The relation between printed colour and paper colour

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Readers will not be surprised if one claims that printing the same amount of an identical ink onto brown and white paper results in a different colour. This is an opinion based on visual observation. To answer the question, »how different«, needs an analysis of correctly collected data, to ensure that the difference is quantified and becomes useful knowledge.

Most of you have seen the effect and just assume that it is a fact. I will not claim that the assumption is wrong but hope that this article will make you aware of the hidden danger of taking an assumption for granted and transfer it into common knowledge. There is just more to it.

The problem

If you take a look at *figure 1* you will have the perception that the grey circle left is darker then the one on the right but in reality by measurement, the grey shade is the same on both sides, it is only the interpretation by the human eye which makes the observer believe there is a difference.

Of course, what we are seeing is the effect of colour contrast. The human eye deals with this in a way which results in us »seeing« a different colour when the same coloured ink is printed next to each other on different background colours.

We must remember that »colour« is a perception and what we see is a darker and a lighter grey shade. Indeed, we could use two different inks adjusted so that the grey colour appears the same for each adjacent background. In this case the two grey ink colours would be instrumentally different and would probably appear different if printed side by side with the same coloured background.

However let us stay with the simple problem of white substrate. White paper from different paper mills around the world has a visible and measurable colour difference. It is commercially interesting to know how much effect the change in paper colour has on the printed colour.

To understand this one needs to collect data of the printed colour and the paper (substrate) colour using the same instrument and measuring method. In this article the data collection will be limited to one brand colour always printed on a white substrate.

Production data

I had the opportunity to look at nine months production data for a brand colour (2384 colour measurements) and also at the same time the paper colour data (926 measurements). A numeric standard for the brand colour as well as the paper colour was available thus it was easy to calculate the CIELab ΔE colour difference for the measurements against the standard and place them on a time line.

The following graph (*figure 2*) shows the colour difference over time for the measured printed colour (Brand colour). The spread of the colour printed around the 26 Aug 2005 was large.

Figure 3 shows the colour difference data collected for the paper the brand colour was printed on. We see clearly that during some periods the colour difference is larger between the measured paper colour and the standard than other periods.

In *figure 4* every dot represents the colour difference between the printed colour and the paper colour at the same moment in time.

We see clearly two groups which are separated by the colour difference of the paper. However there is no correlation between the colour difference for the paper colour and the printed colour in the individual groups. Thus if the paper colour is off then it does not mean that the printed colour is off to the same amount, on the contrary it is very possible that the printed colour is correct and within tolerance.

We have not taken into account that the printer can change the ink formulation to compensate but in reality the printer is very limited and will only use water or medium to make minor changes to the ink formulation. The data shown here is not influenced by ink formulation changes only by the minor changes related to viscosity adjustments.

Let us have a look at a colour difference histogram for the paper

Figure 1: Perceptual influence of background colour on printed colour.

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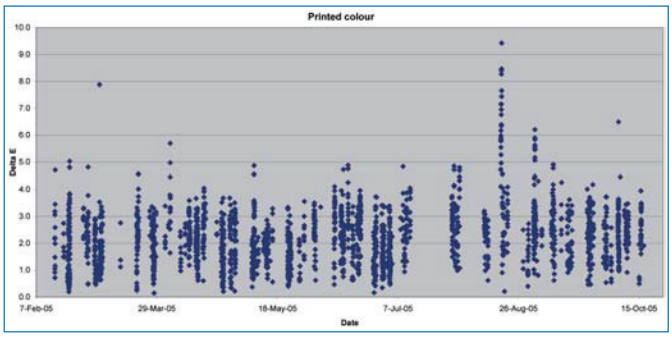


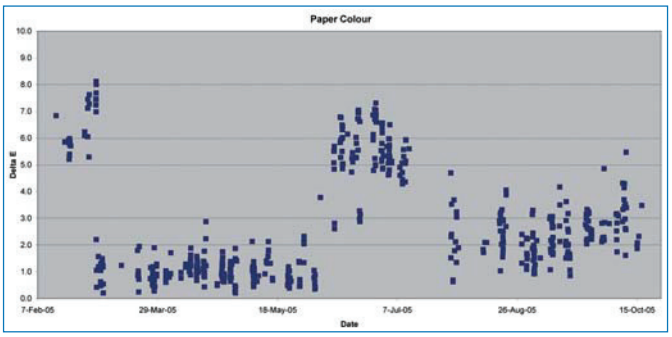
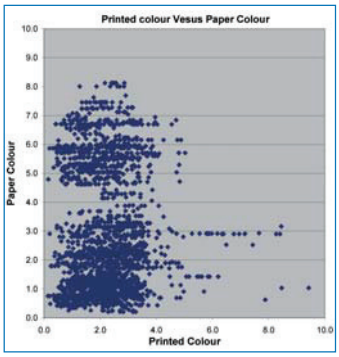


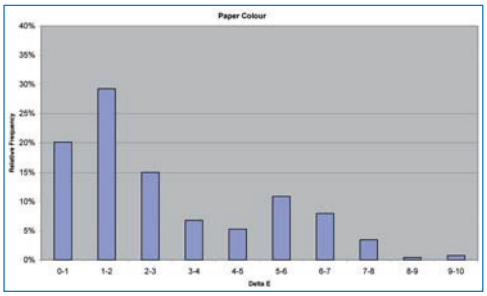
Figure 2 (left): Colour difference over time printed colour.

Figure 3 (right): Colour difference over time paper colour.

colour (*figure 5*).

We see a peak at the ΔE interval 1–2 and a smaller one at ΔE 5–6. This indicates that we might be looking at least at two different populations of paper colour difference data. Two different colour shades of papers have been used in the period observed. We should not mix these populations in any summary statistics. The paper colour difference over time plot shows clearly that these two paper populations have not been mixed but were used discretely; One in February 2005 and July 2005 the other in March/May 2005 and August/October 2005. This information can not be deduced from the histogram plot.





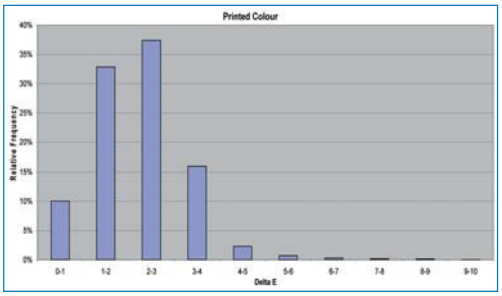


Figure 4 (left): Relation of printed colour and paper colour for ΔE.

Figure 5 (centre): Colour difference histogram paper colour.

Figure 6 (right): Colour difference histogram printed colour.

Let us now look at a colour difference histogram for the printed colour (*figure 6*). Due to the equation used for calculation of ΔE the histogram is only half a Gaussian curve. If it were a normal distribution then the median would be expected at the interval ΔE 0–1. The median is at the interval between ΔE 2–3 indicating that there might be a systematic colour difference between the standard and the printed colour. One could suggest changing the brand colour for this systematic error.

The data collected also allows viewing the L, a, b, C, h data in graphs for printed colour and paper colour. Remember that the value for paper and printed colour are different. The axis of the graphs are adjusted to show the same range.

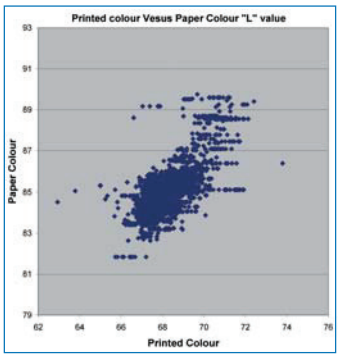
Figure 7 shows the relation for the printed colour and paper colour »L« value. We can see a correlation for the L value.

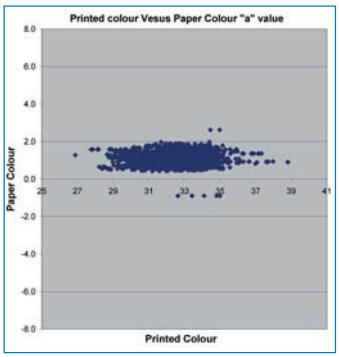
Figure 8 shows the relation for the printed colour and paper colour »a« value. No correlation is visible. The variation for the »a« value is much larger for the printed colour than the paper colour.

Figure 9 shows the relation for the printed colour and paper colour »b« value. No correlation is visible for the »b« value. The variation is of equal magnitude for the paper and the printed colour.

Figure 10 shows the relation for the printed colour and paper colour »C« value. No correlation is visible. The variation for the »C« value is larger for the printed colour than the paper colour.

Figure 11 shows the relation of the printed colour and paper colour »h« value. No correlation is visible.





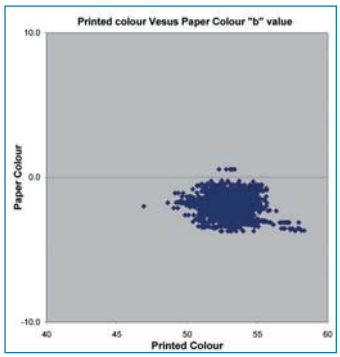
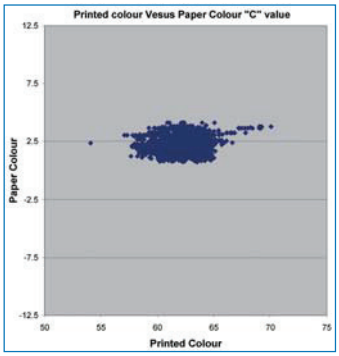


Figure 7 (left): Relationship of printed colour and paper colour for »L« value.

Figure 8 (middle): Relationship of printed colour and paper colour for »a« value.

Figure 9 (right): Relationship of printed colour and paper colour for »b« value.



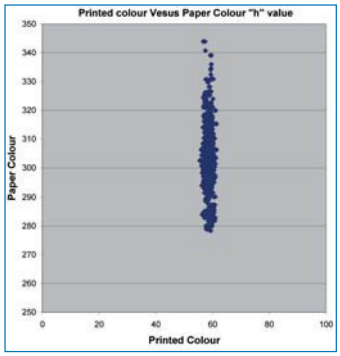


Figure 10 (left): Relationship of printed colour and paper colour for »C« value.

Figure 11 (right): Relationship of printed colour and paper colour for »h« value.

The variation for the »h« value is much larger for the paper colour than the printed colour.

Conclusion and recommendation

The data collected shows that the paper colour changed dramatically over time but that it was limited to non effect on the printed colour. This can be due to the colour shade and/or colour transparency printed so there might be colour shades and transparencies that would show an effect but the data collected did not show it. The general assumption that the printed colour is affected by the substrate colour might not apply.

There is a visible correlation between the »L« values for the printed colour and paper colour. This is probably due to the two paper colours (ΔE of 1–2 and ΔE of 5–7) showing trough the printed colour.

The perceptual colour difference as presented in the artificial image at the start of the article is most likely a more important factor as to why a print customer might complain about the printed colour being off shade.

A printer has no control over the paper colour shade nor is, in most cases, sufficient data provided to decide if the paper supplied would be fit for purpose to produce the order. Colour changes are introduced due to a reel change and also where the paper supplier has spliced different paper production runs together to make a customer reel. Such practices should be prohibited in the paper buying specification.

It is recommended to check printed colour and substrate colour at the same time during production.

It would even be better if paper suppliers would produce a limited number of substrate colour standards (spectral data) with a colour tolerance agreed by all parties involved. ■