Review of Jan Koenderink's *Color for the Sciences*

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Jan Koenderink's *Color for the Sciences*, as its preface says, aims to introduces colorimetry to scientists. Rather than presenting practical techniques, the author seeks to impart an understanding, that requires the reader to "rethink the concepts from the roots." Accordingly, the book looks in depth at the many ways, mostly mathematical, that one could arrive, and that historically researchers did arrive, at the terms of colorimetry. Motivations and insights are emphasized more than definitions. Many of the "exercises" are invitations to elaborate the concepts introduced. Koenderink presents *Color for the Sciences* as a joint exploration, by author and reader, of the thinking behind colorimetry. This book is a tour, rather than a treatise. While that approach is of limited use for newcomers to colorimetry, it succeeds brilliantly for more experienced colour scientists, by highlighting many surprising facets of the subject.

The book focuses, as it says on p. 10, on the "geometry of color space." It should appeal especially to readers who think spatio-visually. Those who enjoyed Koenderink's earlier book, *Solid Shape*, will probably enjoy *Color for the Sciences*. Both books use the language of geometric pictures, rather than abstract definitions. At the end of *Color for the Sciences*, a reader could probably build a concrete model of a spectrum locus. Section 4.7 illustrates multiple geometric ways to construct chromaticity diagrams from the spectrum cone. While the chromaticity diagram is often presented as a simple set of equations, Koenderink's more roundabout presentation gives the reader a "feel" for the interpretations and limitations of chromaticity diagrams. After reading Koenderink's book, many concepts, such as optimal colours or complementary colours, seem natural.

A striking feature of this book is its loose organization. By the end, the reader almost feels that the chapters and sections could be rearranged randomly, without

altering the book's character. Koenderink frequently digresses to discuss alternate interpretations, to introduce peripheral new material, or to tell historical anecdotes. The loose organization is both a strength and a weakness. The multiplicity of viewpoints sometimes provides a new, intuitive grasp of an idea, but a reader who is trying to extract key concepts will likely feel frustrated. For this reason, *Color for the Sciences* is a treasure trove for those who have some familiarity with colour science, and a challenge for those who do not.

Like an all-day tour, *Color for the Sciences* demands much patience from its readers. Even without the index, the book weighs in at 700 pages. A newcomer to colorimetry will likely be quickly disoriented. The first part of Chapter 1 is suitably introductory, giving a high-level discussion of what colour is, and who colorimetry appeals to. The final 25 pages of Chapter 1, however, are unsuitable in an introductory text. The history of colour geometry that they provide could only make sense to readers who are already familiar with colorimetric concepts. Chapter 2 gives verbal instructions (but no worked examples) for calculating XYZ, xyY, and Lab coordinates, and defines the coordinates only as outcomes of the calculations. This chapter can only mystify a newcomer to colorimetry. Fortunately for the patient reader, the subsequent chapters explain colorimetry more systematically.

Though distractions to a novice, the many digressions constitute most of the book's considerable charm for a more experienced reader. Koenderink covers an exhilarating breadth of topics and interpretations, often introducing obscure yet enlightening bits of history. Appendix 12.3, for example, describes, and gives diagrams for, the colour instruments on Ostwald's workbench. Section 5.4 expounds on Schopenhauer's interpretation of spectral regions as "parts of daylight." Section 10.7 describes Schrödinger's isochromes, or constant hue sections of an object-colour solid. Such unexpected topics appear consistently, seemingly without end. Each such excursion provokes the reader into considering some aspect of colorimetry from a new, and usually surprising, angle. Koenderink's book could probably be opened at random, during any spare half-hour, for a stimulating new look at a familiar topic. As such, *Color for the Sciences* can be consulted profitably and enjoyably for years.

The book's greatest recommendation, in terms of content, is its presentation of object-colour solids in CIE XYZ space. Despite the centrality of XYZ coordinates, it seems that Koenderink was the first person, in the early 2000's, to draw an object-colour solid in XYZ space (see his and van Doorn's contribution to the 2003 book, *Colour Perception*[1]). Previously, dating back to the late 1920's and early 1930's, the Rösch-MacAdam and Luther-Nyberg solids were well known and often reproduced. The Rösch-MacAdam solid, however, is in xyY space, and the Luther-Nyberg solid is in a non-standard transformation of XYZ space. Even Wyszecki and Stiles' com-

prehensive 1982 tome, with its long list of references, could only vaguely describe the XYZ solid, as convex, asymmetric, and "torpedo-shaped" (p. 180 of Ref. 2).

In *Color for the Sciences*, Koenderink has more than filled this lacuna. The XYZ colour solid is shown in three-dimensional pictures from a variety of aspects, and in numerous sectioned views. Many of the pictures are full-colour, to indicate which parts of the solid correspond to which colour perceptions. The locations of the neutral axis and the semichrome "equator" are illustrated, along with many other features. A reader who wants to navigate visually around colour space would be very well served by this presentation.

Given the detail elsewhere throughout the book, it is surprising that Koenderink does not show step by step how to construct object-colour solids. Figure 7.5, for example, displays a solid as a polytope, with regularly spaced vertices and edges, but no indication of how those vertices are calculated. Once optimal colours are understood, the vertex calculations are straightforward. While Section 7.3 hints at possible calculation methods, some pseudo-code, or a verbal description, should have been provided, enough that the reader could reproduce such figures himself.

Inevitably, a technical book like *Color for the Sciences* uses a considerable amount of mathematics. While Koenderink presents the details behind most of the math he uses, a reader would be well-advised to have a solid grasp of linear algebra, and in particular of inner product spaces, at about the level of a second-year undergraduate course. Euclidean geometry is used frequently, but can be followed by any reader with a good spatio-visual sense. Projective and Riemannian geometry are touched on occasionally, but not often enough to be considered prerequisites.

In summary, Koenderink's *Color for the Sciences* would be a challenge for novices to colorimetry, but a highly rewarding panorama for those who already have some familiarity with colour science. Its wealth of historical and conceptual material make it a book that a colour scientist could thumb through at odd moments, and return to for years.

1. Rainer Mausfeld & Dieter Heyer, eds. *Colour Perception: Mind and the Physical World*, Oxford University Press, 2003.
2. Günter Wyszecki & W. S. Stiles. *Color Science: Concepts and Methods, Quantitative Data and Formulae,* 2nd *ed.*, John Wiley & Sons, 1982.