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Object-Colour Manifold

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Abstract Colorimetry can predict which lights will look alike. Such lights are called metameric. Two lights are metameric if they have the same tri-stimulus values. Using the tri-stimulus values as Cartesian coordinates one can represent light colours as points in a 3D space (referred to as the colorimetric space). All the light colours make a tri-dimensional manifold which can be represented as a circular cone in the colorimetric space. Furthermore, colorimetry also claims that reflecting objects illuminated by the same light will look alike as soon as they reflect metameric lights. All the object colours are then represented as a closed solid inscribed in the light colour cone provided the illumination is fixed. However, as argued in this article, the reflected light metamerism does not guarantee that the reflecting objects will look identical (referred to as colour equivalence), especially when there are multiple illuminants. Moreover, colour equivalence cannot be derived from metamerism. The colour of a reflecting object under various illuminations is shown to be specified by six numbers (referred to as its six-stimulus values) that can be established by experiment. Using the six-stimulus values one can represent the colours of all the reflecting objects illuminated by various illuminants as a cone (without a vertex) through a 5D ball.

Keywords Colour · Colour space · Colour equivalence · Colour theory

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1 Introduction

Riemann was certainly the first to conjecture that the colour sensations form a manifold of more than one dimension (Riemann 1867). In other words, colours can be represented as points in a geometrical space (referred to as the colour space), and the whole set of these points forms a manifold. While the theory of colour space has since been thoroughly elaborated in colorimetry (Krantz 1975; Schanda 2007b; Brainard and Stockman 2010), the idea of a colour manifold has not gained as much attention. Perhaps, because the colour manifold which colorimetry yields is rather simple: a three-dimensional convex cone (Schrodinger 1970; Weinberg 1976; Suppes et al. 1989; Logvinenko and Levin 2012).

It must be borne in mind that colorimetry deals with the colour of lights. However, of much more interest is the colour of reflecting objects that surround us in everyday life. As is well known, the colour appearance of the light coming to our eyes through a small hole in the opaque screen from a fragment of a reflecting object can be dramatically different from the colour of this fragment observed without the screen (Helmholtz 1867; Katz 1999). It does not take a colour scientist to realise that the colour palette of what we can see through the reduction screen is much poorer as compared to what can be experienced without it. Indeed, through the reduction screen one cannot experience, for example, brown, khaki, and many other object colours, including even black.[1] Therefore, there is every reason to expect the object-colour manifold to be more involved than the light-colour manifold. Yet, in apparent contradiction with

[1]Strictly speaking, light cannot be black. The absence of light is experienced as darkness which is different from the experience of black (Volbrecht and Kliegl 1998).