
Sampling Visual Space

Topography, colour vision and visually guided predator avoidance in fiddler crabs (*Uca vomeris*)



Jochen Smolka

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Title page: Regional specialisations in the *Uca vomeris* compound eyes exploit the differences in information content in different parts of the visual world (right image half, see chapter II). In the lateral visual field, facets are largest, increasing contrast sensitivity for the detection of approaching territory intruders. Frontally, resolution is highest and finely tuned to the short wavelengths that are provided by the crabs' blue carapace patterns (spectra in left image half) and picked up by the crabs' unusual trichromatic colour vision system (spectral sensitivities depicted between eyes, see chapter III). The dorsal eye features poor resolution, but comparatively large facets, leading to a patchy, undersampled visual field, but good sensitivity for the detection of small moving objects like approaching predators (see chapter IV and V).

Declaration

This thesis is an account of research undertaken between March 2005 and May 2009 at the Research School of Biological Sciences, The Australian National University, Canberra, Australia. Except where acknowledged in the customary manner, the material presented in this thesis is, to the best of my knowledge, original and has not been submitted in whole or in part for a degree at any other university. I am the senior author and the principal contributor to all aspects of the co-authored papers within.

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Jochen Smolka

Abstract

Many animals use vision to guide their behaviour and to collect relevant information about their environment. The diversity of visual environments and of visually guided tasks has led to a large variety of specialisations of eyes and visual systems. Our knowledge, however, about how the anatomical and physiological properties of eyes and the behavioural strategies of animals relate to the visual signals that are important to them in their natural environment, is extremely limited. In this thesis, I make use of optical, physiological and behavioural analyses to reconstruct the flow of visual information that the fiddler crab *Uca vomeris* experiences during its daily life on the mudflat. I present a detailed analysis of the first stage of visual processing, the sampling by the ommatidial array of the crabs' compound eye and demonstrate how regional specialisations of optical and sampling resolution reflect the information content and behavioural relevance of different parts of the visual field. Having developed the first intracellular electrophysiological preparation in fiddler crabs, I then examine the spectral sensitivities of photoreceptors – the basis for colour vision. I show that the crabs possess an unusual trichromatic colour vision system featuring a UV-sensitive and a variety of short-wavelength receptor types based on the co-expression of two short-wavelength sensitive pigments. Finally, the natural visual signals that predatory and non-predatory birds present to fiddler crabs are described. The visual cues the crabs use when deciding whether and when to respond to these potential predators are analysed and compared to those used in dummy predator experiments. The crabs use a decision criterion that combines multiple visual cues – including retinal speed, elevation and visual flicker. Neither of these cues accurately predicts risk, but together they reflect the statistical properties of the natural signals the crabs experience.

The complex interactions between the design of the crabs' visual system, the stimuli they experience in their natural context and their behaviour demonstrate that neither of them can be understood without knowledge of the other two.

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