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REVIEW

IRIS COLOUR CLASSIFICATION SCALES – THEN AND NOW

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Abstract
Eye colour is one of the most obvious phenotypic traits of an individual. Since the first documented classification scale developed in 1843, there have been numerous attempts to classify the iris colour.
In the past centuries, iris colour classification scales has had various colour categories and mostly relied on comparison of an individual's eye with painted glass eyes. Once photography techniques were refined, standard iris photographs replaced painted eyes, but this did not solve the problem of painted/ printed colour variability in time. Early clinical scales were easy to use, but lacked objectivity and were not standardised or statistically tested for reproducibility.
The era of automated iris colour classification systems came with the technological development. Spectrophotometry, digital analysis of high-resolution iris images, hyper spectral analysis of the human real iris and the dedicated iris colour analysis software, all accomplished an objective, accurate iris colour classification, but are quite expensive and limited in use to research environment.
Iris colour classification systems evolved continuously due to their use in a wide range of studies, especially in the fields of anthropology, epidemiology and genetics. Despite the wide range of the existing scales, up until present there has been no generally accepted iris colour classification scale.
Keywords: iris, eye colour, scale, review

Introduction

Iris colour is one of the most obvious phenotypic traits of an individual. The genetic and epidemiologic research undergone in the past few decades concerning eye colour revealed many interesting facts about iris pigmentation and led to many correlation studies of iris colour with different diseases of the eye and other organs [**1-7**]. Since the 1800's, there have been many attempts to classify the iris colour. Presently, there is a wide range of iris colour classification scales, most of which can be placed into one of the following two types of approaches:

1. *the clinical approach* - classification scales that may have few or many colour

categories, but most of them can be divided into 2-3 main groups (light/mixt/dark eyes);

2.*the digital approach* – automated, digital, colorimetric methods, that accomplish a more objective iris colour classification.

Iris colour classification - from 1843 until nowadays

The first documented iris colour classification scale, developed by Petrequin, dates back to 1843 and relies on 5 colour categories: grey, blue, hazel, brown and black [**8**]. From that point and until 1990, iris colour classification has represented a research interest mostly for anthropologists, in their studies about racial distribution of phenotypic traits and has relied on a large variety of clinical scales (**Table 1**) [**8-17**].

Table 1. Clinical iris colour classification scales

Clinical Scales	Colour categories
Petrequin, 1843	1.grey 2.blue 3.hazel 4.brown 5.black
Cornaz, 1845	1.blue (with hints of grey, yellow, or green) and 2.brown (with hints of yellow, hazel, light brown, dark brown or black)
Wilde, 1862	1.grey 2.blue 3.hazel 4.brown
Galton, 1886	1.light blue 2.dark blue 3.gray or blue-green 4.dark grey or hazel 5.light brown 6.brown 7.dark brown 8.black
Martin, 1903	16 categories from dark brown (no.1) to blue (no.16); comparison with painted glass eyes
Tocher, 1908	1.blue 2.grey 3.mixt colours 4.brown
Brownlee, 1912	1.pure blue 2.grey or pale yellow 3.yellow 4.dark brown
Carleton-Coon, 1939	1.light (light and light-mixt) 2.mixt 3.dark (mixt-dark and dark)
Ridell, 1942	3 parameters: (1) iris basic colour, (2) diffuse pigmentation and (3) iris spots -each parameter: 0-none,1-blue, 2-grey, 3-green, 4-yellow, 5-tan, 6-chocolate
Grive and Morant, 1946	14 categories: no brown (A-light blue, B-light grey, C-dark blue, D-dark grey), more blue than brown (E-traces of brown, F-more brown, G-even more brown, H-the most brown), more brown than blue or grey (I-the least brown, J-more brown, K-mostly brown), pure brown (L-light brown, M-medium brown, N-dark brown)
Seddon, 1990	5 categories obtained by comparison with 4 standard iris photographs
Fraser, 2008	24 categories, similar to Martin Scale, but the comparison was made with standard photos
Diaz, 2004	1.blue 2.hazel 3.brown
Mackey, 2011	1.light brown 2.dark brown 3.blue with a brown peripupilary ring 4. green 5. green with a brown peripupilary ring 6.green periphery, brown centre 7.brown with little green at periphery 8. light brown 9.dark brown
Simionescu, 2014	3 parameters: 1.periphery: blue/grey/green/hazel/light brown/dark brown 2.colarette: blue/light brown/dark brown 3.iris freckles: absent/ present

In the past centuries, iris colour classification has been made by comparison of a person's eye with artificial painted eyes, made out of glass. One of the major problems concerning the standardisation with these artificial eyes systems was that painted colour modifies in time. The first attempt to standardise iris colour classification was achieved in 1903 by anthropologist Rudolf Martin. He composed a set of 16 artificial painted eyes arranged and numbered from the darkest tint of brown (number 1) to the lightest tint of blue (number 16) [**17**]. In 1939, anthropologist Carleton-Coon grouped the 16 categories of the Martin scale in three main groups (light/mixt/dark) and some secondary ones, with the purpose of simplifying the classification [**15,17**]. On the other hand, in the same time period, some researchers developed more complex clinical scales, but as it can be easily seen in **Table 1**, these scales either introduced some ambiguous terms (iris general colour vs. diffuse pigmentation), either the

multitude of similar colour categories made iris colour classification even more subjective and difficult to use [**10,12**].

The development of photography did not make iris colour classification evolve very much, because the problem of variability of printed colour persisted in time. That is why until 1990, iris colour classification was still based on painted artificial eyes systems [**18**].

An important change in the field of iris colour classification was made in 1990, when Seddon and his team developed The Iris Colour Classification System, which aimed to standardise and objectify the iris colour classification technique and was used in important epidemiologic studies at the time [**16**]. With the Seddon system, the iris colour of an individual is classified by comparison with 4 standard photographs.

The era of automated, digital iris colour classification systems came with the technological development, all of which make a quantitative analysis of iris colour. One of the first automated techniques was the objective quantification of iris colour based on spectrophotometric measurements of iris melanin [**19,20**]. Spectrophotometry determines an iris colour score based on the measurement of the following parameters: luminosity, red light reflection, green light reflection and yellow light reflection. Spectrophotometric studies have shown that blue apparent irises frequently have a brown peripupilary ring and that many eyes that seem light coloured are indeed a mixture of light and dark colours.

Edwards developed an automated iris colour classification method based on the international standardised chromatic system developed to approximate human coloured vision CIELAB (CIE, 1986) [**21**]. The Edwards system analyses three quantitative parameters (luminosity, green-red chromatic spectrum and blue-yellow chromatic spectrum) on high-resolution digital iris photos. Takamoto developed another automated iris colour analysis system that measures chromatic density and dark and light segments on the surface of the iris, on high-resolution digital iris images [**22**]. A system of hyper spectral iris colour analysis was developed by Medina, that measures the reflectance spectrum of a human real iris, in comparison with digital high spatial resolution photos [**23**]. In 2013, a team of researchers elaborated a dedicated software for the analysis of iris colour, named Digital Iris Analysis Tool (DIAT) [**24**]. This software quantifies the number of blue and brown pixels on iris digital images and calculates an iris colour score named Pixel Index Score.

Overview on the existing iris colour classification scales

The early *clinical scales*, although easy to use in practice did not undergo a controlled process of standardisation and statistic validation of consistency and reproducibility. Also, most of them were developed in Western European populations and can be used with much limitation in other types of populations, like the dark skin photo types, of Asian or African descent. The more colour categories a scale has, the more difficult it is to use it in everyday practice and the more subjective eye colour classification becomes. On the other hand, if a scale has only 2-3 colour categories, the classification becomes vague and the scale does not accurately capture the detail differences between individuals. The classification scales based on printed images or painted glass eyes have the disadvantage of colour modifying in time.

The automated *computerised methods* classify iris colour in an objective, linear manner and differentiate with high accuracy between tints of the same colour. They are very useful in populations where clinical scales have limited use, for example for the dark eyes of Asian populations [**25**]. Also, these modern sophisticated methods imply highly expensive tools and trained personnel and though they are very useful in a research environment, they are impossible to use in everyday clinical practice or large cohorts epidemiological studies.

Why classify iris colour?

The numerous clinical scales and also the continuous development of modern classification systems are good indicators for the existing interest on the subject in the scientific community. The need to accurately classify iris

colour in many types of correlation studies has always been the main reason for the development of all existing classification scales and methods. In the past centuries, iris colour has mainly been used in anthropologic and anthropometric studies on distribution of phenotypic human features or on migration patterns of populations on the globe [**10,15**]. Another field of research in which iris colour classification has been important is represented by epidemiologic correlation studies of iris colour with various types of ophthalmologic diseases (like uveal melanoma or cataracts) or with diseases outside of ophthalmology, like cutaneous cancer, diabetes and even endometriosis [**4,5,7,26,27**]. With the growing interest in the study of the human genome, iris colour classification has become important also in correlation studies of iris colour with specific genetic markers, involved in pigmentary traits determinism [**28-30**].

In spite of the wide diversity of the existing scales, the most relevant epidemiologic and genetic research has been done by using the simple, three category scales (blue/mixt/brown) [**11,31-33**]. Moreover, clinical classification scales are still being developed, even more nowadays than they are tested for reproducibility and validity [**9,11,14**]. Structural features on the anterior surface of the iris (freckles, collaret, periphery, crypts) were proven to have impact on eye colour determinism and perception and an iris colour classification scale, that takes into consideration these elements, was also developed [**9,34**].

Any correlation study of the iris colour with any ophthalmological or other type of disease has to begin with the choice of a classification scale, that is characterised by reproducibility, lack of subjectivity and that can be easily used by the researcher. Depending on the type of study in which iris colour classification is needed, the researcher can choose from a wide variety of scales the one that is best suited for its objectives. Despite the numerous attempts to classify iris colour throughout the years, from the simplest clinical scales to the modern digital techniques, there has been no generally accepted iris colour classification scale in the scientific community until present.

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