values. The Aberdeen white fabrics show low, moderate and highest Delta E values. The Aberdeen 6243L-63 fabric shows high Delta E values, particularly for cyan. The Aberdeen 2100-63 fabric shows low Delta E values. The Aberdeen 4200 RS-63 white and Aberdeen QUAD 7-63 show the highest Delta E values, particularly for cyan. This indicates that cyan is prone to color shifts at higher temperatures and longer dwell time conditions, suggesting over-saturation and color fidelity in cyan.

All the fisher fabrics show moderate to low Delta E values. The Fisher GF 1708, Fisher GF 6050 knit fabric and Fisher GF 8880 show moderate and consistent Delta E values, especially in yellow and black, indicating stable color performance. Cyan shows slight deviation. This could be due to fabric density and temperature, which influence the spreading of dye in thicker fabrics.

Temp. (°F)	Time(sec)	Fabric Types	C	M	Y	K
400	55	A-5384-63	2.39	2.4	0.98	2.46
		A-6243L-63	3.4	1.18	0.72	0.92
		A-2100-63	2.54	1.42	0.68	0.81
		A-4200 RS-63	6	1.21	0.39	1.01
		A-QUAD 7-63	6.02	0.33	0.67	0.45
		F-GF 1708	2.43	1.49	0.51	2.46
		F-GF 1707	1.01	0.13	0.44	1.41
		F-GF 4019	1.43	0.63	0.41	1.27
		F-GF 4020	1.89	0.76	0.26	1.36
		F-GF 6050	2.74	1.63	0.88	2.9
		F-GF 8880	2.13	1.46	1.01	1.97

Table 5.2.1.6 Delta E values for CMYK across fabrics at 400°F 55 seconds

Black shows a higher deviation for Fisher GF 8880 blockout fabric. This could be due to dye accumulation or temperature. The soft knit fabric – Fisher GF 1707, and blockout fabrics – Fisher GF 4019 and Fisher GF 4020, display low Delta E values across all colors, maintaining a stable response.

Due to the structure and surface of the soft knit fabrics, the dye absorption is more uniform at this temperature and dwell time conditions. The opacity of the fabrics plays a crucial role in retaining the color accuracy for fabrics with low Delta E values. The OBA helps in improving color stability. The LAB values of the white and backlit fabrics are neutral—however, the LAB values of cyan exhibit higher Delta E values in these fabrics.

Combining a higher temperature of 400°F and a longer dwell time of 55 seconds seems challenging for some white and backlit fabrics. Meanwhile, knit and blockout fabrics provide better color stability.

Color-wise Delta E evaluation across temperatures and dwell time:

These data demonstrate the detailed color-wise representation of Delta E evaluation across various temperature and dwell time settings for each fabric. This analysis will help to understand how each color responds under specific conditions, which is critical to achieve consistent color quality.

Delta E values for Cyan:

Table 5.2.2.1 and Figure 5.2.2.1 below represent the Delta E values for cyan across different combinations of temperatures and dwell times for each fabric.

The temperature of 380°F and the dwell time of 55 seconds show the lower Delta E, indicating longer dwell time shows minimal color deviation. The fabric Aberdeen 5384-63 shows a significant low deviation at 55 seconds. The Delta E variation looks more critical at a temperature of 390°F. The Aberdeen 2100-63 and Aberdeen 4200-63 show higher Delta E at 390°F 55 seconds, indicating this combination might have higher color deviations based on the data.

The higher temperature of 400°F tends to increase the Delta E for some fabrics, such as Aberdeen QUAD 7-63 and Aberdeen 4200-63. These fabrics show a substantial increase in Delta E at 400°F for 55 seconds, reaching above 6. These data indicate that more heat and longer dwell time negatively impact color accuracy for some synthetic fabrics.

Fabrics such as Aberdeen 5384-63, Aberdeen 4200 RS-63, and Aberdeen QUAD 7-63 show higher Delta E across various temperature and dwell time combinations, suggesting they are more prone to color changes. The Fisher fabrics – Fisher GF 1708, Fisher GF 1707, Fisher GF 4019 and Fisher GF 4020 show lower Delta E. The Fisher GF 6050 and Fisher GF 8880 display moderate to low Delta E. Based on the data, these fabrics show stability across different temperature and dwell time combinations, making them preferable where consistent color reproduction is required.

Fabric Types	380 F 45sec	380 F 55sec	390 F 45sec	390 F 55sec	400 F 45sec	400 F 55sec
A-5384-63	5.44	0.57	2.88	2.55	1.84	2.39
A-6243L-63	1.74	0.6	1.65	2.8	1.64	3.4
A-2100-63	1.77	2.06	1.65	5.65	1.76	2.54
A-4200 RS-63	2.58	2.4	1.46	5.3	2.71	6
A-QUAD 7-63	3.55	0.78	1.89	2.09	3.19	6.02
F-GF 1708	1.24	0.89	0.92	1.65	0.92	2.43
F-GF 1707	1.77	1.84	0.63	0.55	0.75	1.01
F-GF 4019	1.28	1.23	0.34	1.01	0.57	1.43
F-GF 4020	1.49	1.42	0.7	1.43	0.86	1.89
F-GF 6050	1.21	2.24	1.84	2.64	1.94	2.74
F-GF 8880	0.5	1.5	1.31	2.11	1.22	2.13

Table 5.2.2.1 Delta E values for Cyan

Based on the data and evaluation, the combination of a temperature of 380°F and a dwell time of 55 seconds seems optimal, indicating reduced Delta E values. The 400°F and 55-second combination is not ideal as it leads to higher Delta E values and does not maintain color fidelity.

Delta E values for Magenta:

Table 5.2.2.2 and Figure 5.2.2.2 below represent the Delta E values for magenta across different combinations of temperatures and dwell times for each fabric.

The temperature of 380°F and the dwell time of 45 seconds show a high Delta E, which significantly goes down at 55 seconds for Aberdeen 5384-63 fabric. The fabric Aberdeen 6243L-63 also shows lower Delta E at longer dwell time. This indicates that longer dwell time at lower temperature settings stabilizes the color. The Delta E values are reduced at a temperature of 390°F for 45 seconds, except for Aberdeen 5384-63 fabric. At 55 seconds, the Delta E values are moderate to low.

The Aberdeen 5384-63 fabric indicates sensitivity to changes at a temperature of 390°F. The highest temperature of 400°F shows more variations. At 45 seconds, Delta E values are reduced for most fabrics. At 55 seconds, Delta E values are increased.

The Aberdeen 5384-63 fabric consistently shows the highest Delta E values at all temperatures and dwell times, except 380°F with 55 seconds.

Fabric Types	380 F 45sec	380 F 55sec	390 F 45sec	390 F 55sec	400 F 45sec	400 F 55sec
A-5384-63	4.12	0.17	3.77	2.54	3.5	2.4
A-6243L-63	0.91	0.12	0.33	0.73	0.57	1.18
A-2100-63	1.8	1.31	0.18	1.19	0.72	1.42
A-4200 RS-63	1.9	1.64	0.27	0.87	0.69	1.21
A-QUAD 7-63	2.32	0.23	0.65	0.96	0.09	0.33
F-GF 1708	0.86	0.67	0.31	0.71	0.58	1.49
F-GF 1707	2.07	2.44	0.88	1.02	0.16	0.13
F-GF 4019	1.18	1.43	0.22	0.2	0.16	0.63
F-GF 4020	1.57	1.7	0.09	0.15	0.32	0.76
F-GF 6050	0.45	0.82	0.81	1.49	0.94	1.63
F-GF 8880	0.22	0.93	0.84	1.25	0.77	1.46

Table 5.2.2.2 Delta E values for Magenta

Other fabrics have low and moderate combinations of Delta E values across all temperatures and dwell times, suggesting their stability. The Delta E values vary for Fisher GF 1707 fabric, with its peak at 380°F for 55 seconds and reduced as the temperature increases.

Delta E values for Yellow:

The table and graph below represent the Delta E values for yellow across different combinations of temperatures and dwell times for each fabric.

The Delta E values are relatively high for fabric Aberdeen 5384-63 at the temperature of 380°F and the dwell time of 45 seconds, which significantly goes down at 55 seconds. This indicates that longer dwell time at lower temperature settings helps to reduce color deviation. The temperature of 390°F with dwell times of 45 seconds and 55 seconds show moderate to low Delta E values for most fabrics, except Aberdeen 5384-63 fabric. This indicates stability and reduced color deviation.

The Aberdeen 5384-63 fabric consistently shows Delta E values, especially at 390°F, indicating a greater sensitivity to temperature and dwell time changes, leading to noticeable color changes. The higher temperature of 400°F and longer dwell times of 45 seconds and 55 seconds show lower Delta E values across all fabrics.

Fabric Types	380 F 45sec	380 F 55sec	390 F 45sec	390 F 55sec	400 F 45sec	400 F 55sec
A-5384-63	3.37	0.49	4.85	4.84	1.22	0.98
A-6243L-63	1.87	0.21	0.1	0.19	0.2	0.72
A-2100-63	1.72	1.62	0.51	0.84	0.36	0.68
A-4200 RS-63	2.3	2.13	0.2	0.6	0.25	0.39
A-QUAD 7-63	2.41	0.42	0.99	1.02	0.56	0.67
F-GF 1708	1.25	1.37	0.28	0.37	0.19	0.51
F-GF 1707	1.35	1.62	1.36	0.95	0.43	0.44
F-GF 4019	2	2.21	0.29	0.29	0.19	0.41
F-GF 4020	2.26	2.35	0.27	0.22	0.1	0.26
F-GF 6050	0.6	0.68	0.34	0.57	0.53	0.88
F-GF 8880	0.15	0.34	0.32	0.46	0.5	1.01

Table 5.2.2.3 Delta E values for Yellow

Delta E values for Black:

Table 5.2.2.4 and Figure 5.2.2.4 below represent the Delta E values for black across different combinations of temperatures and dwell times for each fabric.

The Delta E values are moderate to low across all fabrics. The temperature of 380°F and dwell time of 45 seconds show moderate to low Delta E values. For the Aberdeen fabrics, the Delta E values are reduced at the temperature of 380°F and the dwell time of 55 seconds. For the Fisher fabrics, the Delta E values increased at a dwell time of 55 seconds. The temperature of 380°F and dwell time of 45 seconds also show moderate to low Delta E values.

However, Delta E values tend to decrease for a longer dwell time of 55 seconds, indicating better color stability. The highest temperature of 400°F and dwell time of 45 seconds show mixed variations, though the Delta E values are higher at the longer dwell time of 55 seconds than at the 45 seconds. This indicates that some fabrics may show color deviation at a longer dwell time and at this temperature of 400°F.

The fabric Fisher GF 6050 shows relatively high Delta E values across various temperatures and dwell times. Most of the Aberdeen fabrics, such as Aberdeen 6243L-63 and Aberdeen 2100-63, show lower Delta E values across all temperature and dwell time combinations. This indicates that these fabrics show minimal color deviations and provide a stable color response. The lower temperatures of 380°F and shorter dwell times of 45 seconds tend to produce lower Delta E values for most fabrics. This suggests that to maintain the color fidelity these conditions are better.

Fabric Types	380 F 45sec	380 F 55sec	390 F 45sec	390 F 55sec	400 F 45sec	400 F 55sec
A-5384-63	1.18	0.8	1.95	0.94	0.8	2.46
A-6243L-63	0.59	0.35	0.2	0.15	0.56	0.92
A-2100-63	0.83	0.88	0.18	0.5	0.41	0.81
A-4200 RS-63	1.92	1.83	0.49	0.38	0.65	1.01
A-QUAD 7-63	0.5	0.18	0.33	0.53	0.56	0.45
F-GF 1708	1.32	1.4	0.6	1.58	0.97	2.46
F-GF 1707	1.85	2.41	1.12	1.45	1.01	1.41
F-GF 4019	1.81	2.02	0.35	0.79	0.44	1.27
F-GF 4020	1.78	1.95	0.45	0.94	0.39	1.36
F-GF 6050	1.3	2.01	1.57	2.36	1.59	2.9
F-GF 8880	0.44	1.33	1.01	1.11	1.07	1.97

Table 5.2.2.4 Delta E values for Black

Based on color-wise Delta E evaluation, this analysis exhibits the fabric response to temperature and dwell time changes. Some fabrics are sensitive to higher temperatures, resulting in higher Delta E. While others show lower Delta E, indicating better stability across different temperature and dwell time settings.

It also demonstrates the importance of balancing temperature and dwell time to achieve consistent color outcomes. Based on temperature and dwell time, different synthetic fabrics have varying levels of color stability. These data can be useful, provide insights, and guide fabric selections and printing conditions based on the expected color outcomes.

Dot Gain (TVI) Analysis:

Dot gain or tonal value increase (TVI) is also important in sublimation transfer printing. In sublimation printing, the dot gain occurs differently than in traditional printing methods due to heat transfer. It is affected by various factors related to heat, substrate (fabric) characteristics and ink transfer. It influences the overall quality of the printed image. It includes middle tones, shadows and highlights. The excessive dot gain affects the sharpness of the image, leading to distorted prints, color shifts, loss of fine details and inconsistency in color reproduction across fabrics.

The detailed dot gain data (TVI values) tables for different tint percentages- 25%, 50%, 75% and 100% at three temperatures – 380°F, 390°F and 400°F and three dwell times – 35seconds, 45seconds and 55seconds across all fabrics are provided in the Appendix B. Table B.1 shows dot gain (TVI) values across all fabrics at 380°F for 35 seconds; Table B.2 shows dot gain values at 380°F for 45 seconds, Table B.3 shows dot gain values at 380°F for 55 seconds, Table B.4 shows dot gain values at 390°F for 35 seconds, Table B.5 shows dot gain values at 390°F for 45 seconds, Table B.6 shows dot gain values at 390°F for 55 seconds, Table B.7 shows dot gain values at 400°F for 35 seconds. Table B.8 shows dot gain values at 400°F for 45 seconds and Table B.9 shows dot gain values at 400°F for 55 seconds.

This study shows the dot gain trend at three different temperatures - 380°F, 390°F, and 400°F with three dwell times - 35 seconds, 45 seconds, and 55 seconds across all fabrics- shown in the below Figures. The dot gain is measured at 25%, 50% and 75% tints across all fabrics and colors.

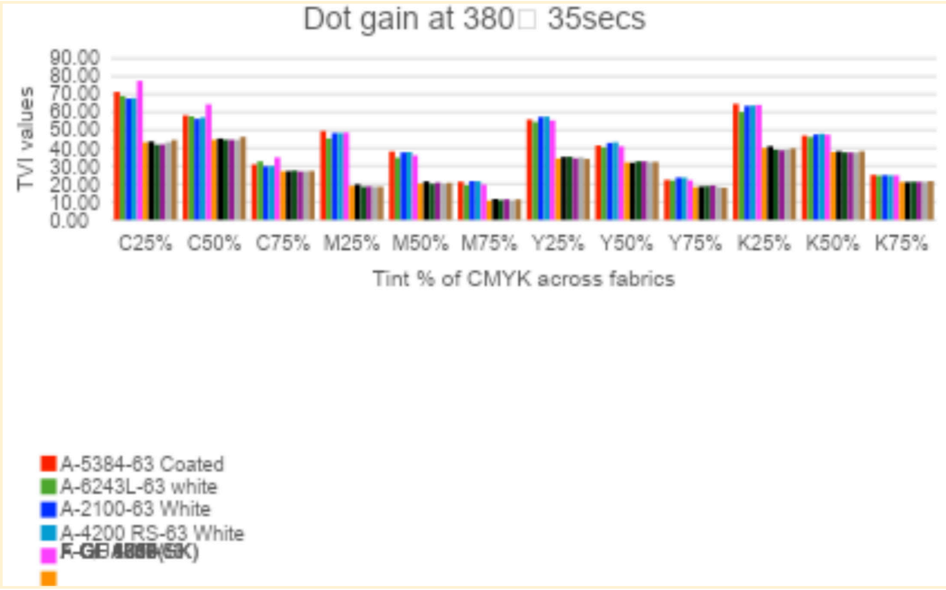


Figure 5.3.1 Dot Gain (TVI) Across Fabrics at 380˚F for 35 seconds

Figure 5.3.2 Dot Gain (TVI) Across Fabrics at 380˚F for 45 seconds

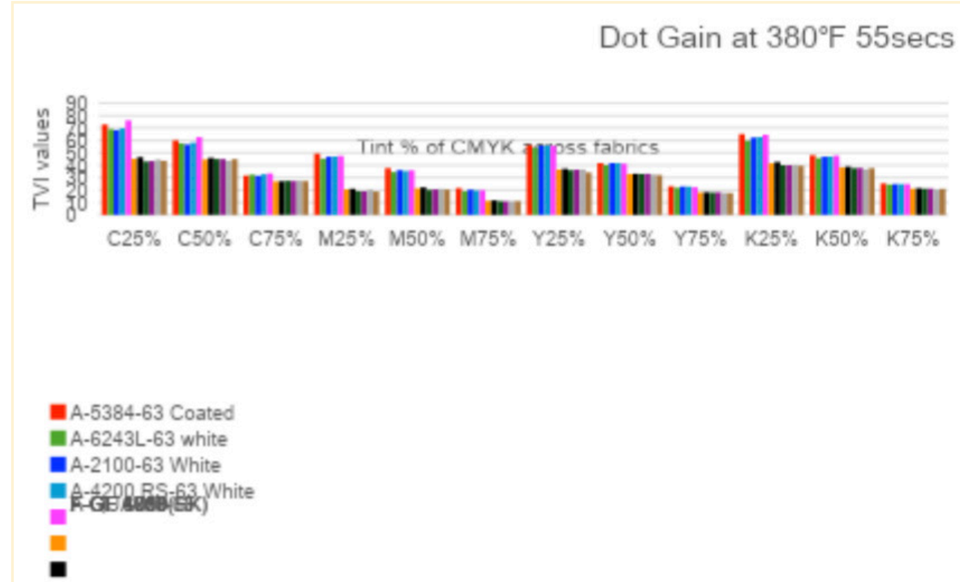


Figure 5.3.3 Dot Gain (TVI) Across Fabrics at 380˚F for 55 seconds

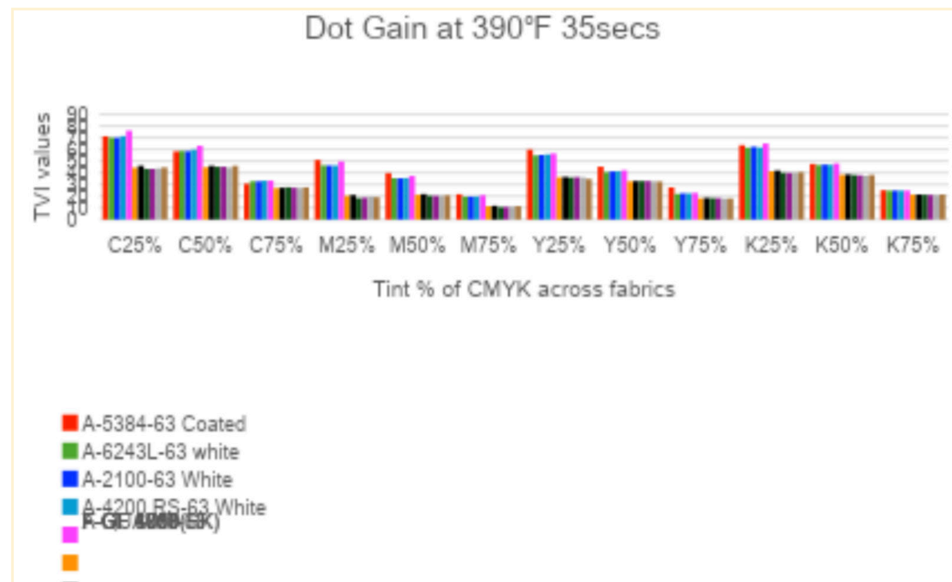


Figure 5.3.4 Dot Gain (TVI) Across Fabrics at 390˚F for 35 seconds

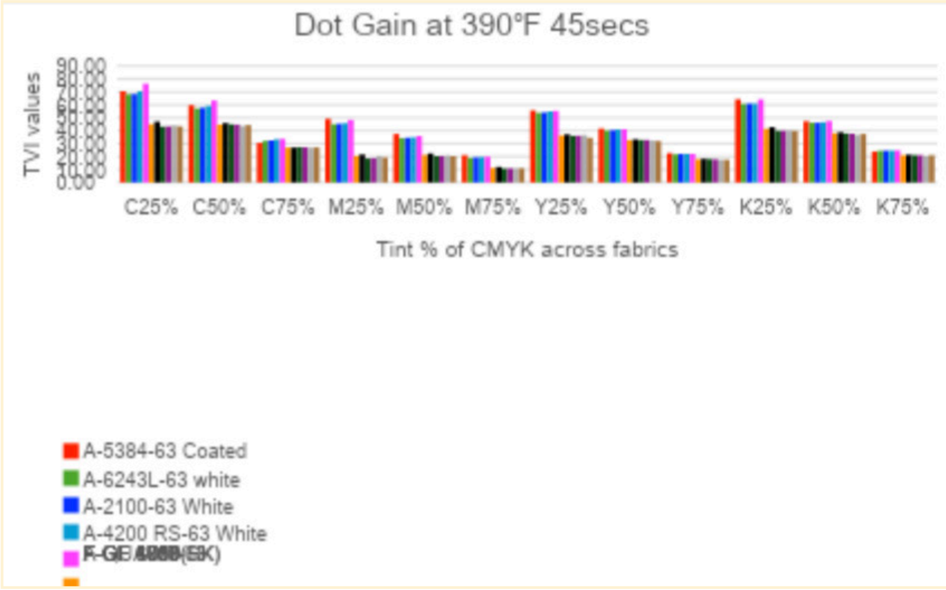


Figure 5.3.5 Dot Gain (TVI) Across Fabrics at 390˚F for 45 seconds

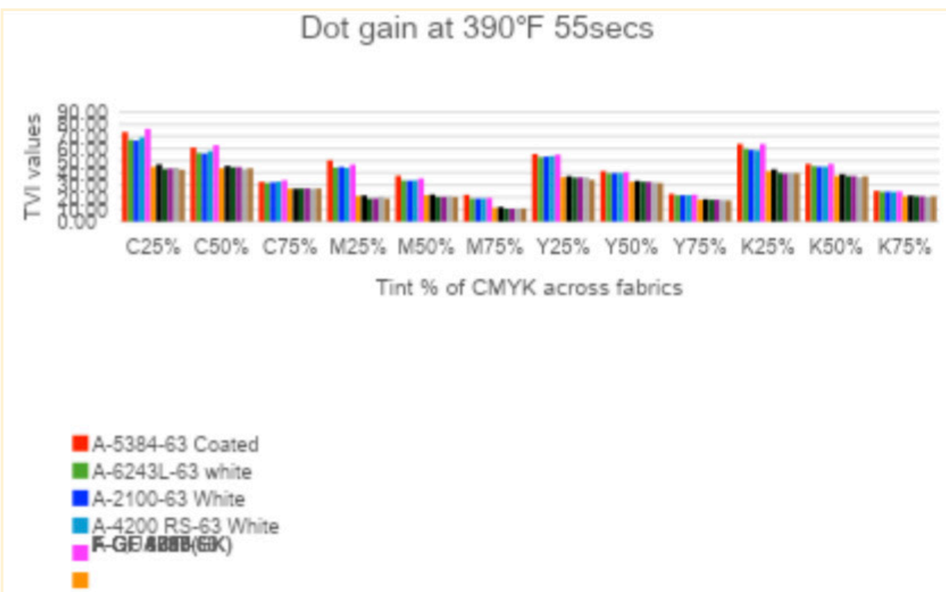


Figure 5.3.6 Dot Gain (TVI) Across Fabrics at 390˚F for 55 Seconds

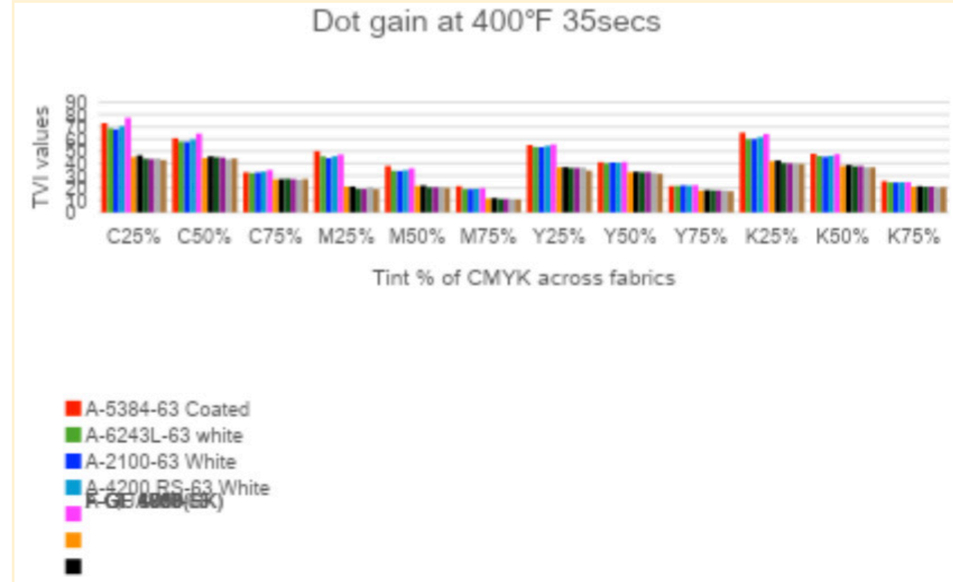


Figure 5.3.7 Dot Gain (TVI) Across Fabrics at 400˚F for 35 seconds

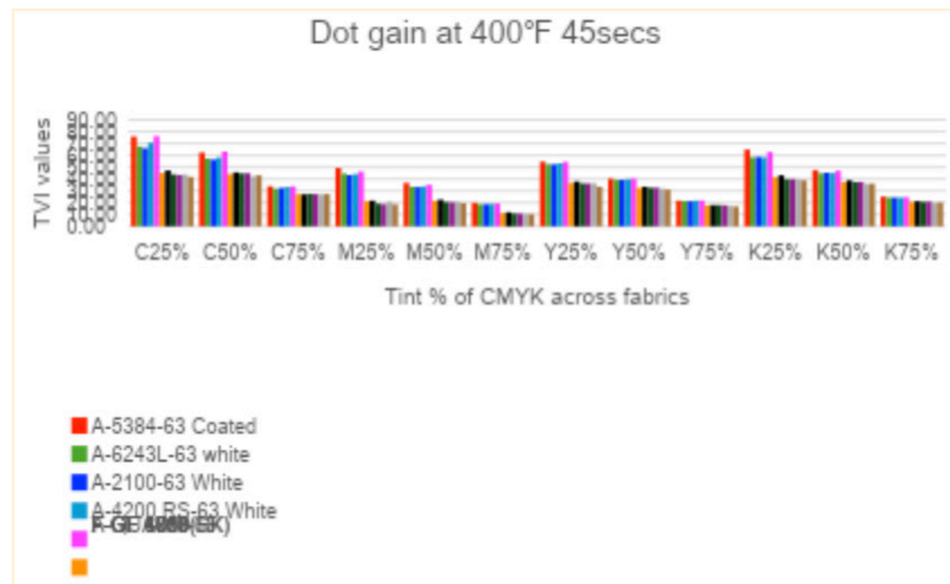


Figure 5.3.8 Dot Gain (TVI) Across Fabrics at 400˚F for 45 seconds

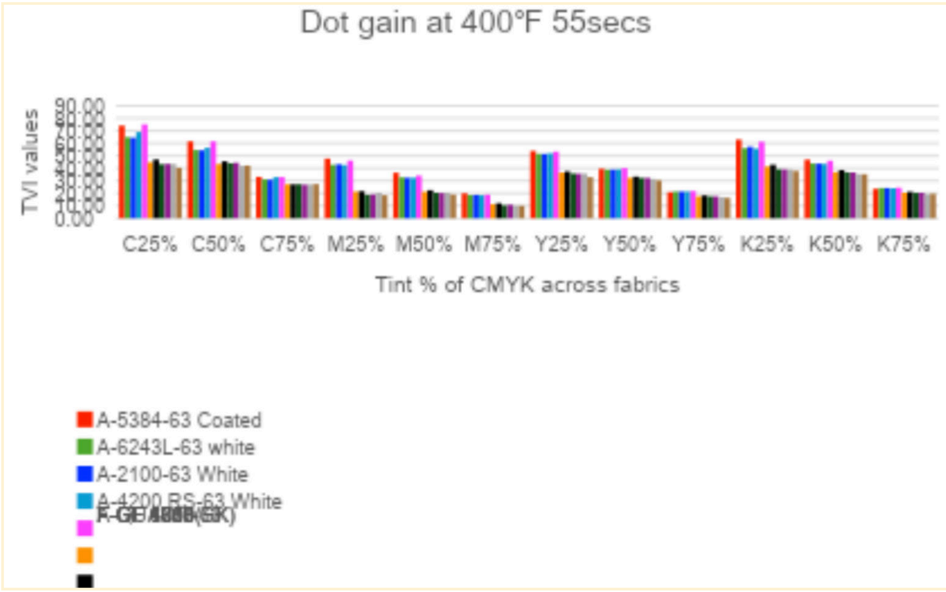


Figure 5.3.9 Dot Gain (TVI) Across Fabrics at 400˚F for 55 seconds

The analysis demonstrates the impact of temperature and dwell time on the quality of the print for the various synthetic fabrics. All of the above dot gain (TVI) Figures show a similar trend across temperatures – 380F,390F and 400F and dwell times – 35 seconds, 45 seconds and 55 seconds. The trend indicates consistent behavior within this specific range of conditions, and the dot gain is not significantly affected by temperature and time for these fabrics. Based on the data, the dot gain is higher at lower tint percentages – 25% across all fabrics and colors, indicating greater ink spread at lighter tones.

Regardless of the fabric, temperature and time setting, the dot gain values decrease gradually as the tint percentages increase to 50% and 75%, which indicates reduced ink spread. The Aberdeen 5384-63 coated and QUAD 7-63 fabrics consistently show the highest dot gain values across all colors, temperatures and dwell times, indicating more ink spread than other fabrics. The Fisher fabrics show relatively consistent dot gain trends, suggesting these fabrics perform similarly under different sublimation conditions.

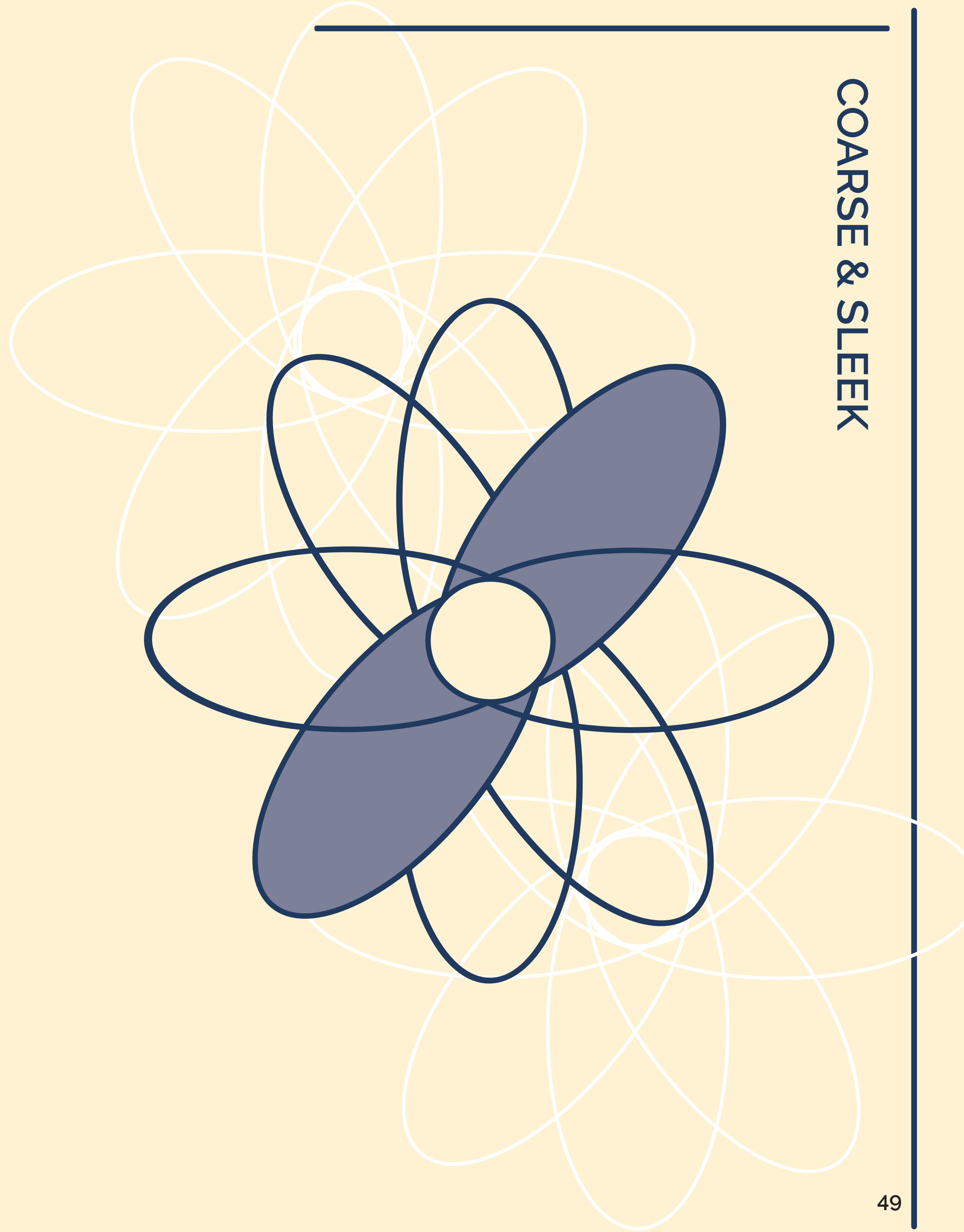
CONCLUSION

In conclusion, based on the collected and analyzed data, temperature and dwell time influence the color quality of the print. This study identifies a temperature of 380°F with a dwell time of 55 seconds, which consistently yields the lowest Delta E values, suggesting this is the best combination for color stability across most fabrics. Higher temperatures and shorter dwell times for some fabrics provide stable color results. However, extreme settings such as 400°F may result in increased Delta E values for some fabrics.

The research demonstrates that fabric also plays an important role, as the results vary based on the fabric type. The Aberdeen fabrics of the coated and backlit categories show more pronounced color shifts and dot gain, while Fisher fabrics maintain consistent and lower Delta E values, making them more suitable for reliable color reproduction. The highest dot gain occurs at lower (25%) tint patches and decreases at higher (50% and 75%) tint patches across all fabrics and colors, affecting clarity and color fidelity in prints.

In addition, the variation in the printer technology and ink type also influences the color accuracy. The findings from this research provide valuable insights into the textile print industry, supporting optimized temperature and dwell time settings, which enhance color accuracy and quality in sublimation printing. Furthermore, the fabric-specific response helps to emphasize the importance of precise settings and develop the quality control standards to ensure accurate, vibrant and consistent color reproduction across various synthetic fabrics as well as the overall color reliability in textile reproduction using sublimation printing. For further research, future studies could explore broader fabric testing by including different fabric blends to examine the adaptability of the fabric to dye sublimation printing. Environmental factors such as humidity, airflow and light exposure could provide insights into their influence on ink transfer, color reproduction and the dye sublimation process. In addition, using different printer technologies, ink formulation and heat presses with various pressure settings could provide more valuable insights into the textile printing industry, assessing the performance of the dye sublimation printing process.

TWO



1 LETTERPRESS
This printing technique is used to create tactile textures directly on paper, adding dimension.

2 EMBOSSING
This finishing technique adds texture and dimension to paper through raised patterns.

3 DEBOSSING
This finishing technique adds texture and dimension to paper through recessed patterns.

4 GRAVURE
This printing method, which uses engraved cylinders, can leave textured edges on printed paper and rough paper stocks.

High Material and Labor Costs.

Specialty textured papers are often more expensive than standard coated stock. Encorporating techniques like letterpress can add labor costs due to setup and handling.

CONS

- POTENTIAL FOR INCONSISTENCY - VARIATIONS IN TEXTURE
- LIMITED VERSATILITY - NOT FOR ALL DESIGN NEEDS
- NOT IDEAL FOR PRINTING FINE DETAILED IMAGES
- POSSIBLE RISK OF INK BLEEDING

WHY COARSE?

Tactile Quality
Coarse paper has a distinct, textured feel, which offers a satisfying tactile experience when touched.

Unique Aesthetic
The quality provides a classic, vintage feel with a touch of elegance. This makes coarse paper ideal for adding depth to printed materials, like business cards.

Higher Durability
Coarse texture is typically resistant to fading and smudging. Printing methods, like letterpress, can increase the paper's durability over time.

CONS

- MAY FEEL IMPERSONAL - DEPENDS ON BRAND'S GOALS
- NOT SUITABLE FOR TACTILE APPLICATIONS
- CHALLENGES IN READING & WRITING
- POTENTIAL FOR HIGHER COST

1 OFFSET
Offset printing most often uses sleek paper due to the high-quality ink transfer that can be achieved.

2 FLEXO
The smooth surface in flexographic print allows for high-resolution images and fine detailing to be reproduced.

3 DIGITAL INKJET
The sleek coating in digital inkjet helps control ink absorption and allows for more saturated color.

4 XEROGRAPHIC
In Xerographic printing, the sleek coating allows for optimal toner adhesion to ensure better print quality.

Moderate Production Costs.

Coated, or sleek, paper stocks are generally affordable. Depending on the print job and scale of print, these costs could rise. However, digital and offset printing processes are cost-effective.

WHY SLEEK?

High Quality Visuals
Printed images are produced with crisp, sharp details and vibrant colors. The smooth coating prevents the ink from bleeding.

Durability
Sleek coatings are resistant to dirt, moisture, and wear and tear, which makes the print and paper last longer.

Professional Finish
This finishing technique offers a glossy, sleek look which is ideal for marketing materials and high-impact publications.

COARSE & SLEEK

2

CHAPTER TWO

"A Case Study: Usability Testing of Mobile Application used in Academic Research" By Catlin Clark Wade

ABSTRACT

This study explores the critical role of user experience in shaping interactions with digital interfaces across devices and platforms. Notably, there needs to be more existing literature regarding the usability of tools employed in research investigations and studies. Researchers are often left to opt to use interfaces deemed satisfactory rather than striving for optimal usability. The primary objective of this study was to conduct a case analysis to investigate and evaluate the usability of a redesigned mobile application created for the data collection of a future research study. The study reveals an above-average System Usability Scale (SUS) score of 79.11, indicating that the redesigned mobile application has a high level of usability. Future research recommendations include recruiting the targeted demographic to validate user results.

INTRODUCTION

Digital technology is dynamically evolving and becoming increasingly integrated into the everyday lives of individuals across the globe. According to DataReportal (2023), over two-thirds of the world's population uses a mobile phone, with smartphones accounting for an estimated 84% of mobile phones used today. The total number of those users reached 5.60 billion in October of 2023.

With growing users, the user experience is becoming progressively critical in both digital and product design. User experience is a pivotal factor influencing how individuals interact with digital interfaces across devices and platforms. It is a fundamental and essential element in the design process, crucial for accommodating the increasing diversity of users and products. A product or application's success can hinge on its user-friendliness quality (Weichborth, 2020). For example, the Nielson Norman Group noted that users leave web pages within 10-20 seconds unless the page communicates a clear value proposition (Nielsen, 2011).

Likewise, despite having an average of 40 applications (apps) on their phones, mobile users only spend time on 18 of those applications (Kataria, 2021). Sometimes, a mobile application only remains on the phone for an average of 3-7 days (Chen). This emphasizes mobile applications' challenge to communicate a clear value proposition. User experience creates value (Mertz, 2022). Without value, products and applications are rendered ineffective. Therefore, problems still need to be solved, and goals still need to be accomplished.

Articulating the value of research study contribution to the public is often challenging across various fields. Complex research methods and lengthy questionnaires often discourage participation, which can be troublesome to find and maintain in the first place. Add a cumbersome experience throughout the data collection process; voluntary participation will 4 likely burn out. If users abandon a web page they searched for within 10-20 seconds, how much quicker will they abandon an online research questionnaire or study that lacks a user-friendly interface?

Unfortunately, literature on the usability of tools employed in research investigations and studies is absent. This gap could exist from the assumption that surveys and questionnaires are efficient in their design. Many researchers also prioritize the research rather than evaluating and analyzing if the tools they have created or utilized for data collection are accomplishing the intended goal. It is easy forresearchers to settle for interfaces that are good enough rather than interfaces that are the best they can be. That could be due to several factors, including time, resources, and access to experienced designers.

The primary objective of this study is to present a case analysis to investigate and evaluate the usability of a redesigned mobile application created for the data collection of a research study. Through a systematic investigation, this study seeks to identify and examine key usability factors associated with the mobile application's functionality and user-friendliness. The findings of this study contribute to enhancing the overall usability of the mobile application through its redesign. It also provides insights for optimizing the data collection process and advancing the quality and reliability of research methodologies that rely on advancing mobile technologies.

LITERATURE REVIEW

Useability

Researchers and practitioners often differ in their perspectives on a shared definition of usability. While practitioners typically concentrate on development tools and design processes to generate finalized products, researchers emphasize usability within the domains of methodology and theory. The disparity in priorities contributes to a need for more consensus for a unified definition of usability. Numerous usability guidelines and definitions have been published by organizations such as Apple, Microsoft, and Google to complicate matters more. Each one has its spin on best practices. To address the lack of consensus, researchers have sought to close the gap by identifying and analyzing 75 usability attributes and over 300 usability guidelines and definitions have been published by organizations such as Apple, Microsoft, and Google to complicate matters more. Each one has its spin on best practices. To address the lack of consensus, researchers have sought to close the gap by identifying and analyzing 75 usability attributes and over 300 usability guidelines (Ahmad et al., 2018; Weichbroth, 2020). This effort sought to pinpoint the most widely utilized and recognized practices.

Two standard definitions of usability have emerged over time and gained recognition in the field. The most frequently cited definition is provided by the International Organization for Standardization (Weichbroth, 2020). In 1998, ISO 9241-11 defined usability as "the extent to which specified users can use a product to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use." Effectiveness refers to how effectively users can precisely complete tasks. Efficiency refers to how conveniently a user can achieve the goal. Satisfaction is the sum of comfortability and positive emotions toward utilizing the product. In 2011, ISO/IEC 25010 revamped the definition. It specified usability as the "degree to which specified users can use a product or system to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use." The three attributes remained the same. Most researchers and practitioners have embraced the definition outlined in ISO 9241-11 since the definition was kept the same.

Jakob Nielsen is often referred to as the father or even the grandfather of usability. He defines usability using five components: learnability, efficiency, memorability, errors, and satisfaction (Nielsen, 2012). Learnability is how easily users can complete basic tasks when interacting with the design. Efficiency refers to how quickly users can complete the tasks. Memorability gauges how easily users can return to the design with proficiency. Errors refers to the number of errors users make, how severe those errors are, and how users can recover from those errors. Satisfaction measures the overall pleasantness experienced by users when they use the design. Nielsen defines usability as "a quality attribute that accesses how easy user interfaces are to use." He also states that utility is a critical attribute that helps determine whether or not a design is functional. His model suggests that usability and utility are of equal importance and aid in assessing the usefulness of a design.

Although less popular than the previous two, the PACMAD usability model offers additional insight into the definition of usability, specifically for mobile applications (Harrison et al., 2013). The model proposed that usability definitions and attributes have traditionally been based on desktop applications and telecom systems. Therefore, they sought to present a usability model highlighting mobile devices' unique characteristics. For example, mobile devices are often restricted by screen size and used in a nomadic context, with users spending an average of 4.8 hours a day on screen time (Zhang & Adipat, 2005; Wakefield, 2022). However, many of the original issues presented, such as connectivity, display resolution, and limited processing capabilities, are diminishing as mobile technology rapidly evolves with larger display sizes and 5G connectivity.

The PACMAD usability model established seven attributes, five overlapping with previous definitions. Effectiveness, efficiency, satisfaction, learnability, memorability, errors, and cognitive load exist. The model adopted corresponding definitions from ISO 9241-11 of effectiveness, efficiency, and satisfaction. The model also adopted learnability and memorability from Nielsen. However, it expanded upon his definition of errors. The model differs as it includes an assessment of errors made by users as they engage with mobile applications to prevent the errors from reoccurring. The fundamental contribution of the PACMAD model is the addition of cognitive load. Cognitive load "refers to the amount of cognitive processing required by the user to use the application." This contribution acknowledges the simultaneous execution of tasks that mobile users often perform. Mobile devices are unique in that they can be used in many environments and are often close to the hands of their users. To validate the addition of cognitive load into the usability model, they found that 26% of reviewed studies acknowledge cognitive load. However, most studies still focused on effectiveness, efficiency, and overall satisfaction.

Overall, ISO 9241-11 can be considered the most widely acknowledged definition, even though many individuals still argue that a universally recognized definition for usability remains evasive (Weichbroth, 2020; Lewis, 2014; Quiñones& Rusu, 2017). As technologyadvances and diverges, the debate will presumably remain complex and multifaceted. Based on this study's nature and testing methodology, the PACMAD usability model takes precedence, given its tailored distinction to mobile applications. By adopting this usability model, the study aims to evaluate a mobile application's distinct challenges and considerations.

User Experience

User Experience Design is an ever-involving concept and field beyond digital platforms and technology. The term was first coined in 1993 by Don Norman when he worked at Apple Computer. However, user experience concepts were utilized before the 1990s (Vinney, 2023). Throughout history, humans have sought ways to improve their experiences to accomplish goals and tasks efficiently. Examples include the inventions of Leonardo da Vinci, the technological advancements of Frederick Winslow Taylor and Henry Ford, and Henry Dreyfuss's study of cognitive science (Vinney, 2023). Jakob Nielsen suggests that Bell Labs was one of the first to significantly transition from traditional human factors to user experience, integrating psychology into the design of the touchstone keypad. The role of "user interface designer" and "human factors" specialists began to show up in the workforce around the 1980s (Mayhew, 2008). User experience (UX) proliferated from the 1980s to 1990s, driven by the PC and web revolutions. As technology evolved, pressure was applied to the computer and software industries to improve the experience of their products (Nielsen, 2017). Nielsen predicts that the field will continue to grow, suggesting there will be 100 million UX professionals by 2050 as UX drives value in the future worldwide economy.

User Experience is defined by ISO 9241-210 as "a person's perceptions and responses that result from the use or anticipated use of a product, system, or service." Therefore, user experience design is creating a product that provides users a meaningful and enjoyable experience. The Interaction Design Foundation states, "[It] involves the design of the entire process of acquiring and integrating the product, including aspects of branding, design, usability and function."

Design Principles

Experts have developed design principles to guide the design process. Once again, the Nielsen Norman Group provides a widely accepted definition of design principles. Design principles are "value statements that describe the most important goals that a product or service should deliver for users and are used to frame design decisions" (Rosala, 2020). In his book, "The Design of Everyday Things," Don Norman provides seven fundamental design principles based on human-centered design (HCD). HCD is an approach that puts the needs and behaviors of human beings first by designing in a way that accommodates those needs and behaviors (p. 8). HCD is different from user experience design in that it is the process of design rather than the area of focus (p. 9). Therefore, HCD informs UX design.

The seven design principles based on this process are signifiers, affordance, feedback, conceptual models, mapping, and constraints. Affordances relate to the relationship between an individual and a physical object, determining how the object could be used (p. 11). Signifiers are related to affordances, referring to any indicator that translates appropriate behavior to an individual (p. 14). Mapping refers to the relationship between "controls and their effect on the world" (Batterbee, 2020). For example, Norman suggests analyzing a car's steering wheel and how it controls the vehicle's direction. He highlights that comprehensive mapping makes the connection between a control and its results more convenient to learn (p. 22). Feedback is articulating informative results of a particular action (p. 23). Conceptual models describe how an object works (p. 25). Lastly, constraints guide actions and interpretations by restricting what occurs (p. 73).

Design Principles for Mobile Applications

Since Norman's design principles are based on general interaction design, design principles precisely for mobile applications were sought out to apply to this study due to crucial differences between mobile applications and other products. Mobile applications are software systems for mobile devices (Lim et al., 2021). They provide access to information anywhere or at any time and make users available to others. The iPhone influenced their popularity in 2007 as users could download various mobile applications and website usability, as expressed by Huang & Benyoucef (2022), are responsible design, flexibility, and system development patterns. As previously stated, mobile applications are also unique in their restrictions of small screen sizes and processing capabilities. This is why mobile application designs should not be purely transferred over from website design or go without consideration of the app's category. Recognized categories by practitioners and academics include health and fitness apps, lifestyle apps, productivity apps, education apps, tool-based apps, music and audio apps, news apps, business and commerce apps, entertainment apps, game apps, and social networking apps. Given the wide variety of mobile applications and their uses, narrowing down design principles can take time and effort. A range of guidelines and processes are available from companies, academics, and practitioners. For example, Google emphasizes animation, color, and accessibility, while Apple emphasizes integrated information, aesthetics, and interaction support (Apple, 2023; Google, 2020; Google, 2014).

Ji et al. (2006) sought to narrow down mobile application usability design to five principles to create a usability checklist for user interface (UI). Those principles include user support, cognition support, interaction support, information support, and performance support. User support entails assisting users who encounter issues due to software defects or limited familiarity (Huang & Benyoucef, 2022). Cognition is guidance a software system offers users in their cognitive processes. Consistent design themes are a vital component that reduces cognitiveload. Interaction support refers to the engagement between users and mobile applications. It encompasses design aesthetics, simplicity, and content distribution. Information support involves the qualities of mobile applications' information presentation. It helps prevent errors and allows easy information input. Performance support involves the facilitation of task execution taken on by a user within a mobile application. It is directly related to efficiency, effectiveness, and satisfaction.

Inclusive Design, Universal Design, and Accessibility

The World Health Organization estimates that 1.3 billion people experience substantial disability. That is every 1 in 6 individuals, making up a large percentage of the world's population. Inclusive design should have always been inherently present. However, in recent years, social movements and disability advocacy have shed light on the need to enhance the digital experience of all users. It provides opportunities for enhanced innovation, social responsibility and universal access to applications and software. Accessibility laws and standards such as WCAG 2 also call for a higher standard of equity and ethical practices. Though separate, inclusive design, universal design, and accessibility are uniquely intertwined. When adopted correctly, these principles lower the exclusion of users, which can result in higher user satisfaction and engagement. However, implementing these principles can be complex and not easily accomplished (Zaina et al., 2022). That is why there is a need for user research throughout the development process and accessibility guidelines (Ahmad et al., 2021; Iancu & Iancu, 2019). The targeted goal is to minimize barriers (Pervall, 2022).

Accessibility is centered on guaranteeing that technology is available and usable by those with disabilities. The ISO/IEC 25010 (2011) defines accessibility as the extent to which a product or system can accommodate the achievement of a goal by individuals with diverse features and capabilities and considers it to be a sub-characteristic of usability. The Web Content Accessibility Guidelines 2.2 offers guidelines for optimizing web accessibility (W3C, 2023). However, it can be applied to mobile applications as well. Zaina et al. (2022) identified accessibility barriers and generated accessibility guidelines for mobile applications to address user interface design patterns. Accessibility is an essential part of both universal and inclusive design practices.

The British Standards Institute defines inclusive design as "the design of mainstream products and services accessible to, and usable by, as many people as reasonably possible... without the need for special adaptation or specialized design" (Mustaquim, 2015). Inclusive design aims to provide products that enable users of all backgrounds and abilities (Joyce, 2022). Microsoft offers three fundamental inclusive design principles. hey advise practitioners to learn from diversity, "solve for one, extend to many," and recognize exclusion (Microsoft, 2015). Other inclusive design principles have been created by Henny Swan, Ian Pouncey, Heydon Pickering, and Leonie WatsonThey urge practitioners to provide comparable experiences, be consistent, consider situations, offer choice, give control, add value, and prioritize content.

Universal design creates environments and products that can be utilized, comprehended, and experienced in the best possible way without additional adaptations or specialized situations (CEUD, 2023; Story, 1998). It intends to be usable by anyone, regardless of age, size, mental or physical capacities. Molly Story (1998) suggests that good universal design features should go unnoticed. To be successful, universal design relies on several principles (Mustaquim, 2015). First, equitable use ensures that a design does not exclude members of any group. Secondly, there must be flexibility in using the design to offer users personal choices. Designs should also be simple to use so that users without experience or knowledge can easily understand and use the product. It must also provide perceptible information that communicates the appropriate information clearly to users. Universal design must maintain a tolerance for error that minimizes the effects of accidental actions. Lastly, it must also allow low physical effort and enough size and space for the application's use.

Informed Design Choices

The design principal exploration aimed to integrate these principles into the mobile application design process to guide the configuration choices. Considerations such as age-related accessibility and colorblindness were of particularconcern for prospective study participants. Beyond this immediate study, the redesigned mobile application will be used for participants aged 40+. Older adults' intention to use smartphone technologies is influenced by perceived usefulness and ease of use (Ma et al., 2016). Iancu & Iancu (2019) also noted that older adults would utilize technology if it were "easier to use, more user-friendly, and more adequate for the needs of an older adult." The intent is that the redesigned mobile app will encourage participant engagement. Research has also shown that attractive things work better and appeal to emotional responses and cognitive perception (Lim, 2014). For these reasons, the redesign sought to increase the mobile application's usability and attractiveness, aligning with the mentioned guidelines and principles. Specific design solutions included large typography, design simplicity, color choice, menu design, slider usage, and icon choice. The subsequent section below provides 12 specific examples of the implemented design changes.

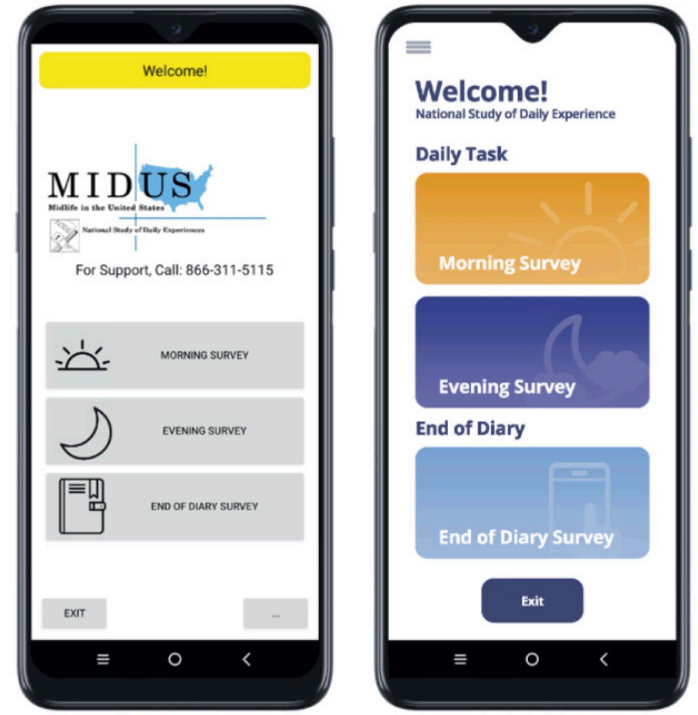


Figure 1. Example comparison of previous (left) and new (right) app homepage.

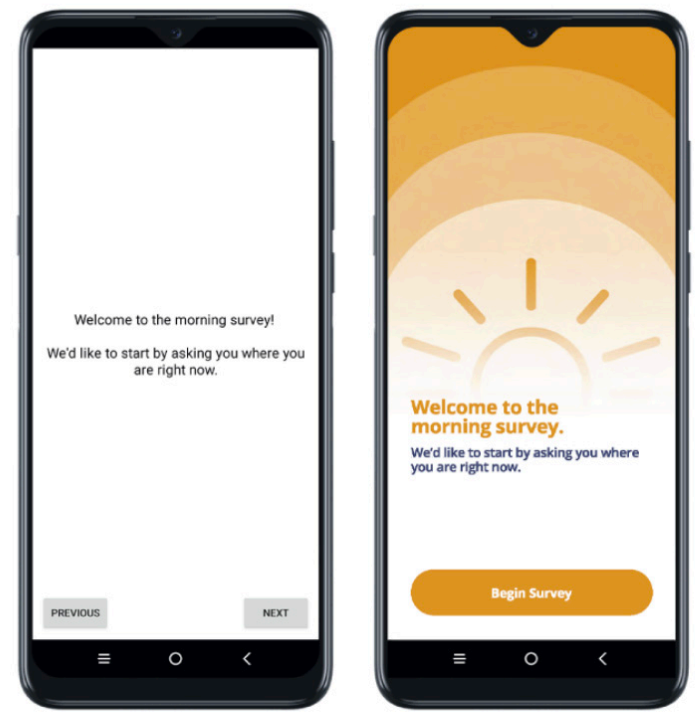


Figure 2. Example comparison of previous (left) and new (right) app survey landing page.

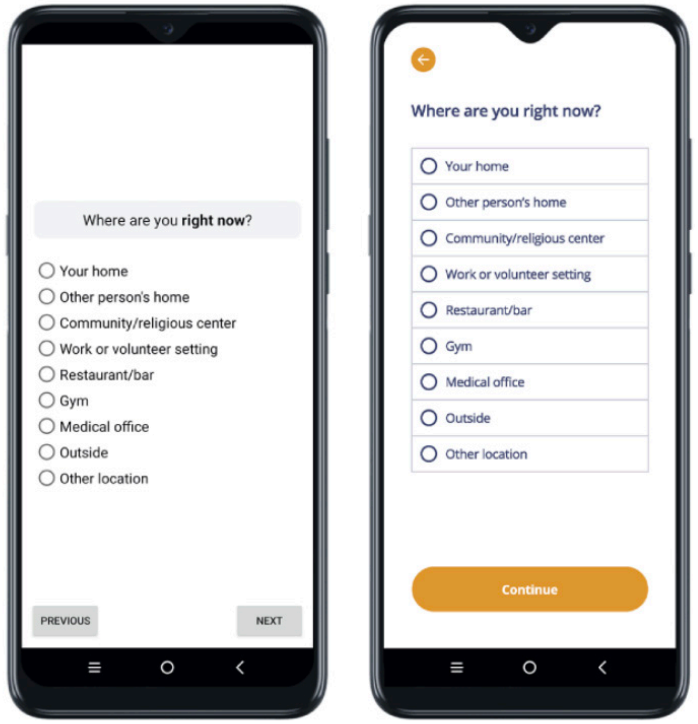


Figure 3. Example comparison of previous (left) and new (right) app ratio question.

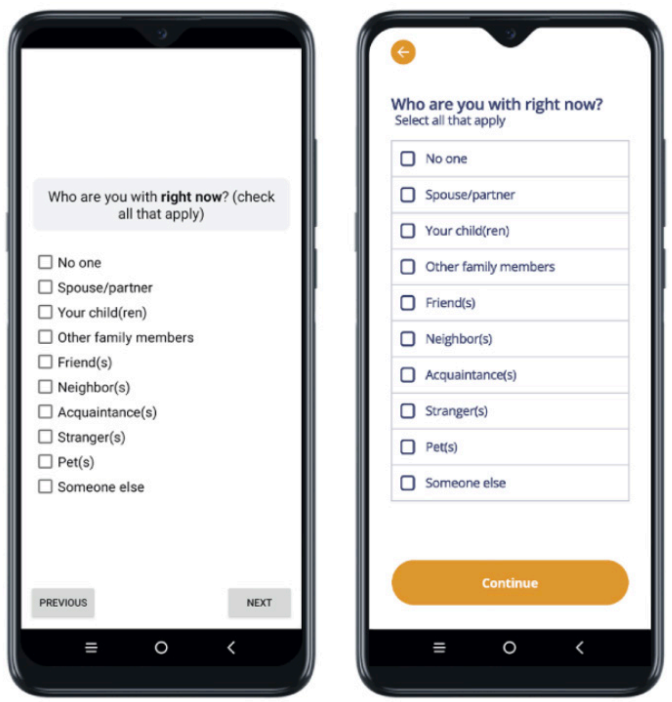


Figure 4. Example comparison of previous (left) and new (right) app multiple selection question.

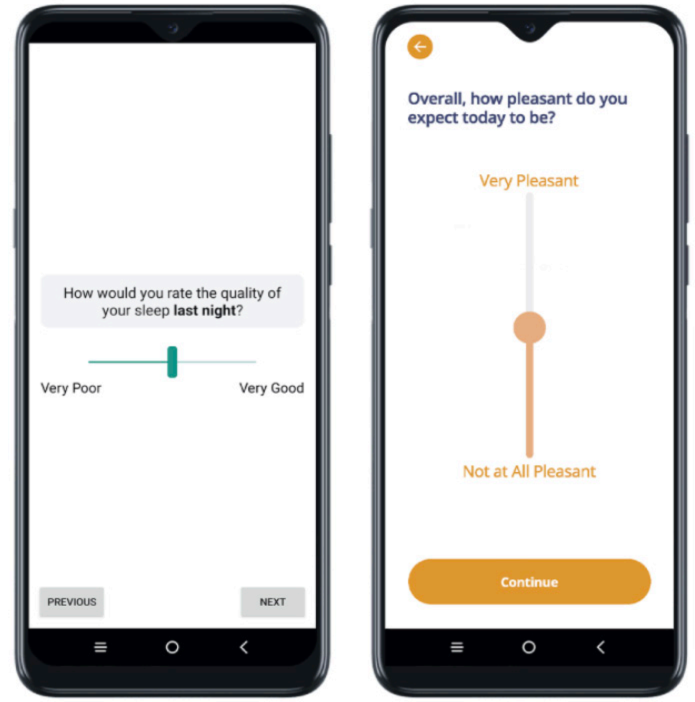


Figure 5. Example comparison of previous (left) and new (right) app slider question.

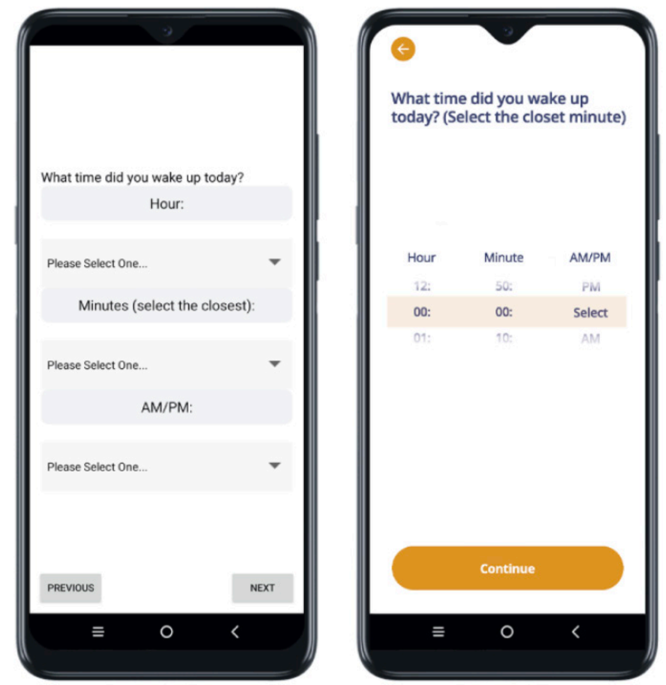


Figure 6. Example comparison of previous (left) and new (right) app time question selection.

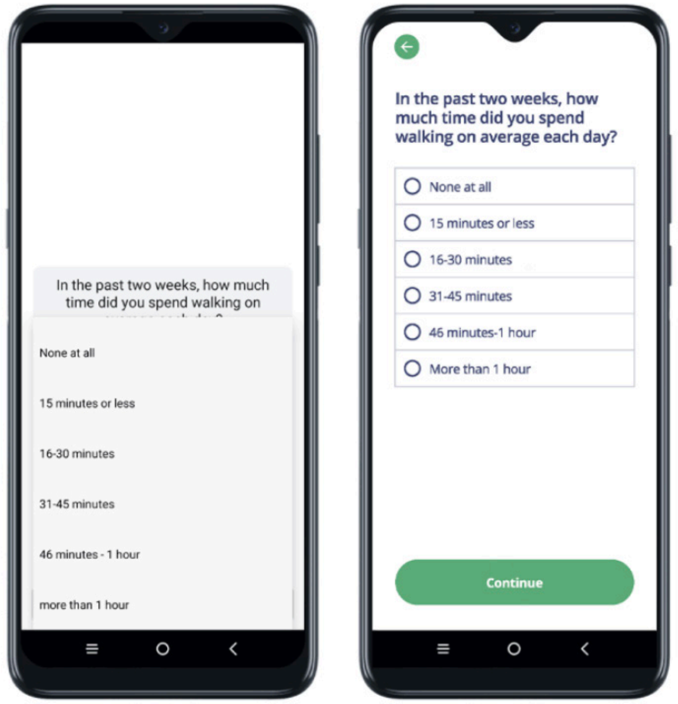


Figure 7. Example comparison of previous (left) and new (right) app question reconfiguration.

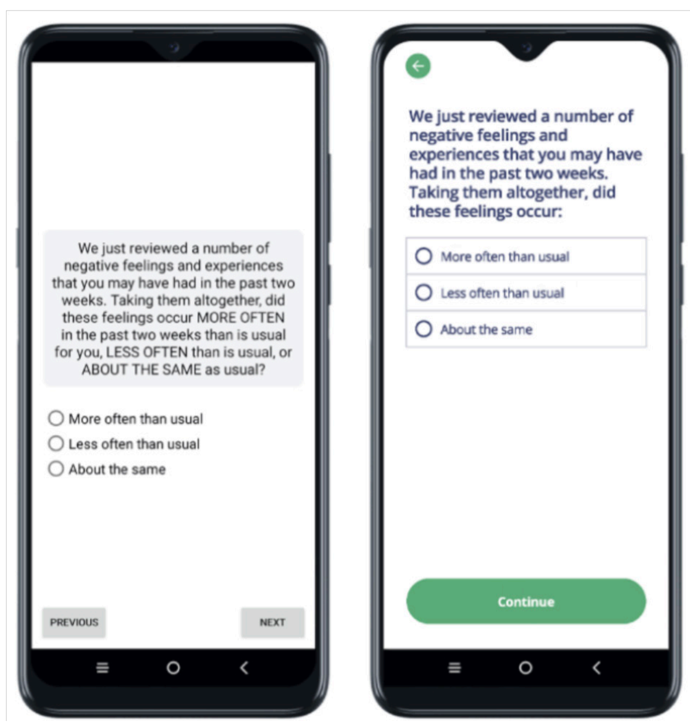


Figure 8. Example comparison of previous (left) and new (right) length text adjustments.

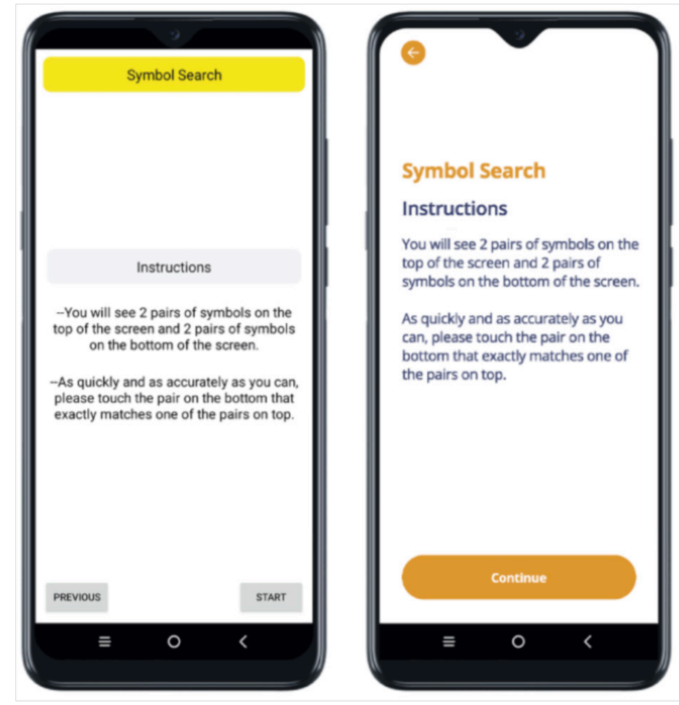


Figure 9. Example comparison of previous (left) and new (right) game instructions.

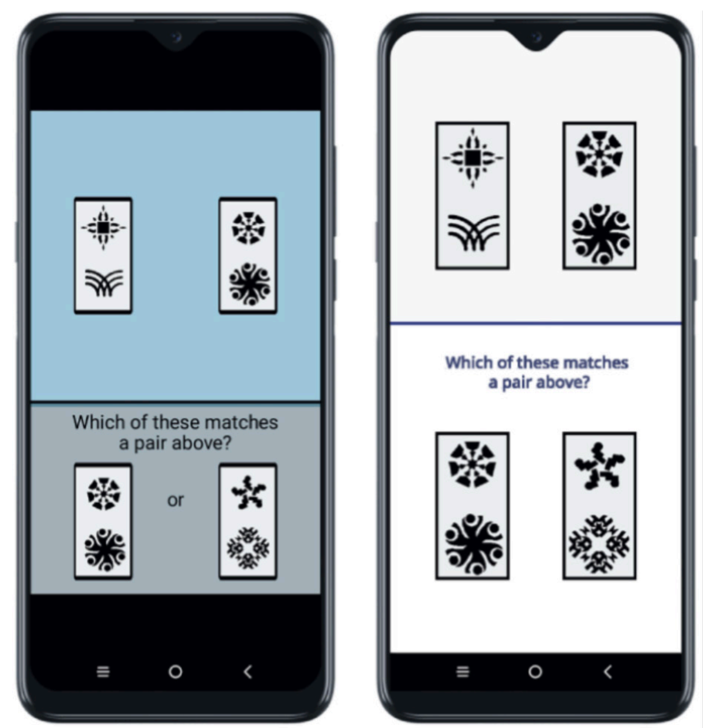


Figure 10. Example comparison of previous (left) and new (right) game launch.

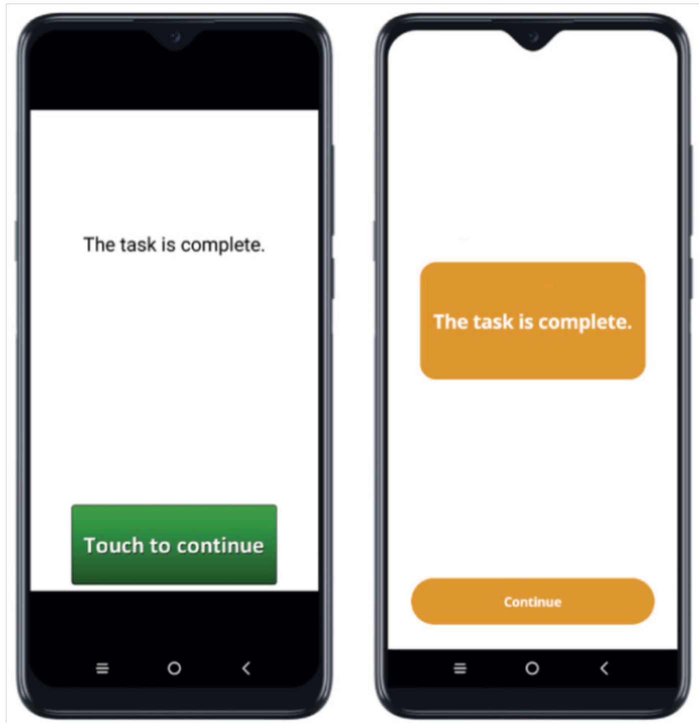


Figure 11. Example comparison of previous (left) and new (right) completion notice.

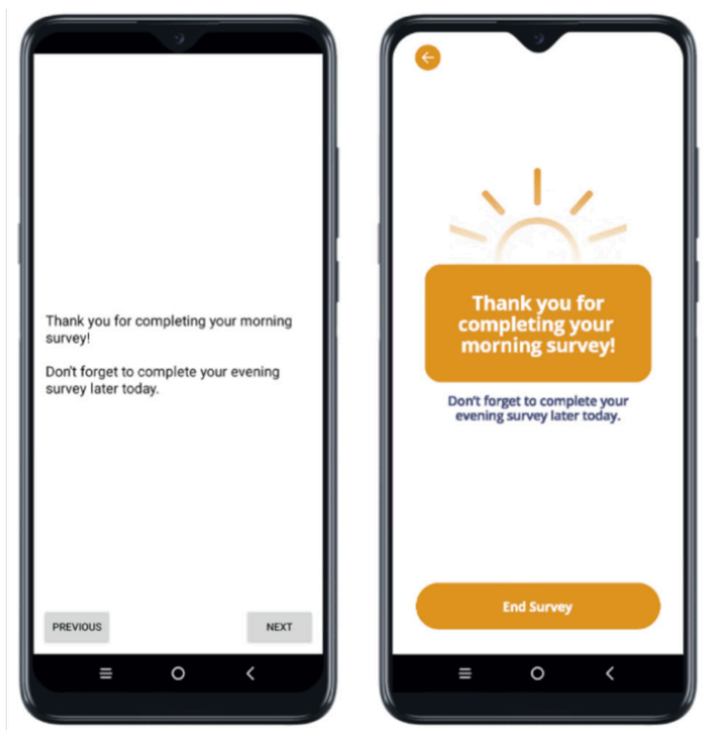


Figure 12. Example comparison of previous (left) and new (right) survey end.

METHODS

Participants were equipped with a TCL 20 SE mobile device and provided access to a prototype of the redesigned mobile application. The primary objective was to evaluate the functionality and usability of the app. Participants were asked to engage with the mobile application by navigating the main features, which include a morning journal, an evening journal, and an end-of-study journal. The morning and evening journal sections were designed to ask participants questions about their daily experiences. The application also incorporated three short games to assess cognitive functioning, specifically at the end of the morning and evening journals.

It is critical to note that the prototype and mobile device did not actively collect participant data. The primary focus of this study was not to gather responses from the games or journals but to gather insight into the usability of the mobile application itself. By excluding the data collection of those features, this methodology focused on evaluating the mobile application's inherent usability and functionality. This allowed the study to remain concentrated on the application's interface without addressing the outcomes of the responses to the journals and games.

After participants navigated the prototype, they completed a digital survey based on the System Usability Scale (SUS), a 10-item Likert scale used to assess the usability of systems and applications (Brooke, 1996). The range goes from "I strongly agree" to "I strongly disagree."

The responses were converted to numbers, calculated, and interpreted at the end of the study. A final score above 70 is considered "good" usability, while scores below 50 are considered "bad" usability (Bangor et al., 2008). Multiple studies have indicated that SUS is reliable (Grier et al., 2013; Borsci et al., 2009; Bangor et al., 2008). It can be used for evaluating various products and is reliable with various sample sizes (Albert et al., 2010; Vlachogianni & Tselios, 2022). The post-survey survey was as follows:

1. I think that I would like to use this system frequently.

2. I found the system unnecessarily complex.

3. I thought the system was easy to use.

4. I think that I would need the support of a technical person to be able to use this system.

5. I found that the various functions in this system were well integrated.

6. I thought there was too much inconsistency in this system.

7. I imagine most people would learn to use this system very quickly.

8. I found the system very cumbersome to use.

9. I felt very confident using the system.

10. I needed to learn a lot of things before I could get going with this system.

A total of 28 responses were collected. Participants were not asked for demographic information. However, only undergraduate students were recruited. Students earned 2 SONA credits by participating in this research study through the Clemson Psychology Research System SONA. Every 15 minutes of participation was worth 1 SONA credit. SONA credits can be applied to earn extra credit points in coursework. Partial credit was not offered.

RESULTS

Table 1 displays the final system usability scale survey results. All participants completed the survey, allowing a 100% completion rate. Participants were allocated 30 minutes to navigate the mobile application and complete the survey.

Table 2 shows the final System Usability Scale (SUS) score of each individual response. SUS assesses the perceived usability of a system. The evaluation sheds light on the user experience, considering factors such as the application's effectiveness, efficiency, and the user's overall satisfaction. The SUS was calculated by finding the score contribution of each item. For odd-numbered items, the score contribution is found by subtracting one from the scale position. The score contribution is found for even-numbered items by subtracting the scale position from 5. The sum of the scores is multiplied by 2.5 to obtain the overall usability score. The highest SUS score was 97.5, and the lowest SUS score was 47.5, with a range of 50. However, the lowest score can be considered an outliner because it falls below the lower bound, as determined by the IQR method.

Response	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Response 1	4	1	5	1	5	1	5	4	5	1
Response 2	4	1	5	1	5	1	5	2	5	1
Response 3	4	1	5	1	3	3	5	1	3	1
Response 4	2	2	4	1	4	2	5	1	5	1
Response 5	3	1	5	1	4	2	5	3	5	1
Response 6	2	1	5	1	4	2	5	3	5	1
Response 7	2	1	5	1	2	2	5	1	3	1
Response 8	3	1	5	1	5	2	5	3	5	1
Response 9	2	1	5	1	4	1	5	3	5	1
Response 10	2	2	5	1	4	2	5	2	5	1
Response 11	4	2	4	1	5	5	5	2	5	1
Response 12	2	3	5	1	4	2	4	3	5	1
Response 13	5	1	5	1	5	1	5	3	5	3
Response 14	4	2	4	2	5	2	5	1	5	1
Response 15	2	1	5	1	4	2	5	1	5	1
Response 16	4	2	4	2	4	4	5	2	5	1
Response 17	3	1	4	3	4	2	5	2	4	1
Response 18	2	4	2	2	3	4	4	2	3	3
Response19	3	1	3	3	3	3	3	3	3	3
Response 20	2	4	4	1	3	3	4	4	4	2
Response 21	4	1	5	1	5	1	5	1	5	1
Response 22	3	3	5	1	4	1	5	2	5	1
Response 23	3	2	4	1	4	3	4	3	4	1
Response 24	4	1	5	1	5	1	5	3	5	1
Response 25	4	1	5	1	4	2	4	3	4	1
Response 26	4	3	4	1	5	1	5	5	4	1
Response 27	1	3	5	1	3	1	5	4	4	1
Response 28	2	1	5	1	4	1	5	3	5	1

Table 1. Results of System Usability Scale Questionnaire

Response	Sum	SUS Score	Response	Sum	SUS Score
Response 1	36	90	Response 15	35	87.5
Response 2	38	95	Response 16	31	77.5
Response 3	35	87.5	Response 17	32	77.5
Response 4	33	82.5	Response 18	19	47.5
Response 5	29	72.5	Response 19	22	55
Response 6	33	82.5	Response 20	23	57.5
Response 7	31	77.5	Response 21	39	97.5
Response 8	35	87.5	Response 22	24	60
Response 9	34	85	Response 23	29	72.5
Response 10	33	82.5	Response 24	37	92.5
Response 11	32	80	Response 25	33	82.5
Response 12	30	75	Response 26	31	77.5
Response 13	36	90	Response 27	28	70
Response 14	35	87.5	Response 28	34	85

Table 2. System Usability Scale

The total average of the collected usability scores was 79.11, with a medium score of 82.5 (SD = 10.59). The mode was 77.5, 82.5, and 87.5, as each score was repeated four times. A higher SUS score indicates that a product or system is more user-friendly, with a score of 85 or higher indicating exceptional usability and a score below 70 indicating unacceptable usability (Grier et al., 2013; Borsci et al., 2009; Bangor et al., 2008; Schrepp et al., 2023).

DISCUSSION

Based on a study by Jeff Sauro (2011) of 500 articles, the average SUS of a product is 68. Therefore, the results indicate that the mobile application has an above-average usability score with opportunities for improvement.

This case study aimed to score the usability of a redesigned mobile application used in a research environment. This article adds to the validation of the SUS questionnaire, provides an example of practical application to usability principles, and provides insight into the broader implications for mobile application design. It also has a unique opportunity to contribute and demonstrate the relevance of usability testing for research methodologies involving extensive technology use. The usability of test methods in research settings must be addressed and can be attributed to a lack of awareness and resource limitations.

The redesign process was informed by fundamental principles and extensive guidelines proposed by Don Norman, Jakub Nielson, industry influencers, and the usability checklist proposed by Ji et al. (2006). Consideration was also devoted to accessibility and inclusive and universal design principles, especially given the future usage by an older demographic. The redesigned application was also evaluated by the primary researcher of the study in which it will be employed.

The mobile application was assessed by the Systems Usability Scale (SUS), which measures the perceived usability of a system. SUS captures insight into the user experience by evaluating the application's effectiveness, efficiency, and the user's overall satisfaction. The results of the case study indicated an above-average SUS score of 79.11. Avenues for refinement could include text-to-speech capabilities, additional instructions, and more accessible participant support.

Limitations of this case study include the need for more intensive and detailed user testing. A qualitative method could have been incorporated into the study to gain more insight into the user's thoughts and offer an opportunity to identify pain points and areas of frustration. Incorporation of an interview or open-ended survey questions would have allowed for discovering unanticipated insights, receiving immediate input on specific design elements, and perhaps offering richer insight into design considerations and potential changes.

For example, the design includes two different slider compositions. Based on the question, the slider is presented in two different ways. The first option begins with the slider signifier in the middle with no color fill in the scale spectrum. The color fill only appears as a user drags the signifier up or down. The secondary design also begins with the slider signifier in the middle. However, there is a color fill between the signifier and the minimum answer to indicate an increase or decrease of a particular feeling, thought or emotion as the user drags the slider up or down. This example demonstrates how there could have been an opportunity to investigate if the design change caused the users' confusion. The study also did not recruit participants of the targeted demographic due to time constraints and available resources.

In the future, a comparative analysis between the old and new designs would be appropriate and add significant insight into the critical use of design principles and guidelines. It would allow an opportunity to observe if the redesign increased the application's usability compared to the previous design. Participant engagement and research response influence could also be points of investigation. Preferably, future studies would also target the intended demographic.

USER EXPERIENCE

In conclusion, the rapid integration of digital technology into our daily lives and research emphasizes the importance of usability and user experience in digital and product design. The absence of literature on the usability of tools utilized in research investigations reflects a presumption that mobile surveys and questionnaires are inherently efficient in their design. This could apply to other forms of digital research tools as well. Through a systematic examination, this study contributes a practical example of user experience design application in digital research tools.

This study identified fundamental design principles and guidelines for enhancing the mobile application's functionality and user-friendliness. These principles informed the redesign of the mobile application. Through usability testing, the application was found to have an above-average systems usability scale score of 79.11 indicating an appropriate usability level to move forward with development. However, additional usability testing should be conducted to find opportunities for additional enhancements, to identify user pain points, and to determine unforeseen findings.

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THREE

ENGRAVING & EMBOSSING

1
MAKE PLATE
Design is created digitally and sent to the engraving machine. The metal plate is then polsihed to prep for print.

2
ENGRAVE
The machine carves the design into the metal plate, creating grooves of varying depths depending on tonal values.

3
INKING
Ink is applied to the plate, filling the engraved grooves. The excess is carefully removed.

4
PRINT
The inked plate is placed into the printing press and pressed aganist the substrate, transferring the image.

Can be Costly to Produce.

The process of engraving paper can be expensive, since the cost is based on the time it takes to produce. It can be charged by the minute, per square inch, or per character.

CONS

- LIMITED COLOR CHOICES - EACH REQUIRES SEPERATE PLATE
- HIGH SETUP COST - DUE TO SPECIALIZED EQUIPMENT
- NOT IDEAL FOR COMPLEX OR HIGH-VOLUME PROJECTS
- LABOR INTENSIVE PROCESS

WHY ENGRAVE?

High Quality Print
Since the laser engraver removes material from the paper, a higer quality result can be acheived. The raising of ink adds texture to the print.

Vivid Coloration
Due to the thick application, ink colors are vibrant and ideal for high-end applications. It is ideal when printing detailed images and fines lines.

Higher Durability
Engraving on paper is resistant to fading and smudging, offering durability over time.

CONS

- LIMITED COLOR CONTRAST - UNLESS PAIRED WITH INKS
- HIGH SETUP COSTS - DUE TO CUSTOM DIE CREATION
- NOT IDEAL FOR PRINTING FINE DETAILS
- LOSES DURABLITY OVER TIME

1
CREATE DIE
A custom die is created to match the desired pattern or design. Multiple dies can be made depending on the design.

2
INSTALL
The die is placed into the embossing machine, followed by the substrate. Markers are added to ensure alignment.

3
FORM
The press is run, and the die is brought together to the substrate with immense pressure.

4
OBSERVE
The substrate conforms to the shape of the die under the pressure and heat from the press, and the raised design is created.

High Production Cost.

The setup cost for embossing is high due to the need for custom dies for each design. However, this process is less costly when comparing to engraving in high volumes.

WHY EMBOSS?

Unique Apperance
Embossing adds a unique, tactile element to any print. It enhances visual intrest through personalized elements and can be highly effective on business cards.

Versatility
This process works well on various types of materials, inclduing paper, cardstock, and foil, and does not require the use of ink.

Sustainable
This finishing technique is a sustainable option, as it doesn't typically require additional materials or resources in print.

ENGRAVING & EMBOSSING

3

CHAPTER THREE

"The Impact of the Graphic Communications and Outreach" By Riley deKrafft

ABSTRACT

The present study evaluates the impact of Clemson Graphic Communication's Outreach and Recruitment program on high school students' perceptions of the major and their college and post-college opportunities. Through surveys and events sponsored by Outreach, the research aims to determine the overall influence of the GC program. Participating students, accompanied by their instructor and guardians, will visit Godfrey Hall, Clemson University's Graphic Communications building. Before the trip, students must complete a comprehensive survey gauging their understanding of the Graphic Communications program and its industry. During the visit, students will engage in rotational activities to experience the daily practices of Graphic Communications students. A panel discussion will allow students to pose questions to current Graphic Communications students about the program and broader college life. After the trip, students will participate in a post-event survey to assess how the experience enriched their knowledge of the program and the graphics industry. The findings from this study suggest that the Outreach event played a valuable role in enhancing participants' understanding of Graphic Communications, broadening their awareness of its applications and career opportunities, and stimulating interest in pursuing a career in the field. These insights can inform future outreach efforts and curriculum development strategies to engage students better and promote awareness of Graphic Communications as a viable career path.

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continuously listened to my frustrations and prevented me from spiraling throughout this endeavor. Their unwavering support, advice, and encouragement—whether related to my thesis, coursework, or personal life—have been invaluable throughout my years in graduate school. I genuinely believe I would not have reached the finish line without their assistance.

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INTRODUCTION

The present study investigates the impact of the Graphic Communications Outreach and Recruitment Program on the Clemson Graphic Communications identity. The research done in this study determines whether Clemson Graphic Communication's Outreach and Recruitment program has an impact on high school students' perspectives on the major, as well as their opportunities during and after college, and the overall GC program through surveys and Outreach sponsored events. The student participants embark on an educational excursion accompanied by their instructor and any accompanying guardians to Godfrey Hall, the building dedicated to Graphic Communications at Clemson University. Before the field trip, students must complete a comprehensive survey to assess their understanding of the Graphic Communications program and its associated industry. Once at Clemson University, the students will be afforded the unique opportunity to engage in a series of rotational activities, affording them firsthand exposure to the daily laboratory practices of Graphic Communications students. The high school students will go through four rotations, where hand-selected Graphic Communications students will educate them in areas of Flexography, Offset Lithography, Dye-Sublimation, and Screen Printing. High school students can produce thwe same projects as our Graphic Communications students in a classroom setting. Students will learn how stickers, notepads, air fresheners or magnets, and pennants are produced through the print process in the rotations. A panel discussion will also be conducted, granting the students the chance to pose inquiries to current Graphic Communications students, encompassing queries about the program or broader aspects of college life. Graphic Communications students will discuss markets and careers within the graphics industry, courses in the curriculum, and popular minors associated with the major. Following the field trip, students will be expected to partake in a post-event survey to evaluate how much the experience enriched their knowledge of the program and the graphics industry.

LITERATURE REVIEW

Graphic Communications Background

The expansive reach of the graphic communications industry significantly impacts the daily lives of most individuals. Its influence extends to a wide array of products, ranging from computers and medical supplies to business cards and billboards, packaging, photographs, and even the design on a car's dashboard or a t-shirt. (Smith, 2014). Graphic Communications, as its name suggests, is the act of conveying messages through visual elements. These elements include symbols like glyphs and icons and visual components such as drawings and photographs. The contextual impact of substrate, color, and surroundings may also play a role. This process involves creating, producing, and distributing content that blends words and images to express information, ideas, and emotions. The graphic communications industry differs from the graphic design industry; graphic design focuses on the creative design process, whereas graphic communications focuses on producing and delivering graphic products and messages (Luttropp & Greenwald, 2009). The field of graphic communications covers every stage of each process. It starts with the conception of an idea involving design, layout, and typography. It continues through reproduction, finishing, and the distribution of two- or three-dimensional products or electronic transmission.

Clemson University Department of Graphic Communication

The Clemson University Graphic Communications Bachelor of Science degree equips students for professional roles in printing, publishing, packaging graphics, digital media, content creation, and the broader communication industry. The comprehensive curriculum adopts a holistic approach, guiding students from creative conception to realization. The program allows students to develop academically and professionally by covering all significant printing and visual communication processes. This journey includes two internships, offering invaluable real- world experience and thorough career preparation (Welcome to the Department of Graphic Communications, n.d.).

Clemson University Outreach and Recruitment Program

The Clemson Outreach and Recruitment class was started in Fall 2018 by Michelle Fox and consists of a dedicated group of students enthusiastic about offering K-12 students an immersive glimpse into life as a Graphic Communications student at Clemson University. These students actively engage with the local community by participating in different events. The goal of the Outreach and Recruitment Program is to spread awareness and clear up misconceptions about the industry.

Outreach attends events such as elementary and middle school activity nights and STEM, science, technology, engineering, and math nights. STEM nights, for instance, provide opportunities for students and families to engage in hands-on science, math, and engineering activities, showcasing various STEM topics and connections to exciting career paths in STEM fields. During these events, typically, outreach students teach screen printing or ink testing because it can be easily explained to them.

Selected Outreach students also have the chance to visit high schools to address misconceptions about graphic communications and raise awareness of our program at Clemson University among students, teachers, and guidance counselors. When they visit these high school career centers, the students have a panel discussion with the students, discussing relative topics and answering any questions they may be asked. The Clemson students also showcase materials, including items created to promote the Outreach Program or completed class projects. This gives high school students insights into the opportunities awaiting them if they pursue further education. While the students engage in discussions, Clemson instructors have the chance to provide additional training to other teachers on equipment they may require to enhance their expertise.

Additionally, high school students are invited to Godfrey Hall to experience a typical day as a Graphic Communications student, participating in rotations and gaining insight into laboratory activities relevant to the major. They will also have the opportunity to interact with current Graphic Communications students, posing questions about courses, college life, and any other inquiries they may have. The Outreach event focused on demonstrating four different printing processes – screen printing, flexography, offset lithography, and dye sublimation. These processes chosen for the rotations aimed to give students a general idea of what their time would look like going through the graphic communications program. The goal was to demonstrate what approximately, each year of their college career would look like. Dye sublimation and screen printing are typically learned during a student's freshman or sophomore year. The basics of flexography are also learned during this time but are focused on heavily throughout one's junior or senior year, along with offset lithography.

Screen Printing

Screen printing is a process that involves the application of ink through a mesh screen onto a substrate (Screenprint, 2018). A stencil is created by rendering specific screen areas impermeable to ink, allowing ink to pass through only in those areas, forming the desired printed image (Screenprint, 2018). The screen has a fine mesh fabric tightly stretched over a metal or wooden frame. Stencils can be composed of and applied to the screen in many ways. However, in Godfrey, the design is created using Adobe Illustrator, and the file is taken through steps to ensure it is in the correct format to export to the Kodak Trendsetter, which prints the film used for the stencil. The screen must be prepared using a scoop coater to apply layers of photo- sensitive emulsion before the stencil can be applied to the screen. After the screen has dried, the film is

positioned on the screen, and it is then placed in the Lawson LED-5000 exposure unit. The exposure unit emits ultraviolet light that hardens the emulsion around the image. The emulsion covered by the design remains soft and is washed out using water, leaving the design on the screen (Screenprint, 2018). Once the screen has dried from washout, Quik-Dry water removable block-out is applied to cover any imperfections on the screen where one may not want the ink to come through. Once the screen has been prepared, it is placed on the carousel press, which has hinges to hold the screen in place. Ink is then applied along the top of the screen and pulled evenly across the screen using a squeegee to push the ink through the screen onto the substrate (Screenprint, 2018).

Flexography

Flexography is a versatile printing process that is capable of printing on various materials and sizes. It encompasses printing everyday items we encounter, such as cereal boxes, bottle labels, potato chip bags, frozen food bags, newspapers, and so much more (ETools: Printing Industry – Flexography, n.d.). The flexographic printing process operates similarly to a rubber stamp and ink pad but is more advanced and conducted on a larger scale. A soft, flexible photopolymer printing plate goes through the plate-making process, including exposure, imaging, and processing. The plate first goes through back exposure, which hardens the back of the plate to create a strong foundation. The plate is then placed in the imager, and a laser transfers an image onto the plate. The plate is then put back in the exposure unit to harden the face of the plate. The plate will then be moved to the processor, where layers of the plate are burned away to create a three-dimensional raised mirror image of the design. In the final preparation of the plate, it will be placed back in the exposure unit for a last round of hardening. Each plate represents an individual color to be printed so that each plate will be trimmed and mounted on a plate cylinder. Stations for each color are assembled on the Comco Captain flexographic press, where the ink will be transferred from the rubber roller to the anilox roll and then to the plate and substrate.

Offset Lithography

Offset lithography, also known as offset printing, is a printing method based on the repulsion of oil and water (Offset Lithography, n.d.). This process involves transferring ink from a plate to a rubber blanket, which then transfers the ink onto various substrates to create high- quality images and designs, often used for mass production. Offset lithography includes printing large quantities of newspapers, brochures, stationery, magazines, and boxes (Iverson, 2023). During this process, files are prepared and sent to the Kodak Trendsetter to produce the lithographic metal plates. The Ryobi 3304HA offset printing press will be prepared for production, and once it is ready, plates can be inserted into the press, followed by the addition of ink.

Dye Sublimation

The dye sublimation process finds widespread application in the textile industry for mass- customizing garments with unique designs. This method suits the textile market well because it involves digital printing, allowing for distinct designs on each garment. With advancements in ink and printer technologies, this process has been increasingly adopted in other sectors where mass customization is sought after (Makenji, 2011). Dye sublimation starts with liquid ink that prints an image onto a carrier and transfers it onto a substrate. When the image carrier is placed on the substrate and heated up by the heat press, it causes the ink on the carrier to sublimate and turn into a gaseous state (What is dye sublimation? - and how does it work?, 2021).

College Ambition Programs & Career and Technical Education Programs

From childhood aspirations of professions to high school expectations of attending prestigious universities, the desire for higher education remains widespread among adolescents (Lomax, 2015). However, the perceived attainability of these aspirations often differs from reality, especially regarding admission to elite institutions. Despite socioeconomic backgrounds, most students aspire to earn a four-year degree, highlighting the pervasive influence of societal expectations (Lomax, 2015). Yet, a lack of information about college major options and admissions criteria contributes to unrealistic expectations. The complexity of selecting a college that aligns with academic strengths, personal preferences, and family resources underscores students' challenges in navigating the application process. The College Ambition Program (CAP) has developed a specialized training initiative for students visiting college campuses to assist them in assessing how well a college aligns with their expectations. Unlike other programs that may limit campus visits to high-achieving students, CAP offers this opportunity to all students without charge, leveraging support from local programs and foundations to cover associated expenses. After each visit, students undergo preparatory sessions to familiarize themselves with what to observe on campus and which questions to pose to admissions staff. This initiative has proven invaluable, particularly for students who have never set foot on a college campus despite residing nearby. Feedback from evaluations of these college visits indicates that, for some students, the experience has significantly influenced their perceptions of the campus environment where they believe they would thrive and feel a sense of belonging. (Lomax, 2015).

The educational sector has responded to the demand for a proficient workforce by integrating vocational education into secondary schooling. Vocational education, or Career and Technical Education (CTE), equips students with both academic and technical expertise essential for immediate employment in existing or emerging industries or for furthering their technical education at the postsecondary level (Gaunt, 2005). All courses are provided at a single site in career technical high schools. Still, the curriculum is more specialized—all classes center on career and technical education programs, complemented by essential academic subjects. Area career technical centers provide technical programs at a different site from the high school. Core academic subjects, physical education, and arts courses are offered and taken at the student's "home" high school. Typically, students split their day between their home high school and an area center. Recruitment strategies are very common with these centers. According to Gaunt, "A variety of marketing strategies are consequently used to positively impact aspiring students, including visits and tours to the area center, brochures and other promotional materials, websites with pertinent information on programs and opportunities, outreach efforts by area center staff into the local schools, and the nurturing of partnerships with the business/industrial community." (Gaunt, 2005).

The CAP and CTE initiatives aim to prepare students for college by engaging them in pre-college activities, college tours, and other strategies to raise awareness of programs and opportunities, mirroring the objective of the Clemson Graphic Communications Outreach program.

Qualitative Research

Qualitative research aids in formulating hypotheses by delving into profound insights regarding real-world issues. The Qualitative Study states, "Qualitative research gathers participants' experiences, perceptions, and behavior. It answers the hows and whys instead of how many or how much" (Tenny, Brannan, & Brannan, 2022). Qualitative research focuses on open-ended questions that allow participants to explain how, why, or what they were thinking, feeling, and experiencing during an event (Tenny et al.,2022). The researcher will focus on discovering common themes or patterns between participants when analyzing the data. Qualitative research employs structured and unstructured interviews, focus groups, and participant observation. It aids in generating hypotheses, which can subsequently be rigorously tested through quantitative research.

Additionally, qualitative research helps researchers interpret quantitative data, discern their significance, and grasp their implications. It offers insights into situations that are not easily classifiable, enabling a deeper understanding of complex phenomena (Grossoehme, 2014). The data for this research was collected through surveys.

Research Methodology

Due to the nature of the research questions, the design of this study results in qualitative data. Qualitative data delineates attributes or features, often gathered through questionnaires, interviews, or observations, and commonly presented in narrative format (All guides: Data module #1: What is research data?: Qualitative vs. quantitative, n.d.). Examining qualitative data can present difficulties owing to its subjective character. This data type typically consists of descriptive language, which researchers can explore for recurring patterns or significance, often utilizing coding methodologies. Coding allows researchers to structure qualitative data into distinct categories, aiding in identifying themes pertinent to the research inquiries (All guides: Data module #1: What is research data?: Qualitative vs. quantitative, n.d.).

Qualitative research presents distinctive prospects for comprehending intricate, nuanced scenarios characterized by interpersonal ambiguity and diverse interpretations. While qualitative research may not offer conclusive solutions to such intricate inquiries, it can furnish a more profound comprehension and be a starting point for subsequent targeted investigations (Austin & Sutton, 2014).

Advantages and Disadvantages of a Qualitative Approach

Qualitative research presents distinctive opportunities for comprehending intricate, nuanced scenarios characterized by interpersonal ambiguity and diverse interpretations. While it may not answer complex questions definitively, qualitative research can enhance understanding and serve as a launch pad for further focused work. Effective qualitative research involves various frameworks, methods, and considerations, typically beginning with self-reflection and articulating the researcher's positionality. While some may perceive qualitative research as intuitive and straightforward, others may find it daunting due to its reliance on direct interactions between participants and researchers. Additionally, some may view qualitative research as subjective and unscientific, leading to skepticism about its reliability. However, these perspectives often stem from a lack of understanding of how rigorous qualitative research is conducted. When executed rigorously, qualitative research provides unique insights into the social and clinical realms we navigate (Austin & Sutton, 2014).

The population selected for this study was high school students throughout the upstate of South Carolina. High schools and career centers were selected with courses relating to graphic communications, such as business, digital design and art, and image editing. High school students were chosen as the target population for this study to enhance awareness of the Clemson University Graphic Communications major among individuals interested in this field or possessing prior knowledge in the subject area. Teachers were notified via email to inform and extend invitations to their classes for the Outreach Event. Although four schools in the upstate region were invited to participate, the sample for this research study is derived from a single high school. These results are from other schools that did not demonstrate interest in the event in the time allotted for this research.

Survey Design and Creation

The survey questions were created with the help of Michelle Fox and Carla Marchione, the Outreach and Recruitment instructors. The questions were developed based on topics discussed and questions asked by students during previous outreach events. The questions on the pre-event survey were catered to discover whether or not the students had prior knowledge of graphic communications, the courses to be completed in the program, and the work fields one could enter upon graduation. The post-event survey questions determine if the students' perspectives changed or if they gained any new insights from the event. The survey questionnaires were administered on paper so that time spent on the surveys could be controlled and to ensure students did not look up answers online or talk to one another. The pre-event survey can be seen in Appendix A, and the post-event survey can be seen in Appendix B. *Procedures.*

The project's nature presents minimal risk to the human participants. Nonetheless, to safeguard their interests, confidentiality was upheld, and consent for the study was secured from the Institutional Review Board (IRB) at Clemson University. Additionally, the researcher underwent online training to conduct research involving human subjects and obtain IRB approval. Since the study involves minors, parent consent must be received for each student to participate, and photos and videos must be taken during the event.

The outreach events occurred in Clemson University's Godfrey Hall, where participants would spend approximately four hours learning about graphic communications. Upon the students' arrival, they were welcomed on a tour and given an explanation of the survey and its questions. After working independently to complete the written survey, introductions were conducted to all students and faculty involved in the outreach course. This allowed the visiting students to get a general idea of each GC student's interest areas and process what Graphic Communications encompasses.

When the introductions were completed, students were split into small groups to participate in a rotational series of activities, which allowed them to experience what a day in the life of the Graphic Communications major would look like. The students participated in four 25-minute rotations, during which the outreach students discussed their definition of graphic communications and a condensed version of the process. Those processes were demonstrated, whether offset lithography, flexography, screen printing, or dye sublimation. Visiting students received the opportunity to work closely with the outreach students and ask questions before all came together for an hour-and-a-half-long lunch and panel discussion. During the interactive panel discussion, topics such as course curriculum, internships, college life, graphic communications careers and markets were discussed, and students were encouraged to ask any questions they may have. Once the panel was concluded, students were given a second written survey to, once again, independently complete.

Data Analysis

As the pre-event and post-event surveys were conducted by hand, they must be entered digitally to initiate the data collection process. The students' pre-event and post-event responses were input into a spreadsheet, ensuring that answers for each question were systematically organized. Responses regarding skills and career interests were compiled into charts and tables to communicate the data visually. For open-ended questions, common words or phrases were found between students' responses to determine results. These common words and phrases were then turned into word maps to display the frequency of the keywords. A SWOT analysis is a tool that is utilized to identify strengths, weaknesses, opportunities, and threats of a specific project or research (Raeburn, 2024). A SWOT analysis was conducted to assess the current state of this research and identify areas for improvement in future endeavors.

RESULTS

PRE-EVENT SURVEY

QUESTION 1: What is your definition of graphic communications?

This question elicits the respondent's understanding and interpretation of "graphic communications." It invites individuals to articulate their own personal definition or conceptualization of this field, which encompasses various forms of visual communication, such as graphic design, printing, typography, and multimedia design. Responses to this question can provide insights into individuals' diverse perspectives and perceptions regarding the scope, purpose, and significance of graphic communications in different contexts.

Based on the responses provided, there is a diverse range of perspectives on the definition of graphic communications. Some respondents mentioned specific activities such as designing and printing graphics, creating designs for marketing purposes, and making graphics for companies or organizations. Others emphasized the role of graphic communication in creating visual materials like posters, t-shirts, logos, and advertisements, as well as its importance in creative marketing and communication through imagery. Several respondents mentioned broader concepts such as designing anything related to art, planning, and creating things, as well as communicating through visual elements. Some respondents admitted not knowing much about graphic communications, while others provided more general descriptions like "making stuff" or "printing stuff."

The responses indicate that graphic communications encompass various activities related to designing, creating, and communicating through visual means, focusing on marketing, advertising, and creating visual materials for companies or organizations. The responses also highlight the importance of creativity and visual communication skills in graphic communications.

QUESTION 2: Circle the skills necessary to succeed in this field.

This question prompts respondents to identify and highlight skills they believe are essential for success in graphic communications. It requires individuals to review a list of skills and indicate those they perceive as critical for thriving in graphic communications-related roles. This question serves as a means of assessing the respondent's understanding of the competencies required for effective performance

in graphic communication professions while also providing insights into their perceptions of the industry's skill requirements.

The responses to the question about skills necessary to succeed in the graphic communications field indicate a variety of skills that respondents believe are important for success in this industry. Many respondents mentioned software applications such as Illustrator, InDesign, Photoshop, and Lightroom. multiple tasks efficiently are essential aspects of success in the fast-paced environment of graphic communications. Respondents mentioned skills related to problem-solving and troubleshooting, such as identifying and resolving issues in the pre-press or press operation stages of printing. Creativity was consistently cited as a crucial skill, and each respondent listed creativity as needed. Graphic communications professionals need to be able to generate innovative ideas, design

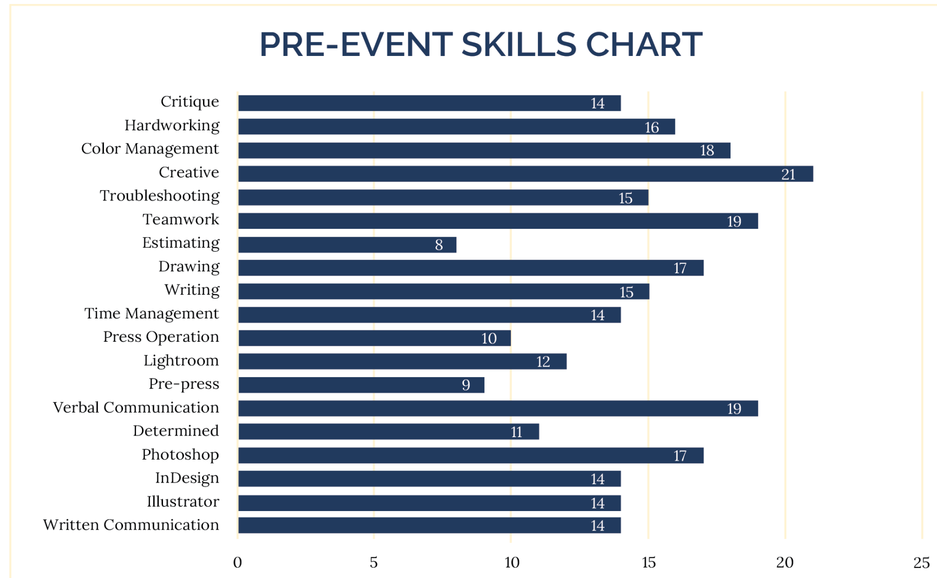


Figure 1. Pre-event Skills Chart

These tools are crucial for graphic design, layout creation, photo editing, and digital asset management. Verbal and written communication skills were frequently mentioned. Effective communication is essential for collaborating with team members, conveying ideas to clients, and presenting work professionally. Several respondents highlighted time management skills. Meeting project deadlines and managing visually appealing materials, and adapt to changing trends and client preferences. Several respondents emphasized the importance of attention to detail, particularly in tasks like drawing and writing. However, estimating and pre-press operations were two of the least listed skills. Precision and accuracy are essential for ensuring high-quality output in graphic communications. Some respondents mentioned giving and receiving constructive criticism as a critical skill. Being able to evaluate and improve upon one's work, as well as provide feedback to others, contributes to professional growth and quality assurance.

Overall, the responses demonstrate that success in the graphic communications field requires a combination of technical proficiency, communication skills, creativity, problem- solving abilities, and attention to detail. These skills enable professionals to create impactful visual materials, collaborate effectively with others, and navigate the industry's complexities.

QUESTION 3: What types of markets do you relate to graphic communications?

This question explores the respondent's associations between graphic communications and various markets or industries. It encourages individuals to identify and describe sectors or segments where they believe graphic communications are relevant or significant. Possible responses may include advertising, publishing, packaging, branding, digital media, and marketing. This question helps researchers or practitioners understand how different individuals perceive the applicability and impact of graphic communications across different market contexts.

From the responses provided, several themes emerge regarding the types of markets that respondents associate with graphic communications. Many respondents mentioned advertising as a market related to graphic communications. This includes social media marketing, product design, food marketing, and new product promotion. Graphic communications are crucial in creating visual materials for advertising campaigns and marketing efforts. Some respondents mentioned the business sector as a market associated with graphic communications. This includes small businesses, big brands, and businesses in general. Graphic communications is essential for businesses to communicate their brand identity, promote their products or services, and engage with their target audience. Respondents also identified markets with a creative side, such as photography and clothing brands, as relevant to graphic communications. These industries use graphic communications to create visually appealing content, including logos, branding, and promotional materials. A third of respondents indicated they were unsure or did not know which markets are related to graphic communications. This suggests a lack of familiarity or awareness about the various industries and sectors that rely on graphic communications for visual communication and marketing purposes.

The responses reflect the diverse range of markets and industries that utilize graphic communications for various purposes, including advertising, branding, marketing, and visual communication. Additionally, the responses highlight the importance of graphic communications across different sectors in conveying messages effectively and engaging audiences.

QUESTION 4: Are there any specific career paths associated with this major that you are aware of?

This question assesses the respondent's knowledge and understanding of potential career opportunities in graphic communications. It invites individuals to identify and describe specific career paths or job roles they are familiar with, which are commonly pursued by graduates with a background in graphic communications. Responses may include roles such as graphic designer, print production manager, web designer, packaging specialist, marketing coordinator, art director, and many others. This question helps the researcher gauge the respondent's awareness of the diverse career options available within the graphic communications industry and their perceptions of the profession's career prospects.

Several specific career paths associated with the graphic communications major were mentioned in the responses provided. Three respondents identified graphic design as a career path associated with the graphic communications major. Graphic designers create visual concepts, using computer software or by hand, to communicate ideas that inspire, inform, and captivate consumers. Photography was also mentioned by approximately 30 percent of respondents as a career path related to the graphic communications major. Photography was also mentioned by approximately 30 percent of respondents as a career path related to the graphic communications major. Photographers capture images that visually communicate messages, stories, and emotions, often for commercial or artistic purposes. Four respondents identified marketing and advertising roles. These careers involve promoting products, services, or brands through various channels, including print, digital, and social media, often utilizing graphic communications techniques. A few respondents mentioned career paths in business and management. These roles may involve overseeing creative projects, managing teams, or running graphic communications-related businesses. One respondent mentioned teaching as a potential career path associated with the graphic communications major. Educators in this field may teach graphic design, photography, or visual communication courses. Two respondents mentioned brand and logo design as career paths related to the graphic communications major. These professionals focus on creating visual identities for companies or brands through logo design, branding materials, and marketing collateral. Over a third of respondents indicated they were unsure or did not know what career paths are associated with graphic communications.

In general, the feedback showcases a wide array of career avenues linked with the graphic communications major. These paths encompass graphic design, photography, marketing, advertising, business, teaching, and branding. Professionals in these fields leverage skills in visual communication, design, creativity, and marketing to effectively convey messages and captivate audiences.

QUESTION 5: Can you name some of the courses or subjects covered in this major?

This question prompts respondents to list specific courses or subjects typically included in a curriculum for a graphic communications major. It encourages individuals to recall and identify key topics or areas of study within graphic communications. Responses may include courses such as graphic design fundamentals, typography, color theory, printing technologies, digital imaging, web design, packaging design, marketing, accounting, and management. This question helps the researcher understand the respondent's familiarity with the content and scope of coursework typically associated with a graphic communications program.

The responses provided show a mix of familiarity and uncertainty regarding the courses or subjects covered in the graphic communications major. Less than a fourth of the respondents indicated that they did not know or were unsure about the specific courses or subjects covered in the major. This suggests a lack of familiarity or awareness about the curriculum and coursework associated with graphic communications. Photography was mentioned by almost half of the respondents as a course or subject covered in the graphic communications major. This indicates an association between graphic communications and photography, suggesting that photography may be a significant component of the curriculum in some programs. Approximately 20 percent of the respondents mentioned marketing and advertising as courses or subjects covered in the major. This suggests that marketing and advertising principles may be incorporated into the curriculum to give students a comprehensive understanding of visual communication and branding strategies. A few respondents mentioned graphic design as a course or subject covered in the major. This aligns with the core focus of graphic communications, which often includes the study of design principles, typography, layout, and visual communication techniques. Individual respondents mentioned creative writing and 3D printing, indicating potential interdisciplinary aspects of the curriculum or specialized courses offered by the graphic communications major.

QUESTION 6: List the types of printing processes you know.

This question prompts respondents to list various methods or techniques used in the printing industry to reproduce text and images onto different substrates. It encourages individuals to recall and identify specific printing processes they are familiar with. Responses may include techniques such as offset printing, digital printing, flexography, gravure printing, screen printing, and sublimation printing. This question helps the researcher assess the respondent's knowledge and understanding of different printing methods and their applications in graphic communications.

From the responses provided, it is evident that there is limited knowledge or awareness about the types of printing processes among the respondents. Over 70 percent of respondents indicated that they did not know or were unsure about the types of printing processes. This suggests a general lack of familiarity or awareness about the various techniques used in the printing industry. Some respondents mentioned specific printing processes, such as screen printing, 3D printing, heat press, and sublimation. These respondents provided more general terms like heat press without specifying a particular technique. While these responses indicate some awareness, they represent only a tiny subset of the wide range of printing processes available.

The responses highlight a need for greater education and awareness about the types of printing processes among the respondents. This could be addressed through targeted educational initiatives or resources to provide information about the different printing techniques used in various industries. Additionally, it underscores the importance of incorporating printing process knowledge into relevant educational curricula to better prepare students for careers in graphic communications and related fields.

QUESTION 7: How interested are you in a career in graphic communications?

This question seeks to gauge the respondent's enthusiasm or inclination toward pursuing a profession in graphic communications. It prompts individuals to reflect on their interest in working in roles related to graphic design, printing, visual communication, or other areas encompassed by the graphic communications industry. Responses may range from indicating a strong interest or passion for pursuing a career in graphic communications to expressing little to no interest in such a career path. This question helps the researcher understand the respondent's aspirations, motivations, and potential career goals in graphic communications.

The responses to the question regarding interest in a career in graphic communications range from 2 to 10, with the average response falling around 4-5. A significant portion of respondents have a moderate interest in pursuing a career in graphic communications, which indicates that while they may be somewhat interested, they may not be fully committed or passionate about pursuing this career path. Three respondents provided higher ratings, indicating a strong interest in pursuing a career in graphic communications. These individuals may have a genuine passion for the field and are more likely to seek opportunities and actively further their education in this area. Five respondents gave lower ratings, suggesting a limited interest in pursuing a career in graphic communications. This may be due to a lack of familiarity with the field, a preference for other career paths, or a perceived lack of opportunities or benefits associated with graphic communications careers.

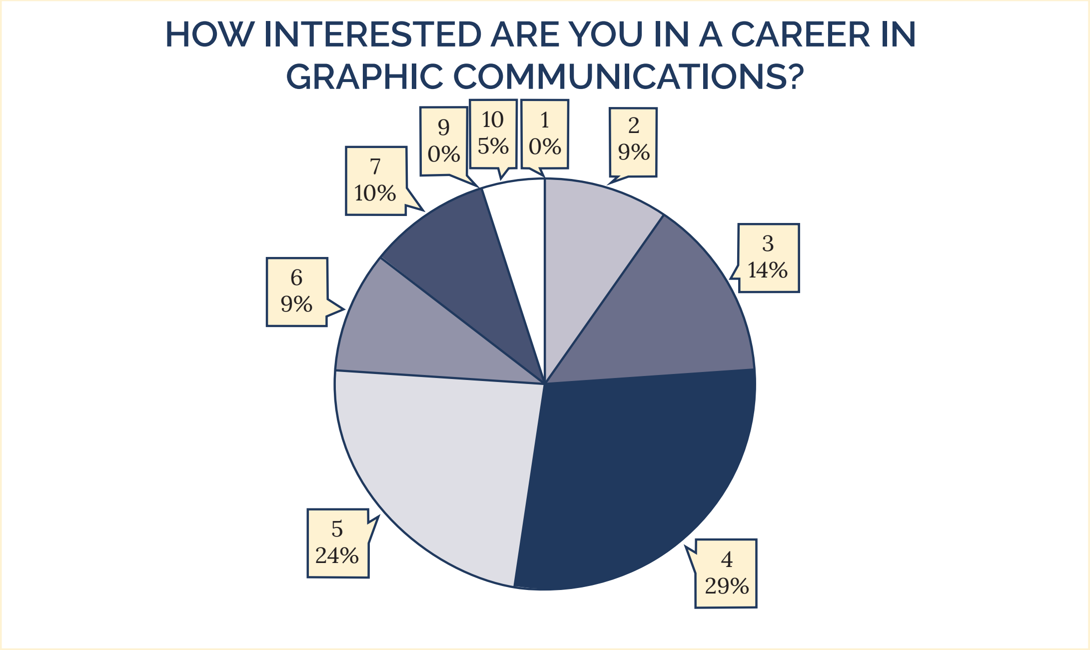


Figure 2. Pre-Event Interest Chart

POST-EVENT SURVEY

QUESTION 1: Did the outreach event change your perspective on graphic communications? If yes, how?

This question aims to assess the impact of the Outreach event on the respondent's perception of graphic communications. It invites individuals to reflect on whether their views or understanding of graphic communications were altered due to attending the event. If the respondent answers affirmatively, they are prompted to elaborate on how their perspective changed. Possible responses may include gaining new insights into the field, developing a deeper appreciation for its applications, or considering career opportunities they hadn't previously considered. This question helps the researcher evaluate the effectiveness of the outreach event in influencing participants' perceptions and attitudes toward graphic communications.

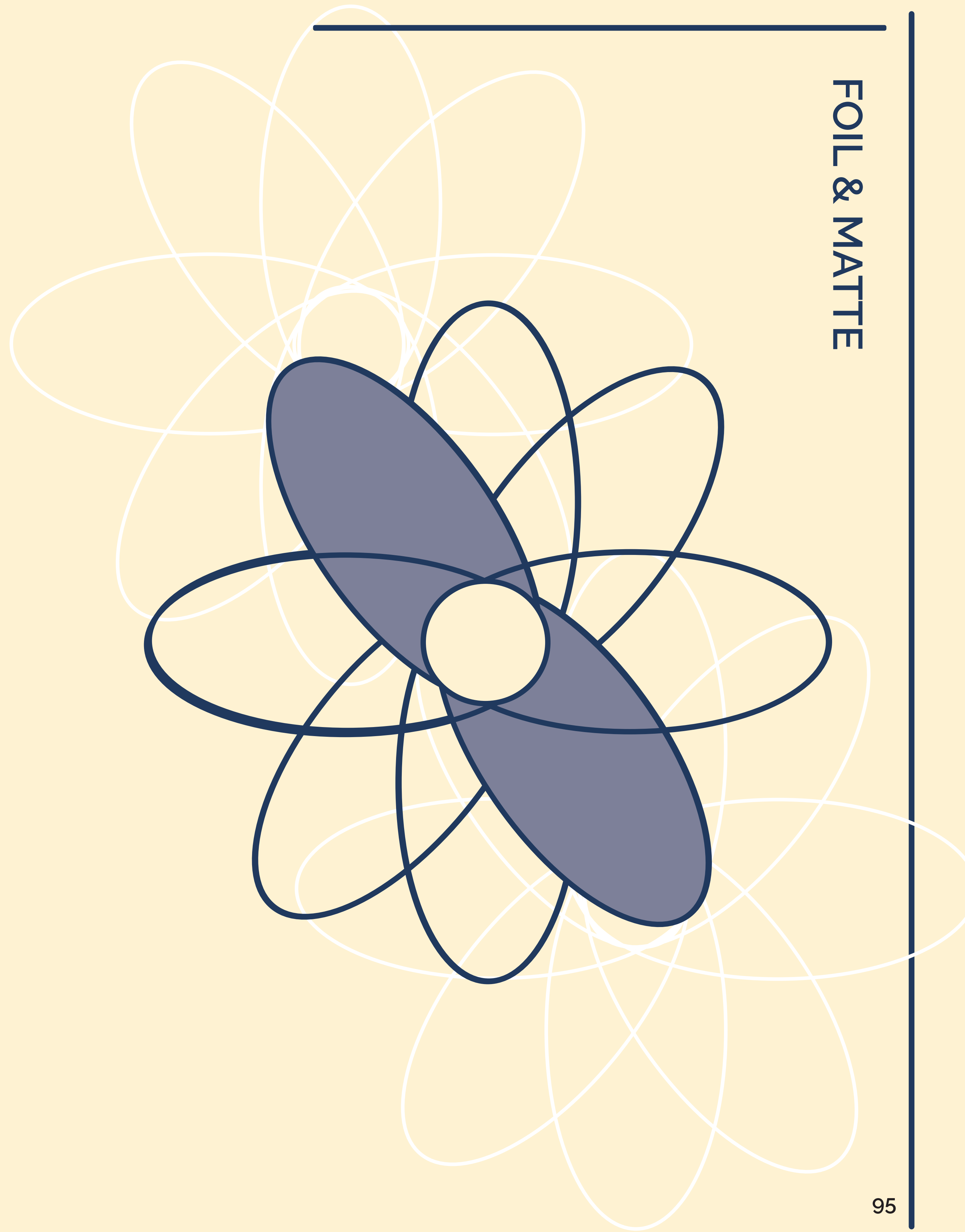
The responses to the question about whether the outreach event changed perspectives on graphic communications were varied, with some indicating a shift in perception and others maintaining their initial views. Several respondents mentioned that the outreach event helped them better understand graphic communications. They learned about the variety of careers available, the hands-on nature of the field, and the different processes involved. This suggests that the event provided valuable insights into the industry and its complexities. Some respondents expressed an increased interest in graphic communications due to the outreach event. They found the field more interesting, fun, and creative than they initially thought. This indicates that the event effectively showcased the appeal and potential of a career in graphic communications, sparking curiosity and enthusiasm among participants.

On the other hand, a few respondents mentioned that the event confirmed their perceptions of graphic communications. While they may have learned new information or gained a deeper understanding of the field, their perspective remained unchanged. There were also mixed reactions among respondents, with some expressing uncertainty or ambivalence about pursuing a career in graphic communications despite attending the event. These individuals may have found certain aspects of the field appealing but still have reservations or conflicting interests in other areas.

Overall, the responses suggest that the outreach event had varying effects on participants' perspectives on graphic communications. For some, it was an eye-opening experience that increased their understanding and interest in the field. In contrast, others may have had their initial perceptions confirmed or remained undecided about pursuing a career in graphic communications.

QUESTION 2: Circle what skills you identify as skills you need to be successful in this field.

Comparing the responses from the pre-survey and post-survey questions about the skills necessary to succeed in the graphic communications field reveals some notable trends. In the post-survey responses, a broader range of skills is mentioned than in the pre-survey. While both surveys emphasize skills like written and verbal communication, Adobe software proficiency (Illustrator, InDesign, Photoshop), and creativity, the post-survey includes additional skills such as determination, pre-press knowledge, press operation, time management, estimating, troubleshooting, and critique. This suggests that participants may have gained a deeper understanding of the specific skills required for success in graphic communications through the outreach event or other experiences during the study period. There is a notable emphasis on technical skills related to graphic communications in the post-survey responses, such as pre-press operations, press press operation, color management, and software proficiency. This indicates that participants may have become more aware of the technical aspects of the field and the importance of mastering specific tools and processes. Some respondents in the post-survey highlight personal qualities like determination, time management, teamwork, and troubleshooting skills as essential for success in graphic communications. This suggests increasing participants' awareness of the importance of soft skills, personal attributes, and technical proficiency. Despite the expansion of skills mentioned in the post-survey, core skills like communication, creativity, and hardworking remain consistently emphasized across both surveys. This indicates that these skills are universally recognized as fundamental for success in the graphic communications field.



FOUR

1

HOT

Hot foiling uses a heated die to press foil onto the material, creating a raised, textured finish, often for packaging.

2

COLD

Cold foil printing does not require heat in print, which makes it faster and more cost-effective for large press runs.

Digital Foiling is a newer method, where the foil is applied using a digital printer. This allows for faster production.

DIGITAL

3

Foil overprint is a technique where foil is applied over an existing printed design to add metallic accents.

OVERPRINT

4

Costly to Produce.

Using foil in print requires additional materials and is a specialized process, making costs high. Due to this, foil is typically used for small areas or specific design elements.

CONS

- LIMITED COLOR OPTIONS - NOT AS MANY SHADES AS INKS
- DESIGN CONSTRAINTS - FINE DETAILS CAN GET LOST
- SLOWER PRODUCTION TIME - MULTISTEP PROCESS
- LABOR INTENSIVE PROCESS

WHY FOIL?

Unique Aesthetic

Foil adds a luxurious, eye-catching element to printed materials. It can significantly improve a brand's image by associating it with quality.

Versatility

Foil can be used on a wide variety of materials to enhance a print, including paper, cardstock, and even fabric. It also can be combined with other print processes.

Contrast & Impact

Adding foil to a print can create a sharp contrast between the metallic foil and paper texture, making any design visually impactful.

CONS

- LACK OF COLOR DEPTH AND SATURATION IN PRINT
- LOW DURABILITY - DEPENDS ON THE PAPER QUALITY
- POTENTIAL FOR DULLER APPERANCE
- SUSCEPTIBLITY TO CREASING

1

MATTE

Durable finish that reduces glare from light sources and scuffs. It's a subtle option that gives a refined apperance.

2

SOFT TOUCH

Similar to matte lamination, but with a softer, velvet-like feel. It's often used for high-end products.

Like soft touch, velvet lamination has a very soft feel. It has enhanced durability compared to matte lamination.

VELVET

3

Silk lamination is a thin plastic layer that is applied and falls in between matte and soft touch. It is a more affordable option

SILK

4

Generally More Expensive.

Matte lamination can be slighlty more costly to produce, depending on the thickness of the laminate, the type of laminate used, and the scale of the print job. The production process itself can also impact cost.

WHY MATTE?

Reduced Glare

Applying a matte laminate to paper produces a non-reflective surface, which minimizes reflections from light.

Fingerprint Resistance

The textured surface from matte lamination helps hide fingerprints and smudges, which is beneficial for frequently handled materials.

Versatility

A matte finish on paper works well with various print applications, including black and white photos and text-heavy documents.

FOIL & MATTE

4

CHAPTER FOUR

"Comparative Analysis of the Usability in Digital Mirrorless Cameras" By Catlin Clark Wade

ABSTRACT

This study investigates the usability of three different mirrorless camera bodies to explore and compare the usability and user experience of each camera. Key features were identified as enhancing the overall user experience or serving as pain points for users. The study also aimed to provide insight into whether those features influenced purchase decisions. It was found that users preferred a lightweight and compact camera body. Initially, each camera earned a Systems Usability Score below the average of 68, indicating that there is continued room for improvement in the usability of mirrorless camera used in the study.

The camera industry can be characterized as a rapidly evolving market that remains innovative and creative. The industry provides a crucial opportunity to document the human experience in daily life and during pivotal moments. The development of camera technology impacts not only the typical photographer that most people imagine in an increased security surveillance, and digital communication across various channels. Cameras are located inside artistic studio or at a wedding but also allows for space exploration, smartphones, drones, and satellites and are integrated seamlessly into our daily lives. Camera technology has an extensive impact on our society as the global market size for digital cameras reached $8.56 billion in 2023, with an expected growth rate of 4.21% between 2023-2030 (Data Bridge, 2024).

However, digital cameras are susceptible to neglect as popular smartphones, such as the Apple iPhone, Google Pixel, and Samsung Galaxy, continue improving camera quality with each addition to their product lines. However, even as smartphone cameras continue to improve, digital camera experts are confident that there will continue to be a segment of the general population who will be willing to purchase dedicated digital cameras regardless of other market forces (Baskin, 2023). Not everyone agrees with such a statement, including professional photographers and camera enthusiasts. It is difficult to ignore the portability and accessibility that smartphone cameras offer. Users and creatives often cite the old saying by Chase Jarvis that "the best camera is the one you have with you." Beautiful image quality is no longer accomplished only with a dedicated camera, and it is difficult to ignore the 84% drop in digital camera sales between 2010 and 2017 as smartphone cameras have improved (Richter, 2020). This new challenge indicates that it is essential for engineers and product designers of digital cameras to explore every avenue of improvement, elevating the overall user experience of digital cameras to stay aligned with current and future market demands.

LITERATURE REVIEW

History of Digital Cameras

To fully understand the usability and user experience of digital cameras, it is important to understand what cameras are. A camera can be defined as a device that captures light and then converts that light into an image, whether a moving image or a still (Dam, 2023). Cameras are critical tools that allow photographers and videographers to accomplish their goals of image capture and complete their jobs effectively. Therefore, it is essential to those users, whether beginners or professionals, that they have a tool that is comfortable and easy to use. Often, photographers pick up their cameras daily and use them for several hours. The user experience of these photographers is essential to understand and investigate in order to offer future innovations that increase positive interactions between the user and the device, as a better user experience creates an increased value (Mertz, 2022). However, there appears to be a lack of research on digital cameras' usability and interaction design. Despite changes and rises in new technologies, cameras' usability appears to go unaddressed. This gap allows researchers to explore users' desires and highlight opportunities for improvement in digital camera designs.

This study focuses on the experience of beginner photographers and their interactions with some of the leading mirrorless camera bodies available in the United States. Digital mirrorless cameras were specifically chosen for this study as the recent industry standard for both professional and beginner photographers. A comparative analysis of mirrorless cameras created by major manufacturers was completed to identify key usability features and investigate which features enhanced the overall user experience. This study aims to provide insight into digital camera features that users find to be the most user-friendly and to evaluate if those features influence purchase decisions. This study also sought to identify pain points that make it more difficult for users to utilize the camera effectively.

The foundational science behind the development of cameras dates back to 1021, when Alhazan, an Arab scientist, defined the nature of light and optics in the Books of Optics. Throughout the 1500s, scientists and engineers built upon this foundation by creating the camera obscura, a term initially coined by Johannes Kelper. This is where the modern-day term "camera" comes from. Kelper was also the first to create a portable version of the camera obscura (Rick, 2016). The camera obscura was a dark room or box with a small hole or lens

on one side that allowed in light and projected an image onto the opposite wall. Many scientists used this invention for astronomy, capturing information about the stars. The camera obscura was also utilized in art for drawing, painting, and general entertainment (Dam, 2023).

Despite the advancements in optics, it was not until the 1800s that proper cameras were created. Joseph Nicéphore Niépce is credited with creating a device that took the first-ever photograph. This device introduced the ability for an image to be recorded. Niépce's method was called heliography (Dam, 2023). A later collaboration with Louis Daguerre resulted in a new process called daguerreotype, which produced better image quality, was more portable, and required less exposure time. This new process was significantly improved compared to the 8 hours of exposure required for Niépce's first image. The process was additionally improved upon by Alphonse Giroux in 1839. Henry Fox Talbot also presented "film" for the first time that year, which can be attributed to the first step away from utilizing plates for photography (Dam, 2023).

Kodak can be attributed to revolutionizing the camera market in 1888. George Eastman, the founder of Kodak, was able to manufacture and sell a camera that used roll film and offered 100 exposures. It was affordable, which made it more accessible to a wide variety of consumers (Dam, 2023). Eastman believed that Kodak's success developed from creating a product that "was as convenient as the pencil" in terms of user-friendliness (Gavetti et al., 2005).

However, today's analog photography standard can be credited to Oskar Barnack and Leica for creating 35mm film in the early 1900s. Leica's cameras introduced interchangeable lenses, a viewfinder, and a range of shutter speeds, which allowed for more artistic freedom (Dam, 2023; Kang & Song, 2016). However, these cameras were not without their drawbacks. SLR cameras were later introduced to the market in 1958, which provided even more flexibility and functionality, solving some of the limitations of the 35mm film cameras (Kang & Song, 2016). By the end of the century, Nikon introduced DSLR cameras into the market with the Nikon D1. DSLR cameras offered a new level of technology in portable camera bodies, allowing them to remain contenders for beginner photographers in today's market. They offer a cheaper alternative to mirrorless cameras while still capturing high-quality images.

Panasonic introduced mirrorless cameras to the market in 2008 (Kang & Song, 2016). This camera was the Lumix DMC-G1. In a DSLR, a mirror would reflect a pentaprism, serving the viewfinder and projecting the image onto the sensor (Kang & Song, 2016; Dam, 2023). These interworking components made the DSLR camera bodies bulky and heavy. DSLRs also have optical viewfinders, meaning users do not always see precisely what they are capturing.

The mirrorless cameras solved both of those issues. Mirrorless cameras allow for more compact bodies since they do not have a reflex mirror. They also use an electronic viewfinder, which means that through the digital image sensor, users can see what the camera processes. This yields more accurate image results. The rise of mirrorless cameras can be seen as in 2003, Nikon and Canon occupied almost 100% of the global interchangeable-lens camera market, but when mirrorless cameras were produced and improved upon by Olympus, Panasonic, and other manufacturers, Nikon and Canon were no longer leader in innovation and lost ground in the market. The two manufacturers eventually contributed to the mirrorless camera market in 2013 and have continued to catch up to their competition (Kang & Song, 2016). Mirrorless cameras have become the go-to photography tool in multiple fields, including wedding photography, social media influencers, health-related fields and more (Chitra et al., 2024; Zoltie, 2018).

Today's Camera Market

There is much debate about which manufacturers produce the best camera on the market, with multiple factors influencing user and buyer decisions. Mirrorless cameras are designed and available for different skill levels and purposes. For example, as content creation continues to be a source of interest for many consumers, cameras such as the Canon R50 are considered a popular choice among social media influencers to vlog and record high-quality videos. There has also been a recent trend of "retro" aesthetics, which encouraged Nikon's release of the Z fc in 2021. The camera provided the advancements of mirrorless camera technology while offering retro aesthetics with its heritage design. Sony has also quickly become a popular choice for professionals and beginners regarding mirrorless camera bodies, as it offers some of the market's best autofocus (AF) capabilities. Sony is also popular among professionals due to having a wide variety of lenses available, both by Sony and third-party lens manufacturers.

Users find several camera specifications (or specs) relevant to their purchase decision and investment in a digital mirrorless camera. Often, these specifications include lens options, resolution, screen articulation, and, recently, video capabilities such as the ability to shoot in 4k and in-camera image stabilization. Many users desire hybrid cameras as video continues to grow more popular. Other specifications include a weather-sealed body, the number of SD card slots, battery life, color science, and overall image quality. Users can also find in-depth information about the camera's sensor, which directly processes the light and converts it into a digital image.

Many users commit to completing their rounds of research before purchasing a digital mirrorless camera. However, the typical user is not guaranteed the opportunity to hold a camera in their hands or compare it in person to other cameras before their purchase. Manufacturers do not operate brick-and-mortar stores, and independent camera stores and retailers have grown few and far between. This means that users must borrow or rent

multiple cameras to compare camera models, which can be costly. Most would take the cheaper route and complete online research by watching review videos and reading articles by well-known camera reviewers who compare the cameras for them.

So, what happens when a user realizes they have purchased a camera they do not enjoy using? For any photographer, it is not only important that the camera is portable, but it is also vital that the camera inspires their work and actively encourages them to participate in their chosen field, whether landscape, fashion, or portrait photography. A lack of usability and a negative user experience can directly impact the quality of work a user can deliver. Rather than encourage the user to capture moments, a negative user experience can end up with a camera on a resell site or, worse, collecting dusk on a shelf. Not to mention, the manufacturer will earn a negative reputation and lose a loyal consumer. For these reasons, it is crucial to explore digital cameras› usability and user experience to benefit both the user and the manufacturer. Regardless of a camera›s specifications, if a user cannot take full advantage of what the camera offers due to bad design choices and a lack of usability, the available specifications do not matter.

Usability and User Experience

Multiple definitions of usability exist as the concept intersects between multiple disciplines, including psychology, human-computer interaction, and graphic design. There are also different perspectives between researchers and practitioners within these disciplines. However, most can agree that Jakob Nielsen is the father or grandfather of usability studies. Nielsen defines usability as «a quality attribute that accesses how easy user interfaces are to use.» He breaks usability into five components: efficiency, errors, learnability, memorability, and satisfaction (Nielsen, 2012). Efficiency pertains to the amount of time it takes for a user to complete tasks. Errors describe how many errors users make and how they can recover from them. Learnability is the ease of completing basic tasks with the design. Memorability addresses how easily a user can come back to the design and use it with proficiency. Lastly, satisfaction relates to how pleasant the experience is when users use the design.

The term «user experience» was coined by Don Norman in the 1990s when he worked for Apple. However, the concept of user experience was understood way before the 1990s as scientists, artists, and engineers sought opportunities to improve people›s lived experiences (Vinney, 2023). Today, user experience is most associated with interface design and computer and mobile device technologies. However, the same fundamental concept of user experience applies to physical products and should be considered critical to product design.

Similar to usability, the concept of user experience varies between researchers, practitioners and members of different fields. This variety has developed into a lack of understanding and concise strategic approaches to innovative user experiences in the context of product design and development (Shin et al., 2017). In "The Design of Everyday Things," Don Norman explains how human-centered design (HCD) informs user experience design. The approach of HCD is to put the needs of users first by designing products in a way that accommodates them rather than forcing the user to accommodate the product. The term user-centered design (UCD) has been used interchangeably with HCD in recent years. Norman's explanation of user experience lacks a formal definition despite coining the term. This has left room for other researchers and academics to attempt to fill in the gap. ISO 9241-210 defines user experience as "a person's perceptions and responses that result from the use or anticipated use of a product, system, or service." Others, including Marc Hassenzahl and Noam Tractinsky, Lauralee Alben, and Jakob Nielsen, have also contributed their definitions, all of which include an understanding of the user's emotional and cognitive state when interacting with a product (Allam et al., 2013). The definition of user experience has continued to be fluid and specific to researcher and practitioner interests and perspectives.

The important thing is that user experience resides within the context of user feelings and emotions through their interaction with a product. At the same time, usability focuses on a product's functionality and ease of use. It can be said that usability is an objective measure while user experience is subjective (Roto et al., 2009; Allam et al., 2013). Both usability and user experience can be evaluated and investigated through various methods. This study utilizes in-person semi-structured interviews and the Systems Usability Scale, which are discussed and described later.

Product Innovation

Regarding product innovation, Norman offers a framework methodology of HCD that can be considered a continuous process of investigation, which can be "characterized by observations, an ideation phase, and rapid prototype and testing" (Norman & Verganti, 2014). In pursuit of nailing down a more strategic, innovative product design process framework, Shin et al. l, 2017, describe the two other standard methodologies: participatory design and contextual design. Participatory design describes a process where the users are actively involved and able to share their opinions about a product. In a contextual design process, designers gain insights by observing users in their real-life settings and authentic environments. Participatory design may happen in a lab, while contextual design insights, for example, can be gathered from collecting data in online spaces or observing users in their natural work environment.

Norman and Verganti, 2014, suggest that product innovation is not driven by HCD, but rather, it fuels product innovation of existing technologies. Norman found that "radical innovation" was not the result of following a careful design strategy or research method but rather that the inventors of such technologies created them out of curiosity and interest. Evidence of this can even be seen in the history of the digital camera, as engineers sought ways to enhance and improve existing camera technologies. Norman and Verganti, 2014 identified two types of innovation: incremental and radical. Incremental innovation offers "improvements within a given frame of solutions," and radical innovation provides "a change of frame" or doing something new (Norman & Verganti, 2014). The goal of this study was not to uncover drastic innovations. Instead, it offers insights and possible suggestions that may contribute to the continued improvement of digital cameras regarding user experience and usability.

METHODS

Undergraduate students from a southeastern university of the United States were recruited via email and by faculty recommendation to participate in this study. A total of 7 students participated, however, one user was unavailable to complete their participation in the study in its entirety. For that reason, the data from that user was removed from the data analysis.

In order to qualify for the study, users had to have no or little experience using digital mirrorless cameras. Users were asked to confirm their prior experience before continuing in the study.

Users were asked to participate in a 45-minute study. The study consisted of a 2-5 minute semi-structured interview, which included demographic questions and information about user's prior experience with digital cameras.

Those questions included:

1. How would you describe your...
   a. Age?
   b. Gender?
   c. Race and/or Ethnicity?
   d. Undergraduate classification?
2. Tell me more about your experience with digital cameras.
3. How do you typically capture images?
4. Do you have future goals that include the use of a digital camera? If so, what are they are and how would you make use of the camera?

Users were then asked to perform a series of 8 tasks on each of the three cameras. The total task performance of all the cameras was estimated to last 15-20 minutes. Users were asked to describe their interactions with the cameras as they performed each task. The time it took to complete each task was also recorded. The tasks included the following:

1. Please pick up the first camera and describe how it feels in your hands.
2. Please turn on the camera.
3. Switch the camera's mode from auto to manual.
4. You're indoors with slow moving subjects. Please change the shutter speed to 1/250.
5. Take an image of an object in the room.
6. Review the image that you just took to see how the photo turned out.

7. Now it's time to clean your SD card. Please format the card that is currently in the camera.
8. Please turn off the camera.

Each camera was set to the same settings before the task performance. The camera was off, set to auto, the menu reset on the start location, and the manual settings were set to ISO Auto, the shutter speed at 1/1000, and the aperture at f/2.8.

Once the task performance was complete for each camera, users were asked to complete a digital survey that consisted of the Systems Usability Scale (SUS). The Systems Usability Scale is a 10 question Likert scale that assess the usability of systems, applications and products (Albert et al., 2010; Brooke, 1996; Vlachogianni & Tselios, 2022). Users were able to select options that range from "I strongly agree" to "I strongly disagree." Their responses to the survey were recorded and then converted into numbers. Those numbers were then calculated and interpreted to determine a final score, which served as an indicator of the product's usability. A final SUS score below 50 is considered "bad" usability, while a SUS score above 70 is considered "good" usability (Bangor et al., 2008). Several studies have demonstrated that the SUS is reliable for measuring the usability of products and systems and can be used with various sample sizes (Grier et al., 2013; Borsci et al., 2009; Bangor et al., 2008, Albert et al., 2010; Vlachogianni & Tselios, 2022).

For the purpose of this study, the term "system" was replaced with "camera." The digital survey was estimated to take users between 2-5 minutes to complete for each camera.

1. I think that I would like to use this [camera] frequently.
2. I found the [camera] unnecessarily complex.
3. I thought the [camera] was easy to use.
4. I think that I would need the support of a technical person to be able to use this [camera].
5. I found various functions in this [camera] were well integrated.
6. I thought there was too much inconsistency in this [camera].
7. I would imagine that most people would learn to use this [camera] very quickly.
8. I found this [camera] very cumbersome to use.
9. I felt very confident using the [camera].
10. I needed to learn a lot of things before I could get going with this [camera].

The study ended with a 5-minute interview, consisting of 4 questions asking users to compare the cameras and describe the features they disliked and liked.

1. Which menu interface did you find most easy to navigate through? Can you describe why?
2. Which camera would you be most inclined to purchase for yourself without costs as a deciding factor and why?
3. Which camera do you believe offered the best overall experience and why?
4. Is there anything else you would like to share about your experience with any or all of the cameras?

The equipment used in this study included the Canon R8 with a Canon RF 50mm f/1.8 STM lens, the Nikon Z6ii with a Nikon Z 50mm f/2.8 Macro lens, and the Sony A7iv with a Sigma 70mm 2.8 DG macro lens. These cameras were chosen based on their status in the market for hobbyist, semi-professional photographers, and professional photographers. The brand markers located on each camera were covered throughout the user interviewers and task performance to avoid potential brand bias.

To account for an order effect, the order of the cameras was randomized for each user. For example, for user 1, the order of cameras included Nikon, Canon, Sony. For the next user, the order of cameras included Canon, Sony, Nikon. The order continued to be randomized until all users had been interviewed.

All users in this study were female undergraduate students, aged between 20-21 years old. They classified as junior and senior students in the third or fourth year of their studies. Three users identified as white/Caucasian, one as Hispanic, one as black/African American, and one as biracial, who specified as both white Caucasian and black/African American.

User	Age	Gender	Race	Class
U1	20	Female	White	Junior
U2	21	Female	White	Senior
U3	20	Female	White	Junior
U4	20	Female	Hispanic	Junior
U5	20	Female	Biracial	Senior
U6	20	Female	Black	Senior

Table 1. User Demographics

RESULTS

User Descriptions

Before completing the tasks on the cameras, users were asked to describe how the camera felt in their hands. 4 out of 6 users described the Nikon z6ii as heavy while 2 users described it as being light. Users enjoyed the large grip that the body offered and felt the grip offered additional support not to drop the camera. The Canon R8 was described as light weight, simple, and small. 2 users felt that the grip on the Canon R8 was almost too small, stating that they would need a strap to feel comfortable keeping the camera from dropping. The Sony a7iv was described as heavy and bulky with “a lot going on.” 2 users expressed feelings of intimidation based on the weight and size of the camera in addition to the number of buttons. 1 user also mentioned that the buttons did not offer a natural placement of the thumb.

Turning the camera on and off (task 2 and task 8) took the less amount of time compared to the other tasks. Users tended to turn the camera off more quickly than turning the camera on. This could be because they became familiar with the location of the on and off switch.

On average, task 7, formatting the SD card, took the longest amount of time for users to complete except on the Canon R8. On the Canon R8, task 4, changing the shutter speed to 1/250, took the longest amount of time on average as users had difficulty locating the appropriate dial. Users also did not discover the camera’s touchscreen functionality.

For each camera, users searched for the shutter speed control in the menu, explored the function of different buttons on the back of the camera, and attempted to use the touchscreen function. For the Sony a7iv, the touchscreen does not allow users to change the shutter speed directly. However, two users discovered the ability to change the shutter speed on the Nikon z6ii and appeared overall impressed with the ability compared to the Sony a7iv and the Canon R8, even though the Canon R8 offered the same functionality. These same users ended up selecting the Nikon z6ii as the camera that offering the best overall experience.

TASK LENGTH

Camera	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	5.67	16.00	28.33	6.33	9.83	51.17	1.83	119
Canon R8	2.33	17.67	64.83	38.33	6.17	22.00	2.50	154
Sony a7iv	3.67	10.17	42.67	9.33	4.00	100.33	2.17	172

Table 4. Average Task Completion in Seconds

User 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	2	15	33	7	1	22	2	82
Canon R8	2	7	20	7	3	24	3	66
Sony a7iv	2	6	3	9	2	31	1	54
User 2	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	2	10	61	3	5	6	2	89
Canon R8	2	18	4	24	4	20	2	74
Sony a7iv	4	5	20	6	2	42	3	82
User 3	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	6	10	18	3	8	167	2	214
Canon R8	4	21	172	13	15	34	3	262
Sony a7iv	5	4	151	4	2	127	1	294
User 4	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	4	22	32	4	12	84	1	159
Canon R8	2	5	30	34	3	10	2	86
Sony a7iv	4	3	3	23	13	99	3	148
User 5	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	2	15	5	2	2	6	2	34
Canon R8	3	28	157	19	3	16	2	228
Sony a7iv	2	24	23	6	2	99	3	159
User 6	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	Task 8	Entire Duration
Nikon z6ii	18	24	21	19	31	22	2	137
Canon R8	1	27	6	133	9	28	3	207
Sony a7iv	5	19	56	8	3	204	2	297

Table 3. Individual Task Completion in Seconds

It took users an average time of 28 seconds to change the shutter speed on the Nikon z6ii, 65 seconds on the Canon R8, and 43 seconds on the Sony a7iv. The dials located on the top of the camera bodes were often the last controls checked compared to the buttons located on the back of the cameras or the touchscreen functionality.

The Sony a7iv averaged 100 seconds for task 7, formatting the SD card. The Nikon z6ii averaged 51 seconds and the Canon R8 averaged 22 seconds. To successfully complete the task on the Sony a7iv, users would have to press the menu button located in the top left corner on the back of the camera. They would travel one option down to "Shooting," which is represented by a red camera icon. Users would than tab over once onto the "Shooting" menu. From there, they would go down 2 tabs to "Media" where "Format" is located. All 3 subsections would be on full display for the users to see the menu options.

For the Canon R8, users would also select the menu button located in the top left corner. Users would then tab to the left 5 times to land on the Setup menu, represented by a wrench icon. Users would land on subsection 1 of the Setup menu and tab down 3 times to locate "Format Card." For the Nikon z6ii, the menu button is located on the button right side of the back of the camera. Users would tab down 5 times to locate the Setup menu, also represented by a wrench icon. There, "Format Memory Card" is the first option available.

All 6 users overlooked the Sony's "Format" function, traveling through the menu several times over in search of the function. 3 users stopped under the "File" subsection before exploring other options in the menus. Users grew increasingly frustrated with the Sony a7iv as more time passed. Once, they finally located the option, they expressed annoyance at being unable to find it more quickly.

User	Easiest Menu Interface	Purchase Preference	Best Overall Experience
U1	Nikon z6ii	Canon R8	Canon R8
U2	Nikon z6ii	Nikon z6ii / Canon R8	Nikon z6ii
U3	Canon R8	Nikon z6ii/ Canon R8	Canon R8
U4	Canon R8	Canon R8	Canon R8
U5	Nikon z6ii	Nikon z6ii	Nikon z6ii
U6	Nikon z6ii	Canon R8	Canon R8

Table. 2 User Camera Selections

Task 5, taking an image of an object in the room, averaged significantly longer on the Canon R8. There are multiple factors that could impact this outcome. For example, user 6 took the longest amount of time at 133 seconds to take an image. The user experienced difficulty obtaining their desired image focus. User 4 and user 2 experienced the same difficulty though it did not take them as long as to take an image. This could be due to user error or due to the connection between the camera body and the lens or simply the lens itself. A defined reason cannot be determined without further inquiry.

Menu Interface

4 out of 6 users selected the Nikon z6ii as the camera with the easiest menu interface. Users described the Nikon's menu interface as the less complex. For example, participant 6 described the Nikon's menu as having "everything... right there. It wasn't hard to swipe through everything to get to wherever you need to get to." Users also mentioned that the Nikon z6ii had less tabs to swipe through in order to get to the format card function.

The Canon R8 was selected by the remaining two users. One user cited their decision on the sentiment that the Canon R8's menu felt more "consolidated" and as if "there wasn't so much to sift through in the menu area."

None of the users selected the Sony a7iv as having the easiest menu interface and it received negative feedback. User 4 described the Sony a7iv menu as "harder, because there's a lot of categories in the menu and it was harder to navigate through and try to find it [format card function]." Another user described the format option as looking like a header and not an option she could select, which caused her confusion. Also, the function was labelled as "Format" and not "Format Card" or "Format SD Card." Further research could determine if this is sentiment is felt among other users. It is important to note that users did overlook the format option in the Nikon z6ii and Canon R8 as well, but it did not take them as long to locate it, which can be seen in Table 3.

Purchase Prefrence

2 users were tied between the Nikon z6ii and the Canon R8 as the camera they would purchase without cost as a factor. One user selected the Nikon z6ii as the camera they would purchase, and the remaining 3 users selected the Canon R8. Users citied the compact size, light weight body, overall comfort in the hand, and menu interface as their reasons for selecting the Canon R8. For example, user 4 described the Canon R8 as "easier to use, it's light, it's smaller, it was just more comfortable to use than the other two."

Users also described the Canon R8 as the least overwhelming due to the small number of buttons located on the back of the camera body. For the Nikon z6ii, users citied the image quality and ease of use as their deciding factors to purchase that camera. However, the additional buttons located on the camera deterred one user.

Overall Experience

4 out of 6 users described the Canon R8 as offering the best overall experienced. Users once again citied compact size, light weight body, and ease of use. Users shared that they had more confidence using the Canon R8 compared to the Nikon z6ii and the Sony a7iv. One user also felt that they would grow frustrated with the Nikon z6ii and the Sony a7iv, and therefore, they found the Canon R8 to offer the best overall experience.

2 users selected the Nikon z6ii as the camera that offered the best overall experience. User 2 stated that the Nikon was the easiest for them to figure out. However, they did mention that there were "some things they didn't like about it," such as the requirement for users to unlock the dial to switch from auto to manual. But they felt the Nikon z6ii was easier to use, felt more natural, and they appreciated the electronic panel on the top. User 5, who selected the Nikon z6ii, also mentioned the perceived image quality as one of their deciding factor.

User Comments

Users were asked to provide any additional comments about the cameras at the end of the study. For the Nikon z6ii, two users mentioned the inconvenience of pressing a button to unlock the mode dial. Another user mentioned that the Nikon z6ii had "the prettiest display." The Nikon z6ii also received the most positive feedback regarding image quality as 3 users described the image quality as "nice," "clear," and "very good quality."

Only user 6 provided additional comments on the Canon R8, stating that they felt as if they couldn't locate the shutter button and when they did, they didn't like that a certain amount of pressure had to be applied to activate the shutter. They citied this as a frustrating interaction. The Sony a7vi did not receive any additional comments from users.

Systems Usability Scale

It is important to note that user 3 experienced a similar issue with the Sony a7iv, where the lens appeared to have difficulty focusing on the user's desired object.

The individual SUS score given by each user was calculated and then averaged to assign an individual SUS score to each camera. The results of each survey can be seen in Table 5. Nikon z6ii and Canon R8 were similar in SUS scores, with Nikon z6ii receiving a rounded score of 57 and the Canon R8 receiving a score of 55. The Sony a7iv received the lowest SUS score at 39. All 3 cameras scored below the average SUS score of 68 (Sauro, 2011), indicating that there is some room for improvement in terms of usability for beginner camera users.

	Nikon z6ii	Canon R8	Sony a7iv
User	SUS Score	SUS Score	SUS Score
U1	32.5	55	32.5
U2	80	67.5	40
U3	42.5	37.5	12.5
U4	42.5	32.5	62.5
U5	80	95	52.5
U6	62.5	45	32.5
Avg	57	55	39

Table 5. Camera System Usability Scale Scores (SUS Score)

DISCUSSION

This study consists of a comparative analysis between 3 popular mirrorless cameras currently available in the industry. The goal of the study is to provide insight into camera features that enhance the product's usability and the overall user experience with hopes to offer a small contribution to future product innovation. Through this investigate, this study was able to identity user pain points, assess four components of usability for each camera, and offer suggestions for opportunities to improve camera usability and user experience.

When users picked up the cameras, their first response was often in reference to the physical weight of the camera and their ability to grip the product comfortably. As users continued their exploration of the camera bodies, they expressed feelings of concern when presented with a large number of buttons located on the back of the camera. As beginners, the buttons intimidated this set of users. The number of buttons appeared to influence the users' perceived usability of the cameras. Opinions on the cameras' grips were varied as well as mention of a location to place their thumb.

Based on user responses, it appears that the weight of the camera bodies and their perceived usability influence their purchase preference. All 6 users cited their consideration of the Canon R8 based on its lightweight body and small number of buttons. As product designers and engineers continue to manufacture and create the next generation of camera bodies, it should be acknowledged that the physical weight of the product will influence the user's overall user experience and should be considered of extreme importance. A lightweight camera body enhances the user experience for beginner photographers as well as a compact design in terms of controls and buttons. A compact design could also decrease the number of user errors and allow for an increase in the product's learnability and memorability, enhancing the overall user satisfaction as users are able to more easily accomplish their goals. This is also demonstrated as 67% of users selected the Canon R8 as having the best overall experience. The Sony a7iv, despite being considered one of the best hybrid professional cameras on the market, fell behind in this study because of its heavy body and additional number of buttons and controls.

The completion of task 7 also appeared to heavily influence the user experience of the cameras. The menu interface of the camera bodies serves as an important function to every photographer. It offers the ability to change the camera's performance features and allows users to change their settings appropriately. Users often want quick access to the menu to adjust the settings and functions efficiently. Task 7 took the longest amount of time for users to complete except for on the Canon R8. What is interesting is that the Sony a7iv averaged the longest amount of time to complete this task despite having the shortest distance to the format card function, meaning the Sony a7iv had the least number of necessary clicks for users to successfully format the SD memory card. The Canon R8 required 9 clicks and the Nikon z6ii required 6. Users overlooked the function on the Sony a7iv several times over and grew frustration at their inability to locate the "Format" option. One user mentioned that they overlooked it because it appeared to be a header and not a clickable option. The other menu interfaces also read as "Format Card" or "Format SD Card," while the Sony a7iv only says "Format." More experienced photographers and camera users may have been able to recognize this function more quickly, but beginners seemed to expect the function to read as "Format Card." Additionally, the Sony a7iv presented 3 subsections of the menu at the one time while the Canon R8 and Nikon z6ii interface's focus on one main section. The large amount of information presented on the Sony a7iv's interface could potentially overloaded users.

Based on user responses and the length of time it took them to successfully complete the task, the Sony a7iv menu interface could improve its efficiency, errors, learnability and satisfaction. One area of improvement could be to redesign the menu interface with an improved visual hierarchy that provides better signifiers to users and reduces the amount of information present on the screen. This would enhance the mentioned components of usability and enhance the overall user experience. This could potentially result in an increase of the Sony a7iv's SUS score as well.

The average completion rate of task 7 was the quickest on the Nikon z6ii at 119 seconds. The Canon R8 averaged at 154 seconds and the Sony a7iv took around 172 seconds. The Nikon z6ii was also selected by 66% of users as having the easiest menu interface. This indicates that the Nikon z6ii's offers a higher level of efficiency with a convenient interface that allows users to quickly navigate and find what they need. The menu interface required 6 clicks, one more than that Sony a7iv. However, the Nikon z6ii's interface communicates more effectively with its users through visual hierarchy while displaying an appropriate amount of information on the screen. In addition, while the Canon R8 averaged 64.83 seconds for task 4, changing the shutter speed, the Nikon z6ii averaged only 28.33 seconds. This could indicate that the Nikon z6ii is also more efficacy in terms of control placement and accessibility. The touchscreen capabilities were discovered by two users while no users utilized the same capability on the Canon R8. This could indicate that the Nikon z6ii communicates the capability to the users while the Canon R8 lacks a signifier. These reasons could also be why the Nikon z6ii received the highest SUS score of 57.

However, users did comment that the Canon R8's menu was easier to navigate through in comparison to the Sony a7iv and the difference was not significant enough to deter most users from selecting the Canon R8 as the camera they would purchase without cost as a factor. Most users also selected the Canon R8 as offering the best overall experience, indicating that it offered a balanced user experience throughout the different tasks despite certain challenges. For example, there were some inconsistencies as some users struggled to capture an image with the Canon R8. This indicates that there is room for improvement with the camera's autofocus system or the camera's shutter controls. However, the inconsistency could be due to user error, the lens connection to the body or even the lens itself. Further inquiry would be necessity to determine what exactly causes the issue and how it can be improved upon to enhance the usability of the Canon R8. Again, this inconsistency did not deter users from selecting the Canon R8 for its compact size, easy to navigate menu interface, and overall comfort. The size and weight of the Canon R8 influenced the user experience by providing the users with a level of confidence that the Nikon z6ii and Sony a7iv did not. It is possible that users experienced this confidence as beginners, but it still speaks to the Canon R8's usability in terms of learnability and satisfaction as users felt more confident navigating the product.

The Nikon z6ii and the Canon R8 received similar SUS scores. The Nikon z6ii received a score of 57 while the Canon R8 received a score of 55. The Sony a7iv received the lowest score of 39. As previously mentioned, all cameras scored below the average SUS score of 68, indicating that there is room for improvement in the usability of all the mirrorless cameras used in this study. Based on the task completion and user feedback, areas for improvement could include the menu interfaces, better control signifiers, and more light-weight product designs. The results of this study emphasize the importance of continued user testing as manufacturer seek out ways to improve their products for their targeted audiences. The pain points users experienced as they attempted to take an image, format the SD card, and change the shutter speed likely impacted the below average SUS scores.

Future Studies

The specific pain points that have been identified through this study have been shown to influence product usability and user experience, which could potentially impact consumer purchase decisions. However, it should be noted that purchase decisions are not based on usability and user experience alone. But a disregard for them could lead to buyer's regret and ultimately influence manufacturer reputations. For example, as Nikon slowly entered the mirrorless camera market, it took a great hit on its reputation as one of the leading manufacturers as it continues to fight to keep up with emerging technologies from Canon and Sony based on camera specifications. This is despite the Nikon z6ii high level of positive feedback in this study. Future studies should investigate the influence of perceived usability and how it effects product purchase decisions for mirrorless cameras.

Future studies could also attempt to offer improvements for the pain points addressed in this study to create camera prototypes that offer solutions. For example, a more in-depth study could investigate the specific elements in the visual hierarchy of the Nikon z6ii's and the Canon R8's menu interfaces that make it easier for users to navigate through the menu interface. Additionally, future studies could implement long-term methodologies that could gather additional insight into the camera's usability, specifically memorability. It would also be important to gather insight into the camera's usability in real-worldsettings, where photographers are attempting to accomplish a number of complex goals to catch their desired image. Beginners are also not the only audience that desire a camera with a high level of usability and a positive user experience. Future studies should also seek out feedback from experience photographers who utilize mirrorless cameras in multiple environments.

Limitations

This study is not without its limitations. As previously mentions, all participants in this study were undergraduate students at a specific university. All the participants were also female within the ages of 20-21. Mirrorless cameras are used for a wide variety of users across the globe and cultural content must also be taken into consideration when exploring the usability and user experience of product design. This researcher also feels as if there were missed opportunity to specifically explore the perceived usability of the mirrorless cameras. Additional interview questions could have been added to investigate how perceived usability influenced user decisions. Lastly, it would have been preferred that the Sony a7iv also have a 50mm 2.8 lens attached, but due to resource constraints, a larger lenses has to be used.

CONCLUSION

In conclusion, continued product innovation is inevitable as camera technology continues to improve and impact our global society. But along with that product innovation, new challenges will arise that impact the camera industry's market as smartphones continue to be improved alongside them. That is why it is important for both researchers and practitioners to fully understand the important role of usability and user experience as they design cameras for a variety of different users. This study offers insight into the usability and user experience of the Nikon z6ii, the Canon R8, and the Sony a7iv, as examples of some of the top mirrorless cameras available on the market. This study aimed to provide insight into the camera features that users found to be most user-friendly to evaluate if those features influence purchase decisions. Pain points were also identified as areas of improvement in terms of usability to enhance the overall user experience.

It was found that a lightweight and compact camera body was preferred by users who are beginner photographers with little to no prior experience with cameras. Users also found the Nikon z6ii's menu interface to be the easiest to interact with as it required a few numbers of clicks and displayed concise information, allowing the users to easily locate their desired function. The Sony a7iv, however, was found to have a difficult menu interface that confused users and increased user frustration. This could have potentially resulted in the Sony a7iv's lower SUS score. This indicates that it is important for designers to successful understand user behaviors and create interfaces with appropriate visual hierarchies and amounts of information. The lack of signifiers for certain controls also influenced the user experience and perceived usability of the camera bodies. Users' confusion when changing the shutter speed indicated that signifiers could be utilized more effectively to increase the camera's usability. Overall, with SUS scores below the average of 68, there is room for improvement in the usability of all 3 cameras used in this study. The investigation of the user-friendly features, pain points, and experience of these users can be used to enhance future product design for mirrorless cameras to enhance the user experience for beginner photographers.

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EMILY TAYLOR

Emily Taylor is a junior majoring in Graphic Communications from Charleston, South Carolina. Alongside her studies, she is an active member of Gamma Epsilon Tau, an honors sorority, and serves as President of the 2024-2025 student chapter of TAGA. Now in her third year with TAGA, Emily has gained extensive hands-on experience in print production, quick problem-solving, time management, and bookbinding. She brings these skills to her leadership role, overseeing this year's book design to uphold industry standards and ensure that quality and attention to detail are reflected in every aspect of the technical journal. She finds great joy in collaborating with her peers and witnessing the hard work that goes into creating this journal.

Emily is passionate about print production, particularly in Direct-to-Garment and Sublimation printing. She also enjoys advancing her design skills by creating business cards for emerging business owners. In the summer of 2024, she completed her first internship with Charleston Cotton Exchange, where she deepened her knowledge of the screen printing industry and explored additional areas such as embroidery. Working closely with press operators, Emily gained valuable insights into project management, attention to detail, and multitasking. Additionally, Emily is a teaching assistant in the Graphic Communications department, helping students master the Adobe Suite and apply their skills to marketing materials like magazine spreads, brochures, posters, and even promotional items such as mugs, coasters, and T-shirts. Outside of teaching and designing projects, she enjoys expanding her knowledge of Adobe Suite applications and exploring Figma for UX/UI design.

CASSIDY WAITES

Cassidy Waites is a junior Graphic Communications major from Newberry, South Carolina. Cassidy is a full time student at Clemson University, where she is a passionate member of Gamma Epsilon Tau, Tiger Vision, FCA, and AWSM (The Association for Women in Sports Media). This is her second year as a member of Clemson TAGA, and she is currently serving as the Vice President. Being involved in TAGA has given her the opportunity to gain valuable hands-on experience in publication design, management, and print production. Cassidy takes pride in being able to collaborate alongside her fellow classmates and is grateful to be apart of such a hardworking, supportive team.

Cassidy has a genuine love for the graphic arts and designing. She also thoroughly enjoys photography, logo design, and video production. Cassidy completed her first Internship in the summer of 2024 with Newberry Academy private school, where she worked as the Sports Media Manager. In this role, she designed specialized content for their varsity athletic teams, arranged and shot media days, maintained the online image of the school and athletic department, and assisted in the development of new marketing strategies for recruitment and enrollment. When Cassidy is not designing, you can find her taking photos, enjoying the outdoors, spending time with her friends and family, or attending Clemson athletic events. After graduation, she plans to pursue a career as a graphic designer or marketing manager.

ZACHARY WALSH

Zachary Walsh, a senior from San Antonio, Texas, is pursuing a degree in Graphic Communications at Clemson University. Now in his second year as a member of the Clemson TAGA team, he is eager to continue contributing his skills and passion to the group. With a strong emphasis on teamwork, Zachary thrives in collaborative environments, working on both creative and technical projects. He is currently working as a Visual Communications Strategist for a startup company and also with Voloridge Investment Management to enhance and implement their brand across various platforms. Previously, he worked as a web developer, designing websites for emerging businesses. Zachary looks forward to applying his expertise to TAGA's initiatives and gaining further valuable experiences with the team.

AMELIA SCHERER

Amelia Scherer is a junior Graphic Communications major at Clemson University. She is a varsity student-athlete and has been a member of the Clemson Women's Rowing team since 2022. This is her first year representing the Clemson Tigers at TAGA, and she is honored to represent a top 100 nationally ranked University. Being both a student-athlete and a dedicated member of the Graphic Communications program, Amelia has learned the importance of time management, discipline, and teamwork. These qualities she brings to both her academic and athletic endeavors. She looks forward to expanding her knowledge and contributing to the field of graphic arts through her involvement with TAGA.

BELLA POLIZZI

Bella Polizzi is a sophomore majoring in Graphic Communications and double minoring in Brand Communications and Business Administration from Dewey Beach, Delaware. Fall 2024 has been her first semester participating in the TAGA creative inquiry at Clemson, and she sees herself staying involved for the remainder of her time on campus. Her favorite experience with TAGA has been getting to become more involved within her major. Bella is also involved with Sigma Kappa and The Tiger newspaper. She is looking forward to the rest of her journey with TAGA!

GWENDALYNNE HANSON

Gwen Hanson is a sophomore at Clemson this year, and is very excited as this is her first year with TAGA. Her hometown is Bridgewater, MA. Apart from TAGA, Gwen is also a member of the Gamma Phi Beta chapter on Clemson's campus. She has loved being a part of the TAGA team this year and learning about the process of bringing a book to life.

MADISON REEVES

Madison Reeves is a junior at Clemson University majoring in Graphic Communications. She is from Columbia, South Carolina. This is Madison's second semester working with TAGA. Last semester, her role in TAGA involved helping with the journal's production, and this year, she is excited to learn about how the journal design comes together. She is a member of Pi Beta Phi, an international women's fraternity member on campus. Madison is also a big fan of motorsports and football, and she plans to pursue a career in graphic design for an NFL team after college.

EMILY ALLEN

Emily Allen is a junior from Newberry, South Carolina, majoring in Graphic Communications at Clemson University. This is her first year with TAGA, and she has enjoyed getting more involved with her major. She is excited about everything TAGA has in store and looks forward to future opportunities. She brings experience in graphic design, pre-press work, and digital content creation. Emily is strongly interested in these areas and enjoys expressing her creativity in various forms, from videography to drawing and everything in between. In addition to TAGA, Emily is actively involved in Clemson's academic fraternity for the graphic arts, Gamma Epsilon Tau (GET), Clemson FCA and intramural sports. She is eager to continue growing her skills and contributing to graphic communications.

ALEX GARRICK

Alex Garrick is a sophomore graphic communications major from Bishopville, South Carolina. Alex is a full-time student at Clemson University, where he is an active member of Central Spirit and a teaching assistant for the Graphic Communication department. Now this is his second year on the production team for TAGA, and he is looking to continue building his skills in a hands-on environment. Alex is extremely passionate about photography, design, and production and hopes to use these skills in his career. Alex looks forward to the work and opportunities that TAGA builds upon.

EIAN TORRES

Eian Torres is from Atlanta, Georgia, and he is a sophomore graphic communications major at Clemson University. This is his first semester participating in TAGA, and he is super excited to be able to work with his fellow peers on all the ends and out of production and designing for TAGA. He is especially happy for the opportunity to work in screen print and production because, over his first couple of years here at Clemson, he has developed a special fondness for screen Print.

MADISON KENNEDY

Madison Kennedy is a sophomore graphic communications major minoring in brand communications from Greenville, South Carolina. She is very excited to be a part of TAGA this semester as it is her first time doing it. Her involvement outside of TAGA includes being a member of Clemson's Pi Beta Phi sorority and a member of Clemson's SCUBA club. She is so glad to be a part of TAGA this year and cannot wait to gain the experience and become more involved within her major!

ERIKA HARDIN

Erika Hardin is from Charlotte, North Carolina, and is a junior majoring in Graphic Communications at Clemson University. Her main interests are direct-to-garment printing and the creative side of graphic design. She has previously worked with The Tiger for Clemson on social media. With The Tiger, Erika designed various types of social media posts including one that was submitted in the South Carolina Press Association Awards. Erika is excited about her first year in TAGA and looks forward to learning new skills.

MG CORBIN

MG Corbin is a sophomore Graphic Communications major from Greenville, South Carolina. In addition to her studies, she is actively involved in the student-led radio station, WSBF-FM, at Clemson University, where she serves as the Promotions Director. She enjoys the challenges that come with Graphic Communications because there is always something unique around every corner. This is her first year participating in TAGA, and she is so excited to be more involved within her major and gain hands-on experience. She is looking forward to collaborating with her peers and representing Clemson University for the 2025 student chapter.

NYLE MCCRAY

Nyle McCray is a senior Graphic Communications major from Anderson, South Carolina, and is thrilled to be participating in TAGA for the first time. A passionate creative, Nyle thrives on collaboration, values teamwork, and excels at being task-focused and detail-oriented. Last fall semester she interned with Direct One in Orlando Fl where she learned valuable skills in digital layout design, variable data printing and creating posts for their social media. Nyle is excited to be back on campus ready to learn and with a drive to innovate and contribute meaningfully, Nyle looks forward to bringing fresh mind and dedication to the TAGA team.

CAMILA SORIA FLORES

Camila Soria Flores, a sophomore from Myrtle Beach, South Carolina, is majoring in Graphic Communications at Clemson University with a minor in Brand Communications. Passionate about the development and evolution of graphic arts and their application to building business market identities, Camila is thrilled to be contributing to the TAGA program for the first time. With four years of experience in the Adobe Creative Suite, Camila has cultivated her creative talents through various leadership roles, including serving as Gamma Epsilon Tau's 2024-25 T-shirt Design Chair, her major's honors fraternity. She has also held the position of Fundraiser Executive Chair for Clemson's FIRST program where she keeps dedicating her time to help first-generation students succeed through mentoring practices as a continuing member. Additionally, as an Adobe intern, she provides guidance and expertise to those with questions about AdobeSuite and video/audio production at Clemson's University's Adobe Studio & Makerspace. Camila is deeply committed to collaborating with peers and industry professionals to deliver creative work that is both innovative and efficient. Through TAGA, she aims to further develop her creative professionalism, focusing on mastering effective production and publication techniques that leave an everlasting impact.

CATALINA ZIEGLER

Catalina Ziegler is a senior at Clemson University majoring in Graphic Communications from a small town called Lewisburg, West Virginia. Outside of her studies, she is involved in Alpha Phi Omega, a national co-ed service fraternity that participates in numerous community projects within the Clemson area. Catalina has a strong creative background, but is looking to grow her print-production skills through TAGA. After graduation, Catalina is looking to pursue a career in graphic design or print production.

PRODUCTION NOTES

TAGA Journal Guidelines

Dimensions: 7.5” x 10.5”
Color Palette: Pantone
Fonts:
Headings: Raleway
Chapter Numbers: Bold 700
Body Text: Lora (Regular)
Theme: Texture

Production Timeline
Fall Semester - 2024

September 13
Assigning Sections

- Cover: Zach
- Divider 1 / Chapter 1: Coated & Uncoated – Table of Contents (Cassidy)
- Divider 2 / Chapter 2: Coarse & Sleek – (Emily)
- Divider 3 / Chapter 3: Engraving & Embossing – (Amelia/Madison)
- Divider 4 / Chapter 4: Foil & Matte – (Bella/Gwen)
- Production Notes: Emily

Homework: Determine layout shapes, brainstorm design and chapter ideas

September 20
Cover Design Finalization

- Finalize cover layout and design elements

September 27
In-House & Outsourcing Discussion

- Determine production/ print capabilities
- Identify elements needing outsourcing

October 4
Colors, Fonts & Chapter Divider Theme Selection

- Define color palette and fonts
- Establish chapter divider style

October 11
Font Selection & Divider Page Completion

- Due Date: October 14 for divider pages

Homework: Complete personal bios

October 18
Journal Size & Technical Papers Selection

- Choose journal dimensions and spiral rings
- Assign technical papers: Ramya, Riley, Caitlin

Homework: Create page templates

October 25
Journal Page Templates & Bio Photos

- Finalize page templates
- Collect bio photos

November 1
Book Layout Printing & Color Check

- Print preliminary book layout
- Verify color accuracy

November 8
Content Integration & Dedicated Print Method Pages

- Assign paper selections
- Add content to book
- Dedicate pages to printing methods

November 15
Proof Printing

- Print select pages as proof

November 22
Indesign File Compilation & Proofing

- Compile all pages into a single InDesign file
- Print a full proof for review

December 6
Finishing Touches

- Brian assists with sleeking & texturing

Final Production
Spring Semester - 2025

Within First 2 Weeks:
- Journal mock-up completed
- T-shirt design finalized
- Materials ordered (paper & t-shirts)

February 3
Journal Design PDF Submitted
- Fully completed journal design is sumbitted to TAGA

ADDITIONAL INFORMATION TO BE ADDED