Instrumental Learning and Pedal Movements in *Bufo americanus*

Rebecca Kern

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Instrumental Learning and Pedal Movements in
*Bufo americanus*

Rebecca Kern

Messiah College

Box 5727

Grantham, PA 17027

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ABSTRACT

Learning ability of *Bufo americanus*, the American toad, was tested to compare the effects of partial reinforcement versus continuous reinforcement schedules. Limited learning ability was demonstrated by this species, possibly due to a lack of subject motivation as a result of temperature or seasonality. During the trials, a distinctive behavior was observed in nearly all subjects where the distal portion of digit IV of the hind limb was moved vigorously up and down. This pedal movement was observed only while toads were actively pursuing or consuming prey, and sometimes occurred more frequently in the digit in closest proximity to the prey. Other species of anurans, including leptodactylids and hylids, are known to employ pedal-luring strategies during prey capture, so a pedal-luring hypothesis was investigated. No evidence supporting this hypothesis was discovered in this study, but further research is needed to continue to examine the purpose of this behavior.
INTRODUCTION

While much is known about the learning ability of some vertebrates, including mice, pigeons and goldfish, studies of learning in amphibians have not been widely performed. In frogs and toads, more is known about physiology and neurology than about learning ability (Schmajuk et al. 1980). Instrumental learning or conditioning, which involves learning to associate a behavior with its consequences through positive or negative reinforcement (Zimbardo 1979), is understood in some taxa, but has not been tested extensively in amphibians (Thorpe 1966). Recently, several studies have attempted, with moderate success, to demonstrate instrumental learning in frogs and toads (Muzio and Segura 1992; Papini et al. 1995).

Muzio and Segura (1992) studied learning in *Bufo arenarum* and observed several paradoxical learning effects, or learning phenomena in which different magnitudes and schedules of reinforcement affect the persistence of a learned behavior (Zimbardo 1979). One such effect, the partial reinforcement extinction effect (PREE), refers to a behavior learned by training with partial rather than continuous reinforcement showing greater resistance to extinction. For Muzio and Segura (1992), the PREE failed to emerge, possibly due to an inappropriate form of reinforcement or number of reinforced trials. They suggest using a different type of reward or altering the reinforcement schedule in future work. The first part of my study focused on observing the PREE in toads (*Bufo americanus*) using the modifications suggested by Muzio and Segura (1992).

During the course of our learning experiments, a unique pedal movement was observed which lead to a secondary line of research. In the presence of prey, nearly all experimental toads exhibited a rapid up-and-down movement of the elongated middle digit (IV) of the hind feet. This pedal movement remains undescribed in this species, but personal observation indicated the
possibility that it could be a form of pedal luring. Other species of anurans display a variety of pedal movements, including “toe trembling” in the presence of mates or rivals, or during agonistic interactions (Hödl and Amézquita 2001). Still other species use pedal luring techniques to attract prey items. Terrestrial leptodactylid frogs, Ceratophrys calcarata and C. ornata, have been shown to use pedal luring in their feeding behavior (Murphy 1976; Radcliffe et al. 1986), as has one species of hylid leaf frog, Phyllomedusa burmeisteri (Bertoluci 2002). We examined this possibility in Bufo americanus during the final part of this study.

METHODS

INSTRUMENTAL LEARNING

Fourteen experimental toads were collected from forested and suburban areas in the south/central Pennsylvania region. Toads were housed, either singly or with a partner of similar size, in ten gallon aquaria containing dry leaf litter substrate. Free-choice fresh water was provided and toads were fed mealworms or crickets every 2-3 days. The room containing the aquaria had ambient lighting from several windows and was maintained at around 21°C (except for several weeks in November 2006 when the temperature dropped to approximately 16 °C).

The experimental chamber was constructed by modifying a 55 gallon aquarium to contain a runway 100 cm long and 20 cm wide. Start and goal compartments (20 cm long) were delineated with black marker. The start compartment contained a box that could be remotely raised under which the toad was placed at the start of every trial. The goal compartment contained a Petri dish into which the reinforcement (mealworms) could be placed via a tubing system. The chamber sat within a PVC structure covered in dark fabric to block exterior light and visual stimuli, so fluorescent lighting was provided. Closed-circuit video allowed the interior of the chamber to be visualized remotely.
From the group of fourteen toads, six died over the winter months and one was deemed unsuitable for testing due to its extreme fear of humans. The seven remaining toads were randomly assigned to either the continuous or the partial group. The continuous group received reinforcement each time the correct behavior was performed, while the partial group was reinforced on the following schedule: RNRNRRNRRNRN (R indicates a reinforced trial; N indicates a non-reinforced trial).

Following the procedure outlined by Muzio and Segura (1992), the toads underwent three days of pretrials in which they spent 15 minutes within the experimental chamber every twelve hours. During the first two sessions, four mealworms were scattered around the runway, while in the third, two of those were placed in the dish in the goal compartment. Twelve acquisition trials were then conducted with an intertrial interval (ITI) of 12 hours with the purpose of teaching the toads to travel the length of the runway using food reinforcement. The running latency was recorded as the time it took the toads to travel the length of the runway. Once they entered the goal, three mealworms were placed into the dish and the toads remained there for a ten minute reinforcement period. Time restrictions on the trial were as follows: 300 seconds to leave the start box or 180 seconds to travel the length of the runway after leaving the start box. If these were not met, toads were picked up and moved to the goal for the reinforcement period and assigned the maximum latency of 180 seconds.

Twelve sessions of extinction trials, in which the reinforcement was not provided, followed acquisition. These trials used the aforementioned procedure with one alteration – if the time restrictions failed to be met, the toad was removed and the trial ended without a reinforcement period. Running latencies were measured and compared to those of acquisition.
PEDAL LURING

To test the pedal luring hypothesis, toad/prey interactions were monitored from above. An observational unit was constructed by dividing a ten gallon aquarium with clear Plexiglas to create two chambers. The outer walls of the aquarium were blocked with cardboard to minimize other visual stimuli and a closed-circuit video system was used to monitor the unit from above.

Fourteen additional toads were collected from the central Pennsylvania region during March 2007. All twenty toads were observed in the chamber for at least two sessions after being deprived of food for between two and four days. During these sessions, toads were placed in the larger chamber and one cricket (*Acheta domesticus*) was placed in the smaller chamber. Interactions were monitored for ten minutes and any pedal movements or “toe tapping events” were noted.

A toe tapping event is defined as a period of movement of digit IV of the hind feet in the presence of prey (Fig. 1). Toes can be moved bilaterally or asymmetrically (left or right). Cessation of movement for five seconds or more was recorded as the end of an event. Video recordings of toe tapping events were analyzed to determine: the distance between toad and cricket, the lateralization of toe movement (left, right or both) and the orientation of the cricket within the toad’s visual field, which was divided into six quadrants (Fig. 2). If the event lasted longer than five seconds, data was taken at the beginning and end, as well as whenever the tapping changed lateralization for greater than five seconds within it. If the event lasted less than five seconds, data was taken at the beginning and it was recorded as a “single event.” Only those events in which both toes were equally visible were considered.
RESULTS

INSTRUMENTAL LEARNING

After the acquisition phase, only Toad 12 showed evidence of learning the behavior (Table 1). Five other toads completed acquisition, but rarely had running latencies under the maximum allotted time. Toad 4 had to be removed from the experiment after trial 8 due to increased agitation and signs of distress. Toad 12 underwent extinction trials (Table 2), but no evidence of the PREE was observed because no comparison could be made between groups.

PEDAL LURING

After recording forty-three events from twelve individuals, no correlation was found between lateralization of toe movement and cricket orientation that would indicate pedal luring. Data was taken only from the first session in which each toad toe-tapped; after one event was observed, the individual was not tested further. The number of sessions needed to evoke a tapping event ranged from two to seven. The eight toads that did not demonstrate the behavior underwent six or seven sessions. The majority of the events were bilateral (63%) and occurred when the cricket was within quadrant three (70%) (Table 3). Most toads tapped when they were between 15-20 cm away from the prey (Fig. 3).

Toe-tapping events were classified as ipsilateral or contralateral; for example, a left tapping event occurring when the cricket was in quadrant 1, 2 or 3 was called ipsilateral, while a right event occurring under the same circumstances was contralateral. Only left or right events could be definitively labeled ipsilateral or contralateral (bilateral events were counted as both). More ipsilateral events would support a pedal luring hypothesis by showing that toads choose which toe to move based on prey location in order to maximize visibility and likelihood of luring.
success. After analysis, however, the number of ipsilateral and contralateral events were statistically similar (Fig. 4).

**DISCUSSION**

**INSTRUMENTAL LEARNING**

Numerous factors may have influenced the absence of acquisition in six of the seven toads. Trials were held during the winter months, during which amphibian metabolism slows dramatically to send them into a state of dormancy. Even though the room was maintained at a warm temperature for the majority of the season, the one short period of cold temperatures in November combined with the decreasing day length may have been sufficient to slow the toads’ metabolism so that they were not highly motivated by food. Also, all seven toads had been used in previous experiments, so the situation was not novel for them. The factors that allowed Toad 12 to acquire the behavior are unknown. It is interesting to note that this toad was in the partial reinforcement group, which should have placed it at a disadvantage for learning as compared to those toads in the continuous group.

Most toads did not seem overly affected by the use of an artificial environment in the experimental chamber. Toad 4, however, appeared seriously distressed within the chamber and was unable to learn as a result. Unlike the other toads, which seemed to become increasingly comfortable within the experimental chamber over time, Toad 4 became increasingly agitated.

**PEDAL LURING**

Classifying toe tapping events as ipsilateral or contralateral provides the most crucial evidence for or against the pedal luring hypothesis. A preponderance of ipsilateral events would support such a hypothesis because a successful lure must be visible to the organism it is intended to attract. In most contralateral events, the digit in motion would be obscured from the prey by
the toad’s body, nullifying its ability to lure. Because our data shows virtually no difference in the number of ipsilateral versus contralateral events, we conclude that a pedal luring strategy is not likely employed by *B. americanus* in all circumstances.

Thus, the purpose of this pedal movement still remains to be described. Further study is needed to clarify the specific circumstances and factors which may influence the use of this movement, such as prey size, rate of prey motion, distance between toad and prey, level of toad hunger, and seasonality. Observing multiple toe tapping events from the same individuals would also be useful in determining any individual variability or patterns in the use of this behavior. Based on personal observation, such studies would be more successful than the present one if they attempted to observe the behavior in a more naturalistic setting. The artificial setup used in this study undoubtedly influenced some toads and their willingness to display the behavior as some individuals that did not tap during the sessions were seen to do so during normal feeding time in their aquaria.

This study also did not consider any effect the pedal movements might have had on the prey itself. No noticeable effects on the behavior of either mealworms or crickets were observed, but further studies could investigate the influences of toe tapping on larger prey items. Also, until this point we have considered the function and impact of these movements visually, but future research could examine them in an auditory or tactile sense. In natural habitats, these pedal movements may produce sounds or vibrations that are attractive to prey items, making their lateralization irrelevant to their effectiveness.
FIGURE LEGENDS

Figure 1. Example of digit IV, used for toe tapping behavior.

Figure 2. Map of quadrants within toad’s visual field as measured from the tip of the nose.

Figure 3. Number of toe tapping events recorded at each distance unit.

Figure 4. Number of tapping events classified as ipsilateral or contralateral.
**TABLES**

Table 1. Running latencies during acquisition.

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<th>7</th>
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Table 2. Running latency of Toad 12 during extinction. Trial 19 was not performed due to researcher error.

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Table 3. Number and lateralization of toe tapping events recorded in each quadrant.
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<th>Quadrant 3</th>
<th>Quadrant 4</th>
<th>Quadrant 5</th>
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<td>3</td>
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<td>Left</td>
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<td>1</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Right</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>1</td>
<td>0</td>
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</table>
Figure 1.

Figure 2.
Figure 3.

Figure 4.
ACKNOWLEDGMENTS

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