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Reviews

Colour perception: Mind and the physical world edited by R Mausfeld, D Heyer; Oxford University Press, Oxford, 2003, 538 pages, £69.95 (US $144.50) ISBN 0 19 850500 0

> "The colours red, blue and green are real. The colour yellow is a mystical experience shared by everybody." (Stoppard 1967)

Colour is a vivid visual experience we (almost) all share. But what exactly is it that we are experiencing when we see red (or yellow)? When two people agree that something looks yellow, how can they know if they are actually sharing an experience or if they have simply learned a common association. For example, we all grow up learning that bananas are yellow, so we know that the colour we experience when looking at a banana must be yellow. But is my experience of yellow the same as yours, and is it meaningful even to ask this question? In some ways our understanding of colour vision has advanced enormously in recent years. Thanks to the advent of single-cell electrophysiology we have learnt a lot about the neural basis of the processing of chromatic information. However, on a philosophical level some fundamental questions are still unresolved. For example, what is the proper metaphysical status of colour? Is it the property of an object or is it a purely subjective experience?

Colour Perception: Mind and the Physical World is an eclectic and rather esoteric collection of chapters resulting from a year spent by its authors at the Zentrum für interdisziplinäre Forschung of the University of Bielefeld. The format of the book is of sixteen chapters, each followed by a commentary or commentaries, usually from authors of other chapters. The subject matter ranges from computational accounts of issues such as colour constancy to philosophical discussions of the realism, or otherwise, of colour.

The essential problem of colour constancy, the principal focus of Chapters 7 – 11, is how our visual systems factor the wavelength composition of light incident on our retinas into a multiplicative combination of the spectrum of the illumination and the surface reflectance properties of objects. The solution of this inverse problem would allow the observer to discount the effects of illumination and thus recover veridically the surface reflectances (colours) of objects, making colour a valuable aid in object recognition. According to this view, colour is a property of objects and our perception of colour depends upon neural mechanisms dedicated to solution of this problem. Thus, implicit in computational accounts of colour constancy is a particular perspective on the ontological status of colour.

Of the chapters in this volume, one stands out from the rest as being a result of genuine interdisciplinary collaboration resulting from dialogues in Bielefeld. Don MacLeod is a visual psychophysicist from UC San Diego while Tassilo von der Twer is a mathematician from Wuppertal. Together they determine the optimal form of the neuronal response function for coding a distribution of chromatic inputs under a range of different assumptions about the statistics of neuronal noise. They show that when a single stimulus dimension can be represented by more than one neuron then an opponent split-range code enhances coding efficiency. For example, the existence of separate 'on' and 'off' channels in the coding of luminance allows each neuron to devote its full dynamic range to coding only one half of the input range. These results have implications far beyond the perception of colour. As the commentary from Michael Webster puts it, the power of the approaches they develop is hard to overemphasise.

Webster himself has contributed a very strong chapter on colour perception and adaptation, though much of the content is based on an earlier review paper (Webster 1996). In it he looks at the mechanistic and functional basis of light and contrast adaptation, adaptation of post-receptoral chromatic channels, and adaptation and the statistics of natural images. The chapter by Michael D'Zmura also provides a concise review of recent work on the processing of chromatic information in the human visual system, in particular his own elegant noise-masking work measuring the spectral properties of chromatic detection mechanisms (D'Zmura and Knoblauch 1998). These are chapters I certainly envisage myself referring to in the future.

Parts of this book will be of interest to researchers from a range of disciplines who are interested in colour vision, but there is little to attract a wider non-specialist audience. Comparisons with *Color Vision: From Genes to Perception* (Gegenfurtner and Sharpe 2001) are inevitable. The latter is strong on the neurobiology of vision, while the present volume is pitched at a more theoretical and philosophical level. I must admit that my attitude to much of the philosophical discussion in this book is summed up in the title of Paul Whittle's commentary on Gary Hatfield's chapter. Hatfield writes on objectivity and subjectivity revisited: colour as a psychobiological property. Whittle entitles his commentary "Why is this game still being played?". One thing is for sure: despite a long history of study from a range of perspectives, and notwithstanding significant theoretical and neurobiological advances, the experience of the colour yellow has lost none of its mystery.

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Sight unseen: An exploration of conscious and unconscious vision by M A Goodale, A D Milner; Oxford University Press, Oxford, 2003, 146 pages, £25.00 cloth, £14.99 paper (US $49.00 cloth)
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Fifteen years after the authors met 'Dee', a patient with visual form agnosia, and eight years after the seminal work *The Visual Brain in Action* [Milner and Goodale 1995) was published, Goodale and Milner have written *Sight Unseen*, an updated account of the perception – action hypothesis aimed at a wider, more general audience. That the brain may process visual information in fundamentally different ways for perception and the control of action, and that this processing may take place on two largely separate parallel processing streams (the ventral and dorsal cortical streams, respectively) has been one of the most important and intriguing ideas to appear in recent vision research. There can be no people better placed to describe these ideas, which have shaped a large body of scientific research.

Sight Unseen combines recent research in visual neuroscience, with the development of the perception – action hypothesis in a way that will be relevant for those studying vision and for a wider non-scientific audience. It describes how Dee tragically suffered carbon monoxide poisoning that caused damage largely, but not completely, localised to her ventral stream. In particular, Dee has bilateral damage to the lateral occipital region of the ventral stream, area LO, an area defined mainly through brain-imaging studies. The resulting visual form agnosia means that Dee has great difficulty in identifying objects and object attributes, such as orientation, from 'form' information alone. The authors and coworkers suggest that Dee's bilateral LO lesions have damaged/removed a cortical 'form processing network' (James et al 2003). This is evidenced by Dee's difficulty in identifying objects defined mainly by form information, and in her difficulty in reporting the orientation and shape of objects in the world.

Dee is much more proficient in identifying objects defined by other visual cues in addition to form, such as colour and texture, and has much less problem in identifying real world objects defined by multiple visual cues. This is presumably due to those intact areas of the ventral stream out-with the bilaterally damaged LO that still receive input along the ventral stream, or alternative cortical pathways, in addition to possible cortical reorganisation and behavioural strategies that Dee may unconsciously employ. Notably, Dee is still able to use information regarding the form, orientation, and shape of objects for visuomotor tasks such as reaching to grasp. A dissociation thus exists between the use of information within the two streams. The important variable in this dissociation seems to be the goal of the action rather than a perception – action

distinction per se, as perceptual reports via action show the same inaccuracies as verbal perceptual report. This finding is complemented further by the double disassociation that exists between patients with visual form agnosia, such as Dee, and patients with optic ataxia who show the opposite pattern of response, ie accurate perceptual report but difficulty in the control of actions, such as reaching to grasp.

The book describes Dee's visual agnosia in relation to optic ataxia, blindsight, and modularity amongst other things, within an evolutionary perspective. Throughout the book, ideas are clearly discussed and illustrated with separate in-text 'boxes' giving an explanation of key concepts or techniques that may be unfamiliar to those without a background in this area. The book also gives more informal observations and descriptions of Dee's interaction in the world and introspection regarding her visual experience. These are important from both a lay and scientific perspective in gaining a clearer understanding of the phenomena that the perception – action hypothesis is hoped to account for, and is one of the strengths of the book. *Sight Unseen* highlights how science works, how phenomena in need of explanation are identified, and how theories are developed from detailed observation, in the hope of a clearer and more accurate understanding. The book is, however, written from the perspective of the perception – action hypothesis, and the authors argue persuasively, but from a clearly defined standpoint. Surprising is the omission of a discussion of the recent debate regarding evidence of the perception – action distinction in neurologically intact individuals, in particular that from pictorial visual illusions. These illusions are thought to predominantly reflect processing in the ventral perceptual stream whilst leaving the dorsal visuomotor stream largely unaffected. This is an area of active and lively debate (eg de Grave et al 2004), and, although the book is written in favour of this disassociation, it would have benefitted from a rounder discussion of this area. A more detailed discussion of the type and nature of the information used by each stream would also be an advantage, in particular how the differential use of information in each stream could account for the 'metric' or 'veridical' performance of the dorsal compared to ventral stream. This is important for understanding how the different sources of information processed in each stream may interact to mediate behaviour.

Sight Unseen brings, as the authors state, the visuomotor system out of the shadows of our concurrent visual experience. The visual system has clearly evolved for both the visuomotor control of action and the mediation of our perceptual experience, and for too long this perceptual experience has obscured the importance of vision for the control of action. However, the ventral stream may have more to tell us about the visual control of actions than the authors at times suggest. The authors clearly and rightly refute the notion of the ventral stream creating 'picture-in-the-head'-type representations of the world, but general understanding of the ventral stream seems to rest in this camp. Understanding how perception, cognition, action, and the environment are part of one integrated, coupled system (Clark 1997, 1999) may allow a greater understanding of how the 'perception' and 'action' streams are interrelated. Investigation of how the dorsal and ventral streams may closely cooperate in the generation of a more action-orientated or 'virtual' representation (Rensink 2000), such as the buildup of a scene 'representation' over saccades (Hollingworth and Henderson 2002), may start to demystify aspects of processing in the ventral stream and highlight ways in which the two streams are interrelated.

As discussed in the book, the ventral stream seems to have a greater role to play in the identification of goals for action, and is related more to planning and memory systems, and what could broadly be termed 'conscious vision', but as the authors suggest "[i]n practice it is going to be very difficult to tease apart the different elements that are contributed by the two streams even in an apparently simple everyday action ..." (page 108). The above problems are, however, in part due to the difficulty in understanding how consciousness fits into any explanation of brain and behaviour. The authors are not scared to take these issues on, and the perception – action hypothesis as a whole offers a fascinating and important take on this area. But, the 'conscious visual perception' – ventral stream versus 'robotic control of action' – dorsal stream distinction may be a simplification of a more complicated picture.

In summary, *Sight Unseen* offers an excellent introduction to the perception – action hypothesis that will appeal to a wide audience, including arts students and those without a scientific background. It is a concise and clearly written introduction to the area, by those at the centre of this field of research. It is written in a way that gets across the importance and excitement of science,

and thus deserves to be read by a greater audience. It will also be of some interest to those who have read *The Visual Brain in Action* and are more acquainted with perceptual research. It is not, however, the place to go for a more critical analysis of the perception – action distinction, and the large body of research it has produced. Understanding what each stream does, the information each stream uses, the limitations of this information, and, importantly, how the streams may interact in a more integrated 'coupled' system (Clark 1997, 1999) must be the focus of further research. The book is also excellent in putting a human face to science, and in helping us try to understand what it is like to live in a different visual world. Reading it makes you understand that science is a cooperative endeavour in which knowledge and friendships grow and evolve over time. This book will encourage people to do science.

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