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DEPTH/DISTANCE PERCEPTION IN GERBILS AND SPINY MICE: ECOLOGICAL CONSIDERATIONS

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ABSTRACT: Adult and young gerbils and spiny mice were tested for their ability to discriminate between a short and a long arm in a T-maze. Animals were given 20 training trials/day for 5 days. The gerbils' performance improved from about 45% correct responses on Day 1 to about 80% on Day 5; the performances of the spiny mice stayed at about 40-50% over the training period. There were no age differences. These findings complement those of an earlier study in which spiny mice did demonstrate depth perception on a visual cliff while the gerbils did not. Both sets of data are interpreted from an evolutionary perspective which relates depth perception ability to the organism's natural ecological niche: gerbils are burrowing animals and spiny mice are surface and rock dwellers.

A multifaceted comparative question we have been pursuing focuses on developmental aspects of various sensory systems in gerbils and spiny mice. That this is a useful question seems clear both from our own work and the work of others extending back many years (Honzik, 1936; Schiffman, 1970; Webster & Caccavale, 1966; Greenberg, 1986; Yahr, 1977). While these are closely related species (Ellerman, 1940/1966), there are many differences in their ecology. The spiny mouse (*Acomys cahirinus*) is primarily a rock-dwelling organism and does not burrow in regard to reproduction or food management, while the Mongolian gerbil (*Meriones unguiculatus*) is a burrowing animal.

Our first experiments (Greenberg, 1986) examined the depth perception abilities of these two species on a modified visual cliff. We concluded that both species demonstrated depth perception. The spiny mice showed this by increasing descent times as the platform height

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increased. Although descent times did not vary with platform height for the gerbils, their descent times were slower than those of the spiny mice at the shallow platform heights, suggesting that they were making cautious approaches to the platform drop-offs.

Subsequent replications of these studies (ms in preparation) have caused us to rethink our earlier conclusions. We now believe that while spiny mice do indeed display depth perception in these platform situations, gerbils do not. Their descent times simply do not vary significantly with platform height, a finding of our first study (Greenberg, 1986). However, the literature indicates that gerbils can perceive depth. Indeed, upon reading the published account of our research, a colleague sent a report of his research which shows good distance perception by gerbils when measured in a situation that requires the animal to jump horizontally from one ledge to another (Ellard, Goodale & Timney, 1984).

This caused us to reflect on the ecological differences between these species, as alluded to above. We reasoned that the platforms we had been using were more analogous to the natural environment of the spiny mouse than of the gerbil. Would the gerbil display depth/distance perception in a T-maze, in which the arms were analogous to the environment of a burrow?

METHOD

Animals. Twenty Mongolian gerbils (*Meriones unguiculatus*) and 28 spiny mice (*Acomys cahirinus*) were observed in this experiment. All animals were bred and raised in our laboratories, fed Purina lab chow ad libitum, and given free access to water (gerbils) or carrots (spiny mice). All animals were maintained in same sex pairs; the gerbils were housed in translucent shoe box cages (29.2 x 28.45 x 15.24 cm) on corn cob bedding and the spiny mice were housed in 10 gallon glass aquaria on a sand substrate containing a large rock. At the start of the experiment half of the gerbils were about 30 days of age and half were about 250 days of age; 8 of the spiny mice were about 60 days of age and 20 of the spiny mice were more than 1 year of age.

Apparatus. Animals were tested in a T-maze with a 51 cm main alley (including a 9 cm start box) and short (22 cm) and long (45 cm) choice alleys. The alleys were 10 cm wide and 14 cm high. Illumination was provided by a 52 watt white light suspended 70 cm above the choice point. The floor of the alleys were lined with clear plexiglass and the entire maze was enclosed with wire mesh to prevent animals from escaping. The entire apparatus was enclosed in a large cardboard box to minimize extra-maze cues.

Procedure. Ten days prior to the start of the experiment all animals were placed in individual cages and put on a 22 hour water deprivation schedule. Spiny mice were water deprived by removing carrots from their diets six days prior to the beginning of the experiment; they were given 2 hour free access to carrot pieces in their cages during this period. To assess the relative motivating properties of carrots and water for the spiny mice, 10 animals were maintained on an ad libitum water schedule for several weeks prior to the start of the experiment; ten days before testing began these animals were water deprived in the same manner as were the gerbils.

The ability of the animals to discriminate between the long and short arm of the maze was tested in five daily sessions of 20 discrimination trials. Correct choices were reinforced with saccharin sweetened water for the gerbils and unsweetened water and 5-10 mg carrot pieces for the spiny mice. For half of the animals the correct choice was the short arm and for half it was the long arm. The position of the correct choice was randomly assigned for each trial. When water was the reinforcement both arms contained drinking tubes, although only one provided water; when reinforcement was a carrot piece it was placed in a small food cup and a similar empty food cup was placed in the incorrect arm. Both maze arms, then, were visually identical.

All animals were allowed a single free exploration trial and a forced trial to the opposite arm prior to testing; both trials were reinforced. Trials consisted of placing the animal in the start box for 10 seconds after which time the door to this box was raised. The animals were then free to explore the maze. The arm the animal selected on each trial was recorded as a correct or incorrect response.

RESULTS

The mean correct responses made by the five separate groups over the five days of testing are shown in Table 1. This is illustrated in Figure 1. Both show that the gerbils improved their discrimination over the training period while the spiny mice did not. An ANOVA indicated no significant differences between the adult spiny mice reinforced with carrots and those reinforced with water ($F_{(1,18)} = 1.24$, $p < .28$) and so the results of those groups were pooled. A second ANOVA showed no significant age differences ($F_{(1,44)} = 0.44$); there was, however, a significant difference between the overall gerbil and spiny mouse performance ($F_{(1,44)} = 35.27$, $p < .001$). The Newman-Keuls Statistic revealed that Day 5 performance was significantly better than Day 1 performance for the young gerbils ($p < .01$) and the old gerbils ($p < .01$), but not for the spiny mice.

TABLE 1
Mean Correct Responses (20 Trials/Day)

		Day 1	*Day 2*	*Day 3*	*Day 4*	*Day 5*
Young gerbils	$\overline{X}$	9.1	10.7	13.0	14.6	16.5
	S.D.	1.4	5.1	5.3	4.9	7.4
Old gerbils	$\overline{X}$	9.9	11.0	11.6	13.5	14.1
	S.D.	2.8	3.8	1.6	13.7	7.7
Young spiny mice	$\overline{X}$	9.6	8.8	10.5	10.0	10.6
	S.D.	5.4	2.2	4.9	3.4	10.0
Old spiny mice	$\overline{X}$	8.7	10.7	10.7	9.5	9.6
	S.D.	8.7	6.0	1.6	7.2	6.9

DISCUSSION

These results indicate that gerbils can readily learn to discriminate depth/distance in a horizontal T-maze, while spiny mice apparently cannot, at least under the present conditions. However, the results of our earlier work (Greenberg, 1986) show that spiny mice can indeed make this discrimination when tested on a visual cliff, whereas gerbils cannot when tested this way. We believe that these differences in discriminating depth/distance reflect natural ecological adaptations made by these species. Gerbils are burrowing animals and our experiments show that they can discriminate depth/distance in the burrow-like arms of a maze: spiny mice are rock and vertical surface dwellers and they can discriminate depth/distance when tested on a cliff-like device.

Our interpretation of these data is consistent with the statement by Brown (1975) in a discussion of responsiveness to stimuli that are of biological significance to an organism, that "Evolutionary theory suggests that the nervous systems of animals have been specialized through natural selection for the performance of tasks relevant to the way of life of each species (p. 537)." This idea is related to the concept of "feature detectors" in sensory systems, initially described by Lettvin, Maturana, McCulloch and Pitts (1959) and now included in virtually all treatments of the neurophysiology of sensation and perception (Carlson, 1988). Indeed, there is even some evidence for the presence of depth detectors, neurons in the striate cortex which respond differentially to retinal disparity (Poggio & Poggio, 1984).

As structures, feature detectors are subject to evolutionary modification (Tierney, 1986). Such structural adaptations would seem to

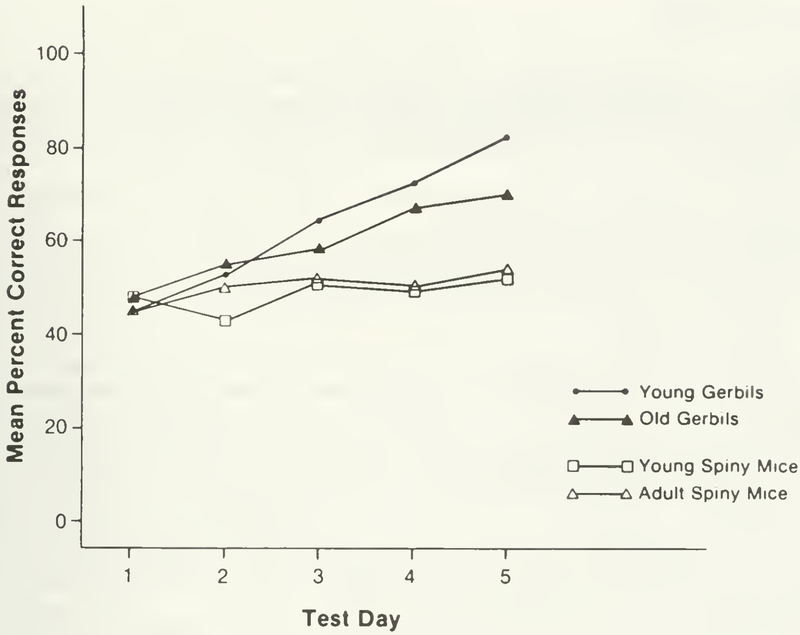

FIGURE 1. Mean percent correct responses.

be an an important basis for an organism's fit with its ecological niche as a recent analysis of the biophysics of burrowing behavior indicates (Reed, 1985). It is even possible to account for the ability of monkeys to identify conspecifics and their various facial expressions and characteristics by invoking the idea of inherited feature detectors (Perrett & Mistlin, 1990). What we are suggesting is that gerbils have evolved a visual system that functions more effectively in the horizontal dimension than it does in the vertical (a finding confirmed by Ellard, Goodale & Timney, 1984) while the visual system of the spiny mouse seems to function more effectively in the vertical dimension.

Another result of this experiment that warrants mention was the finding that the young gerbils outperformed the old gerbils on days 3 through 5. Although these differences were not significant, they are consistent with our earlier findings that young gerbils are superior to older ones in a simple visual discrimination task, and points to a developmental course of sensory efficiency (Greenberg, 1978; Greenberg & Dieffenbacher, 1976). We believe that vision is prepotent in this species early in its life and that other senses, such as touch, which is more involved in burrowing, become prepotent in adult animals. We are currently addressing this problem with the two species studied here.