Color Vision in Salamander Larvae

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Z. Naturforsch. **34 c**, 890 – 891 (1979); received May 17, 1979

Salamandra salamandra, Color Vision, Retina, Prey-Catching Behavior

In behavioral experiments using monochromatic prey-patterns, larval salamanders (*Salamandra salamandra*) are able to discriminate colored from white light. In the retina only blue-yellow opponent-color ganglion cells were recorded. Thus the color vision in these animals is dichromatic.

Color vision is the ability to discriminate wavelengths independently of their intensities. It requires at least two receptor types with different spectral sensitivities. Several animals including man have a trichromatic color vision, using three different receptor types. Salamanders and newts of the family Salamandridae are able to discriminate colors of different wavelengths from 450 nm to 635 nm [1]. In the amphibian retina five morphologically different receptor types which contain three different photopigments were described [2, 3]. It was uncertain how these receptor types contribute to the color vision in urodele amphibians. Since larval salamanders usually are more active in prey-catching behavior than adult animals they were chosen for the behavioral experiments. Furthermore electrophysiological recordings from the retinae were carried out.

Larvae of *Salamandra salamandra* born and raised in the laboratory were used. The behavioral studies were performed similar as in former experiments [1] where monochromatic moving prey dummies contrasting to a grey background were presented. The intensities of the color stimulus and of the background could be changed by neutral density filters and neutral density wedges. If the animals are able to discriminate colored from white light, they can always detect the movement of the border between the colored and the white area regardless of the luminosities. The perception of this moving pattern releases prey-capture behavior. If the animals have no color vision there must be a level of contrast at which the white light and the colored light appear equally bright; in this case the movement could not be detected and no reactions would occur.

If identical neutral density filters were placed in the two beams of light the larvae did not respond (Fig. 1). But if there was a certain degree of contrast they responded with prey-capture behavior. For each tested color a region with less response frequency was found in which the colored and the non colored area presumably were subjective equally bright for the larvae. This point was placed at contrast =0 in the diagram.

With none of the four test colors, however, a matching white light could be found that eliminated the reactions. The response levels at contrast 0 are significantly higher than with the white – white pattern (Fig. 1). Thus the larvae of *Salamandra salamandra* are capable to discriminate 439 nm (blue), 544 nm (green), 577 nm (yellow) and 620 nm (red) from white light of equal subjective brightness.

The electrophysiological experiments were performed with isolated retinae, placed in an experimental chamber at 13 °C, using standard recording techniques [4]. Ganglion cell responses were recorded extracellularly with tungsten microelectrodes. The spectral sensitivities of the neurons were determined by means of threshold measurements at different wavelengths.

Most of the retinal ganglion cells were luminosity neurons with a maximum sensitivity in the yellow spectral region. Eight of 57 neurons were recorded that showed color specific responses. These units are opponent-color cells which give an on-response at short wavelengths and an off-response at longer wavelengths. They receive inputs from two types of receptors which are blue- and yellow-sensitive respectively (Fig. 2). These cells were the only type of color coding units that could be recorded.

The results show that the opponent-color cells get excitatory signals from the green rods and inhibitory inputs from the single and double cones. The green-sensitive pigment rhodopsin P 502 which occurs in the red rods and in the accessory members of the double cones [2] does not drive a third color mechanism. Since similar types of color responses were recorded in the retina of *Rana temporaria* [5] and in the tectum opticum of *Salamandra* and *Triturus* [3, 6], this dichromatic color vision presumably is a common property in amphibians.

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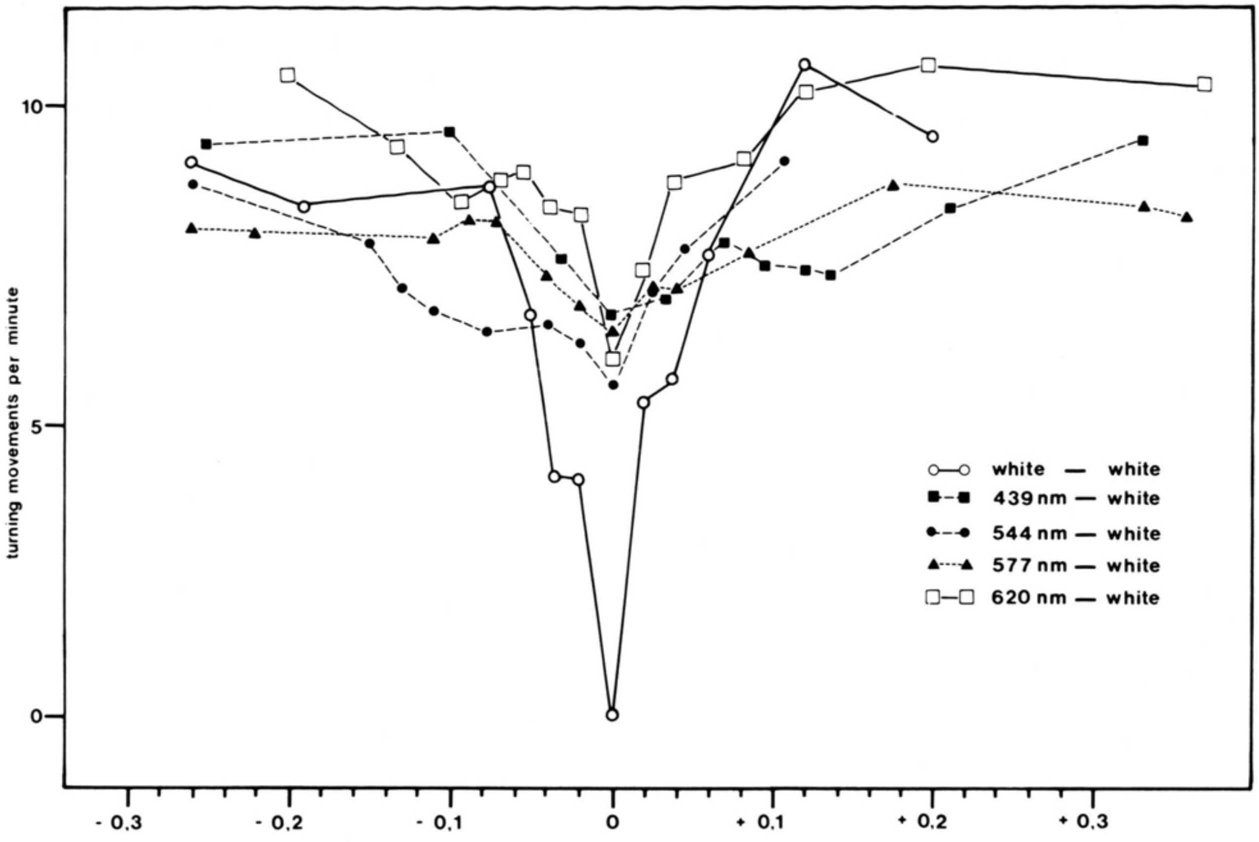

Fig. 1. Dependency of the reactions (turning towards the prey pattern) from the contrast between the white and colored areas. The luminosity of the white background was increased stepwise (negative values of contrast) or decreased (positive values of contrast).

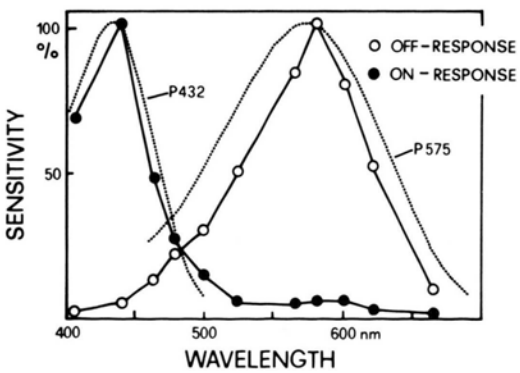

Fig. 2. Spectral sensitivity of opponent-color ganglion cells in the retina of larval *Salamandra salamandra;* mean values of six neurons. P 432 = absorption of the green rod pigment, P 575 = absorption of the cone pigment [2].

Acknowledgements

This research has been supported by the Deutsche Forschungsgemeinschaft.

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Verantwortlich für den Inhalt: A. KLEMM
Satz und Druck: Konrad Triltsch, Würzburg