

Sex Recognition by Males of the Lizard *Lacerta vivipara*: An Introductory Study

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Abstract The role of colour pattern and olfactory cues in sex identification by adult males of the lizard *Lacerta vivipara* was examined by observing their behavioural response towards several types of introduced conspecific adults. Reproductive males courted both receptive and non-receptive adult females. In addition, they courted introduced males that were painted to mimic the females' colour pattern, indicating that pigmentation functions in sex recognition. Responses of males to females painted as males, untreated females, and uniformly black painted females were identical. This demonstrates that males do not rely exclusively on colour pattern for sex recognition. Odour does not seem to be important as a secondary factor in stimulating courtship. The possible contribution of other stimuli to sex identification is discussed.

Introduction

The majority of vertebrates shows a pronounced sexual dimorphism in size, colour or colour pattern. Among reptiles, sexual dichromatism is most marked in several agamid and iguanid lizards where members of one sex, usually the males, possess conspicuous pigmentation of the flanks, head, throat or dewlap. The presence of such coloration is often accentuated during agonistic and courtship displays, and is therefore expected to be functional in social communication. It has been shown that sex recognition, one possible function of sexual coloration, is at least partly based on colour signals in *Agama agama* (Harris, 1964), *Uta stansburiana* (Ferguson, 1966), *Sceloporus virgatus* (Vinciger, 1972), *Anolis carolinensis* (Greenberg & Noble, 1944; Crews, 1975; Sigmund, 1983), *Holbrookia tropicallia* (Cooper, 198+) and in some *Lacerta* (Kramer, 1937; Kitzler, 1941).

Although sexual dimorphism is rather inconspicuous in the lizard *Lacerta vivipara*, some slight differences between males and females can be found. Adult males are on the average slightly smaller than adult females, but have relatively longer legs and tail,

and bigger heads (Wermuth, 1955). The sexes differ somewhat in dorsal coloration and pattern. Females usually have a continuous vertebral band and a pair of distinct dorsolateral stripes, with little spotting on the flanks. Males are sometimes similar, but generally they have better developed, scattered dark spots or ocelli on their back and flanks, and/or lack distinct stripes. Still, dorsal coloration and pattern is very variable within each sex and there is a considerable overlap between the sexes. Sexual dichromatism is more apparent in the coloration of the belly. The underside in males is often yellow, orange or red with many dark spots or blotches. In females, the belly is generally cream or yellow with little dark pigmentation. Again, this distinction is not absolute, as we have seen females with heavily spotted vents and males with unmarked bellies. It should also be noted that vent colours are rarely observable in unrestrained lizards, at least for a human observer. Finally, the sexes are best distinguished by the presence of a swelling at the base of the tail in males, but this is only noticeable when the lizard is picked up.

During the course of a study on the reproductive biology of *Lacerta vivipara* (Bauwens & Verheyen, 1985 and in prep.) we frequently observed males initiating courtship by running quickly and from a large distance, towards an introduced adult female. Based on these observations, we hypothesised that these lizards would be able to identify the sex of their conspecifics, despite the absence of a conspicuous sexual dimorphism. In the present paper we will present data from behavioural experiments designed to determine 1) whether male *L. vivipara* can indeed identify the sex of conspecifics, and 2) to what extent certain visual stimuli and odiferous cues are involved in sex discrimination.

Material and Methods

Reproductive behaviour.

Lacerta vivipara is a small (adult body length: 50-60 mm; weight: 3-4 g), ground-dwelling lizard that behaves like a typical heliotherm (Avery, 1976). This live-bearing lizard reproduces once a year and has a distinct annual reproductive cycle. Mating and ovulation occur in April and May respectively, and the young are born during the last week of July and the first half of August (for details see Bauwens & Verheyen, 1985). Lizards hibernate from October to the end of February (adult males) or the onset of April (adult females and immature lizards) (Bauwens, 1981).

Reproductive behaviour in *L. vivipara* is relatively simple as preliminary courtship displays are completely absent (Vrbicek, 1972; own observ.). Upon confrontation of the two sexes, a sexually active male will approach the female and attempt to obtain a mouth-hold on her flank, neck or tail. Initially, females often respond by vigorous flight or flight, but will soon become passive if they are receptive. The male is then allowed to obtain a mouth-hold on the female's flank, immediately before the pelvic region. After a variable pause the male curls his tail underneath the female's and inserts his hemipenis.

quently, lizards were coated with vasoline. The latter technique has been used successfully in both snakes (Noble, 1937) and lizards (Ferguson, 1966).

We tested the significance of differences in the reactions of resident males towards different types of non-residents by the McNemar test for the significance of changes and the Cochran Q test (Siegel, 1956).

Experiment 1

The first experiment was conducted to determine whether resident males responded differently towards introduced males and females, and towards introduced receptive and non-receptive females.

Resident males approached receptive females more frequently than introduced males (table 1, $P < 0.01$). All males approached and grasped the reproductive female, and maintained the bite-hold. Some residents also approached the introduced male. It is difficult to classify this response either as an initiation of courtship or as aggression, since the agonistic behaviour of *L. vivipara* is restricted to approaching and biting the opponent (Verbeek, 1972; own observations). However, residents never held a mouth-hold when they bit the introduced male, suggesting either that the resident was forced to release the bite-hold by the challenged male, or that the appearance of the introduced male stimulated aggression instead of courtship behaviour in the resident.

The non-reproductive females, in contrast to the reproductive individuals, performed submissive displays (foot shaking and tail waving) (Verbeek, 1972) and/or fled when they were approached by the male. Upon being bitten, these females vigorously and persistently fought and rolled over to free themselves. Despite obvious differences in behaviour between reproductive and non-reproductive females, the response of residents towards both groups of females did not differ significantly (table 1, $P > 0.50$). This implies that the release of courtship behaviour in male *L. vivipara* is independent of the females' reproductive state.

Experiment 2

This experiment was designed to determine to what extent colour pattern is involved in sexual discrimination by male *L. vivipara*.

In first instance, the response of resident males towards an introduced male that was painted as an adult female, and towards an untreated male was examined. If colour stimuli are significant for recognition of potential mates, the female impersonator is expected to be approached more frequently than the male, provided that our painting accurately mimicked a female's appearance. Residents were indeed more likely to approach the "females" than the untreated males (table 1, $P = 0.0+$). In some instances the painted male was bitten persistently and/or was pursued during fleeing.

We subsequently examined whether females can be recognized by features other than their colour pattern. If males would rely exclusively on a conspecific's colour pattern to identify its sex, they would not respond to a male that is painted as an adult female.

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Table 1. The number of resident males showing ("approach" or "neutral" behaviours) towards various types of introduced conspecifics.

Type of introduced conspecific	response of resident	
	"approach"	"neutral"
<i>Experiment 1</i>		
female	10	0
male	2	8
non-reproductive female	8	2
<i>Experiment 2</i>		
male	3	
male painted as female	9	1
female	10	0
female painted as male	9	1
female painted black	10	0
<i>Experiment 3</i>		
male	5	9
male with painted back	6	8
male with painted belly	5	9
<i>Experiment 4</i>		
female	11	0
non-reproductive female painted as male	11	3

If other features are also significant in sex recognition, males are expected to identify accurately, and therefore to court a male-like coloured female. The same ten males used in the previous trials were confronted with an untreated adult female and with a female painted as a male. Responses of the residents to both females were similar (table 1, $P > 0.90$), suggesting that the sex of the painted females was correctly identified. However, this result might be an artifact induced by an imperfect imitation of the male colour pattern. Therefore, the experiment was extended by introducing a female whose colour pattern was obscured by a uniform black painting. This female was approached and bitten by all residents (table 1), demonstrating that males can identify females by characteristics other than their colour pattern.

Experiment 3

Having established that the females' colour pattern is a factor involved in sex recognition, an attempt was made to determine whether some particular feature of the colour pattern stimulated courtship behaviour in the male. Two types of treated males were introduced: i) a male lizard with an untreated belly, but with dorsum and flanks painted to mimic the female pattern, and ii) a male with untreated flanks and dorsum, but with a painted female-like belly. The observed responses of residents did not differ significantly from those towards an untreated male (table 1, $P > 0.50$), indicating

that the painted males were not identified as females. This suggests that the combination of dorsal and ventral pigmentations, rather than some particular colour or marking, elicits courtship in male *L. vivipara*. It also discouraged further experimental isolation of particular features of the female colour pattern.

Experiment 4

The fact that male *L. vivipara* courted male-like and black coloured females indicates that stimuli not related to their colour pattern are involved in sex identification. Therefore, the hypothesis that males would be able to distinguish the sexes by odours was tested. We introduced a male-like coloured female which was treated to eliminate odiferous secretions. No significant differences in the responses to the manipulated and to an untreated female were observed (table 1. $P > 0.20$), suggesting that odiferous cues are unimportant in initiating courtship.

Discussion

Our observations confirm that *L. vivipara* has few stereotyped postural movements (Vrbeek, 1972; Avery, 1976). The absence of both preliminary courtship displays and agonistic postures obscures the distinction between attacks and mating attempts, and hampers the interpretation of some of the observed responses. The results show that resident males approached and bit introduced females significantly more often than males. Some residents approached both introduced males and females, but subtle differences were then apparent in the responses toward both sexes, suggesting that the presence of a male released aggressive rather than courtship behaviour in the residents. We therefore conclude that in most staged encounters, male *L. vivipara* accurately identified the sex of untreated conspecific adults.

Our data show that colour pattern is important in inducing courtship behaviour. Resident males treated non-resident males which were painted with female colour patterns as if they were actually females. This result is complementary to those of other studies that demonstrated the role of colour and pattern in sex recognition in lizards (Kramer, 1937; Kitzler, 1941; Harris, 1964; Ferguson, 1966; Vinegar, 1972; Cooper, 198+).

However, we have not been able to identify the features of the colour pattern which are critical to the response. Males that were partly (dorsum or belly) coloured as females were not rejected, suggesting that the global configuration of the pigmentations, rather than some particular colour or marking, is critical for eliciting courtship behaviour in male *L. vivipara*. Hence, it appears that different stimuli from the colour pattern are perceived in a non-additive manner, with the response elicited by the whole being more intense than that elicited by the sum of its parts (the "Gestalt" principle - see Hinde, 1970). These findings contrast those made in some other lizard species, including the rattlesnake *Crotalus agilis* and *L. iris*, in which some discrete feature of the pattern can be considered as a sign-stimulus in sex recognition (Kitzler, 1941;

Harris, 1964; Ferguson, 1966; Ingram, 1972; Cooper 1984). It should nevertheless be pointed out that these species are, unlike *L. uici para*, strongly sexually dimorphic by the presence of bright colorations in one sex.

The fact that male *L. vivipara* courted females whose colour pattern was obscured by a male-like or a uniform black painting indicates that they do not rely exclusively on colour pattern for sex recognition. Yet, colour seemed unimportant as a secondary factor in initiating courtship. In all experiments we observed that some residents ran towards an introduced female before they had apparently approached close enough to detect odours. In addition, residents courted male-like coloured females even when they were presumably deodorised. Although it has been shown that some lizards distinguish sexes by chemoreception (Duvall, 1979; Simon, 1983; Cooper & Vitt, 1984), few studies have determined the importance of chemical cues relative to other stimuli in sex recognition. Both behavioural and chemoreceptive cues play a significant role in distinguishing between the sexes in the gecko *Coleonyx variegatus* (Greenberg, 1943). Although colour seems to be most important in *Lacerla agilis* and *L. viridis*, they also rely to some extent on chemoreception during courtship (Kitzler, 1941). In contrast, odorous stimuli do not seem essential for the release of courtship in *Uta stansburiana* (Ferguson, 1966).

We can only speculate what kind of additional stimuli assist in sex recognition in *L. vivipara*. Tactile stimuli, which are involved in the early stages of courtship in some geckos, snakes and turtles (Carpenter & Ferguson, 1977), might be important in the initiation of copulation in *L. vivipara*, but it is unlikely that they are involved in the initial recognition of partners. We have not observed the adoption of stereotyped postures in neither male or female, and therefore dismiss the importance of visual behavioural cues in sex recognition. There exist rather small differences between the sexes in the form and proportions of head length, width and height (Wermuth, 1955; van Wezel & Nuijten, 1984). Greenberg and Noble (1944) suggested that certain subtle differences in morphological proportions could assist in sex recognition in *Anolis carolinensis*. In his experimental study, Ferguson (1966) concluded that body form was the most important factor in releasing the initial stages of courtship in *Uta stansburiana*. We suggest that male *L. vivipara* would likewise rely on head and body form as a secondary factor in the identification of the sex of conspecific adults. Yet, additional experiments are needed to test this hypothesis.

Our results indicate that male *L. vivipara* do not rely on a single cue for the recognition of potential partners. Regarding the considerable overlap between the sexes in both dorsal and ventral colorations, the non-exclusive reliance on colour pattern can be considered as a mechanism that reduces the probability of mistaking a conspecific's sex. We suggest that a reliable recognition of potential partners would reduce the time that males spend in mate-searching. This seems especially advantageous in a lizard like *L. vivipara*, that lives in a cool temperate environment where the demands of thermoregulation leave a restricted amount of time available for other activities (Avery, 1976). Also, receptivity in individual females is restricted to a short period (2-4 days;

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