Spatial reversal learning in the lizard *Coleonyx variegatus*

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Banded geckos (*Coleonyx variegatus*) were trained, at the rate of five daily trials, on eight intradimensional spatial shifts to a criterion of 80% correct per reversal. In contrast to several previously reported failures to obtain reversal learning, *Coleonyx* demonstrated significant improvement on both errors and trials to criterion. Their reversal performance compares favorably with that of birds and mammals and a common index of reversal ability, the mean total error, did not differentiate between taxa.

While numerous species of birds and mammals have consistently demonstrated progressive improvement on spatial reversals (Warren, 1965, 1973), the data are conflicting for fish and reptiles. It was only after frequent failures (Behrend, Domesick, & Bitterman, 1965; Bitterman, 1965a, 1965b; Bitterman, Wodinsky, & Candland, 1958) that fish were reported to display improvement on such tasks (Mackintosh & Cauty, 1971; Setterington & Bishop, 1967; see also Squier, 1969). Since some of these successful investigations were with species previously reported not to demonstrate improvement, it now seems likely that these contrasting results with reversal learning (RL) performance represent differences due to procedural variations rather than due to functional differences between adjacent taxa.

A somewhat similar state of contradiction exists within the class reptilia in that while crocodilia (caiman, alligator, and crocodile) were reported to improve between reversals (Gossette & Hombach, 1969; R. S. Williams, 1968), data for chelonina (turtle and terrapin) and squamata (lizard) are difficult to interpret. No improvement was initially reported for turtles tested by a correction procedure with both fixed number of trials and criterion methods (Kirk & Bitterman, 1963). Eventually, however, this species was reported to improve when tested with guidance and a substantially greater fixed number of trials per reversal (Holmes & Bitterman, 1966). The other chelonina, terrapin, were tested by a procedure that was inelegant to the point of eliminating any conclusion about their reversal ability (Seidman, 1949).

Two families of squamata have been tested for spatial reversal and several species of iguanidae (desert iguana and american chameleon) have been reported to demonstrate improvement (Norton, Peterson, & Richardson, Note 1; Richardson, Garzanit, & Albano,

Note 2). However, Gekkonidae (geckos) have been reported to show no improvement when tested with either a fixed number of trials (20) or a criterion (17/20) procedure (Baird, 1970; Baird & Vance, Note 3). These failures to obtain spatial reversal improvement with *Coleonyx variegatus* are striking. In addition to the contrast in performance compared with other reptiles, geckos' successful acquisition of presumably more difficult tasks such as brightness and pattern discriminations (Baird, 1970) is difficult to reconcile. To avoid the confusion that ensued from acceptance of negative results with fish and other reptiles and the assertion that RL ability indicated functional differences (Bitterman, 1965a, 1965b, 1975), the present investigation was undertaken in the attempt to demonstrate spatial RL in geckos.

METHOD

Subjects

Subjects were three male and two female adult western banded geckos (*Coleonyx variegatus*) with an average snout-vent length of 6.5 cm. They were communally housed in a glass terrarium (46 x 61 x 91 cm) furnished with flat rocks, wooden stumps, and hollow bamboo tubes on 27°C sand. The lizards were gently handled by 20 min of daily handling for 2 weeks prior to beginning the study.

Apparatus

Spatial reversal training was conducted in a Y maze (30-deg radials) featuring a 27°C substrate. Both choice arms led to identical darkened goalboxes with 31°C substrates. While a hinged door allowed ready access to the goalbox on the correct side (S+), entrance to the goal on the incorrect side (S-) was precluded by affixing the door in a closed position.

Procedure

Data were collected with these nocturnal subjects tested during the light phase of their daily cycle. While this may initially appear counterintuitive, superior learning performance has been reported for this species tested under such conditions (Baird, 1970), which may be due to a darkened goal having enhanced incentive value under such circumstances. A spatial choice was scored as the subjects' rear legs entered the left or right maze arm. While only the initial radial choice was subsequently analyzed, a correction procedure was employed in that retracing was permitted after selection of the S- maze

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arm. If retracing was successful and the lizard found its way into the correct radial and goalbox, it was allowed to remain in the box for 2 min, as was the case subsequent to an initially correct choice. If the lizard did not retrace, it was removed 2 min after having crossed into the S- alley arm. After each trial the maze was cleaned to reduce the possibility of chemical cue contribution.

Subjects were tested daily for five trials with an average intertrial interval of 7 min. Pretraining consisted of 60 trials with both goals accessible, during which individual spatial preferences were noted, and in the following acquisition phase individual nonpreferred sides were used as the S+. Subjects were trained to a criterion of 80% correct (16/20). Upon reaching criterion in the acquisition phase (Reversal₀), subjects were tested with the same criterion on eight spatial reversals that featured an intradimensional spatial shift of the S+ and S- between reversals.

RESULTS

Data consisting of errors and trials to criterion across acquisition and reversals were separately analyzed by repeated-measures analyses of variance. Both errors to criterion [$F(8,32) = 3.12$, $p < .025$] and trials to criterion [$F(8,32) = 2.67$, $p < .025$] significantly differed and are depicted in Figure 1.

Post hoc analyses of these effects by Duncan multiple range tests ($p < .05$) indicated: (1) improvement across reversals on both errors and trials to criterion (the number of errors and trials was greater on the first than on the sixth, seventh, or eighth reversal), and (2) the functions relating reversals to trials and errors to criterion were linear with a negative slope (Reversals 2, 3, and 4 did not significantly differ in the number of errors or trials). The mean cumulative error for the eight reversals was 122, and the reversal index scores (Rajalakshmi & Jeeves, 1965) were .84 for errors and .75 for trials to criterion.

DISCUSSION

The present study clearly indicates improvement by geckos on intradimensional spatial shift, an ability not previously demonstrated possibly due to insufficient testing (fewer

Table 1
Average Total Errors Across the Initial Eight Reversals

Taxa	Mean Total Error	Source
Aves		
chicken	345	Gossette, 1969c
chukar	106	Gossette and Hood, 1967
dove	266	Gossette and Hood, 1967
guinea fowl	367	Gossette, 1969c
magpie	88	Gossette, 1969c
myna	193	Gossette and Hood, 1967
pigeon	122	Gossette, 1969c
trumpeter	654	Gossette, 1969c
Mammalia		
bat	134	Ellins and Masterton, 1971
cacomistle	52	Gossette et al., 1968
capuchin monkey	34	Gossette, 1970a
coati-mundi	125	Gossette et al., 1968
gibbon	82	Gossette, 1970a
kinkajou	130	Gossette et al., 1968
mouse	56	Elias, 1970
owl monkey	101	Gossette, 1970a
raccoon	110	Gossette et al., 1968
rat	117	Mackintosh and Cauty, 1971
skunk	128	Gossette et al., 1968
squirrel monkey	175	Gossette, 1970a
Osteichthyes		
goldfish	152	Mackintosh and Cauty, 1971
Reptilia		
American chameleon	104	Norton et al., Note 1
gecko	122	Present investigation

Note—Values estimated from published figures.

reversals) and inappropriate statistical analysis (Baird, 1970; Baird & Vance, Note 3). An additional factor that may have resulted in the present success is that of methodology. RL performance has been reported to be a function of: (1) schedule of reinforcement, deprivation level, and incentive magnitude (Gossette, 1969b; Kendler & Lachman, 1958; Levine, 1974), (2) intertrial interval (Alpern & Marriott, 1972; North, 1950; B. A. Williams, 1971), (3) number of trials per reversal (Holmes & Bitterman, 1966; Pubols, 1962), (4) response criteria (Gossette, 1969a), (5) correction or noncorrection training (Gossette, 1969a; Miller, Hansen, & Thomas, 1972), and (6) distance between manipulanda, as well as limited or unlimited correction (Setterington & Bishop, 1967).

In order to assess geckos' performance, it was compared with that of other reptiles, fish, birds, and mammals. Comparisons were made by a method advocated by Gossette (1970a, 1970b) that uses a measure consisting of the average total number of errors across a constant number of reversals. Bearing in mind the limitations of contrasting studies with differing procedures and criteria, on the basis of this measure (across the eight reversals), geckos' performance was inferior to that of American chameleons (Norton et al., Note 1) and superior to that of goldfish (Mackintosh & Cauty, 1971). Contrasted with avians, geckos were comparable to pigeons (Gossette, 1969c) and superior to chickens, doves, guinea fowl, mynas, and trumpeters (Gossette, 1969c; Gossette & Hood, 1967). Performance comparisons with mammals led to the most striking conclusion: Geckos were comparable with coati-mundi, kinkajou, and skunks (Gossette, Kraus, & Speiss, 1968) and were superior to bats and squirrel monkeys (Ellins & Masterton, 1971; Gossette, 1970a). To determine the predictive value of RL in general, and of this apparent aberrant ability of geckos in particular, we computed where possible the average total number of errors across the first eight spatial reversals, as depicted in Table 1.

Figure 1. Average number of trials and errors to criterion with 1 standard deviation around the mean.

No systemic relationship between this RL measure and taxonomic class was supported by a Kruskal-Wallis test, which failed to indicate a significant difference (fish were not included in the analysis). Thus, not only can geckos learn spatial reversals, but their performance is at least comparable with a variety of species.

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