

**FOOD CHOICE, REINFORCER PREFERENCE, AND VISUAL DISCRIMINATION IN
MONITOR LIZARDS (*VARANUS SPP.*)**

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**FOOD CHOICE, REINFORCER PREFERENCE, AND VISUAL DISCRIMINATION IN
MONITOR LIZARDS (*VARANUS SPP.*)**

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SUMMARY

Learning in reptiles has been studied with a variety of methods and included numerous species. However, research on learning in lizards has generally focused on spatial memory and has used only a few species. No research has specifically investigated and documented the use of visual discrimination in monitor lizards. The ability of monitor lizards (*Varanus spp.*) to discriminate between visual stimuli was investigated. Subjects were tested on acquisition and two reversals of a discrimination task between black and white stimuli. A food-choice procedure was used to determine if consistent rankings of food items could be determined using a multiple-stimulus choice procedure. The functional value of the rankings was assessed using a progressive ratio technique. The subjects formed stable food preferences, which were reflected in increased response requirement completed for preferred items and subjects did successfully learn the initial discrimination task and the following reversals.

CHAPTER 1

INTRODUCTION

Learning in reptiles has a long history with the first documented experiment by Yerkes (1901) (as cited in Burghardt, 1977). Yerkes ran a single spotted turtle (*Clemmys guttata*) through a maze. The turtle successfully learned the maze, decreasing in time required from 35 minutes to a mere 3.5 minutes. This early report, and the subsequent century's worth of work on learning in reptiles (anecdotal and experimental), may have stemmed from earlier reports that reptiles were too instinctive to be capable of much learning. The studies conducted to disprove this assumption have included various subjects ranging from crocodiles to tuatara and include representatives from all groups within the reptile class except Amphisbaenia (a limbless, eyeless reptile that lives underground). The methods used to study learning in reptiles have ranged from habituation to probability learning. Although a large number of reptile learning reports exist, they are often rarely referenced or difficult to locate. Burghardt concluded that many of these studies remain rarely referenced due to obscure place of publication and a hybrid psychology/biology methodology.

Visual Discrimination in Reptiles

Within Burghardt's (1977) review of reptile learning, a section is dedicated to visual stimulus discrimination. Several methods have been employed to study visual discrimination. Yerkes (1907) invented the discrimination box, which quickly became an experimental standard. It consisted of a starting box which would open into a divided alleyway. Each alleyway was painted with different colors, or oriented lines, or would

have stimuli placed at the end of the tunnels (shapes, colors, etc.) and the animal would be required to enter a tunnel. Correct choices were rewarded; incorrect choices either ended the trial or were punished with shock or time-outs. The discrimination box was used extensively with turtles to study discrimination of brightness, color, form, size, line orientation, monochromatic light thresholds, and infrared light versus visible light. This method has also been used in one study of crocodilian color discrimination and a few lizard studies looking at color, black versus white, form, line width and brightness.

Another less commonly used methodology to study color vision in lizards was the Wagner method (Burghardt, 1977). In this methodology a two tined fork was used to present a mealworm with a colored background. Correct stimuli were paired with palatable mealworms and incorrect stimuli were paired with mealworms soaked in saltwater. Using this method, color vision was examined in several turtle and lizard species.

A few studies examined visual discrimination in crocodilians using T-mazes. The T-maze is a modified discrimination box where the subject must make a full 90° turn before being able to enter the choice tunnels. Several studies reviewed by Burghardt (1977) employed this method to study brightness discrimination and conditioned discrimination using the brightness of the ambient light as the stimulus.

Recent Work on Stimulus Discrimination in Reptiles

In more recent work, the most comprehensive studies of stimulus discrimination in reptiles have been conducted in turtles. Learning studies in reptiles may be biased towards turtles for several reasons; turtles are regular eaters and consequently can be

reinforced consistently using food, keep well in captivity, and are potentially closer to the ancient common ancestor of mammal/reptile than most reptiles (Powers, 1990).

Researchers have used behavioral methods (as opposed to physiological) to study a variety of topics. Some such research areas include: telencephalic function in reptiles (reviewed in Peterson, 1980; Powers, 1990), the evolution of taste aversion (Paradis & Cabanac, 2004), auditory localization in turtles (Lenhardt, 1981), and visual acuity in loggerhead sea turtles (Bartol, Mellgren & Musick, 2003). Even with the variety of topics studied, most of the discrimination work in reptiles is done with turtles.

Recent Work on Stimulus Discrimination in Lizards

In 1978 Brattstrom reviewed work on lizard learning. While not comprehensive (the review did not include much of the work reviewed in Burghardt, 1977 or work published in languages other than English), it does illustrate some interesting trends. Brattstrom noted early failures to train lizards to discriminate and cautioned against testing under non-optimal temperatures as well as using stimuli or rewards that were not ecologically relevant. However, he did conclude that lizards are able to learn to perform a variety of tasks such as wheel running and lever pressing given appropriate reinforcers.

Within the lizard taxon, researchers have continued to employ behavioral methods to attempt to test various hypotheses. Often, behavioral methods have been used to test the functions of particular portions of the brain. Punzo (1985) tested the role of the basal forebrain in the brown anole (*Anolis sagrei*), Ivanzov (1983) examined the role of the hippocampal cortex and dorsal ventricular ridge (DVR) in the scheltopusik lizard (*Ophisaurus apodus*), Day, Crews and Wilczynski (1999) examined whether spatial memory in lizards was correlated with medial (MC) and dorsal cortex (DC) size

(hippocampal homologues in these species), and Day, Crews, & Wilczynski (2001) examined the role of the medial and dorsal cortex on spatial memory in *Cnemidophorus inornatus*.

Other studies have looked at the effectiveness of different types of cues used with lizards. Day, Ismail and Wilczynski (2003) trained whiptail lizards (*Cnemidophorus inornatus*) to escape intense heat by entering a shelter whose position was indicated by either visual or spatial cues. The researchers found that the rate of learning and reversing the discrimination was affected by cue type, with positional cues more effective than feature cues.

In a similar study, sleepy lizards (*Tilqua rugosa*) were trained to locate shelters based on visual and spatial cues (Zuri & Bull, 2000). Visual cues were used preferentially to spatial cues, and black and white signals and triangles and circles were more easily discriminated than red and green signals. The reason for the lack of discrimination between red and green wavelengths is unknown; however, perhaps these colors are not salient cues to refuge location in these animals.

Some stimulus discrimination work has also been done in the field. For example, Martín and López (2003) studied how repeated intrusion by a predator changed the escape responses of a lizard (*Acanthodactylus erythrurus*). They found that the lizards did indeed change their escape strategy after repeated intrusions by adjusting their choice of refuge. Similarly, Martín and López (2004) found that Iberian rock lizards (*Lacerta monticola*) had a flexible assessment of predation risk, with behavior based on previous experiences of that individual.

While there has been a reasonable amount of diversity in species and methods used in reptile learning studies, biases still exist. After his review of reptile learning, Burghardt (1977) noted that turtles were over-represented, and that more diversity in type of species used should be considered in the future. Lizards, which are a more diverse group than turtles are not nearly as well represented in the reptile learning literature. Within lizards, species bias also occurs. While *Lacerta spp.* and *Dipsosaurus dorsalis* are commonly used as subjects (Brattstrom, 1978), only two monitor learning studies have been conducted. One study looked at the role of the hypothalamus in classical conditioning of *Varanus griseus* and the other examined effective autoshaping (automatic training of an animal to engage in an operant response, e.g. lever pressing) in *Varanus bengalensis* (as cited in Burghardt, 1977). While these two studies show that some monitors can be classically conditioned and that others can learn to press levers, relatively basic knowledge about learning processes in monitor lizards is still missing. Additionally, few recent learning studies have examined visual discrimination. Studies of the morphology of monitor lizards show that their visual system is well developed with the potential for color vision (Underwood, 1970). However there have been no behavioral studies designed to test these assumptions. Therefore, the visual capabilities of monitor lizards is an area rife with opportunity for study.

Monitor Lizards and Stimulus Discrimination

Stimulus discrimination, as a task, can be compared to foraging behavior (Kamil and Roitblat, 1985). For an active predator that searches for their food, certain stimuli (olfactory, movement, a particular burrow) should be associated with a higher probability of obtaining food. To optimize foraging behavior a forager would need to be sensitive to

changes in the probability of obtaining food associated with a particular stimulus. Thus, stimuli (visual, spatial, etc.) associated with a higher rate of food should be visited at a higher frequency. Most monitors (including those in this study) are active foragers and spend much of their day actively searching for food (King and Green, 1999). Being active foragers, monitor lizards may be similar to the turtles mentioned earlier, in that they might be better suited for behavioral testing using food than other lizards. As well as being active foragers, most monitors forage on the ground and are hypothesized to focus on particular visual cues such as thick leaf litter or burrow entrances when looking for prey. Therefore, monitors should be sensitive to contingencies involving particular visual stimuli and food reinforcers. However, few studies have looked at the foraging dynamics of lizard species. Although, in one exception, Kaufman, Burghardt and Phillips (1996) studied how white-throated monitors discriminate between potential food items.

Of all the lizards, monitor lizards are touted as being the most “intelligent” and “mammal-like” (King and Green, 1999; Sweet & Pianka, 2003). Monitors are thought to be highly “intelligent” based on observations from captivity and the field. There are reports of monitor lizards intercepting rather than chasing prey, taking food to a protected area before swallowing it, recognizing their keepers, and avoiding the scent trails of humans (Sweet and Pianka, 2003). One research study mentioned in the Sweet and Pianka paper even claims that white-throated monitors may be able to “count” to six. However, many of these reports are in the form of popular articles and have yet to be supported in the peer reviewed literature. Also, as intelligence is a term hard to define, especially in animals, other terms might be better employed such as “less stimulus-bound,” “less instinctive” or “capable of behavioral flexibility” (Burghardt, 1977). While

these are terms that are relative and also warrant further definition, they are at least less controversial than the alternative.

Several characteristics, including behavioral flexibility, make monitors good candidates for visual stimulus discrimination studies using food as reinforcement. Monitor lizards are highly food motivated (Gaalema & Benboe, 2005) and have physiological metabolic control similar to mammals, making them more active and responsive than most lizards (Porges, Riniolo, McBride, & Campbell, 2003). Also, monitors have been shown to use visual cues while foraging, with white-throated monitors (*Varanus albigularis*) discriminating between prey items based on static visual cues (Kaufman, Burghardt, and Phillips, 1996). Accordingly, monitors should be sensitive to contingencies involving food reinforcement and visual stimuli. Thus, for all the reasons listed, monitors are ideal candidates for studying visual stimulus discrimination using positive reinforcement techniques in reptiles.

Food Choice and Reinforcer Preference

One way to increase the effectiveness of a behavioral learning study is to employ a preferred reinforcer (Treichler, 1967). A reinforcer is defined as a stimulus (food, heat, social interaction, etc.) that when it follows a behavior, increases the probability of that behavior occurring. Therefore, identifying a stimulus (a preferred reinforcer) that is more effective at increasing a target behavior should increase the effectiveness of a learning study by increasing the probability of the target behavior from the subject. Research has shown that highly preferred items tend to function as reinforcers (Piazza, Fisher, Hagopian, Bowman & Toole, 1996), and that preferred items sustain greater levels of behavior and faster acquisition of target behaviors, than items that are rated as less

preferred (Caldwell, Taylor & Bloom, 1986; Treichler, 1967). Research has also shown that animals can form stable rankings of items (e.g., Silberberg et al., 1998), suggesting that one should be able to identify preferred food items for monitor lizards.

Several methods have been developed to ascertain preference for an item. Stimulus choice procedures measure a subject's theoretical preference for an item. Preference can be represented by bias in behavior. Perfect matching of behavior between two options shows indifference between reinforcers obtained by those schedules, thus bias in behavior implies preference for one of the reinforcers (McDowell, 1989).

Preference is often measured by presenting stimuli singly, in pairs, or in sets of multiple items and choice can be determined by measuring, for example, latency to approach an item, amount of time an item is interacted with, or choice of that item to the exclusion of other items (e.g., Aaker, Bagozzi, Carman & MacLachlan, 1980; Green et al., 1988; Pace et al., 1985). Usually stimulus preference results in a ranking of items within the tested item set.

Related procedures, such as food preference tests, have been used with a variety of animals, including reptiles (e.g. Morpurgo, Gvoryahu, & Robinson, 1991). However, these tests are usually run to test palatability of food, determine taste thresholds, or see if animals are choosing food based on nutrient content, not to determine usefulness of a food item as a reinforcer (Molloy & Hart, 2002; Matson, Milliam, & Klasing, 2001; Bosque & Calchi, 2003).

Although occasionally used synonymously, food (or stimulus) preference and reinforcer preference are two different procedures with different implications. While food preference might measure what an animal would consume first, a reinforcer preference

assessment would measure the effects of that item on behavior. Additionally, most reinforcer preference assessments have the added benefit of measuring preference instead of simply ranking items. For example, Bron, Sumpter, Foster, and Temple (2003) studied opossum preference for food items by looking at bias in responding on concurrent schedules as a measure of preference. The possums responded more to schedules that resulted in food items with a lower salt content. The possum study would be an example of a reinforcer preference test because the effect on behavior as a function of different food items was examined.

Reinforcer preference identification techniques have been used to test theories for economics (Silberberg et al. 1998), drug addiction (Nader and Woolverton, 1992), and animal welfare (Sumpter, Foster and Temple, 2002), as well as used for many years to increase the effectiveness of teaching children and the disabled (Tighe and Tighe, 1969; Pace et al. 1985). However, this technique has never been used for reptiles, even though it could have easily been employed in studies of learning in reptiles using behavioral methods (e.g., Bartol, Mellgren & Musick, 2003; Lenhardt, 1981; Benes, 1969). Using an effective reinforcer is especially important when the number of trials required to complete a project run from hundreds to thousands, which can occur when using reptiles (e.g., Ishida & Papini, 1997). In a salient example, Lenhardt (1981) trained two species of turtle to locate an auditory cue in a Y-maze. The researcher found that the turtles could use an auditory cue to navigate the maze, but an average of 240 trials was needed to reach about 60% correct performance. With such a large number of trials required to reach only 60% performance, using a preferred reinforcer may have been very useful.

The three main objectives for this project were as follows. First, to see whether monitor lizards form stable preferences for food items while testing the feasibility of using a multiple choice preference procedure in reptiles. Second, to test whether these preferences translate into increased work output for preferred food items. Third, to train a simple visual discrimination in monitor lizards. It was hypothesized that stable food item hierarchies would be found, effective reinforcers established, and that the discriminations and their reversals would be successfully learned.

CHAPTER 2

EXPERIMENT 1: FOOD CHOICE

Methods

Subjects

Subjects involved in this experiment included 1.0 Komodo dragon (*Varanus komodoensis*), 2.1 rough-necked monitors (*Varanus rudicollis*), and 1.1 desert monitors (*Varanus griseus*) housed at Zoo Atlanta.

Apparatus

Subjects were tested in their home cages. Some of these animals are handled infrequently and were assumed not likely to respond if removed to be tested in a novel environment. Removal for simple husbandry procedures, such as weighing, has resulted in thrashing, clawing, and tail whipping in the smaller animals (personal observation). Because of this, it was assumed that removal of these animals from the home cage is detrimental and should be avoided. Additionally, while in their cage these animals have been responsive to a keeper with tongs, approaching the edge of the cage and orienting towards the tongs, which provides evidence for the likelihood of the subjects reacting to a testing regime in this modality. For the duration of the testing phase, all subjects were housed singly, although part of the pre-testing training for the two male rough-necked monitors was conducted while they were housed together.

Procedure

For this experiment, food items were chosen as the possible reinforcers. Food was chosen because previous work with the Komodo dragon had shown the subject to be highly food motivated (unpublished results). Only food reinforcers were used to avoid potential issues inherent in testing preferences between items affecting different sensory modalities (DeLeon, Iwata, Goh & Worsdell, 1997). Food items used in these trials were all meat items, as all the animals in this study are carnivorous, as are most monitor lizards (Struck, Altenbach, Gaulke, & Glaw, 2002). Potential reinforcers were taken from the animals' usual diets. All items had been consumed by the subjects prior to this procedure, so no item was novel and items of equal size were used. Equal size was used as opposed to nutritional content for several reasons. The items varied in their nutritional content and choosing to match on calorie, fat, or protein content would have resulted in different proportions. Also matching on any one of those items could result in a large disparity in size between items. Food items in this study were matched on size because previous research has shown that white-throated monitors choose food items almost exclusively based on size (Kaufman, Burghardt & Phillips, 1996). During testing the subjects' diets were obtained only through the testing procedure. By removing access to food items outside the testing procedure, the possible issues of selective food satiation were controlled (Warren, 1958).

All possible reinforcers were tested in a multiple-stimulus without replacement (MSWO) presentation format choice procedure based on work by DeLeon and Iwata (1996). The MSWO presentation has been found to share the advantages of other choice procedures with the added benefits of taking less time than the pair-choice procedure and identifying more possible reinforcers than a free operant procedure (Oritz & Carr, 2000).

Choice procedures have been used successfully in other reptiles, for example, to assess food preference in Nile crocodiles (*Crocodylus niloticus*) (Morpurgo, Gvoryahu & Robinson, 1991). Preference for food items was tested for each subject over six sessions. Previous work has shown that five sessions of preference testing were sufficient to identify reinforcers in a population of developmentally disabled individuals (Graff & Ciccone, 2002) and that food preferences are very stable over a period of months in both people and non-human primates (Harlow & Meyer, 1952). Therefore, it was assumed that the six sessions of preference assessment would be sufficient to identify food items and these items would function as reinforcers over the testing period.

Trials were run in the home exhibit (smaller monitors) or in an adjacent holding area (Komodo dragon), and potential reinforcers were placed on the floor of the holding area, the floor of the exhibit, or held in front of the monitor on three sets of tongs. At the beginning of each session, the food items were placed in a pre-determined, quasi-randomized order. The subject was then allowed to approach, and preferences were determined by the order in which the reinforcers were consumed. Previous evolutionary work on lizards suggests that for active foragers, chemical identification of a food item may be particularly important (Cooper Jr., 2003) and that visual inspection may not be sufficient for item identification and thus preference. As such, consumption was used as the definitive choice behavior. If the subject did not make a choice within 60 seconds the trial was ended. This procedure was conducted to ascertain the most highly preferred food item as well as to habituate the subjects to the experimental context. This procedure was repeated six times and preference scores were calculated using an alternate MSWO scoring method resulting in a ranked order of food preferences (Ciccone, Graff, &

Ahearn, 2005). The highest rated item was then used as a subject-specific reinforcer to train the animal on the visual discrimination task.

Results

Food item preferences were assessed using an alternate scoring method for the MSWO procedure (Ciccone, Graff, & Ahearn, 2005). Scores for food items were weighted based on the trial in which they were consumed. Items chosen on the first trial received a score of three, items chosen on the second trial received a two, items chosen on the third trial received a one, and items not consumed within a session received a score of zero for that session. Scores were totaled for the item across sessions with the total being divided by the total points possible. Preference was determined by the percentage score an item received with categories based on the following scores: high preference 80-100%, moderate preference 50-79%, non-preferred 0-49% (Pace, Ivancic, Edwards, Iwata, & Page, 1985). A high preference item was identified for each subject (Table 1) and this item was the same for all subjects. However, due to varied diets, the third item available was different for different subjects.

Table 1: Preference scores for food items by each subject

Subject 1	Mouse	Fish	Chick
	100%	44%	50%
Subject 2	Mouse	Fish	Cricket
	100%	61%	39%
Subject 3	Mouse	Fish	Cricket
	100%	56%	33%
Subject 4	Mouse	Fish	Cricket
	100%	44%	50%
Subject 5	Mouse	Fish	Egg
	83%	22%	28%
Subject 6	Mouse	Fish	Egg
	100%	39%	44%

Discussion

The success of the food choice procedure demonstrates that multiple stimulus presentation can be employed successfully with monitor lizards. A high preference item was determined for all subjects in the free choice procedure. The top rated item was consistent across all subjects, however only two of the three items were consistent across all six subjects. Similarly, other research has found consistent food item rankings within a species of primate (Fay, Miller & Harlow, 1953). These consistencies could be explained by the subjects having been exposed to similar environments. For example, previous studies of food preference have shown that the more a food item was offered to an animal early in its life the more that item will be preferred later (Vargas & Anderson, 1996). Early diet may explain the preference for mice in this population as these animals' diets have primarily consisted of rodents (personal communication).

Usually, food preference tests in animals outside of the learning paradigm, are done as a pair choice or cafeteria-style (several types of food simultaneously and continuously available) procedure (Morpurgo, Gvoryahu, & Robinson, 1991; Berteaux, Crête, Huot, Maltais, & Ouellet, 1998). The results of this experiment suggest that the more efficient MSWO procedure could be used with a variety of animals for food choice experiments. The success of this procedure has implications for many possible applications with animals. This procedure could streamline palatability and discrimination tests. Similar procedures could be used to test preference for flavors alone instead of for whole food items (e.g. Dwyer, 2005). By identifying flavor preferences, less preferred items (i.e., medicine), could be made more palatable.

CHAPTER 3

EXPERIMENT 2: REINFORCER PREFERENCE

Methods

Subjects

Subjects involved in this experiment included 1.0 Komodo dragon (*Varanus komodoensis*) and 2.0 rough-necked monitors (*Varanus rudicollis*) housed at Zoo Atlanta. All animals had previously been run in the food choice experiment.

Apparatus

The testing stimulus consisted of a wooden circle painted gray that attached to a wooden rod (rough-necked monitors) or to the mesh wall of the holding area (Komodo dragon). The stimuli were made too large to be swallowed and were painted with non-toxic, water soluble paint. Reinforcers for this experiment consisted of items rated as either low-preference (fish) or high-preference (mouse) in the food choice experiment.

Procedure

To test the effectiveness as reinforcers of these food item choices, a reinforcer preference assessment was run with three of the subjects; the Komodo dragon and the two male rough-necked monitors. Research has shown that people can rank items by preference and that ranking is fairly predictive of the amount of work they would be willing to do to obtain that item (e.g., Wilder, Ellsworth, White & Schock, 2003).

However, stimulus preference and reinforcer preference do not always produce the same results (e.g., Logan et al., 2001). A more rigorous reinforcer preference test was run to

see if stimulus and reinforcer preference were correlated in these monitor lizards. The functional effectiveness of the reinforcer was tested by measuring the breaking point of both a high rated and low rated item using progressive ratios. In a progressive ratio the response requirement needed to obtain each reinforcer is increased until the subject stops responding. Preference for an item should correlate with a higher sustained progressive ratio for that item. Additionally, increased schedule requirements can magnify relatively small preference differences, which might be missed by using some other methods (DeLeon, Iwata, Goh & Worsdell, 1997).

For this assessment, each subject was presented with a single stimulus. Response to the stimulus was reinforced on a progressive scale with the first reinforcer requiring a single response, the second two responses and so on. Six sessions were run for each subject, three sessions each with either a low-preference item (fish) or a high-preference item (mouse). Sessions lasted until the subject did not respond for 60 seconds. The highest ratio successfully completed for each item was averaged across sessions for each subject.

Results

The highest progressive ratio completed for each item for each subject was averaged across the three trials (Table 2). For all subjects, the ratio reached for the higher preference item was greater than the ratio reached for the lower preference item.

Table 2: Highest ratio completed for each subject for each item across trials.

		Trial 1	Trial 2	Trial 3	Mean	SD
Subject 1	Mouse	8	8	9	8.33	0.471
	Fish	6	5	6	5.67	0.471
Subject 2	Mouse	12	10	9	10.33	1.247
	Fish	8	6	6	6.67	0.943
Subject 3	Mouse	10	10	9	9.67	0.471
	Fish	6	6	7	6.33	0.471

Discussion

In addition to the stimulus preference test, the effectiveness as reinforcers, of these top rated food items was tested. The higher ranked item did indeed sustain higher progressive ratios than a lower ranked item for all three subjects tested. This is consistent with the human literature showing that highly preferred items do tend to function better as reinforcers than less preferred items (Piazza, Fisher, Hagopian, Bowman & Toole, 1996). The current results showing the consistency between ranking and response requirements is encouraging. This suggests that if there is not time to conduct a reinforcer preference assessment a stimulus preference assessment can still be used to identify potential reinforcers. Given that consistent rankings were obtained, and that these rankings translated into more work for preferred items, this methodology is an effective way to test food preferences and possibly choose more effective reinforcers. Although a comparison of the effectiveness of the chosen reinforcers versus a random reinforcer would be needed to test this definitively.

It is important to systematically test food and reinforcer preference. Research has shown that caregiver reports do not necessarily coincide with actual preferences of the subjects (Green, Reid, White, Halford, Brittain, & Gardner, 1988). Similarly, in this experiment, the top rated food item for the desert monitors was mice, instead of the quail eggs the staff predicted. Also, items that are chosen in a stimulus choice procedure do not always function as reinforcers, (e.g. Logan, Jacobs, Gast, Smith, Daniel & Rawls, 2001). As such, if possible, the efficacy of a chosen stimulus as a reinforcer should be tested. Additionally, although only food items were used in this experiment, future testing of reinforcer preference in reptiles should include stimuli of other modalities (Logan & Gast, 2001). Past studies with reptiles have used food, water, heat, escape, and changes in illumination as possible reinforcers (Burghardt, 1977) though none of them has been tested against the others for effectiveness. Given past issues of finding appropriate reinforcers when working with reptiles (Brattstrom, 1978), cross-modality reinforcer preference could be a fruitful avenue for future research.

Recently there has been increased interest in using applied behavior analysis techniques developed for working with people for working with captive animals (Bloomsith, Marr & Maple, 2007). One of the techniques mentioned that could easily be applied to the animal side is reinforcer preference assessments. Some progress has been made in this area (e.g., Fernandez, Dorey, & Rosales-Ruiz, 2004; Harlow & Meyer, 1952), however, these techniques have been mostly restricted to primates (for an exception see Hudson, Foster & Temple, 1999). When working with humans, reinforcer preference techniques have been used for decades and copious amounts of research has shown that items chosen more frequently tend to function as better reinforcers than items

chosen less (Caldwell, Taylor & Bloom, 1986). Opportunity exists for the testing of reinforcer preference outside of the restricted taxa in which they are normally employed.

Many applications exist for testing reinforcer preference in animals. For example, if more preferred reinforcers are more effective at maintaining higher rates of behavior (Caldwell, Taylor & Bloom, 1986) then using reinforcer preference has the potential to increase the effectiveness of several techniques already in use with captive animals such as environmental enrichment, positive reinforcement training, as well as possibly increasing the efficiency of some types of behavioral research. In fact, operant techniques have been used to test preference for types of enrichment (Harris, Briand, Orth & Galbicka, 1999), why should we not test preference for the results from interacting with enrichment? For example a highly preferred item could be used to encourage interaction with a particular enrichment device (Tarou & Bashaw, 2007). Extrinsic reinforcement (which would include food) has been hypothesized to be the most effective way to encourage interaction with an enrichment device; thus a highly preferred food item should be even more effective.

Additionally, just having a chance to choose between reinforcers has been shown to be preferred over just having access to a reinforcer (Catania & Sagvolden, 1980). So, adding choice (e.g., a stimulus preference procedure) to any event has the potential to make it more preferable. For example, Fisher and Mazur (1997) found that adding an element of choice to treatments improved clinical interventions.

Another application of reinforcer assessment is use in training using positive reinforcement. Reptile training in zoos has been slowly gaining momentum in recent years. No longer is it assumed that reptiles are incapable of learning, or too fixed in their

behavioral patterns for training to be practical (Burghardt, 1977). Instead a national conference has been formed around the topic of training and enrichment for reptiles and amphibians (RATE). With this increased amount of training comes an opportunity to increase the effectiveness of training. Brattstrom (1978) stated that a major limitation of working with reptiles was identifying appropriate reinforcers.

CHAPTER 4

EXPERIMENT 3: VISUAL DISCRIMINATION

Methods

Subjects

Subjects involved in this experiment included 1.0 Komodo dragon (*Varanus komodoensis*) and 2.0 rough-necked monitors (*Varanus rudicollis*) housed at Zoo Atlanta. All animals had previously been run in the food choice and reinforcer preference experiments.

Apparatus

The testing stimuli consisted of wooden circles painted either white or black that attached to a wooden rod (rough-necked monitors) or to the mesh wall of the holding area (Komodo dragon). The stimuli were made too large to be swallowed and were painted with non-toxic, water soluble paint. These stimuli were chosen because in a previous study researchers found that black and white were discriminated more easily by a lizard than red and green (Zuri and Bull, 2000). Having tong-mounted stimuli has several benefits. When an exhibit housed multiple animals, the stimuli could be brought to the animal currently being tested. Additionally moving the stimuli made the stimuli more salient and encouraged responding in the initial training phases (Washburn, 1993). The highest rated items from the food choice procedure were used as subject-specific reinforcers to train the animals on the visual discrimination task.

Procedure

Training:

The reinforcer used in the discrimination training and testing was the highest rated food item determined by the food preference assessment. Subjects were first exposed to pre-training sessions to encourage responding in the experimental testing phase. During pre-training, responding to both of the stimuli was reinforced. Pre-exposure to the testing stimuli has been shown to increase the salience of those stimuli, possibly increasing responding to the stimuli in the testing phase (Jagadeesh, Chelazzi, Mishkin & Desimone, 2001). A single stimulus was used and alternated between white and black within a session. Subjects were reinforced for coming into contact with the stimulus and were run in this phase until they respond at criteria for both stimuli. Criteria was defined as responding correctly to each stimulus at 80% or above for two sessions in a row.

Testing:

Subjects were then tested using the black and white stimuli. Subjects were randomly assigned to either black or white as the positive stimuli. Sessions were run three times a week, prior to feeding, with either 20 (Komodo dragon) or ten (rough-necked monitor) trials per session. Prior to this experiment subjects were fed two or three times a week. During testing, the diets of the monitors were obtained only through the discrimination procedure, unless not all of the reinforcers were earned, in which case the remaining items were fed an hour after the session ended. By only feeding during and after the session motivational levels were controlled. Position of the positive stimuli within a trial was determined using a preset value table from Fellows (1967) (Table 3). These stimulus sequences have been specifically formulated to ensure that a position bias will not produce better than chance performance on a two-choice discrimination task.

Table 3: Sample stimuli presentation sequences.

Position of positive stimulus

Session 1	1	2	1	1	2	2	2	1	1	1	2	2
Session 2	2	1	2	2	1	1	1	2	2	2	1	1
Session 3	1	1	2	2	2	1	1	1	2	2	1	2
Session 4	2	2	1	1	1	2	2	2	1	1	2	1
Session 5	1	2	2	1	1	1	2	2	2	1	1	2
Session 6	2	1	1	2	2	2	1	1	1	2	2	1
Session 7	1	1	2	1	1	1	2	2	1	2	2	2
Session 8	2	2	1	2	2	2	1	1	2	1	1	1

At the start of the session, the stimuli were placed in the cage, in front of the subject. Responses were scored as the subject coming into contact with a stimulus by touching it with their snout. Correct choice was reinforced, whereas an incorrect choice ended the trial and resulted in a 20 second time-out where the stimuli were not available. In addition, a correction procedure was employed, if the subject responded incorrectly the order of the stimuli was preserved for the next trial. The time-out and correction procedures were used to attempt to reduce random responses and position biases. If the subject did not respond within 30 seconds, the trial was ended. Three consecutive non-response trials ended a session. Once a subject reached criterion (80% or higher correct for two consecutive sessions), the correct stimulus was reversed. Two reversals were run for each of the subjects.

Results

To ensure that acquisition of the task was not due to chance, the calculation of reaching criterion based on random chance was made. For pre-training, training and reversal phases, in a given set of trials, the criterion was 80% correct, 8 out of 10 (for the rough-necked monitors) and 16 out of 20 (for the Komodo dragon). For criteria to be met the subject had to respond correctly at 80% or above for two consecutive trials. Using a binomial distribution, the probability of the subject correctly selecting the positive stimulus by random chance on 16 or more trials out of 20 was equal to .0059, less than 1% and for 32 out of 40 trials .00009, less than a hundredth of a percent. All three subjects successfully reached criteria for the initial discrimination and two reversals (Figures 1-3). However, due to subject 2's lack of progress at completing the first reversal a secondary reinforcer (clicker) was introduced for that subject at session 24. All subjects completed the second reversal in the minimum time possible (two sessions). The number of trials required for initial discrimination, first reversal and second reversal for each subject was as follows. For the Komodo Dragon the number of trials required were nine, seven and two. For the first rough-necked monitor the number of trials required were three, twenty-eight and two. For the second rough-necked monitor the number of trials required were eleven, five and two.

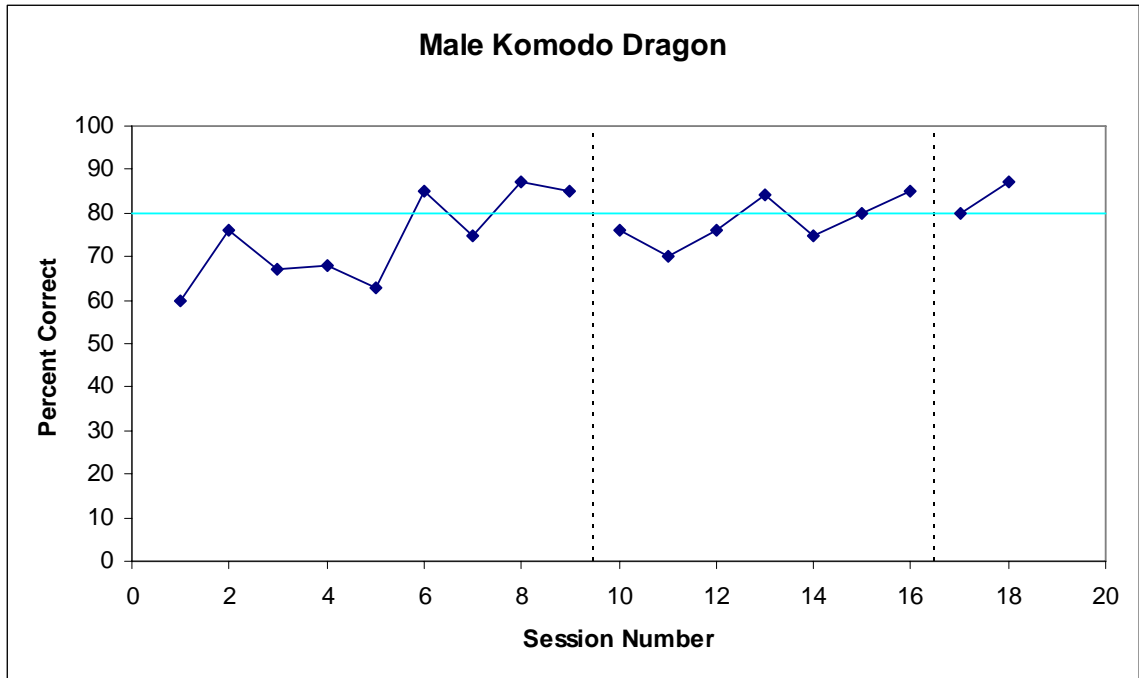


Figure 1: Male Komodo Dragon discrimination trials

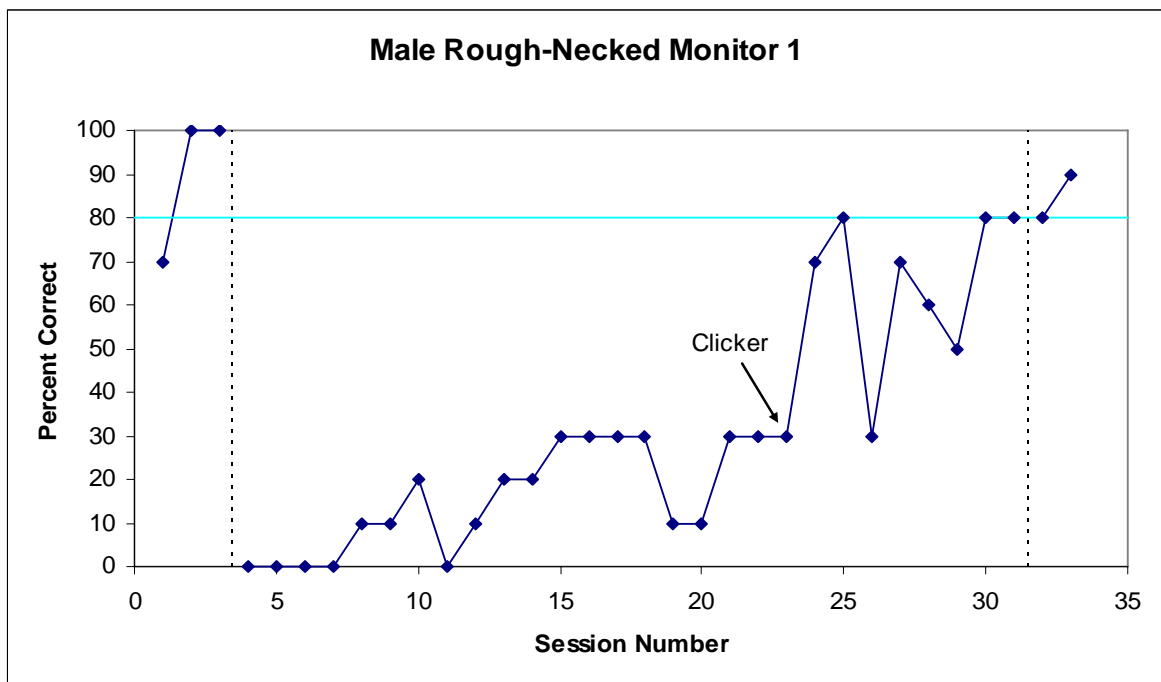


Figure 2: Male rough-necked monitor 1 discrimination trials

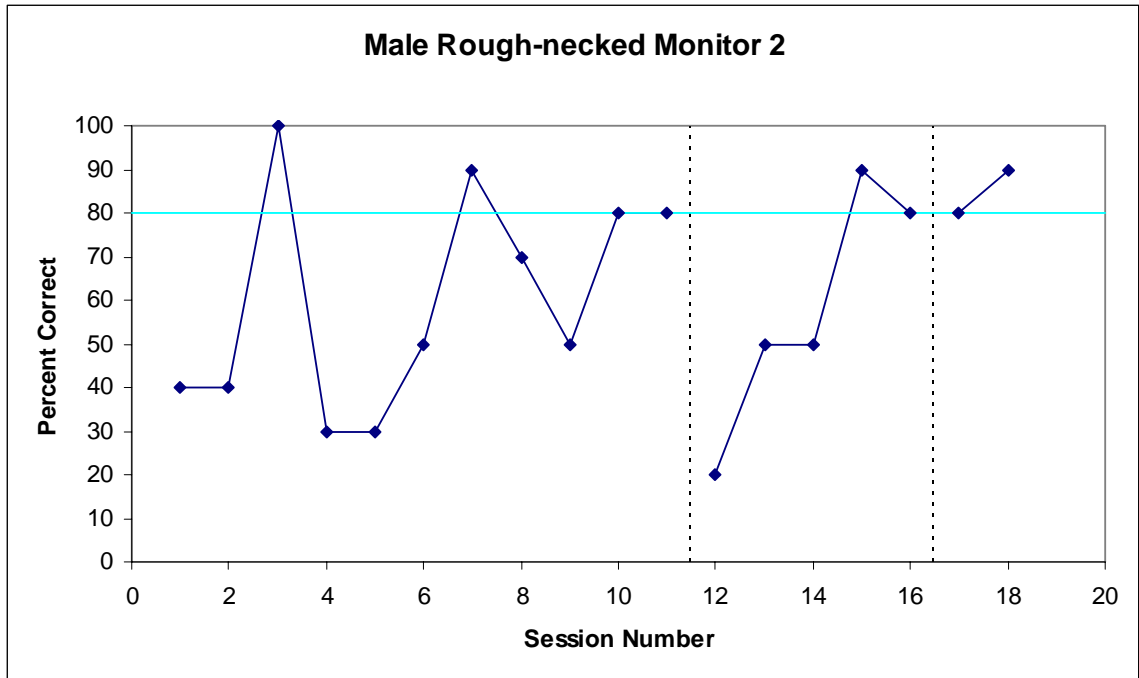


Figure 3: Male rough-necked monitor 2 discrimination trials

Discussion

The results of this study show that roughneck monitors and Komodo dragons can discriminate using visual stimuli and successfully learn reversals of that discrimination. All three animals successfully learned an initial discrimination and two reversals of the discrimination. Despite success across subjects, differences in training and testing did arise in this study, although with the small sample size all the following comments are purely speculative. Pre-training progressed faster with the rough-necked monitors than with the Komodo dragon. One possible explanation for this difference is that the visual stimuli for the Komodo dragon were less salient as they had to be presented on the other

side of a mesh wall. This visual occlusion as well as the inability to make physical contact with the stimulus may have reduced its saliency.

The female roughneck had been selected to also participate in the discrimination procedure. However, she was not nearly as food motivated as the males. She consumed much less, and was less willing to move to obtain a food item. As such she was only used in the food preference tests. Her behavior during testing may reflect a general tendency in the females of this species to engage in less risky behavior (e.g., Cooper Jr., Vitt, Hedges, & Huey, 1990) or it may be an individual difference based on personal history. Not enough female subjects were included in this project to be able to make this distinction.

One interesting difference that arose in the testing phase was the number of trials the first male rough-necked monitor required to learn the first reversal compared to the number of trials required to learn the initial discrimination. This subject took the longest time learning the first reversal, eventually requiring the addition of a conditioned reinforcer to encourage responding to the white stimulus in the presence of the black stimulus. One possible explanation for the difficulty with the reversal is that this subject learned the initial discrimination so quickly that it interfered with learning of the reversal.

The rapidity of learning the initial discrimination may be due to a response bias to the color black. Various response biases have been reported in the learning literature including biases towards certain colors, positions (Alves, Chichery, Boal & Dickel, 2007), and even novel stimuli (Lynn, Cnaani & Papaj, 2005). It has also been shown that some lizards and turtles have shown a bias towards responding to black in discrimination training paradigms (Burghardt, 1977). This bias may have influenced the quick initial learning of the discrimination for this subject and thus interfered with subsequent reversal

learning. This perseverant behavior may be similar to that seen in errorless learning; discriminations that have been learned with fewer errors may take longer to reverse as subjects continue to respond to the previously correct stimulus after the contingencies have changed (McCoy and Pratt, 1976; Robinson & Storm, 1978).

CHAPTER 5

GENERAL DISCUSSION

Testing Advanced Concepts in Reptiles

The experimental set-up used in this study can serve as an example of how behavioral testing might be approached in a zoo setting. This technique, which is employed inside the home cage, may be particularly useful when testing fragile, flighty, or temperamental animals. Additionally, these methods could be adapted to allow for the testing of more advanced concepts. Similar operant techniques have been used to behaviorally test various hypotheses ranging from visual acuity to olfactory discrimination (Bartol, Mellgren, and Musick, 2003; Slotnick and Bodyak, 2002).

A similar set-up could also be used to demonstrate concept learning in these animals, as well as allow for definitive tests of some of the hypothesized abilities of monitors. For example, Phillips and colleagues hypothesized that white-throated monitors (*Varanus albigularis*) can “count to six” (as cited in Sweet and Pianka, 2003). The monitors had been trained to walk through a room and eat snails. The monitors were consistently exposed to the same number of snails per room and after several sessions the number of snails was altered. If the number the monitor had been trained on was 6 or less it would “act surprised” (continue searching) if the number present was less than they had been trained on. A similar setup to the one described in the current study could be used to further test this assumption. Additionally testing more advanced concepts would also allow for discovery of species differences between lizards and other animals, as has been

demonstrated for other species using operant techniques (e.g., Mazur, 2005; Bron, Sumpter, Foster and Temple, 2003).

Reptile Research in Zoos

While reptile research continues to be conducted, there is a trend in research publications from zoos to focus on mammals, especially primates (Maple, Anderson, and Kelling, in press). Only 7% of the publications in *Zoo Biology* over the past 20 years included reptiles. Therefore, research with reptiles should be encouraged; an endeavor for which the diverse collections kept in herpetology departments would be an incredible asset. Zoological institutions continue to be an important resource for herpetological research. One of the benefits of zoo herpetology departments is the variety and diversity of the animals that make up their collections. This diversity could be used to promote learning of understudied species. As such, research with these animals should be increased to make use of this unrealized potential. Card, Roberts & Odum, (1998) stated that most zoo herpetology departments are not reaching their formal research potential given that 44% of the 164 technical reports and 42% of the 101 non-technical reports they had examined had originated from a single institution. They also note that research done in zoos is disseminated mostly to people in the zoo world and attendance of zoo herpetologists to herpetological conferences has been declining.

A trend also exists concerning the amount of basic research conducted in zoos. Hosey (1997) found that 40% of the articles published in *Zoo Biology* between 1989 and 1994 were behavioral studies, but only 35% of these articles reported basic research. Like Card et al., Hosey states that zoos are not reaching their research potential, and that research conducted at zoos, especially basic research, should be increased. As such,

increasing the amount of basic research that is done in zoos and the dissemination of the results to the herpetological world as well as the zoo world should be encouraged.

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