Sampling Visual Space

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

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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.

.................................................................

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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Contents

Chapter I: Introduction ..................................................................................................1

I.1 Sensory systems and natural stimuli ..................................................................................................3
  I.1.1 Visual sampling .................................................................................................................3
I.2 The visual world of fiddler crabs ...........................................................................................................4
  I.2.1 Life in a dangerous world ........................................................................................................5
I.3 Thesis outline .................................................................................................................................6

Chapter II: Topography of fiddler crab vision and its relation to behaviour .........................9

II.1 Summary .................................................................................................................................11
II.2 Introduction .............................................................................................................................13
II.3 Materials and methods ..............................................................................................................16
  II.3.1 Animals, morphology and optical apparatus ...............................................................................16
  II.3.2 Optical measurements .............................................................................................................17
  II.3.3 Analysis ................................................................................................................................18
  II.3.4 Extrapolation to a full eye model ..........................................................................................20
II.4 Results ..........................................................................................................................................20
  II.4.1 Morphology of the eye ..........................................................................................................20
  II.4.2 Visual field and facet numbers ..............................................................................................22
  II.4.3 Variation in sampling resolution ...........................................................................................26
  II.4.4 Optical vs. sampling resolution ..............................................................................................28
  II.4.5 Eye shape ..............................................................................................................................32
II.5 Discussion ....................................................................................................................................34
  II.5.1 Comparison with earlier studies ..........................................................................................34
  II.5.2 The visual information zones ..............................................................................................35
  II.5.3 Ventral zone .........................................................................................................................35
  II.5.4 Dorsal zone .........................................................................................................................37
  II.5.5 Frontal zone .........................................................................................................................38
  II.5.6 Lateral zone .........................................................................................................................40
  II.5.7 Medial zone .........................................................................................................................41
  II.5.8 Distance estimation in crab compound eyes ........................................................................42

Chapter III: Uca vomeris – an unusual trichomat ........................................................... 47

III.1 Summary .................................................................................................................................49
III.2 Introduction .............................................................................................................................51
  III.2.1 Crustacean colour vision .......................................................................................................51
  III.2.2 Fiddler crab colour vision ....................................................................................................53
III.3 Materials and methods ............................................................................................................56
  III.3.1 Animals .................................................................................................................................56
  III.3.2 Preparation and recording setup ............................................................................................56
### Chapter III: Visual System in Uca vomeris

**III.3.3** Optical stimulation ................................................................. 58  
**III.3.4** Experimental protocol .............................................................. 59  
**III.3.5** Data analysis ............................................................................. 61  
**III.3.6** Sensitivity modelling ................................................................. 63  
**III.3.7** Interneuron recordings ................................................................. 64  

**III.4** Results .......................................................................................... 64  
**III.4.1** Photoreceptor properties ............................................................ 64  
**III.4.2** Spectral sensitivities ................................................................. 66  
**III.4.3** Spectral receptor classes and visual pigments ............................ 69  
**III.4.4** Polarisation sensitivity ............................................................... 74  
**III.4.5** Visual interneurons .................................................................... 74  

**III.5** Discussion ..................................................................................... 78  
**III.5.1** Electrophysiological preparation .................................................. 78  
**III.5.2** Uca vomeris spectral sensitivities ............................................... 79  
**III.5.3** Comparison to previous studies .................................................. 83  
**III.5.4** Uca vomeris ‘spectral ecology’ ..................................................... 86  
**III.5.5** Polarisation sensitivity ............................................................... 90  
**III.5.6** Future directions ....................................................................... 91  
**III.5.7** Conclusions ............................................................................... 92  

### Chapter IV: Natural visual cues eliciting predator avoidance in fiddler crabs

**IV.1** Summary ....................................................................................... 97  
**IV.2** Introduction .................................................................................... 99  
**IV.2.1** Predator avoidance in fiddler crabs ............................................. 99  
**IV.2.2** Natural visual cues .................................................................... 101  

**IV.3** Materials and methods ................................................................ 103  
**IV.3.1** Animals, apparatus and synchronisation .................................... 103  
**IV.3.2** Video analysis .......................................................................... 104  
**IV.3.3** Selection of trials ...................................................................... 106  
**IV.3.4** Statistical analysis ..................................................................... 106  

**IV.4** Results .......................................................................................... 107  
**IV.4.1** Description of and responses to different signals categories ....... 108  
**IV.4.2** Terns ......................................................................................... 109  
**IV.4.3** Kites ......................................................................................... 113  
**IV.4.4** Dragonflies ............................................................................... 120  
**IV.4.5** Migrants (high-flying, passing birds) .......................................... 120  
**IV.4.6** Response criteria ....................................................................... 121  
**IV.4.7** Statistical analysis ..................................................................... 124  

**IV.5** Discussion ..................................................................................... 127  
**IV.5.1** Natural signals in the context of predation ................................. 127  
**IV.5.2** Visual cues in natural escape responses ..................................... 128  
**IV.5.3** After the home run .................................................................... 131
Chapter V: The influence of fast contrast changes (flicker) on escape responses ... 135

| V.1  | Summary ....................................................................................................... 137 |
| V.2  | Introduction ............................................................................................ 139 |
| V.3  | Materials and methods ........................................................................... 141 |
| V.3.1 | Animals, apparatus and video analysis ............................................ 141 |
| V.3.2 | Selection of trials and statistical analysis .......................................... 143 |
| V.4  | Results ..................................................................................................... 144 |
| V.4.1 | Flicker triggers earlier home runs ...................................................... 144 |
| V.4.2 | Flicker overrides speed dependence ..................................................... 146 |
| V.4.3 | Motion detectors are (probably) not involved ....................................... 148 |
| V.5  | Discussion ............................................................................................... 150 |
| V.5.1 | Flicker as a response cue ...................................................................... 150 |
| V.5.2 | Flicker as part of a multiple-cue response criterion ............................. 153 |

Chapter VI: Summary and conclusions ........................................................................ 157

Appendices ................................................................................................................. 163

References ............................................................................................................... 193
List of figures

Figure II.1: The goniometer microscope........................................................................18
Figure II.2: Anatomical eye parameters.......................................................................21
Figure II.3: Optical axes of ommatidia ........................................................................23
Figure II.4: Most ommatidia sample the horizon........................................................25
Figure II.5: Vertical and horizontal sampling resolution..............................................27
Figure II.6: Optical resolution and Airy discs.............................................................30
Figure II.7: Comparison of vertical sampling resolution and optical resolution ..........32
Figure II.8: Eye model .................................................................................................33
Figure II.9: Vertical sampling resolution predicts size-constancy..............................37
Figure II.10: Size constancy and distance estimation................................................42

Figure III.1: *U. vomeris* compound eye .................................................................53
Figure III.2: The electrophysiological setup ...............................................................58
Figure III.3: Photoreceptor light responses.................................................................66
Figure III.4: Spectral sensitivity analysis in a short-wavelength receptor (PR9)..........68
Figure III.5: $V/\log(I)$ measurement error does not explain poor single-pigment fit ...69
Figure III.6: Photoreceptor spectral types...................................................................71
Figure III.7: Two-pigment fit error surface..................................................................73
Figure III.8: Polarisation sensitivity of *U. vomeris* photoreceptors .........................75
Figure III.9: Light responses of five *U. vomeris* interneurons...................................77
Figure III.10: Wavelength-specificity of a sustaining neuron’s flash response ......77
Figure III.11: The unusual trichromatic colour vision system of *Uca vomeris* .......79
Figure III.12: Previous studies re-evaluated ...............................................................84
Figure III.13: Visual pigments in crustaceans.............................................................87
Figure III.14: Chromaticity diagram of claws and back patterns.................................88

Figure IV.1: The hunting strategy of the gull-billed tern (*Gelochelidon nilotica*) ....102
Figure IV.2: The synchronised four-camera setup......................................................104
List of tables

Table II.1: Anatomical eye parameters ................................................................. 22
Table II.2: Horizontal ommatidial row counts compared. .................................. 25

Table IV.1: Recording times and elicited responses ............................................ 107
Table IV.2: Natural visual cues affecting escape decisions .................................. 126

Table V.1: Black vs. flickering dummy ............................................................... 145
Table V.2: White vs. flickering dummy .............................................................. 146
Table V.3: Black fast vs. black slow dummy ....................................................... 148
Table V.4: Flickering fast vs. flickering slow dummy .......................................... 148
Table V.5: Horizontally vs. vertically flickering dummy ..................................... 149