THE PROBLEM OF DOMESTICATION IN THE LABORATORY RAT AND A COMPARISON OF PARTIALLY REINFORCED "DISCRIMINATORY" AND ANTICIPATORY LICKING IN DOMESTIC AND WILD STRAINS OF <u>RATTUS</u> <u>NORVEGICUS</u>

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ABSTRACT

THE PROBLEM OF DOMESTICATION IN THE LABORATORY RAT AND A COMPARISON OF PARTIALLY REINFORCED "DISCRIMINATORY" AND ANTICIPATORY LICKING IN DOMESTIC AND WILD STRAINS OF *RATTUS NORVEGICUS*

By Robert Boice

Psychology has received deserved criticism for its exclusion of undomesticated Norway rats in learning research. It is surprising that the rather widely acclaimed learning deficits which are assumed to accompany domestication (e.g., the assumptions of degeneracy and limited phyletic generality) have gone essentially untested by psychologists. Research on wild rat learning has apparently remained in the "armchair" stage because of the wild rat's reputation as being obviously more intelligent (i.e., fierce and wiley) and almost impossible to procure and maintain.

This thesis presents three basic considerations designed to evaluate the possible contribution of wild-type rats to research in learning: 1. Practical techinques for trapping, breeding, and maintaining wild rats in a typical laboratory setting. 2. *Ad lib.* and time-restricted water intake as measures of emotionality and domestication. 3. Inhibitory and excitatory patterns of responding in noncontingent learning

to lick.

Selection of a land-fill where the refuse was constantly rearranged allowed unprecedented speed in trapping (mean latency of capture = 15 min.) as well as sampling the high status population segment which usually avoids new objects such as traps in a more stable environment. There is reason to believe that the "trap-shy" rats in the usual environment are more dominant and fertile than the oft-wounded low social status rats. The expectation that the captured high social status rats would exhibit better mating and maternal success than is traditionally reported was supported with a result of 100 per cent breeding success, large litter sizes, and no savagery or neglect of litters.

Two captured wild rats judged to be of low social status fared differently. The low social status male died as a result of his initial mating encounter, and the low status female destroyed both of her litters. Observations of mating behaviors suggested that the success of the breeding experiment was aided by the use of special, gated breeding cages which provided olfactory acquaintance before, and restriction of fighting during, initial encounters of male-female pairs.

Previous research has suggested that stressed laboratory rats (i.e., more emotional) and undomesticated rats (i.e., more emotional) drink more water than normal

domestic rats. This investigation compared domestic, nonagouti rats with wild F_1s and found no differences in ad lib. water intake, followed by a slight superiority of the domestic rats in deprivation adjustment. There were no detectable differences in lick rates (mean or range) between strains. Another deviation from usual measures of emotionality was the relative absence of defecation in newly captured wild rats.

The conditioned (noncontingent) licking technique as developed by Weisman (Ph.D. dissertation, Michigan State University, 1964) was selected for the strain comparison of learning. The Weisman technique had the advantage of producing fast habituation and requiring limited motor responding for the more neophobic wild F_1 strain. Learning to lick in this investigation proceeded according to the two-stage model of noncontingent learning developed in this thesis: The consistent emission of discrete UCRs to the UCS, ("discriminatory" responding) appears to have been necessary before consistent elicitation of discrete CRs by the CS (anticipatory responding) occurred. Two hypotheses were derived from the two-stage noncontingent learning model. The first, that the two stages (DRs, then ARs) are characterized by inhibitory and then excitatory modes of

responding, was supported in analyses of individual lick topographies as in cases of inhibition of delay and excitation in reacquisition. The second, that wild F_1 rats would learn the inhibitory stage (DRs) quickly but that the excitatory stage (ARs) would be delayed as compared to domestic rats, was also essentially supported. More emphatic evidence for the relatively inhibited learning style of the wild F_1 came in the last extinction. The introduction of a novel stimulus on the tenth trial caused the domestic rats to stop responding for about three or four trials. Most of the wild F_1 rats did not resume responding.

Strain similarities in the learning study were most evident in the superiority of CRF over PR for both stages (DRs and ARs), and in the within session response decrements.

In sum, there is no support in this investigation for the notion that wild rats are more capable in appetitive learning studies which traditionally use domestic rats. It could be argued that performance inhibitions rendered the learning results from the wild F_1 rats less phyletically gereralizable than the results from the domestic strain. Although the wild-type rats provided more interesting results in the studies of

emotional and mating behaviors, this dissertation accepts the view that domestication has probably enhanced the value of the Norway rat for learning research.

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This thesis is dedicated to S.A. Barnett, of the Department of Zoology, University of Glasgow, whose publications were the primary inspiration for this thesis.

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INTRODUCTION

> "From the point of view of all living creatures, the rat is an unmitigated nusiance and pest. There is nothing that can be said in its favor. It can live anywhere and eat anything"(pg.150). "The rat has an excuse. As far as we know it does not appear to have developed a soul, or that intangible quality of justice, mercy, and reason that psychic evolution has bestowed upon man"(pg. 155; Zinsser, 1935).

Since the time of Watson and Carr, the mutant rat, *Rattus norvegicus albinicus*, has been the favorite subject for psychological research (Munn,1953). Although selection in breeding has established the domestic rat as an excellent subject, two factors have led to a serious reconsideration of the emphasis on the "laboratorized" rat (e.g., Beach, 1950; Bitterman, 1960): First, it has become apparent that not everything in psychology can be investigated, as Tolman (1938) once believed, through analyses of the determinants of rat behavior at a maze choice point. Second, many years of selective breeding in the laboratory have probably produced a specialized rat which limits the generality of experimentation to other animal research (Fuller, 1960). Another possible consideration for psychology is that the rat may have been studied too extensively with standard techniques.

Assuming that over fifty years of data merit a

consideration for the retention of the Norway rat as a research animal, this thesis will investigate two problems designed to evaluate the role that relatively undomesticated rats could assume in learning psychology: 1. Can wild rats be utilized efficiently in a typical laboratory setting? 2. Is there a learning paradigm which can demonstrate the important effects of domestication, as opposed to wildness in the rat?

The Study of Domestication and the Practicality of Wild Rats as Experimental Subjects

> "We do not know of any research being done with wild rats. If you have to capture and handle wild rats by yourself, be very careful because wild rats bite viciously and carry many diseases; almost a perfect contrast with our tame, healthy rats."[1]

A marked genetic change can be expected after only a few generations of breeding in the laboratory, without deliberate selection of any kind (Spurway, 1955). In psychology, there is general agreement that rats have been selectively bred for such qualities as docility, readiness to learn, and fecundity. Some of the conditions peculiar to domestication include dietary deficiencies (Zucker, 1953), confinement in small cages, lack of practice in meeting new situations

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1. Jon Holtzman, Holtzman Company, Madison. Personal communication. 1965.

(Griffiths, 1944), and propensities for uniform infection (Russell, 1941).

The morphological and fecundity changes of rats in captivity have been well documented by zoologists such as Donaldson (1915), King (1939), and Richter (1944). For example, by the twenty-fifth generation of laboratorization, King found marked increases in average length of reproductive period, body weight, rate of growth, and mutations in either color or structure of hair.

The genetics of behavior (psychogenetics) involves more difficulties of interpretation than the genetics of morphology (Broadhurst, 1965), especially in terms of measurement (Ratner and Denny, 1964). There are, however, reasons to believe that changes in the structure of rats do correspond to changes in behavior (Barnett, 1963). Differences in viciousness and emotionality between feral and domestic rats, for example, are reliable enough (i.e., the two strains breed true for wildness and tameness) to indicate an hereditary basis for the difference (Hall, 1941). Other strain differences in rats have been found in threat displays (Barnett and Evans, 1965), social behavior (Barnett, 1960), emotionality (Broadhurst and Levine, 1963; Farris and Yeakel, 1945), audiogenic seizures (Farris and Yeakel, 1943; Martin and Hall, 1941), aggressiveness (Hall and Klein, 1942), speed of reaction

(Utsurikawa, 1917), geotropism (Crozier and Hoagland, 1934), exploratory behavior (Barnett, 1958a), feeding behavior (Barnett, 1956), maze performance (Tryon, 1932), and avoidance learning (Broadhurst and Bignami, 1965; Zerbolio, Reynierse and Denny, 1965). Not only is the laboratory rat susceptible to behavioral changes in selective breeding, but as inbreeding and homozygosity increase, the variability of behavior decreases up to a point (Barnett, 1963). One of the main advantages of rats that are tame and inbred (perhaps the factor which overcomes the resultant limited phyletic generality),lies in the reduction of genetic variability and a necessary limitation of individual differences.

The point of critics such as Beach and Bitterman is that psychology has overemphasized research with specialized rats which lack the full-range and vigor of behaviors available in wild animals (Kavanaugh, 1964). A crucial point for psychogenetics is the fact that almost nothing is known about differences in learning ability between domestic rats and their progenitors, wild rats. Among the voluminous work on strain differences (Robinson, 1965), only one learning study (Stone, 1932) has employed a direct wild-domestic comparison. The lack of such studies is probably due to these considerations: First, wild rats are reputed to be impractical for use as subjects in learning studies (Fuller, 1960). Second, with the exception of some

unpublished research using Sidman Schedules[2], few efforts have been made to develop reliable learning techniques for use with the neophobic, wild-type strains.

Stone's isolated study tested the effects of wildness in a simple maze. The wild rats in that study typically crouched or ran frantically in response to the slightest disturbance. In sum, Stone's study points out the desirability of limiting the amount of instrumental responding in an appetitive study of wild rat learning. Problems basic to the study of learning and performance in wild rats include representative sampling of the feral population (Calhoun, 1962), efficient trapping (Chitty, 1954; Thompson, 1953), and maintenance and breeding (King, 1939).

"Discriminatory" and Anticipatory Learning to Lick As a Comparative Technique for Emotional and Docile Strains

> "The chief difference in the different types of learning is that in some cases activities already organized are *modified* by experience, while in others the activities are *organized* by experience" (Kirkpatrick, 1908, pg. 2[illegible]).

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[2] M. Patterson, Grinnell College, Personal communication. 1965.

While some investigators feel that the learning process is best demonstrated by classical conditioning (e.g., Scheffield, 1965; Spence, 1956), it is hard, in actuality to separate classical from instrumental learning. Denny and Adelman (1955) note that establishing a CR involves considerable discrimination learning in terms of specifying the CR to the momentary CS and not to the stimulus complex in general. Kimmel (1966), on the other hand, views the CR as an instrumental response in GSR conditioning. Collateral to the break from traditional dichotomies in learning is a new trend of conditioning wherein novel responses (e.g., sand digging in Peromyscus--King and Weisman, 1964; the nictitating membrane in the frog--Goldstein, Spies and Sepinwall, 1964) act as UCRs. In the same vein, claims have been made for the classical conditioning of the rat's licking response (the UCR) by Weisman (1965), Miller and DeBold (1965), and Patten and Deaux (1966). Even though the just mentioned studies are inextricably bound in the theoretical problem of what constitutes a pure conditioned response (Kimble, 1964), the licking technique for rats does provide an interesting demonstration of instrumental--then classical conditioning in one paradigm. Specifically, the licking technique developed by Weisman (1964) shows two stage noncontingent learning--"discriminatory" then anticipatory licking--in a situation which is not usually observable

in faster noncontingent paradigms (e.g., Voeks, 1954). This two-stage facet of the Weisman technique, which has gone unnoticed until now, may have special significance for studying learning in wild-domestic strain comparisons.

For one thing, the drinking (i.e., licking) response in wild rats can be elicited in a laboratory situation (Richter, 1944). The stereotypy of the domestic rat's licking response (Stellar and Hill, 1952) is well established to have a mean of six or seven licks per second (range = 5-8) independent of age, sex, deprivation state, or type of non-viscous solution (Keehn and Arnold, 1960; Schaeffer and Premack, 1961). Thus, assuming that the rat's licking rate is species-specific, relative simplicity and reflexiveness should render licking a good unconditioned response for both strains. Also, the Weisman technique employs a confined drinking apparatus in which very little instrumental responding is required. Pilot work for this dissertation has shown that both strains seem to habituate to the licker boxes quickly, with licking responses being initiated a few minutes after being introduced into the boxes.

Another point is that performance difficulties are somewhat inevitable in an appetitive comparison of wild and domestic strains. It is possible that the most

interesting results will appear in the comparative style of "discriminatory" responding (discrete UCRs) and then anticipatory responding (discrete CRs), and not just in terms of final levels of conditioning. The stages approach to noncontingent learning around and within the ISI is similar to the most recent theoretical developments in classical conditioning (Lockhart and Grings, 1964; Colavita, 1965; Kimmel, 1966). In addition, the licking technique expands rat research into the area once pioneered by Hughes and Schlosberg (1938) and Biel and Wickens (1941) but long since abandoned.

The Choice of Variables and Some Expectations

> "In sum, the psychogeneticist must always remember that in studying trait inheritance he puts himself in the difficult position of trying to prove a negative; that the trait in question is not due to extragenetic factors. He adds to the plausibility of his conclusions in direct measure as he controls the effects of extraneous influences" (Hall, 1951, pg. 309).

The two most basic considerations in this approach to a strain comparison of learning are techniques of subject and response selection. The first of those considerations concerns methods used in trapping and breeding wild rats, the most crucial steps in the process of laboratorizing rats. The second consideration involves the measurement of

appetitive learning in the more timid wild rats.

Previous studies which brought wild rats into the laboratory (e.g., King, 1939; Richter, 1944) made no mention of attempts to trap "representative" samples of feral populations. The fact that segments of feral rat populations survive extensive campaigns of trapping or poisoning (Thompson, 1953) indicates that the collection of specimens for laboratory study usually favors one segment of the population. Calhoun (1962), who has made a comprehensive study of the sociology of wild Norway rats, has observed marked social differences which seem to relate to important behavioral differences in wild rat populations. He notes that the...."tendency of socially low-ranking rats to exhibit a reduced avoidance of traps is so characteristic that it forms a portion of the syndrome of abnormal behavior discussed with respect to the extremely low ranking rats"....(pg. 88). Other characteristics of the socially low ranking rats in Calhoun's study included segregation to old burrows, "fouled" nests, and poor fecundity.

The first main hypothesis of this study is that if the feral population can be sampled for its more dominant and fertile members, then the usual poor success of breeding wild rats in the laboratory (King and Donaldson, 1929; Richter, 1944) should be

reversed. This hypothesis has special significance for theories of domestication because it may well indicate that sampling (i.e., trapping) should precede other considerations in the selection process of laboratorization of rats.

Another prime consideration in the study of domestication is the marked decline in emotionality and increase in docility over gerneations in captivity (Robinson, 1965). Accompanying the behavioral changes in domestication are physiological changes; for instance, the laboratory rat has a lower metabolic rate as shown by its lower water intake (Richter, 1944). Such differences were presumably illustrated in a study by Richter and Mosier (1954) wherein many wild rats showed extremely high and irregular water intake when brought into the laboratory. It is also possible to induce increased water intake by stressing domestic rats (Siegel and Siegel, 1948).

The second main hypothesis of this dissertation is that a wild F_1 strain bred from high social status rats will not differ markedly from domestic rats in measures of ad lib. and time-restricted water intake. The reasoning behind the second hypothesis is basically that starting with high social status rats for breeding will short cut the usual domestication process. The relation between social status and domestication will be discussed anon. The high social status parent strain should produce

less emotional F_1s than in traditional studies.

If the wild F_1 strain does approximate the domestic strain in water intake, some assumption of equality of water "need" can be made in using the licker box technique where strict deprivation is essential to consistent performance in the apparatus. Pilot work has shown that the important difference between the two strains is the conservative licking style of the wild strain. That is, although the wild rats licked throughout the session, their bursts of licking were shorter and inter-response times (IRTs) longer. Other investigators have emphasized the cautiousness of wild rats in consummatory situations (Thompson, 1953; Barnett, 1956), and thus it is assumed that the wild rat's more inhibitory approach may differentiate the wild rat from a domestic rat in positively reinforced learning situations.

The third main hypothesis in this dissertation is that the primary difference in the patterns of learning to lick will occur in inhibitory versus excitatory styles. An example of dichotomizing learning in terms of inhibitory and excitatory components is Colavita's (1966) approach to salivary conditioning. Colavita views the UCR as a reflex mechanism, and as an emotional or intensifying mechanism. The approach to be developed here is that the stages of noncontingent

learning to lick in the Weisman technique represent mechanisms of inhibitory and then excitatory responding: First, an inhibition of the licking response (which is normally an operant--always reinforced), should reduce licking in the noncontingent situation in a discriminatory manner. Second, when the discriminatory response is established to the extent that most licking bursts are reinforced, then an excitatory process should cause the rat to respond in an anticipatory manner to the CS. The specific expectation is that both strains should master the discriminatory response quickly, but that the wild F_1 strain will be slower to break the inhibitory set and thus delay showing anticipatory responses. With this same approach in mind, independent variables of intermittent reinforcement, repeated extinctions and acquisitions, and external inhibition/disinhibition will be employed in the learning study in an attempt to further study patterns of inhibitory and excitatory responding. There is no general agreement in the literature on what one should expect in a wild-domestic strain comparison. In the only published study which attempted to evaluate wild versus domestic learning abilities, Stone (1932) found that wild F_1s, when habituated to the apparatus, showed superior performance compared to tame rats. Barnett (1963) surmises that wild rats might find double alternation learning easier than laboratory rats, and Robinson (1965)

goes so far as to state that, "On a cautious view, there would be little in the normal course of laboratory routine to prevent a fall in maze ability. Shelter, food and mates are provided without the individual making a move to fend for himself. Even an idiot rat could flourish in such an environment" (pg. 514). On the other hand, it is reasonable to expect that wild rats, in spite of their reputation as vigorous and wiley animals, would fare poorly in many standard laboratory learning situations (Tinbergen, 1965). This thesis favors the second view primarily because it seems that psychologists probably retain the most cooperative rats (i.e., quick to learn) for breeding.

Thus, the two basic problems of this thesis center around the comparability of wild rats and domestic rats as standard laboratory animals, and around the importance of differences in behaviors (e.g., learning) in the two strains to the tradition of using tractable rats in psychological research.

CHAPTER I

TRAPPING, BREEDING AND MAINTAINING WILD NORWAY RATS

One of the few fallacies among the beliefs about trapping wild Norway rats is that human odors on traps prevent capturing the wary animals (Chitty and Shorten, 1946). Calhoun (1962) reports that wild Norway rats are difficult to capture with commercial traps primarily because such traps represent new objects in the rats' environment. For instance, Thompson (1953) and Chitty (1954) report a lag of one to ten days before "entry" and recommend unvaried trap placement for a week before baiting. Even the researcher who wishes only to collect small samples will typically find that wild rats cannot be taken quickly (Barnett, 1958b).

Representative sampling is another problem in trapping rats from feral populations. Intrapopulation differences in feeding habits, for instance, make location and time of day important considerations in trapping (Chitty and Shorten, 1946). Thompson (1953) found that regardless of the interval between trappings, at least half of the population avoids entering traps. Calhoun (1962), who observed marked rats, noticed a trend of socially low ranking rats to exhibit "a reduced avoidance" of traps. Calhoun's

observation, which has apparently gone unnoticed by students of domestication, may have profound importance for the studies which have reported difficulties in breeding (e.g., King and Donaldson, 1929) or those which have domonstrated other extremes in emotional behavior of newly captured wild rats (e.g., Richter and Rice, 1954; Richter and Mosier, 1954). The assumption being made in this study of trapping is that in traditional approaches to trapping, the most easily captured rats are most likely to be infertile and more emotional (Scott and Fredericson, 1951). The crucial problem seems to be the need for a technique wherein the general neophobia (Barnett, 1963) of wild rats would be reduced. For example, even laboratory albinos in the wild travel only in the same paths (Minckler and Pease, 1938), except to skirt unfamiliar objects in the paths.

With the exception of Barnett's (1958b) excellent manuscript, little of a constructive nature has been written which would aid researchers in the laboratory maintenance of wild rats. For instance, Crandall (1964) dismisses Norway rats as animals not usually displayed but instead eliminated. A good reason for the stigma on wild rats is the fact that the Muridae (old world rats and mice) transmit over 35 known diseases to man and

his animals.[3] Once in the laboratory, these animals are also renowned for their intractability. King and Donaldson (1929) describe the behavior of feral rats in the laboratory as "highly excitable and savage", accompanied by constant gnawing of cages and attempts to escape. The relatively high emotionality of newly captured wild rats may even lead to their death by shock (Richter, 1957), although Barnett (1958b) contends that such instances are probably rare.

Breeding in the confined conditions of the laboratory was reported by King (1939) to produce only occasional small litters which were subsequently savaged or neglected. The traditionally poor success in breeding and raising captive wild rats has led Richter (1944) to assert that the two most important stages in the selection process are breeding and maternal care.

Thus, the general trend of the literature is mostly discouraging to the researcher who wishes to establish a colony of wild rats in his laboratory. Initial trapping excursions made in the spring of 1965 to a typical refuse dump (located on south campus, Michigan State University) confirmed the findings in the literature. No captures were made using overnight

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[3] *Facts about rats and mice.* U.S. Fish and Wildlife Service Bulletin #316. 1961.

settings. In the fall of 1965 a more promising trapping locality, the Meridian Township Dry-Land-Fill, was discovered. A land-fill, unlike a common refuse dump, consists mostly of non-garbage material which is bull-dozed, along with layers of dirt, to fill swamp areas. The significance of a land-fill population of rats for trapping is twofold: First, there is no stable arrangement of environmental objects, including food, in such a setting, and therefore trapping should be facilitated. Second, a baited trap in such an unstable environment should elicit the entry of both high and low status rats.

The first main hypothesis of this dissertation, restated, is that in the land-fill situation, efficient and representative trapping should be possible. An emphasis on breeding the socially high ranking rats should promote better fecundity and maternal behaviors than has been found previously.

METHOD

Equipment--Two Havahart (size #2) live traps were used because they generally capture only one rat at a time--a feature which made transfer to individual wire cages (Bussey #1425), without handling, quite simple. Because of its odorous qualities, Puss 'n Boots cat food was used as bait.

Procedure--All trap placements were made in the Meridian Township Dry-Land-Fill (Haslett, Michigan) between the hours of 10 P.M. and 4 A.M. and between the dates of September 7 and November 29, 1965. No special attention was given to trap placement location in the land fill, except to avoid areas which were actively burning.

Baiting involved the liberal sprinkling of cat food throughout the trap and around both doors. After placement, *E*s would walk away to a distance of up to 100 ft. and wait for the clanging noise which signalled a capture. Rats which had fresh wounds, a notable incidence of back scars, or tattered ears were not usually retained because this study aimed to utilize mostly high social status rats. Transfer to the wire cages was effected by allowing the captive to jump out of the lowered end of the trap into the opened cage, followed by a rapid closure of the cage top.

Before being brought into the laboratory, the wild rats were carefully sprayed with Sergeant's Flea and Tic Spray. In the laboratory, the *S*s were maintained on *ad lib.* Wayne Lab Blox and tap water. Removal of a section of one bar in the front of the individual cages allowed insertion of food pellets without having to open the top. Daily observations of behavior were made throughout the fall months with the

E sitting quietly at a distance of 5ft. from the rack of cages. Particularly good observations were obtained by turning off the lights until general movement of the rats ensued. If the E remained quiet after turning on the lights, the wild rats would continue moving--quite unlike their usual posture of crouching in the back of the cage in response to observers.

The rats retained for breeding purposes were transferred, without handling, to cages identical to the originals except for modifications made to allow separable but interlocking cages with sliding doors (Fig. 1). String and shredded paper toweling were placed through the food hole in the female's cage for use as future nesting material. Pairs of rats to be bred were first housed with cage tunnels connected but with doors in place. Presumably, the separated pairing allowed for some olfactory acquaintance in prospective pairs. After a period of about one week, or until both rats in the pair appeared to be acclimitized to the laboratory (e.g., habituation of extreme threat behaviors such as teeth chattering, and hissing to the appearance of the E),

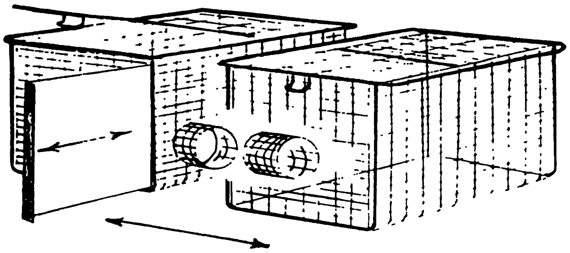

Fig. 1. Breeding cages comprised of two individual wire cages with interlocking hardware-cloth tunnels and a sliding aluminum door.

the doors were removed to allow intercrossing between cages. The period of initial mating was carefully monitored to prevent the development of injurious fighting by re-separating the pair. Movement of either rat to either cage could be accomplished by the E's blowing air at the rats. For the first month of attempts at breeding the wild rats, a 12 hr. light, 12 hr. dark cycle was maintained. Subsequently, the wild rat colony room was maintained in constant light-on conditions.

Four pairs of domestic rats (two pairs of Sprague-Dawley albinos and two pairs of Long Evans non agouti), plus four pairs with wild males and domestic females (three albinos and one black) were similarly employed for comparison purposes.

Upon appearance of a litter, the male was permanently closed off in the opposite cage and kept there until the litter was weaned at the age of 30 days.

RESULTS

Trapping--A total of 27 wild rats were captured at the land-fill, 20 of which (eleven females and nine males) were taken into the laboratory for observation. Of the additional seven, four were judged to be of quite low social status and three escaped in the process of transfer from the trap to the cage. Latencies for

capture varied between 3 min. and 2 hrs. with most triggerings occurring within 15 min. or immediately following the passage of a train on the nearby tracks. The only unsuccessful setting resulted in the capture of an enraged <u>Felis</u> <u>cattus</u>.

Dates of capture varied between September 7 and November 29, 1965, with no apparent differences in population activity or trapping latency in warm or in ice and snow conditions. Two observations were made with respect to newly captured wild rats: 1. There were no deaths due to shock. 2. None of the captives defecated while in the trap or while in the cage enroute to the laboratory.

<u>Breeding</u>--Because of limited housing facilities, only five male and five female wild rats were retained for breeding purposes. The breeding success of the five selected females is depicted in Table 1. Table 1 also lists the origin of the wild F_1 rats which will be used in the later studies of drinking and learning behavior (Chapters II and III).

All five wild females were eventually induced to breed in the laboratory. Two litters came from females which were evidently pregnant when captured (WRs # 2 and 8). The first of those, WR 2 had a litter two days after capture, and this being the first wild litter in this laboratory, the pups were fostered with

Table 1

Breeding Success of Selected Wild Females

Female Number	Date of Capture	Date of Pairing	With Male Number	Date of Litter	Size of Litter	Per Cent Raised to Weaning
2	9/13	---*		9/15	11	18%***
		9/31	1	11/8	7	100%
4	9/17	10/1	3	(#3 Died 10/16)		
		10/24	5	12/3	12	100%
		1/9	5	2/2	9	100%
		---**		3/17	6	100%
7	10/23	12/1	1	1/4	5	100%
		---**		2/17	3	100%
8	10/27	---*		11/7	9	0%
		12/1	10	1/8	9	0%
9	10/27	11/2	6	2/9	11	100%

Total F_1s = 87

Mean Litter Size = 8.7

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*Pregnant when trapped.

**No male in cage since weaning of previous litter.

***Litter fostered with lactating albino.

a lactating female albino as per King and Donaldson (1929). Because the foster mother ate most of that first litter, it was decided that subsequent litters would be left with their natural mothers. Only one of the five females (the only one with scars incurred in the wild) savaged and neglected her litters. WR 8 did not, incidentally, show acclimitization to the laboratory, using, for instance, the nesting material only as an apparent hiding place. Eighty seven per cent of the litters born in captivity were raised to weaning age by wild mothers. The mean litter size was 8.7 with a range of five to twelve.

The other moderately low status wild rat retained for breeding (WR 3) was the only exception to successful pairings. WR 3, who did not acclimitize well, died from infected wounds received in initial mating encounters with WR 4 when he continually refused to show submissive behaviors. More extensive details of the mating behaviors of the study will be outlined in the discussion section.

A mysterious result of the breeding experiment is indicated in Table 1 by the presence of two sets of double asterisks. Two litters were born only 13 or 15 days, respectively, after the weaning of a previous litter. In these as in all cases, the adult male rats were excluded from the female's cage for the entire

period from the date of birth until the removal of that litter, 30 days later.

The four pairings of domestic rats resulted in four litters (mean litter size = 9.0) with a mean delay of 36 days. Two of the three albino-wild matings produced no litters over a period of two months. The third as well as the black-wild pairing was quite fast (27 and 24 days respectively). The hybrid litter sizes were eight for the albino and 14 for the black. Unlike the foster albino mother, none of these domestic rats evidenced abnormal maternal behavior.

The only obviously adverse effect of using wire bottom cages for breeding was a small incidence of "ring-tail" in the wild F_1s (Farris and Griffith,1949).

DISCUSSION

The efficiency of the trapping venture surpassed all original expectations, with captures usually being possible after a wait of only 15 minutes. It must be emphasized, however, that these data do not contradict the findings of more traditional research (e.g., Chitty, 1954; Thompson, 1955) which were primarily concerned with large scale trapping as a control measure in relatively stable environments. The expectations of quick captures and representative selection were presumably both realized. Extensive observations of the

land-fill population indicated a marked social dichotomy as revealed in strict dominance patterns in both sexes, with frequent injuries to the submissive members (e.g., wounds on the back area just above the base of the tail, and severely torn ears). Although specimens of both types were captured, there may have been some over-selection for the high status members in this population. This apparent artifact of an unusual environment is probably related to observations where more dominant rats were seen to exercise priority over submissive rats in approaching the traps. Unlike Calhoun's finding, no wild rats in the land-fill were observed to show behaviors characteristic of "trap shyness". All of the results of the trapping study were essentially replicated in an unpublished study in the spring and early summer of 1966 with the exception being that trapping produced a higher incidence of injured rats.

Several aspects of the behavioral observations made concomitant to the trapping experiment are interesting in their own right. Without exception, the newly trapped wild rats exhibited no obvious reaction to the closed trap, continuing to eat the food (usually along with two or three others on the outside) until the presence of E was noticed. When the trap was raised from the ground, the captive typically reacted by

running around the inside of the trap, squealing loudly, and thrusting its nose in every possible place as if attempting to escape. Careful observations were made with all captives to determine the degree of elimination (defecation and unination) present during the time *S* was in the trap and in the individual cage enroute to the laboratory. The surprising result of this set of observations was that only slight urination and *no* defecation was evidenced. This finding, which should place some restrictions on approaches that relate elimination directly to anxiety (e.g., Broadhurst, 1965), was unequivocally replicated in a more recent trapping study.

The expectation that good breeding success could be obtained with high social status rats appears to have some merit. Of course, the small sample of supposedly lower status rats in this study leaves the question open to further investigation. Two other very important factors in the breeding success may have been the novel system of breeding (i.e., implementing periods of acclimitization and olfactory acquainting, the separate but connected breeding cages, and the monitoring of initial contact) used in this study, and the nature of the whole feral population which was sampled. It could be argued, for instance, that limiting the intensive fighting in the first

meeting helps insure breeding success in wild rats. The description of initial breeding behaviors which follows seems to support the latter contention.

Upon removal of the aluminum doors which blocked the connecting tunnel in the breeding cages, a pattern of remarkably stereotyped behaviors followed (Fig. 2). In most cases, the female took the initiative in crossing over to the other cage. Latencies for crossing ranged from 10 sec. to 2 min. After about a minute of interspersed standing and sniffing, and making hesitant approaches, the male rat made the final approach which terminated in sniffing the female's genitalia (Fig. 2-A). Unless the female was evidently sexually receptive, she would begin kicking off the male with a hind foot while swinging the posterior end of the body (Fig. 2-B). The third and most crucial step in the mating sequence involved the threat behaviors which followed the male

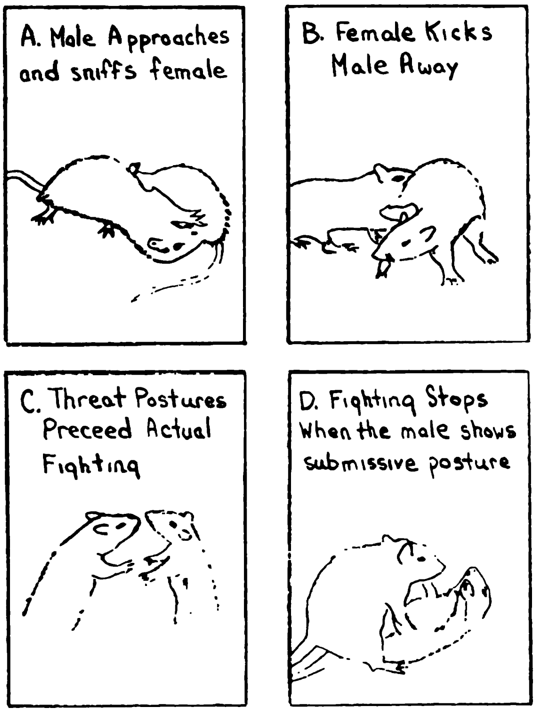

Fig. 2. Typical four-step sequence of initial mating behavior in adult wild rats (in small breeding cages shown in Fig. 1).

rat's refusal to cease attempted genitalia sniffing and mounting (Fig. 2-C). At this point (and in these confined cages) the females were dominant over the males and unless the male assumed a submissive posture (e.g., Fig. 2-D), fighting ensued. Careful monitoring of the doors at this stage prevented extended fighting and presumably heightened the eventual sexual compatibility of breeding pairs. That is, pairs which were separated in the heat of intense fighting rarely resumed fighting to such a degree in later monitored meetings.

The threat behaviors exhibited were generally those of hissing, teeth chattering, sparring postures where the heads and forefeet of the two rats moved in unison, and erected hair in the female. When a fight did occur it was usually short in duration, consisting of much tumbling, squealing, and biting (with the female doing most of the biting), ending when the male assumed a submissive posture. The intensity and frequency of such fights decreased over time for all pairs.

The pairings of domestic rats did not produce most of the postures or behaviors described in the wild rats. For instance, the domestic pairs usually spent most of the time sniffing the cages after the doors were removed. Some moderate instances of the behaviors illustrated in parts A, B, and C of Fig. 2 were observed,

but fighting, erected hair, hissing, or teeth chattering were absent. The wild male-domestic female pairings were more variant. In two cases the domestic females engaged the wild males in fighting, even proving to be dominant on occasion. In the other two cases, the wild male initiated the acquaintances by repeatedly walking over the domestic female. The two females in the latter cases produced the two hybrid litters.

It is assumed that these behaviors in confined cages were highly artifactual but that there is significance for techniques of breeding wild rats in the above observations. Since flight and evasion behaviors are reduced by the small cages (8" x 8" x 13") the behaviors which are then intensified (e.g., fighting) must then be controlled if compatibility is desired.

The relatively good maternal behavior of the five selected wild females also fits with the general hypothesis about using high social versus low social status samples. The one female selected as being representative of moderately low social status was the only wild female in this study to savage or neglect her litters. Here again, the overall success might in part be attributed to maintenance techniques: 1. Cautions were taken to avoid disturbances in the colony room when new litters were present. 2. The wild mothers were given large daily quantities of

peanut butter for the first week of nursing in the hope that they would prefer the peanut butter to eating the pups. In any case, this study indicates that small-scale breeding operations can, in certain situations, result in good productivity in wild rats. Not only did most of the pairings result in matings and fertilization, but the average litter size (mean = 8.7) was similar to that of the domestic pairs in the same situation (mean = 9.0). The maternal behavior of the wild females was, with the exception of WR 8, quite similar to that of the domestic females. The domestic females with hybrid litters showed no unusual maternal behaviors.

In one respect, the wild mothers showed superior maternal care by carefully removing waste materials to the front of the cage--even dropping the bolluses through the food opening at times. Such behaviors were not observed in the domestic mothers. On the other hand, it seemed to be necessary to place a water bottle close to the nest area to induce the wild mothers to drink much water in the first few days after birth. The most obvious difference in maternal behaviors between the two strains was that the wild mothers invariably left the nest and litter in response to a colony room visitor, whereas it was quite difficult to distract the domestic mothers.

The general conclusion of this study on trapping

and breeding is concerned with relevance to theories of mechanisms in domestication. These results seem to suggest that sampling of the feral population as to social types should precede mating and nursing as the stages in which the process of domestication has the most effect. Richter's (1944) hypothesis that laboratory rats become progressively tamer because tame rats breed better in the laboratory avoids the question of why some of the original sample are "tamer". Also, a notion of domestication which starts with considerations of the feral population and assumes proliferation of mostly high social status rats in captivity, does not necessarily equate laboratorization of the Norway rat with degeneration as does Robinson (1965).

CHAPTER II

ADJUSTMENT TO DEPRIVATION AND NONCONTINGENT OPERANT LICKING IN A WILD F_1 AND A DOMESTIC STRAIN OF NORWAY RATS

One important effect of domestication and captivity may be genetic changes in water balance processes (Chew, 1965). Although amounts of water consumed voluntarily in captivity are possibly not good indicators of water needs in nature, the higher ad lib. water intake of emotional as opposed to non-emotional laboratory rats (Siegel and Siegel, 1948) can be interpreted as being relevant to domestication processes. For example, both wild rats and stressed laboratory rats share a tendency toward large adrenal glands and high water intake (Robinson, 1965). Richter and Mosier (1954) found that wild rats apparently have a greater need for water when they ingest various concentrations of salt than do the domestic rats. They attribute the excessive water intake primarily to the larger and more active adrenals of the wild rats. Another factor which probably necessitates increased water intake is the readily observable urine and fecal water loss in rats made emotional. The importance of water intake to the study of domestication is that indices of water balance seem to parallel the important

physiological and emotional changes which distinguish laboratory rats from wild rats.

There are, however, three important detractors to the water intake approach as it now stands: First, there is limited theoretical generality to the hypothesis of Siegel and Siegel (1948) that emotionality in the rat induces thirst. Levine (1958) found that unhandled (more emotional) rats drank significantly less water than handled rats both before and after being shocked. Amsel and Cole (1953) have found evidence for the generalization of fear-producing cues which interfere with water intake, and Beck (1964) has demonstrated inhibition of drinking in rats in the presence of novel stimuli.

Second, the most crucial tests for domestication should involve the comparison of wild rats, and not just stressed domestic rats, in measures of water intake. Only one investigator, Richter (e.g., Richter and Mosier, 1954), has utilized wild rats in studies of water intake. Assuming that dominance is inversely related to emotionality (Scott and Fredericson, 1951), then it is possible that Richter's traditional mode of trapping does not permit generalization to wild rats as a whole (Chapter I). For instance, an unpublished study in this laboratory by R. Almli, G.I. Hatton and the present writer, showed that some wild rats do level off to an _ad lib._ water intake comparable to that of domestic rats

(30-40 ml./day) in less than a month, with initial intake in captivity being only twice that of domestic rats. The latter study employed only a small sample (N = 6 males and 1 female), but it did suggest some promise for the social status hypothesis of this dissertation.

The third detractor is that no wild-type versus domestic comparisons have been made with measures of restricted water intake. Chew (1965) notes that the major source of water for feral mammals is the fluid in the food whereas the major source for domestic mammals is drinking water. It seems that laboratory rats do not "need" all the water they ingest in conditions of free access. Logan (1960) has shown that introducing the contingency of bar pressing reduces water intake even though the rats are required to spend only a moderate amount of time working. Thus, it seems that measuring some form of restricted water intake would give more meaningful results to the study of domestication and water intake needs.

The first portion of this study will be concerned with the ad lib. and time-restricted water intake in a domestic strain (Long Evans non agouti) and a wild F_1 strain as both strains adjust to a deprivation schedule preceeding and concurrent with the licker box study in Chapter III. The second main hypothesis of this dissertation, restated, is that a wild F_1 strain bred

from high social status rats and maintained in a non-stressful situation should not differ markedly from domestic rats in measures of unrestricted and time-restricted water intake. The second hypothesis is based on the observations that truly wild rats do sometimes show a decline in water intake as acclimitization proceeds, and that the parents of the F_1s showed relatively low interference of emotionality in breeding and nursing. The wild F_1 rats are, of course, more emotional than the domestic strain, but it is expected that reducing stress where possible (e.g., no daily weighing) will allow for more reliable water intake measures.

The second portion of this study is concerned with the licking component in the drinking behavior of both strains. The remarkable stereotypy of the domestic rat's licking response has already been discussed, but it is important to note here that two important measures in its study have been neglected: 1. Lick rates when licking is noncontingent upon reinforcement. 2. Lick rates in undomesticated rats. Deviations in either of these measures from the usual rate of 6-7/sec. would have interesting implications for the studies that assume the rat's licking response to be independently constant and species-specific. The expectation is that both of these previously

unreported rates, as measured in the licker boxes, will not differ markedly from the rates found previously. It seems logical that there would be no selection,in the wild or in the laboratory, for different lick rates between strains or for noncontingent situations.

The licking response can also be considered as an operant. In fact, the licking response in the noncontingent situation used in this dissertation has a dual role: First, in terms of total licks per session, much as an operant response on a schedule. Second, as a base rate for the study of anticipatory responses in Chapter III, analogous to spontaneous salivation or blinking (DeBold, Miller and Jensen, 1965). The licking response as a true operant (with response patterns similar to those of VI schedules) preceeds and is superseded by the licking response as a respondent as discriminatory learning occurs in the licker boxes. The licking response in the licker box situation can also be considered as a more general kind of operant where total licks per session would indicate the degree to which both strains "participate" in the licker boxes. The latter conception of an operant will be considered in this chapter as a second type of general drinking behavior in wild F_1 and domestic rats. More specifically, this index of participation deals with the performance problems which are crucial to the learning study in

Chapter III. It is suggested that the wild F_1 rats will be considerably more conservative in terms of total licks per session than the domestic rats even though both strains should show similarities in apparent habituation.

It is also expected that the licking totals for sessions will decrease as discrimination learning proceeds. The decrease, however, should be considerably larger for the domestic strain than for the wild F_1 strain which should start with fewer non-reinforced licks. Lick rate totals should reflect reinforcement conditions in sessions, as for example the frustration in a reacquisition session.

The restricted water intake following experimental sessions should also reflect reinforcement conditions with, for example, intake increasing on extinction days. Although there are no expected strain differences in overall intake during deprivation, the notion of conservativism developed above does suggest probable differences in initial adjustment to the deprivation schedule. Adjustment to a deprivation schedule, which may or may not involve considerable learning (Ghent, 1957; O'Kelly, 1960), should be initially more difficult for the wild F_1 rats, demonstrating the phenomenon which Jacobs calls "psychogenic hypodipsia" (Beck, 1964).

METHOD

Subjects A. Black Strain--These Ss were 32 (16 males, 16 females) experimentally naive, black (non agouti) rats of the Long Evans strain which were relatively inbred as compared to the general stock in this laboratory. The black strain was chosen to represent domestic strains because their eyesight, unlike the albino's, is presumably similar to that of the wild strain, and because previous research (Boice and Denny, 1964) has shown a marked similarity in licker box learning between the black and an albino (Sprague-Dawley) strain. B. Wild F_1 Strain--These Ss were 32 (16 males, 16 females) experimentally naive agouti rats of the F_1 generation in captivity. The details of trapping and breeding in the parent strain are covered in Chapter I of this thesis. F_1s were selected for use in the drinking and learning studies in preference to the wild-caught strain because of advantages in control such as age determination and environmental homogeneity afforded by the former.

Both strains were bred, housed, fed, and maintained using conditions as similar as the two separate colony rooms would allow. All Ss were weaned at the age of four weeks, at which time they were placed in individual cages. In no instance was any S handled by the E, all transfers being effected

mechanically. Both colony rooms had constant lighting and general maintenance activities such as sawdust-changing and water bottle cleaning were done in equal intervals for all S̲s. Neither strain was noticeably afflicted with parasites and general health was excellent except for occasional instances of the mild snuffles (Gollender, 1965) in both colonies.

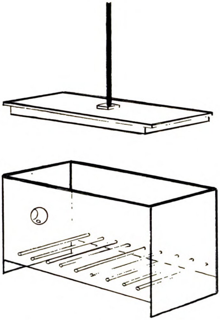

Fig. 3. The plastic licker box with the fitted plastic piston-top.

Apparatus--The apparatus was basically that developed by Weisman (1965), with changes made to allow mechanical insertion of, and to discourage escape by the wild strain. An idealized representation of one of two identical licker boxes is shown in Fig. 3. Each of the plexiglass licker boxes was 8 in. long, with a 1/8 in. stainless steel grid spaced 5/8 in. apart as the floor. The end containing the 1½ in. enclosed drinking well was modified so that its facing was covered with a 1/8 in. aluminum pannel to minimize gnawing by the S̲s. Another modification from Weisman was the pinned,

fitted plastic top which permitted more positive confinement of the S. The top, with its detachable brass push rod also served as the piston in a plastic and masonite chute constructed to permit mechanical transfer of the wild F_1 S from his home cage into the licker box (Fig. 4). During experimentation, each licker box was enclosed in a converted refrigerator to insure some sound insulation. Two matched systems were incorporated to allow the simultaneous conditioning of two animals.

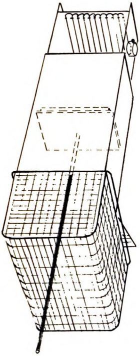

Fig. 4. Transfer chute and plastic licking box (see Weisman, 1965) shown attached to an individual cage in position to remove a wild rat from the apparatus to its living quarters without handling.

Each experimental chamber contained a 60 ft./min. exhaust fan for ventilation purposes and a white noise speaker for masking apparatus clicks. All recording and programming equipment was located in an adjoining room leaving the Skinner water solenoid as the only source of intermittent noise in the experimental chambers.

Water was presented in the licker boxes one drop at a time (.18 ml.), controlled by a Skinner solenoid valve, from a #11 hypodermic needle (ground flat

and smooth) which projected through a small opening in the bottom of the drinking well. A small copper ring encircled this opening to prevent gnawing and measure licking. The CS (which has significance primarily for Chapter III) was a 10 watt bulb wired independently from the other circuitry, and mounted 4 in. from the right side of the drinking well-end of the licker box. The general illumination in the experimental chambers was 5 ft. c.

Licking was measured by Grason-Stadler Lickometers (model E4690A) and transferred via pulse-formers to a Esterline Angus pen recorder (model AW) and to Grason-Stadler counters (model E3700). Appropriate relay circuitry allowed for differentiated pen recording in the ITI and ISI. A Lehigh Valley tape programmer (models 1319FC and 1418) and Hunter Timers (model 111B) were used to provide the temporal intervals. A stepping switch was installed to allow programming of non-reinforced trials. The white noise speakers were also used to transmit a novel stimulus on the last extinction day with a transistorized buzzer (Malis and Curran, 1960) at approximately 30 db.

Procedure--All Ss were maintained on ab lib. Wayne Lab Blox throughout, and with ad lib. tap water until the start of water deprivation. Water intake was measured with inverted 100 ml. cylinders serving as the bottles.

All *S*s were tested starting at the age of 110-120 days, with assignment to experimental groups (CRF vs. PR) random except for matching of sex and litter size.

Both strains of 32 rats were placed on a 23 hr. and 50 min. deprivation schedule 10 days before the start of experimentation. During deprivation and on the three days preceeding, ml. water intake was recorded. Drinking time in deprivation occurred at approximately the same time of day that the later running time of *S*s occurred. Deprivation and measuring continued throughout experimentation in the licker boxes; that is, 10 min. drinking time was allowed after each session.

In the licker box training, all *S*s were first exposed to an habituation session of 50 UCS (water)-only trials presented on a 90 sec. ITI (VI). Subsequently, the two strains were divided into two groups of 16 *S*s each (8 males, 8 females). Groups CRF then received four sessions of 100 continuously reinforced, noncontingent conditioning trials per day. Groups PR next received four sessions of 50% reinforced noncontingent conditioning trials, 100 per day. The sequence of reinforced (R) and nonreinforced trials is shown in Table 2. For all acquisition and extinction sessions, the interval between light onset and the normal time of water presentation on reinforced trials was 2 sec. with a 2 sec. CS overlap (after

Boice and Denny, 1965). The ITI, as in habituation, was 90 sec. VI with a range of 60-120 sec.

Table 2

Sequence of Partial Reinforcement
Used in This Study

Trial	1	2	3	4	5	6	7	8	9	10
Type	NR	R	R	NR	R	NR	R	NR	NR	R
Trial	11	12	13	14	15	16	17	18	19	20
Type	R	NR	R	NR	NR	R	R	NR	NR	R

On the fourth day of experimentation in the licker boxes, all Ss were extinguished (no UCS) to a criterion of 10 successive trials with absolutely no licking responses occurring. The sixth day, in turn, consisted of identical re-extinction (spontaneous recovery) for all Ss, with an intervening 20 min. break with system equipment turned off, and a re-acquisition, for all groups in a standard 100 trial session. The last, and seventh day, of experimentation featured the third extinction to the same criterion for all Ss. An externally inhibiting stimulus, the buzzer replaced the white noise for 24 sec. around the CS and the experimental chamber door was opened coincident to the onset of the CS, was added to this final extinction on the tenth trial therein.

RESULTS

Five different analyses of variance were performed: (1) Ad lib. water intake over three days, (2) water intake on a deprivation schedule over 10 days, (3) restricted water intake following experimental sessions, (4) number of licks per acquisition sessions, and (5) number of licks per extinction sessions.

All differences at or less than the .05 level are considered to be significant (two-tailed).

(1) Ad lib. intake over days.

The mean water intake per day for both sexes and strains appears in Figure 5. A four factor analysis of variance with repeated measures on the last factor (Winer, 1962) was performed. No main effects were found due to strain or to assignment to a reinforcement group (not treated differently until experimentation days). The variable of sex produced a significant effect (F = 11.77, df = 1,56, p = .00) as did days (F = 3.65, df = 1,112, p = .03). The only significant interaction involved days x sex (F = 4.14, df = 2,112, p = .02).

(2) Water intake on a deprivation schedule over 10 days.

The mean water intake per day for both sexes and strains appears in Figure 5. A four factor

Table 3

Analysis of Variance for *Ad Lib.* Water Intake With Strain, Sex, Days, and Future Assignment to Reinforcement Group as Factors

Source	df	Mean Square	*F*	*p*
A (Strain)	1	24.80	.34	.57
B (Reinf. Cond.)	1	.42	.01	.90
C (Sex)	1	854.30	11.77	.00
AB	1	94.92	1.31	.26
AC	1	1.88	.03	.85
BC	1	121.92	1.68	.20
ABC	1	89.38	1.23	.27
Error Between	56	72.60		
D (Day)	2	31.83	3.65	.03
AD	2	.20	.02	.96
BD	2	1.98	.23	.80
CD	2	36.11	4.14	.02
ABD	2	20.92	2.40	.09
ACD	2	9.01	1.03	.36
BCD	2	2.83	.32	.73
ABCD	2	2.41	.28	.76
Error Within	112	8.73		

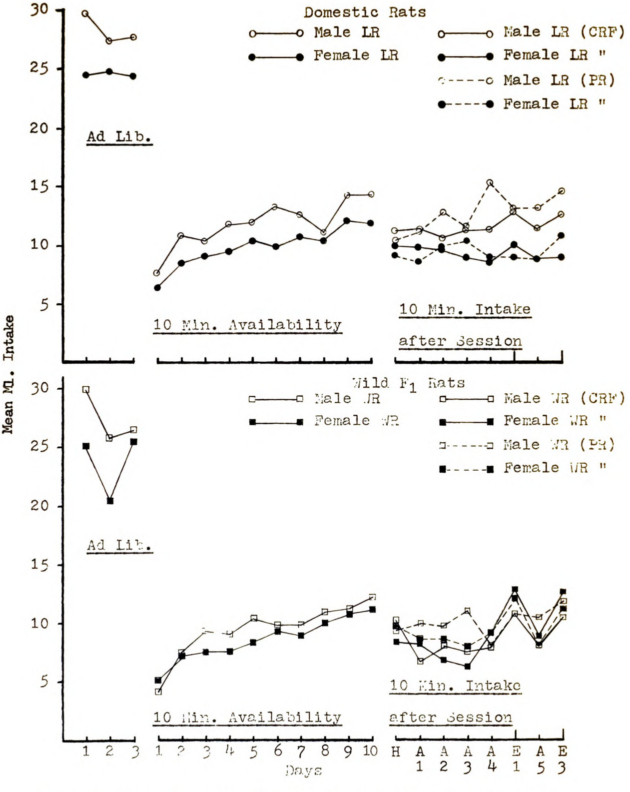

Fig. 5. Mean Ml. water intake in home cage for domestic rats (upper graph) and wild F_1 rats (lower graph) on ad lib., deprivation, and experimental session days.

analysis of variance with repeated measures on the last factor (Winer, 1962) revealed significance for three main effects (strain, F = 9.37, df = 1,56, p = .00; sex, F = 4.05, df = 1,56, p = .05; days, F = 45.65, df = 9,504, p = .00) and no significance for any of the interactions (Table 4).

(3) Restricted water intake following experimental sessions. The mean intake per day for strains, sex, reinforcement condition in experimentation (CRF vs. PR), and days appears in Figure 5. An analysis of variance similar to the above revealed significance for strain (F = 4.48, df = 1,56, p = .04), for sex (F = 7.10, df = 1,56, p = .00) but not for the variable of days (Table 5). The only significant interaction involved strain x days (F = 2.87, df = 7,392, p = .01).

(4) Number of licks per acquisition session. The mean number of licks per acquisition sessions appears in Figure 6. A four factor analysis of variance with repeated measures on the last factor (Winer, 1962) was performed on the data. No main effects due to sex or reinforcement condition (CRF vs. PR) were found (Table 6). The variable of strain was extremely significant (F = 58.63, df = 1,56, p = .00) as was the variable of days (F = 11.74, df = 4,224, p = .00). The only

Table 4

Analysis of Variance for Deprivation Water Intake
With Strain, Sex, Days, and Future Assignment to
Reinforcement Group as Factors

Source	df	Mean Square	*F*	*p*
A (Strain)	1	470.94	9.37	.00
B (Reinf. Cond.)	1	.13	.00	.91
C (Sex)	1	203.63	4.05	.05
AB	1	81.94	1.63	.20
AC	1	28.48	.57	.46
BC	1	.26	.01	.90
ABC	1	165.04	3.28	.09
Error Between	56	50.28		
D (Days)	9	242.71	47.66	.00
AD	9	5.56	1.09	.37
BD	9	7.00	1.37	.20
CD	9	5.71	1.12	.35
ABD	9	6.23	1.22	.28
ACD	9	9.13	1.79	.07
BCD	9	8.98	1.76	.07
ABCD	9	4.28	.84	.58
Error Within	504	5.09		

Table 5

Analysis of Variance for Restricted Water Intake Following Experimental Sessions

Source	df	Mean Square	F	p
A (Strain)	1	225.78	4.48	.04
B (Reinf. Cond.)	1	94.53	1.88	.17
C (Sex)	1	357.78	7.10	.01
AB	1	.50	.01	.88
AC	1	220.50	4.38	.04
BC	1	52.53	1.04	.31
ABC	1	.28	.01	.90
Error Between	56	50.38		
D (Days)	7	60.58	9.73	.00
AD	7	17.89	2.87	.01
BD	7	9.47	1.52	.16
CD	7	4.47	.72	.66
ABD	7	9.04	1.45	.18
ACD	7	7.75	1.25	.28
BCD	7	7.49	1.20	.30
ABCD	7	4.94	.79	.59
Error Within	392	6.22		

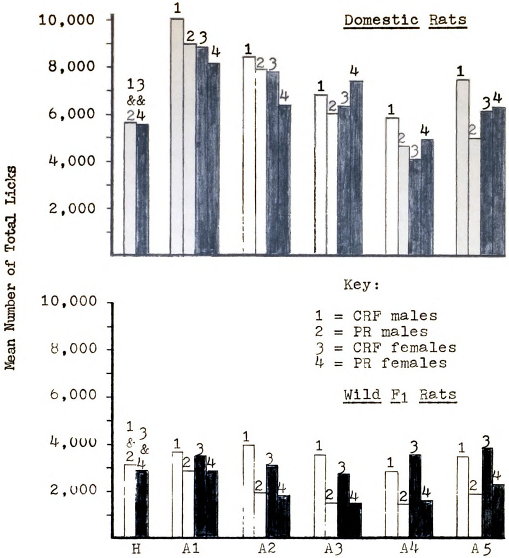

Fig. 6. Mean number of total licks for the habituation session (H) and for the five acquisition sessions(A1...A5) for domestic rats (upper graph) and wild F_1 rats (lower graph).

Table 6

Analysis of Variance of Total Licks in Acquisition Sessions

Source	df	Mean Square	*F*	*p*
A (Strain)	1	1434064269.00	58.63	.00
B (Reinf. Cond.)	1	80440605.00	3.29	.09
C (Sex)	1	2536856.45	.10	.74
AB	1	14301632.81	.58	.45
AC	1	2018348.11	.08	.77
BC	1	12766422.05	.52	.48
ABC	1	6607326.01	.27	.61
Error Between	56	24458158.35		
D (Days)	4	49991556.19	11.74	.00
AD	4	22025568.39	5.17	.00
BD	4	1398337.95	.32	.86
CD	4	3540139.95	.83	.51
ABD	4	2620117.53	.61	.66
ACD	4	2186663.63	.51	.73
BCD	4	1248657.96	.29	.88
ABCD	4	2813761.84	.66	.62
Error Within	224	4257277.40		

interaction with an F value greater than one was that of strain x days ($F = 5.17$, df = 4,224, $p = .00$).

(5) Number of licks per extinction session.

The mean number of licks per extinction sessions appears in Figure 7. An analysis of variance similar to the above analyses (Table 7) revealed significance for only one main effect (strain, $F = 24.59$, df = 1,56, $p = .00$).

There were no apparent differences in habituation to the licker boxes over any of the above factors. Most rats began licking within three minutes after the start of the habituation session. On subsequent training days all Ss began licking within one minute after placement in the apparatus.

The transfer chute (Fig. 4) did not work for the domestic strain because its members invariably refused to run out of their home cage into the chute. They were thus transferred by "dumping" in and out of the licker boxes, without handling. The wild F_1 usually rushed into the transfer chute as soon as the top-piston entered their cage far enough to allow their exit. Although a few of the wild F_1 rats delayed entrance on the first few transfers (especially in the presence of observers), all came to evidence short latencies by the fourth day. The accompanying

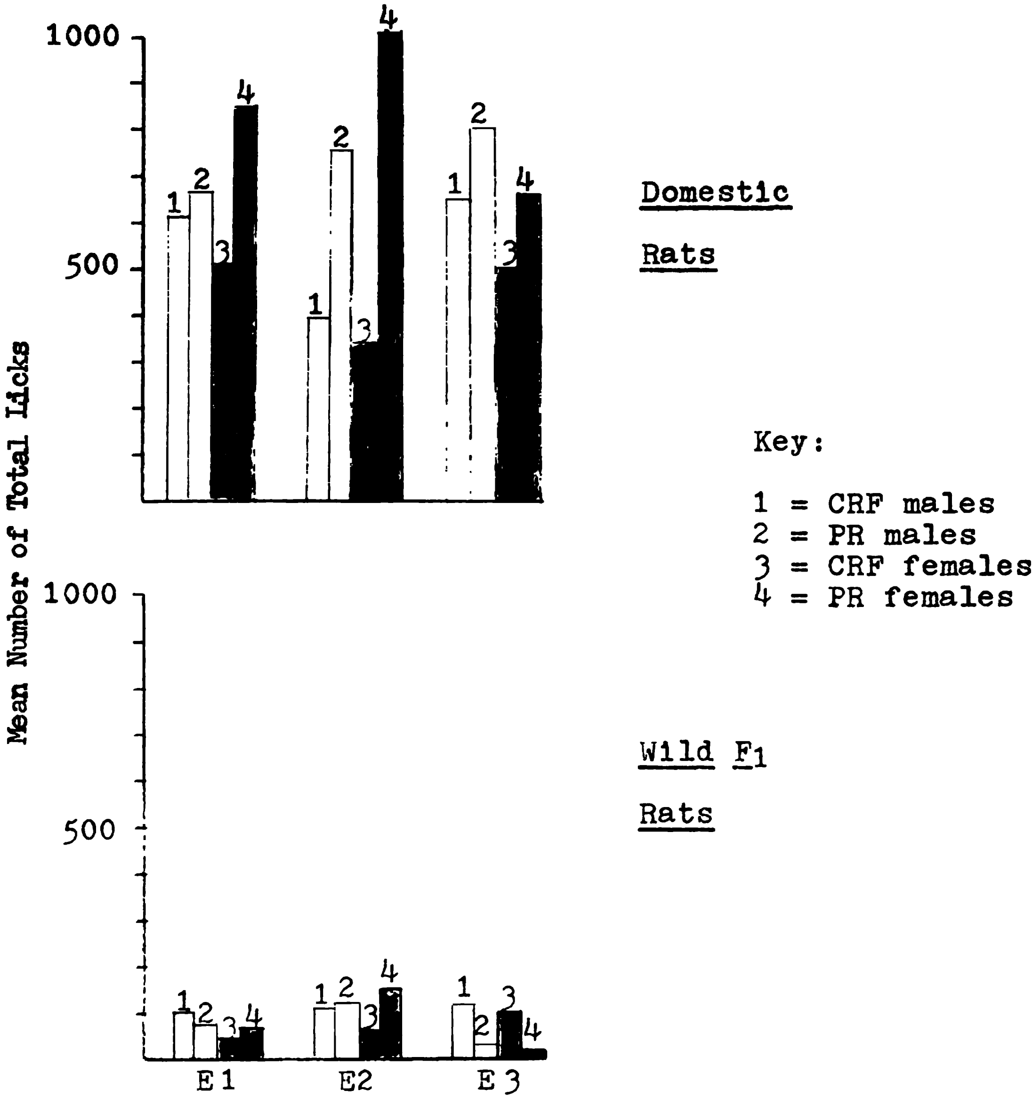

Fig. 7. Mean number of licks for domestic rats (upper graph) and wild F_1 rats (lower graph) during the three extinction sessions.

Table 7

Analysis of Variance of Total Licks in Extinction Sessions

Source	df	Mean Square	F	p
A (Strain)	1	12938671.69	24.59	.00
B (Reinf. Cond.)	1	1378713.02	2.62	.11
C (Sex)	1	40950.08	.08	.77
AB	1	1600525.52	3.04	.10
AC	1	10208.33	.02	.86
BC	1	301150.08	.57	.46
ABC	1	179585.33	.34	.57
Error Between	56	526167.69		
D (Days)	2	17727.77	.16	.85
AD	2	12708.33	.11	.89
BD	2	129500.10	1.15	.32
CD	2	121620.01	1.08	.34
ABD	2	45951.16	.41	.67
ACD	2	130459.69	1.16	.32
BCD	2	6190.69	.05	.94
ABCD	2	2000.51	.02	.97
Error Within	112	112277.51		

emotional reactions in the wild F_1 rats (e.g., squealing, hissing, teeth chattering, elimination, and pressing closely against the cage sides) showed a marked reduction over repetitions. Two of the emotional behaviors shown by some of the wild F_1 rats in the transfer situation are especially noteworthy: First, most of the females, but none of the males, squealed very loudly while still in their home cages as preparations were being made for the transfer. This type of squealing differed from that observed in other situations primarily in terms of pitch, as it resembled the cry of a domestic rat in extreme pain. Second, some of the females crawled across the inside of the top of their home cages with ventral sides down and backs flattened against the top as they moved. No obvious relations between extreme emotionality and measures of intake, licking, habituation, or learning were observed within strain.

Two sets of linear correlations, between the variables of licks during acquisition days and restricted water intake following the sessions (Table 8) and between discriminatory responses (i.e., UCRs) or anticipatory responses (i.e. CRs) and water intake following sessions, were performed. The trend for the relationship between licks in the apparatus and water intake for 10 min. following the session is a

Table 8

Correlations Between Measures of Licks During and Restricted Water Intake Following Acquisition Sessions

Acquisition Day	Variates	Correlation Coefficient
1	Intake Following A1 and Licks in A1	+.29
2	Intake Following A2 and Licks in A2	+.27
3	Intake Following A3 and Licks in A3	+.16
4	Intake Following A4 and Licks in A4	+.15
5	Intake Following A5 and Licks in A5	+.08

regular decrease, starting with a moderate value (r = +.29) and dropping to almost no relationship (r = +.08). The degree to which Ss successfully ingested rewards in the experimental situations had almost no relation to water intake in the 10 min. period of water bottle availability (Table 9).

Lick rates in the experimental situation were determined by counting all licks in four randomly selected groups of two rats (grouped according to reinforcement condition). The lick rates varied between five to nine licks per second, when rates were determined by counting only bursts of licking at least one second long. Neither the mean rate, which was typically six or seven

Table 9

Correlations Between Anticipatory (AR) or Discriminatory (DR) Responses During and Restricted Intake Following Experimental Sessions

Variates	Correlation Coefficient
DRs in A1 and Intake after A1	+.07
DRs in A2 and Intake after A2	-.02
DRs in A3 and Intake after A3	-.04
DRs in A4 and Intake after A4	-.05
DRs in A5 and Intake after A5	-.13
ARs in A1 and Intake after A1	+.09
ARs in A2 and Intake after A2	+.04
ARs in A3 and Intake after A3	+.04
ARs in A4 and Intake after A4	+.00
ARs in A5 and Intake after A5	+.06

licks per second, nor the range was detectably different for either strain over all experimental conditions. Extensive sampling of all other Ss response tapes verified the above finding. Graphs of representative responses for the eight selected rats appear in Appendices A and B.

Discussion

The first theoretically important finding is that rats which are usually considered as being highly emotional and undomesticated do not necessarily show greater water intake than domestic, docile rats. As was predicted, there was no significant difference between the wild F_1s and the Long-Evans blacks in unrestricted water intake. The results of the deprivation study extend the finding of non-excessive drinking by the more "emotional" rats to a restricted availability situation. These data seem to question the very basis of previous uses of water intake as an index of domestication (e.g., Richter and Mosier, 1954). Two questions are relevant at this point: 1. What is emotionality, especially as it distinguishes domesticated from undomesticated rats? 2. In what respect is "thirst" measured by conventional drinking measures such as those in this study?

The area of emotionality is hardly without extensive research consideration (e.g., Farris and Yeakel, 1945; Broadhurst, 1965), but it does seem to lack valid measurement. The instance cited earlier (Chapter 1) of no defecation in newly captured wild rats is a good example. Perhaps limiting even mild stress of the rats in this study produced artifactual results in the case

of the undomesticated rats. On the other hand, what would stressing the wild F_1 rats tell us about "thirst" except that frequent urination and defecation cause an increase in water intake?

The fact that deprivation intake was different from ad lib. does indicate the importance of using both types of measures in strain comparisons, but there are problems of interpretation inherent in both. On unrestricted intake, there is no question that the rat ingests (i.e., activates the recording device) more than is "necessary", (Logan, 1960). The author has observed numerous instances of water drainage from standard inverted bottles when rats leaned against the spout, causing water to run into the fur, or when rats licked on the spouts without ingesting the water. Figure 5 indicates a trend for unusually high intake on the first day of ad lib. drinking. Observations made over the three days of unrestricted intake suggest that, at first, the rats displayed much investigatory behavior, including licking, to the novel graduated cylinder used for measurement purposes.

The sudden switch to time-restricted availability may also mask water "needs" although it does presumably more closely parallel natural conditions for feral strains. Figure 8 depicts two of the deprivation drinking behaviors which seemed to contribute to the deficit in intake shown by the wild F_1 strain. Even

with the observer apparently unnoticed, the deprived wild F_1s approached the water spout after several pauses, as though in an approach-avoidance situation (Fig. 8-A). All the deprived domestic rats were at the spot where the spout was normally placed as the E readied the bottles. Another difference from the domestic strain can be seen in the typical sideward drinking posture of the deprived wild-type rats (Fig. 8-B). The sideward posture seemed to facilitate a fast withdrawal response to the slightest disturbance. Thus, the deficit for the wild F_1 rats may have been dictated more by neophobia than water balance processes.

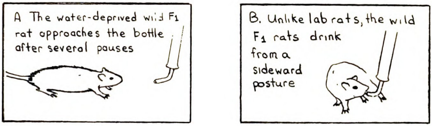

Fig. 8. Typical drinking behaviors of the wild F_1 rats on a severe deprivation schedule.

It was expected that reinforcement conditions (i.e., CRF vs. PR) in the experimental sessions would be reflected in the time-restricted intake which followed. Instead, there were no significant differences between subgroups for the variable of reinforcement condition (Table 5). Also, there does not seem to have been any relationship between measures of water ingestion

in the apparatus and subsequent deprivation intake (Table 9). Whereas the wild F_1 strain showed a direct effect of extinctions on deprivation intake, the domestic rats demonstrated only a trend toward an increase following the third extinction (Fig. 5). The overall lack of clear relationships between these two measures is another example of problems in using water intake as an index of water balance processes. In this case it is possible that the severe time-restriction used (Stellar and Hill, 1952) was unaffected by the additional intake in the apparatus.

The other type of drinking measure used in this study was the noncontingent licking response, considered as a general operant. For one thing, these data (Figs. 6 and 7, Tables 6 and 7) give overwhelming support to the hypothesis that the undomesticated rats would approach an appetitive learning situation with comparative conservatism. These data also point out further problems in interpreting drinking measures. Licking totals were not significantly affected by reinforcement condition; that is, partially reinforced rats licked about as much as continuously reinforced rats. Considering that, with training, more of the rat's licks should become reinforced, then the decreasing positive correlation between session licks and subsequent intake (Table 8) is possibly understandable. The point is that

genetic changes in water balance (Chew, 1965) may be a function of the measures used--of emotionality and of thirst. They may also be more a function of inherited social status than of relative laboratorization. The question of social status as an emotional influence is left open to direct test, but the fact remains that existent theories of domestication can not handle the strain similarities or differences found in this study.

As responses, the rat's licking and drinking behaviors remain as highly desirable phenomena for purposes of study (Stellar and Hill, 1952; Weisman, 1964). It was encouraging for the plight of the supposedly degenerate domestic rat (Robinson, 1965) to find that licking response rate for both the black and the brown rats was identical. The only deviation from the usual range of licking rates listed in the literature (e.g., Davis and Keehn, 1959; Schaeffer and Premack, 1961) was that both strains frequently ranged up to nine, instead of eight licks per second. It is assumed that the noncontingency of most of the licking extended the range to nine. Also encouraging to the licker box study of Chapter III was the comparability of strains in water intake and in habituation to the apparatus.

In sum, this study has attempted to focus on problem areas in approaches which utilize measures of drinking behavior as indices of domestication. The

assumptions that emotionality induces thirst (Siegel and Siegel, 1948) and that undomesticated rats need more water (Richter, 1944) were not substantiated in this study. It appears that previous investigations could have gained theoretical generality through a more careful study of the stimulus aspects of emotionality (i.e., what environmental aspects interact with the genetics of domestication) and of the genetics of the undomesticated sample (i.e., which portion of the feral population is being tested).

CHAPTER III

PATTERNS OF LICKING AS DISCRIMINATORY AND ANTICIPATORY LEARNING IN A WILD F_1 AND A DOMESTIC STRAIN OF NORWAY RATS

The usual result of conditioning procedures is not simply a change in a single response, but rather a modification of the entire behavior pattern given to the reinforcing stimulus (Weisman, 1964). One difference in responding in traditional conditioning paradigms is that operant learning usually involves the extinction of unreinforced responding in the S^{Δ}, while the level of intertrial responding in classical conditioning may differ little from its original level. There are reasons to believe, however, that the processes involved are too inseparable to allow the exclusive study of either type of conditioning (Denny and Adelman, 1955). Thorpe (1956), for instance, contends that Pavlov missed the essential fact of classical conditioning in minimizing and not measuring motor behavior. Even the phenomenon of inhibition of delay can be viewed as an instrumental process which is differentially reinforced by UCS attenuation (Kimmel, 1966).

The three approaches to conditioning the licking response of rats provide an interesting example of the

transitional zone between the traditional techniques of classical and instrumental conditioning. Chronologically, the first originated at Yale University (DeBold, Miller and Jensen, 1965; Miller and DeBold, 1965), and is the most clearly "classical" technique of the three. The crucial factor of the Yale technique is an oral fistula which injects water into the rat's mouth whether or not he is thirsty. The second noncontingent licking technique for rats was developed at the University of Iowa (Deaux and Patten, 1964; Patten and Deaux, 1966). The Iowa technique utilizes an elastically mounted drinking tube which delivers water (the UCS) 1/8 in. in front of the rat's mouth. Although the rat in this second technique is not obligated to respond to each UCS as in the Yale technique, the UCR (licking) can be elicited without the need for gross motor behaviors (instrumental responding) on the part of the S. Elements of UCR consistency and instrumental responding are evidently crucial to "pure" classical conditioning (Kimble, 1961).

The third approach was developed, independently, in this laboratory by Weisman (1964). This technique, which is probably the least "classical" of the three, has demonstrated clear-cut classical conditioning phenomena (Weisman, 1965). Not only is the rat in the Weisman technique not required to respond to UCSs, but he must also maintain a drinking well-oriented posture

if his licking responses are to be reinforced. The advantage of the Weisman technique is that it allows an emphasis of the instrumental aspects which necessarily precede the respondent aspects of noncontingent learning. Traditional conditioning studies tend to minimize operant responding and therefore they neglect the factors which may be the most basic to the noncontingent learning process. That is, they neglect the roles of discrimination and consistent UCR elicitation (Denny and Adelman, 1955), even though the joint establishment of the two phenomena probably mediates anticipatory responses (CRs). For example, if conditioning is to occur to a particular CS, the UCS must be the most prepotent stimulus (consistent elicitor) on every trial (Denny, in press). Given an effective UCS, there are two kinds of discrimination learning necessary to anticipatory responding: First, the elimination of competing responses (i.e., those other than the UCR) to the UCS. Second, the inhibition of UCR-type responses during the ITI. The latter type of discrimination corresponds to the "discriminatory response"(DR) as the term is used in this dissertation. Implicit to the use of the term "discriminatory response" is the assumption that responses to the UCS are not considered as UCRs unless the responses are discrete and follow in close proximity to the UCS

(i.e., reflexive responses to the stimulus). This approach considers UCR-type responses which occur during the ITI to be operants and only UCR-type responses which occur discretely during the CS-UCS interval as anticipatory responses.

The importance of discriminatory, as opposed to operant, licking to the occurrence of CRs was pointed out in an unpublished study in this laboratory conducted by Carol Boice, Loretta Johnston, and the present author in 1965. To insure UCS ingestion, another graduate student, D.J. Zerbolio, had modified the apparatus built by Weisman so that the drops of water (UCSs) would be retained in a brass collar encircling the water delivery tube. Thus, with the Zerbolio modification the UCS was not momentary as in Weisman's study but was available throughout the ITI. The interesting result of the study by Boice, Johnston, and Boice was that no anticipatory responding occurred with the Zerbolio modification, even though the CS signalled the occurrence of the water pulse. Observations of the Ss in this condition revealed that most water pulses were ingested but that the rats would wait until varying times after the UCS to begin licking. It seemed obvious that the rats did not learn to anticipate to the CS for two basic reasons: First, the pattern of responding was operant in the sense that the rat could

be reinforced simply by spacing his responses. Second, the rats did not show good discrete responses to the CS. On the other hand, rats run in the unmodified licker boxes showed a definite trend to "discriminatory" responding which was followed by anticipatory responding to the CS. Both of the apparatus variations produced discrete licking patterns but only the Weisman technique produced CR- or UCR-type responses in strict contiguity with the UCS. The differences in learning styles between the two techniques held true over a variety of CS-UCS intervals.

The Boice, Johnston, and Boice study not only cast doubt on Zerbolio's contention that his modification rendered the Weisman technique more "classical", but it also pointed out the role of "discriminatory" licking (DRs) in preceding and mediating anticipatory responding (ARs). The most important observation was that conditioning took place in two stages, DRs and then ARs. These are stages which probably operate in all types of noncontingent learning situations but usually with conditions (e.g., UCS control) necessitating a fast transition into the second stage (e.g., Voeks, 1954).

The first hypothesis of this chapter is that the rats will show consistent <u>anticipatory responding</u> to the CS (in the Weisman technique) only after consistent <u>discriminatory responding</u> has been well established. In

addition, it is expected that discriminatory responding is facilitated by overt mediating chains during the ITI (e.g., Laties, et al., 1965).

Basic to the two-stage approach is the assumption that processes of inhibition and then disinhibition are involved. It seems that the mechanism of discriminatory responding involves the inhibition of operant licking in a noncontingent situation. Operant licking in a truly instrumental situation is excitatory (i.e., non-inhibitory) to the extent that each lick is reinforced. In a noncontingent situation, it is expected that inhibition would operate until the lick bursts are few enough and discrete enough (i.e., good UCRs) that most licks would be reinforced. When the lick bursts are mostly reinforced, then it is assumed that excitation re-enters, causing the lick response which is already controlled by the CS overlap to anticipate to the CS. Lockhart and Grings (1964) have evidence which indicates that test trial responses occur first in the UCR region and then in the CR region. They suggest that the second response (the UCR) is more basic than first interval discrimination.

Inhibition of delay in the licking response has already been observed (Boice and Denny, 1965), a fact which seems to provide further evidence for the operation of inhibition in the Weisman technique. As

anticipatory responding to the CS is mostly unrewarded, inhibition delays the CR to a point where it is most compatible with the UCR (Kimmel, 1966). An approach to noncontingent learning which has notions similar to the one being developed here is that of Colavita (1965). Colavita assumes that the UCR in classical salivary conditioning has two components: 1. A reflex mechanism whereby the UCS reliably evokes the UCR. 2. An intensifying mechanism that magnifies the emotional consequences of a CS-UCS pairing. Colavita's first component is analogous to the discriminatory stage, and the second analogous to the anticipatory (excitatory) stage of the two stage approach to conditioned licking. Lovejoy's (1966) two-stage approach of attention and then choice for the Overlearning Reversal Effect also seems to be roughly analogous to discrimination and then anticipation.

An example of the discrimination and anticipation stages can be seen in a two-way shuttlebox. Initially, the rat only escapes the shock with some delay. Discrimination seems to consist of inhibiting responses other than those which lead the animal to the non-shock area. Once discriminatory responding is well established (minimal escape latencies), then the rat begins anticipating to the CS (avoidance responses).

In addition to the novel approach to conditioning

offered by the two stage approach, there should also be especial significance in an inhibitory-excitatory technique for use in studying undomesticated rats. It has already been established that wild F_1 rats show a more conservative approach to appetitive learning situations (Stone, 1932). The conservatism in the wild rats' licking response (Chapter II) is assumed to be an indication that the feral strain is more likely to respond in a consistently inhibitory rather than in an inhibitory <u>and</u> excitatory manner as compared to domestic rats. The third major hypothesis of this dissertation, restated, is that the primary difference in the patterns of learning to lick will occur in inhibitory versus excitatory styles. That is, it is expected that both strains, the wild F_1 and the domestic, will learn the discriminatory (inhibitory) stage equally fast, but that the wild F_1 strain will be considerably slower in showing anticipatory (excitatory) responses.

Several independent variables will be employed in the learning study to allow the observation of inhibitory and excitatory processes in both strains. Long acquisition sessions (100 trials per day), for example, should allow for ample habituation and intrasession decrements which are common to extended noncontingent training (Pavlov, 1927; Runquist and Muir,

1965). Further, five successive 100 trial acquistion sessions will be given to all Ss, far beyond the time that should be required for both DRs and ARs to develop (Patten and Deaux, 1966).

Three extinction sessions will be interjected into the learning study for various reasons: First, extinction measures will be used as indices of the learning processes. Second, one extinction session will look at inhibition in terms of spontaneous recovery and another session in terms of disinhibition. Third, it is expected that the wild F_1 rats will be more conservative in extinction, showing less resistance to extinction than the domestic rats. A reacquisition which follows two extinctions will also measure spontaneous recovery as will as excitatory responding following extensive frustration.

Another important parameter in the study of wild-type versus domestic learning is partial reinforcement. Half of the Ss in each strain will receive 50% partial reinforcement schedules and half CRF in still another lock at inhibition, as generated perhaps by the nonreinforced trials (Runquist, 1963) or perhaps across all trials (Boice and Boice, 1966).

Method

Subjects--This study used the two strains of 32 rats

each described in Chapter II.

Apparatus--See Chapter II for the description and illustrations of the apparatus used in this study.

Procedure--Chapter II lists all essential details of the procedure used in this study except to mention that during various portions of the learning experiment, the E observed and recorded Ss' behavior through a plexiglass window in the experimental chamber. When observations were being made, room lights were turned off and a cover was removed from the plexiglass window. There was no apparent evidence that the rats detected E's presence during this operation.

Results

Seven different analyses of variance were performed: (1) Discriminatory responses in habituation, (2) Anticipatory responses in habituation, (3) Discriminatory responses over five acquisition sessions, (4) Anticipatory responses over five acquisition sessions, (5) Discriminatory responses in extinction, (6) Anticipatory responses in extinction, and, (7) Trials to extinction criterion. Grouped data from all of the above analyses of variance appear graphically in Figures 9, 10, and 11.

All differences at or less than the .05 level are considered to be significant (two-tailed).

(1) DRs in habituation.

A four factor analysis of variance with repeated measures on the last factor (Winer, 1962) was performed (Table 10). No significant main effects were found for sex, future assignment to reinforcement groups, or trial blocks. The variable of strain was highly significant ($\underline{F}$ = 33.92, df = 1,56, $\underline{p}$ = .00). The only significant interaction involved strain x sex ($\underline{F}$ = 6.94, df = 1,56, $\underline{p}$ = .01).

(2) ARs in habituation.

A four factor analysis of variance with repeated measures on the last factor (Winer, 1962) was

performed (Table 11). There were no significant main effects for sex, future assignment to reinforcement groups or trial blocks. The variable of strain produced the only significant F value in this analysis (F = 7.56, df = 1,56, p = .01).

(3) DRs in acquisition.

A five factor analysis of variance with repeated measures on the last two factors (Winer, 1962) was performed (Table 12). Only one main variable, sex, did not produce a significant effect. There were main effects due to strain (F = 23.60, df = 1,56, p = .00), to reinforcement condition (F = 76.70, df = 1,56, p = .00), to days (F = 199.81, df = 4, 2744, p = .00), and to trial blocks within sessions (F = 30.92, df = 9,2744, p = .00). There were significant interactions involving the variables of strain x days (F = 8.09, df = 4,2744, p = .00), reinforcement condition x days (F = 26.40, df = 4, 2744, p = .00), reinforcement condition x trial blocks (F = 6.18, df = 9,2744, p = .00), sex x trial blocks (F = 1.91, df = 9,2744, p = .05), days x trial blocks (F = 1.78, df = 36,2744, p = .00), strain x reinforcement condition x days (F = 7.75, df = 4,2744, p = .00), strain x reinforcement condition x trial blocks (F = 9.08, df = 4,2744, p = .00), reinforcement condition x sex x days (F = 2.68, df = 4,2744, p =.03), and strain

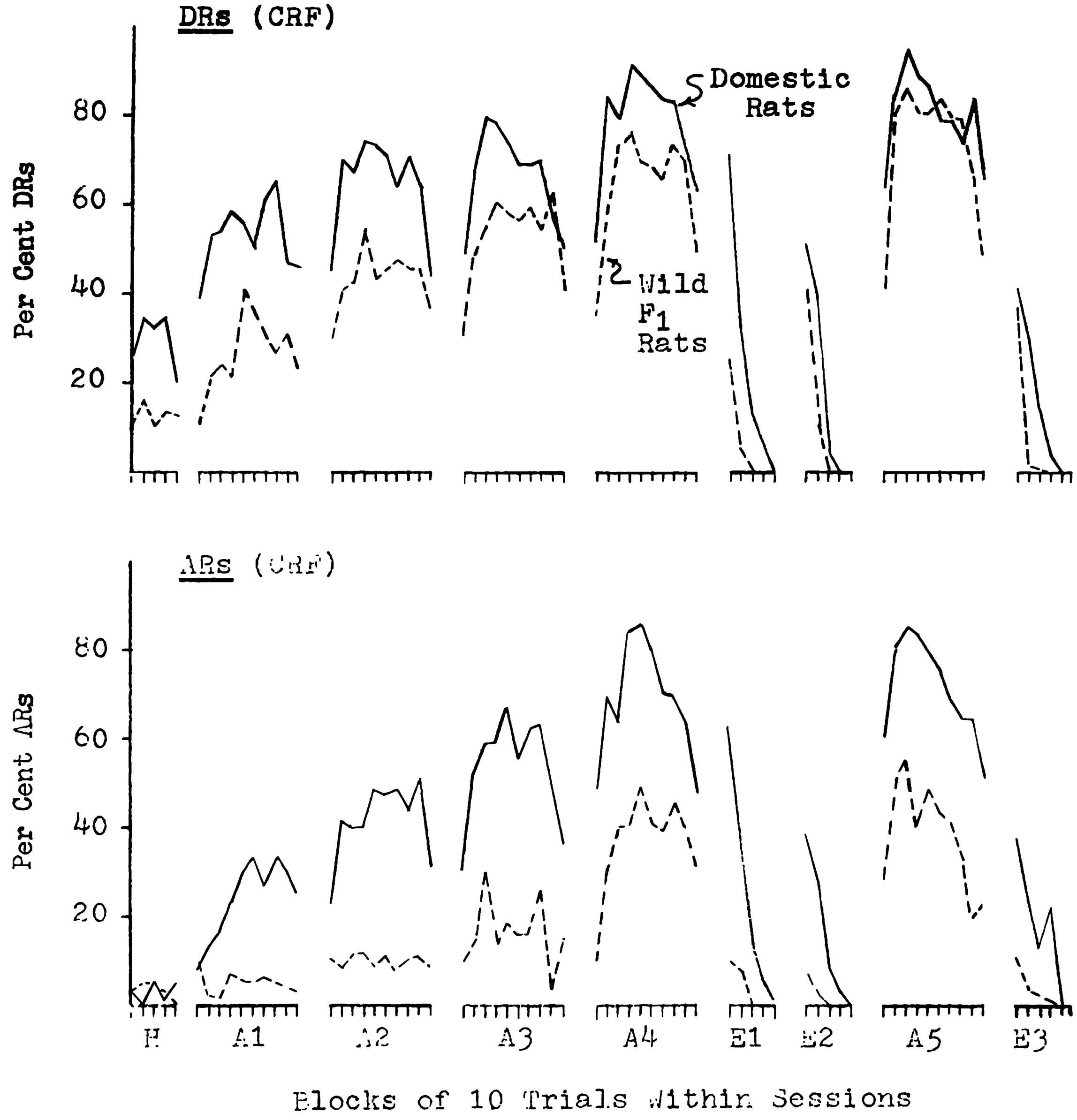

Fig. 9. Acquisition and extinction curves for the wild F_1 and domestic strains in the continuous reinforcement condition.

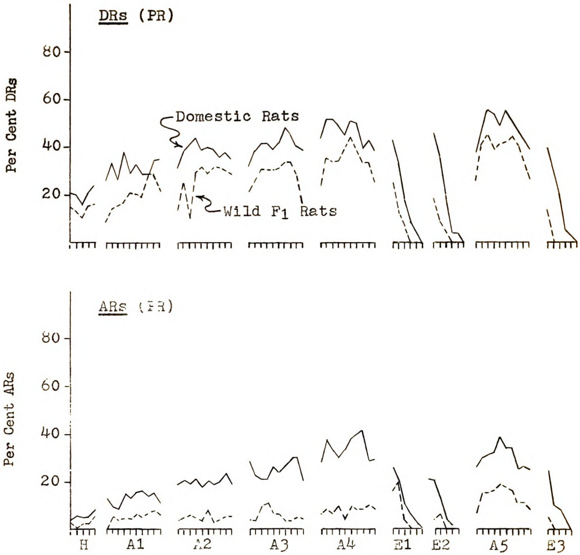

Fig. 10. Acquisition and extinction curves for the wild F_1 and domestic strains in the partial reinforcement condition.

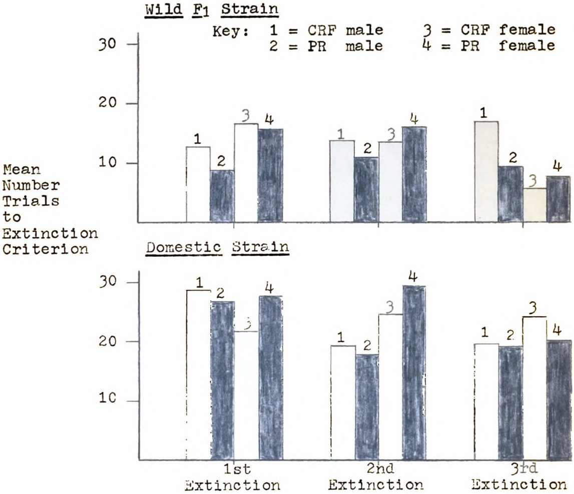

Fig. 11. Mean trials to the extinction criterion (excluding the ten no-response criterion trials) for the wild F_1 and domestic strains over three extinction sessions.

Table 10

Analysis of Variance for Discriminatory
Responses During Habituation

Source	df	Mean Square	F	p
A (Strain)	1	88.20	33.92	.00
B (Reinf. Cond.)	1	4.05	1.58	.21
C (Sex)	1	7.20	2.77	.10
AB	1	5.00	1.92	.17
AC	1	18.05	6.94	.01
BC	1	1.80	.69	.41
ABC	1	2.45	.94	.34
Error Between	56	2.60		
D (Trial Blocks)	4	3.86	1.91	.11
AD	4	.77	.38	.82
BD	4	3.43	1.69	.15
CD	4	2.07	1.02	.40
ABD	4	1.32	.65	.63
ACD	4	.79	.39	.82
BCD	4	.73	.36	.84
ABCD	4	.79	.39	.82
Error Within	224	2.03		

Table 11

Analysis of Variance for Scored Anticipatory Responses in Habituation

Source	df	Mean Square	F	p
A (Strain)	1	4.28	7.56	.01
B (Reinf. Cond.)	1	1.38	2.44	.12
C (Sex)	1	.00	.01	.90
AB	1	1.38	2.44	.12
AC	1	.25	.45	.51
BC	1	1.13	1.99	.16
ABC	1	.38	.67	.42
Error Between	56	.57		
D (Trial Blocks)	4	.52	1.03	.39
AD	4	.18	.37	.83
BD	4	.68	1.34	.25
CD	4	.16	.32	.87
ABD	4	.50	1.00	.41
ACD	4	.46	.91	.46
BCD	4	.85	1.69	.15
ABCD	4	.14	.29	.89
Error Within	224	.50		

Table 12

Analysis of Variance of Discriminatory Responses over the Five Acquisition Sessions

Source	df	Mean Square	F	p
A (Strain)	1	1613.12	23.60	.00
B (Reinf. Cond.)	1	5242.88	76.70	.00
C (Sex)	1	.10	.00	.92
AB	1	50.50	.74	.39
AC	1	24.50	.36	.56
BC	1	68.44	1.01	.32
ABC	1	223.66	3.27	.08
Error Between	56	68.35		
D (Days)	4	746.17	199.81	.00
E (Trial Blocks)	9	115.45	30.92	.00
AD	4	30.21	8.09	.00
BD	4	98.62	26.41	.00
CD	4	6.68	1.79	.13
AE	9	3.29	.88	.54
BE	9	23.08	6.18	.00
CE	9	7.14	1.91	.05
DE	36	6.67	1.78	.00
ABD	4	28.97	7.76	.00
ABE	9	2.44	.65	.75
ACD	4	33.92	9.08	.00

Table 12 (cont.)

Source	df	Mean Square	F	p
ACE	9	3.28	.88	.54
ADE	36	2.63	.70	.91
BCD	4	10.02	2.68	.03
BCE	9	1.81	.48	.89
BDE	36	2.77	.74	.87
CDE	36	1.94	.52	.99
ABCD	4	16.37	4.38	.00
ABCE	9	4.25	1.14	.33
BCDE	36	2.31	.62	.96
ACDE	36	2.97	.79	.80
ABDE	36	2.63	.70	.91
ABCDE	36	3.67	.98	.50
Error Within	2744	3.73		

Table 13

Analysis of Variance of Anticipatory
Responses over the Five Acquisition Sessions

Source	df	Mean Square	F	p
A (Strain)	1	4179.27	83.88	.00
B (Reinf. Cond.)	1	3226.05	64.75	.00
C (Sex)	1	66.41	1.33	.25
AB	1	342.57	6.88	.01
AC	1	199.50	4.00	.06
BC	1	43.48	.87	.36
ABC	1	130.01	2.61	.11
Error Between	56	49.82		
D (Days)	4	875.60	308.54	.00
E (Trial Blocks)	9	49.75	17.53	.00
AD	4	52.52	18.51	.00
BD	4	229.10	80.73	.00
CD	4	5.14	1.81	.12
AE	9	11.12	3.92	.00
BE	9	23.35	8.23	.00
CE	9	7.57	2.67	.00
DE	36	6.16	2.17	.00
ABD	4	8.87	3.12	.01
ABE	9	7.23	2.55	.01
ACD	4	11.73	4.13	.00

Table 13 (cont.)

Source	df	Mean Square	F	p
ACE	9	2.57	.91	.52
ADE	36	1.94	.68	.92
BCD	4	12.13	4.28	.00
BCE	9	3.67	1.29	.23
BDE	36	4.32	1.52	.02
CDE	36	2.11	.74	.87
ABCD	4	8.61	3.03	.02
ABCE	9	1.22	.43	.92
BCDE	36	1.39	.49	1.00
ACDE	36	1.93	.68	.93
ABDE	36	2.45	.86	.70
ABCDE	36	1.49	.52	.99
Error Within	2744	2.84		

Table 14

Analysis of Variance for Discriminatory Responses During All Extinction Sessions

Source	df	Mean Square	F	p
A (Strain)	1	345.63	45.93	.00
B (Reinf. Cond.)	1	8.86	1.18	.28
C (Sex)	1	2.82	.37	.55
AB	1	8.51	1.13	.29
AC	1	12.29	1.63	.20
BC	1	29.07	3.86	.06
ABC	1	.15	.02	.86
Error Between	56	7.52		
D (Days)	2	13.18	8.80	.00
E (Trial Blocks)	5	460.32	307.47	.00
AD	2	4.21	2.81	.06
BD	2	1.19	.80	.46
CD	2	3.20	2.14	.12
AE	5	55.85	37.30	.00
BE	5	22.46	15.00	.00
CE	5	.79	.53	.76
DE	10	3.10	2.07	.02
ABD	2	10.72	7.16	.00
ABE	5	1.92	1.28	.27
ACD	2	.32	.21	.81

Table 14 (cont.)

Source	df	Mean Square	*F*	*p*
ADE	10	1.78	1.19	.29
ACE	5	4.00	2.67	.02
BCD	2	.88	.58	.56
BCE	5	3.49	2.33	.04
BDE	10	.51	.34	.97
CDE	10	2.25	1.50	.13
ABCD	2	2.05	1.37	.25
ABCE	5	2.67	1.78	.11
BCDE	10	.61	.40	.94
ACDE	10	.73	.49	.90
ABDE	10	3.98	2.66	.00
ABCDE	10	.16	.11	1.00
Error Within	952	1.50		

Table 14 (cont.)

Source	df	Mean Square	F	p
ADE	10	1.78	1.19	.29
ACE	5	4.00	2.67	.02
BCD	2	.88	.58	.56
BCE	5	3.49	2.33	.04
BDE	10	.51	.34	.97
CDE	10	2.25	1.50	.13
ABCD	2	2.05	1.37	.25
ABCE	5	2.67	1.78	.11
BCDE	10	.61	.40	.94
ACDE	10	.73	.49	.90
ABDE	10	3.98	2.66	.00
ABCDE	10	.16	.11	1.00
Error Within	952	1.50		

Table 15

Analysis of Variance for Anticipatory Responses During All Extinction Sessions

Source	df	Mean Square	F	p
A (Strain)	1	286.00	54.89	.00
B (Reinf. Cond.)	1	23.92	4.59	.04
C (Sex)	1	6.42	1.23	.27
AB	1	15.12	2.90	.09
AC	1	12.50	2.39	.13
BC	1	25.68	4.92	.03
ABC	1	1.00	.19	.67
Error Between	56	5.21		
D (Days)	2	11.70	11.73	.00
E (Trial Blocks)	5	148.32	148.67	.00
AD	2	4.67	4.68	.01
BD	2	.66	.66	.52
CD	2	2.61	2.61	.07
AE	5	57.42	57.56	.00
BE	5	14.86	14.89	.00
CE	5	1.43	1.43	.21
DE	10	2.86	2.86	.00
ABD	2	6.15	6.16	.00
ABE	5	9.38	9.40	.00
ACD	2	.78	.79	.46

Table 15 (cont.)

Source	df	Mean Square	F	p
ACE	5	1.89	1.89	.09
ADE	10	.98	.98	.46
BCD	2	1.03	1.03	.36
BCE	5	2.09	2.09	.06
BDE	10	.90	.91	.53
CDE	10	.73	.73	.70
ABCD	2	.82	.83	.44
ABCE	5	.60	.60	.70
BCDE	10	.76	.76	.67
ACDE	10	.23	.23	.99
ABDE	10	1.63	1.63	.09
ABCDE	10	.42	.42	.93
Error Within	952	1.00		

Table 16

Analysis of Variance of Trials to Extinction Criterion (Excluding 10 Criterion Trials) For All Extinctions

Source	df	Mean Square	*F*	*p*
A (Strain)	1	5852.08	31.76	.00
B (Reinf. Cond.)	1	123.52	.67	.42
C (Sex)	1	16.33	.09	.76
AB	1	67.69	.37	.55
AC	1	56.33	.31	.59
BC	1	285.19	1.55	.22
ABC	1	17.52	.10	.75
Error Between	56	184.28		
D (Days)	2	328.32	5.62	.00
AD	2	56.26	.96	.39
BD	2	206.10	3.53	.03
CD	2	46.72	.80	.46
ABD	2	364.33	6.24	.00
ACD	2	13.97	.24	.79
BCD	2	8.17	.14	.87
ABCD	2	88.01	1.51	.22
Error Within	112	58.41		

Table 17

Mean Number of Trials Without Responding Following the Novel Stimulus in the Third Extinction

Group	Number of Trials Without Responding											
	0	1	2	3	4	5	6	7	8	9	10	10+
LR CRF	1	3	5	0	2	1	2	1	0	0	0	1
LR PR	1	1	1	5	3	2	2	0	0	0	0	1
WRF_1 CRF	0	0	0	0	0	1	3	0	0	0	0	12
WRF_1 PR	0	0	0	0	0	1	0	0	0	0	1	14

x reinforcement condition x sex x days (*F* = 9.08, df = 4,2744, *p* = .00).

(4) ARs in acquisition.

A five factor analysis of variance with repeated measures on the last two factors (Winer, 1962) was performed (Table 13). All main effects except sex were significant: Strain (*F* = 83.88, df = 1,56, *p* = .00), reinforcement condition (*F* = 64.75, df = 1,56, *p* = .00), days (*F* = 308.54, df = 4,2744, *p* = .00), and trial blocks (*F* = 17.53, df = 9,2744, *p* = .00). There were significant interactions involving the variables of strain x reinforcement condition (*F* = 6.88, df = 1,56, *p* = .01), strain x days

Table 18

Correlations Between Anticipatory (AR) and Discriminatory (DR) Responses in Acquisition Sessions (A1....A5)

Variates	Correlation Coefficient
ARs in A1 and DRs in A1	+.75
ARs in A2 and DRs in A2	+.66
ARs in A3 and DRs in A3	+.74
ARs in A4 and DRs in A4	+.76
ARs in A5 and DRs in A5	+.82

(F =18.51, df = 4,2744, p = .00), reinforcement condition x days (F = 80.73, df = 4,2744, p = .00), strain x trial blocks (F = 3.92, df = 9,2744, p = .00), reinforcement condition x trial blocks (F = 8.23, df = 9,2744, p = .00), sex x trial blocks (F = 2.67, df = 9,2744, p = .00), days x trial blocks (F = 2.17, df = 36,2744, p = .00), strain x reinforcement condition x days (F = 3.12, df = 4,2744, p = .01), strain x reinforcement condition x trial blocks (F = 2.55, df = 9,2744, p = .01), strain x sex x days (F = 4.13, df = 4,2744, p = .00), sex x reinforcement condition x days (F = 4.28, df = 4,2744, p = .00), and strain x reinforcement condition x sex x days (F = 3.03, df = 4,2744, p = .02).

Table 19

Correlations Between Measures of Discriminatory (DR) or Anticipatory (AR) Responses and Total Licks Within Acquisition Sessions (A1...A5)

Variates	Correlation Coefficient
DRs in A1 and Total Licks in A1	+.26
DRs in A2 and Total Licks in A2	+.31
DRs in A3 and Total Licks in A3	+.32
DRs in A4 and Total Licks in A4	+.37
DRs in A5 and Total Licks in A5	+.27
ARs in A1 and Total Licks in A1	+.27
ARs in A2 and Total Licks in A2	+.39
ARs in A3 and Total Licks in A3	+.44
ARs in A4 and Total Licks in A4	+.42
ARs in A5 and Total Licks in A5	+.41

(5) DRs in extinction.

A five factor analysis of variance with repeated measures on the last two factors (Winer, 1962) was performed (Table 14). The three significant main effects were strain (*F* = 45.93, df = 1,56, *p* = .00), days (*F* = 8.80, df = 2,952, *p* = .00), and trial blocks (*F* = 307.47, df = 5,952, *p* = .00). The six significant interactions involved the variables of sex x days (*F* = 37.30, df = 5,952, *p* .00),

Table 20

Correlations Between Discriminatory Responses (DRs) or Anticipatory Responses (ARs) or Total Licks Per Session and Number of Trials to Extinction

Acq. Session	Ext. Session	Variates	Correlation Coefficient
A4	E1	DRs in A4 and Trials to Criterion in E1	+.26
A4	E2	DRs in A4 and Trials to Criterion in E2	+.12
A5	E3	DRs in A5 and Trials to Criterion in E3	+.43
A4	E1	ARs in A4 and Trials to Criterion in E1	+.43
A4	E2	ARs in A4 and Trials to Criterion in E2	+.15
A5	E3	ARs in A5 and Trials to Criterion in E3	+.63
A4	E1	Licks in A4 and Trials to Criterion in E1	+.36
A4	E2	Licks in A4 and Trials to Criterion in E2	+.44
A5	E3	Licks in A5 and Trials to Criterion in E3	+.46

reinforcement condition x trial blocks (*F* = 15.00, df = 5,952, *p* = .00), days x trial blocks (*F* = 2.07, df = 10,952, *p* =.02), strain x reinforcement condition x days (*F* = 7.16, df = 2,952, *p* = .00),

Table 21

Correlations Between Anticipatory Responses in the Fourth Acquisition Session and Trials to Criterion in the First Extinction Session

Group	N	Correlation Coefficient
Domestic CRF Males	8	+.30
Domestic PR Males	8	+.67
Domestic CRF Females	8	+.06
Domestic PR Females	8	+.87
Wild F_1 CRF Males	8	+.53
Wild F_1 PR Males	8	+.42
Wild F_1 CRF Females	8	+.06
Wild F_1 PR Females	8	+.29

strain x sex x trial blocks (<u>F</u> = 2.67, df = 5,952, <u>p</u> = .02), and reinforcement condition x sex x trial blocks (<u>F</u> = 2.33, df = 5,952, <u>p</u> = .04).

(6) ARs in extinction.

A five factor analysis of variance with repeated measures on the last two factors (Winer, 1962) was performed (Table 15). All main effects except sex were significant: Strain (<u>F</u> = 54.89, df = 1,56, <u>p</u> = .00), reinforcement condition in acquisition

(*F* = 4.59, df = 1,56, *p* = .04), days (*F* = 11.73, df = 2,952, *p* = .00), and trial blocks (*F* = 148.67, df = 5,952, *p* = .00). There were significant interactions involving the variables of reinforcement condition x sex (*F* = 4.92, df = 1,56, *p* = .03), strain x days (*F* = 4.86, df = 2,952, *p* = .01), strain x trial blocks (*F* = 57.56, df = 5,952, *p* =.01), sex x trial blocks (*F* = 14.89, df = 5,952, *p* = .00), days x trial blocks (*F* = 2.86, df = 10,952, *p* = .00), strain x reinforcement condition x days (*F* = 6.16, df = 2,952, *p* = .00), and strain x reinforcement condition x trial blocks (*F* = 9.40, df = 5,952, *p* =.00).

(7) Number of trials to extinction criterion. A four factor analysis of variance with repeated measures on the last factor (Winer, 1962) was performed (Table 16). Two of the main effects were significant: Strain (*F* = 31.76, df = 1,56, *p* = .00), and days (*F* = 5.62, df = 2,112, *p* = .00). There were significant interactions involving the variables of reinforcement condition x days (*F* = 3.53, df = 2,112, *p* = .03), and strain x reinforcement conditions x days (*F* = 6.23, df = 2,112, *p* = .00).

The dependent variable of number of trials without responding following the novel stimulus during the third extinction (Table 17) was not subjected to an analysis of variance because of the obvious difference

between strains.

Four different sets of linear correlations were performed: (1) Between discriminatory and anticipatory responses within acquisition sessions, (2) Between discriminatory or anticipatory responses and total licks in the same acquisition sessions, (3) Between discriminatory responses,or anticipatory responses, or total licks per session and number of trials to extinction criterion, and (4) Between anticipatory responses in the fourth acquisition session and trials to criterion in the first extinction session, with a break-down for strain x reinforcement condition x sex groups.

(1) DRs vs. ARs within sessions (Table 18).

The correlation coefficients ranged between +.66 on the second day of acquisition and +.82 on the fifth day of acquisition. There were, however, no outstanding trends over sessions, with the $\underline{r}$ usually being high (around +.75).

(2) DRs or ARs vs. within session lick totals (Table 19).

The correlation between measures of DRs and accompanying lick totals did not vary greatly or systematically over sessions (range = +.26 to +.37). The $\underline{r}$s for ARs and licks were more systematic (range = +.27 to +.44).

(3) DRs or ARs or total session licks vs. number of trials

to extinction criterion (Table 20). All of the correlations were moderately positive with only ARs and DRs on the fourth day being rather poor predictors of resistance to eyinction in the second extinction ($\underline{r}$ = +.12, $\underline{r}$ = +.15). The best predictor of resistance to extinction was ARs in reacquisition ($\underline{r}$ =+63). Because, however, the second and third extinctions are somewhat contaminated by the additional learning (e.g., DRs) which occurs in the conditioned licking technique during extinction sessions, ARs in the fourth acquisition and trials to the first extinction criterion ($\underline{r}$ = +.43) have been selected for a consideration of a possible covariance to compensate for strain differences in learning (Figs. 9 and 10). The appropriate breakdown of that general correlation follows.

(4) ARs in A4 and trials to criterion in E1 (Table 21). The general correlation between ARs in A4 and resistance to extinction in E1 from Table 20 ($\underline{r}$ = +.43) is reflected in all the small subgroups (N = 8 per group) except for the CRF females in both strains.

The problem is whether or not an analysis of covariance would properly adjust ARs and afford an "unbiased" estimate of the first extinction measure of

trials to criterion. Winer (1962) lists two reasons why a graphical rather than a covariance analysis would be preferable in this situation: First, the positive correlation between the covariate and the variate should reduce the error mean square between and thus increase the already highly significant strain difference (Table 16, Fig. 11). Second, in cases where differences between the covariate means (Fig. 9 and 10) are relatively large, an analysis of covariance is not based on statistically sound principles.

Discussion

The general trend of the results in the learning study is compatible with predictions derived from the two-stage model for noncontingent learning. The first hypothesis predicted a relatively conservative approach of the wild F_1 strain to the licker box situation when an operant but noncontingent mode of licking was most appropriate. As in the case of licking behaviors in Chapter II, the wild F_1 rats performed at significantly lower rates than the black rats in the habituation (no CS) session (Tables 10 and 11). Figures 9 and 10 indicate two relationships in habituation (H) performance which can be interpreted as lending support to the two-stage model: First, the "basic" discriminatory responses (DRs) were much more

plentiful than the anticipatory responses (ARs) for either strain in habituation. Second, the less conservative domestic strain, which licked more vigorously in the habituation (Fig. 6, Chapter II), was apparently "operant" enough to surpass the wild F_1 rats in moderate learning of discriminatory responses. The negligible occurrence of ARs was presumably due to the lack of a CS and to the absence of consistently discrete UCRs (DRs) in habituation. As in other noncontingent paradigms, habituation responses scored as ARs constitute the "base rate" for comparison with subsequent conditioning sessions. Licking as a base rate is presumably analogous to spontaneous salivation or eye lid closure (DeBold, Miller, and Jensen, 1965).

The second hypothesis concerned the comparative styles of learning the two stages of noncontingent licking in the five acquisition sessions. More specifically, it was predicted that the highest degree of strain similarities would result in the inhibitory stage of discriminatory responding, and not in the more excitatory stage of anticipatory responding. Inspection of the graphs in Figures 9 and 10 clearly indicates the consistent deficit in both DRs and ARs and the marked retardation of anticipatory responding for the wild F_1s. The undomesticated rats did more closely approximate the

black rats in learning DRs than ARs, but only in one acquisition session (Fig. 9-A5) was there a noticeable coincidence of DR functions for both strains. Even in the extreme situation of DR comparability, the continuously reinforced wild rats maintained their relative deficit in the excitatory or anticipatory stage of learning (Fig. 9-A5). It is interesting to note that the modest success of the wild F_1s in discriminatory responding was accomplished in spite of continued conservativeness in emitting intrasession licks. Fig. 6. (Chapter II) depicts sizeable strain differences in acquisition session licks, with the disparity in A1 averaging approximately 6,000 licks in favor of the domestic rats.

Because the transitions from inhibitory to excitatory learning stages, and vice versa, tend to be somewhat masked by group graphs, more detailed analyses of phenomena such as inhibition of delay will appear later in conjunction with the consideration of an individual rat's licking topographies (Appendices A and B).

Two additional considerations of the learning data were deemed necessary: The first involved measuring the predicted intrasession (i.e., postasymptotic) performance decrements in conditioned responses. An extra factor, trial blocks, was added to the four factor acquisition analysis of variance (Tables 12 and 13)

to partial out the non-monotonic effects due to the CR decrement within sessions. The postasymptotic decrement for both the DRs and ARs in the acquisition sessions of this investigation produced effects which can be readily observed in Figures 9 and 10 (i.e., inverted U-shaped functions). The effect of intrasession decrement on performance did not appear to act differentially across strains, paralleling the uncomplicated finding by Pavlov (1927) that well established CRs tend to disappear with extended training.

The second consideration involved interpreting the effects of partial versus continuous reinforcement in the licker box. It was expected that these data would not differ from the usual result that PR in noncontingent paradigms seriously interferes with learning (Kimble, 1961). Although there is some evidence to the contrary (Capaldi, 1964), it was also predicted that DRs and ARs would not follow the pattern of reinforced and nonreinforced trials (Kimble, 1961).

The large discrepancy between PR and CRF learning over acquisition sessions is illustrated in Figures 9 and 10. An interesting result, which can be seen in Figure 10, is that the additional inhibition generated by partial reinforcement seems to have especially retarded the development of ARs in this wild F_1 subgroup. A graphical plotting of the ARs and DRs following reinforced

or nonreinforced trials suggested that neither PR group was affected by types of trials but that the inhibiting effect spread to the entire PR learning situation (Boice and Boice, 1966). The relatively slow rate of learning for all groups in this study was assumed to be due in part, to differences from studies with faster conditioning (Patten and Deaux, 1965; Weisman, 1964) such as a shorter ITI and Skinnerian shaping, respectively.

The third hypothesis was that the conservative approach of the wild F_1 strain would extend to the three extinction sessions. The extinction data are not as easily interpreted as were the acquisition data.

Three dependent variables (DRs, ARs, and trials to criterion) were used as indices of learning phenomena over three extinction sessions. The initial extinction session (E1) was preceded by four sequential acquisition sessions. Next in sequence, came the second day of extinction (E2) which was designed to test for spontaneous recovery. The third extinction (E3), which followed an interpolated acquisition (A5), was unique in that it included the presentation of an intense "disinhibiting" stimulus on the tenth extinction trial.

An extinction measure which provided theoretically interesting and unambiguous results was based on the "disinhibition" in E3. Table 17 indicates marked strain

differences in the number of trials without responding following the novel stimulus. Twenty-six of thirty-two wild F_1 rats still had not returned to responding by the time they were transferred to their home cages. Twenty-nine of thirty-two domestic rats waited a maximum of six trials before resuming recorded licking, with a mode between two and three trials. Both strains had averaged more than 10 trials to extinction for all sub-groups in E2 (Fig. 11). Two main conclusions stem from this unique study of extinction: 1. The almost complete suppression of the wild F_1 rats by the novel stimulus is a strong reiteration of the fact that the wild-type rats are more inhibitory in their approach to appetitive learning. 2. It seems apparent that these results do not correspond to the familiar definition of "disinhibition" as a restorer of an extinguished response. Perhaps the concept of "external inhibition", which is defined as the reduction in the strength of the CR by a novel stimulus presented along with the CS in acquisition (Pavlov, 1927), would have been a more appropriate label.

The effect of the three extinctions on the number of trials to criterion was a decreasing resistance to extinction (RTE) (Fig. 11, Table 16) as per Weisman, (1964). It must be remembered, however, that a progressive decrease in RTE was facilitated by the

limitation of E3 due to the inhibiting stimulus on the tenth trial. Whereas the wild F_1 strain usually responded through the tenth trial before extinguishing, the black rats typically ranged between 20 and 30 trials to criterion.

Kimble (1961) notes that spontaneous recovery occurs when an extinguished response recovers some of its strength with rest. There is no general agreement among the researchers in the area of conditioned rat licking as to spontaneous recovery--Patten and Deaux (1965) report little recovery and Weisman (1964) reports almost complete recovery. This investigation provided eight distinct measures of spontaneous recovery with reinforcement condition (i.e., CRF vs. PR) and strain as independent variables, and DRs, ARs, and RTE as dependent variables (see sessions E2 versus E1 in Figures 9, 10, 11). The trend for spontaneous recovery in this study was generally quite high but also quite variable between the eight subgroups. Most subgroups showed a DR or AR loss in E2 of between two and twenty per cent with one outstanding exception wherein a gain of approximately twenty per cent was shown (Fig. 9).

The analyses of DRs and ARs in extinction (Tables 14 and 15) proved to be essentially uninteresting because of the degree to which extinction DRs and ARs paralleled the differences of DRs and ARs in acquisition (e.g., the decrements in wild F_1 rats and partially reinforced

performance). Although the graphs in Figures 10 and 11 do offer some support for the hypothesis of wild F_1 conservatism in extinction responding, the strict statistical assumptions necessary to the proper use of analysis of covariance (Winer, 1962) makes a quantitative adjustment of wild F_1 and PR extinction measures impractical in this situation. It must be emphasized at this point that the primary interest of this learning study was focused on two-stage learning and accompanying lick topographies in acquisition sessions. The purpose of the interpolated extinction sessions was to induce emotional or inhibitory styles of lick responses, to compare learning in a reacquisition session, and not necessarily to infer "learning" from resistance to extinction measures.

Appendices A and B contain eight individual graphs for eight randomly selected rats. Each of the eight figures contains 20 histograms which depict the rate and topography of licking responses in and around a particular ISI. The twenty trials in each figure have been arbitrarily chosen to illustrate response patterns typical to the more crucial stages of learning to lick over all sessions.

The value of the figures in Appendices A and B to this investigation is that the graphs for individual subjects provide uniquely meaningful data in terms of subtle changes in rate and/or topography. Several

consistent and interesting learning phenomena are depicted: First the transition from the undifferentiated, operant mode of licking in habituation to the initial phases of discriminatory licking is shown in the upper four frames in each figure. As the noncontingent inhibition presumably began to operate, the incidence of "operant" licks in the pre-CS period declined. The early DRs were usually delayed for a second after the UCS presentation, and as learning proceeded, the DRs became more instantaneous. In the Weisman technique, the UCRs are not always "short latency" as is claimed for the Miller technique (DeBold, Miller, and Jensen, 1965)

Once consistently discrete DRs were established, then, and only then, were ARs consistently elicited. Behavioral observations at this point indicated that most of the domestic rats were utilizing some sort of mediating behaviors (e.g., grooming) to inhibit responding in the ITI (Laties, et al.,1965), The wild F_1 rats sometimes seemed to mediate the ITIs, but their behavior when not responding was usually motionless.

The conservative licking style of the wild F_1s is also apparent; for instance, their lick bursts throughout learning were generally briefer.

The condition of 50 per cent partial reinforcement had a distinct decremental effect on both strains. Partially reinforced ARs were slower to appear and inhibition

of delay was relatively faster than in the CRF condition. Although there was no apparent discrimination of nonreinforced trials in ARs, the absence of the UCS typically produced a brief, low-rate DR. Similarly small DRs alternated with a few, presumably "frustrated", high-rate and long-burst DRs in extinction. There appeared to be no systematic sequence for the relative resistance to extinction of the DRs and ARs.

The results of inhibition of delay were especially gratifying in that the phenomenon generally produced both a delay in the AR (Kimmel, 1966) and a rate decrease in the AR (Colavita, 1965). Frames 17 and 18 in Appendix A illustrate the "inhibition" of inhibition of delay which was fairly common to the initial trials of reacquisition. The reinstatement of licking in the first portion of the CS-UCS interval was presumably facilitated by the excitation (i.e., frustration induced aggression) still extant from the extinction session just 20 minutes previous. Further support came from the more "inhibited" partial reinforcement situation where the just mentioned excitatory shift was less common (Appendix B, frames 15 and 16). Each of the important findings derived from Appendices A and B were extensively corroborated in analyses of all other rats' records.

It is concluded that the two-stage model developed in this thesis has achieved its present goals of

demonstrating inhibitory-excitatory stages in noncontingent learning, and of indicating the factor which limits wild performance in appetitive situations.

This investigation concurs with Tinbergen's (1965) uncommon opinion that, "...white rats, through a process of breeding and training are a far cry from their natural cousins. Admittedly, no sewer rat could perform these feats." (pp. 140).

A concession must be made to the performance problems as detractors to the wild F_1s appetitive learning ability. The fact remains, however, that even when given enough training to produce consistent discriminatory responding (UCRs), the undomesticated rats did not show conditioning comparable to that of the domestic rats. It follows from the hypothesis of wild rat "conservatism" that more comparability of learning between feral and laboratory rats would occur in a negatively reinforcing paradigm. An, as yet, unpublished study (by M.R. Denny, T. Evans, and the present author) which used wild F_1 and albino rats in a two-way shuttle box seems to have supported that contention.

GENERAL DISCUSSION AND SUMMARY

> "The existence of a number of tame strains of a species which is also easily available in the wild form makes Rattus norvegicus a particularly convenient animal in which to study behavior" (Barnett, 1963, pg.3).

Psychology has received much deserved criticism for its exclusion of undomesticated Norway rats in learning research (Beach, 1950; Bitterman, 1960). It is surprising that the widely acclaimed learning deficits due to domestication (e.g., the assumption of degeneracy, Robinson, 1965; the assumption of limited phyletic generality, Bitterman, 1960) have gone essentially untested by psychologists. Research on wild rat learning has apparently remained in the "armchair" stage due to the reputation of wild rats as being obviously more intelligent (i.e., fiercer and more aggressive) and almost impossible to maintain in a typical laboratory setting (Fuller, 1960).

This dissertation employed three basic considerations of the wild-type Norway rat in an attempt to initiate research in psychology which will assess the domestic rat as a "comparative" animal: 1. Is it practical to trap, breed, and maintain wild rats? 2. How does domestication seem to affect emotionality? 3. What, if anything, does an appetitive learning situation indicate about

the effects of domestication?

Although traditional trapping studies (Chitty, 1954; Thompson, 1953) report an entry lag of at least several days, this investigation achieved an average trapping time of 15 min. by sampling from a land-fill where the refuse was constantly being moved. The fact that a live-trap evidently did not constitute a novel object in the unstable land-fill seemed to reduce neophobia in the wild rats to the extent that trapping was quite easy. The land-fill situation also seemed to facilitate capture of the population segment which usually avoids being live trapped (Thompson, 1953). Extensive behavioral observations at the trapping site supported Calhoun's (1962) observation that there are marked differences in a wild rat population in social status as indicated by dominance and incidence of wounds. In the stable environment studied by Calhoun the low social status rats were most likely to be trapped. In the land-fill environment, trapping seemed to be more representative except for instances where dominant rats exercised priorities in approaching the bait.

It was hypothesized that the utilization of mostly high social status wild rats (i.e., no back scars or tattered ears) would result in unusually high breeding and maternal care success. The wild rats judged to be

of high social status performed beyond expectations; that is, every mating produced a viable litter (mean litter size = 8.7), and there was no savagery or neglect of the litters. Previous research with wild rats (King, 1939; Richter, 1944) has found a low percentage of breeding and a high percentage of savagery. Two wild rats judged to be of low social status produced poor results as was predicted on the basis of Calhoun's observations. The low social status male was killed in his initial breeding encounter, and the low social status female savaged or neglected both of her litters. Observations of breeding behaviors suggested that the success of the breeding experiment was implemented by the use of special, gated cages and by the restriction of fighting in the initial encounters. It appears that small-scale trapping and breeding of wild rats can, in some situations, be accomplished efficiently. There is also good reason to believe that the mating and nursing crucial to domestication (Richter, 1944) should be preceded by feral sampling considerations.

Once in the laboratory, the most obvious difference between wild and domestic strains is evidenced in terms of "emotional" behavior (Farris and Yeakel, 1945). The basic assumption of most theories which deal with rat domestication is that indices of emotionality parallel

the changes which occur in domestication. A common index of emotionality in rats is the rate of elimination (Hall, 1941; Broadhurst, 1965). In this study none of the newly trapped wild-rats defecated while still in the trap or while in transit to the laboratory. Another index of domestication and emotionality is water intake (Chew, 1965; Richter, 1944). Although previous research suggests that emotionality induces thirst (Siegel and Siegel, 1948), the more "emotional" wild F_1 strain in this investigation drank no more water than the domestic, black strain. Two conclusions follow from the above results: 1. "Emotionality", which needs careful definition, is not always directly related to domestication in rats, when domestication is measured in terms of generations in captivity. 2. The use of undomesticated, and not just stressed, rats is essential to an elimination or water-intake approach to the study of rat domestication.

The finding that wild F_1 rats did not show a higher water intake than the black rats in ad lib. or severe deprivation was presumably influenced by the high social status of the parent wild strain and by the lack of environmental stress. That is, dominance is probably inversely related to emotionality (Scott and Fredericson, 1951), and some of the thirst in undomesticated rats is probably a direct result of induced defecation and urination.

Water intake in severe deprivation was important

for the reason that restricted intake probably better reflects the water balance processes of feral-type animals (Chew, 1965). The results of this investigation indicate that the wild F_1 strain might have adjusted to the deprivation schedule as well as the black strain if "cautious" behaviors had not interfered. The conservative drinking style of the wild F_1 strain also extended to the licker box apparatus. Total licks per session, which were considered as a general operant or index of participation, were far fewer for the wild F_1 strain. The relevance of these considerations is the finding that drinking behaviors can be inhibited by the apparent emotionality which is characteristic of undomesticated rats. The conservative approach of the wild F_1 strain in the above appetitive situations portended some of the difficulties which would be encountered in the learning study.

In the only previous wild-type versus domestic strain comparison of learning, Stone (1932) used a simple maze and obtained rather vague results. It was decided that the learning task for this study should limit gross motor activities to, in part, compensate for the conservativeness of the wild F_1 strain. The conditioned licking technique as developed by Weisman (1964) was used because it sequentially combines aspects of operant and respondent learning. More specifically, the

conditioned licking technique was shown to consist of two distinct stages: Learning to emit discrete UCRs to the UCS (discriminatory responding) and the elicitation of discrete CRs to the CS (anticipatory responding). The special relevance of the conditioned licking paradigm to the strain comparison was that both differences in conditioning and differences in transition delay from the DR stage appeared. Because the wild F_1s did not "participate" well in the learning situation, the two stage--DRs then ARs--approach to learning style provided valuable data. In either the CRF or the PR situations, the wild F_1 rats learned DRs at a rate and level more comparable to the black rats than in the case of ARs. The relative retardation of anticipatory responding in the wild F_1 rats is interpreted as support for the inhibition-disinhibition theory of noncontingent learning developed in this dissertation. It was hypothesized that the wild F_1 and domestic strains would perform comparably in the inhibitory phase (DRs). The extent to which the wild F_1 rats fell short of the domestic rat DR performance was probably due to the lack of enough initial operant licking which could then be inhibited. The relative delay of ARs by the wild F_1 strain is assumed to be a result of a conservative learning style in an appetitive situation wherein excitation (ARs) is more restrained

than in the case of domestic rats.

Additional support for the two-process theory came in terms of the inhibition of delay and the "external inhibition" results. The almost complete suppression of responding by the novel stimulus in the wild F_1 strain during the last extinction session was actually most illustrative for summing up the learning performance of wild-type rats in this investigation. The wild F_1 rats were so easily and thoroughly inhibited that their performance appeared to approach that of the domestic rats only as an upper limit. Thus, the data in this investigation suggest that there is probably little of value to be gained by using wild type rats in an <u>appetitive</u> learning situation. The domestic rats' reputed degeneracy did not prevent them from learning faster in both the operant (DR) and respondent (AR) phases of non-contingent licking. Even with comparable habituation to the apparatus and with the use of an easily elicited UCR (licking), the performance difficulties of the wild F_1 strain seems to limit generality of results with them as opposed to the domestic rats.

In summary, it should be emphasized that this dissertation has hardly settled the issue on the comparative value of domestic and feral Norway rats for learning research. In fact, it is hoped that the

results of the trapping and breeding studies will encourage more work with wild rats by psychologists. There is no question, for instance, that rat studies which utilize aggressive, sexual, or emotional behaviors should include undomesticated rats. The important thing for traditional psychology, however, is that domestication has probably enhanced the value of the laboratory rat for learning studies--the extreme cautiousness is gone and mostly the more cooperative behavior remains.

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APPENDICES

APPENDIX A

REPRESENTATIVE LICK TOPOGRAPHIES FOR CONTINUOUSLY REINFORCED RATS

Table 22

Key to Figures 12-15 of Appendix A

Frame	Exp. Session	Type of Response Being Illustrated
1.	Habituation	Initial undifferentiated licking
2.	Habituation	Late trials undifferentiated licking
3.	Habituation	Start of discriminatory licking
4.	1st Acquisition	DR without strong stimulus control
5.	1st Acquisition	Discrete, short latency DR
6.	1st Acquisition	Discrete, short latency DR
7.	1st or 2nd Acq.	AR without inhibition
8.	1st or 2nd Acq.	AR without inhibition
9.	2nd or 3rd Acq.	AR with inhibition of delay
10.	2nd or 3rd Acq.	AR with inhibition of delay
11.	3rd Acquisition	AR and DR at asymptote
12.	3rd Acquisition	AR and DR at dropoff
13.	4th Acquisition	First AR and DR
14.	4th Acquisition	AR and DR at dropoff
15.	1st Extinction	Initial AR and DR
16.	2nd Extinction	Terminal AR and/or DR
17.	5th Acquisition	Initial AR and DR
18.	5th Acquisition	AR and DR at asymptote
19.	5th Acquisition	AR and DR at dropoff
20.	3rd Extinction	Terminal AR and/or DR

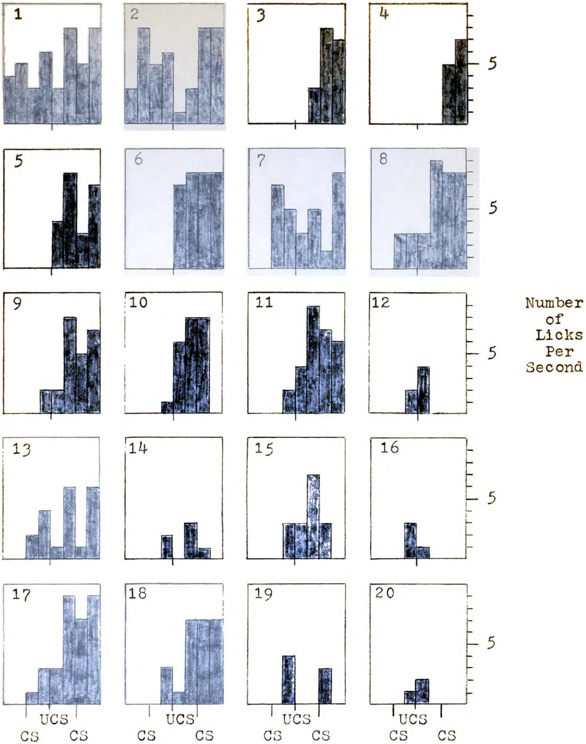

Fig. 12. Representative lick topographies of domestic rat 19 (female) in and around the ISI (see Table 22).

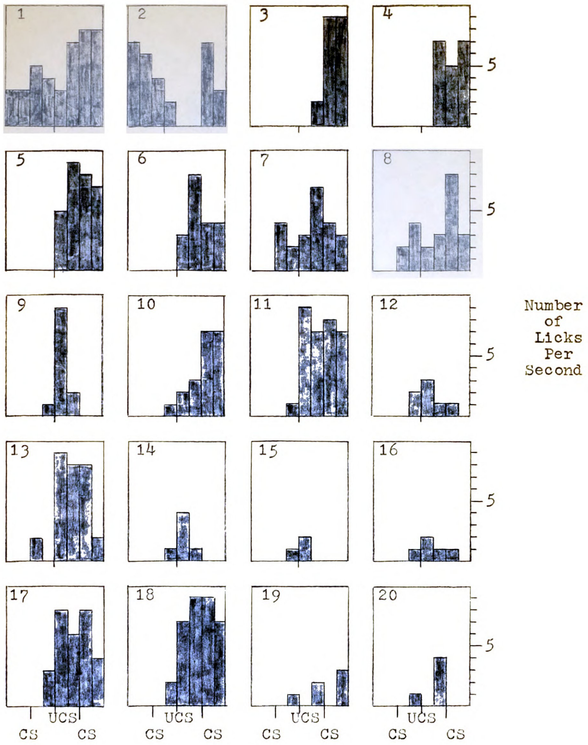

Fig. 13. Representative lick topographies of domestic rat 23 (female) in and around the ISI (see Table 22).

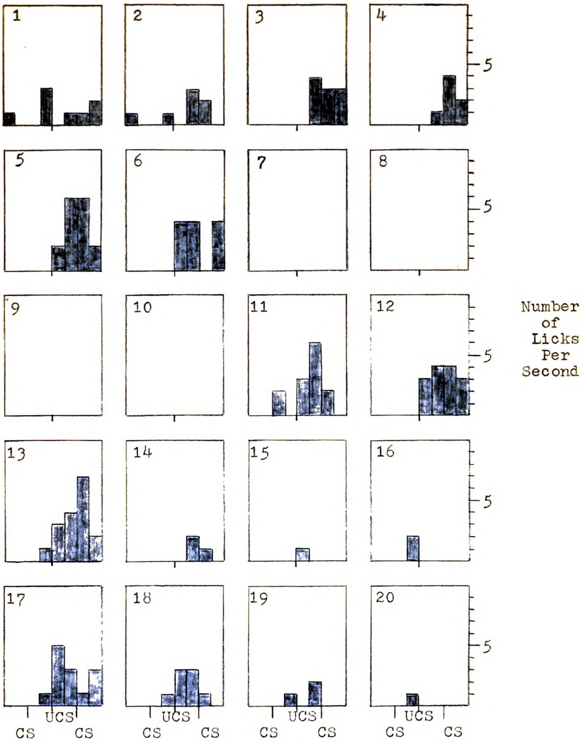

Fig. 14. Representative lick topographies of wild F_1 rat 15 (female) in and around the ISI (see Table 22).

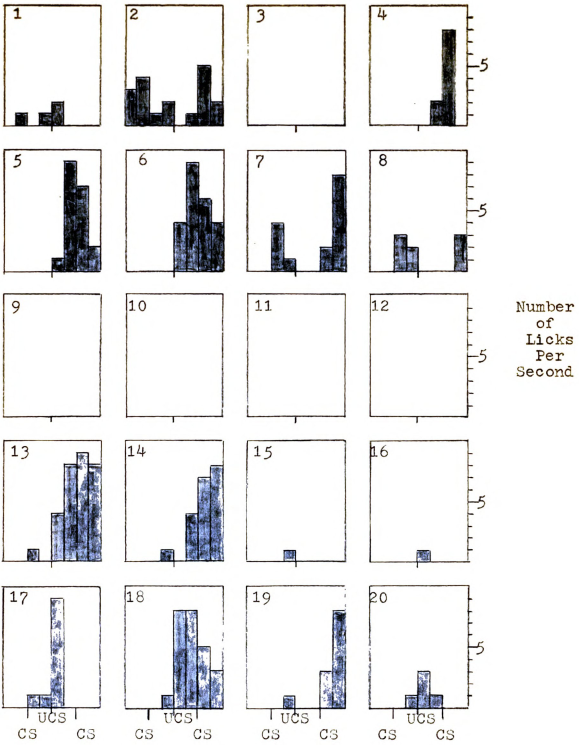

Fig. 15. Representative lick topographies of wild F_1 rat 3 (male) in and around the ISI (see Table 22).

APPENDIX B

REPRESENTATIVE LICK TOPOGRAPHIES FOR PARTIALLY REINFORCED RATS

Table 23

Key to Figures 16-19 of Appendix B

Frame	Exp. Session	Type of Response Being Illustrated
1.	Habituation	Undifferentiated licking
2.	Habituation	Start of discriminatory licking
3.	1st Acquisition	Good discriminatory responding
4.	2nd Acquisition	AR without inhibition
5.	3rd Acquisition	AR with inhibition of delay
6.	4th Acquisition	AR and DR on nonreinforced trial
7.	4th Acquisition	First AR and DR after dropoff (reinforced trial)
8.	4th Acquisition	Final AR and DR
9.	1st Extinction	First AR and DR
10.	1st Extinction	Last DR
11.	1st Extinction	Last AR
12.	2nd Extinction	First AR and DR
13.	2nd Extinction	Last DR
14.	2nd Extinction	Last AR
15.	5th Acquisition	Initial nonreinforced AR and DR
16.	5th Acquisition	Initial reinforced AR and DR
17.	5th Acquisition	Last nonreinforced AR and DR
18.	5th Acquisition	Last reinforced AR and DR
19.	3rd Extinction	Last DR
20.	3rd Extinction	Last AR

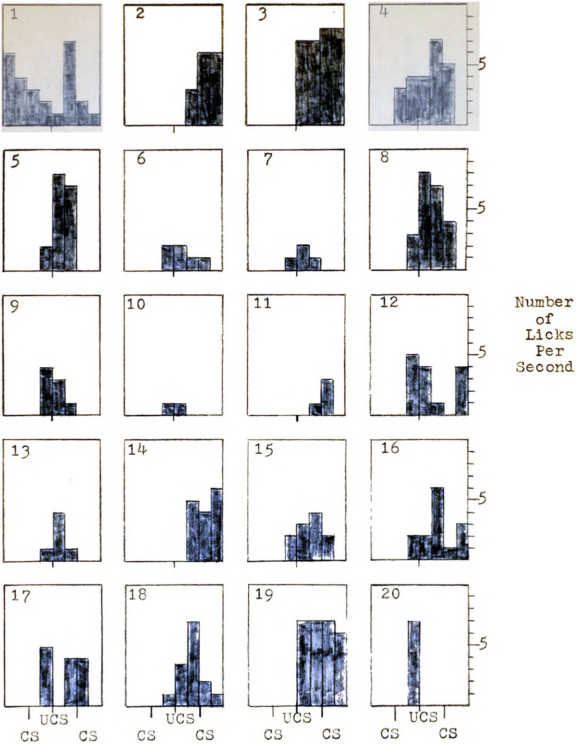

Fig. 16. Representative lick topographies of domestic rat 7 (female) in and around the ISI (see Table 23).

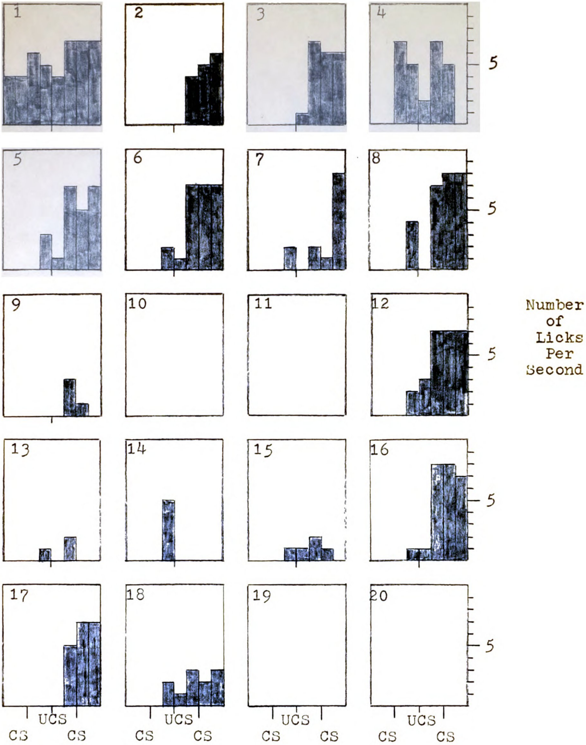

Fig. 17. Representative lick topographies of domestic rat 10 (male) in and around the ISI (see Table 23).

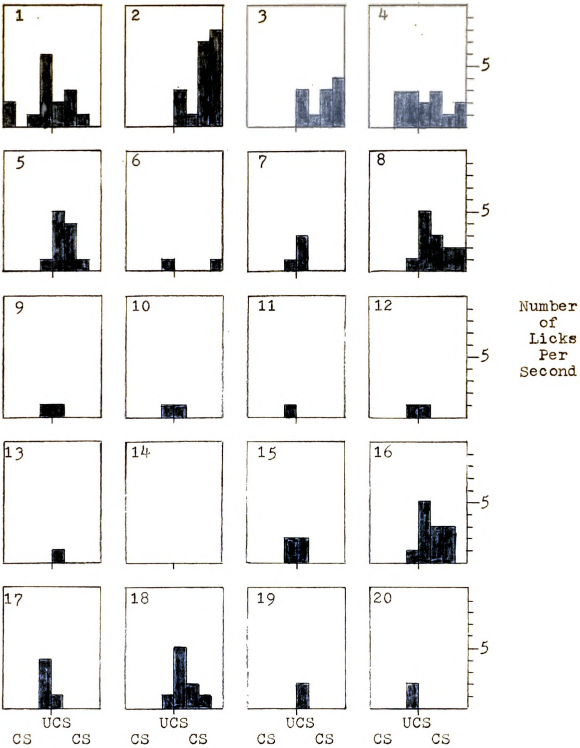

Fig. 18. Representative lick topographies of wild F_1 rat 21 (female) in and around the ISI (see Table 23).

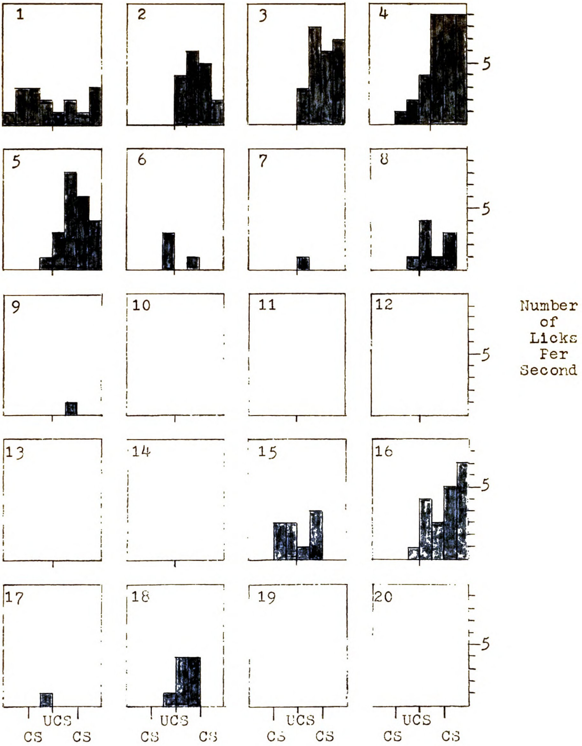

Fig. 19. Representative lick topographies of wild F_1 rat 12 (female) in and around the ISI (see Table 23).