‘Colour, it’s just a constant problem’: an examination of practice, infrastructure and workflow in colour printing

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Abstract. This paper examines the work to control colour in graphic design and printing focusing on the reasons why practitioners do not implement ‘colour managed’ (CM) workflows. CM workflows should allow for successful transfer and reproduction of colour information from e.g. computer to print. However, the technical requirements – in terms of equipment ‘set-up’ and knowledge – prove to be beyond most of those working in the industry. We examine the reasons for this and the different cooperative practices that designers and print workers use in the ‘real-world’ to control colour. This paper contributes to studies of cooperative work and technologies by providing a critical appraisal of infrastructure and workflow as a means of supporting cooperative work in design and printing.

Keywords. Colour printing, colour management, infrastructure, workflow, ethnography, ethnomethodology

1 Introduction

Two inter-related topics that have been of enduring interest to researchers in studying cooperative work practices and the design and use of technologies to support those practices are workflow and, to a slightly lesser extent, infrastructure. Workflow systems are a classic form of technology employed to coordinate cooperative work along a process of production where different workers (potentially in different companies and locations) complete different tasks along a ‘line’ of production. The workflow and the technologies that embody or enforce it are designed to maintain adherence to procedure and coordination across time and space. The central issues surrounding the treatment of workflow in Computer Supported Cooperative Work (CSCW) and related disciplines has been the problem of getting workflow systems to mesh with the particularities of local flows of work amongst people. Since Suchman [1] at least there has been a presiding concern with the ways in which workflow models fail to take into account the local, embodied, non-prescriptive and emergent manner (responding to dynamic local circumstances) in which people organise their work. People end up having to organise or translate (potentially after-the-fact) their work so it fits with the workflow system or workaround or ignore the technology completely (see Bowers et al. [2] for examples from the print industry).

Consequent to such studies there has been considerable work in looking at the possibility for adaptive workflow systems that could be altered to fit disrupted and evolving work patterns during a period of 'domestication' (see for example the Klein et al. [3] special issue on such systems). It is now clearly acknowledged that while it may be easy to take the stance of 'bad fit' of system with existing practice, this ignores the fact that new systems are specifically bought and deployed to transform work in some way – sometimes purely with the intention of making things more efficient, other-times with notions like improving quality or conditions. A more sophisticated analysis of the situation has developed that acknowledges the complexity of providing generic products that can still be useful over a wide series of circumstances [4] while also considering that the process of tailoring and change management – deciding what practices need to be preserved and which may be transformed, and how this is handled politically – may be crucial to the success of systems involving workflows [5].

In many ways the literature on infrastructure [6,7,8] presented in venues like CSCW has a similar flavour to the literature on workflow, while dealing with e.g. technical structures that 'sit behind' the interface level and thus may be less visible to the user while still impacting on how their work is achieved. It has been concerned with infrastructure as a "relational concept" – specifically with the relations between certain identified people, their work and the infrastructural technologies that serve as a "substrate" for that work. In following this agenda the research has looked at the impacts and miss-matches between people, their work and infrastructures, and the work to produce and manage infrastructures. Star and Ruhleder [6] identified several features of infrastructures that are useful for this study. Infrastructures tend to be *embedded* (sunk into other structures, technologies and social arrangements), *transparent* (not noticed), *linked with conventions of practice*, and they *become visible upon breakdown.* They are seen as relational in that what constitutes one person's infrastructure is not the same for another depending on such things as their relative jobs. In this paper we examine the relation between the work of graphic designers and print workers, the workflows and technologies they employ and the technical infrastructure imbedded in their technologies that is installed with the purpose of managing colour (communicating and translating it from device to device and application to application)[1]. We believe that this is interesting and important both in a domain specific and generic way: specifically because managing colour across a distributed workflow is a complex cooperative problem, and generically, because it touches on classic topics concerning the inter-relation of practice, workflow and infrastructure. We think it does so in a manner that illuminates these in an original way, mainly because; (1) while the infrastructure is problematic it is difficult to imagine any reasonable alternative, and (2) because of the interesting ways in which it impinges on work and is misunderstood by practitioners.

[1] As an example of the relational (rather than absolute) features of infrastructure one can see how the CM infrastructure for graphic designers' work is the topic of research and development for colour scientists rather than being an infrastructure that supports their work

2 The Problem of Colour Print Production

Producing colour prints is complex and when problems occur, understanding their root causes, where they are located (in the workflow, or in the file, or at the printing device and just where exactly within any of these?) and how to solve them is very difficult even for domain experts. Putting aside problems with print devices, how they are calibrated and maintained, and issues to do with humidity, temperature, and how inks and toners react, one of the main problems of producing colour is achieving the 'correct' or at least a 'good' mapping between what is created and observed on screen and what is produced in print.

The technologies involved in colour work – input (e.g. scanners and cameras), display (e.g. monitors) and output (e.g. printers) devices – have device centric ways of producing and encoding colour (i.e. different colour spaces). Colour is produced differently on screen, by combining red, green and blue (RGB) light sources, than in print, made of cyan, magenta, yellow and black (CMYK) ink or toner pigments which are applied to some substrate (e.g. paper). On top of this, different devices (even different devices of the same order, e.g. two printers) have different gamuts (ranges of colours) they can produce. Furthermore, design choices, technical constraints and manufacturer preferences also create differential colour production. This clearly sets up an issue for how files or documents, passed between devices, are represented. There needs to be some method of translating between these different colour spaces, particularly for deciding how colour definitions within one gamut should map on to those in a different gamut.

Colour management (CM) was developed by The International Colour Consortium (ICC)[2]. CM is an industry-standard technical system designed to enable translation between different colour spaces and colour devices (monitors, printers, etc.). Essentially this means that when a file is transferred from one device to the other, it should come with a profile that indicates how to interpret its colour information. This profile is then translated into a device independent colour space defined by the ICC before it can be re-interpreted correctly in terms of the new device. CM is a technically correct solution, in that the system, when used properly, can translate colours between say a screen and a print device such that colours seen on screen should correlate as highly as possible with those printed out.

Over the last two years we have been studying the work involved in creating and producing graphic designs, with a focus on colour printing. Our studies show that the successful implementation of properly colour managed workflows is rare in the print industry, and that achieving printed results that satisfy the customer is often a complicated business involving a number of print-proof-adjust-reprint cycles. Practitioners mostly do not have any kind of systematic understanding of what it is, in particular, about a certain document that when printed on a certain machine will cause a particular type of problem. It is not that they do not have any knowledge of problems, their causes, and potential solutions, it is just that this knowledge maps in complicated (not always accurate) ways to what is actually going on.

[2] http://www.color.org/index.xalter

3 Method and Settings

The paper describes the findings of a series of ethnographic studies undertaken at a number of print-shops and graphic design agencies in the UK and Europe over a two year period. We carried out this work in conjunction with colleagues in our sister organisation in the US, as well as market research carried out internally and externally to our company. Including the US work and the market research allows us to make reasonable claims about the generalisability of our results. Observation is our primary method, supplemented by in situ interviewing, with site visits varying between two days and three weeks. Our fieldwork data was audio and video recordings, photographs, notes and artefacts from the sites. Our materials were gathered and analysed with an ethnomethodological orientation which emphasises how work is organised as a recognisable social accomplishment. We were interested in how practitioners understood, oriented to, reasoned about and managed colour.

4 Infrastructures and Workflows

Colour management is a technical 'infrastructure' upon which CM workflows can be built to achieve consistent colour reproduction (most faithful to the original source, most consonant with what is seen on screen etc.). Every screen-to-print workflow uses some colour management technology components whether, and this as we shall see, is crucial, this is the knowing intention of designers and print workers or not. Although CM is not in itself a workflow system, to use it successfully necessarily implies a workflow where a specific instantiation is *rigorously followed* and *understood* (at least in a functional sense, by following a strict set of procedures) *by all* of those involved in the process.

Unfortunately developing a correctly operating workflow and adhering to it is not simple. Different devices offer different settings for handling (e.g. recording, producing) colour. Different design applications offer various settings for working with documents and encoding colour data in files, including differing default settings. Successfully managing colour across a screen-to-print workflow requires that the users ensure that 'appropriate' profiles are always attached to files and that these are translated in the 'correct' places Users must be able to understand the separation between how an image is displayed and how it is encoded, as well as potentially taking into account the capabilities of the print device. Defining the appropriate workflow requires a degree of technical knowledge not normally found among design and print professionals. Ordinarily, in the realms of computing, the complexity 'going on behind the scenes' is hidden from the user, often with a 'graspable' workflow sitting on top of a complex infrastructure. Here, implementing a good workflow requires a sophisticated understanding of just how the CM infrastructure works.

In our studies of print shops (firstly) and graphic designers (secondly) the most obvious finding was that properly colour managed workflows were not implemented anywhere, even in a fine art museum. In our studies of print shops [9] we became aware that most files reaching the print shops contained no colour profiles (attachments indicating the colour management information), and that those that did, had the profiles discarded by the print workers as untrustworthy. We also became

aware that tools on print devices, designed to be used with colour managed files were being used 'inappropriately' or 'creatively' to try and effect aesthetic changes. This lead us to look upstream in the process, to graphic designers to try and understand why colour management was not being used by them. Our research indicates that it is because colour management, and the way it is presented in tools and technologies is very complex, and practitioners all along the process have varying knowledge and understanding of it but do not have the knowledge, desire or resources to implement a properly colour managed workflow. The situation is made even more difficult due to the fact that different people in different organizations using different technologies work to produce and print designs with elements from different sources (e.g. graphics, photos, text). Indeed, such a finding is re-enforced by the fact that it is photographers who are the people who are most likely to colour manage. They can exercise more direct control over their workflow as it involves fewer people and they are often interested in *preserving* the colour data from camera to print whereas graphic design is much more about *creation* and *production* that involves the assembly and transformation of material from several sources.

5 Non-CM Workflows in Graphic Design and Printing

Our studies of graphic designers added strength to the idea that CM was proving too technically complex to understand and implement across the print workflow. Graphic designers showed variable levels of understanding of CM and it was seen as too complex to implement properly. There was, also, quite a degree of confusion about elements of CM; few had anything approaching an in-depth knowledge.

In the absence of CM workflows, designers and print shops strive to control colour in more local and practical ways. Practitioners were found to have developed several related techniques and practices for achieving the colour results they required, or at least reducing the inconsistencies and uncertainties between screen and print. And most obviously graphic designers develop relationships with print shops that they trust; who help them achieve good prints, without specifically inquiring into what it is about the print shop (their set-up, staff, equipment?) that enables this. In the following section we detail various practices used to control colour, and note that the interesting thing that unifies them is their *tangibility* and *comprehensibility*; they deal with samples and more straightforward, everyday ways of viewing and encoding colours such that the reproduction should be close to something they have previously seen. This stands opposed to the mathematical models of colour encoding embodied in CM.

6 Examples of Ad Hoc Colour Management

In our previous paper (O'Neill et al. 2007) we discussed our studies of print shops. We noted that CM did not seem to be used at all and discussed the ways in which print workers tried to correct problematic colour in prints by adjusting several controls. We also described how print shops worked with customers to set up colour libraries for important colours like brand colours and that they tried to educate

customers both about the potential problems with files and colours and about how they might be improved. Looking at graphic designers has re-enforced our understanding of the importance of relationships in printing; graphic designers often have favoured print shops that help them to produce a quality product. Although print shops often do more of the correctional work, graphic designers may also spend considerable time managing customer expectations, e.g. making them aware of colour differences between screen and print. Designers' basic advice on colour is that offset is better than digital, if one has strict colour requirements; spending time (and more money) proofing with the print shop is crucial; and pantone inks (bespoke mixed colours used in off-set printing) are the most dependable ways of getting colour right.

6.1 Pantone swatch books

Pantone produces a range of swatch books and charts (see figure 1) of their proprietary colour space, that show the Pantone colours that can be reproduced, given the substrate and print technology that are used. The range of colours, their 'intensity' and general look and feel vary across the range. When used properly – i.e. the correct book for the correct print device for the correct substrate – pantone books work pretty well for controlling colour from screen to print. The designer selects the desired colour from the book or chart and then can encode the colour as a pantone in the image file and it will be interpreted as such by the print device (figure 2 shows a leaflet produced by using the chart in figure 1). We observed a widespread use of pantone swatch books and charts) for selecting and controlling colour in all the design houses we visited. In the best cases, the designers were using print device and substrate (e.g. coated/uncoated) appropriate pantone swatch books bought by them or provided to them by their print shop.

For example, one of the UK agencies had just invested in a full set of pantone swatch books and the designers showed us that they now had an off-set process colour swatch book that had been giving them particularly good results. However, some design houses used pantone swatch books that were not specific to a print device or substrate. In these cases, the relationship between the chosen pantones or CMYK process colours and what the print device could produce was more variable. A key problem from the perspective of designers is that the pantone system is confusing. Pantones are stipulated as a set of equidistant numbered colours within the range (gamut) that can be produced by a machine. This means that a specific pantone number may well be a different colour when produced on different machines. Unfortunately this is not widely known and many people labour under the misapprehension that choosing a specific pantone (e.g. for a brand) will ensure consistent reproduction across print devices and substrates. Furthermore, the differentiation between pantones and their CMYK process versions was, again, understood differently in different locations.

Fig. 1: Digital pantone swatch chart

Fig. 2 : Deli flyer (produced from the swatch chart)

An advantage of using pantone swatches is that it allows the matching of colours by eye, which is one of the designers' preferred methods. Although, they are aware that matching colours individually between screen and swatch book is somewhat imperfect due to the different media of instantiation. *Importantly*, this technique can only be used for *blocks of colour* which can be treated as separate 'objects' in the printing process and not for coloured items which are only regions within objects (e.g. elements of a photograph).

6.2 Work in default CMYK colour space to help with gamut issues

Two design houses we observed work by default in a CMYK 'emulation' space on screen when they are producing a printed product. By working in CMYK they believe the discrepancy between what they see on screen and what will eventually be printed is minimised (i.e. in comparison with working in RGB). Working in CMYK means that designers are showing some orientation to printing in their work. In general the effect of this is that they are less likely to choose colours for their designs that are out of gamut; there will be generally a greater consonance between what is seen on screen and what will be printed. However, understanding just how what appears on screen will relate to a print is still complicated, especially if using an un-calibrated monitor. This is exacerbated when the user does not know which settings they have and their impacts, e.g., in one of the settings colour management tools were turned off, while in the other they were set at a North American default setting (it was in the UK). In both cases (even when turned off) colour management is setting and altering the colour values in the files for printing. This can lead to some unexpected effects on printing.

6.3 Preferred Palettes and Known About and 'simple' colours

Graphic designers we observed had 'preferred' palettes and 'known about' colours. These are colours and sets of colours that, by experience, designers had found seemed to print well. This was not simply a matter of perceived consonance between screen and print but was also to do with having seen the colours printed a number of times and having been pleased with the results. When colour choices were left open they tended towards guiding customers to one of those colours if they felt it was appropriate for the product. On the other hand certain colours were known to be

problematic. For example, vibrant orange is difficult to reproduce using process colour (CMYK) combinations. This was one of the UK Universities' corporate colours for which they had a specific preferred print shop.

Another method that designers used to manage colour is to use 'simple' colours in their designs. What this amounts to varies across jobs. For example simple colours might be considered to be colours made up of 100% or CMY or K; or a mixture of just two of CMYK, but also 25% C 50% Y…etc. as opposed to 17%C 39%Y…etc. Another technique the designers used was to use shades (lightening/darkening) of the same colours. The extent to which a colour made up of varying percentages of four colours is 'complex' is open for discussion. Some designers reported that it is more difficult for them to know how a colour composed in a more complex way will look 'in real life' when it is printed out. For example, in one situation observed, a brown with a high magenta content looked like a rich brown on screen or printed on off-set but printed on a digital print device it was burgundy in colour.

We have two examples of designers using 100% cyan. In the first, the brief was to provide some 'straightforward/clean' designs for a plumbing parts company. The catalogues were black and white with one extra colour. Looking through various samples of previous work the designer noticed that out of four colours used, one appeared to be 100% cyan. As one of the four colours in colour printing (CMYK), it is easy to 'hit' this colour consistently, as it does not involve mixing any colours (Figure 3).

Figure 3: Mission Rubber 100% cyan

Fig. 4: University review 100% cyan

At another design agency, the designer was showing us a university newsletter and noted how he had picked 100% cyan as the key colour (Figure 4) along with black, white and grey because it looked good and was easy to produce.

6.4 Work with the print shop to set the colour values

In situations where customers have very particular colour requirements, they or the designers must put in extra work with the print shop (and pay more) to ensure that the colour requirements can be met. This is done through printer (machine and person) selection, through encouraging customers to pay for pantone inks and through process colour proofing, and proofing in general. In this way tolerable/desired colours are achieved. We have seen these colours encoded as keys on files and print samples

(Figures 5 and 6). Certain print shops also get the reputation of being able to do certain things. For example (as pointed out above), the University designers went to a certain print shop when needed "because they could produce a really strong orange".

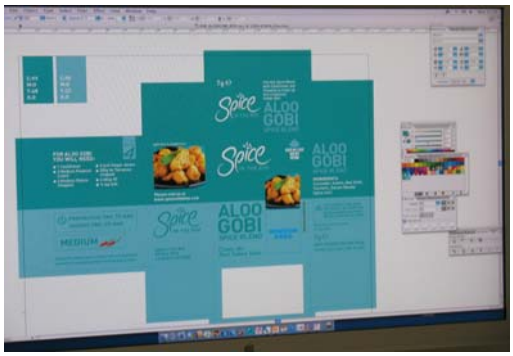

Fig. 5: CMYK key (top left) for block colours

Fig. 6: Colour proof test prints

We observed the design of boxes for curry spice recipes (figure 5) where the design house sent the customer to the print shop because the customer had 'very particular' colour requirements. They were particular in that she wanted very specific colours (like the 'jade' green above) with very little tolerance but did not want to pay for specific pantones. The designers told her that she needed to go to the print shop and work out the precise CMYK mixes that fitted her requirements. In figure 5 the CMYK process mixes have been added to the image as a key. The same process occurred for this design house when producing a set of boxes for some 'puddings' (see colour proofs, figure 6). By getting the customer to collaborate directly with both the print shop and the design house, good colour can be achieved. However, this is at a high cost if, for example, the run is expected to be short. Some design houses may tell customers who will be printing on digital that they must relax their colour requirements and graphic designers tend to consider that offset printing produces better quality colour than digital.

7 Discussion: No 'Working Around' Colour Management

A common feature of CSCW studies of workflow systems is that people often *work-around* difficult elements of such systems. What is interesting here is that, being an infrastructure, it is not possible to truly work around CM. In our studies, supported by other work [10], we did not see any examples of properly implemented CM workflows. It is not that CM workflows are tried but fail in implementation rather it is simply incredibly rare that any attempt is made to construct and use them. This produces the consequent problem that colour results from printing can be highly variable in relation to what was expected. Our studies of print-shops showed that the majority of files that arrived at the shops did not have profiles attached containing CM information. Furthermore, even when files arrived with profiles attached these were discarded as not being trustworthy. When problems occurred, print operators attempted to solve them, but effecting a solution often proved difficult [9]. CM is

non-robust, in that for it to work a CM workflow must be followed throughout the process. That is, it must be initiated upstream at document design. Our subsequent studies of graphic designers confirmed they were not using CM workflows.

However, in *all cases* (irrespective of conscious knowledge) the CM infrastructure is being called upon as it is *impossible* to produce digital colour without some translation between devices and their colour spaces. Thus, although some applications offer the possibility to 'turn CM off' (and indeed some graphic designers choose these settings), colour data is still being processed according to the default settings of the device, which are oriented towards a CM workflow. This work goes on without the correct 'encryption keys' and thus can be misinterpreted – often without the user having any idea what is going on. This makes 'non-CM' workflows *opaque* as a variety of transformations and encodings are going on in the background.

We suggest that that colour production printing is an intriguing example of cooperative work that enabled us to examine some issues concerning infrastructure and workflow. These provide a different 'take' to the investigations of workflow systems previously presented in the CSCW literature. What marks this investigation out from previous work is the fact that we investigate the link between a particular infrastructure and the workflows that it implies. The nature of CM as an infrastructure means that even when using non-colour managed workflows it still necessarily impacts on the way colour is processed and rendered and therefore affects the appearance of colour in documents. CM is an infrastructure which is 'scientifically' correct. It makes sense from a purely technical point of view, but it is incredibly complex to put into place the workflows required to successfully make the infrastructure work to produce consistent and good colour. To make informed choices between the many possibilities offered by applications and devices, one needs to have a technical understanding of how CM actually works, i.e. some understanding of colour science. Currently such specialised knowledge and skills are largely absent in the design and print industries. Below we list three points which illustrate the complexity of CM and its presentation to the average user.

7.1 Confusing Presentation of CM Functions and Options

It is clear that the way in which CM options and controls are presented on the graphical user interface (GUI) of common editing and design applications means that the average user has problems understanding if they are operating, how they are operating, what would be the best option for 'this document' and so forth. For example, colour translation takes place, irrespective of whether CM is supposedly 'switched on or off', or whether the practitioners know what the settings are. The CM options offered up are often opaque to practitioners and explanations are not ready-to-hand (rather they are hidden in the help systems) nor articulated in a way that is comprehensible to them. In many cases their decisions are not based on clear understanding, or they simply accept the checked box. This makes things incredibly confusing and can lead to all sorts of problems in the translation of colour in the files when printing. Designers often believe that they are using procedures, such as working in CMYK emulation space, that constitute a basic form of colour management, but the extent to which this is successful depends on things like the

profiles in the input to the design, the default settings on their software and the way the destination printer is set up.

7.2 No Means of Recovery

There is a related issue around recovering CM information from documents at different stages of the workflow. Neither the system nor the user will necessarily know just how the current set of encodings actually relates to what was intended or desired – there is no meaningful audit trail. This will continue to be the case unless there is some way to preserve the information on where colour data has come from and how it has been translated. This may begin to address the 'intelligence' of the system but one should also consider how this might be communicated to the user.

7.3 Difficult to Understand Impacts of Selections

That colour is an issue which those in the design workflow strive to control is evident in the many non-colour managed workflows we observed. These methods tend to be far more *visible*, *tangible* and *collaborative*. However, because they do not specifically orient to the infrastructure they produce varying results. Examining these methods raises a second issue; CM by its nature is somewhat abstract and the complexity of the possible workflows makes it very hard to make *concrete visual* mappings between the colour choices, encodings and their effects on a current document and a future print – to some extent colour must be understood abstractly.

8 Conclusion

While it might be straightforward to make a critique of CM on the basis that it is not used, not understood and does not fit with the work of practitioners, we do this while appreciating that some system must be in place to transfer colour information from application to application and device to device. CM is an infrastructure that provides for a standard means of translation enabling diverse manufacturers to produce products that can integrate successfully with others to communicate colour information across that workflow. We understand that unfortunately CM has to be complex but somehow this complexity needs to be further reduced in the way it is presented to users or the problem of non-use and misuse will not go away. One can think about the problem as a classic interoperability problem but with a twist; providing translation between devices that 'speak different languages' or do things different ways is a classic computing problem, however, one that is usually solved by engineers and kept hidden from the users. Unfortunately in the case of CM not only must the users understand – at least to some extent – the processing and translation of colour but there must be close coordination and strict adherence to specific procedure across the workflow. This raises questions about who in the process should be responsible for recruiting the required expertise to design, implement and manage such a workflow, and whether this would make economic sense in the light of

possible benefits. In this paper we have not sought to provide answers to questions such as these, but rather to provide insight into a complex problem. Although many colour scientists may not understand why colour management is not used, we feel these issues will be familiar to those in the CSCW community. This research identifies the need for an additional software layer to bridge the gap between the current CM infrastructure and the actors of the workflow. However, it also shows how far the current practices are from those required for the CM infrastructure to work correctly. We can infer from this that any attempt to impose a strict adhesion to these requirements would lead to a failure in adoption or to the introduction of workarounds. This has led us towards the design of technology supporting the workflow that is based on two principles; (1) that achievable, 'good enough' colour is better for most situations than an unreachable gold standard and (2) that non-CM documents can be assessed for certain detectable and correctable colour problems prior to printing. We are currently beginning to develop this technology as a prototype and will report on it at a later date.

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