THE RELATIONSHIP BETWEEN PRINTED COLOUR AND PAPER COLOUR

No one is surprised when it is said that printing the same amount of ink on brown and white paper results in a different colour — this opinion is based on visual observation. To truly determine how different the same colour appears, an analysis of correctly collected data needs to be undertaken. Most printers have seen the effect and assume that it is 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 assumptions for granted and allow it to become 'common knowledge'.

The Problem

Look at Figure 1. You may have the perception that the grey circle at left is darker then the one on the right. In reality, the grey shades are both the same — it is only the interpretation by the human eye that makes the observer believe there is a difference.

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 a different background colour. We must remember that 'colour' is a perception — and what we see is a darker and a lighter grey.

We could of course use two different inks adjusted so that the grey colour appears the same on different backgrounds. In this case, the two grey ink colours would be different and would appear different if printed side by side on the same coloured background.

Let's stay with the simple problem of a white substrate. White paper from different mills around the world have visible and measurable colour difference. It is essential 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

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

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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.

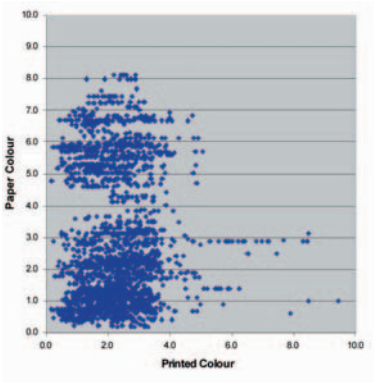
Production Data

I had the opportunity to look at nine months of production data for a brand colour (2,384 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 Δ E colour difference for the measurements against the standard and place them on a time line.

The graph below (2) shows the colour difference over time for the measured printed colour (Brand colour). The spread of the colour printed around the 26th Aug 2005 was particularly significant.

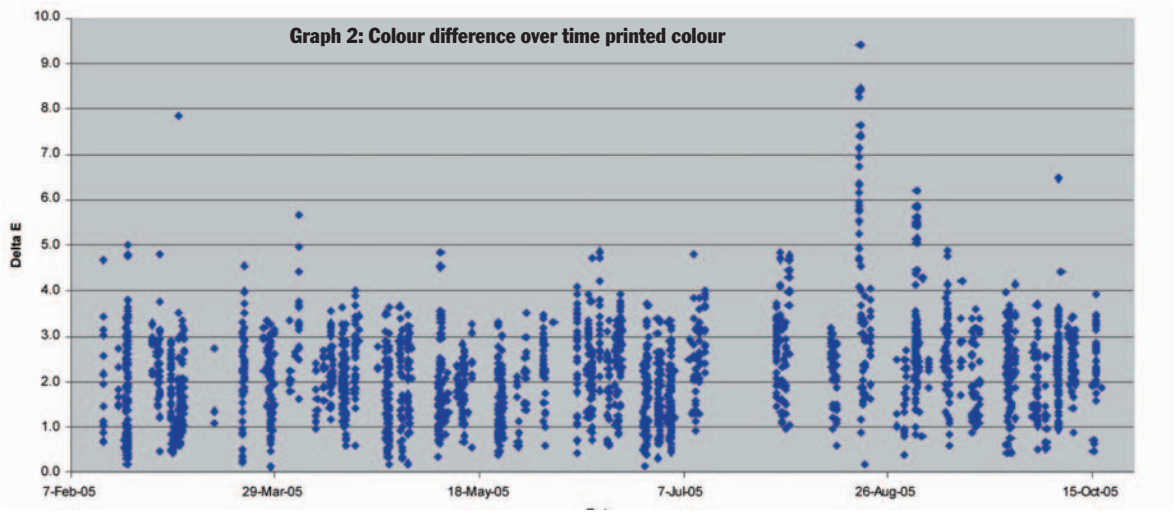
Graph 3 (bottom) shows the colour difference data collected for the paper that the brand colour was printed on. We see that in some periods, the colour difference is larger between the measured paper colour and the 'standard' in other periods.

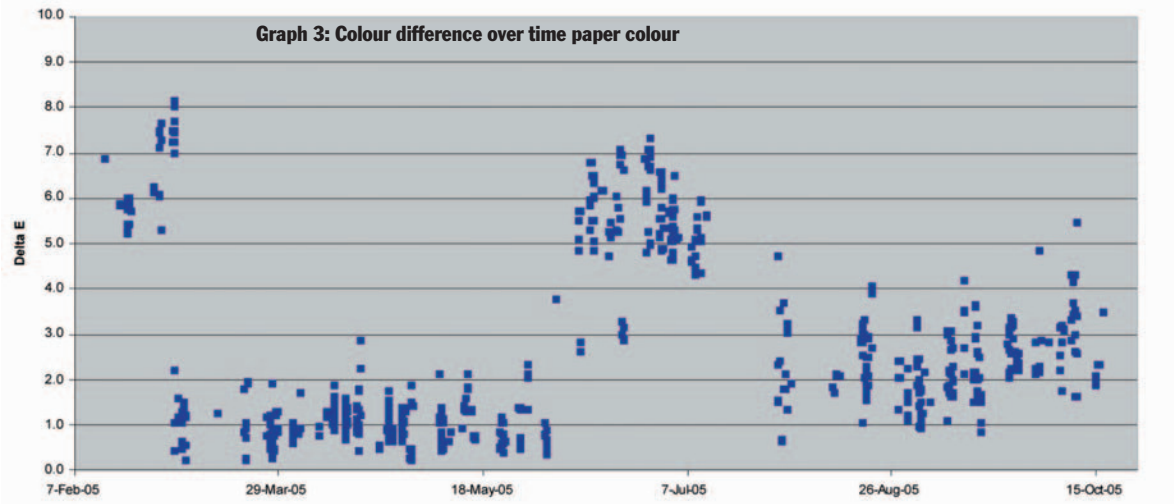
Graph 4 (right), every dot represents the colour difference between the printed colour and the paper colour at the same moment in time. We see clearly two separate groups on the colour difference of the paper. But there is no correlation between the colour difference for the paper colour and the printed colour in the individual groups. 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 possible that the printed colour is correct and within tolerance.



Graph 4: Relation printed colour and paper colour for Δ E

We have not taken into account that the printer can of course change the ink formulation to compensate — but reality they're limited as to how much change can be made. The data shown here is not influenced by ink formulation changes — only the minor changes that relate to viscosity adjustments.





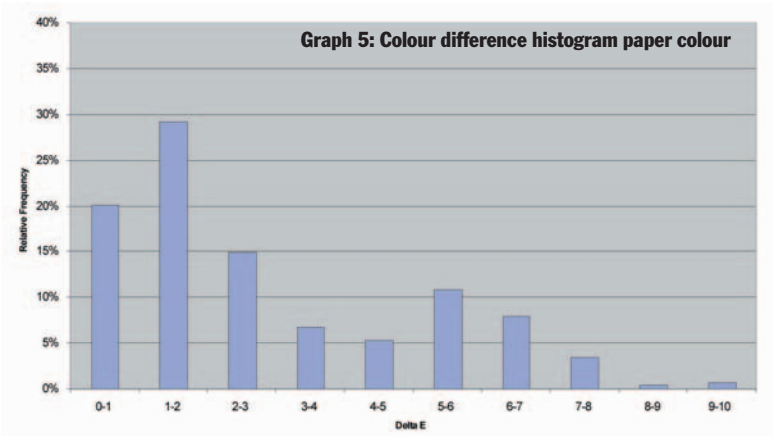
Let us have a look at a colour difference histogram for the paper colour (graph 5). We see one peak at the Δ E interval 1-2 and a smaller one at Δ E 5-6. This indicates that we might be looking at two different populations of paper colour difference data. Two different colour shades of paper have been used in the period observed. We should not mix these populations in any summary statistics. The paper colour difference over time shows clearly that these two paper populations have not been mixed but where used discretely — one in Feb-05 and Jul-05 and the other in Mar/May-05 and Aug/Oct 05. This information can not be deduced from the histogram plot.

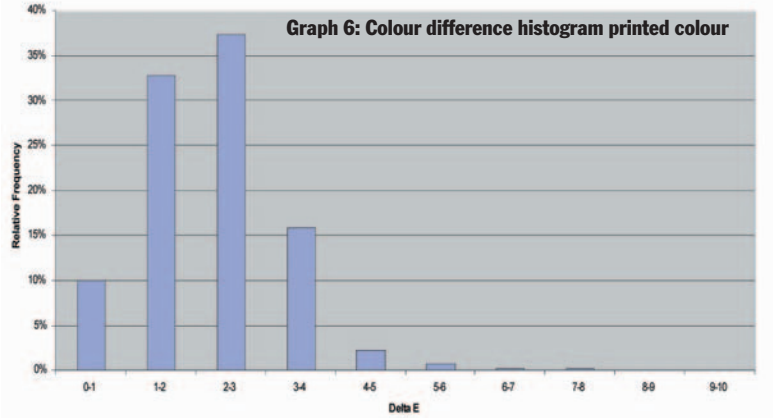
Let us have a look at a colour difference histogram for the printed colour (Graph 6).

Due to the equation used for calculation of Δ E, the histogram is only half a Gaussian curve. If it was a normal distribution then the median was expected at the interval Δ E 0-1. The median is at the interval between Δ E 2 to 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 graph form 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.

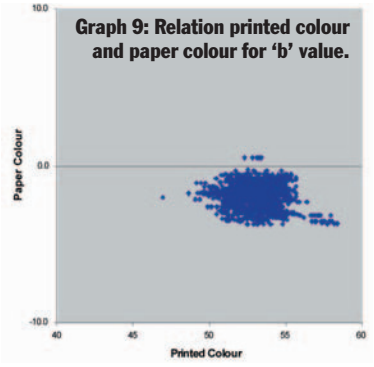
Graph 7 shows the relation for the printed colour and paper colour "L" value. We can see a correlation for the L value.



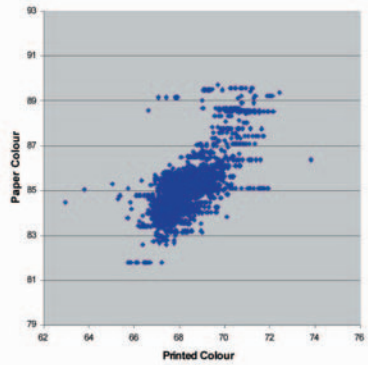


Graph 8 (below) shows the relation for the printed colour and paper colour "a" value. No correlation is visible. The variation for the "a" value is much larger for the printed colour than the paper colour.

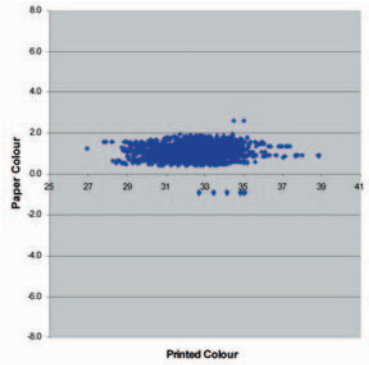
Graph 9 (right) shows the relation for the printed colour and paper colour "b" value. No correlation is visible for the "b" value. The variation is of an equal magnitude for the paper and the printed colour.



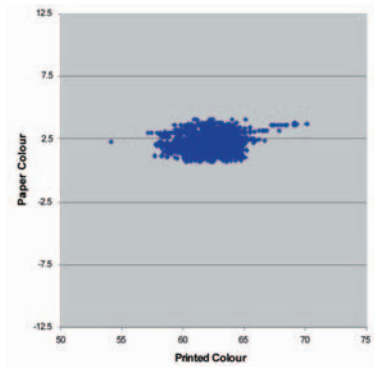
Graph 10 (above) shows the relation for the printed colour and paper colour "C" value. No correlation is visible. The



Graph 7: Relation printed colour and paper colour for 'L' value



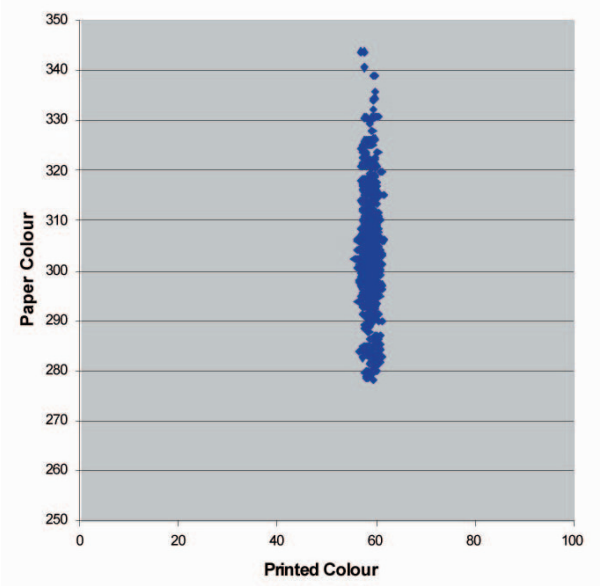
Graph 8: Relation printed colour and paper colour for 'a' value.



Graph 10: Relation printed colour and paper colour for 'C' value.

variation for the "C" value is larger for the printed colour than the paper colour.

Graph 11 shows the relation for the printed colour and paper colour "h" value. No correlation is visible. The variation for the "h" value is much larger for the paper colour than the printed colour.



Graph 11: Relation printed colour and paper colour for 'h' value.

Conclusion and recommendation

The data collected shows that paper colour was dramatically changing over time but that it had limited or no 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 to 2 and ΔE of 5 to 7) showing trough the printed colour.

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

An operator has no control over the paper colour shade nor, in most cases, sufficient data provided to decide if the paper supplied would be fit for purpose to produce the order. Paper colour changes occur due to a reel change or where the mill has spliced different paper production runs together to make a reel. Such practices should be prohibited in the paper buying specification.

— It is recommended that you check printed colour and substrate colour at the same time during production.

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

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