Online supporting information for

Sexual signals for the colour-blind: cryptic female mantids signal quality through brightness

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Supplementary Materials and Methods

VISUAL MODELLING

For all observers quantum catch Q, corrected for background adaptation k, for a given spectrum in photoreceptor i is:

$$Q_i = k_i \int_{300}^{700} R_i(\lambda)\, S(\lambda) I(\lambda) d\lambda \qquad (1)$$

where R(λ) is the reflectance spectrum of the mantid body part or background, S(λ) is the sensitivity function of the photoreceptor i in the visual system, and I(λ) is the irradiance spectrum, here taken to be D65 standard daylight. The constant k describes the von Kries transformation that accounts for receptor adaptation by normalising receptor quantum catches to the background:

$$k_i = \frac{1}{\int_{300}^{700} R_i(\lambda)\, S(\lambda) I(\lambda) d\lambda} \qquad (2)$$

In the trichromatic eyes of honeybees, chromatic contrast in JND units (ΔS) between each mantid body part and the background is calculated as:

$$\Delta S = \sqrt{\frac{e_{UV}^2 (\Delta f_G - \Delta f_B)^2 + e_B^2 (\Delta f_G - \Delta f_{UV})^2 + e_G^2 (\Delta f_{UV} - \Delta f_B)^2}{(e_{UV} e_B)^2 + (e_{UV} e_G)^2 + (e_B e_G)^2}} \qquad (3)$$

where e_i is the internal receptor noise for each receptor class of bees (with sensitivity peaks at 344 nm, 436 nm, 556 nm; Peitsch *et al.* 1992) and Δf_i is the log of quantum catches for receptor i between mantids and the background. Internal receptor noise is calculated as:

$$e_i = \varpi \Big/ \sqrt{n_i} \qquad\qquad (4)$$

where ϖ is the Weber fraction assigned to each receptor class (0.13 for honeybees; Vorobyev & Osorio 1998) and n_i is the relative density of the receptor class i. In the honeybee eye, the distribution of photoreceptors within ommatidia and the distribution of ommatidia classes across the eye is highly heterogeneous (Spaethe & Briscoe 2005; Wakakuwa *et al.* 2005). Accordingly, we used a ratio of 1:0.471:4.412 for the relative density UV, B, and G, receptors as per Defrize et al. (2010).

Achromatic contrast in the honeybee is simply the green contrast, and is calculated as:

$$\Delta L = \left| \frac{\Delta f_i}{e_i} \right| = \left| \ln\left(\frac{Q_{i-M}}{Q_{i-B}} \right) \Big/ e_i \right| \qquad\qquad (5)$$

where Δf_i is the log of quantum catch (Q) for the relevant photoreceptor i between mantid body part (M) and background (B).

For the tetrachromatic visual system of the blue tit we calculated quantum catch (Eqn. 1) using the spectral sensitivities of Hart et al. (2000) which take into account the influence of visual pigments, oil droplets and ocular media transmittance. Relative densities of the ultraviolet sensitive (uvs), short wavelength sensitive (sws), medium-wavelength sensitive (mws), and long-wavelength sensitive (lws) photoreceptors were 1:2:2:4, respectively (Schaefer, Schaefer & Vorobyev 2007). Chromatic contrast in this system is given by:

$$(\Delta S)^2 = ((e_{UVS}e_{SWS})^2(\Delta f_{LWS-}\Delta f_{MWS})^2 + (e_{UVS}e_{MWS})^2(\Delta f_{LWS-}\Delta f_{SWS})^2$$
$$+ (e_{UVS}e_{LWS})^2(\Delta f_{SWS-}\Delta f_{MWS})^2 + (e_{SWS}e_{MWS})^2(\Delta f_{LWS-}\Delta f_{UVS}$$
$$+ (e_{SWS}e_{LWS})^2(\Delta f_{MWS-}\Delta f_{UVS})^2 \tag{6}$$
$$+ (e_{MWS}e_{LWS})^2(\Delta f_{SWS-}\Delta f_{UVS})^2)/((e_{UVS}e_{SWS}e_{MWS})^2$$
$$+ (e_{UVS}e_{SWS}e_{LWS})^2 + (e_{UVS}e_{MWS}e_{LWS})^2 + (e_{SWS}e_{MWS}e_{LWS})^2)$$

where e_i is the internal receptor noise for each receptor class i of birds (Eqn. 4). We use the behaviourally derived Weber fraction value of 0.1 (Maier & Bowmaker 1993), which corresponds to a threshold value of 1 JND, while acknowledging that our understanding of photoreceptor noise in avian systems remains unclear (Lind & Kelber 2009). Birds are thought to use achromatic vision at long range through the use of double cones (Osorio, Miklósi & Gonda 1999). Achromatic contrast is calculated as per equation 5, where i is the spectral sensitivity function of the blue tit double cone.

The structure of the visual system of *P. albofimbriata* is unknown. We therefore used a monochromatic model of mantid vision with peak sensitivity in a single photoreceptor at 515 nm, based on data from two related species from the Mantidae family (*Tenodera aridifolia*, Sontag 1971; *Tenodera australasiae*, Rossel 1979). Lacking precise physiological data on photoreceptor noise levels, we estimated receptor noise using the honeybee Weber fraction of 0.13 (Vorobyev & Osorio 1998), as has been successfully done in other insect systems (e.g. Schultz & Fincke 2013). Since only the achromatic channel is available to mantids (i.e. no colour vision), contrast is calculated by equation 5, where i is the spectral sensitivity function of the single mantid photoreceptor.

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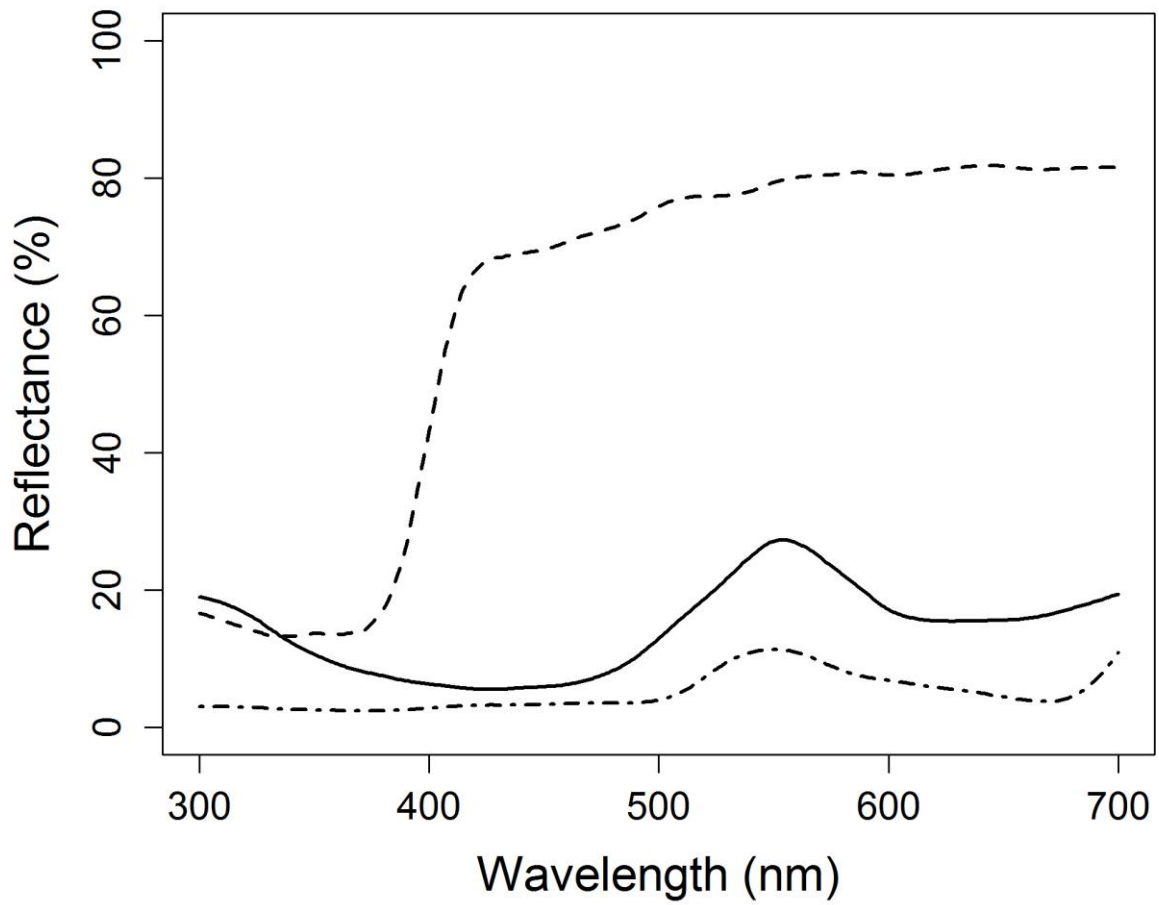
Figure S1: Reflectance spectra of paints used to dull (solid line) and brighten (dashed line) the abdomens of female *Pseudomantis albofimbriata* in conspecific choice experiments. For clarity, the mean spectrum of background vegetation is included (dot-dash).

Table S1: Summary of Wilcoxon rank-sum tests (V and p values) comparing chromatic and achromatic contrasts of male (n = 7) and female (n = 27) *P. albofimbriata* body segments, calculated against a typical background, with a threshold of 1 JND in hymenopteran, avian, and mantid visual systems. Stars indicate significance following Bonferroni correction.

Sex	Region	Honeybee		Blue tit		Mantid	
		V	p	V	p	V	p
Female	*Head*						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
	Pronotum						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
	Left arm						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
	Right arm						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
	Wing						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	150.00	0.826	158.00	0.772	128	0.929
	Abdomen						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	371.00	< 0.001*	372.00	< 0.001*	372	< 0.001*
Male	*All*						
	Chromatic	0.00	1.00	0.00	1.00	NA	NA
	Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
	Pronotum						

Chromatic	0.00	1.00	0.00	1.00	NA	NA
Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
Left arm						
Chromatic	0.00	1.00	0.00	1.00	NA	NA
Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
Right arm						
Chromatic	0.00	1.00	0.00	1.00	NA	NA
Achromatic	0.00	1.00	0.00	1.00	0.00	1.00
Wing						
Chromatic	0.00	1.00	0.00	1.00	NA	NA
Achromatic	6.00	0.922	6.00	0.922	6.00	0.922