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Replication of Screen-Printing Fabric via Ink-jet Textile Printing

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Abstract. *Digital textile printing (DTP) is fast, flexible, and relatively inexpensive for sample printing, and can be applied quickly in response to consumer demand. The aim of this two-stage research was to analyze the potential of DTP to replace traditional screen printing for a specific textile product. In Stage One, an optimal DTP workflow was established. The workflow included determination of the colorant and substrate combination, color calibration, CAD file, and the necessity of pretreatment. In Stage Two, a visual assessment instrument and protocol were established to evaluate the acceptance of replicated ink-jet printed fabric. The visual assessment and protocol were designed to evaluate the acceptance of the ink-jet printed sample to fully replicate the screen-printed sample via seven measured aspects. These seven aspects include: perceived color difference, lightness difference, overall color, scale, line quality, visual texture, and overall appearance. Data gathered from the visual assessment was then analyzed and compared using SPSS statistics software. The results indicate that DTP demonstrates a significant potential alternative for traditional screen printing.* © *2019 Society for Imaging Science and Technology.*
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1. INTRODUCTION

As the digital world continuously creates new possibilities, digital textile printing (DTP) represents the future direction of technology development in the textile printing and dyeing industry [1]. Global annual consumption of printed textile products is expected to reach 29.8 billion square meters by 2021 with 17.5 percent annual growth rate. Screen printing is the most acceptable textile printing method, accounting for about 35 percent of the overall market in 2017. Although ink-jet printing is expected to replace screen printing as the primary method in 2021 with an 18.5 percent annual growth rate, screen printing remains the most widely used printing method in the textile industry today [2–4]. However, despite its productivity, the dominant rotary screen-printing method has several limitations [1]. One limitation is that color and pattern changes are slow and expensive because rotary screen printing requires a long time to set up (up to 6–8 weeks) [1–4]. The screens needed for traditional printing machines are not as durable as digital file storage, and also require more space for storage and operation [2]. As the textile industry continues to mature, the demand for quicker product production that is responsive to fashion changes is important to compete in consumer markets. Printing of smaller collections, unique textile products, and the sampling process, require greater flexibility of printers and, consequently, faster prepress and printing of color designs [5]. The most promising opportunity to date for addressing these challenges for the printing industry is ink-jet digital printing.

The aim of this research was to analyze the potential of DTP to replace traditional screen printing for a specific textile product. To achieve the research goal, two experimental stages, which address three research objectives, were conducted: (1) To develop a workflow for the fabric replication of a screen-printed fabric using ink-jet textile digital printing; (2) To develop a visual assessment instrument and protocol to evaluate the acceptance of the replicated ink-jet printed fabric; (3) To determine if the ink-jet printed sample was a suitable substitute for screen-printed sample via an expert visual assessment pilot testing.

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2. EXPERIMENTAL STAGE ONE

2.1 *Material*

A rotary screen-printed, 100 percent cotton sample for interior home furniture end use was supplied by Springs Creative Products Group LLC., USA. The corresponding digital design TIFF file, in RGB color mode, color separated into eight channels was also provided. Pretreated and untreated 100 percent cotton was used by Principal Investigator (PI) for ink-jet digital printing. The fabric was supplied by Premex and had a weight of 228 gsm, with a fiber content of 96% cotton and 4% linen. A noncommercial eight-color nanopigment was used.

2.2 *File Preparation*

Color reduction is necessary to control color variety, clean up stray pixels, and ensure color consistency [6]. To guarantee the best replication result, the RGB digital design file was opened in Lectra Kaledo Print software, color reduced, stray pixels cleaned up, recolored using an RGB color table, and kept in an RGB color mode, TIFF format (Figure 1(a)).

2.3 *Color Calibration and Profiling*

Color calibration for all devices is a requirement that actively contributes to a color-managed workflow, and can

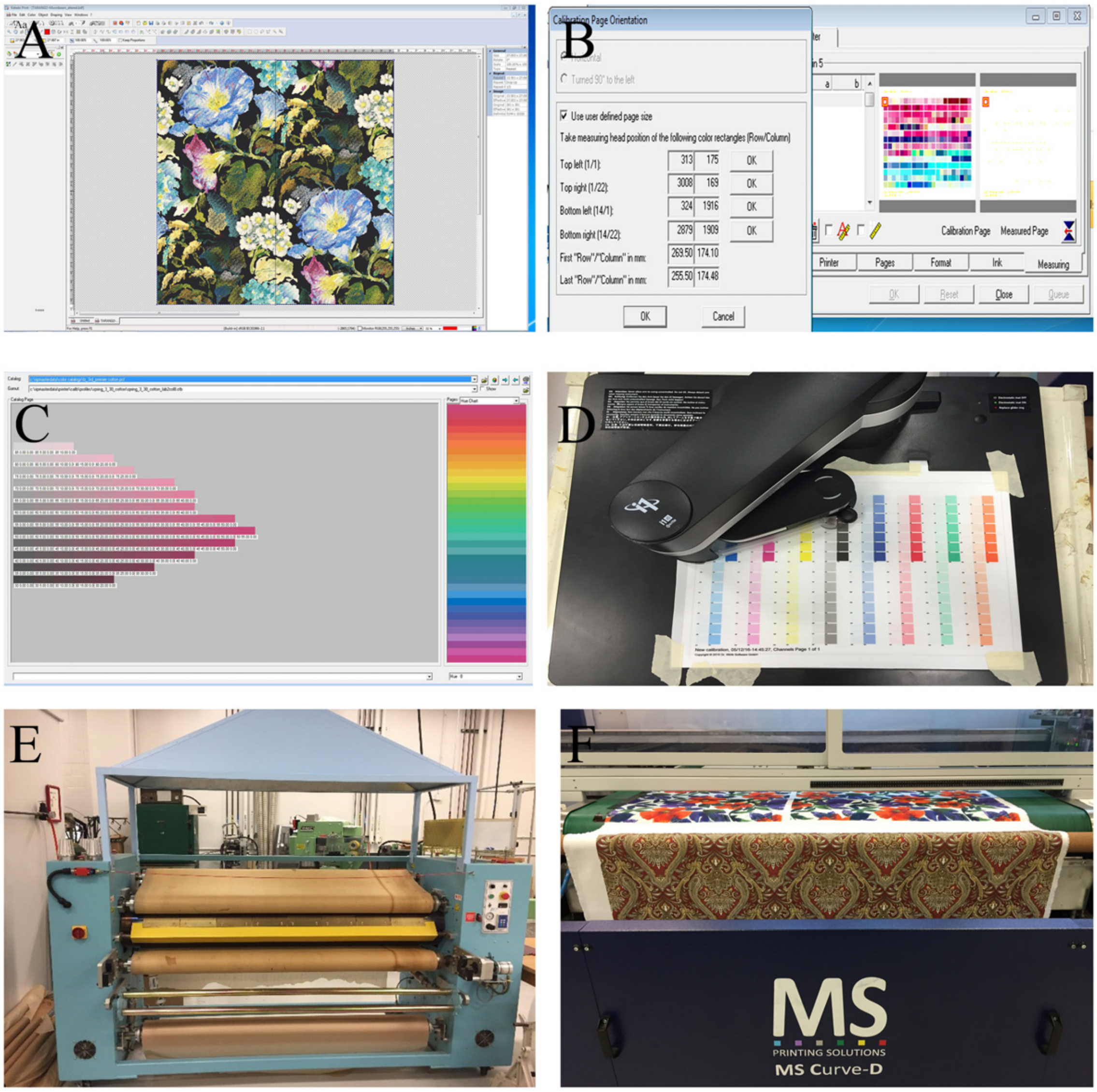

Figure 1. Facilities and process for conducting ink-jet printed sample (A) Color reduction in Lectra Kaledo, (B) Creation of enhanced color profile in RipMaster 10.0, (C) Part of color profile for nanopigment printing on pretreated cotton for MS JP5, (D) X-Rite i1iO spectrophotometer, (E) Practix Mfg heat calendar, (F) MS JP5 Evo Printer.

be used to create a color profile that represents the range of printable colors specifically for a specific substrate and ink combination [6, 7]. For digital textile printing, color calibration provides the color gamut and controls printing process accuracy [7]. As shown in Fig. 1(c), color calibration was performed for each colorant and substrate combination using an X-Rite i1iO spectrophotometer (Fig. 1d) and MS JP5 Evo printer. All steps for creating an enhanced color profile followed a specific workflow.

2.4 *Variables Effecting Ink-jet Textile Printing Results*

Printer setting, pretreatment, as well as the ink and substrate combination were identified as variables affecting the quality of ink-jet textile printed samples. For printer settings, the MS JP5 Evo Printer (Fig. 1f) has eight different modes that varies the ink volume and drop sizes from 4 to 72 picoliters. In this study, individual ink limitations were 100 percent for cyan, red, magenta, orange, yellow, violet, and gray and 120 percent for black. The C setting is the most commonly used production print mode requiring a balance between production speed and print quality. The pretreatment process is time-consuming, and add cost to the final product [8, 9]. Both pretreated and non-pretreated cotton substrates were provided by Springs Creative Products Group LLC., USA. The pretreatment DP-300 (45% solids) for cotton was developed by Lubrizol Corporation specifically for pigment-based ink-jet printing on textiles. The main components in the pretreatment reagents were multivalent metal salts as ink coagulants, acrylic resin for ink anchoring to the substrate, and additives for wetting and surface tension

Figure 2. Screen-printed sample (left) and ink-jet printed sample (right).

control such as isopropyl alcohol, propylene glycol, and silicone-based compounds.

2.5 *Conduct Ink-jet Textile Printing Trial*

The ink-jet sample was printed based on the identified variables. The print trials were conducted with an MS JP5 Evo Printer with Kyocera Drop-on-Demand (DOD) piezoelectric print heads. The Kyocera head has four printing heads with each head containing up to two colors. The eight-color ink set consisted of black, cyan, red, magenta, orange, yellow, violet, and gray. The ink-jet printed sample was heat fixed after printing by Practix Mfg heat calendar (Fig. 1e) with 400 degrees Fahrenheit fixation temperature and 30 seconds dwell time. After fixation, the nanopigment printed cotton sample (Figure 2) was used for conducting the expert visual assessment in experimental stage two.

3. EXPERIMENTAL STAGE TWO

3.1 *Determination of Variables*

To conduct the visual assessment comparison between the screen-printed sample (Sample A) and ink-jet printed sample (Sample B), variables needed to be determined for the assessment protocol and survey instrument. Five variables were controlled consistently during assessment process: illuminant, viewing environment, observers, frequency and interval, and viewing order. Seven variables were chosen to evaluate the perceived difference between the two samples: color, lightness, overall color, scale, line quality, visual texture, and overall appearance.

3.2 *Illuminant and Viewing Environment*

The visual assessment was carried out in the Color Science Lab in the Wilson College of Textiles at North Carolina State University. To minimize variability, the PI arranged carefully controlled viewing conditions, which were kept the same throughout the test trials. A Macbeth Spectra Light III viewing booth with a filtered tungsten daylight-simulating lamp (D65) was switched on during the experiment. This light source was the only illumination in the lab, with all other sources of light turned off. The samples were placed on a 15 × 15 inch medium gray-colored PVC easel, which was set at a 45-degree angle at the center of the viewing booth. Two 15 × 15 inch medium gray-colored PVC easels were used, one for viewing the screen-printed sample and one for viewing the digital printed sample. The lamp of the viewing booth had a color temperature of 6500 ± 200 K and constant illumination of approximately 1400 lx [9–16].

3.3 *Observers, Frequency, and Interval*

Experienced participants are recommended for visual assessment rather than inexperienced participants to increase the accuracy and shorten the total experiment time [13, 14, 16]. To streamline the assessment process, all the participants in the assessment were experienced experts in ink-jet digital printing, color matching, screen printing, apparel product development, home interior product development, or other related areas. AATCC provided a pair of blue dyed fabrics samples so that participants could practice an assessment before the official experiment. Moreover, the Neitz test was taken before the official experiment to determine whether the participants had normal or abnormal vision.

According to the American Association of Textile Chemists and Colorists (AATCC) standard, each participant would repeat the assessment three times with 24 hours between each trial. The time interval was needed as participants may memorize their answers or get tired if they complete three trials at once [17–19]. Pearson (Pearson Correlation Reliabilities) and ANOVA (Analysis of Variance) were used to analyze the correlation and reliability of the three trials [13].

3.4 *Viewing Order*

Screen-printed and ink-jet printed samples were all multi-color samples, where distinct colors would affect each other during the observation process [13, 16]. Variance could happen if an observer viewed the colors in a different order [13]. Evaluating the color in the same order can eliminate the variance [17, 20]. A color key was created by PI which represented the main colors on the screen-printed sample. As shown in Figure 3, Color 1 is Black, Color 2 is Yellow, Color 3 is Dark Green, Color 4 is Gray, Color 5 is Blue, Color 6 is Red, and Color 7 is Cyan. Observers viewed the sample based on the numbered order.

3.5 *Expert Visual Assessment Instrument Variables Determination*

Color difference was used to determine how close the color matched between the ink-jet printed and screen-printed samples, including a comparison between color values matching of each single color listed on the color key [19]. Lightness is the most direct color visual effect and a very important quality index for a textile product [19, 20]. After identifying the single color change level, participants compared the lightness of each color. Participants were asked to rate the overall color when assessing how well the appearance of the ink-jet printed sample matched the screen-printed sample [16, 19, 20]. Scale was used to evaluate the overall print size proportion of the ink-jet printed sample compared to the screen-printed sample [18]. Line quality was

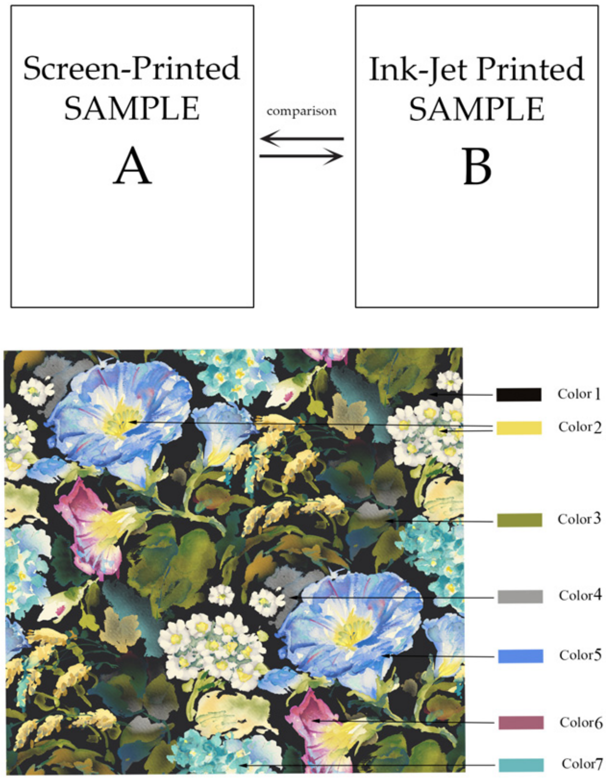

Figure 3. Color key for visual assessment.

Figure 4. Gray Scale for Color Change (AATCC).

used to evaluate how well the weight, clarity, and uniformity of the print in the ink-jet printed sample were compared to the screen-printed sample [15]. Visual texture was used to evaluate the ability of the ink-jet printed sample to replicate print combined with the woven structure of screen-printed sample [15, 17]. Overall appearance was used to evaluate how well the color, scale, line quality, and visual texture interacted in the ink-jet printed sample compared to the screen-printed sample [9, 16–20].

3.5.1 *Development of Survey Instrument*

A survey instrument was developed and submitted to North Carolina State University's Institutional Review Board (IRB) for approval prior to the assessment. The survey instrument included questions relating to the three trials the participants were to complete. The instrument included informed consent, demographics, the Neitz vision test and the practice visual assessment test, and the first assessment trial (4, 5). During the second and third trials, participants were asked to complete the second (6, 7) and third assessment (8, 9), respectively. In the second and third assessment trials, the same questions used in the first assessment were asked. In total, each participant repeated the assessment three times, but participants were not informed in advance that the same questions would be repeated for each trial.

3.6 *Scale Description*

AATCC Gray Scale was used to evaluate the perceived color shade differences between two samples. As shown in Figure 4, participants assigned a value of 1–5 after comparing colors, with 5 representing no color difference between samples and 1 representing the highest color difference between samples [19]. The participants were able to move the AATCC Gray Scale freely when compared to the color difference but were instructed not to move the samples to be assessed. Regarding overall color matching, line quality, visual texture, and overall appearance, five feasible options were given to participants to describe the matching level between two samples which were: Not at all (1), Slightly (2), Somewhat (3), Mostly (4), and Exactly (5). Each option was given a number for statistical analysis purposes. Regarding the question of scale matching, participants gave an answer of either yes or no. For the color lightness, participants were asked to choose one of three options that best described the lightness relationship between the two samples; A is lighter than B1 ($A > B$), B1 is lighter than A ($A < B$), and A1 is the same lightness as B ($A = B$).

3.7 *Identify Participants and Samples Preparation*

A list of possible participants either from experienced industry professionals or Ph.D. students from North Carolina State University was created. The industry professionals were working in the areas of fabric design, home interior product development, color matching, ink-jet digital printing, or screen printing. The Ph.D. students were performing research in color science field. Research information and invitations were sent out through e-mail to 25 potential

Figure 5. Viewing Booth Setup: Screen-Printed Sample (Left), Ink-jet Printed Sample (Right).

Figure 6. Viewing set up for practice sample.

participants and 12 of them finished all three trials. To help control for any possible effects caused by gender and occupation, six females and six male participants, six from industry and six from academia, were selected. The ink-jet printed cotton fabric and original screen-printed fabric were both folded into 15 × 15 inch rectangles (Figure 5). Every color used in the design was shown in the pattern size selected, which was smaller than one repeat to protect the copyright of Springs Creative Products Group LLC., USA.

3.8 *Expert Visual Assessment Viewing Protocol*

The participants wore gray gloves to minimize color variability as well as to prevent damaging the samples and the AATCC gray scale. The participants sat in front of the Macbeth Spectra Light III viewing booth, and the filtered tungsten daylight-simulating lamp (D65) was turned on by the PI. While the participants adapted to the light source by sitting in the viewing booth for 2 minutes, the steps of the experimental process were explained to them. After participants adapted to the viewing conditions in the lab, they were shown the informed consent form. Once they gave their consent, the Neitz Color Vision Test was given to the participants and their answers were evaluated by the PI immediately. While their answers were scored, the participants were asked to complete the demographic information part of the survey. A pass or fail score was assigned to each participant based on the Neitz Color Vision Test results. If a participant failed the test, the experiment would be immediately stopped; otherwise, the experiment continued to the second test. The test samples which were provided by the AATCC Color Change Evaluation Proficiency Testing Program were given to participants for viewing practice. A pair of blue 3 × 3 inch samples were placed in the viewing booth on the easel with a hairline gap between them (Figure 6). Participants sat in front of the viewing booth with gray gloves on and used the AATCC Gray Scale freely to identify the color shade change for this pair of samples. The PI stood near the participants and assisted with using the AATCC Gray Scale as needed to ensure correct use.

The color key, which pointed out the specific color that needed to be observed for any noticeable changes from Color 1 to Color 7, was provided to participants. The participants were free to move the color key and AATCC Gray Scale to identify the color change value for the seven corresponding colors between the pair of samples, but they were not allowed to move or change the display of samples. The screen and the digital printed sample were identified by labels on the back of the 15 × 15 inch medium gray-colored PVC easel (one for each sample) to maintain consistency during experiment. Participants performed color visual assessment and were asked to finish all the survey questions. Each participant would repeat the assessment three times with 24 hours between each trial. The same sample sets, viewing booth, and viewing conditions were kept through all the trials.

4. RESULTS AND DISCUSSION

4.1 *Stage One Result*

An optimal workflow for the replication of screen-printed fabrics via ink-jet textile printing (Figure 7) was developed during experimental stage one. Through this effort the process was streamlined and can be effectively used for future research and production applications. The ink-jet printed sample B was selected and approved by the PI to conduct expert visual assessment.

4.2 *Stage Two Result: Expert Visual Assessment*

After successful completion of stage one, a visual assessment protocol (Figure 8) was established to evaluate the acceptance of the replicated ink-jet printed fabric. The expert visual assessment was undertaken following this process.

4.3 *Sample Characteristics*

A total of 25 possible subjects either working in U.S. textile industry or performing textile-related research (Ph.D. students) were e-mailed invitations to participate in the study. Twelve of them (48%) completed the visual assessment and their answers were recorded for analysis. To eliminate potential gender bias, six males and six females

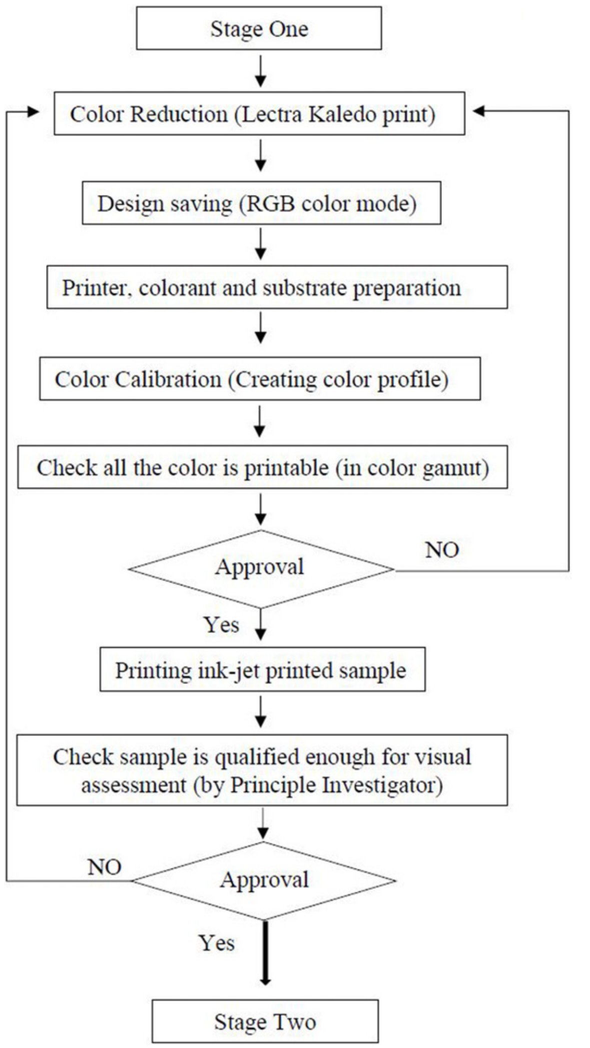

Figure 7. Research stage one diagram: workflow of fabric replication.

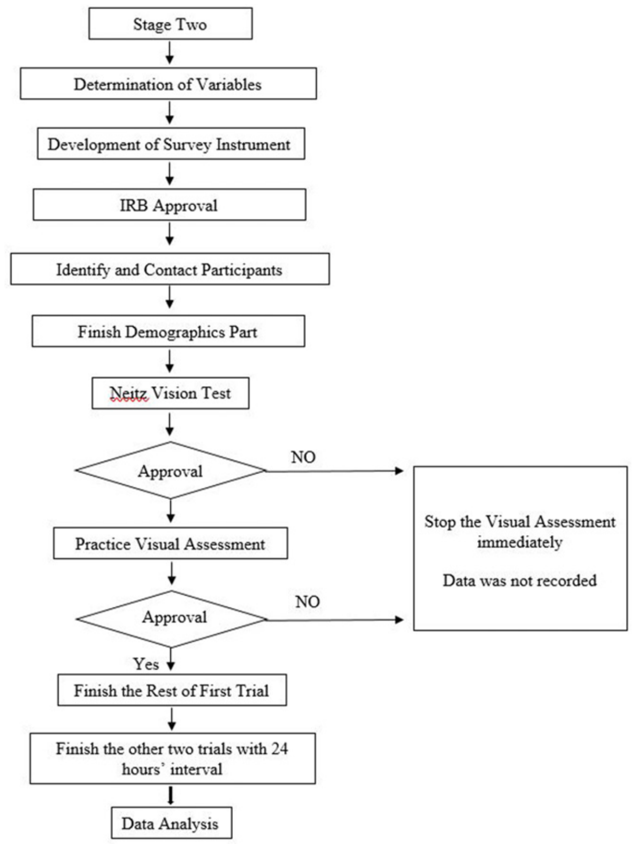

Figure 8. Research stage two diagram: expert visual assessment protocol.

Table I. Demographic Information.

E-mail Response	Total e-mailed	Responses	Response Rate
	25	12	48%
Gender	Male	Female	Gender Ratio
	6	6	1:1
Year of Birth	>=1990	1980–1989	<1979
	32%	53%	15%
	Minimum	Maximum	Mean
	1950	1994	1979
		Range	
		1950–1994	

participated in the assessment. The participants' ages were quite different. Young, middle aged, and senior participants were all involved in the experiment. As shown in Table I, 32 percent of participants were born after 1990, 15 percent were born before 1979, and more than half (53%) of participants were born between 1980 and 1989. The minimum birth year was 1950 (66 years old), the maximum birth year was 1994 (approximately 22 years old), and 1978 (38 years old) was the mean birth year identified for all participants.

Every participant selected at least one and up to three work areas (Table II). Half of the participants (6) identified their occupation as a Ph.D. student (50.0%), with the other half identifying their occupation as an Industry Professional (50.0%). Participants also identified their specialization in the areas of fabric design (16.7%), color matching (41.7%), ink-jet printing (41.7%), apparel product development (16.7%), and others (25%). A total of 17 responses were gathered, and the percentages reflect how many times this option was selected in the total 17 responses. Occupations provided by participants include association executive, dyeing technician, textile color matching technician, and textile chemist.

4.4 *Frequency and Length of Time*

The length of time and frequency for approving sample color difference reflected participants' level of experience in visual assessment. As shown in Figure 9, for the length of time, the majority of participants identified their sample approval experience as 2–3 years (42%), 6 or more years (25%), 7 months to a year (17%), 1–6 months (8%), and 4–5 years (6.7%). No one had never approved samples (0.0%). The standard deviation of the sample approving experience was 1.63; for the frequency, most participants selected 1–3 times

Table II. Occupation Information.

Occupation	
Industry professional	Ph.D. Students
6 (50%)	6 (50%)
Details	
Area of work	Percent (%)
Fabric Design	16.7%
Color Matching	41.7%
Screen Printing	0.0%
Ink-Jet Printing	41.7%
Apparel Product Development	16.7%
Home Interior Product	0.0%
Other	25%
Note*: Each participant selected at least one and up to three areas of work	
Text Response (other)	
Area of Work	Response number
Dyeing	1
Association Executive	1
Color Matching Testing Method Developer	1

Table III. Neitz and Viewing practice.

The Neitz test results	
Participants' Response	Percent (%)
Yes	100%
No	0%
Totally	100%
Color change response for test sample (viewing practice)	
2.5	8%
2	33%
1.5	58%
Totally	100%
Participants' Response Range	1.5–2.5
AATCC Suggested Response Range	1.5–2.5

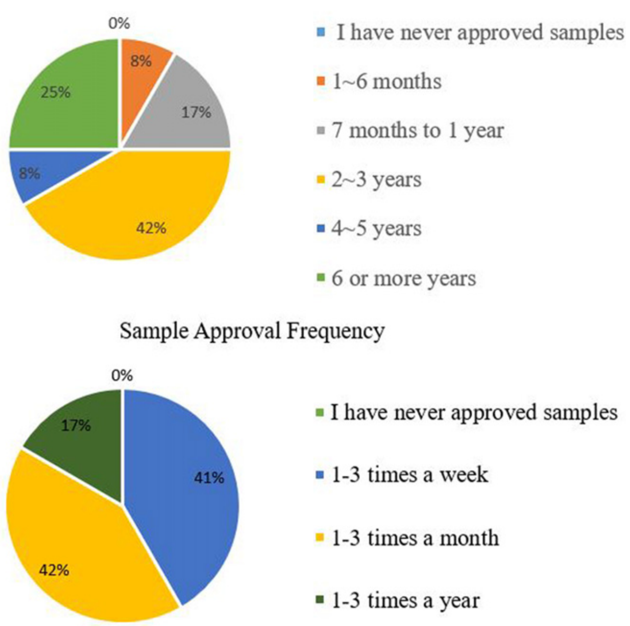

Figure 9. Sample approval experience and frequency.

a week (42%) and 1–3 times a month (42%). Some selected 1–3 times a year (20%), and no one selected a frequency of never. The standard deviation of sample approval frequency is 2.12.

4.5 *Neitz Test and Viewing Practice*

After completing the survey demographics, two tests were administered to participants. The first one was the Neitz test, which is used for a red–green and/or yellow–blue color deficiency. To validate the responses of the visual assessment, all participants that attended the next step had to pass the test. The PI evaluated participants' Neitz test results and marked their results as *pass* or *fail*. A *pass* score was defined as answering seven or more of the nine questions correctly. The third version of the Neitz Test was used for this experiment and each version is the same for the color blindness test. All participants (100%) passed the test (Table III), indicating there should be no negative influence on the next test step. The goal of the second test was to practice the visual assessment by using AATCC Gray Scale. As shown in Table III, a majority of participants identified their samples as 1.5 (58%); some participants identified their samples as 2 (33%); and fewer participants identified their samples as 2.5 (8.0%). All results fell within the suggested color range, while only one (8%) chose 2.5. A standard color change range based on the previous data, between 1.5 and 2.5, was established by AATCC before the test started. Based on the AATCC standard color change range, the PI identified the participants' understanding and ability to observe the sample color change which were acceptable.

4.6 *Visual Assessment Results*

For the individual color visual assessment mean response, black was perceived to have the strongest color match. Yellow, Dark Green, Red, and Gray were in the second strongest color match group. Blue and Cyan were perceived to have the weakest color match (Figure 10).

For the overall matching visual assessment, the overall color appearance received the highest match. Overall appearance and overall matching were also consistent between the two samples. Compared to the other aspects, the line texture and visual texture received the lowest match (Figure 11). For the scale match, all participants (100%) identified that the scales of samples A and B matched.

Visual assessment results indicated that all participants agreed that the digital printed sample matched well with the screen-printed sample, as judged by color difference, scale, line quality, visual texture, and overall appearance.

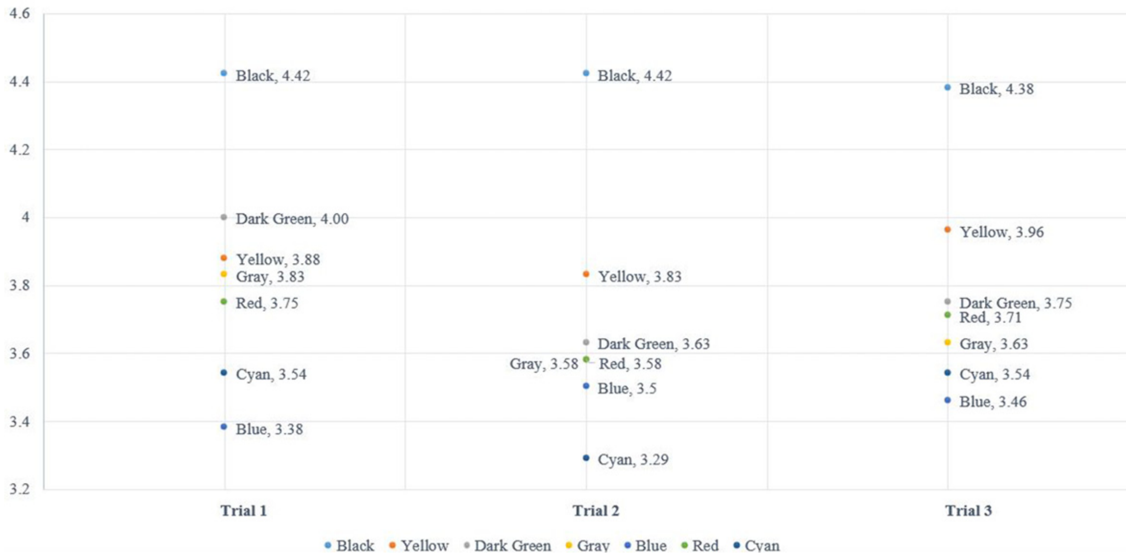

Figure 10. Mean Response for Individual Color Visual Assessment.

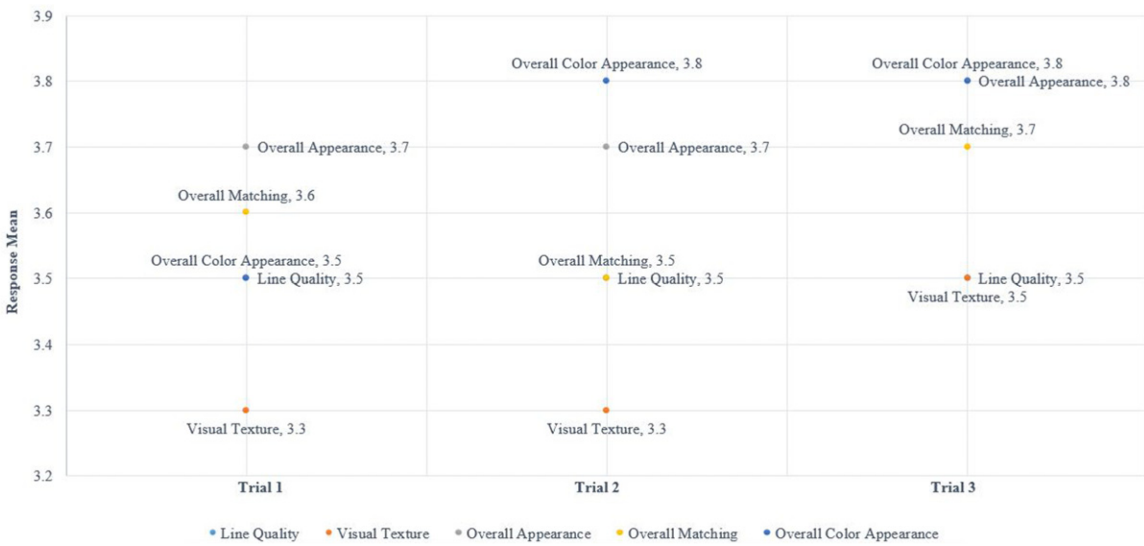

Figure 11. Mean Response for Overall Matching Visual Assessment.

4.7 *Perceived Lightness Results*

As shown in Table IV, most participants identified Black, Dark Green, and Gray as appearing lighter in sample B (ink-jet printed sample). The majority of participants identified Blue, Red, and Cyan as appearing lighter in sample A (screen-printed sample). All participants (100 percent) identified Blue and Cyan as appearing lighter in sample A. For Yellow, results indicated a color shade change in grayscale.

4.8 *Correlation and Reliability Statistics*

Although the viewing experiment was effectively controlled through the experimental method, variation among observers may still exist, such as mood, fatigue, or stress level, which may uniquely impact different trials [15, 18], influence the researchers, or the experimental environment. For this reason, statistical analysis was conducted to examine the consistency and reliability of the results from all the three trials [21]. Analysis of variance (ANOVA) and Pearson's correlation, were used to analyze the data.

A significance level (denoted as α or alpha) of 0.05 was used for statistical analyses. As shown in Tables V and VI, the significance level of the seven individual colors and overall difference were found to be greater than 0.05, supporting the conclusion that the scores for these three trials are consistent and can be interpreted with confidence.

The Pearson correlation coefficient is a measure of the linear dependence between two variables X and Y. Coefficients have values between $+1$ and -1 inclusive, where 1 is total positive linear correlation, 0 is no linear correlation, and -1 is total negative linear correlation. As shown in Table VII, all of the correlation coefficients are positive and all seven colors of Trials 2 and 3 are positively correlated,

Table IV. Perceived Lightness Difference.

Lightness		Trial 1 (%)	Trial 2 (%)	Trial 3 (%)
	A < B	75.0	75.0	67.0
Color 1	B < A	17.0	25.0	33.0
	A = B	8.0	0.0	0.0
	A < B	33.0	33.0	25.0
Color 2	B < A	42.0	50.0	75.0
	A = B	25.0	17.0	0.0
	A < B	75.0	83.0	83.0
Color 3	B < A	8.0	8.0	8.0
	A = B	17.0	8.0	8.0
	A < B	83.0	92.0	92.0
Color 4	B < A	17.0	8.0	8.0
	A = B	0.0	0.0	0.0
	A < B	0.0	8.0	0.0
Color 5	B < A	100.0	92.0	100.0
	A = B	0.0	0.0	0.0
	A < B	25.0	25.0	17.0
Color 6	B < A	67.0	75.0	83.0
	A = B	8.0	0.0	0.0
	A < B	0.0	8.0	0.0
Color 7	B < A	100.0	92.0	100.0
	A = B	0.0	0.0	0.0

Table V. Individual Color Difference—Analysis of Variance (ANOVA).

		SS	DF	MS	F	Sig
Color 1	Between Groups	0.14	2	0.007	0.079	0.924
	Within Groups	2.896	33	0.088		
	Total	2.910	35			
Color 2	Between Groups	0.097	2	0.049	0.405	0.670
	Within Groups	3.958	33	0.120		
	Total	4.056	35			
Color 3	Between Groups	0.875	2	0.437	2.287	0.117
	Within Groups	6.313	33	0.191		
	Total	7.188	35			
Color 4	Between Groups	0.431	2	0.215	1.714	0.196
	Within Groups	4.146	33	0.126		
	Total	4.576	35			
Color 5	Between Groups	0.097	2	0.049	0.255	0.776
	Within Groups	6.292	33	0.191		
	Total	6.389	35			
Color 6	Between Groups	0.181	2	0.090	0.317	0.730
	Within Groups	9.396	33	0.285		
	Total	9.576	35			
	Between Groups	0.500	2	0.250	1.333	0.277
Color 7	Within Groups	6.188	33	0.188		
	Total	6.688	35			

which indicated that these two trials appeared to be in the most agreement. This could be a result of the learning process of the participants. In total, 14 of the 21 tests indicated significant values (P values <0.05) and two additional tests suggest significant value for the one-tail test.

5. CONCLUSIONS

This study succeeded in developing an optimal workflow for the replication of screen-printed fabrics via ink-jet textile printing. The process is streamlined and effective and can be used in the future by researchers and practitioners. A visual assessment instrument and protocol were established to conduct expert visual assessment for digital textile printed media. The ANOVA statistics and Pearson correlation reliabilities indicated no significant difference between the three trials and the results are consistent in supporting validity among the observed data. For the color difference comparison, Black was perceived to have the highest match; however, the target color was not a true black. Yellow, Dark Green, Gray, and Red were in the middle group. Blue and Cyan had the lowest perceived match. Overall, the primary colors chosen for evaluation from the screen-printed sample were well matched by the ink-jet printed sample. For the assessment of scale, line quality, visual texture, and overall appearance, expert participants agreed there was an adequate match between two printed samples based on data analysis.

Table VI. Overall Difference—Analysis of Variance (ANOVA).

		SS	DF	MS	F	Sig
Overall appearance of color	Between Trials	0.500	2	0.250	0.868	0.429
	Within Trials	9.500	33	0.288		
	Total	10.000	35			
Line Quality	Between Trials	0.056	2	0.028	0.061	0.941
	Within Trials	14.917	33	0.452		
	Total	14.972	35			
Visual Texture	Between Trials	0.500	2	0.250	0.611	0.549
	Within Trials	13.500	33	0.409		
	Total	14.000	35			
Overall appearance	Between Trials	0.056	2	0.028	0.121	0.887
	Within Trials	7.583	33	0.230		
	Total	7.639	35			
Overall Matching	Between Trials	0.167	2	0.083	0.148	0.863
	Within Trials	18.583	33	0.563		
	Total	18.750	35			

However, the mean of line texture and visual texture was slightly lower than the other aspects, which may indicate that digital printing technology at this stage cannot completely

Table VII. Perceived Color Lightness Difference — Pearson Correlation Reliabilities

		T1&T2	T1&T3	T2&T3
Color 1	Pearson Correlation	0.444	0.204	0.683
	Sig. (2-tailed)	0.149	0.525	0.014
	N	12	12	12
Color 2	Pearson Correlation	0.736	0.502	0.750
	Sig. (2-tailed)	0.006	0.096	0.005
	N	12	12	12
Color 3	Pearson Correlation	0.449	0.449	1.000
	Sig. (2-tailed)	0.143	0.143	0.000
	N	12	12	12
Color 4	Pearson Correlation	0.674	0.674	1.000
	Sig. (2-tailed)	0.016	0.016	0.000
	N	12	12	12
Color 5	Pearson Correlation	0.110	0.496	0.721
	Sig. (2-tailed)	0.733	0.101(.05)*	0.008
	N	12	12	12
Color 6	Pearson Correlation	0.949	0.735	0.775
	Sig. (2-tailed)	0.000	0.006	0.006
	N	12	12	12
Color 7	Pearson Correlation	0.349	0.451	0.508
	Sig. (2-tailed)	0.266	0.141	0.092(.046)*
	N	12	12	12

*Note: Significant value for one-tail test

express the thick layering effect produced by traditional printing technology [5, 14, 20, 21]. In general, all participants agreed that the digital printed sample well matched the screen-printed sample, as judged by color difference, scale, line quality, visual texture, and overall appearance. From this perspective, the results suggest promise for using DTP samples as substitutes for screen-printed samples in the future which can support quicker response to consumer preferences and contribute to advances in the product development process for a vast range of textile products.

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