The relationship between printed colour and paper colour

Readers will not be surprised if one claims that printing the same amount of the same ink on 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. In this way the difference is quantified and becomes useful knowledge. *Wilbert Streefland* explains.

Most have seen the effect and just assume that it is a fact. The writer does not claim that the assumption is wrong but hopes that this article will give awareness 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 figure 1 is looked at then it will be perceived 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 of the human eye that makes the observer believe there is a difference.

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

Of course, what is seen is the effect of colour contrast. The human eye deals with this in a way which results in one 'seeing' a different colour when the same coloured ink is printed adjacent but on different background colours.

It must be remembered that 'colour' is a perception and what is seen is a darker and a lighter grey shade. Indeed, two different inks could be used 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.

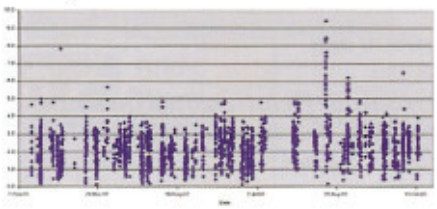
Let us stay with the simple problem of white substrate. White papers from different paper mills around the world have a visible and measurable colour difference. It is commercially interesting to know how much effect the change in paper colour has on the printed colour.

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

The writer had the opportunity to look at nine months 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 $\triangle E$ colour difference for the measurements against the standard and place them on a time line.

The following graph shows the colour difference over time for the measured printed colour (brand colour).

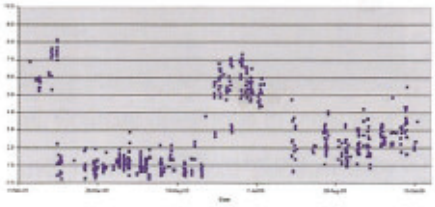


Graph 2: Colour difference over time printed colour.

The spread of the colour printed around the 26 Aug 2005 was large.

Graph 3 shows the colour difference data collected for the paper the brand colour was printed on.

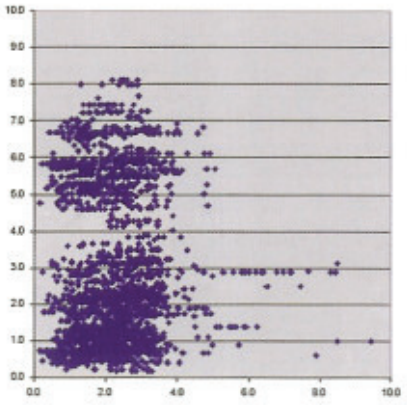
It is seen clearly that during some periods the colour difference is larger between the measured paper colour and the standard than at other periods.



Graph 3: Colour difference over time paper colour.

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

It is seen clearly two groups that separate 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. Thus if the paper colour is off then it does not mean that the printed colour is off in the same amount, on the contrary it is very well possible that the printed colour is correct and within tolerance.

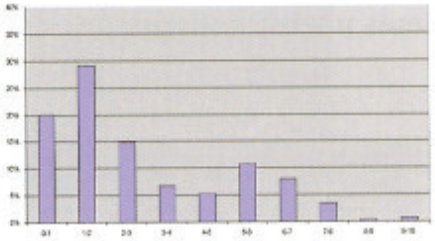


Graph 4: Relationship between printed colour and paper colour for $\triangle E$.

It has not been taken into account that the printer can change the ink formulation to compensate but in

reality the printer is very limited and only will use water or medium to make minor changes to the ink formulation. The data shown here is not influenced by ink formulation changes only the minor changes related to viscosity adjustments.

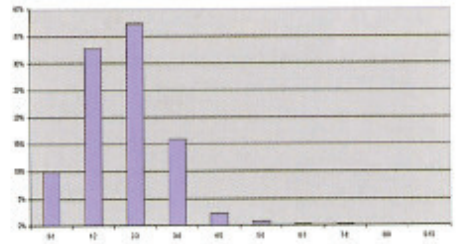
Take a look at a colour difference histogram for the paper colour (graph 5).



Graph 5: Colour difference histogram colour.

One peak at the △E interval 1-2 and a smaller one at △E 5-6 are observed. This indicates that one might be looking at least at two different types of paper colour difference data. Two different colour shades of papers have been used in the period observed. These types in any summary statistics should not be mixed. The paper colour difference over time plot shows clearly that these two paper types have not been mixed but were used carefully; one in Feb-05 and Jul-05 the other in Mar/May-05 and Aug/Oct 05. This information can not be deduced from the histogram plot.

Look at a colour difference histogram for the printed colour (Graph 6).

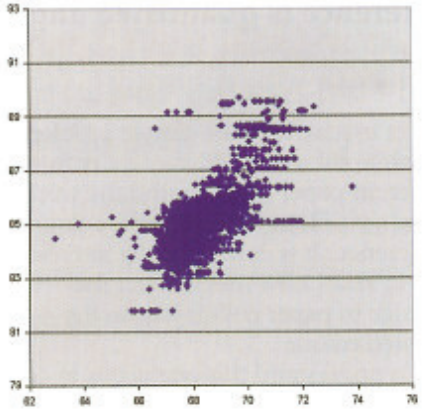


Graph 6: Colour difference histogram printed colour.

Due to the equation used for calculation of △E the histogram is only half a Gaussian curve. If it was a normal distribution then the median was expected at the interval △E 0-1. The median is at the interval between △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 graphs for printed colour and paper colour. Remember that the value for paper and printed colour are different. The axes of the graphs are adjusted to show the same range.

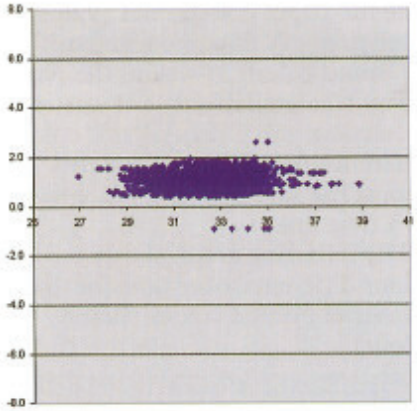
Graph 7 shows the relation for the printed colour and paper colour 'L' value:



Graph 7: Relationship between printed colour and paper colour for 'L'

A correlation for the L value can be seen.

Graph 8 shows the relationship for the printed colour and paper colour 'a' value:

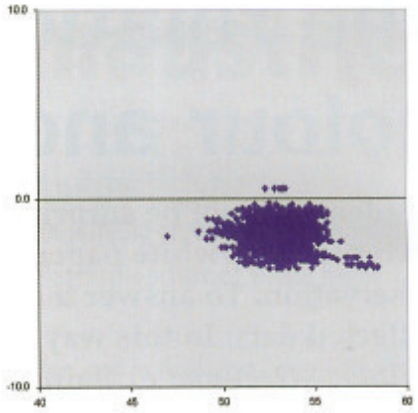


Graph 8: Relationship between printed colour and paper colour for 'a' value.

No correlation visible. The variation for the 'a' value is much larger for the printed colour than the paper colour.

Graph 9 shows the relationship 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 9: Relationship between printed colour and paper colour for 'b' value.

Conclusion and recommendation

The data collected shows that paper colour was changed dramatically over time but that it had 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 (△E of 1 to 2 and △E of 5 to 7) showing through 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's 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 to a limited number of substrate colour standards (spectral data) with an agreed colour tolerance by all parties involved.■