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CHEMICAL DISCRIMINATION OF PREY BY NAIVE NEONATE GOULD'S MONITORS *Varanus gouldii*

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Abstract—Previous studies have demonstrated that actively foraging autarchoglossan lizards rely in part on chemoreception to detect and locate prey. In one of two experiments, neonate Gould's monitors *Varanus gouldii* were studied to determine whether they were able to discriminate between multiple prey odors and control odors by tongue-flicking. Responses of lizards to deionized water, a pungency control (cologne), mouse, gecko, and cricket odors on cotton-tipped applicators were studied in experiments using repeated-measures designs and using the tongue-flick attack score (TFAS) as the primary measure of response strength. The TFAS was greater in response to cricket odors than to other prey odors or to either of the control stimuli, and there was no statistically significant difference in response between control stimuli. Range of tongue-flicks elicited by cricket odor were greater than those for other prey odors and control stimuli. Only applicators bearing cricket odor were bitten. In the second experiment, lizards were tested to determine whether they respond differently to chemical stimuli taken from the exoskeleton vs. internal fluids of crickets. TFAS were slightly higher for chemical stimuli taken from internal fluids, but not significantly so. Lizards bit applicators in both conditions. Details of responses to experimental trials are discussed in relation to the feeding behavior of this species.

Key Words—*Varanus gouldii,* lizard, Sauria, Varanidae, chemoreception, vomerolfaction, prey discrimination.

INTRODUCTION

Response to chemical cues sampled by tongue-flicking has been established in various lizard species and is known to be important in numerous ecologically

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important contexts (Simon, 1983; Auffenberg, 1984; Cooper, 1989, 1990a,b; 1991). Varanid lizards are opportunistic predators that tongue-flick frequently while active. Chemical cues from prey are important stimuli for varanid lizards and may facilitate the location and identification of prey items (Auffenburg, 1981, 1984). Varanid tongue morphology is very snakelike (McDowell, 1972). In snakes, other lizards, and presumably varanids, molecules sampled by the tongue when it is protruded are thought to be transferred to the vomeronasal ducts and then to the vomeronasal epithelia, the site of the chemoreceptor cells (Halpern and Fruman, 1979; Halpern, 1992). The ability to detect chemical prey odors and discriminate them from nonodorous and biologically irrelevant odorous controls has been demonstrated in a variety of autarchoglossan lizards (Burghardt, 1973; Cooper and Vitt, 1989; Cooper, 1990a).

Gould's monitor lizard (*Varanus gouldii*) is found in a wide variety of habitats throughout most of Australia (Mertens, 1958; Pianka, 1972; King and Green, 1979). This species forages widely, often covering nearly two square kilometers per day (Pianka, 1970). The diet of wild *V. gouldii* consists mainly of mole crickets, grasshoppers, beetles, spiders, and frogs, most often encountered while the lizards are burrowing (Pianka, 1970; Pengilly, 1981).

This paper describes two experiments: experiment 1 is designed to determine whether naive (no previous exposure to food or prey chemicals) neonate *Varanus gouldii* can detect prey chemicals and discriminate chemically between prey, odorless stimuli, and odorous, but irrelevant stimuli; experiment 2 is designed to determine whether lizards respond differently to chemical stimuli taken from the exoskeleton vs. internal fluids of a cricket. The experimental techniques have been applied to a wide variety of lizard taxa in studies of prey chemical discrimination (Burghardt 1973; Cooper, 1989, 1990a; Cooper and Vitt, 1989; Achen and Rakestraw, 1984).

METHODS AND MATERIALS

Seven Gould's monitors (sex unknown) were hatched from a single clutch at the Dallas Zoo in November 1992. The lizards were housed individually in glass aquaria (50 × 25 × 29 cm) with metal screen tops. Blank newsprint served as substrate. Each lizard was provided with a 75-W incandescent lamp, a 20-W fluorescent ultraviolet lamp (Sylvania BL 350) and an ABS plastic hidebox. Water was available ad libitum. Lizards were acclimated to laboratory conditions for at least three days and not tested until the umbilicus retracted and retained yolk was visibly absorbed. These experiments were conducted between November 17, and December 10, 1992, between 1300 and 1500 hr. One trial per day was conducted for each lizard. The ambient temperature was ca. 29°C and the photoperiod was ca. 10:14 hr light–dark.

Experiment 1 Design. To detect ability to discriminate between prey chemicals and other chemical stimuli, responses of *V. gouldii* were tested with cricket (*Acheta domestica*), gecko (*Hemidactylus frenatus*), and mouse (*Mus musculus*) chemicals. Cologne (Spice Bracer) and distilled water were used as controls. Each of the five stimuli was presented to each lizard once in a randomized block design. All stimuli were first prepared by immersing a cotton-tipped applicator in distilled water. To add other chemical cues, the wet applicator was dipped in cologne, or rolled over the dorsal and ventral aspect of a gecko or mouse. The invertebrate stimuli were applied by pressing a wet applicator onto a mashed cricket. Trials were initiated by slowly approaching a lizard's enclosure and gently removing the top. The cotton-tipped applicator was slowly moved to within 2 cm of the lizard's snout. Beginning with the first tongue-flick, tongue-flicks directed at the applicator were counted for 60 sec or until the lizard bit the swab, whichever occurred first. For lizards that bit the swab, latency to biting in seconds and number of tongue-flicks before biting were recorded. Tongue-flicks directed away from the applicator were not counted.

The measure of predatory response strength to a stimulus condition was the tongue-flick attack score (TFAS), a composite variable. When the stimulus does not elicit biting, it is the number of tongue-flicks. When biting occurs, it is the maximum number of tongue-flicks emitted by any individual in any stimulus condition plus (60 minus the latency to bite in seconds). This measure, developed by Burghardt (1967, 1969, 1970), assumes that increasing numbers of tongue-flicks represents increasing chemosensory examination of the stimulus and that biting represents a predatory attack (Cooper and Burghardt, 1990). A bite is thus weighted more heavily than any number of tongue-flicks.

Experiment 2 Design. Methods used to detect ability to discriminate between chemical stimuli taken from the exoskeleton vs. internal fluids of a cricket, followed that of experiment 1.

Analysis. Data are presented as means ± 1 SE of the mean. Analysis was conducted using procedures for single-factor experiments having repeated-measures designs. Bartlett's tests were conducted to determine homogeneity of variances among conditions. Raw data or homoscedastic transformed data were subjected to ANOVA. Significance for the two-tailed alpha was accepted at $P < 0.05$. Kruskal-Wallis tests and paired t tests were used for multiple comparisons.

RESULTS

Experiment 1. The lizards tongue-flicked applicators in all test conditions; four lizards bit applicators bearing cricket odors (Table 1). Because variances in the TFAS were heterogeneous ($F = 7.26$; $df = 4$; $P < 0.001$), a 3rd root

TABLE 1. TONGUE-FLICK RESPONSE (TFAS) TO TEST CONDITIONS BY NAIVE *Varanus gouldii*

	Cologne	Cricket	Gecko	Mouse	Water
Mean TFAS	6.43	38.00	7.58	12.71	4.14
Range of TFAS	1–14	2–63	1–13	2–24	1–14
SE of TFAS	1.85	9.74	1.91	3.36	1.79
No. of attacks	0	4	0	0	0
X latency to attack (sec)		13.25			

transformation was performed that yielded homogeneous variances ($F = 1.63$; $df = 4$; $P > 0.05$). The main stimulus condition effect was highly significant ($F = 4.96$; $df = 4$; $P < 0.003$). Multiple comparisons revealed a significantly higher TFAS for cricket stimuli than for other prey chemicals, cologne, and water (H corrected for ties, $P < 0.045$). The TFAS for water, cologne, gecko, and mouse odors did not differ significantly (Table 1).

For all seven monitors, the highest TFAS was emitted in response to cricket odors. The mean TFAS was 38.0, with a range of 2–63; for the remaining conditions number of tongue-flicks and the TFAS were identical. Greater numbers of tongue-flicks were elicited by cricket odors than by either control treatment, and there was no significant difference in response to the two control conditions ($t = 0.84$, $df = 6$, $P = 0.4334$).

Four individuals bit applicators bearing cricket chemicals within 18 sec, and no bites occurred in the other conditions. A binomial test revealed that lizards were significantly more likely to bite in the cricket condition than in the others (two-tailed binomial $P = 0.0004$).

Experiment 2. Lizards tongue-flicked applicators in both test conditions; four bit applicators bearing cricket chemicals from internal fluids, while only one lizard bit an applicator bearing chemical stimuli from the exoskeleton (Table 2).

Variance in tongue-flick rate was homogeneous (approximate $F = 1.83$; $df = 1$; $P > 0.05$). Variance in the TFAS were homogeneous (approximate $F = 0.23$; $df = 1$; $P > 0.05$). A paired t test revealed that the difference in response to the two conditions was not significant ($t = 1.69$; $df = 6$; $P = 0.1427$).

DISCUSSION

Neonate reptiles of many species exhibit well-developed behavioral repertoires immediately after parturition or hatching (Burghardt, 1977; Fuchs and Burghardt, 1971). Naive *V. gouldii* in this study readily distinguished cricket

TABLE 2. TONGUE-FLICK RESPONSES (TFAS) TO TEST CONDITIONS BY NEONATE *Varanus gouldii*

	Chemical stimuli from	
	Exoskeleton	Internal fluids
Mean TFAS	26.14	41.14
Range of TFAS	12-60	15-62
SE of TFAS	6.58	8.11
No. of attacks	1	5
X latency to attack (sec)	7.0	10.0

odors from controls, demonstrating that chemoreception and prey chemical discrimination are innate functions that are well developed at birth and that previous exposure to prey chemicals is not necessary to elicit a significant response (see Burghardt, 1973). While visual cues may be the primary means of prey location for most varanids (Auffenberg, 1984), chemosensory trailing may occur in some species (Auffenberg, 1981). It is possible that burrowing species such as *V. gouldii* can detect residual chemical cues or trails left on substrata by invertebrates, thus facilitating the detection of subterranean prey.

The geckkonid species used as a source of prey chemical stimuli in this experiment was selected because neonate *V. gouldii* may encounter this species in the wild, even considering that this species is predominantly nonterrestrial. However, as results indicate, responses were not significantly different from controls. The TFAS for neonatal mouse stimuli were greater than that to stimuli other than cricket stimuli. Hence, it was not surprising that lizards readily accepted neonatal mice at ca. one week after the termination of these trials.

In the first experiment, response to cricket odors was consistent with the invertebrate diet of *V. gouldii*, but we could not specify whether the effective chemical cues were of external or internal origin. However, the results of experiment 2 led us to conclude that responses to cricket stimuli were based on both classes of chemical cues (see Chiszar et al., 1993).

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