The Role of Eye Accommodation in the Depth Perception of Common Toads

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Distance estimation in prey catching was as exact in monocular toads (*Bufo bufo* (L.)) as in binocular ones. Application of Atropine or Miotic® had no significant effect on binocular animals, whereas in monocular toads it made accurate distance estimation impossible. The accommodative state of the eye is decisive for depth estimation of monocular, but not of binocular toads.

In the prey catching behaviour of amphibians precise estimation of the distance of a prey object is essential. It was shown by several authors that the loss of eye does not significantly impair depth perception in anurans. Therefore, binocularity is not a necessary condition for depth perception [1–5]. It is still unclear which are the underlying mechanisms. It is suggested that for both binocular and monocular depth perception eye accommodation plays a crucial role [1, 3, 6]. In the relaxed state the amphibian eye is in a position for far vision; in order to accommodate for near objects the two protractor lentis muscles (in urodeles only one) have to pull the lense forward.

In order to investigate the role of accommodation in binocular and monocular depth perception, we first carried out a detailed analysis of maximal snapping distance (m. s. d.) for the toads by continuously pushing a screen with moving prey objects towards the subjects sitting in a translucent container until the first snapping responses occured. The m. s. d. of monocular toads was slightly larger than that of binocular ones (4.6 cm instead of 4.3 cm; the difference is not significant, $p > 0.5$), which means that in the natural prey catching situation monocular toads' snap falls slightly short (Fig. 1). The actual prey catching rate was reduced by only 10–15% with respect to binocular toads.

Next, eye accommodation was disturbed both in binocular and monocular toads by using Atropine which leads to a full relaxation of the smooth protractor muscles, and Miotic® (Carbachol + Neostigmine) which produces strong muscle contraction. In the binocular subjects Atropine slightly but significantly increased the m. s. d. from 4.3 to 5.0 cm ($p < 0.01$) (Fig. 2). In contrast, Miotic slightly reduced the m. s. d. from 4.3 to 3.7 cm ($p < 0.01$). In monocular subjects the effects of the drugs were much stronger: Atropine increased the m. s. d. to 7.2 cm ($p < 0.001$). These subjects snapped far short of living prey. Miotic, on the other hand, reduced the m. s. d. to 3.2 ($p < 0.001$). These animals usually snapped beyond the prey. The difference between binocular and monocular subjects treated with Atropine is highly significant ($p < 0.001$).

Since neither Atropine nor Miotic has an essential effect on depth perception and snapping accuracy in binocular toads whereas in monocular animals it makes accurate prey catching nearly impossible, one has to assume that binocular animals use additional mechanisms for depth perception which can almost fully compensate the loss of eye accommodation. Because convergence of the eyes – an important depth cue in other vertebrates – is not known in amphibians, and jerky head movements (*e.g.* to make use of parallax) are rare, the possibility remains that toads calculate the distance of a moving object by shifts of the retinal images in the two eyes. This hypothesis has to be proved by further experiments.

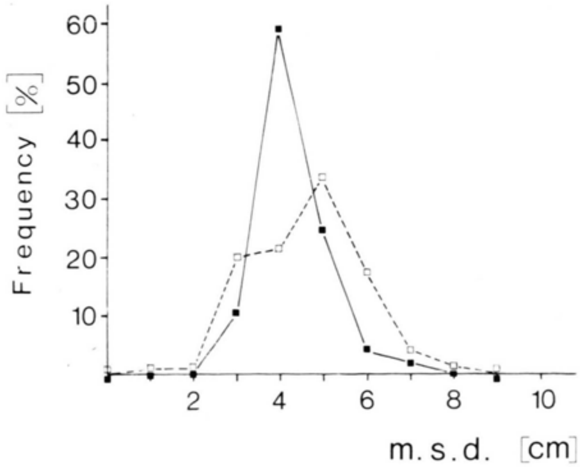

Fig. 1. Frequency distribution [%] of maximal snapping distance (m. s. d.). ■ binocular toads; □ monocular toads; (100% ≙ total number of snapping reactions).

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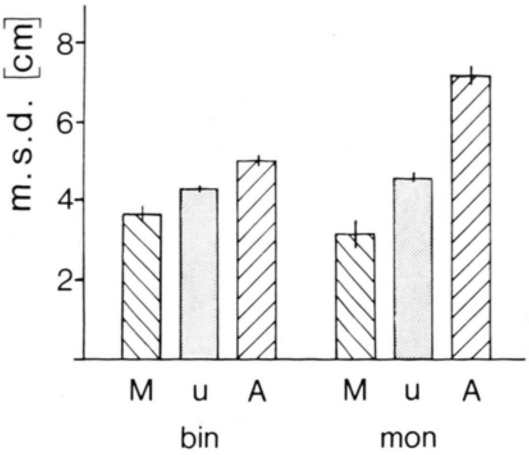

Fig. 2. Maximal snapping distance [cm] of binocular (bin) and monocular (mon) toads. M: after application of Miotic®; u: untreated toads; A: after application of Atropin. Vertical bars show the standard error of the mean.

We assume that in monocular toads' prey catching, the accommodation of the eye follows a moving prey object so that it remains in the zone of sharp vision, until the state of maximal accommodation is reached. When the object passes the border of sharp vision, it is in the reach of the tongue and the animal snaps. Total relaxation of the accomodation muscle due to the application of Atropine moves the border of sharp vision away from the eye. Since the accommodation muscle cannot be further contracted when the object passes the border the animal snaps too short. On the other hand, Miotic leads to an abnormal contraction of the accommodation muscle and therefore to an abnormally close position of the border of sharp vision. Hence, the monocular toad snaps beyond the prey.

Our hypothesis, that in anurans the snapping response occurs when a prey object passes the inner border of sharp vision, might also be true for many urodeles (*e. g.* Plethodontids). In these animals very little or no accommodation is possible due to the enormous size of the lense and the existence of only one m. protractor lentis which seems to have only a stabilizing function for the lense.

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