of the number of items in the list to be retrieved (*7*) but not of the number of items in the potential search space in LTS.

These findings appear to indicate that free recall verbal learning may require retrieval from LTS and that most recall failures after initial recall represent retrieval failures rather than loss of (information about) items retained in LTS. Apparently, presentation of items only until they have been recalled at least once is sufficient for storage and retention of almost all items, as demonstrated by subsequent spontaneous retrieval without any further presentation. Once an item has been spontaneously retrieved from LTS the probability of subsequent retrieval is very great, so that retrieval from LTS increases without further presentation. There is very little support in these data for the assumption that (information about) items is lost from LTS during verbal learning. These results support the assumptions previously made in the analysis of verbal learning by selective reminding (*8*) that items remain in LTS and that recall failures may reasonably be regarded as retrieval failures.

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References and Notes

1. The items in the animal list were: dog, fox, horse, buffalo, lion, rhinoceros, elephant, antelope, bear, lamb, rat, raccoon, sheep, llama, goat, cheetah, squirrel, beaver, donkey, and turtle.
2. The items in the mixed list were: Chicago, hand, tulip, zebra, carpenter, brandy, clarinet, Norway, train, cup, slippers, tennis, lemon, pigeon, corn, desk, spider, garlic, elm, and shark.
3. The following categories were used for verbal interference by spontaneous retrieval before recall of the list to be learned: names of states, boys' names, articles of clothing, verbs, colors, occupations or professions, musical instruments, foreign countries, trees, girls' names, relatives (types of), and natural earth formations.
4. Both extended recall on each recall attempt and many recall attempts (without further presentation) seem to be needed to obtain the maximum spontaneous retrieval from LTS necessary to evaluate storage, retention, and retrieval accurately. Since the subject must learn that it is possible to retrieve additional items by such extended recall, it is important to provide enough time and encouragement to allow maximum retrieval from the very first trial on. This also requires the subject to try to recall all items in the list, rather than just some self-selected part of the list. Our subjects have reacted positively to the challenge of achieving their own maximum retrieval without further presentation.
5. Such consistent retrieval from LTS on all subsequent recall attempts without any further presentation may also provide an estimate of list learning. We would ordinarily say that a list has been learned when the subject can consistently recall all of the items in that list without any further presentations. Therefore, it would also seem reasonable to say that when a subject can recall half of the items consistently on all subsequent recall attempts, without any further presentation of those items, the subject has learned a (smaller) list of just those items (and has learned half of the entire list to be learned), since this seems to be what we mean when we say that a list has been learned. The cumulative number of items that are consistently retrieved from LTS on all subsequent recall attempts should therefore provide an estimate of list learning for comparison with item learning.
6. F. I. M. Craik [*J. Verb. Learn. Verb. Behav.* **7**, 996 (1968); *ibid.* **9**, 143 (1970)] has shown that items from short-term storage are not recalled at delayed testing after presentation and testing of other lists, even though they are recalled at immediate testing. This effect is shown in the present data by failure to retrieve about one item again after the first recall. Since retrieval from LTS may occur only after many recall attempts, this effect would have been greater if repeated retrieval attempts had not been used.
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Coyote Predation Control by Aversive Conditioning

Abstract. *Conditioned aversions were induced in coyotes by producing lithium chloride illness in them following a meal, and the effects upon eating and attack behavior were observed. One trial with a given meat and lithium is sufficient to establish a strong aversion which inhibits eating the flesh of that prey. One or two trials with a given flesh (lamb or rabbit) specifically suppresses the attack upon the averted prey but leaves the coyote free to attack the alternative prey. A method of saving both prey and predator is discussed.*

Predation of lambs by feral coyotes, in the public lands of the western United States, has led to a sharp controversy between naturalists who wish to see this carnivore survive in its natural habitat and stockmen who wish to reduce sheep losses to predatory coyotes. The principal method of controlling predation has been simply to kill the coyotes, employing bounty hunters, traps, and lethal poisons. These methods do not distinguish between the sheep killers and other coyotes (*1*). We are devising behavioral methods which spare both prey and predator.

If an animal eats a poisoned meal and survives, it will develop an aversion for the flavor of that meal. Such conditioned aversions have been studied most extensively in the rat, which is an omnivore specialized in seeking and testing new sources of food, including many plants which could be toxic (*2*). Several general questions arise: (i) Can such aversions be as readily established in a feral carnivore which preys principally on animals? (ii) Will gustatory aversions inhibit attack behavior directed at olfactory, auditory, and visual aspects of living prey? (iii) Can the inhibitory effect be limited to a specific prey (for example, lambs), leaving other options (for example, rabbits) open to the predator?

Our subjects were seven adult coyotes, approximately 2 to 4 years of age, maintained in individual dog runs. Five coyotes were removed from their feral den at approximately 3 weeks of age. Three (male "Brujo" and females "Luna" and "Coty") had hunted rabbits in the desert, while two (male "Feisty" and female "Dizzy") had no hunting experience. All were relatively domesticated and readily attacked both lambs and rabbits. The male "Sam" and female "Mary" were trapped as adults and were shy feral animals, each with an amputated forepaw, a result of the trapping. After several months of habituation to captivity Sam attacked and ate rabbits, but refused to attack lambs even when they were placed in his pen for hours. Mary would not attack either animal.

Our general procedure was to maintain the animals on one "safe food" and then present a "poison food" laced with lithium chloride or followed by an intraperitoneal injection of lithium chloride. In the hamburger experiment, four coyotes (Brujo, Coty, Luna, and Mary) were maintained on dog food and given fresh hamburger on two occasions. On the first hamburger trial the meat contained 6.0 g of lithium chloride in 31 capsules (No. 4 gelatin coated with a cellulose acetate compound). All the animals became ill and vomited after that meal (*3*). Three days later the animals were presented with unpoisoned hamburger and refused to eat the meat. After the hamburger test, they ate a full ration of dog food, indicating the aversion was specific to hamburger (see Fig. 1). During the attack experiment, each coyote was placed in an individual pen approximately 4 by 5 by 4 feet high (1 foot = 0.3 m). The individual pens were located on the perimeter of a large grassy enclosure approximately 30 by 40 feet, where the animals were exercised daily. Latencies to attack, to eat, and to vomit after lithium treatment were timed by stop watch and photographed with still or motion picture cameras. During this period the coyotes were given a safe meal of rabbit every 48 hours and lamb was substituted on test days. Attacks on lambs and rabbits were usually fatal.

On day 1, a rabbit was released into the large enclosure in view of the coyote. The coyote pen door was opened and timing started for the attack latency. On day 3 this test was repeated with a lamb. On day 5, each coyote was given a bait packet of minced lamb flesh wrapped in a fresh woolly lamb hide. On day 7, they were tested with a rabbit which they attacked immediately and then consumed. On day 9, this test was repeated with a live lamb. Brujo and Coty immediately attacked and killed their lambs but the latency to begin feeding increased markedly (Brujo, from 270 seconds to 1200 seconds; Coty, from 600 seconds to 1680 seconds), and the rate of feeding was decreased. In contrast, Luna did not attack; instead she actively avoided the lamb. After 15 minutes the lamb was removed and a rabbit was presented. Luna immediately attacked the rabbit and subsequently ate it. Luna's attack data are summarized on line 1 of Table 1.

The two coyotes whose attacks were not suppressed vomited soon after eating the bait packet containing lithium (Brujo, 42 minutes; Coty, 30 minutes). Luna vomited later (80 minutes) and thus may have absorbed more lithium chloride. Therefore, on day 13 we gave Brujo and Coty a second lamb meat–lithium treatment followed by an intraperitoneal injection of 2.5 g of lithium chloride in 100 ml of water (*4*). On day 15, the two coyotes were tested with a rabbit which they attacked immediately and then consumed. On day 17, they were presented with a lamb which they did not attack (Table 1, lines 2 and 3).

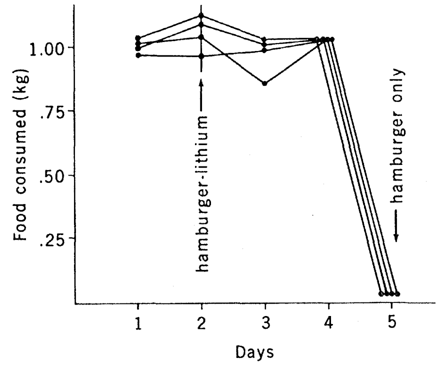

Fig. 1. Individual graphs, for four coyotes, of food consumed: dog food (days 1, 3, and 4), poisoned hamburger (day 2), and unpoisoned hamburger (day 5).

We then tested two more animals (Dizzy and Feisty) which had no prior experience with lithium illness. The procedures were essentially the same, except that dog food was the safe food provided on the intervening days and a rabbit carcass perfused with 5 g of lithium chloride in 50 ml of water was the poison food. The poison meal was followed by the immediate injection described above. The results paralleled the earlier studies. One treatment did not suppress attacks upon the rabbit but did suppress feeding during the 15-minute period. When presented with a dead rabbit during the second treatment, they mouthed it but did not actually eat it. They were then given a second injection. Subsequently they refused to attack the rabbit but immediately attacked the lamb (Table 1, lines 4 and 5). The feral male (Sam) would not attack a lamb, so he was tested with rabbits only on the same schedule. One meal of the toxic rabbit was sufficient to suppress his attack upon live rabbits (Table 1, line 6).

The behavior of the coyotes in the posttreatment tests and the extinction tests in which the averted animals were presented at weekly intervals revealed some interesting patterns. After becoming sick on hamburger, they buried their vomitus. When presented with hamburger, Luna sniffed and licked it and then turned away. Brujo buried his hamburger. Coty urinated on her hamburger and repeated this behavior with the lamb she killed after the first flesh-lithium treatment.

After a single lamb flesh–lithium treatment, Luna loped up to the lamb, sniffed it, and circled back, hiding under a cage and vomiting within 1 minute. She then retreated into her pen. When the lamb followed her into her pen, she growled and snapped at the lamb, then gagged and retched, breaking off the attack with no injury to the lamb. Luna died several days later. Since she showed good activity and appetite following her last treatment, and her autopsy was negative, the cause of death was uncertain.

Coty made a lunge at the lamb after the second treatment but stopped abruptly, turned her back to the lamb, and spent the rest of the test period eating grass. Brujo also ate grass on his last three extinction trials. This behavior was observed only during posttreatment tests with lambs, thus it may be an example of "displacement behavior" often observed when motivation or drive is high but consummatory behavior is blocked. A week later, Coty attacked a lamb but interrupted her attack without killing. Brujo was tested for 8 weeks without a single attack.

The group conditioned with rabbit and lithium was also variable in extinction. Feisty attacked in 140 seconds after 4 weeks, Dizzy in 400 seconds after 2 weeks, and Sam in 120 seconds after 1 week. In the identical pattern, each coyote carefully first chewed off and consumed the ears, then ceased eating for about 30 minutes. Next, he ate the head and waited another half hour before returning to consume the rest of the body. Before treatment, the coyotes attacked the back of the neck and began consuming the neck, head, and finally the ears without long periods between bouts of eating before commencing on the body. The animals appear to be reacquiring a taste for rabbit meat, as eating is now followed by nutritious effects without toxic effects.

We propose a two-phase conditioning process in mammals on the basis of previous work (*5*). In phase one, the

Table 1. The time taken by coyotes to attack a live rabbit and a live lamb before and after experimental treatment, which consisted of pairing lamb or rabbit flesh with illness-producing lithium chloride. No att., no attack.

Coyote	Before treatment		Treatment: LiCl paired with	After treatment	
	Rabbit	Lamb		Rabbit	Lamb
Luna	4 sec	1 sec	Lamb flesh (once)	1 sec	No att.
Brujo	1 sec	1 sec	Lamb flesh (twice)	1 sec	No att.
Coty	1 sec	1 sec	Lamb flesh (twice)	2 sec	No att.
Dizzy	1 sec	1 sec	Rabbit flesh (twice)	No att.	2 sec
Feisty	61 sec	6 sec	Rabbit flesh (twice)	No att.	2 sec
Sam	231 sec	No att.	Rabbit flesh (once)	No att.	No test

flavor of food becomes aversive after one illness, after which the sights and sounds of the prey may still elicit attack but the aversive flavor inhibits feeding. Phase two occurs when the auditory, visual, and olfactory cues from the prey become associated with the now aversive flavor, thus subsequent attacks are inhibited and perhaps a second treatment is unnecessary. In some cases emesis may forge an association between vomited gustatory cues and odors of the vomitus which is sufficient for the second phase of conditioning.

For suppressing sheep predation, we could scatter baits that smell like sheep, taste like sheep, and contain a nonlethal emetic toxin. We could also perfuse carcasses of lambs and sheep with lithium. The predator could then be expected to subject himself to repeated trials until the flavor and the spoor of sheep becomes aversive. Subsequently, when foraging it would turn away before it sights sheep. Thus in open range, the aversive effect may be much more durable than our extinction data indicate. Our coyotes had no other food and few other activity options in the small enclosure. The lambs persisted in following the coyotes, and occasionally a rabbit literally leaped into a coyote's jaws.

In addition, the feeding habits of the mother coyote averted to sheep might be transmitted to her pups, via flavor which her diet imparts to her milk, and by their early experience with the prey she brings to the den. Similar mechanisms have been demonstrated in the rat (*6*). This method should be effective against other predators, such as large cat species and eagles. Studies (*7*) indicate that birds form aversions to the visual as well as gustatory aspects of food, so the infused lamb may be the method of choice for eagles. Finally, since it is known that flavors are enhanced when beneficial effects follow ingestion (*8*), this method could also be used to change the food preferences of some species that are endangered because their naturally preferred food is diminishing owing to ecological change.

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3. One coyote (Mary) gulped the entire hamburger with 6.0 g of lithium chloride; the others gingerly separated out some of the capsules; however, they all ingested 3.0 g or more. The dose absorbed cannot be specified because of vomiting. Other tests indicate that for intraperitoneal injections of 0.12*M* LiCl, 100 ml induces vomiting and 250 ml produces a strong aversion in coyotes weighing 9 to 13 kg. The cellulose-covered capsules were designed to pass through the stomach into the intestine, thus avoiding ejection by vomiting.
4. To establish maximal learning in one or two trials and thus minimize attack testing, we employed the combination of (i) LiCl (6.0 g) treated food in case the animal vomited and reingested the vomitus and (ii) intraperitoneal injection to ensure an effective absorbed dose. Since 0.12*M* LiCl is similar in flavor to physiological saline, lithium treatment does not radically alter the flavor of the prey.
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Sugar Sweetness and Pleasantness: Evidence for Different Psychological Laws

Abstract. *Sweetness and the pleasantness of sweetness of sucrose solutions and sweetened food conform to different functions. Sweetness rises with concentration, whereas pleasantness first rises and then decreases. The breakpoint appears to occur at a constant sweetness (that is, constant sensory) level.*

The "sweet tooth" is a widespread phenomenon of animal behavior, and the exceptions, according to Pfaffmann (*1*), are ". . . remarkable largely for their divergence from what otherwise appears to be a general rule . . . . Gustatory stimuli, therefore, appear to be biologically determined as the instigator of consummatory . . . responses." From studies of animal behavior it is relatively difficult to distinguish between the discriminative function of sweetness as information and the reinforcing property of sweetness, although direct methods have been used with some success in specific experimental paradigms (*2*). Electrophysiological evidence from the recordings of chorda tympani suggest that the hedonic and intensity aspects of taste conform to quite different laws (*1*), but relatively little attention has been paid to man, whose capacity for language can allow him to evaluate, simultaneously, the intensity and hedonic aspects of taste stimuli.

Investigations of sweetness and the pleasantness of sweetness through human psychophysical scaling raise the possibility that two quite different growth laws may be obtained, by instructing the observer to attend to these two separate aspects of taste impressions. When an observer matches numbers to sweetness so that ratios of these numbers reflect ratios among perceived sweetness, then rated sweetness appears to increase systematically according to a power function of concentration: $S = kC^n$ (*3*), where S is sweetness; *C*, concentration; and *k* and exponent *n* are constants. The pleasantness of the same sweet taste does not, however, rise continuously with concentration (*4*) but either flattens out or may even decrease at very high concentrations. Human psychophysical scaling of taste intensity and taste pleasantness rely upon short-term exposures to sugar solutions (a model system), so that the scientific study of taste hedonics is based upon stimuli that do not resemble actual foods. This study concerns functional relations for both the model system and real foods, and thus bridges the gap between stimuli that are usually not consumed and foods that are. As a result, one can determine whether functions obtained in simple systems have applicability to the world in which behavior takes place and whether the parameters determined in the former domain apply to the latter.

In a previous study by Moskowitz (*4*) the sweetness-pleasantness relation was reported for sugar plus water. The method of magnitude estimation was used in order to obtain ratio-scale values for both sweetness and pleasantness. For the same set of concentrations of sugars, rated sweetness grew more rapidly than rated pleasantness, and up to the sweetness of 1.0*M* glucose, pleas-