Colour order systems - Diversity and congruence

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A colour order system is a set of principles for the ordering and notation of colours, usually according to defined scales. A related concept, a colour atlas, is a collection of physical colour samples arranged according to a colour order system. The purpose of colour order systems and atlases vary. Some are designed to describe colour perceptions (sometimes called percepts). Others define colour stimuli, illustrate colour reproduction processes, illustrate colour harmonics and aesthetics, illustrate colour differences, or illustrate the colours of a company's products. Well known examples are the Coloroid System, the DIN System, the Munsell System, the Natural Colour System (NCS), the Optical Society of America (OSA) System, and the Ostwald System.

Recently there has been considerable interest in the possibility of international standardization of a single system for the notation of colour perceptions. In particular, two international committees (ISO/TC187 - Colour Notations, and CIE TC 1-31 Colour Notations and Colour Order Systems) have been working in cooperation to examine the problem. The two systems on which the Committees have concentrated their interest are the Munsell System and the NCS. Both systems represent colours in a three-dimensional space formed by the systematic variation of visual attributes', but the methods by which the perceptions are organized and analyzed in the two systems are quite different. The Munsell System uses scaling of hue, lightness and chroma, whereas NCS scaling is based on resemblances to six elementary colours. Despite these differences, it is theoretically possible to map one system into the other as both represent the same universe of colour perceptions.

The Munsell System is described and defined in a paper by Newhall et al[1] and in an ASTM Test Method[2]. The NCS System is described and defined in two Swedish Standards[3,4]. The Scandinavian Colour Institute has recently published a key[5] that gives the NCS notations for the colours in the Munsell Book of Color, an atlas based on the Munsell System. These five references provided the data on which this paper is based.

In the Munsell System, hue is defined as the attribute by means of which a colour perception is judged to be red, orange, yellow, green, blue, purple or intermediate between adjacent pairs of these. In the NCS, hue is defined as the ratio between the two chromatic elementary attributes of a colour perception. (An elementary attribute is the degree of resemblance to one of the six elementary colour perceptions: white, black, yellow, red, blue and green.) These definitions are sufficiently similar that one would expect that colours that have the same Munsell hue as each other would also have the same NCS hue as each other although the spacing between hues might be different.

Nuance, the two-dimensional attribute that distinguishes amongst colours of the same hue is organized quite differently in the two systems, although both have one attribute that describes the

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variation from black to white and one that describes the variation from achromatic to strongly chromatic. In the Munsell System, the two attributes of nuance are value (the attribute by which a surface is judged to reflect more or less light) and chroma (the attribute that indicates the degree of departure from a

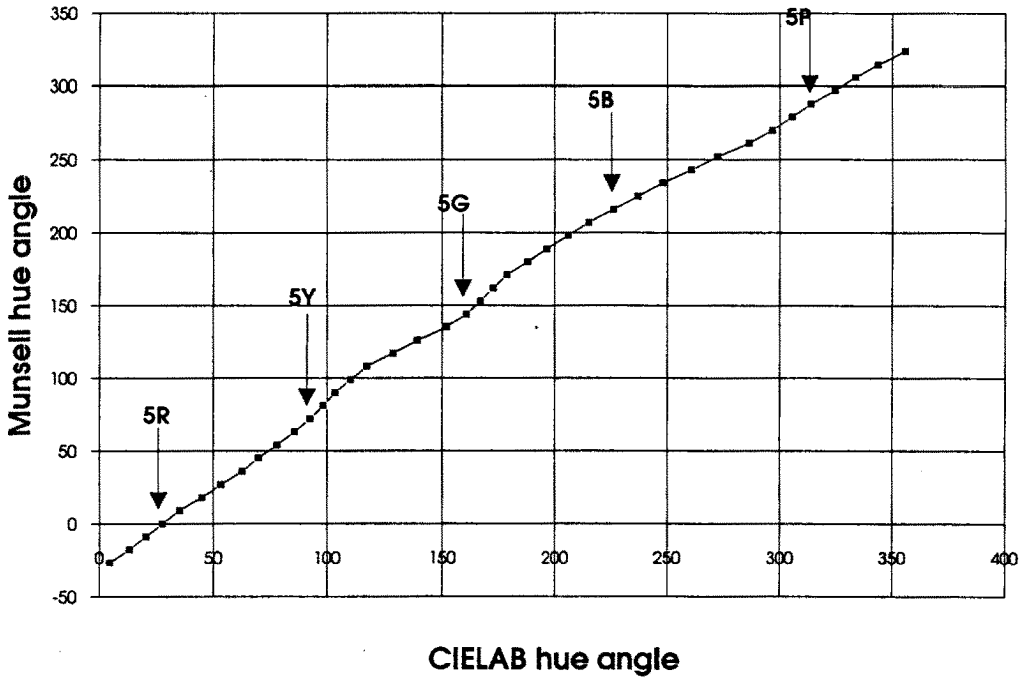

Fig. 1 Munsell hue angle as a function of CIELAB hue angle for the 6/6 hue circuit

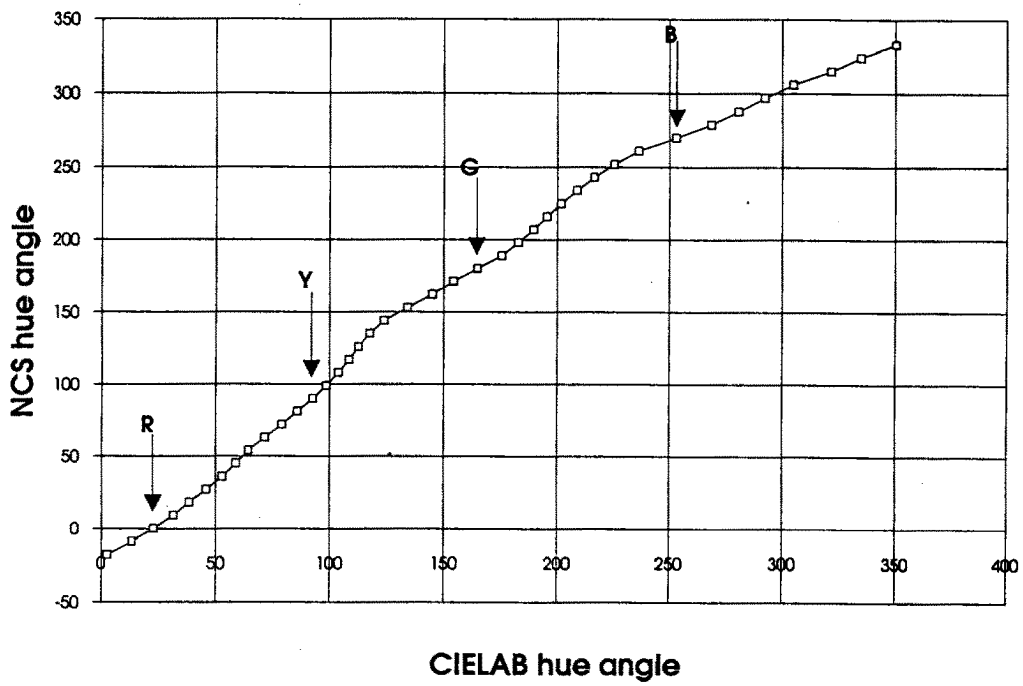

Fig. 2 NCS hue angle as a function of CIELAB hue angle for the 3040 hue circuit

grey of the same value). In the NCS, the two attributes are whiteness (the degree of resemblance to the elementary colour, white) and chromaticness (the sum of the degrees of resemblance to the two neighbouring chromatic elementary colours).

The relationships between hues in the two systems are similar in that both systems arrange hues in a continuous circuit, but the spacing is different. The major difference is in the cardinal points - the points that anchor the relationships between hues. In the NCS the four unique hues (red, yellow, green and blue) are placed 90° apart, whereas the Munsell System has five cardinal hues (red, yellow, green, blue and purple) which are placed 72° apart and chosen to give a uniform representation of hue differences throughout the circuit.

A careful study of the NCS hue notations for colours of equal Munsell hue, based on reference 5, shows typical variations of about 10 NCS hue units (9°). Whether these variations result from the slightly different definitions, from differences in the viewing conditions in which the systems were developed, or from errors in the definitions of the systems is not clear.

In order to investigate the hue spacing in the two systems in more detail, two particular hue circuits were chosen. These were the circuits for value 6/ and chroma /6 in Munsell, and for blackness = 30, chromaticness = 40 in NCS. For ease of comparison, the hue notations in each system were converted to degrees and plotted against CIELAB hue angle. For "Munsell hue angle", 5R was arbitrarily chosen as the zero point. For "NCS hue angle", unique red was chosen as zero. The results are shown in **Figs. 1** and **2** with the cardinal points marked. The major differences result from the choice of cardinal points. The four elementary hues in the NCS have Munsell notations of approximately 5R, 5Y, 7.5G and 10B (0°, 72°, 153° and 234° respectively). A new variable called "NCS uniform hue angle" was therefore calculated with these values at the cardinal (elementary) hues and with the other hues spaced proportionately. Comparison of NCS uniform hue angle with Munsell hue angle

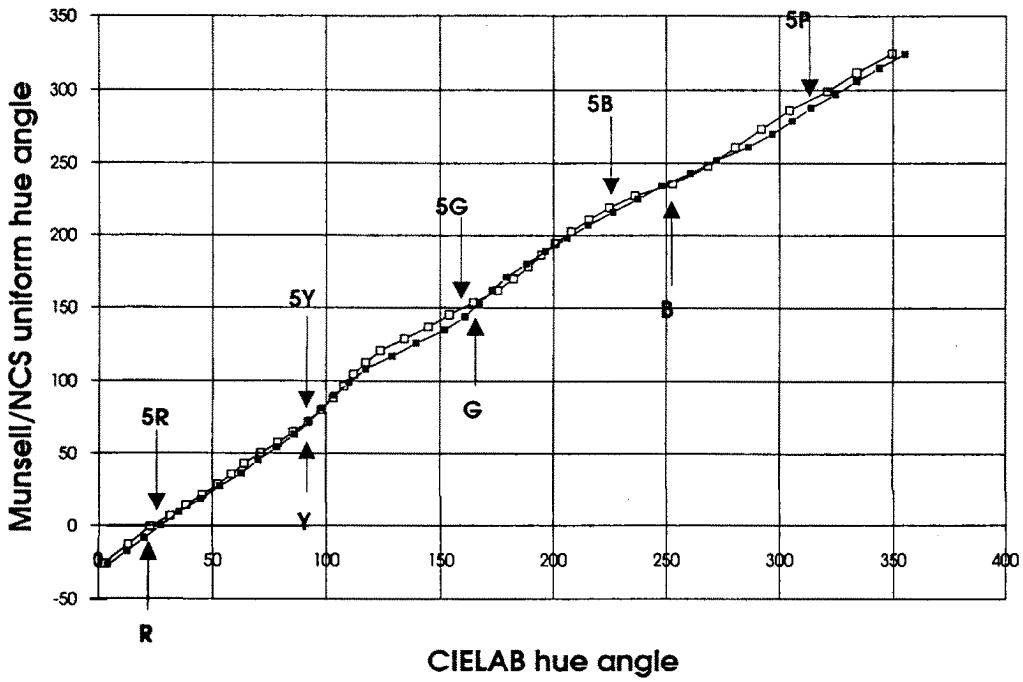

Fig. 3 Comparison of Munsell hue angle for 6/6 (solid squares) and NCS uniform hue angle for 3040 (open squares) as a function of CIELAB hue angle

(**Fig. 3**) shows general similarity but some small differences remain, particularly in the yellow-green and purple areas.

For neutral colours, Munsell value and NCS whiteness can both be described by mathematical equations so their relationship is easy to determine. However, this relationship is different for different levels of NCS chromaticness and for different hues so further equations need to be developed.

The third attributes (chroma for the Munsell System and chromaticness for the NCS) are so different in concept that it is unlikely that anything other than an empirical relationship can ever be derived.

Colour atlases are available for both systems but the emphasis placed on the atlas is different. The NCS is defined in terms of visual perceptions with the atlas being merely illustrative for a particular set of viewing conditions. Although this was originally true for the Munsell System, the colorimetric specifications of the atlas samples are now the definition of the system. Thus, at least at present, the fundamental significance of the atlas and of colorimetric specifications is different. This may change in the future as the NCS matures, but in any case should not be a bar to comparisons of the two systems and to specifications of the relationships between them.

Much work remains to be done to explore these relationships and it seems that international standardization of a single colour order system for colour perceptions is unlikely in the foreseeable future. In fact, the question of which principle of analysis is "better" - hue/value/chroma or resemblance to elementary colours may never be resolved.

References

1) S. M. Newhall, D. Nickerson and D. B. Judd: Final Report of the O.S.A. Subcommittee on the Spacing of the Munsell Colors. *Journal of the Optical Society of America*, **33**, 385-418, 1943.
2) ASTM Test Method D1535-89, Specifying Color by the Munsell System, 1989.
3) Swedish Standard: Colour notation system. SS 01 91 00 E, 1978.
4) Swedish Standard: CIE tristimulus values and chromaticity coordinates for some 16 000 colour notations according to SS 01 91 00. SS 01 91 01, 1983.
5) Scandinavian Colour Institute: Key Munsell Book of Color- NCS. 1993.