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Abstract: In an enclosure-type study, I investigated the use of odor, auditory, and visual cues to enhance lithium-chloride (LiCl)-induced prey aversion in coyotes (*Canis latrans*). Eight adult, male, wild-caught coyotes that killed 2 adult sheep during successive daily, 1-hr trials were assigned to LiCl- and sodium-chloride (NaCl)-bait groups. The 4 LiCl-bait coyotes were sequentially presented with leg-of-sheep and whole-sheep carcasses injected with a 33% LiCl water solution (4.5 ml/kg) 1-hr daily until bait shy. The 4 NaCl coyotes were exposed to baits and carcasses injected with 25% NaCl/water solution (4.5 ml/kg) for matched trials. Additionally, 2 coyotes within each LiCl and NaCl group were presented with baits/carcasses sprayed with cologne and fitted with a red collar and attached bell, and 2 "reference coyotes" within each LiCl and NaCl group were offered similar baits/carcasses without these stimuli. Following onset of bait aversion, coyotes were again paired for 1 hr daily with a live sheep that had either the "stimuli" or "no stimuli" affixed until 2 sheep were killed. Coyotes required 7 to 23 1-hr exposures to LiCl meats to cease ingestion (develop bait shyness). Coyotes presented both LiCl-baits/carcasses and subsequent live sheep affixed with stimuli showed greater suppression of predation, but this effect was of limited duration (≤9 pairings with sheep).

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Key words: auditory cue, bait shyness, *Canis latrans*, coyote, lithium chloride, olfactory cue, prey aversion, sheep, taste aversion, visual cue.

Lithium-chloride (LiCl) is an emetic drug. If an animal is dosed with sufficient LiCl (approx. 120 mg/kg) shortly after (<6 hr) tasting a novel-flavored substance, later ingestion of that substance is decreased or avoided (Garcia et al. 1966, Riley and Tuck 1985). This effect is termed conditioned taste aversion - a behavioral concept with potential applications to reducing diverse types of damage by wildlife (e.g., rat (*Rattus* spp.) destruction of stored grain, raven (*Corvus corax*) predation of waterfowl eggs).

Gustavson et al. (1974) reported that coyotes (*Canis latrans*) learned to avoid hamburger after eating hamburger treated with LiCl and could transfer such a drug-induced aversion of LiCl-tainted sheep or rabbit (*Sylvilagus* sp.) flesh to the corresponding live prey. Since then, numerous enclosure and field studies focused on the concept (Gustavson et al. 1976, 1982; Conover et al. 1977; Ellins et al. 1977; Burns 1980, 1983; Ellins and Catalano 1980; Bourne and Dorrance 1982; Horn, 1983). Some reports confirmed effectiveness of the baiting strategy (e.g., Gustavson et al. 1976, 1982; Ellins et al. 1977; Ellins and Catalano 1980) while others reported "no effect" (Conover et al. 1977; Burns 1980, 1983; Bourne and Dorrance 1982; Horn 1983). The "transfer" of bait shyness to live prey has been difficult to demonstrate in carnivores, but the idea of conditioning predatory animals to avoid attacking live prey remains intriguing.

A discussion of issues resulting from early studies of the LiCl technique related to coyote predation behavior appeared in the journal, *Appetite*, in 1985. A number of scientists (Burns and Connolly 1985, Ellins 1985, Forthman-Quick et al. 1985, Lehner and Horn 1985, Wade 1985) published technical comments and data reviews of the research. These critiques focused on the research paradigm; whether or not coyotes that develop aversion to fleece-covered, LiCl-laced baits (mutton, dog food, etc.) subsequently decrease predation of live sheep (Booth 1985). While the discourse helped to elucidate issues, findings remained equivocal; registration of LiCl for pesticide applications was not pursued.

This paper describes a study of cue enhancement and LiCl-induced-prey aversion in coyotes. While observations were limited and sample sizes small, the observations warrant consideration by scientists interested in development of nonlethal methods for reducing predation. The purpose of the enclosure-type study was twofold: (1) to further characterize onset/development of LiCl-induced shyness of mutton in coyotes, and (2) to evaluate the potential of olfactory, visual, and auditory cues as a means of inhibiting sheep-attack behaviors in coyotes following LiCl-induced-mutton aversion.

I thank Philip Lehner and Steven Horn for discussions of prominent stimuli as enhancers of LiCl-bait aversion; these researchers explored this concept using rabbit prey (Lehner and Horn 1977). Thanks also to Ken Crane and Jerry Roberts for assistance with the sheep-coyote trials. Guy Connolly, Kathy Fagerstone, and Michael Fall provided helpful comments on the manuscript. References to trade names or commercial products do not constitute endorsement by the Federal Government.

METHODS

Animals

Eight adult male, wild-trapped coyotes ($\bar{x}$ body weight = 10.2±1.2 kg) were used. Coyotes were partially food deprived - 300 g of Purina® Dog Chow (Purina Mills, St. Louis, MO) were fed to each coyote every third day; water was provided *ad libitum* and coyotes were allowed to ingest portions of mutton baits/carcasses during the aversion procedures. Thirty-two sheep, weighing between 12.3 and 27.3 kg, served as prey; additional sheep were sacrificed to prepare mutton baits/carcasses.

Facilities

Baiting/sheep-pairing trials were conducted in a 1271-m^2 (41 X 31 m) fenced enclosure. Sides of the enclosure were 2.4-m high and composed of 2 joined sections of 1.2 m woven-V-wire fence or 1 V-wire section and 1.2 m rippled-steel.

Two brick observation buildings (3.1 X 2.0 X 2.9 m), fitted with one-way-glass windows near the roof, were located in the southeast and southwest corners of the enclosure. Approximately 40-m^2 of the southeast corner was enclosed with 4.8-m high V-wire fence; this formed a release pen for coyotes and was equipped with entry-exit guillotine doors (100 X 60 X 2 cm). A rope affixed to the entry door allowed release of coyotes into the enclosure by the researcher from inside the southeast observation building. A 1.2-m high V-wire sheep fence also encircled each observation building (1-2 m away) to ensure unblinded views of animals.

A row of 8 coyote-housing cages (3.0- X 1.5- X 1.8-m) was located 2-16 m south of the release pen. Coyotes were housed individually in these cages. Coyotes moved to and from the release pen through a wire-enclosed walkway (14 X 12 X 2.5 m) along cage fronts.

LiCl/NaCl Baits/Carcasses

Two types of mutton baits were prepared: leg-of-sheep and whole-carcass. Leg-of-sheep baits consisted of 3-5 kg legs of sheep (fleece intact); whereas, whole-carcass baits were eviscerated sheep carcasses (fleece intact).

Preparation of LiCl baits was modified after a Saskatchewan Agriculture Department procedure (1977). A 33% solution of technical grade LiCl (Lithium Corp. of Am., Bessemer City, N.C.) in deionized water (wt/vol) was prepared. Baits were then injected with 22 cm^3 of solution per kg of bait using an 18-gauge hypodermic and 100 cm^3 disposable syringe. Multiple injection sites of 2.5-5.0 cm^3 quantities of solution were then used to uniformly distribute the LiCl throughout the muscle within the bait item (e.g., a 3.6 kg leg-of-sheep would be injected 16 to 32 times using 80 cm^3 of LiCl solution, with half of the injection sites on each side of the bait). Control baits were prepared in a similar manner; however, these baits were injected with a 25% NaCl in deionized water solution.

Stimuli

Three distinctive stimuli (auditory, olfactory, and visual) served as cues. These were affixed to both the leg-of-sheep and whole-carcass baits, as well as to live sheep during the post-bait-shyness assessment. The auditory and visual stimuli were a small, conical-shaped bell (5.5-cm ht X 3.5-cm base) affixed to the center of a 3-cm-wide red leather collar (51-cm length). This was buckled around the respective bait or sheep's neck using a stainless steel buckle. The olfactory stimulus refers to the spraying of approximately 10-30 ml of cologne (Jade East™, Swank Dist., New York, N.Y.) onto the fleece of respective baits prior to tests.

Design And Procedures

The study involved 4 groups of sheep-attacking coyotes (2 coyotes/group): LiCl-baits/stimuli, NaCl-baits/stimuli, LiCl-baits/no stimuli, and NaCl-baits/no stimuli. A "yoked procedure" was used; yoked refers to the conduct of matched numbers and lengths of baiting trials for the NaCl-baited coyotes (stimuli and no stimuli, respectively) as were observed for the LiCl-baited animals. The study was also accomplished as 4 replications of 2 coyotes each; that is, to manage daily research activities, respective "yoked pairs" of LiCl- and NaCl-bait animals (with or without stimuli) were tested sequentially.

Procedures were accomplished in 3 successive phases involving 1-hour daily trials: (1) initial sheep-predation phase, (2) bait-shyness phase, and (3) post-bait-shyness sheep-predation phase.

Initial Sheep-Predation Phase. -- Each coyote received 5 successive 1-hour daily acclimatization trials to familiarize the animal with the behavioral enclosure and handling regimen. Next, each coyote was paired individually (1 hr daily) with a live, unrestrained sheep for a maximum of 20 days or until the coyote fatally attacked and fed upon 2 sheep. Only coyotes that killed 2 sheep were used.

Bait-shyness Phase. -- This was the main procedural phase. Two sheep-attacking coyotes were randomly assigned to each of the 4 groups. Coyotes in the LiCl-bait/stimuli and LiCl-bait/no stimuli groups were exposed successively to leg-of-sheep and whole carcass baits (1 hr/day) until "shy". Bait shyness was defined as a 1-hour trial without bait consumption. Coyotes in the matched (yoked) NaCl-bait/stimuli and NaCl-bait/no stimuli groups were presented with baits/carcasses injected with the 25% NaCl solution for matched numbers of 1 hour/day trials as displayed by the LiCl-bait/stimuli and LiCl-bait/no stimuli animals, respectively.

Post-bait-shyness/Sheep-Predation Phase. -- This phase of the procedure measured suppression of sheep predation behaviors among the groups. Following demonstration of bait shyness or matched numbers of control trials (NaCl-bait/stimuli and NaCl-bait/no stimuli, respectively), coyotes were paired with a live sheep that either had "stimuli" or "no stimuli" affixed, respectively, until 2 fatal attacks occurred.

Data Analysis

Data were analyzed using descriptive statistics. Number of 1-hour daily trials preceding 2 fatal attacks of sheep in the post-bait-shyness/sheep-predation phase was the main dependent variable.

RESULTS

Shyness to LiCl-baits/carcasses having stimuli affixed required 15 and 7 daily trials for coyotes 1 and 2, respectively (Table 1). Onset of shyness to these emetic baits/carcasses without stimuli took coyotes 5 and 6 a total of 23 and 20 trials, respectively; however, coyote 6 never demonstrated complete shyness of mutton. Typically, these animals would ingest 0.5-1.0 kg of bait during the first exposure trial, regurgitate shortly afterwards, and then display "cautious, nibbling behaviors" on subsequently presented bait/carcass items.

Coyotes 1 and 2 (LiCl-baits/stimuli) required 9 and 6 post-baiting trials to fatally attack 2 sheep affixed with the collar, bell, and cologne as compared to 2 and 5 trials for yoked control (NaCl-baits/stimuli) (coyotes 3 and 4). All coyotes exposed to either LiCl or NaCl baits without the stimuli (5, 6, 7, and 8) fatally attacked sheep during each post-baiting trial; no suppression of predation was evident for these animals.

DISCUSSION

Attachment of the stimuli to LiCl-injected baits/carcasses and subsequent live sheep appeared to facilitate transfer of predatory suppression in coyotes. Occurrence of the 2-kill post-aversion criterion was delayed 2 to 4 fold in experimental coyotes relative to controls. While this is an encouraging scientific finding, resumption of sheep predation by coyotes in ≤9 days would limit practical application of this result.

Bait shyness of LiCl-injected leg-of-sheep/carcass baits was slow to develop in these partially food-deprived sheep-attacking coyotes, requiring ≥3 successive exposures (1-hr/day trials) for leg-of-sheep baits and ≥4 more trials for carcasses. Of course, novelty of foods is a requirement for acquired taste aversion. In this and many earlier studies (e.g., Gustavson et al. 1974, 1982; Burns 1980, 1983; Ellins and Catalano 1980; Bourne and Dorrance 1982; Ellins 1985), the prior familiarity of coyotes with mutton (i.e., previous kills) probably accounts for the slow onset of bait shyness as well as some equivocal field results. Still, this is a "real-world" issue impacting the feasibility of LiCl-induced sheep aversions in free-roaming coyotes. Obviously, bait shyness to leg-of-sheep baits is not readily generalized to other forms of mutton carrion (carcasses). Each bait type required multiple exposures for onset of shyness. Without taste novelty, LiCl aversion is not a 1-trial event for experienced predators nor is it equivalent to prey shyness.

Despite practical limitations, the current results offer some insight into ways that coyote predation behavior can be modified. This alone should prove of interest to biologists interested in developing non-lethal methods for reducing wildlife damage to livestock. Results also point out the need for new models of conditioned taste aversion and predatory behavior. Scrutiny of past models suggests that researchers may have ignored premises of food novelty and that attack, kill, and ingestion behaviors of large carnivores are elicited by distinct prey stimuli (e.g., experience, movement, odor). Drug effects may have to be paired with movement and odor responses of prey, rather than taste/ingestion responses, to inhibit attacks.

Table 1. Trials (1-hr/day) required for coyotes to display shyness of LiCl- and NaCl-injected (yoked) leg-of-sheep/carcass baits affixed with either stimuli or no stimuli (control); and the number of 1-hour/day trials for each coyote to fatally attack 2 live sheep post baiting.

			Trials to bait shyness[a]		
Condition	Drug	Coyote	Leg of sheep	Carcass	Post-baiting trials until 2 fatal attacks
Stimuli	LiCl	1	11	4	9
		2	3	4	6
	NaCl	3	11	4	2
		4	3	4	5
No-stimuli	LiCl	5	3	20[b]	2
		6	3	17	2
	NaCl	7	3	20[b]	2
		8	3	17	2

[a] Trials of NaCl-dosed coyotes were matched (yoked) to respective coyotes in the LiCl groups — received identical numbers and lengths of trials displayed by LiCl coyotes.

[b] Carcass presentations for coyotes 5 and 7 were stopped after 20 trials; coyote 5 did not display complete shyness of the LiCl-injected carcass — some "nibbling" still occurred on day 20.

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