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Conditioned avoidance in coyotes: Effects of administering LiCl during selected phases of the predatory sequence

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Nine coyotes (*Canis latrans*) were tested for conditioned aversions to killing rabbits after lithium chloride (LiCl) was injected during three phases of the predatory sequence: approach, capture, and consumption. No long-term aversions were demonstrated following injections during the approach and capture phases. Aversions to killing rabbits lasted up to 20 days following injection during or shortly after the consumption phase.

Traditionally, conditioned taste aversions have been established by the administration of an aversive agent during or shortly after the consummatory act. This method appears to work quite well in suppressing the consummatory response in laboratory rats. However, the question exists as to whether similar techniques can effectively inhibit killing. Numerous studies have demonstrated that killing and feeding are controlled by separate motivational and/or physiological mechanisms (Berg & Baenninger, 1974; Clody & Vogel, 1973; Gay, Leaf, & Arble, 1975; Krames, Milgram, & Christie, 1973; O'Boyle, Looney, & Cohen, 1973). It becomes a relatively easy task, using traditional aversive conditioning techniques, to inhibit consumption, but some degree of difficulty is encountered when trying to suppress killing.

The sequence of behaviors composing the predatory act in coyotes can be listed as a series of events and states: (1) search–the coyote actively seeking the prey, (2) orientation–the coyote locating and attending to the prey but remaining immobile, (3) approach–movement toward the prey, (4) capture–grasping the prey, (5) consumption–eating of the prey. The last three components of the predatory sequence are the primary phases in terms of temporal and spatial contiguity with the prey.

The objectives of this experiment were to evaluate: (1) the effectiveness of using lithium chloride (LiCl) in suppressing coyote attacks on rabbits in an aversive conditioning paradigm, and (2) the differential effectiveness of delivering LiCl during selected phases of the predatory sequence.

METHOD

Facilities

The research was conducted at the Colorado State University Maxwell Ranch Coyote Research Facility, located approximately 48 km north of Fort Collins, Colorado. Coyote kennels were connected by a runway to a coyote-proof enclosure. The runway terminated in a startbox that opened into the enclosure. Above the startbox was an observation tower, which housed the experimenter and the recording equipment. The enclosure measured 6,400 m^2 and was surrounded by a 2.3-m welded-wire fence with an inward overhang of barbed wire.

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Experimental Animals

Coyotes. A total of nine experimentally naive coyotes, six females and three males, were used in this experiment. Five of the subjects were hand reared; one coyote of uncertain origin and the remaining three coyotes were adult wild-caught animals. All of the coyotes were maintained on a 24-h food-deprivation schedule during baseline trials, with their only food being rabbits consumed during a trial. After a successful treatment, the coyotes were placed on a 120-h food-deprivation schedule. If the coyote had not killed after 120 h, it was then given a ration (3-4 cups) of commercial dry dog meal every 48 h.

Rabbits. Domestic rabbits (*Oryctolagus cuniculus*) were used as the experimental prey. The rabbits used in this experiment averaged 1 kg in weight and varied in color and color patterns.

Apparatus

In order to inject LiCl at the three phases of the predatory sequence, a 10.7-m-long funnel-shaped apparatus was constructed 40 m from a startbox in the center of the enclosure (Figure 1). The funnel was constructed using 5.08 cm x 10.16 cm x 1.2 m welded-wire fence and steel fence posts. The funnel was divided into three main compartments, separated by double Plexiglas partitions. Access from one compartment to another was gained through a 17.78-cm-diam hole (adjustable to 12.70 cm) located in the center of each partition, with the bottom of the hole 40.64 cm from the ground. The double partitions between compartments were separated by a distance of 20.32 cm, insuring that the coyote was unable to have both forelimbs and hindlimbs on the ground at the same time. The distance between partitions caused the animal to stretch out while maneuvering through the partitions, thus exposing the stomach region and making it more accessible for injections.

An electromechanical device was designed to remotely deliver an injection at each partition and in the center of the funnel (Figure 1). This injection device consisted of a modified 60-cc disposable Monoject syringe with a 2.54-cm 12-gauge needle mounted upright on the end of a 60-cm lever arm that pivoted in the middle of a vertical shaft. The lever arm was spring loaded and was released to swing upward, thus hitting the abdominal region of the coyote. The delivery mechanisms were triggered by

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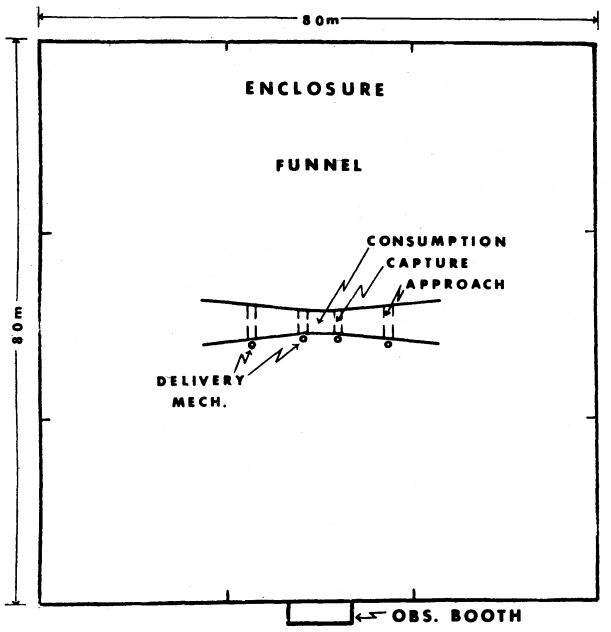

Figure 1. Schematic representation of funnel apparatus within the test enclosure.

solenoids located on the devices and remotely operated from the observation booth. Various dosages were tested during pilot studies to determine a solution that produced illness immediately. An effective dosage of LiCl was found with a total volume of only 10 ml, with a 2.36-M concentration, and averaging 2.15 mEq/kg. The use of the modified 60-cc syringe with a 12-gauge needle greatly reduced the injection time. Five delivery mechanisms were constructed, two operable and three sham. The operable devices were placed at the appropriate partitions, depending on which phase was being tested (two operable mechanisms were necessary because the coyotes were free to enter the funnel from two different directions).

Trials

Baseline trials. Each coyote was trained by successive approximation to enter the funnel from either end, pass through the partitions, capture, and consume a rabbit tethered in the center of the funnel. With this arrangement, it was possible to define by the coyote's position within the funnel the approach, capture, and consumption phases of the predatory sequence. During the approach phase, the coyote entered the funnel from either end and passed through the first set of partitions. As the coyote entered through the second set of partitions to make the capture, the approach phase was considered terminated and the capture phase initiated. With the coyote now in the center of the funnel and the rabbit captured, the consumption phase began. The rabbit was visible to the coyote during all phases of the predatory sequence.

The nine coyotes were divided into three groups of three coyotes each, one group to receive treatments at the approach phase, one at the capture phase, and one at the consumption phase. After initial training trials, the animals began baseline trials. The established criterion was that the coyotes each make five consecutive kills in the center compartment within 2 min after leaving the startbox. Six coyotes, three from the capture group and three from the consumption group, served as their own controls. In addition, the coyotes in the capture group served as controls for the subjects in the approach group, since the delivery mechanisms used for both groups were the same. The control animals were injected with a 10% NaCl solution after reaching criterion, in order to determine whether injections would cause an aversion to the test apparatus or other stimuli associated with the funnel.

Treatment trials. Each coyote was treated by injections of LiCl during one phase of the predatory sequence. A total of 64 injections were attempted, 21 (33%) of which were successful. An injection was deemed successful when: (1) the animal was hit in the abdominal region, (2) the syringe was essentially empty and intact, (3) the needle was not broken from the syringe, and, most important, (4) the coyote showed signs of illness, to include retching and regurgitation.

After several unsuccessful attempts at injection during the consumption phase, remote injections were abandoned in favor of a manual treatment. During this procedure, the coyote was sealed in the center compartment midway into consumption by trapdoors operated by the same delivery mechanisms used during the capture phase. The same modified 60-cc syringe and 12-gauge needle were mounted on the end of a 1.2-m aluminum pole. The experimenter then walked out to the funnel, thrust the syringe and pole through the wire, and injected the coyote without actually handling the animal. The trapdoors were then opened, and the coyote was allowed to exit the funnel.

Posttreatment trials. After a treatment trial, the coyote was observed for 1 h, to note the effects of the treatment. The animal was tested at 24-h intervals for 1-h durations for a maximum of 20 encounters. If the coyote killed a rabbit within 20 days of treatment, it was again exposed to the same treatment conditions. If, after a second treatment, the coyote again killed, further tests on that animal were terminated. If, after receiving a single or double dose of LiCl, the coyote failed to kill for a period of 20 days, further tests on that animal were also terminated.

Movements of the coyote within the enclosure, relative to the prey, were recorded for all posttreatment trials on an Esterline-Angus 20-channel event recorder connected to a keyboard.

RESULTS

Trials

A total of 601 trials were run, including 270 baseline trials, 331 additional baseline trials (trials required to bring a coyote back to criterion after an unsuccessful treatment), and 100 posttreatment trials. A significant difference [$F(2,6) = 7.75$, $p < .05$] was observed between treatment groups in the number of baseline trials required, with the consumption group taking significantly longer to reach criterion. No significant differences were observed between treatment groups in the number of treatment, retreatment, and posttreatment trials required [$F(2,6) = 1.28$, $p > .05$].

Controls

The three coyotes composing the capture group served as the first control group. The animals all indicated signs of discomfort, sitting or lying down and inspecting their abdominal regions. However, aversions were short-lived; all animals reentered the funnel, killed, and consumed the rabbit within a short period of time. The latencies between injections and subsequent killing and/or consumption of the prey were 24 min, 5 min, and 57 sec. This indicated that aversion to the apparatus was minimal.

The second group of coyotes to receive control injections were the consumption-phase animals. Two of the animals exited the funnel immediately but demonstrated

only minimal or no discomfort. The third animal remained in the center compartment after treatment and continued to consume the rabbit, leaving the funnel only when the rabbit was entirely consumed. All three coyotes killed on the next trial (24 h later) and continued to do so as they were brought back to criterion. Therefore, it was determined that very little or no aversion existed toward the rabbit or the test apparatus.

Approach and Capture Groups

Each coyote in both the approach and capture groups received two successful treatments. All animals treated at the capture phase killed and consumed at least a portion of the rabbit at some point during the treatment trial (Table 1). This was expected, since the coyote was treated at the time it was making the capture. However, in several instances, the coyote merely wounded the rabbit and did not continue the attack until several minutes had elapsed. Even if the coyote killed immediatley (or after a short period of time), consumption never began until after several minutes had elapsed. Occasionally, the coyotes fed only sporadically and minimally before leaving the carcass and funnel. That is, the animals killed and fed on the rabbit up to 19 min after being injected, even though discomfort was almost instantaneous after treatment. During the approach phase, two of the three coyotes killed the prey on three of the six treatment trials. In one case, a coyote killed and consumed the rabbit 21 min after treatment.

Table 1
Results of Injections of LiCl to Coyotes During Three Phases of the Predatory Sequence

Coyote	Baseline Trials	Killed	Aversion (Days) Apparatus	Aversion (Days) Prey	Posttreatment
		Approach Treatment Phase			
1	48	N	2	0	2479
		N	1	1	
2	42	N	0	0	1518
		Y	0	0	
3	18	Y	33	0	181
		Y	0	0	
		Capture Treatment Phase			
4	10	Y	2	1	1528
		Y	0	0	
5	9	Y	0	0	380
		Y	0	0	
6	9	Y	1	0	1443
		Y	1	0	
		Consumption Treatment Phase			
7	58	Y	0	16	42
8	35	Y	0	5	0
9	41	Y	0	20	181

Note–Coyotes in the approach and consumption groups served as their own controls. "Killed" indicates whether the animal killed prey during the treatment trial (N = no, Y = yes). "Posttreatment" refers to the mean amount of time (in seconds) each coyote spent within a 13-m radius of prey during the posttreatment trials. Coyote 8 died after demonstrating 5 days of avoidance.

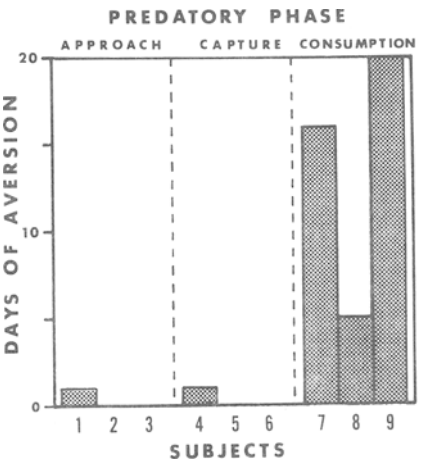

Figure 2. Duration of LiCl-induced aversions obtained during three selected phases of the predatory sequence.

In most cases in which an aversion was indicated for both the approach and capture groups (Table 1), the coyotes either spent a great deal of time trying to capture the rabbit in a way other than going through the funnel or they made the kill in some unconventional manner before going through the appropriate partitions. This suggests that the coyotes may not have been showing aversion to the rabbit but, rather, avoiding the particular partition at which they were injected. The animals also appeared to generalize their aversion from the west partitions to the east and vice versa; however, they only generalized to the opposite partition that corresponded to the one at which they were injected.

The animals became "bait shy" and/or "apparatus shy" after their first treatments. The usual result of an unsuccessful attempt at injection was a repetition of the avoidance behaviors associated with the various barriers in the test apparatus until the avoidance gradually broke down again.

In only two coyotes, Coyotes 1 and 4, were aversions demonstrated (Figure 2). However, it is difficult to determine whether the aversions were specific to the prey or were more generalized aversions to the test apparatus. In the four other animals composing these two groups, no prey aversions were demonstrated. Aversions appeared to be associated only with the very localized portion of the test apparatus at which the coyote was treated.

Consumption Group

All three coyotes demonstrated lengthy aversions that appeared to be specific to the prey and not the apparatus. The aversions were significantly longer [$F(2,6) = 8.74$, $p < .05$] than those obtained for either the approach or capture group (Figure 2). Coyote 7 demonstrated a 16-day aversion, making a surprise kill (no advance indication of aversion deterioration) at 50 min into the 17th trial day. However, it did not consume the rabbit; instead, it left the funnel and the general are immediately after making the kill and did not return. It again

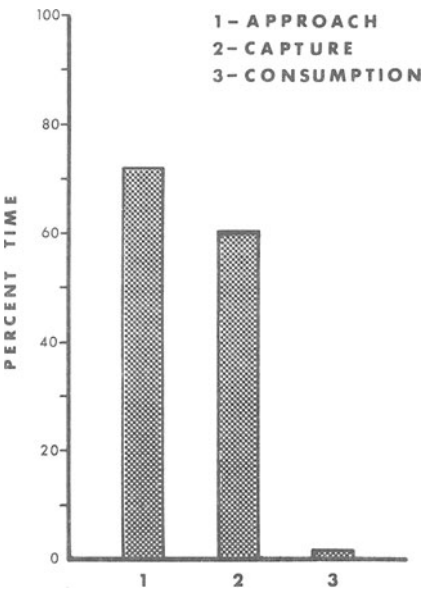

Figure 3. Total percent of posttreatment time spent within a 13-m radius of the prey.

killed on the 18th day without consuming. On the 19th day, it killed and consumed and was terminated from further research due to a shortage of rabbits. Coyote 8 died 5 days after treatment from undetermined causes. Coyote 9 demonstrated a 20-day aversion (Figure 2), after which it was terminated from further research.

Distance relative to the prey following treatment trials was used as an indication of aversion. Figure 3 shows the total percent of time after treatment spent by each group in the immediate vicinity of the prey (within a 13-m radius of the rabbit, comprising an area of 676 m^2 within the 6,400-m^2 enclosure). It can be seen that the coyotes in both the approach and capture groups spent more time in the area in which the rabbit was tethered than in any other area of the enclosure. Coyotes spent more time in the immediate vicinity of the rabbit not only as a group, but also as individuals (Table 1). Coyotes 7, 8, and 9 (the consumption group) spent their greatest proportion of time in areas of the enclosure that were located as far away as possible from the prey (approximately 57 m); they spent most of their trials lying down in the extreme corners of the enclosure.

DISCUSSION

Aversions to the test apparatus appeared to be more pronounced than aversions to the prey in both the approach and capture groups. Because discomfort and illness were almost always immediate, it is believed that there was maximal association between the point of injection and resulting illness. Therefore, it seems reasonable to assume that during the consumption phase, when the association between the prey and illness was greatest, long-term aversions would have occurred more readily.

The fact that the consumption animals did not demonstrate any aversions after receiving the control injections suggests that LiCl in the dosages administered may be an effective aversive agent for use of coyotes under the conditions described here. Therefore, the consummatory phase of the predatory act appears to be the most amenable for conditioning avoidance to rabbits.

LiCl at 2.15 mEq/kg is a hypertonic solution, which accounts for the immediate discomfort observed in all the coyotes. Nachman and Ashe (1973) have shown that LiCl aversions are dependent on the absolute quantity of LiCl and not on the concentration or volume of the solution. These hypertonic solutions of LiCl caused immediate abdominal pain, not immediate nausea. This distinction should be made, since the temporal relationships between the associated events is an important concern. The killing and consumption of the prey within 20 min after treatment might be expected. The abdominal pain induced by the hypertonic LiCl solution may have passed relatively soon after the injection, and the nauseous illness effects induced by LiCl may not yet have become strong enough to completely deter the subject from attacking and initiating consumption.

Nachman and Ashe (1973) also demonstrated that LiCl was equally effective in producing learned aversions whether administered intraperitoneally, subcutaneously, or by stomach tube. This finding is important in terms of considering field-practical techniques of delivering the aversive agent. However, a great deal more research is required before LiCl or aversive conditioning can be used as a widespread tool for controlling coyote depredations on domestic livestock.

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