J Forensic Sci, Jul. 1976, Vol. 21, No. 3

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The Application of a Standard Color Coding System to Paint in Forensic Science

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Much of the effort of forensic scientists is directed towards establishing the possibility of a relationship between two or more items. The approaches vary, but generally, after a visual comparison, the items are subjected to several physical and chemical tests. In the case of paint samples, a visual examination will afford information as to the color [*1*], layer structure [*2*], thickness, pigment distribution, and so on. Subsequent tests could include pyrolysis gas chromatography [*3*] to establish the resin type and infrared spectroscopy [*4,5*] to examine both the paint vehicle and pigment. The visual examination of paint samples is one of the most valuable tests as it is easily and inexpensively carried out, affords high discrimination, and is nondestructive.

With the comparison of colors there are a number of problems; first, although the eye is capable of discriminating between different hues, tones, and intensities, it is highly subjective; and second, the matching of small samples is prone to errors. Accepting this, there is the major additional problem of the significance of the color match.

The prime objective of a color system in forensic science is that it should provide a standard means of describing a color and communicating this information to other individuals. If the color of an object can be accurately described, the information can be recorded to provide the frequency of occurrence of objects with a given color and hence the significance of a color match.

At the time of writing no instrument has been found which is suitable for recording objectively the color of small irregular samples frequently encountered in forensic science casework. In this paper it is proposed that colors could be more objectively described by reference to a color system involving the use of colored chips or plates. A basic requirement of such a scheme should be that it contains a suitable number of colors arranged in some systematic manner and that it is both robust and inexpensive. For the purposes of the work described here the *Methuen Handbook of Color* [*6*] has been used.

The Handbook consists of 30 double pages, on each of which there are 48 small (3 by 1½ cm) rectangles of different colors, arranged in a 6 by 8-sample array, together with various descriptive information. In this form any color in the book may be indexed by a page number and its array position. A color is therefore defined under the system by three parameters.

Received for publication 16 July 1975; revised manuscript received 23 Oct. 1975; accepted for publication 3 Nov. 1975.

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1. The wavelength of a color in the visible spectrum is related to the hue, and is defined by a page number.

2. The tone of a sample is described by a letter: A (white) through increasing degrees of darkness to F.

3. The intensity of a color is described by a number: 1 (neutral) through increasing degrees of intensity to 8.

Thus a designation 10F8 refers to p. 10, column F, row 8 and completely defines that color.

The first page of the book contains plates with a yellow-green color, and as the page numbers increase there is a gradual change from one color to the next through red, blue, and finally back to green. The last page in the book (p. 30) is green and is adjacent in the color spectrum to p. 1. Hence the book is in effect a color solid where each color is defined by three parameters. The neutral tone scale with white at the top forms the central vertical axis. The hue scale is arranged in visual steps around the neutral axis, and the intensity scale radiates in visual steps from the neutral axis outwards to the periphery of the color solid.

A diagram of the concept of the color solid with reference to the Handbook is shown in Fig. 1.

Investigation of the Errors Involved

To use the system as a means of standardizing color recording, the errors involved in its practical use had to be assessed. Twenty car-color cards, prepared using manufacturers' car paints, were therefore selected to include colors of varying hue, tone, and

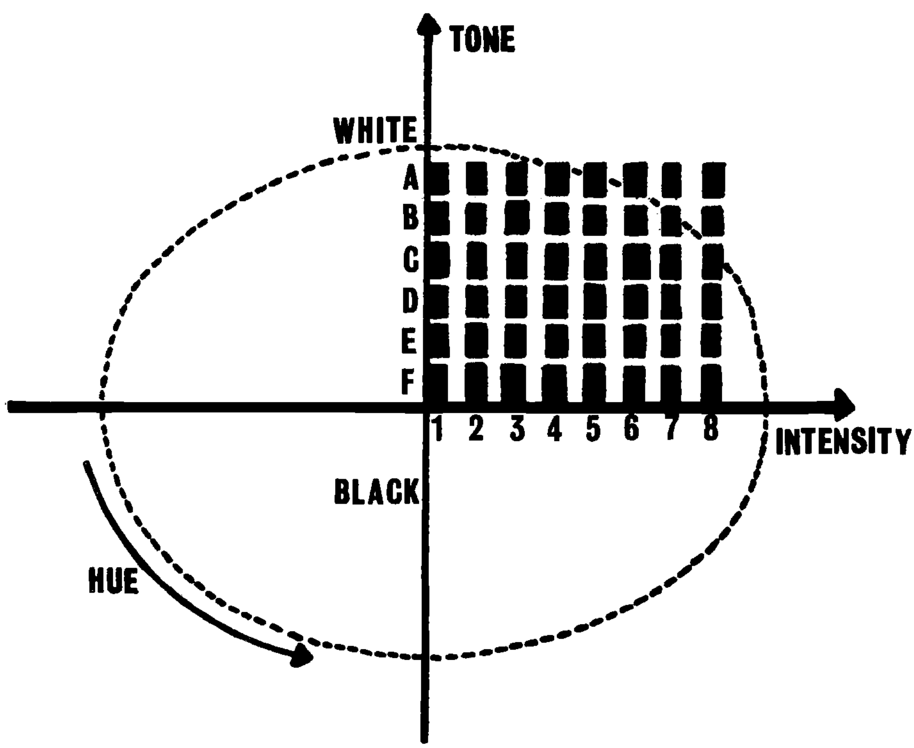

FIG. 1—*Diagrammatic representation of the concept of the color solid in Ref 6.*

intensity described throughout the color solid. Included were eight samples considered by the experiment designers to be good matches to a particular color square and five samples considered very poor matches. Each color card was divided into three sizes (1 in.^{2}, 1 cm^2, and 1 mm^2) and the colors of the samples were matched to those in the book by ten independent observers[4] (making 600 comparisons in all). All the comparisons were carried out under normal laboratory conditions, that is, no specific restrictions were made on lighting used.

Although the same book was used for all these observations, approximately twenty different books were checked for reproducibility, and no significant differences were noted.

Results and Conclusions of Error Investigation

The results from the comparisons with the largest samples (1 in.^{2}) were examined to establish the modal color for a particular sample. Two typical results are shown in Table 1.

Where the match with a brownish-grey 9C2 was considered good by the experiment designers, there was little disagreement among the observers, as shown in Table 1; whereas the violet color 17B4 proved to be much more difficult and six different colors were suggested. If the scheme is to be used to record and transmit the colors of individual items then there is obviously a need to establish the differences that can occur in the description of a specifc color. This can be described as the error from the modal color.

Three possible margins of error were considered and are defined diagrammatically in Figs. 2–4. An error of 1, 1, 1 (1 square in every direction from the modal value) defines a total of 26 color squares around any given square. An error of 2, 2, 2 (2 squares in the hue, tone, or intensity planes from the modal value) is defined in Fig. 3. An error limit of six nearest neighbors is defined in Fig. 4.

It can be seen from Table 2 that for samples of 1 cm^2 with an error margin of 1, 1, 1, 89% of all measurements were within one square of the modal value for a given determination. Measurement of control samples of paint received in the Home Office Forensic Science Laboratory, Aldermaston, has shown that in most cases the samples are greater than 1 cm^2 in area, and thus for samples of this size approximately 89% of all color comparisons using this sytem will be within an error limit of 1, 1, 1 of the modal value for a particular sample.

TABLE 1—*Results of comparisons of 1-in.^{2} samples.*

Match	Modal Value	Colors Mentioned by 10 Observers
Good	9C2	9 = 9C2; 1 = 8C2
Poor	17B4	3 = 17B4, 2 = 16C4, 2 = 17B3, 1: 15C3, 1 = 16B4, 1 = 16B3

TABLE 2—*Error margins for samples.*

	Comparisons		
Sample	Within 1, 1, 1 of Mode, %	Within 6 Nearest Neighbors of Mode, %	Within 2, 2, 2 of Mode, %
1 in.^{2}	95.5	85.5	96.5
1 cm^2	89	78.5	92
1 mm^2	81	62.5	86

[4] All ten observers had normal color vision when tested with Ishihara color test cards.

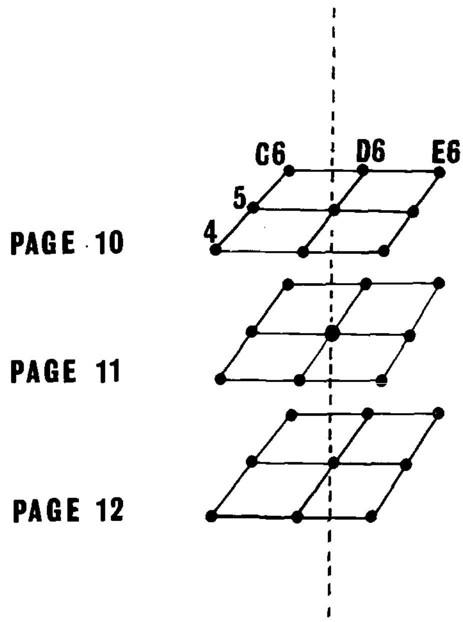

FIG. 2—*Diagram of an error limit of 1,1,1.*

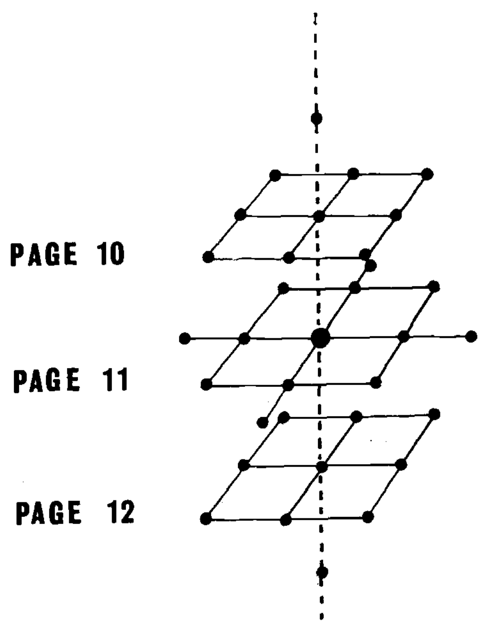

FIG. 3—*Diagram of an error limit of 2,2,2.*

One of the major limitations of the system is its nonlinearity: not all the color steps from one chip to another are equal visual steps. Because of this limitation and the problems involved in the psychological and physiological color responses, the error does vary with hue, tone, and intensity [7]. However, to provide an error limit which changes with page and position is both cumbersome and probably unnecessarily complicated for this particular application.

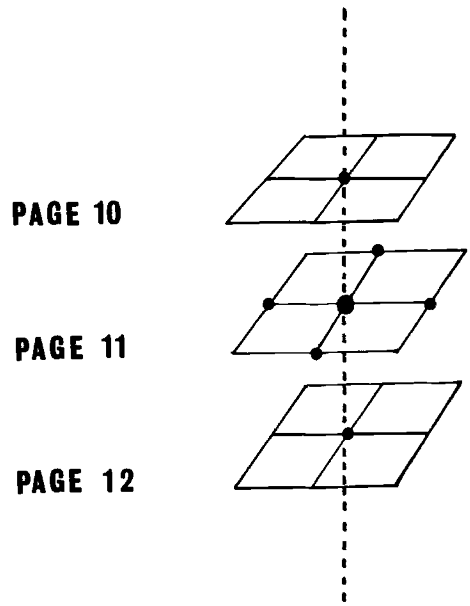

FIG. 4—*Diagram of an error limit of six nearest neighbors.*

Table 3 shows that although values of hue are affected more by sample size than tone values and intensity values are consistently higher than tone values, averaged over 20 different samples, the average error is of the same order of magnitude for all three parameters.

Survey of Building Colors

Having decided that the system was sufficiently reliable for coding colors of automobile paints a survey of the occurrence of various colors on buildings in the town of Basingstoke was conducted. Basingstoke is a rapidly expanding London overspill town with a population of 52 502 (based on 1971 census figures).

Arbitrary grid lines were drawn on a map of Basingstoke to yield rectangles representing an area $\frac{8}{45}$ by $\frac{16}{45}$ of a mile (286.5 by 573 m). The points of intersection were visited with an observer and the colors of doors, windows, and their respective frames on the ten nearest buildings were compared to the Handbook colors.

Results and Conclusions of Building Survey

The data obtained from this survey were treated by counting the number of times a given color square was observed and indicating this number in a facsimile page of the

TABLE 3—*Variation of errors with hue tone, and intensity, by 10 observers.*

Sample	Observations Differing by 1 or More Squares from Modal Value, no.[a]		
	Hue	Tone	Intensity
1 in.^{2}	35	33	46
1 cm^2	49	36	64
1 mm^2	94	50	80

[a] Based on 600 individual observations.

book (Fig. 5). Examination of these results indicates the frequency of occurrence of a given color in the population. The results from the color comparisons of windows, doors, and their respective frames were treated separately. The results showed that there were marked differences between the distribution of colors on doors and windows but very little difference between the window frames and door frames. The results from the door and window frame colors were therefore combined. The distribution of white and black paint in Basingstoke is shown in Table 4, these two colors representing more than 65% of the color population.

This procedure could provide a means of color measurement for samples other than paint, such as drug tablets, plastics, fibers, soil or any colored material encountered in a forensic science laboratory.

Summary

The procedure described for the measurement of paint colors represents an attempt to standardize the measurement of color in the forensic science service and provides a means of communicating colors between individuals. The effect of sample size on color comparisons has been discussed. It has been shown that color data collected from

	A	B	C	D	E	F	PAGE 1
			1	2			8
			6				7
		2		3			6
	1						5
	1	3					4
	3						3
	1		2				2
	78	1		10		17	1

FIG. 5—*Facsimilie page of Ref 6*.

TABLE 4—*Distribution of black and white paint in a survey of Basingstoke.*

Area	Number of Locations	Black	White	Other
Door	500	17	78	405
Window	500	14	400	86
Frame	1000	50	757	193

many control samples of paint flakes can provide the frequency of occurrence of paint colors. The errors involved in color comparisons have been assessed and the system has been shown to be a practicable one.

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