The Development of Methodologies for Designers Engaging with Digital Colour Inkjet Printing in Textile Design

Becky, Gooby

UWE, Bristol, UK
becky@beckygooby.co.uk

ABSTRACT
Digital textile printing (DTP) offers exciting, creative potential and entrepreneurial business models in textile design. However, there is a marked difference between screen-colour to print-colour. Colour results are affected by numerous variables which a textile designer will be required to understand, and experiment with, in order to feel colour confident. A number of variables were tested using a Practice as Research methodology, to determine the impact on printed colour outcome. This paper presents investigations which focused on the development, and generation of, visual indicator methods and ICC profiles generated from data, accumulated through measuring printed colour differences on substrates. The aim to provide an indication of colour changes when printing on different fabric substrates, allowing designers to make adjustments to designs to obtain a better colour match, and develop their colour expectation knowledge.

Keywords: *Colorimetry, Colour in the Arts and Design, Digital Colour, Digital Textile Printing*

INTRODUCTION
The development of digital printing is a major change within the textile design process as a designer is no longer restricted to number of colours or repeat patterns, and may include photographic images and intricate detail in their design work. Digital textile printing (DTP) provides unprecedented opportunity for designers to offer bespoke, and customisation of, designs without large set up costs, leading to new entrepreneurial business models in the textile industry.

Digital textile inkjet printing is a non surface-impact print process where colorants (primarily dyes, but increasingly pigment inks) are jetted in a dithered, matrix of dots, onto specially treated fabric, to create the appearance of solid colour. The colorant sits on the surface, although, secondary processes, allow dye molecules to further permeate the fibres. Additionally, DTP may include dye sublimation, solvent, latex, ultra-violet and direct-to-garment printing, for example T-shirt printers.

Reduced ink wastage and water use makes DTP a more environmentally sustainable printing method in comparison to screen and rotary printing. Short print runs and the ability to react quickly to market trends allow businesses to carry less stock, reducing storage costs, and the likelihood of stock wastage as fabric is printed to demand.

However, there is a marked difference between screen-colour and print-colour. A textile designer will be required to experiment with a number of variables in order to feel confident about the colour outcome of their print. For example: the ink range and colour bank of the printer, variations between one machine and another, the structure and composition of the substrate, fabric pre-treatment, secondary processes and the printer's achievable gamut will all affect final results. Colour is critical in the textile industry both in terms of meeting trends, client requirements and obtaining consistent colour.

THE RESEARCH PROJECT
The wider research inquiry considers how designers can ensure colour assurance when digitally printing through an exploration of existing colour tools and methods. The aim, to produce an

accessible colour toolkit for practitioners and SMEs, that may not have access to highly technical equipment and software.

The research set out to identify the variables which affect colour outcome. These were then explored, using a Practice as Research methodology, to discover the impact on printed colour. Existing software, methods and processes were surveyed to determine their usefulness and accessibility. The work was documented, and reflected upon, providing a durable record of the practice and progress of the research inquiry. The thinking-doing approach was informed by Professor Robin Nelson's understanding of Practice as Research and follows the 'know-how', 'know-that', 'know-what' model of praxis he has established. This model is useful for the research because textile design, and working with cloth, is naturally a nonverbal experience.

This paper presents investigations which focused on the generation of ICC profiles using data accumulated from measuring printed colour differences on substrates.

EXPERIMENTAL: THE GENERATION OF INDICATOR ICC PROFILES

The research observed changes to the overall appearance of an image displayed on screen and subsequently printed, by assigning different output profiles to a specifically created colour test collage in Adobe Photoshop Creative Cloud (APCC). The research considered whether an output profile could be created which indicated to the viewer the colour alterations to expect when printing onto different textile substrates. The profiles were developed using existing data, produced by the research project, which analysed colour shifts from the intended screen colour to the printed colour, across four substrates. The aim to provide an indication of expected colour changes to a designer viewing their image on a computer display, allowing them to make adjustments to obtain a better colour match and developing colour expectation knowledge.

Profiling is a means of comparing measured reflectance data, from RGB or CMYK colour ranges, produced by a particular device or devices, with known reflectance data from CIE models. Additionally, a profile describes each device's parameters (dynamic range, gamut and the tone reproduction characteristics). Data is stored in a look up table, used for mapping an input to an output value. Output profiles, used to display and output colour, are large two-way profiles which require multiple look up tables, to provide information about numerous colour possibilities. Profile maker software uses a colour target as a means of gathering information about the device's colour reproduction. This is measured and the returned data used to provide an overview of colour options for the look up table, limiting the amount of data to be stored. ICC profiles were developed by the International Colour Commission in 1993 as an open profile format which could be used universally across different software and devices.

To evidence that there is a difference between screen colour and print colour, and further variations between substrates, a colour chart was created, using the 1137 colours in the Pantone© solid uncoated colour library in APCC (Figure 1). The chart was printed onto four different substrates (wool, linen, cotton and silk) using a digital textile inkjet Mimaki TX2-1600 printer, with reactive dyes. The fabric swatches were compiled in a colour reference book alongside the corresponding numerical values (RGB, CMYK, HSB, Hex and LAB) and a paper print, as the closest visual match to the screen colour. This provided a broad range of colours and data for comparison, and demonstrated differences across the printed colour to the screen colour, particularly in neutral ranges such as greys, blacks and browns, as well as colours from the blue and magenta tonal ranges.

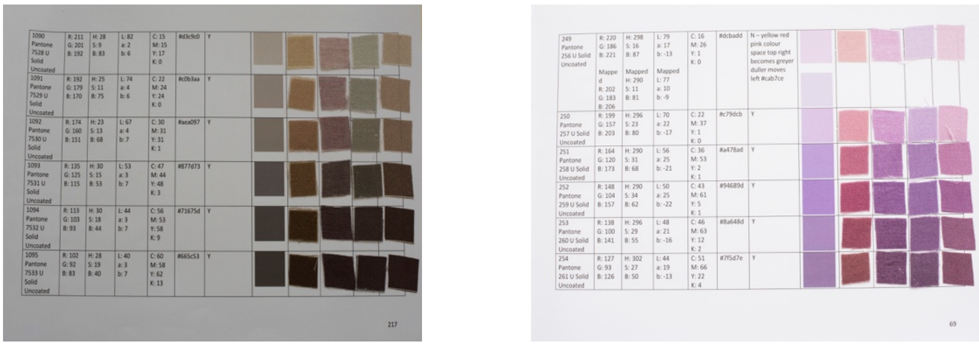

Figure 1: Gooby, B, 2017 Colour Reference Book (Researcher's own collection) Examples of the colour reference book. Each row consists of the digital numeric values (RGB, HSB, Lab, CMYK and Hex) The swatches (left to right) are paper print, wool, linen, cotton and silk.

A colour set, consisting of the first 24 colours in the Pantone© Library was used to reduce the data range from over five thousand swatches. This set covered a range of highly saturated, spectral colours (red to purple). The fabric swatches from this set were measured using a Kodak-Minolta FD-7 spectrodensitometer which returns sophisticated colour measurements using filters to measure the wavelengths reflected from the colour sample. The spectrodensitometer was set up to measure the reflectance value under D65 illuminant conditions, the standard for measuring textiles, and return LAB and wavelength (nm) values from 380-730nms. The LAB coordinates were entered into the colour picker tool in APCC to display a digitised version of the printed swatch, and corresponding HSB (hue, saturation and brightness) values recorded.

Substrate	Average Hue Shift	Average Saturation Shift	Average Brightness Shift
Wool	Reduced by 4 degrees	Reduced by 18.5 %	Reduced by 29 %
Linen	Increased by 3.5 degrees	Reduced by 26.5 %	Reduced by 24 %
Cotton	Increased by 3 degrees	Reduced by 30 %	Reduced by 20 %
Silk	Reduced by 4 degrees	Reduced by 25.5 %	Reduced by 24 %

Table 1: Median Hue, Saturation and Brightness value shift by substrate

The digitised swatches were plotted onto colour maps to visualise hue, saturation and brightness (HSB) shifts from the screen colour, symbolising a digital lab dip test (Figure 2), to visualise for a designer how a colour might be expected to print, depending on substrate. The HSB colour model was chosen as a more accessible, and visual means, of representing colour changes, in comparison to the mathematical LAB model. A median value for each substrate's HSB shifts was calculated and recorded. A series of colour maps was produced and presented at the DataAche Conference, Plymouth University, 10-13 September 2017 and a selection displayed at the Gallery Kopio, University of Lapland, Finland from July to September 2017.

Figure 2: Gooby, B, 2017 Example of a Colour Map (Researcher's own collection) An example of a digital colour map. The hue circle is divided into 6 degree segments beginning at red 0/360 degree through to tones of magenta from 300 degrees and the rings decrease in saturation (S) and brightness (B). In this example the centre is filled by the screen colour with its original HSB values, and the digital versions of the fabric swatches placed around the outside to indicate HSB shifts.

Finally, the median HSB value shifts were applied to an RGB colour target which was subsequently measured to create an indicator display profile to imply substrate colour shifts to the viewer. The target file was edited in APCC to apply an overall median HSB adjustment (Table 1) for each substrate and then printed onto Cotton Satin. Cotton Satin has a tight weave and smooth surface and proved to have good colour results in previous experiments.

Figure 3: Gooby, B, 2018 AVA CAD CAM 1748 RGB Colour Target and the four adjusted targets L-R (Researcher's own collection)

The targets were measured with an Xrite EyeOne Profiler Spectrophotometer to create an ICC Profile. The Profile Maker Software used was AVA CAD CAM's Printer Cal and the colour target selected consisted of 1748 colour swatches. The profiles were then assigned to a specifically created colour test collage image file in APCC to observe the subsequent colour changes on screen. Profiles were further compared using Apple's ColorSync Utility with two standard generic ICC profiles, Adobe RGB (1998) and sRGB IEC61966-2.1.

RESULTS AND DISCUSSION

Figure 4: Gooby, B, 2018 Colour Collages with assigned profiles. Top Row L-R Wool, Linen, Silk. Bottom Row L-R Cotton, sRGB IEC61966-2.1, Adobe RGB 1998 (Researcher's own collection)

Six colour collages images were produced, four images with assigned indicator profiles (wool, linen, cotton, silk), and the additional two assigned standard, generic ICC profiles (sRGB IEC61966-2.1 and Adobe RGB 1998) as a comparable (Figure 4). Visual analysis observed subtle colour differences between the appearance of the six images.

Wool: The image had a slightly orange appearance which was most noticeable in the neutral colour ranges. The colours appeared muted in comparison with the images assigned with standard generic profiles. Colours from the blue/magenta tonal ranges were most vivid and green tones appeared bluer. The neutral ranges had a soft contrast and appeared to have a sepia like appearance.
Linen: The image had a slightly yellower appearance which was most noticeable in the neutral colour ranges and in the red tones. Blue and green tonal ranges appeared yellower. Neutral tones had a strong contrast but instead there was a loss of tone quality.
Silk: The image had a slightly magenta appearance which was most noticeable in the neutral colour ranges. The red tonal ranges appeared strong and spectral colours are saturated. Neutral ranges appeared darker than the linen or wool images, with a strong contrast.
Cotton: The image had a slightly orange-red appearance but neutral ranges did not. The colours were strong and saturated similar to the silk profile except that there was improved tonal quality and decreased contrast which achieves a better colour balance.
sRGB IEC61966-2.1: The image had strong saturated colours in comparison to the indicator profiles with no apparent overall colour tint. The neutral ranges had a slight green quality to them but contrast, tonal quality and colour balance were all good.
Adobe RGB 1998: The image had incredibly strong saturated colours, particularly in the blue tonal ranges, in comparison to the indicator profiles with no apparent overall colour tint. There was strong contrast but a lack of tonal quality. The neutral ranges had no apparent colour tint.

The underlying tints in the indicator profiles may be a consequence of adjusting the hue values, moving hues around the colour circle. The wool indicator having an orange tint is in keeping with the natural yellow of unbleached wool and therefore provides a good indication of colour changes. The yellow and magenta appearances of the Linen and Silk however do not match visual observations of printed colour from the colour reference book and would need to be corrected. The orange-red appearance of the Cotton shows that stronger red hues can be achieved when printing onto Cotton substrates as does the increased saturation in colours in the Silk profile. All indicator profiles demonstrated a loss of brightness and saturation in comparison with the standard, generic profiles which is true for printed colour. User testing of these indicator profiles would be required to demonstrate if they are a useful tool for designers.

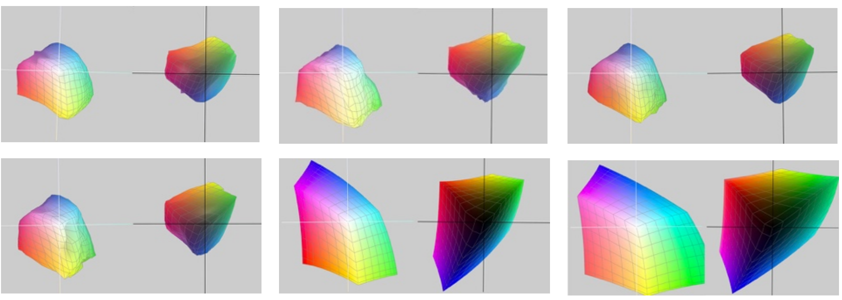

Figure 5: Gooby, B, 2018 Apple ColorSync Screen Grab Profile comparisons viewed from lightest and darkest points. Top Row L-R Wool, Linen, Silk Bottom Row L-R Cotton, sRGB IEC61966-2.1, Adobe RGB 1998 (Researcher's own collection)

Comparisons in Apple's ColorSync Utility showed that the gamut of the four indicator profiles was considerably smaller than the standard, generic profiles (Figure 5). The Wool indicator profile had the smallest achievable gamut and Linen the largest. The Linen indicator profile extended to the palest of shades whereas the Silk indicator profile achieved the darkest colour ranges of the four.

These results had some correlation with the findings of visual analysis of the colour reference book. Linen, a cellulose fiber constructed from flax plants, does not absorb dye particularly well. The juniper linen tested has the loosest weave of all four substrates and whilst colour matches on linen appeared good, the saturation was greatly reduced. Wool is a keratin protein, animal fibre which naturally repels moisture but does absorb dyes. However whitening pre-treatments are complex and wool in its natural state has a yellow undertone which affects the printed colour. Similarly, silk is an animal fibre and absorbs dye well. The smooth texture and reflective qualities of the satin silk tested provided strong colour results but darker than the screen colour. Cotton is cellulose, derived from cotton plants, but absorbs and retains dye well. Like the silk, both the linen and cotton were bleached white in the preparation for print.

CONCLUSION

The research presents three visual indications of colour changes when digitally printing to textiles for a designer to utilise, allowing them to make adjustments to design work in order to obtain a better colour match and develop their colour expectation knowledge; a colour reference book, digital lap dip tests with corresponding HSB values and indicator ICC profiles. The colour reference book may be used to look up different colours to determine how they might be expected to print. The digital lap dip tests provide an indication of how a colour might alter in hue, saturation and brightness when printed upon different textile substrates. The indicator ICC profiles offer a means of obtaining an overall sense of colour shifts when printing upon different substrates. The research project will develop these further to focus colour target adjustments on particular tonal ranges such as problematic neutrals, including greyscale ranges, as well as magenta and blue hues to determine whether isolating these ranges provides a more accurate reflection of colour printing issues.

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