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COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE
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INTERNATIONALE BELEUCHTUNGSKOMMISSION

CIE COLLECTION

in COLOUR and VISION

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THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organisation devoted to international co-operation and exchange of information among its member countries on all matters relating to the art and science of lighting. Its membership consists of the National Committees in 40 countries and one geographical area and of 12 individual members.

The objectives of the CIE are :

1. To provide an international forum for the discussion of all matters relating to the science, technology and art in the fields of light and lighting and for the interchange of information in these fields between countries.
2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
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A plenary session is held every four years at which the work of the Divisions and Technical Committees is reviewed, reported and plans are made for the future. The CIE is recognised as the authority on all aspects of light and lighting. As such it occupies an important position among international organisations.

LA COMMISSION INTERNATIONALE DE L'ÉCLAIRAGE

La Commission Internationale de l'Éclairage (CIE) est une organisation qui se donne pour but la coopération internationale et l'échange d'informations entre les Pays membres sur toutes les questions relatives à l'art et à la science de l'éclairage. Elle est composée de Comités Nationaux représentant 40 pays plus un territoire géographique, et de 12 membres individuels.

Les objectifs de la CIE sont :

1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ 20 Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

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Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in 40 Ländern und einem geographischen Gebiet und aus 12 persönlichen Mitgliedern.

Die Ziele der CIE sind :

1. Ein internationaler Mittelpunkt für Diskussionen aller Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik und für den Informationsaustausch auf diesen Gebieten zwischen den einzelnen Ländern zu sein.
2. Grundnormen und Verfahren der Meßtechnik auf dem Gebiet der Lichttechnik zu entwickeln.
3. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
4. Normen, Berichte und andere Publikationen zu erstellen und zu veröffentlichen, die alle Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik betreffen.
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Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtenwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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The Reports in this publication have been prepared by various CIE Technical Committees and Reporters within Division 1 "Vision and Colour". The reports draw on current knowledge and experience within the specific field of light and lighting described, and are intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of the reports is advisory and not mandatory. The latest CIE proceedings, CIE NEWS, future issues in the "CIE Collection" Series or publication listing should be consulted regarding possible subsequent amendments.

Les rapports ont été préparé par différents Comités Techniques et Rapporteurs de la CIE la Division 1 "Vision et couleur". Les rapports traitent des connaissances courantes et de l'expérience dans le domaine spécifique indiqué de la lumière et de l'éclairage, et il est établi pour l'usage des membres de la CIE et autres groupements intéressés. Il faut cependant noter que les rapports sont indicatifs et non obligatoires. Pour connaître d'éventuels amendements, consulter les plus récents comptes rendus de la CIE, CIE NEWS, éditions futures de la série "CIE Collection" ou les listes de publications de la CIE.

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CIE TC 1-31 Report:**Colour notations and colour order systems****A report in response to a request from ISO/TC187****Foreword**

The following members of TC 1-31 "Colour notations and colour order systems" took part in the preparation of this technical report. TC 1-31 comes under CIE Division 1 "Vision and Colour".

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1. PURPOSE

Technical Committee 187 (TC187) of the International Organisation for Standardisation (ISO) requested the International Commission on Illumination (CIE) to address some issues related to the question of international standardisation of a colour-order system and to report its conclusions. In response to that request, technical committee TC1-31 Colour Notations and Colour-Order Systems was formed by Division 1 of the CIE, at its meeting in Melbourne, in July 1991. This is the final report of that technical committee.

ISO TC187 document N 31 listed the following issues for consideration:

- (a) To consider further the terms and definitions which are based mainly on phenomenological concepts, and which are given in document TC 187/WG 1:N8 rev.
- (b) To consider and describe existing colour-order systems in relation to the basic principles given in document TC 187/WG 2:N8 rev.
- (c) To make recommendations as to whether and how congruence can be achieved between different colour-order systems by appropriate adaptation to the terminology and principles given by documents TC 187/WG 1:N8 rev and TC/WG 2:N8 rev.
- (d) To consider whether any colour system can be chosen as being better than the others from a theoretical viewpoint.
- (e) To consider available information concerning the extent to which different colour-order systems have been proven to be useful, helpful and applicable to different use situations.
- (f) To consider the colorimetric conditions to be used for the comparison and measurement of samples illustrating colour-order systems, with reference to documents TC 187 N19, N22, and N30.
- (g) To consider the technical questions associated with the use of self-luminous displays in association with colour-order systems.

2. SCOPE

The scope of this CIE committee activity was confined to the specific issues raised by the ISO committee. The statements of issues referred to "existing colour-order systems", "any colour system", and "colour-order systems", without restriction. It was pointed out subsequently that the specific task to which ISO/TC187 is committed is related to the standardisation of descriptive colour notations. Thus, while not addressing specifically the limitations introduced by the word "descriptive", the committee has concentrated on colour-appearance systems. Other types of colour-order systems were explored only to the extent necessary to address the specific issues and support the conclusions.

3. INTRODUCTION

3.1 Colour Terms

Discussions of colour are often complicated by the different meanings of the noun "colour." The CIE defines colour in two ways, 1. *perceived colour* and 2. *psychophysical colour*. Perceived colour depends on many factors other than the spectral power distribution of the physical stimulus associated with the area to which the colour is ascribed. These factors include the size, shape, and structure of the area itself; the size, shape, and properties of areas surrounding the specified area; the state of adaptation of the observer's visual system; and the observer's experience in making similar observations. Psychophysical colour is a specification of a colour stimulus itself, in terms of operationally defined values, based on standard data obtained by visual colour-matching experiments. Such a specification does not describe the colour appearance, and identifies it only under very restricted observation conditions. Such specifications are of great commercial importance as measures of degree of colour match under specified conditions of observation. We speak of the colour of an object, although the perceived colour depends not only on the object, but on many aspects of the illumination and viewing situation. Only the physics of the object (the way it emits, reflects, transmits, and scatters or otherwise modulates light) can truly be attributed to the object.

3.2 Colour-Order Systems

A colour-order system is a method of arranging colours, so that like colours are brought together and colour variations are arrayed in a continuous organised way. There are several ways to achieve such an arrangement^{2-8, 36-38}.

One way is to develop a gamut of colours from a given set of colorants, by varying the proportions of mixture in some systematic way. The system is called a "*colorant-mixture system*".

Another way is to produce an array of colours by varying their tristimulus values in a systematic way. The system is called a "*colour-mixture system*" or, perhaps more appropriately, a "*colour-stimulus system*".

A third way is to arrange colours according to their appearance to normal human observers. The colorants or other mechanisms of producing the colours are immaterial. The system is called a "*colour-appearance system*". This CIE committee activity was limited to such systems.

A colour-order system may be a statement of the plan for systematic arrangement of colours. Such a colour-order system is an abstract system, as distinguished from a concrete system, which exemplifies the abstract system in the form of a coloured specimen display arranged in accordance with the prescribed method.⁹ This distinction may be quite important in some respects. The abstract system may be applicable without a concrete embodiment or it may be defined, in part or wholly, by the concrete system. Concrete systems are valid only under specified illumination and viewing conditions. The abstract system may be in the public domain, while a concrete embodiment may be a proprietary product marketed commercially under a trademark protected by law. There may be more than one concrete embodiment of a given abstract colour-order system.

Coloured specimens must be used to define terms for hue, in a given language. Such definition by demonstration is called "ostensive definition". Once the terms are defined, a system of organisation can be described in words, without having an array of specimens so organised.

Colour appearance systems may differ in the choice of parameters used to specify colours, the choice of perceptual reference points, and the choice of psychometric methodology employed to establish the relationships among colours. The scaling of colour-appearance systems may be based on different principles. Two different and incompatible approaches may be cited as examples:

- a. The aim may be to establish the order and scaling of colours according to their perceived resemblance to some generally recognised set of reference colours, six reference colours being necessary and sufficient.
- b. The aim may be to establish the order and scaling of colours to achieve nearly uniform visual spacing in colour space.

These distinctions must be considered in the study of items referred by ISO to the CIE, as addressed in the following paragraphs.

4. ISSUE (a), TERMS and DEFINITIONS

The terms and definitions cited in ISO document TC 187/WG 1:N8 rev have been referred to CIE TC 7-06 (Lighting Terminology) as considerations as inclusions in the next revision of the CIE vocabulary¹. There are many terms and definitions based on phenomenological concepts that should be considered³⁵. There is a notable lack of such terms and definitions in the current vocabulary, which tends to concentrate on the terminology of the psychophysics of colour measurement. The terminology of various aspects of colour science must be considered together, to assure consistency of the entire set of terms and definitions and to assure that necessary distinctions are drawn.

The committee emphasises that the ISO adoption of different colour terms or definitions would be a disservice to the unifying principle of international standardisation. At the same time, it is essential that the CIE, which has traditionally been primarily concerned with the colour stimuli terminology, pay proper attention to including new terms or revising old terms that have a perceptual rather than a physical content.

5. ISSUE (b), DESCRIPTION of EXISTING SYSTEMS

There are various abstract colour-appearance systems in use, all employing three independent attributes as an organisation basis. Each has been exemplified by a concrete coloured specimen set.

In the *Natural Colour System* (NCS), the appearances of colours (in any prevailing illumination and viewing condition) are scaled according to their degrees of resemblance to six elementary colours: white, black, red, yellow, green, and blue, following Hering's opponent colour theory^{10,36-38}. Resemblances are expressed by the variables hue, whiteness, blackness, and chromaticness. The latter three, one of which is redundant for notational purposes, constitute the nuance of the colour. Lightness and saturation are identified indirectly, but are not fundamental to the system. No overall equal spacing is intended, but the subspace within a hue quadrant is reasonably equispaced. The NCS atlas illustrates the Natural Colour System with coloured specimens, colorimetrically defined for CIE Illuminant C and the CIE 1931 Standard Observer¹¹. It illustrates the scales established by many visual observations, under specified illumination and viewing conditions, and documented by CIE colorimetry^{12,13}.

In the *Munsell colour-order system*, the appearances of colours are scaled according to nearly uniform scales of the psychological attributes hue, value, and chroma, which are used for notational purposes¹⁴. These scales have perceptual definitions refined by psychophysical

methods aimed at an equal spacing. Value is a lightness correlate. Chroma is the degree to which a colour differs from a neutral colour of the same value. The Munsell Book of Color and the atlas of the Japan Color Research Institute illustrate the Munsell system with coloured specimens, colorimetrically defined for CIE Illuminant C and the CIE 1931 Standard Observer. They illustrate the scales established by many visual observations by members of a subcommittee of the Optical Society of America, under specified illumination and viewing conditions, and documented by CIE colorimetry¹⁵.

The *German Standard Colour Chart*, known as the DIN 6164 system, after the Deutsches Institut für Normung, uses scales of darkness (Dunkelstufe), hue (Farbton), and saturation (Sättigung)¹⁶. An atlas based on CIE colorimetry has been prepared.

The Optical Society of America identified an array of colours, the *OSA-UCS System*, in which each colour differs from its nearest neighbours by nearly equal amounts¹⁷. Coloured specimens were made to exemplify the system.

These systems illustrate the kinds of differences in fundamental approach cited in the committee's conclusions. They and other systems have been described in greater detail in readily available technical literature²⁻¹⁸. The colour-order systems listed all employ three independent attributes as a basis for their organisation and denotation of colour percepts, but the attributes chosen differ in each system.

A further analysis of these systems may be made by applying the principles listed in document TC 187/WG2:N8 rev and it might be appropriate to create a special CIE technical committee to review this document and consider its preparation and publication as a CIE document.

6. ISSUE (c), ACHIEVING CONGRUENCE of COLOR-ORDER SYSTEMS

If the expression "how congruence can be achieved between different colour-order systems" means to establish simple rules or equations, based on a simple model, for translation from one system to another, such congruence is not possible, given present knowledge. These systems are based on fundamentally different attributes and fundamentally different scaling methods. The relationship of one colour-order system to another may be shown by mapping the embodiment of one in the colour space of the other or by mapping both embodiments in a colorimetric space. However, the embodiments may not accurately reflect the abstract systems, so caution must be exercised when interpreting such mappings. Discrepancies may suggest the need for research into embodiment accuracy. When conversions are necessary, they may be derived by mapping, curve-fitting, and interpolation and these methods have been used to produce comparative tables.

If "achieving congruence" means changing some aspect of one system to make it like another, then the one system would no longer be what it was. It would be some compromise between two fundamentally different approaches, unlikely to satisfy needs that were satisfied by the original systems.

Rather than seeking congruence, it would be more useful to clarify the differences among the systems and to dispel the notion that they are slightly different ways of saying the same thing. These objectives could be achieved by the CIE adoption of the terminology used to describe colour-order systems, colour linguistics, and colour categories, and other psychological terminology needed to draw distinctions among the various colour-order systems. The documents prepared by ISO TC187 are contributions to such an effort.

7. ISSUE (d), WHETHER ANY SYSTEM IS THEORETICALLY BETTER THAN THE OTHERS

The variety of systems to organise the same universe of possible colours demonstrates that there are various ways to look at colours, various ways to describe them, various ways to think about them, and various ways to quantify or scale relationships among them. Each system has advocates who regard it as the natural way, the most useful way, or somehow the best way. Once a system is fixed in the mind, it may not be easy to adopt a basically different approach.

Although three perceptual attributes are sufficient to denote a colour, there are many more attributes associated with a given colour percept; the choice of three depends on the actual application and also on personal preferences. The validity of a hue circle and the concept of constant hue, as in the Munsell and NCS systems, is important. The sometimes fairly large discrepancies between the two systems' constant-hue planes is probably due to experimental uncertainties and errors in the evaluation and extrapolation of data. It should be possible to reduce these discrepancies through further research.

For the variables within a constant-hue plane there are diverging preferences among the users of colour-order systems, which confirms the need for different sets of variables for various applications. Because of this, no recommendation to favour only one system can be made. However colour scientists should be encouraged to investigate the relations between systems, for example by comparing the Munsell type variables "value" and "chroma" to the Hering type "whiteness", "blackness", and "chromaticness", taking care to ensure that the difference between the open-ended scale of chroma, and the scaling of chromaticness to the full chromatic colour is observed.

The relative claims of different systems to be considered the "best" system can also be discussed from a practical viewpoint. In this context, the committee considered possible criteria such as

- (a) extent of use by colour scientists as a model of colour space,
- (b) extent of use by practical colourists and artists,
- (c) availability of a physical embodiment, and
- (d) length of time in satisfactory service,

but was unable to make any choice on this basis. It was for instance realised that the long service of the Munsell system is a factor in its favour, although at the same time the subsequent emergence of a new system may be interpreted as an indication that the Munsell system is not completely satisfactory. No adequate information is available to indicate the extent to which the different systems are in fact used by different industrial groups.

One system may be better suited to certain purposes, while another is better suited to others. In 1952, Judd said, "Arguments about the relative merits of various collections of colour chips for various purposes have gone on for years. Up to about 1940 these arguments were bitter and involved considerable unfair sniping. Since that time the arguments have become more good natured as it has become generally recognised that the various collections serve different purposes and to a large extent supplement each other"¹⁸.

For that reason, the committee finds no theoretical basis to choose one system as being better than the others. To select one for international standardisation would be a disservice. The adoption of several as standard would not serve the unifying purpose of standardisation, nor any other useful purpose, because these systems are already fully described in national standards and other well-known publications.

8. ISSUE (e), THE EXTENT TO WHICH DIFFERENT COLOUR-ORDER SYSTEMS ARE USEFUL, HELPFUL, AND APPLICABLE TO DIFFERENT USES

During the past 25 years, the Natural Colour System has become increasingly known and it has been used in many scientific investigations¹⁹⁻²⁵. The NCS atlas has been used by

architects, designers, and industrial colourists, particularly in the Scandinavian countries, but also in the rest of Europe, and recently also in other countries. It is the national standard colour-order system in Sweden, Norway, and Spain²⁶. A colour atlas and painted chips of various sizes are available from a supplier in Sweden.

The DIN System has been used similarly, primarily in central Europe²⁷.

The Munsell System has been used in North America for about 70 years and in South America for several decades. Its use is the subject of an American Society for Testing and Materials standard²⁸ and it is the national standard colour-order system in Japan. Colour-order systems have been important tools in the pursuit of colour science and the Munsell system has often been used as a model of visual space. Because the Munsell system aimed to represent uniform visual spacing, it was a natural choice for comparisons of perceptual colour space and colorimetric spaces²⁹. When the Inter-Society Color Council and the U.S. National Bureau of Standards developed a guide to colour names, their system was based on the Munsell system, though they and others have found it necessary to depart from the Munsell hue names in the blue region^{30,31}. The Munsell Book of Color, painted chips of various sizes, and special sets of chips for several technical purposes are available from independent suppliers in the United States and Japan.

The OSA-UCS System has been little used, except to display novel and interesting colour arrays that can be identified in a simple mathematical way. Colour chips representing this system have not been available in the variety of sizes, shapes, and forms in which the NCS and Munsell embodiments are available and future availability of any chips is doubtful.

The extent to which abstract colour-order systems are used by practical colourists, designers, architects, and other artists is not easily ascertained, even when the numbers of sales of various embodiments is known. Many practitioners make extensive use of collections of colour chips, with little or no regard for the system of scaling. To them the availability of chips with assigned notations may be more important than organising principles. They may consider the collection a reasonably good sampling of all colours from which to select a colour and a simple way to specify that colour. The number of chips in the collection, their availability, durability, reproducibility, and price may determine which collection is chosen and how it is used. In fact, in the colour-printing industry, colours are most frequently identified by readily available and inexpensive colour chips assigned proprietary identification numbers not related to any colour-order system.

When artists comprehend a structure similar to their intuitive understanding of colour and begin to explore the colour solid with that structure in mind, they begin to appreciate collections based on that structure. Industrial colorists, even those who depend on colorimetry, find it cost-effective to take into account the psychological differences between the three attributes of colour order: hue, lightness, and chroma, when setting colour tolerances³².

9. ISSUE (f), COLORIMETRY OF CONCRETE COLOR-ORDER SYSTEMS

The colorimetry of concrete colour-order systems has been referred to CIE Division 1, Vision and Colour. It is appropriate for that Division to consider this matter and, if desirable, to issue a CIE report of their recommendations or include their recommendations in the next revision of the CIE report on colorimetry. The separate standardisation of this colorimetric aspect by the ISO would be inappropriate and undesirable. All colorimetric aspects must be well co-ordinated and such co-ordination is best achieved within a single organisation.

Perceived colours depend on many aspects of the illumination and viewing conditions. These factors must be taken into account, not only when making visual observations, but when making measurements to correlate with such observations³³⁻³⁵. Concrete embodiments of colour-order systems must be prepared under rigidly specified viewing conditions and are valid only under such conditions.

10. ISSUE (g), COLOR-ORDER SYSTEMS AND SELF-LUMINOUS DISPLAYS

Technical questions involving the use of self-luminous displays in association with colour-order systems have been referred to the CIE Division 1 for consideration in the light of the TC 1-27 work which is currently studying the problems of comparing opaque reflecting specimens with self-luminous displays renditions. This is an important question which is engaging the attention of researchers in many parts of the world, and it is hoped that results will soon be forthcoming. Viewing conditions and display calibration are among the most important components of these problems.

11. SUMMARY OF CONCLUSIONS

- a. The terms and definitions developed by ISO TC187 have been referred to the appropriate CIE committee, noting a need for the definition of new terms pertaining to visual perception.
- b. The principles listed in document ISO TC187/WG2:N8 rev merit further consideration by the CIE, including the possibility of including them in a CIE publication.
- c. There is no known way to establish congruence between colour-order systems based on different underlying principles, although translation between embodiments of them may be achieved using computational methods. The essential differences among systems would be clarified by the adoption of appropriate terminology.
- d. The committee finds no theoretical or other basis for regarding one system as better than all others. The systems satisfy different artistic, intellectual, scientific, or practical needs.
- e. All of the major colour-order systems described, with the possible exception of the OSA-UCS system, have been found useful, helpful, and broadly applicable in art and industry.
- f. The consideration of colorimetric conditions for measuring concrete embodiments of colour-order systems has been referred to CIE Division 1, Vision and Colour.
- g. The consideration of technical questions regarding the use of self-luminous displays in association with colour-order systems has been referred to the CIE Division 1, which has a committee currently addressing related issues.
- h. Because of conclusions d and e, the CIE does not at the present time support the international standardisation of a colour-order system.

12. REFERENCES

1. International Commission on Illumination, "International Lighting Vocabulary", Publication CIE 17.4, Bureau Central de la Commission Electrotechnique Internationale, Geneve, Switzerland (1987).
2. Sven Hesselgren, Why Colour Order Systems?, *Color Res. Appl.* **9**, 220-228 (1984).
3. W. D. Wright, The Basic Concepts and Attributes of Colour Order Systems, *Color Res. Appl.* **9**, 229-233 (1984).
4. Alan R. Robertson, Colour Order Systems: An Introductory Review, *Color Res. Appl.* **9**, 234-240 (1984).
5. Fred W. Billmeyer, Jr., Survey of Color Order Systems, Proc. 5th AIC Congress, "Mondial Couleur", International Color Association, 1985. Reprinted in *Color Res. Appl.* **12**, 173-186 (1987).
6. Gunnar Tonquist, Philosophy of Perceptive Colour Order Systems, *Color Res. Appl.* **11**, 51-55 (1986).

7. W. N. Hale, Color Order Systems and Color Notation, *Die Farbe*, **35/36**, 293-301 (1989).
8. Gunilla Derefeldt, Colour Appearance Systems, a chapter in "*The Perception of Colour*", Peter Gouras, Ed., Vol. 6 of "Vision and Visual Dysfunction", John Cronly-Dillon, Ed., Macmillan, London (1991).
9. C. S. McCamy, Physical Exemplification of Color Order Systems, *Color Res. Appl.* **10**, 20-25 (1985).
10. A. Hard and Lars Sivik, NCS - Natural Color System: A Swedish Standard for Color Notation, *Color Res. Appl.* **6**, 129-138 (1981).
11. Svensk Standard SS 01 91 02, Fargatlas (Colour atlas), Standardisering-kommissionen i Sverige (SIS), Stockholm (1979).
12. Svensk Standard SS 01 91 03, CIE Tristimulusvarden och trikromatiskakoordinater for fargprovern SS 01 91 02 (Svensk-Engelsk) [CIE tristimulus values and chromaticity coordinates for the colour samples in SS 01 91 02 (Swedish-English)], Standardiseringskommissionen i Sverige (SIS), Stockholm(1982).
13. Svensk Standard SS 01 91 01, CIE tristimulusvarden och trikromatiskakoordinater for ca 16 000 fargbeteckningar enligt SS 01 91 00 (CIE tristimulus values and chromaticity coordinates for some 16 000 colour notations according to SS 01 91 00), Standardiseringskommissionen i Sverige (SIS), Stockholm(1983).
14. A. H. Munsell, A Color Notation, 12th ed., Munsell Color Company, Baltimore MD, (1975), 1st ed. Geo. H. Ellis Co., Boston (1905). See also: Ref 15.
15. Sidney M. Newhall, Dorothy Nickerson, and Deanne B. Judd, Final Report of the OSA Subcommittee on the Spacing of the Munsell Colors, *J. Opt. Soc. Am.* **33**, 385-418 (1943).
16. Manfred Richter, The Official German Standard Color Chart, *J. Opt. Soc. Am.* **45**, 223-226 (1955).
17. David L. MacAdam, Uniform Color Scales, *J. Opt. Soc. Am.* **64**, 1691-1702 (1974).
18. Deanne B. Judd, "Color in Business, Science, and Industry", John Wiley & Sons, New York (1952) pp. 200, 201. Wyszecki retained this passage through the 3rd. ed. (1975) p. 274.
19. B. Berglund and A. Stenius, A Methodological Study of the Evaluation of Perceptual Whiteness, *Die Farbe*, **26**, 17-45 (1977).
20. S.S. Bergstrom, Colour Constancy: Support to a Vector Model for the Perception of Illumination, Colour, and Depth, Univ. of Umea, *Dept. of Psychology Reports (DAPS)* No. **26** (1987).
21. O. Da Pos, trasparenze (a monograph including Un modello di trasparenzaapparente, with an English translation: A Model of Transparency), ICONE s.r.l., Department of General Psychology, Univ. of Padua (1989).
22. G. Derefeldt, O.G. Holmgren, and S.S. Bergstrom, Hue Shift of Induced Color as a Function of Luminance Relations, *Scand. J. of Psychol.*, **20**, 239-249 (1979).
23. A. Hard and L. Sivik, Distinctness of Border: An Alternative Concept for a Uniform Color Space, *Color Res. Appl.*, **11**, 169-175 (1986).
24. Y. Nayatani, Y. Umemura, K. Hashimoto, K. Takahama, and H. Sobagaki, Analyzing the Natural Color System's Color-Order System by Using a Nonlinear Color-Appearance Model, *Color Res. Appl.*, **14**, 69-78 (1989).
25. L Sivik and A. Hard, Methodological Studies of Color Changes Due to Distance and Lighting: Direct Assessment Using the Natural Color System, Proc. 3rd AIC Congress, *Color* **77**, 362-364, Adam Hilger, Bristol (1978).

26. Svensk Standard SS 01 91 00, Fargbeteckningssystem (Colour Notation System), Standardiseringskommissionen i Sverige (SIS), Stockholm (1979).
27. Normblatt DIN 6164 Teil 1-3: DIN-Farbenkarte, Beuth-Vertrieb, Berlin (1953).
28. ASTM D-1535, Standard Practice for Specifying Color by the Munsell System, American Society for Testing and Materials, West Conshohocken, PA (1995).
29. W. D. Wright, "The Measurement of Colour", 3rd ed., D. Van Nostrand Co., Princeton (1964) pp. 187,188.
30. Kenneth L. Kelly and Deanne B. Judd, "The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names", *National Bureau of Standards Circular 553*, U. S. Gov't. Printing Office (1955).
31. C.S. McCamy, The Primary Hue Circle, *Color Res. Appl.*, **18**, 3-10 (1993).
32. ANSI/SAE J1545-JUN86, Instrumental Color Difference Measurement for Exterior Finishes, Textiles, and Colored Trim, American National Standards Institute, New York (1986).
33. K. Witt, Call for Common Colorimetric Parameters in Defining Color-Charts, The Forsius Symposium on Colour Order Systems, AIC Midterm Meeting, Kungälv, Scand. Color Inst., Stockholm (1985).
34. R.W.G. Hunt, Perceptual Factors Affecting Colour Order Systems, *Color Res. Appl.*, **10**, 12-19 (1985).
35. C.S. McCamy, Relating Colorimetry to Visual Observations, *Die Farbe*, **37**, 43-53 (1990).
36. L. Sivik, System for Descriptive Color Notations - Implications of Definitions and Methodology, *Die Farbe*, **40**, 37-49 (1994).
37. A. Hard, L. Sivik, and G. Tonnquist, NCS, Natural Color System - from Concept to Research and Applications. Part I, *Color Res. Appl.*, **21**, 180-205 (1996).
38. A. Hard, L. Sivik, and G. Tonnquist, NCS, Natural Color System - from Concept to Research and Applications. Part II, *Color Res. Appl.*, **21**, 206-220 (1996).

CIE TC 1-18 Chairman's Report

Foreword

CIE TC 1- 18, Disability Glare and Division 1 decided at their meeting in Göteborg, 1996-06-13/14, to disband the committee TC 1-18, and asked the Chairman to submit a report of the work done. The following report was prepared by Drs. JJ Vos and TJTP van den Berg. It is not a CIE agreed technical report, it summarizes the findings of the authors and serves as basis for further CIE Division 1 activity.

On the course of the disability glare function and its attribution to components of ocular scatter

by JJ Vos and TJTP van den Berg

Abstract

Recent investigations have strengthened doubts on the validity of the Stiles-Holladay glare formula for large glare angles. Calculations partly based on an earlier theoretical analysis turned out to be helpful to understand the deviations from Stiles-Holladay and to extrapolate the glare function, in its dependence on age and pigmentation, into the large angle domain. A trend towards a $1/\theta$ rather than a $1/\theta^2$ fall off predominates. This document is intended as a background study for a planned definition of a CIE standard glare observer.

Zusammenfassung

Neuere Untersuchungen haben Zweifel verstärkt über die Gültigkeit der Stiles-Holladay Blendungsformel für große Blendungswinkel. Berechnungen, die teilweise auf frühere theoretische Analysen zurückgehen, konnten die Abweichungen von Stiles-Holladay erklären und gestatten die Extrapolation der Blendungsformel bis in den großen Winkelbereich, in Abhängigkeit von Alter und Pigmentation. In der Tendenz überwiegt eine $1/\theta$ statt einer $1/\theta^2$ Abhängigkeit. Dieses Dokument ist als eine Hintergrundstudie gedacht für die geplante Definition eines CIE Standardblendungsbeobachters.

Résumé

Des recherches récentes ont renforcé des doutes sur la validité à grandes angles de la formule Stiles-Holladay pour l'éblouissement. Calculations partiellement fondées sur analyses théoriques antérieures permettaient l'éclaircissement des déviations de Stiles-Holladay et l'extrapolation, en dépendance de l'âge et de la pigmentation, de la formule d'éblouissement jusqu' à la domaine des grandes angles. Une tendance à une tombe comme $1/\theta$ en lieu de $1/\theta^2$ est prévalente. L'intention de ce document est d'être une étude sur le fond d'une définition prévue d'un observateur standard CIE d'éblouissement.

1. Introduction

In the 1920s and 1930s Holladay [1,2] and Stiles [3-5] did basic studies on disability glare. Their results were more or less canonized by CIE [6] in the so-called Stiles-Holladay glare formula

$$\frac{L_{eq}}{E_{gl}} = \frac{10}{\theta^2} \quad \text{with } \theta \text{ in degrees} \quad (1)$$

expressing that, for young adults, the masking effect of a glare source producing E_{gl} lux at the pupillar plane [7] could be well described as that of an equivalent light veil with luminance L_{eq} cd/m² that decreases with $1/\theta^2$, θ being the glare angle in degrees. The factor 10 is a rough average, which actually may vary considerably between individuals. This formula, originally only established between about 4° and 30°, was later confirmed up to some 90° by Stiles and Crawford [5]. Since then it has become increasingly clear that L_{eq} is more than only equivalent to, but rather a very real intraocular straylight veil indeed [8].

Of course, Eq.(1) cannot be valid for small angles, and Vos et al [9], compiling data from various other literature sources, produced an extended glare function that was steeper between 8° and 1°, but then flattened to some bell-shaped spread function in the minutes of arc domain around the origin. But next to that, IJspeert et al.[10] have more recently raised doubts about the classic $1/\theta^2$ course for large glare angles. With their technique they could measure L_{eq} by direct flicker photometry at four pre-selected glare angles, viz. 3,5°, 7,0°, 13,6° and 25,4°. This technique allowed them, as firsts, to do reliable and quick field studies, and so to obtain data for an extensive population, in particular on the increase with age of glare susceptibility. Their main results on the angular dependence, averaged over many subjects, are summarised in Fig. 1, which is an adaptation of Figs 1 and 2 in Van den Berg et al.[12].

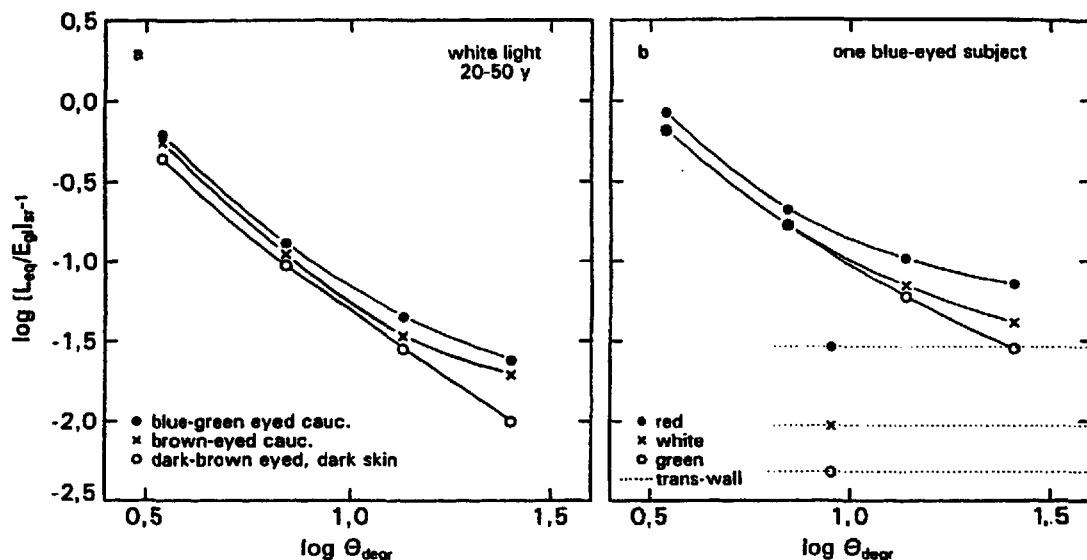


Fig. 1 L_{eq}/E_{gl} as a function of glare angle θ .

- for three pigmentation groups with white glare light;
- for one blue eyed subject with three colors of the glare light. The indicated horizontal levels are the measured base lines toward which the respective curves should flatten off if that light level were due only to trans-wall straylight. Replot of Van den Berg et al [11], Figs 1 and 2.

One notices a flattening trend, a gradual change from $1/\theta^2$ to an approximate $1/\theta$ behavior, more pronounced in light than in dark eyes, and in red than in white light. This led the authors to investigate a possible attribution to light scatter through the ocular wall, either