Relationships between percent dot area and colour perception for primary colour in printing

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1. Introduction
A colour-order system is a system that specifies colours by words or symbols for communication. Therefore colour samples bearing the same words or symbols would have the same colour appearance [1]. There are several colour-order systems in use; among them are Munsell, DIN 6164, and NCS. These systems specify colours by hue, chroma, and lightness, which are colour perception attributes. However, these systems do not correspond to the subtractive colour-mixing system in a printing process, which generates colours by overprinting half-tone dots of cyan, magenta, yellow, and black. The percentages of dot area for each primary colour varied from 0-100 with 5 percent intervals. But the percentages of dot area for black varied from 0-100 with 1 percent intervals. In the process control of printing, the samples were reproduced with controlled settings according to the Graphic technology-Process control for the production of half-tone colour separations, proof and production prints-Part 1 (ISO 12647-1) [5].

However, the specification of colour by percentage of dot area must be used with care for communication or reference.

For better communication in the printing industry, it is useful to have a colour system that relates percentages of dot area to attributes of colour perception. To establish such a system, the relationship between percent dot area and colour perception must be determined. In this study, the term colour strength is adopted to represent the perceptual attribute of colour that relates to the colour-mixing system in printing. It is defined as the chroma of an area judged in inverse proportion to its lightness. That means when chroma increases with decreasing lightness, colour strength increases, which relates to the increasing percentages of dot area in printing. This study thus investigates the relationship between percent dot areas of prints and their colour strength. In visual experiments, observers estimate colour strength for a given colour sample that is printed with AM (Amplitude Modulation) screen and offset printing process. AM screening is selected in this study, based on results found in Brozovic et al’s study [4].

2. Experiment
Preparation reference scale
Colour samples were created using a vector image application program. Each sample was a 3-cm square filled with either one of the four primary colours in printing, i.e. cyan, magenta, yellow, and black. The percentages of dot area for each primary colour varied from 0-100 with 5 percent intervals. But the percentages of dot area for black varied from 0-100 with 1 percent intervals. In the process control of printing, the samples were reproduced with controlled settings according to the Graphic technology-Process control for the production of half-tone colour separations, proof and production prints-Part 1 (ISO 12647-1) [5].

The grey scale (printed samples of black ink with different percentages of dot area from 0-100) was used to define a reference scale of colour strength. This is because the grey scale is devoid of hue and has the lightness from 0-100, which will cover the range of colour strength of other primary colours. In this experiment, the grey patches were presented in a viewing cabinet illuminated with D50. Observers were asked to arrange the patches from white (0% dot area, or no print) to black (100% dot area). Any patches that observers could not differentiate the difference in lightness between them were sorted into the same level. This experiment aimed at finding the perceptual scale of colour strength that observers can distinguish between different percentages of dot area of prints.

Matching colour perception
The reference scale found from the experiment explained above was used to compare colour strength between the reference and the colour sample patches (Fig.1). This was done by asking observers to compare a given colour chip, for example 20% dot area of cyan, to the reference scale and identify the level in the reference scale to which the given chip matches in terms of colour strength. In the case that no exact level can be found, observers were asked to identify the two adjacent levels in the scale that the colour chip falls between them.
3. Result and Discussion

The grey scale with black ink printed in different percentages of dot area from 0-100% was rearranged by 30 observers to from perceptual scale of colour strength that observers could differential between the grey patches. It was found that observers could distinguish 70 steps from 100 printed steps. The percentages of dot area representing each step were derived from the median values of all observers’ results – all patches that were sorted into the particular steps. For example, 1% dot area is taken to represent the first step because observers sorted 0%, 1% and 2% patches into this step, i.e. observers perceived these 3 patches as having the same colour strength. Fig. 2 shows a plot between percent dot area of black ink (x axis) and its corresponding percent dot area of perceptual colour strength (y axis). The results showed that the scattered points were somewhat more expansive at the low percent dot area (0-30%) than at the high percent dot area (80-100%). This reveals that observers could differentiate colour strength of patches with high percent dot area better than low percent dot area. In other words, observers had better colour strength perception for the shadow area of prints than the highlight area. This indicates that the perception of colour strength is non-linear. This result conforms with the print contrast measurement for quality control in printing process that uses the halftone area at the three-quarter tone (shadow zone), normally 70-80%. Shadow contrast is an attribute of print quality that is particularly sensitive to most of the variables affecting printing for quantifying the effect of change in area coverage [6].

In the colour strength matching experiments, 30 observers completed the experiments and the corresponding percent dot area of black having the same perceptual colour strength with the primary colours in each step were averaged from all observers. The results are plotted in Fig.2. When the percent dot area of primary colours increased, the colour strength increased. For the percent dot area lower than 40%, different primary colours behaved in the same way, as can be seen from the trend lines of cyan, magenta, and yellow inks being almost identical to the trend line of black ink. From the mid-tone to shadow area (40%-100%), the trend lines of different primary inks were different, revealing that hue has an effect on the perception of colour strength and the effect is prominent when percent dot area is high enough. The vertical line at 50% dot area of C, M, and Y shows the corresponding percent dot area of black at 54%, 56%, and 57%, respectively. This means that at the same percent dot area, yellow had the highest colour strength, and cyan the lowest. The coefficient of variance (CV) was used to analyse the inter-observer agreement in each step. The overall agreement was found to be 22%, which indicates reasonable agreement between observers’ results.

Fig.2. Relationships between percent dot area and colour strength.

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References

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