PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

Preface

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Preface

The visual world provides an abundance of polarized light stimuli hidden to the human eye. Many organisms, and probably far more species than currently described, can exploit the polarization of light as a useful source of visual information. In August 2008, a number of scientists met on Heron Island, off the coast of Queensland (Australia), to debate the latest developments in the field of natural polarized light and its perception. The setting of the conference could not have been more appropriate: a small, isolated island exposed to a wide, polarized sky and surrounded by a coral reef teeming with many of those organisms which were discussed during the meeting. The sessions started early, closing around noon, followed by live demonstrations in the afternoon including diving and snorkelling excursions to the reef. We participants, scientists coming from all over the world thanks to the generous sponsors, are all extremely grateful to the organizers for this memorable meeting. The conference ignited the idea of a special issue of the Royal Society's *Philosophical Transactions B* dedicated to polarization vision. Apart from the meeting's participants, other researchers in the field joined in along the way such that the present volume presents an excellent overview of current knowledge in this exciting field of sensory physiology.

As is obvious to anyone studying this volume, polarization sensitivity is a multi-purpose visual ability, including the following proposed or actually demonstrated functions. Polarized skylight provides insects with a useful reference for a visual compass, which can be employed for navigation in the context of path integration, or simply for keeping a constant course during a journey. The detection of water bodies by the horizontal linear polarization of light reflected from their surfaces is common in many water-dependent flying insects. In the underwater world, the evaluation of e-vector information can increase object contrast improving visibility, and polarized signals on the bodies of cephalopods and mantis shrimps can serve communication even under the monochromatic conditions of deep water, where colour vision becomes impossible.

All these functions exploit e-vector information. Does that mean that the e-vector orientation of linearly polarized light is perceived as a separate modality of light in the same way that we perceive different spectral lights as different colours? Not necessarily! To detect water bodies, a simple detector for strong horizontal polarization (for instance, consisting of two opponent horizontally and vertically tuned analysers), oriented obliquely downwards, suffices and no coding of e-vector orientation is required.

Improving underwater visibility using polarization increases brightness contrast, while e-vector information is lost. Polarization has also been proposed to interact with the colour vision system in some animals, influencing and potentially enhancing colour contrast in a visual scene. In both colour and brightness perception, therefore, polarization sensitivity has a mere helper function!

The polarization pattern of the sky covers the whole celestial hemisphere. It consists of e-vectors oriented in concentric circles around the Sun and the antisolar point and, except for sunrise and sunset, it contains a whole range of different e-vectors (see Homberg's fig. 1*a* in this volume). The insect polarization compass seems to be a non-imaging, wide-field visual sub-system that integrates over a wide area of sky. This excludes the analysis of the individual e-vectors composing the celestial polarization pattern. In locusts, information on the chromatic gradient in the sky also seems to enter the system. Thus, although driven by polarized light, the output of the insect polarization compass provides a signal for body orientation (with respect to the sky) rather than representing the celestial e-vector pattern. At best, one could argue that the compass indicates an average e-vector orientation in the sky within its field of view (weighted by the gradient of the degree of polarization in the sky). Not surprisingly, under experimental conditions bees, locusts and other insects also do respond to single e-vector stimuli, but such a situation rarely occurs in the field.

The analysis of polarized body patterns could, in principle, be linked to brightness perception in the same way as contrast enhancement. However, experiments with cephalopods and mantis shrimps strongly suggest that these animals can indeed discriminate between e-vectors independent of brightness information, meaning that they must see real polarization images of a conspecific's polarized body signals, and of any other polarization-active object for that matter. How e-vector orientation actually looks to those creatures, is of course anyone's guess.

In conclusion, in the majority of known cases, the polarization of light is not really perceived as such. Perplexing as this may seem to some, the biological purpose of polarization sensitivity is not for an animal to admire different e-vector orientations but to gain useful visual information from them. Actually, in the spectral domain, the situation is not entirely different—although colour vision may be more common than real polarization vision. For instance, animal motion detection is generally driven by

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long-wavelength receptors only, which are often part of the colour vision system. Thus, the monochromatic motion detection system is colour blind and no colour is perceived, in an analogous way as e-vector orientation is probably not perceived by a flying back-swimmer seeking small water pools. Instead, the two systems signal 'motion' and 'water', respectively.

The recent detection of circular polarization vision in mantis shrimp, a completely new category of animal polarization sensitivity, suggests that the wonderful world of polarization still holds many treasures in store waiting to be unearthed by present and future scientists.

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