Conditioned Defensive Burying

in Rats

Under Various Conditions of

Shock Presentation, Extinction, and Contingent

and Noncontingent Food Delivery

by

Linda L. Ross

A thesis submitted to the Faculty of Graduate Studies

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dear friend Malcolm. Pausing now to consider, I find that our friendship has spanned some twenty years. In light of that, my perception that you have always been there when I needed a friend, is an accurate one. Thank you.

I wish to thank my parents. I thank my father for encouraging me, from the time when I was a very small child, to pursue my goals, whatever they might be, and for supporting me in any endeavour that I might undertake. I thank my mother for sharing my father's confidence, and especially for providing me with the nurturing environment that made it possible to achieve those goals once undertaken. Your concern, your every effort to help in any way possible, provided a measure of emotional support that cannot be easily expressed.

Lastly, I thank Bill. Your assistance in programming the apparatus, redesigning equipment to do what I wanted it to do when no one else could, solving innumerable technical problems along the way, was invaluable. Mostly, however, I thank you for your love, which was a constant throughout a period when I was often unloveable, and without which I am not at all certain that this task could have been completed.

Abstract

Experiment 1 of this research indicated that conditioned burying

of a shock source occurred when the form of the shock source was

different from the traditional wire wrapped wooden prod. In this

experiment, shock was delivered through a response lever. In

Experiment 2, little or no burying of a response lever, on which a

continuous reinforcement schedule for lever pressing had been

previously programmed, was observed during a subsequent extinction

phase. These results suggest that not all aversive stimulus

conditions are sufficient to generate burying. In Experiment 3,

when shock was delivered through a response lever on which

continuous food reinforcement for lever pressing was concurrently

programmed, minimal or no burying of the shock source occurred.

Further, shock presentation produced only a minor disruption of

lever press performance, and that behavior rapidly recovered. It

is plausible that it was the history of food reinforcement

contingent on lever pressing that was responsible for the

attenuation of conditioned burying of a shock source, when that

shock source is also the manipulandum, and hence, a food source

for food deprived subjects. Given that in Experiment 3 one shock

was insufficient to produce defensive burying of the "shock" lever

on which continuous reinforcement was programmed, Experiment 4a

examined the effects of presentation of multiple shocks through

the response lever, using subjects with a reinforcement history

similar to that of the subjects in Experiment 3. In this

experiment, none of the four subjects showed burying of the shock

source after a single shock, when that shock was delivered through the lever. All subjects, however, showed burying after receiving multiple shocks. Experiment 4b addressed the issue of whether it was the history of food reinforcement contingent on lever pressing that was responsible for the minimal burying of the "shock" lever in Experiment 3. In this study, food pellets were delivered on a fixed time basis, independent of any response requirement. During a "shock" session subsequent to the fixed time phase, two subjects showed burying after one shock; the remaining two subjects received multiple shocks prior to burying. Whereas in Experiment 4a, none of the subjects buried after one shock in Experiment 4b two subjects buried after one shock. These data indicate a trend suggesting that with continuous reinforcement contingent on lever pressing, a greater number of shocks, when delivered through the lever, are required to generate burying. That none of the subjects in Experiment 4a buried after one shock, that two subjects in Experiment 4b buried after one shock, as well as the observed differences in the number of shocks received by subjects in Experiment 4a compared to subjects in Experiment 4b, before burying occurred, supports the position that it was the reinforcement contingency in Experiment 3 that interfered with burying when only a single shock was delivered.

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Bolles (1970) has suggested that defense reactions in rodents are limited to the responses of flight, freezing and threat. Pinel and Treit (1978), however, have countered that restricting rodents' defense responses to the above three behaviors may reflect constraints imposed by the traditional experimental apparatus, such that the full range of possible defensive reactions is not observed. On the basis of their research, Pinel and his colleagues have suggested that Bolles' (1970) classification of species-specific defense reactions in rats should be expanded to include a "burying" response (Pinel & Treit, 1978, 1979; Pinel, Treit & Wilkie, 1980; Terlecki, Pinel & Treit, 1979; Wilkie, MacLennan & Pinel, 1979).

The burying response is typically directed toward some object, and the behavior has been described as one in which the rodents spray "the bedding ahead with rapid shovelling movements of their snouts and alternating pushing movements of their forepaws" (Terlecki et al., 1979, p. 338). Both unconditioned burying (that is, burying of a novel stimulus, in the absence of aversive stimulation) and conditioned burying (that is, burying of a source of aversive stimulation, after contact with that aversive stimulus) have been observed. There is typically no manipulable material on the floor of the traditional experimental apparatus (Pinel & Treit, 1978). This situation may account for the fact that until recently, the burying response had rarely been documented (Hudson, 1950).

If burying is a defense reaction, it is reasonable to expect its occurrence in response to a variety of sources of aversive stimulation. For purposes of this discussion, aversive stimulation is defined as a stimulus against which organisms will agress and/or as stimulus conditions which organisms will respond to escape from or terminate.

There is a large body of research documenting the occurrence of aggression following shock presentation (e.g. Azrin, Hutchinson, & Sallery, 1964; Azrin, Hutchinson, & Hake, 1967; Ulrich, 1966; Ulrich & Azrin, 1962). Shock, therefore, qualifies as an aversive stimulus, according to the definition provided. There is also considerable evidence demonstrating that aggressive behavior occurs in conjunction with extinction (Azrin, Hutchinson, & Hake, 1966; Davis & Donenfeld, 1967; Hutchinson, Azrin, & Hunt, 1968; Knutson, 1970; Thompson, & Bloom, 1966), as well as with various intermittent reinforcement schedules (Cherek & Pickens, 1970; Cherek, Thompson & Heistad, 1973; Flory, 1969; Gentry, 1968; Gentry & Schaeffer, 1969; Hutchinson et al., 1968; Knutson, 1970). It should be noted that periods of extinction are a characteristic feature of intermittent reinforcement schedules (Azrin et al. 1966). It has also been repeatedly demonstrated that organisms will respond to escape from or terminate conditions of extinction (Terrace, 1971; Thomas & Sherman, 1965; Thompson, 1964), and various intermittent reinforcement schedules (Azrin, 1961; Brown & Flory, 1972; Thomas & Sherman, 1965; Thompson, 1964; 1965a).

Extinction, therefore, also qualifies as an aversive stimulus, according to the definition provided.

Thus, according to the definition above, both shock and extinction are aversive stimuli. Since burying of a shock source has been repeatedly observed (Hudson, 1950; Pinel & Treit, 1978, 1979; Pinel, Treit, Ladak & MacLennan, 1980; Pinel, Treit & Wilkie, 1980; Terlecki et al., 1979), it is possible that defensive burying would also be observed under conditions of extinction or under conditions of intermittent reinforcement, a characteristic feature of which is periods of extinction (Azrin et al., 1966).

The following review will document: (1) research demonstrating the phenomenon of burying both of novel stimuli, and of a variety of aversive stimuli; (2) research demonstrating aggression following shock presentation; and (3) research suggesting that extinction and various intermittent reinforcement schedules possess aversive qualities.

Unconditioned Burying

Bolles (1970) indicated that the defensive reactions of flight, freezing, and threat occur in response to both predators and "the sudden appearance of innocuous objects" (p. 33). Burying by rats directed towards novel, but harmless, stimuli has also been frequently documented.

Hudson (1950) observed that some rats pushed shavings toward a patterned stimulus when it was initially introduced. Terlecki et al. (1979) also reported unconditioned burying by rats directed towards both a flashbulb assembly, prior to presentation of the

light flash, and towards a mousetrap, prior to activation of the trap mechanism. Poling, Cleary, & Monaghan (1981) observed burying of both marbles, and of quinine-coated Rat Chow by rats which had not been exposed to such stimuli. Burying of a shock electrode prior to shock delivery was also observed in some rats by McKim and Lett (1979).

That such instances of burying as documented above occurred in response to the presentation of a novel stimulus was further substantiated by the observation that unconditioned burying was attenuated by habituation to those objects (Terlecki et al., 1979), or by habituation to the experimental apparatus (McKim & Lett, 1979; Moser & Tait, 1983). In addition, Shettleworth (1975) observed that "Digging is unequivocally a hamster's response to novelty," (p. 73). Digging, defined as "scraping with forepaws directed in front of face at sawdust, bare floor, or wall" (Shettleworth, 1975, p. 59), appears to be similar in topography to the burying response.

Conditioned Burying

Conditioned burying (that is, burying of a source of aversive stimulation, after contact with that aversive stimulus) has been repeatedly documented with a variety of aversive stimuli. Several investigators have observed that rats will bury a prod through which a shock has been delivered (Hudson, 1950; Pinel & Treit, 1978, 1979; Pinel, Treit, Ladak, & MacLennan, 1980; Pinel, Treit & Wilkie, 1980; Terlecki et al., 1979).

A noticeable exception is the work of Buchanan (1981) in which most subjects failed to bury the shock prod. This is perhaps attributable to considerable differences in both experimental design and experimental apparatus, which make it impossible to compare Buchanan's results with those of the above mentioned investigators. An examination of these differences indicate that in the work of Pinel and Treit, 1978, 1979; Pinel, Treit, Ladak, and MacLennan, 1980; Pinel, Treit and Wilkie, 1980; and Terlecki et al., 1979, shock was delivered through a prod when the animal made contact with the prod. Similarly, in Hudson's (1950) work, shock was delivered through a food holder when the animal made contact with it. In contrast, Buchanan (1981) employed an instrumental conditioning paradigm in which rats were required to complete a four component response. "The instrumental response involved: leaving the start box; moving to bar press mechanism; pressing the bar thus opening the exit door; leaving the bar press box through the exit door; traversing the alleyway; entering the food box; locating the food cup; eating the food pellets" (Buchanan, 1981, p. 8-9). Prior to the test condition, in a separate chamber, shock was delivered through a prod when the subject made contact with the prod. In the test condition, the prod was located in the bar press chamber for some subjects, and in the food chamber for the remaining subjects. Only three of 11 animals which had been exposed to prod shock were observed to engage in burying behavior.

Although burying of a shock source has been reliably observed, it is interesting to note that burying (as indicated by the two measures of duration of burying and height of accumulated burying material) is attenuated both when the size of the chamber is increased and when the chamber is divided such that the shock source is contained in one-half of the chamber, thereby making the other half of the chamber a "safe" environment (Moser & Tait, 1983; Pinel, Treit, Ladak, & MacLennan, 1980). For the factor of chamber size, however, this decrease in burying may be accounted for, at least in part, by a difference in response topography:

Some rats tested in the larger chambers tended to spray the bedding material from a distance, and thus in some instances, the accumulated bedding material was not always centered directly over the prod...Therefore, the height of the pile of bedding material accumulated directly over the prod is not always a sensitive measure of burying behavior in large chambers.

(Pinel, Treit, Ladak, & MacLennan, 1980, p. 449).

In addition to conditioned burying of a shock source, rats have been observed to bury other sources of aversive stimulation, (e.g., a blast of air, a light flash, physical impact (Terlecki et al., 1979)).

Several researchers have also observed burying of aversive food sources. Wilkie et al. (1979) noted that rats buried the source of a sweetened milk solution that was paired with lithium chloride induced toxicosis. Poling et al. (1981) similarly

reported burying of the source of a sweetened milk solution paired with an injection of d-amphetamine by rats. Further, these authors have indicated that such burying cannot be interpreted as the burying of novel sources of food since Wilkie et al. (1979) noted that subjects failed to bury either the source of a saccharin solution or an unpoisoned milk solution, and Poling et al. (1981) observed that subjects failed to bury the source through which apple juice was delivered. Other aversive food sources buried by rats include Tabasco sauce (Poling et al. 1981; Wilkie et al., 1979) and Purina Rat Chow covered with quinine (Poling et al., 1981). Also, the burying of the source of a sweetened milk solution that was paired with lithium chloride induced toxicosis (Wilkie et al., 1979) and the burying of quinine covered Rat Chow (Poling et al., 1981), was observed to be topographically similar to the burying of a shock source.

In contrast to the findings of Pinel, Treit, Ladak, and MacLennan (1980), Poling et al. (1981) did not observe attenuation of the burying response when chamber size was increased. The work of Poling et al. differed from that of Pinel, Treit, Ladak, and MacLennan, however, both in the dimensions of the chambers used and in the objects buried.

It has been noted repeatedly (e.g., Pinel & Treit, 1978, 1979) that the conditioned burying response is clearly directed toward a specific source. When two prods were present in the chamber, for example, and shock was delivered through only one of them, burying was directed primarily toward the source of the

shock (Pinel & Treit, 1978, 1979). Similar findings were obtained when shock was delivered through either a white or a black source; duration of burying and height of accumulated burying materials were greater for the shock source (Terlecki et al., 1979). That shock delivery alone is not sufficient to generate burying behavior in rats is demonstrated by the work of Pinel and Treit (1978) who failed to find burying of a prod in the test chamber when shock had been delivered through a grid floor.

Other research concerned with stimulus control of the burying response further attests that conditioned burying is a directed activity. In the work of Pinel, Treit, and Wilkie (1980), the shock prod could be varied along one or both of the two dimensions of position (front wall or back wall) and brightness (black prod or white prod). Decreases in both measures of burying (i.e., duration, and height of accumulated burying material) were observed when brightness and/or position of the prod was changed in the test condition. The extent of this decrease was not substantially affected if only one or both of these dimensions (i.e., brightness, position) had been changed. It was noted that for some of the subjects for which the position of the prod had been altered in the test condition, that after burying the shock prod, burying was then directed towards the hole in the opposite wall (i.e., the wall where the prod was formerly positioned). This anecdotal evidence suggests that burying may be under multiple control of both the shock source, and the location of that source in the larger environment. This notion was further

substantiated in the work of Pinel, Treit and Wilkie (1980) by the observation that when the positions of two prods, one black and one white, were reversed, following delivery of shock through one of the prods, burying was directed toward both prods. The pattern of this burying was also of interest:

> Prior to burying the prods, eight of the Switch rats scurried back and forth between the two prods. Moreover, this vascillating behavior often perseverated into the burying sequence itself, with animals directing bedding material toward one of the prods, then quickly reversing their direction and spraying toward the opposite prod.
>
> (Pinel, Treit & Wilkie, 1980, p. 156).

Conditioned burying also appears to be a directed activity with sources of aversive stimulation other than shock. Terlecki et al. (1979) employed shock, a blast of air, physical impact, and a sudden light flash as aversive stimuli. With each of these stimuli, two sources, one black, one white, were placed in the chamber, although aversive stimulation was delivered through only one of these sources. The aversive stimulus was delivered through the white source for half of the subjects, and through the black source for the remaining half of the subjects. More burying was directed toward the actual source of the aversive stimulation than toward the nonfunctional source.

Similarly, rats have been observed to direct more burying activity toward a spout through which Tabasco sauce was delivered than toward a water spout (Poling et al., 1981; Wilkie et al.,

1979), toward a spout through which a milk solution paired with lithium chloride induced toxicosis was delivered than toward a water spout (Wilkie et al., 1979), and toward a spout through which a milk solution paired with d-amphetamine was delivered than toward a water spout (Poling et al., 1981). It should be noted, however, that in the experiments of Wilkie et al. (1979), the spout through which the aversive stimulus was delivered was striped, thereby differentiating it from the water spout.

The body of research cited above repeatedly documents: (1) the occurrence of conditioned burying by rats (i.e., burying of a source of aversive stimulation, after contact with that aversive stimulus); and (2) that the conditioned burying response in rats is directed toward a specific source. These findings lend support to the notion that burying by rats is a defensive response according to the criteria of Pinel and Treit (1978). They suggested that in order for burying to be considered as a defense reaction, it "must be shown to occur in response to aversive stimulation" (Pinel & Treit, 1978, p. 710) and "must be adaptive; that is, it must potentially afford the animal some protection from the noxious agent...it must be directed at the source of aversive stimulation" (Pinel & Treit, 1978, p. 711).

Natural analogues of burying add credibility to the suggestion that the burying response is a defensive one. Pinel and his colleagues cite the observations of Calhoun (1962), who reported that in the wild, rats will stop up the entrances to their burrows against invasion (cited in Pinel & Treit, 1978,

1979; Pinel, Treit & Wilkie, 1980). Owings, Borchert, and

Virginia (1977) also noted that when snakes were placed in a pen

with squirrels, one of the responses emitted by these rodents was

kicking "sand into the snake's face via a forward-thrusting

movement of their forepaws...The sand-kicking behaviour seemed

effective in causing the snakes to retreat" (p. 229). This

response appears to be topographically similar to the burying

response as described earlier by Terlecki et al. (1979). Owings

and Coss (1978) have similarly noted sand-kicking by squirrels

directed toward snakes.

Thus, it has been demonstrated: (1) that rats will bury the

source of aversive stimulation, after contact with that aversive

stimulus; (2) that the conditioned burying response in rats is

directed toward a specific source; and (3) that there are natural

analogues of burying. These observations support the position

that burying by rats is a defensive response according to the

criteria of Pinel and Treit (1978), cited above.

Aggression Following Shock Presentation

It has been demonstrated that contact with shock can generate

burying of the shock source (Hudson, 1950; Pinel & Treit, 1978,

1979; Pinel, Treit, Ladak, & MacLennan, 1980; Pinel, Treit &

Wilkie, 1980; Terlecki et al., 1979). It has also been repeatedly

demonstrated that shock can generate aggressive behavior toward

conspecifics and inanimate objects (e.g. Azrin et al., 1967; Azrin

et al., 1964; Blanchard, Blanchard, & Takahashi, 1978; Blanchard,

Kleinschmidt, Fukunagar-Stinson, & Blanchard, 1980; Ulrich, 1966; Ulrich & Azrin, 1962).

Intra-species attack behavior, elicited by presentation of brief electric shock has been observed in several strains of paired rats (Ulrich & Azrin, 1962; Ulrich & Craine, 1964; Ulrich, 1966), in paired hamsters (Ulrich & Azrin, 1962), in paired cats (Ulrich, Wolff, & Azrin, 1964), and in pairs of squirrel monkeys (Azrin, Hutchinson, & Hake, 1963; Azrin et al., 1964). Interspecies shock-elicited attack behavior has also been observed between rats and hamsters (Ulrich & Azrin, 1962) and between cats and rats (Ulrich et al., 1964). Azrin et al. (1964) similarly found that shock presentation resulted in attacks on a rat or a mouse by a squirrel monkey. Thus, shock-induced fighting has been demonstrated across and between several species.

Elicited aggressive responding is not restricted to animate targets. In response to electric shock, squirrel monkeys have been observed to attack a stuffed doll and a cloth covered ball (Azrin et al., 1964; Azrin, Hutchinson & McLaughlin, 1965). Biting attacks following noncontingent shock (i.e., shock not contingent on any specific response) have also been recorded towards wood, rubber, and metal targets by rats (Azrin, Rubin, & Hutchinson, 1968), and on a pneumatic bite hose by monkeys (e.g., Ulrich, Wolfe, & Dulaney, 1969).

There is also evidence indicating that when shock is presented contingent on a response (e.g., in an escape, avoidance, or punishment paradigm), operandum attacking may occur. Azrin et

al. (1964) and Azrin et al. (1967) noted that during acquisition of avoidance behavior, squirrel monkeys frequently bit the response lever and other protruding objects immediately following the delivery of shock. More conclusive data are obtained from negative reinforcement studies that measured attack behavior directly. In Experiment 2, Azrin et al. (1967) provided squirrel monkeys with a pneumatic hose, on which bites could be recorded, as well as a response lever. During a free-operant avoidance procedure attacks on the hose occurred immediately after shock. Cumulative recording demonstrated postshock bursting of biting responses. Delivery of shock during a shock-escape procedure resulted in similar attack behavior. Using a fixed interval avoidance procedure, in which the first response to a recessed key (on which aggressive responding, at least biting, was not possible) after a fixed interval of time postponed the delivery of shock for a specified period, Hake and Campbell (1972), in Experiment 2, noted a predominantly postshock pattern of biting (i.e., a rapid succession of bites immediately after shock presentation) on a pneumatic bite hose provided for aggressive responding. Pear, Moody, and Persinger (1972), using a free-operant avoidance paradigm, measured attacks to the operandum with a lever that recorded bites as well as presses. The occurrence of all biting attacks almost immediately after shock was documented with event pen recordings. These findings were supported by a later study (Pear & Hemingway, 1973), in which the temporal distribution of responding during free-operant avoidance

was recorded. Rates of biting were much higher during the first 2 seconds after shock than during later intervals.

Attacks on the operanda have also been noted elsewhere, although no measurement was made of their temporal relation to the presentation of shock. Utilizing a paradigm whereby rats responded to reduce the intensity of the shocks delivered, Powell and Peck (1969) observed that many of the recorded responses were biting attacks on the lever. Biting of the response lever was also observed in squirrel monkeys by Hake and Campbell (1972), in Experiment 1, in which the first response after a fixed interval of time postponed regularly spaced shocks for a fixed time designated as the reinforcement period. In a study utilizing rats with a history of free-operant avoidance, Powell (1972) observed that elicited attack behavior was frequently directed toward the response lever when response-independent shocks were presented. Davis and Burton (1974) using an escape procedure in which shocks were scheduled to occur every 30 seconds, observed postshock response bursts for one of three albino rats. This postshock bursting was consistently attributable to attack directed at the lever following shock.

Aversive Properties of Extinction and Intermittent Reinforcement Schedules

If burying is a defense reaction, occurring in response to aversive stimulation, it may also be observed in appetitive conditioning situations in which reinforcement has been terminated (i.e., extinction), or in which reinforcement is only

intermittent, since periods of extinction are a characteristic feature of intermittent reinforcement schedules (Azrin et al., 1966). When behavior is reinforced only intermittently, by definition, repeated instances of a behavior must occur with no reinforcement.

It has frequently been suggested that aversive properties may be inherent both in conditions of extinction (Azrin, Hutchinson, & Hake, 1966; Terrace, 1971), and of intermittent schedules of reinforcement (Azrin, 1961; Gentry, 1968; Thompson, 1964; 1965a). That such conditions have aversive qualities is based on observations that organisms will respond to escape from or terminate stimuli associated with extinction and intermittent reinforcement, and/or that organisms will engage in aggressive behavior directed towards a particular condition.

Escape from Stimulus Conditions Associated with Extinction or Intermittent Reinforcement Schedules

That organisms will respond to escape from or terminate stimulus conditions associated with extinction or intermittent reinforcement attests to the aversive quality of various intermittent schedules.

Extinction   Thompson (1964) employed a situation in which a water-deprived rat could respond on two levers. Responses on one lever were continuously reinforced with water; three responses on the second lever produced a 30 second period during which there were no programmed consequences for responding. When an extinction contingency was implemented for responses to the

"water" lever, responding on the second lever increased. Thomas and Sherman (1965) used a similar procedure with pigeons, such that responses to one key were reinforced on a ratio schedule while responses to a second key produced a 30 second period during which the chamber was darkened and there were no programmed consequences for responding. Responses on the second key increased in frequency when extinction was first introduced for responses to the ratio reinforcement key, and then decreased. A further demonstration that organisms will respond to terminate stimuli associated with extinction is provided by Terrace (1971). Pigeons were taught a vertical-horizontal discrimination. For one group of subjects a procedure in which the discrimination was trained with errors was used. The S+ (cue signalling the availability of reinforcement) and S- (cue signalling that reinforcement is not available) were projected on one key. Responses to the second key terminated the presentation of S- for 5 seconds. Under these conditions, subjects were observed to respond to the second key predominantly during S- presentations. When responses to the second key were made ineffective, i.e. they no longer terminated S-, responses to that key decreased. Little responding was observed on the second key by subjects for which the discrimination was trained with an errorless discrimination procedure, by subjects for which there were no programmed consequences for responses to the second key, or by subjects for which responses to the second key merely produced a change in stimulus conditions. That pigeons were observed to respond to the

second key primarily when such responses terminated S- and not under other conditions lends further credibility to the position that subjects will respond to terminate conditions associated with extinction.

Intermittent Reinforcement Schedules

Fixed Interval Schedules Brown and Flory (1972) exposed pigeons to a situation in which pecks to one key were reinforced with food on a fixed interval schedule, while pecks to a second key implemented an escape contingency -- that is, the feeder was rendered inoperative by responses to the second key. Fixed interval values were first increased and then decreased. Generally, for both the ascending and descending presentations of the fixed interval values, bitonic functions of escape responding were observed; that is, "the percentage of session time spent in escape as well as frequency, duration, and rate of escape increased to a maximum and then decreased" (Brown & Flory, 1972, p. 401).

In terms of temporal distribution, escape responding occurred more typically following food reinforcement. This escape responding which disabled the fixed interval reinforcement contingency suggests that such reinforcement schedules may have aversive qualities.

Fixed Ratio Schedules. Azrin (1961) employed a procedure with pigeons in which responses to one key were reinforced on a fixed ratio schedule while a response to a second key both introduced a timeout period (i.e., a period during which

reinforcement is not available) and produced a change in the stimulus conditions. The change in the stimulus conditions consisted of a change in the intensity and the color both of the ambient light, and of the light on the response keys. The reinforcement contingency could be reinstated by a second response to the timeout key as could the initial stimulus conditions. A functional relationship was observed between the size of the ratio and duration of the timeout condition imposed by responses to the second key. Appel (1963) compared pigeons' behavior under three conditions. The first condition approximated that of Azrin (1961); that is, a response to the right key produced a timeout period and change in the stimulus conditions. The change in the stimulus conditions consisted of a change in the color of the key lights, and turning off the house lights. Again, the reinforcement contingency and the initial stimulus conditions could be reinstated by a second response to the timeout key. In the second condition, responses to the right key resulted only in the change in stimulus conditions, and in the third condition no changes occurred following responses to the right key. Under all conditions, responses to the left key were reinforced according to a fixed ratio schedule of reinforcement. Under the third condition, right key responses were infrequent. Under the first and second conditions, the frequency of right key responses increased with the size of the ratio value programmed on the left key. Appel (1963) suggests that "the presence or absence of reinforcement during the periods of stimulus change had little

apparent effect upon the frequency of pecking the right key"

(p. 425). Data presented in one of Appel's (1963) figures,

however, shows that the frequency of right key responses was

slightly higher at five of the seven ratio values in the first

condition, where right key responses resulted in a timeout period

from reinforcement. That animals will respond when such responses

produce a timeout from a fixed ratio reinforcement contingency is

further substantiated by the work of Thompson (Experiment 1, 1964,

1965a), using rats and pigeons. In both studies, responses to one

operandum were reinforced on a fixed ratio schedule, and responses

on the second operandum produced a timeout period of 30 seconds,

as well as effecting a change in stimulus conditions. The change

in the stimulus conditions in the first of these studies

(Thompson, 1964) consisted of turning off the houselight and in

the second (Thompson, 1965a) consisted of turning off the key

lights and turning on the houselight. Again, in both of these

studies, the frequency of timeout responses increased with the

value of the ratio. Using a similar paradigm, in which pigeons

were reinforced on a fixed ratio schedule for responses to one

key, while responses to a second key produced a timeout period of

30 seconds, and changed the stimulus conditions, Thomas and

Sherman (1965) also observed that the frequency of timeout

responses increased as the ratio requirement increased, for two of

three subjects. The change in the stimulus conditions in this

study consisted of turning off the key lights and turning on the

houselight.

Similar temporal distributions of timeout responses were observed by all of the above investigators except Thomas and Sherman (1965). Timeout responses occurred predominantly in the pauses following reinforcement rather than during the ratio run (i.e., that portion of fixed ratio performance in which a high response rate following a pause is observed). Azrin (1961) reported that timeout responses occurred most usually during that portion of the pause before the ratio run, rather than at the onset of the pause immediately following reinforcement delivery. Appel (1963) noted that responses to the key which effected stimulus change, or stimulus change and a time out from the fixed ratio reinforcement contingency, "almost invariably occurred before ratio runs and during pauses after reinforcement...although they could sometimes be observed during an early portion of a run..." (p. 425). Thompson (Experiment 1, 1964), using rats also observed timeout responses predominantly in the pause following reinforcement. Thompson (1965a) replicated this finding with pigeons, observing that "TOs [timeouts] typically occurred after reinforcement and before the next ratio burst" (p. 110). Thomas and Sherman (1965) on the other hand, found that although at their lower ratio values timeout responses occurred most commonly in the pause before the ratio run, such responses were sometimes observed during the run, and that at their highest ratio value (FR200), most timeout responses were observed during the run.

The findings of Zimmerman and Ferster (1964) employed pigeons in a procedure in which reinforcement was delivered on a fixed

ratio schedule for responses to one key and in which responses to

a second key (referred to as the "switching key") produced a

timeout period and a change in the stimulus conditions. The

change in stimulus conditions consisted of changing the color of

the fixed ratio response key. Subjects were on either a

"free-switching" schedule (i.e., a response to the switching key

produced timeout and a subsequent response reversed those

conditions, etc.), or a "minimum-duration" schedule (i.e., a

switching key response instated timeout for a minimum of 10

seconds. A 10 second absence of responding on both keys

terminated the timeout condition). Zimmerman and Ferster (1964)

failed to find a relationship between the size of the ratio and

"switching" responses (i.e., responses which altered the

reinforcement contingencies and the stimulus conditions).

On the basis of their results, Zimmerman and Ferster (1964)

questioned the notion that "switching" responses are negatively

reinforced by terminating the fixed-ratio reinforcement

contingency, which may have aversive properties. They suggest

rather that stimulus change may be implicated. They noted that:

"A marked increase in switching behavior occurred with the

introduction of the novel stimulus" (p. 18), associated with the

fixed ratio response key (i.e., the color of the key associated

with fixed ratio reinforcement was changed from red to blue); and

that "All measures of switching behavior increased and switching

behavior occurred more consistently from session to session as the

degree of stimulus change [produced by switching key

responses]...increased" (p. 18).

Appel (1963) similarly suggested that responses that produce

a timeout from fixed ratio reinforcement may be accounted for by

the change in stimulus conditions which occurs simultaneously, and

are not necessarily attributable to the termination of the

fixed ratio reinforcement contingency. Indeed Appel (1963)

reported that the frequency of right-key responses increased with

the size of the ratio value programmed on the left key when

right-key responses produced a change in stimulus conditions,

regardless of whether or not right-key responses also rendered the

fixed ratio reinforcement contingency on the left-key

nonfunctional. When no changes occurred with right-key

responses, however, these responses were infrequent.

Although Appel (1963) argues for a stimulus change

interpretation, he does not negate the hypothesized aversiveness

that may be inherent in the fixed-ratio schedule:

It does not seem unreasonable to hypothesize that an

organism will impose a stimulus change when the original

stimulating conditions become aversive. A right-key peck

can be viewed as an escape response from some noxious

aspect of the positively reinforcing FR [fixed ratio]

schedule, e.g., the conditions after reinforcement are

aversive in the sense that a relatively long time and

large amount of work are required before another

reinforcement can be obtained, particularly at high

ratios. (p. 427).

Zimmerman and Ferster (1964) argued that:

The acceptance of a hypothesis which states that
switching behavior is reinforced because it removes
a subject from an aversive condition would depend upon
independent measurements of the aversiveness of schedules
in which for example, an avoidance response is maintained
by preventing a shift from one schedule to another. Only
a correlation between switching behavior and such direct
measurements of "aversiveness" could establish that escape
from a positive schedule of reinforcement to extinction was
reinforcing. (p. 19).

Indeed such independent indicators of aversiveness are
available. Thompson (1964, 1965b) cites the findings of
Herrnstein (1958) and of Findley (1958): "For example, when two
response keys are associated with different values of fixed ratio
(FR20 and FR50), pigeons are found consistently to avoid the
higher requirement (Herrnstein, 1958)" (Thompson, 1964, p. 1 and
"Further support for the notion of FR aversiveness is the finding
that an avoidance response can be established and maintained when
it prevents an increase in the ratio requirement (Findley, 1958)"
(Thompson, 1965b, p. 189).

Evidence that responses that terminate fixed ratio
reinforcement contingencies are maintained by the aversiveness of
the reinforcement schedule and not by stimulus change was
indirectly provided by Terrace (1971). Although Terrace (1971)
was not concerned with responding that terminated fixed ratio

reinforcement, he did observe that when pigeons were taught a vertical-horizontal discrimination using a procedure in which the S+ and S- were projected on one key, little responding was observed on a second key by subjects for which responses to that second key merely produced a change in stimulus conditions. When responses to the second key terminated the presentation of S- for 5 seconds, on the other hand, subjects were observed to respond to the second key predominantly during S- presentations.

Further, Thompson (1965b) observed that a stimulus associated with a reinforcement schedule with a high fixed ratio value could decrease responding if that stimulus were presented contingent on responding. In a multiple FR VI schedule with pigeons, VI responses changed the stimulus conditions either to a stimulus associated with the FR component or to a stimulus not associated with the FR component. At high fixed ratio values (FR 150 and FR 300), VI responding was suppressed by both stimulus change manipulations. Greater response suppression, however, was observed when the change in the stimulus conditions was to that associated with the FR component. Thompson (1965b) suggested that that responding was suppressed at all when responses produced a change to a stimulus not associated with the FR component may have been attributable to a change in topography of response, which would decrease response rate.

     The most likely is that SC [stimulus change] per se

     produces an alteration in response topography...It

     is clear, however, that the decrease in responding

produced by CSC [stimulus change in which the stimulus

is correlated with the fixed ratio component] at high

FR values was greater, both absolutely and

proportionally, than that produced by USC [stimulus

change in which the stimulus is not correlated with

either component]. Since the only difference

between CSC and USC was the association with the

FR schedule, it is reasonable to conclude that

stimuli associated with high FR schedules served

as punishment for the ongoing behavior. (Thompson,

1965b, p. 194).

That a stimulus associated with a fixed ratio reinforcement

schedule functioned as a punisher and decreased responding when

that stimulus was presented contingent on responding attests to

the aversive quality of that fixed ratio schedule, at least at

those high ratio values (Thompson, 1965b).

Thus, it has been repeatedly demonstrated that organisms will

respond to escape from or terminate stimuli associated with

extinction and intermittent reinforcement (at least if that

intermittent reinforcement is delivered on a fixed interval or

fixed ratio schedule), suggesting that such conditions may have

certain aversive qualities.

Aggressive Behavior under Conditions of Extinction or of

Intermittent Reinforcement

Aggressive behavior directed towards a particular condition

is perhaps a further indicator of the aversiveness of that

condition. The occurrence of aggressive behavior in appetitive conditioning situations has been repeatedly observed.

Extinction   Extinction-induced aggressive behavior has been repeatedly documented. Azrin et al. (1966), for example, observed increased attack (over a baseline condition of no reinforcement) by pigeons toward a target bird when periods of continuous reinforcement were alternated with periods of extinction. The greatest attack duration was noted in the first 30 or 60 seconds of extinction and decreased thereafter. A direct relationship was observed between the duration of attack and the number of reinforcers presented before extinction. This series of experiments further demonstrated that this aggressive behavior was not attributable either to "displacement" of key pecks, or to "a history of competition over food" (Azrin et al., 1966, p. 200). Azrin et al. (1966) suggest that their observation that attack was greatest at extinction onset supports the notion that there is an aversive quality to extinction.

Thompson and Bloom (1966) observed extinction-induced aggression in rats when extinction followed continuous reinforcement. The measure of aggression was duration of fighting between the experimental subject and a satiated animal also located in the chamber. The temporal distribution of aggression observed in this study differs from that of Azrin et al. (1966). Thompson and Bloom (1966) noted that:

The greatest increase in lever-pressing rate occurred during the first minute of extinction, while increased

fighting was greatest during the second or third minute of extinction...These data indicate that not only does discontinuing positive reinforcement increase the probability of occurrence of aggressive behavior as reported by Azrin, Hutchinson, and Hake (1965) but that there is a systematic relation between the increase in the rate of the previously reinforced response and the tendency for fighting to occur...The temporal relation between the two suggests that the previously reinforced operant has an initially higher probability of occurrence but that this is followed by an increased tendency for aggressive behavior. (p. 336).

Aggressive behavior during extinction has also been recorded when extinction followed fixed ratio reinforcement (Hutchinson, et al., 1968; Knutson, 1970). Hutchinson et al. (1968) observed that squirrel monkeys bit a pneumatic rubber hose when extinction followed fixed ratio reinforcement. Knutson (1970), using a multiple schedule with fixed ratio and extinction components, observed that pigeons attacked target birds during extinction. Under schedule conditions of multiple FR N extinction FR 1 extinction, rate of attack was similar in both extinction components. As the ratio was changed in the FR N component, however, there was a change in rate of aggression during both extinction components. It is interesting that for three of the five subjects, when the ratio requirement of the FR N component was increased attack during extinction decreased; for four of five

subjects, however, when the ratio requirement of the FR $\underline{N}$
component was increased attack during the FR $\underline{N}$ component
increased.

The temporal distribution of aggressive behavior observed by
Knutson (1970) was similar to that noted by Azrin et al.
(1966); that is, aggressive behavior decreased as a function of
time in the extinction component. Although Hutchinson et al.
(1968) present data for only one subject, their findings concur
more closely with those of Thompson and Bloom (1966); that is,
"Biting did not start when extinction was introduced but only
after some minutes" (Hutchinson et al., 1968, p. 490).

Davis and Donenfeld (1967) have also noted aggressive
behavior between pairs of rats under conditions of extinction,
following individual training on various reinforcement schedules.
For some animals, training was conducted under a DRL schedule
(differential reinforcement of low rates), and for others,
training was conducted under an FR (fixed ratio) schedule. One
animal was experimentally naive, and one animal trained on a DRL
schedule was not exposed to an extinction condition. Four pairs
of rats were run in the extinction conditions: two animals were
run simultaneously in a two-lever, two feeder chamber. Different
extinction conditions were programmed as follows on each lever:

	Left Lever (A)	Right Lever (B)
Pair 1	DRL 10 ext	FR 24 ext
Pair 2	DRL 10 ext	Naive
Pair 3	DRL 10 ext	FR 24 ext
Pair 4	DRL 10	FR 24 ext

(Davis & Donenfeld, 1967, p. 85)

Although postural threat was observed in all four pairs of animals, fighting was observed only for Pairs 1 and 3, for which extinction was in effect for both subjects. "This would seem to indicate that the probability of this higher degree of aggression is positively related to the summed effects of the pair's extinction" (Davis & Donenfeld, 1967, p. 86).

Extinction-induced aggression has been observed in a variety of species (rats, pigeons, squirrel monkeys), and when extinction follows a variety of reinforcement schedules (CRF, FR, DRL) (Azrin et al., 1966; Davis & Donenfeld, 1967; Hutchinson et al., 1968; Knutson, 1970; Thompson & Bloom, 1966). The generality of the effect (i.e., across species and across schedules) adds further credibility to the notion that extinction has aversive properties.

Intermittent Reinforcement Schedules

Fixed-Interval Schedules   Aggressive behavior has also been observed when reinforcement is delivered on a fixed interval schedule (Cherek et al., 1973; Flory, 1969; Richards & Rilling, 1972). For three of five pigeons, Richards and Rilling (1972) observed an increase in attack behavior (over the recorded free operant level, i.e., during a no reinforcement condition) under a fixed interval schedule of reinforcement. Cherek et al. Experiment 1, 1973) implemented a procedure in which pigeons' responses to one key produced food on a fixed interval schedule, and responses to a second key produced a target bird which could be attacked on a fixed ratio schedule. The value of the interval was changed throughout the experiment, being first increased and

then decreased. Both rate of responding on the key which produced the target bird and rate of attack were a bitonic function of the value of the interval, such that rate initially increased and then decreased.

Similar findings have been obtained when food is delivered to pigeons on a fixed-time basis without a response requirement. Flory (1969) also noted that rate of attack behavior was bitonically related to the value of the interfood interval, such that rate initially increased and then decreased. Cherek et al. (Experiment 3, 1973) compared pigeons' key-peck responses that produced a target bird, and attack behavior toward the target, under a condition where there was no response requirement for food delivery and a condition where food was delivered on a fixed interval schedule for responses to a second key. Cherek et al. (1973) suggested that:

> it appears that under the conditions of this experiment,
> the presentation of food was sufficient to maintain
> responding on the target key. Rate of responding on
> the target key was either not changed or decreased
> when food deliveries were presented in the absence of
> any specified operant response requirement. (Cherek et al.,
> 1973, p. 119).

From visual inspection of the data, however, it appears that both rate of responding on that key and rate of attack generally were lower in the response-independent condition (see Cherek et al., 1973, Figures 5 and 6, p. 119). In light of these findings, the

following comments of Richard and Rilling (1972) regarding Flory's

(1969) work may be questioned:

> Flory's (1969) demonstration that the independent
>
> delivery of food after a fixed period of time elicits
>
> aggression suggests that it is not the response
>
> requirement of the FI schedule, but the period of
>
> nonreinforcement immediately after reinforcement

that elicits the attack (Richard & Rilling, 1972, p. 409).

Given the findings of Cherek et al. (Experiment 3, 1973), it would

appear that although nonreinforcement is important in generating

attack behavior, the response requirement also plays some role.

That aversiveness is inherent in fixed interval schedules of

reinforcement is further substantiated by a fourth experiment

conducted by Cherek et al. (1973). Using an ABAB design, in which

reinforcement was delivered to pigeons on a fixed interval

schedule in one condition (A), and in which no reinforcement was

presented and no responses were possible in a second condition

(B), responding on a key that produced a target, and attack toward

that target, were maintained in the fixed interval reinforcement

condition, but decreased to zero in the nonreinforcement

condition. The authors point out that:

> The phenomenon of schedule-induced escape suggests
>
> that intermittent schedules of food presentation
>
> possess aversive properties (Azrin et al., 1966;
>
> Falk, 1960), and the results of Experiment IV
>
> seem to support this in that subjects responded

for target presentation only in the presence of an

intermittent schedule of food presentations. (Cherek

et al., 1973, p. 121).

Cherek et al. (Experiment , 1973), Flory (1969), and Richards

and Rilling (1972) all noted a similar temporal distribution of

aggressive behavior; that is, aggressive behavior

was more probable soon after food delivery. This is consistent

with the findings both of Azrin et al. (1966), who observed that

the greatest attack duration occurred at extinction onset when

periods of continuous reinforcement were alternated with periods

of extinction, and with those of Knutson (1970), who, using a

multiple schedule with fixed ratio and extinction components,

observed that aggressive behavior decreased as a function of time

in the extinction component.

The research cited above demonstrating the occurrence of

aggressive behavior during fixed interval schedules of

reinforcement further attests to the aversive quality of

intermittent schedules.

Fixed Ratio Schedules Aggressive behavior has also been

noted under fixed ratio schedules of reinforcement (Cherek &

Pickens, 1970; Gentry, 1968; Gentry & Schaeffer, 1969; Hutchinson,

Azrin, & Hunt, 1968; Knutson, 1970). Cherek and Pickens (1970),

Gentry (1968), and Knutson (1970) have all observed attack towards

a target bird by pigeons when fixed ratio reinforcement

contingencies were in effect. Pigeons displaying stable

fixed ratio behavior were observed to attack target birds when

they were placed in the chamber (Cherek & Pickens, 1970). Gentry (1968), using a design in which a no-reinforcement condition was alternated with a fixed ratio condition, found more aggressive behavior towards a target bird in the fixed ratio condition than in the no-reinforcement condition. Knutson (1970), in a multiple schedule with fixed ratio and extinction components, also observed aggression by pigeons towards a target bird in both the extinction and the fixed ratio components. Due to the manner in which Knutson's (1970) data is presented however, it is difficult to ascertain whether there is more aggressive behavior in the fixed ratio or the extinction component.

In addition to Knutson (1970), Davis and Donenfeld (1967) and Hutchinson et al. (1968) also investigated aggressive behavior during extinction when extinction follows fixed ratio reinforcement. Davis and Donenfeld (1967) provide data on aggressive behavior in pairs of rats trained under various reinforcement schedules, only during extinction, not during fixed ratio reinforcement, making a comparison of aggressive behavior under the two conditions impossible. Hutchinson et al. (1968), in a study using squirrel monkeys and measuring bites on a pneumatic rubber hose, presented limited data suggesting that unlike the findings of Gentry (1968), there is more aggressive behavior under conditions of extinction than under fixed ratio reinforcement. Hutchinson et al. (1968) report data from one subject when extinction followed FR 2 reinforcement and FR 20 reinforcement. It is possible that the relative amounts of aggression observed

under fixed ratio schedules and under extinction may be influenced by such variables as the size of the ratio and/or object of aggression (Knutson, 1970), that is, whether the object of aggression is a conspecific or an inanimate object.

Aggressive behavior under fixed ratio reinforcement has also been observed in other species. Hutchinson et al. (1968) observed that as the ratio requirement was increased, squirrel monkeys showed aggressive behavior, measured by bites to a pneumatic bite-hose. Gentry and Schaeffer (1969) noted in three of four pairs of rats that attack by the experimental subject toward the target rat was greater under a fixed ratio 20 schedule than that observed during a no-reinforcement condition. This relationship, however, did not hold at higher ratio values.

The data regarding the relation between aggressive behavior and ratio size is inconsistent. Hutchinson et al. (1968) observed that attacks by squirrel monkeys to a pneumatic bite tube increased over sessions following an increase in the ratio requirement, and likewise decreased over sessions with a reduction in the ratio requirement. Similarly, Knutson (1970), reporting on aggressive behavior by pigeons during the fixed ratio $\underline{N}$ component of a multiple fixed ratio $\underline{N}$, extinction, fixed ratio 1, extinction schedule, noted that for four of five subjects attack towards a target bird increased as the response requirement in the fixed ratio $\underline{N}$ component was increased. A similar pattern of increasing attack with increases in the ratio was also exhibited by the fifth subject up to a fixed ratio value of 60; when the ratio was

further increased to 120, attacks decreased. It is interesting

that although frequency of attack increased with increases in the

ratio, there was no substantial increase in duration of attack.

Cherek and Pickens (1970) observed that pigeons' attack toward a

target bird increased each time the fixed ratio requirement was

raised. This did not, however, reflect a monotonic function

between ratio size and frequency of attack. With their procedure,

the ratio requirement was not changed "until a criterion of three

successive sessions with 10 or fewer aggressive responses in each

was achieved" (Cherek & Pickens, 1970, p. 310). Thus, although

attack increased each time the ratio was increased, this reflected

an increase over a low rate of attack occurring at the previous

ratio value. As Cherek & Pickens (1970) indicated, however, the

increase in aggression with an increase in the value of the ratio

attenuated over time: "Aggression produced by ratio increases

thus appears to be a transient effect" (Cherek & Pickens, 1970,

p. 311). More discrepant data concerning the relation between

aggressive behavior and ratio size are reported by Gentry and

Schaeffer (1969). Gentry and Schaeffer (1969) observed attack by

rats towards a conspecific under a no-reinforcement condition and

at fixed ratio water-reinforcement values of 20, 40, and 60. For

three of four pairs of these subjects under the fixed ratio 20

condition, frequency of attack increased over that observed during

the no-reinforcement condition but decreased under the higher

ratio conditions. Gentry and Schaeffer (1969) suggested that this

discrepancy may be "attributable to species differences in

aggressive behavior, or associated with differential effects of differing reinforcers (e.g., food vs. water) on aggressive behavior" (Gentry & Schaeffer, 1969, p. 238).

The data concerning the temporal distribution of aggressive behavior under fixed ratio schedules of reinforcement is also somewhat inconsistent. Gentry (1969) reported that fixed ratio induced aggressive behavior occurred primarily in the post reinforcement pause. Cherek and Pickens (1970) and Hutchinson et al. (1968) similarly observed attack primarily during the post reinforcement pause and early segments of the ratio run. Knutson's (1970) findings coincide with the above only at some ratio values: with lower fixed ratio values aggressive behavior occurred primarily during the post reinforcement pause, but with higher fixed ratio values, attack was less confined to the post reinforcement pause. In the temporal distribution of aggressive behavior obtained by Gentry and Schaeffer (1969), however, attack was not localized in the post reinforcement pause, but rather occurred at various points during the interreinforcement interval.

In addition to the research described above demonstrating fixed ratio induced aggressive behavior, an experimental manipulation by Knutson (1970) further suggests the aversiveness of fixed ratio schedules. When the presentation of the discriminative stimuli associated with fixed ratio 1 or fixed ratio 120 was made contingent upon attack behavior, aggressive behavior was observed to stop when the fixed ratio 1 stimulus was

presented but to persist when the fixed ratio 120 stimulus was presented.

Further, the work of Knutson and Kleinknecht (1970) has suggested that reinforcement density, rather than the increase in the number of responses required for reinforcement, may be the more important of the two factors in generating fixed ratio induced aggressive behavior. Knutson and Kleinknecht (1970) observed more attack on target birds by pigeons under a DRL schedule of reinforcement, than under a continuous reinforcement schedule. By using a DRL schedule, these investigators controlled for the effect of an increase in response requirement.

> While the DRL 20 has a much lower number of nonreinforced responses than FR 120, both schedules are associated with a low density of reinforcement. Perhaps it is the reinforcement density which determines whether attack will occur during a period of time closely following reinforcement. (Knutson & Kleinknecht, 1970, p. 290).

Statement of the Problem

The evidence documented above demonstrates that aggressive behavior occurs in conjunction with extinction and with various intermittent reinforcement schedules, a characteristic feature of which is periods of extinction (Azrin et al., 1966). That evidence, as well as the research showing that organisms will respond to escape from or terminate conditions of extinction and various intermittent reinforcement schedules, strongly suggests that such schedules possess certain aversive qualities.

Therefore, if burying is indeed a defense reaction occurring in response to aversive stimulation, and directed toward the source of that aversive stimulation, it is reasonable to expect that burying might also be observed when the aversive stimulation occurs in the form of extinction. Further, the literature reviewed indicates that:

    (1) shock generates aggressive behavior

    (2) shock generates burying behavior

    (3) aggressive behavior occurs in conjunction with extinction

        and with various intermittent reinforcement schedules.

Given that shock generates both aggressive behavior and burying, it is possible that burying, like aggressive behavior, may also be observed in conjunction with extinction. There is some documented evidence to support this position (Buchanan, 1981; Shettleworth, 1975).

In Experiment 4, Shettleworth (1975) reinforced golden hamsters on one of a number of cumulative duration schedules for one of six categories of behavior (scrabbling, open rearing, digging, face washing, scratching, scent marking). This reinforcement condition was followed by two extinction sessions.

It is important to note here that Shettleworth (1975) defined the "digging" response as: "Scraping with forepaws directed in front of face at sawdust, bare floor or wall" (Shettleworth, 1975, p. 59). This description appears topographically similar to the burying response in rats described earlier: that is, "spraying the bedding ahead with rapid shovelling movements of their snouts

and alternating pushing movements of their forepaws" (Terlecki et al., 1979, p. 339). It should be noted, however, that Shettleworth (1975) does not specify that the "digging" response is a directed activity whereas it has been noted repeatedly (e.g., Pinel & Treit, 1978, 1979) that the conditioned burying response is clearly directed toward a specific source.

The data presented by Shettleworth (1975) show that digging increased in the reinforcement condition and decreased in the extinction condition. Also among her findings was the observation that:

after decreasing slightly over sessions during magazine training, digging increased in all animals reinforced for marking and then decreased again in extinction. In contrast when hamsters are given free food, or reinforced for APs [Shettleworth (1975) notes that the term action pattern (AP) "is not meant to imply that they meet all the traditional criteria for fixed action patterns...It is a convenient shorthand for discrete, topographically identifiable patterns of movement and is not meant to suggest that they have a single type of development or control". (p. 57-58)], other than marking or digging, digging invariably increased in extinction (Shettleworth, Note 2). These results can perhaps be understood by noting that digging normally precedes marking and so was often reinforced when marking was.

(Shettleworth, 1975, p. 82).

Thus, it appears that if digging is the behavior specified by the reinforcement contingency, or, if digging constitutes part of a behavioral chain specified by the reinforcement contingency (e.g., digging-marking reinforcer), the behavior of digging comes under the control of the contingencies in effect. That is, digging behavior increases with reinforcement, and decreases with extinction. If, however, digging is not the behavior specified by the reinforcement contingency, when the behavior so specified is extinguished, digging increases. This increase in digging when another behavior is placed on extinction can perhaps be viewed as a defensive response, in much the same way that escape and aggressive behavior is considered when those behaviors are observed under conditions of extinction or under conditions of intermittency of reinforcement, as discussed in the literature reviewed earlier.

Buchanan (1981) employed an instrumental conditioning paradigm in which rats were required to complete a four component response.

"The instrumental response involved: leaving

the start box; moving to bar press mechanism;

pressing the bar thus opening the exit door;

leaving the bar press box through the exit door;

traversing the alleyway; entering the food box;

locating the food cup; eating the food pellets"

(Buchanan, 1981, p. 8-9).

The floor of the apparatus was covered with sawdust. Prior to the test condition (described below), in a separate chamber, the

floor of which was also covered with sawdust, a prod was established as an aversive stimulus. For 11 subjects shock was delivered through the prod when the subject made contact with the prod.

In the test condition, the prod was located: (a) in the bar press chamber for six subjects previously exposed to prod shock, and also for three control subjects who had been exposed to the prod but not shocked; and (b) in the food chamber for five subjects previously exposed to prod shock, and also for three control subjects who had been exposed to the prod but not shocked. Three animals, all of which had been exposed to prod shock, were observed to engage in burying behavior. For two of these subjects, in the test condition the prod was located in the food chamber, and for one of these subjects the prod was located in the bar press chamber.

Interestingly, two of the three subjects that did bury did so only after they had consumed the food. Casual observations of one burying subject's behavior were as follows: the subject, following consumption of the food, vascilated between the prod and the empty food cup for approximately 30 seconds; subsequently the animal sprayed some sawdust at the prod, moved over beside the food cup, pushed the empty cup beside the prod and proceeded to completely bury both of these objects. (Buchanan, 1981, p. 16).

Buchanan (1981) has further suggested that an absence of
food (characteristic of extinction of a previously food
reinforced response) may facilitate burying behavior.

This phenomenon warrants further study. If
such relationships prove to be reliable then it may
be suggested that the subsequent result of food
consumption (i.e. no food) may give rise to a
state (frustration?) that may facilitate the
generation of the appropriate motive state necessary
for burying to occur. (Buchanan, 1981, p. 16).

That the phenomenon of burying under conditions of extinction
has not been frequently recorded to date may reflect the
constraints of the traditional experimental apparatus, such that
burying materials are not typically available in the experimental
chamber. The present research, therefore, investigated the
burying response under various conditions of shock presentation,
extinction, contingent food delivery, and non contingent food
delivery.

Experiment 1

Since the apparatus employed in the following experiments
differed from that used for example by Pinel and Treit (1978,
1979), Pinel, Treit, Ladak, and MacLennan (1980), Pinel, Treit and
Wilkie, 1980, and Terlecki et al., 1979. Experiment 1 was
conducted to determine if the phenomenon of conditioned burying of
a shock source would be observed under these slightly different

conditions. The primary difference in the apparatus of the following experiments, and that of the above investigators was that shock was delivered through a response lever rather than through a shock prod.

<div align="center">Method</div>

Subjects

Four experimentally naive, male, adult Long Evans hooded rats (Canadian Breeding Laboratories, La Prairie, Quebec) served as subjects. Subjects were individually housed in wire mesh cages under a 16 hour light/8 hour dark cycle. Purina rat chow and water were available on an ad lib basis.

Apparatus

The experimental chamber was constructed of Plexiglas, 5 mm thick. The exterior dimensions of the chamber were 46.7 cm long by 30.5 cm wide by 45.8 cm high. The chamber sat in a stainless steel tray 48.3 cm x 32.6 cm x 1.1 cm. The floor of the chamber was covered with a commercial bedding material (sawdust) to a depth of 5 cm. Two levers were inserted in the front wall of the chamber at a height of 7 cm; the left lever was positioned 4.5 cm in from the left side wall; the right lever was positioned 4.1 cm in from the right side wall. The levers used were similar to those used by Pear et al. (1972), and were constructed in such a way that a sufficiently large force applied simultaneously to the top and bottom of the lever caused a microswitch to record a "bite". Lever press responses were recorded in the usual way. Each lever recorded presses above 0.49 N and bites above 2.45 N

force. The levers were also constructed in such a way that an electric shock could be delivered through them (See Appendix). A food magazine was located mid way between the two levers, above the bedding material.

Procedure

Subjects were pre exposed to the experimental chamber individually for a 30-minute session on each of five consecutive days. The levers were not present in the chamber during these five sessions. On the sixth day, the two levers were inserted as described above.

On the sixth day, subjects were placed individually in the chamber facing the wall opposite that on which the levers were located. When a subject made contact with one lever (the left lever for Rats 1 and 2; the right lever for Rats 3 and 4), a shock, approximately 8 mA in intensity was delivered to the animal. The lever through which shock was delivered is referred to as the operative lever. The second lever is referred to as the non operative lever. Shock was terminated when the subject broke contact with the lever. The lever remained electrified throughout the session. No shock was delivered through the second lever. For each subject, the sixth session continued until 30 minutes had elapsed since the last shock had been received.

All sessions were videotaped. Duration of burying and frequency of lever presses and lever bites on both levers were recorded throughout the session. At the end of each session, the height of the bedding material at both levers was measured.

Dependent Measures

1) Frequency of lever presses on each lever

2) Frequency of lever bites on each lever

3) Duration of Burying Measurement of burying was based on

the characterization of the response provided by Terlecki

et al. (1979): "spraying the bedding ahead with rapid

shovelling movements of their snouts and alternating

pushing movements of their forepaws." (p. 338). Duration

of burying was measured by depressing a key on a keyboard,

interfaced with a Commodore VIC 20, when burying was

observed. A software program recorded duration of

burying by accumulating the total time in a session that

the key was depressed. These data were recorded in

5-minute intervals for the duration of each session.

4) Height of bedding material at each lever The maximum

height of bedding material at each lever was measured.

For those sessions in which the levers were not present

in the chamber, the maximum height of bedding material

within the area which the levers later occupied was

measured.

Inter observer Reliability

Twenty-five percent of all sessions were randomly selected

for inter observer reliability after tapes had been viewed and

duration of burying recorded by the experimenter. The observer's

data was also recorded in 5-minute intervals for the duration of

each session.

A correlation coefficient was calculated, using the measurements in each 5-minute interval for Experiment 1 in which either the experimenter or the observer recorded burying. Any interval in which neither the experimenter nor the observer recorded any burying were excluded, to guard against any inflation of the correlation coefficient.

The correlation coefficient was calculated for the entire experiment, rather than for each session, as the total number of intervals in which burying was observed was small.

Results

In the sixth session of Experiment 1, Rats 2 and 4 each made contact with the electrified lever once, and therefore experienced only one shock; Rat 3 made contact with the electrified lever twice, experiencing two shocks; Rat 1 made contact with the electrified lever three times, experiencing three shocks.

No bites were recorded on either lever for any of the four subjects. Lever pressing was absent except for one press on the left lever by Rat 4.

Rats 1 and 2 showed no increase in the amount of time spent burying in the sixth session when shock was presented, over that observed in the previous five sessions (see Figure 1). (The duration of burying data for Session 4 for Rats 1 and 2 are unavailable. When reviewing the videotapes, the image was too "snowy" to clearly discern the animals' activity. From notes made during the original viewing, however, it is known that any burying that might have occurred during these sessions was negligible).

Figure 1. Total duration of burying (in seconds) for each session

for rats 1, 2, 3 and 4.
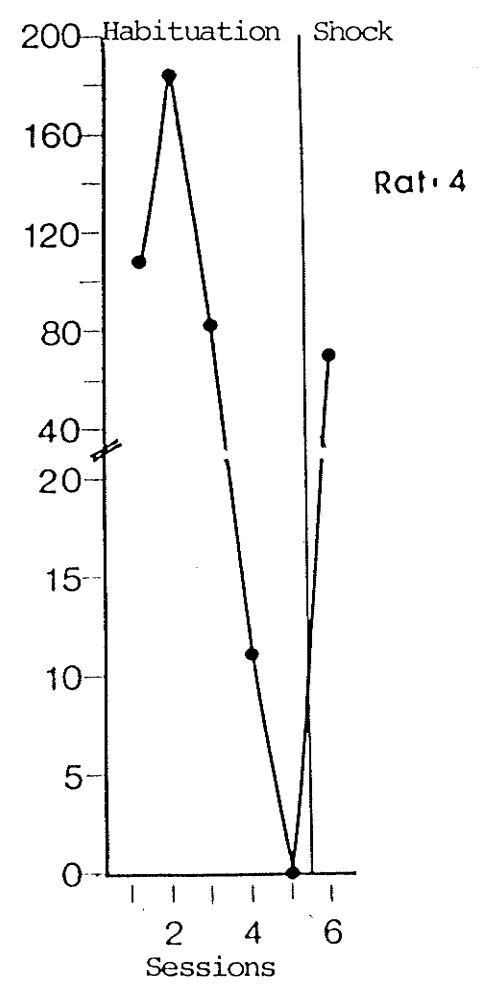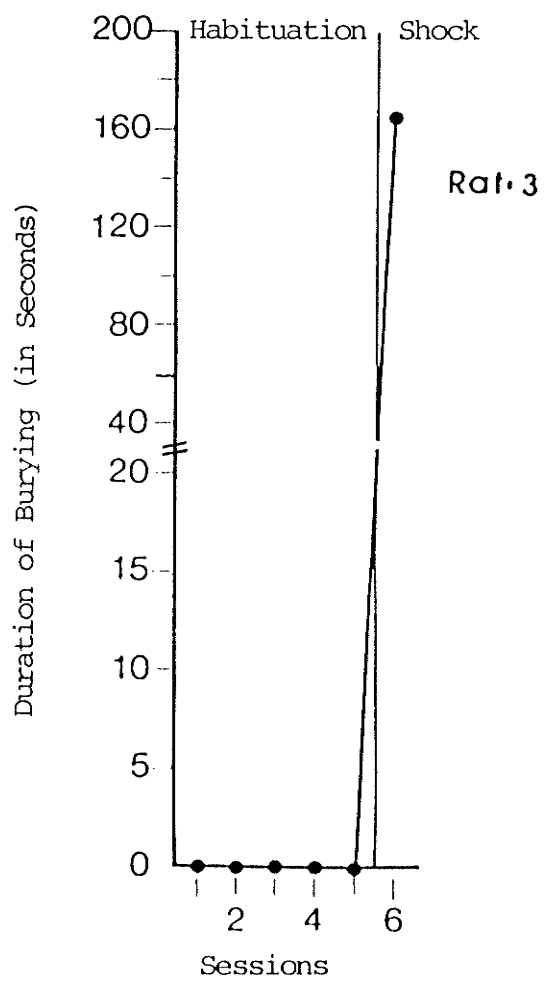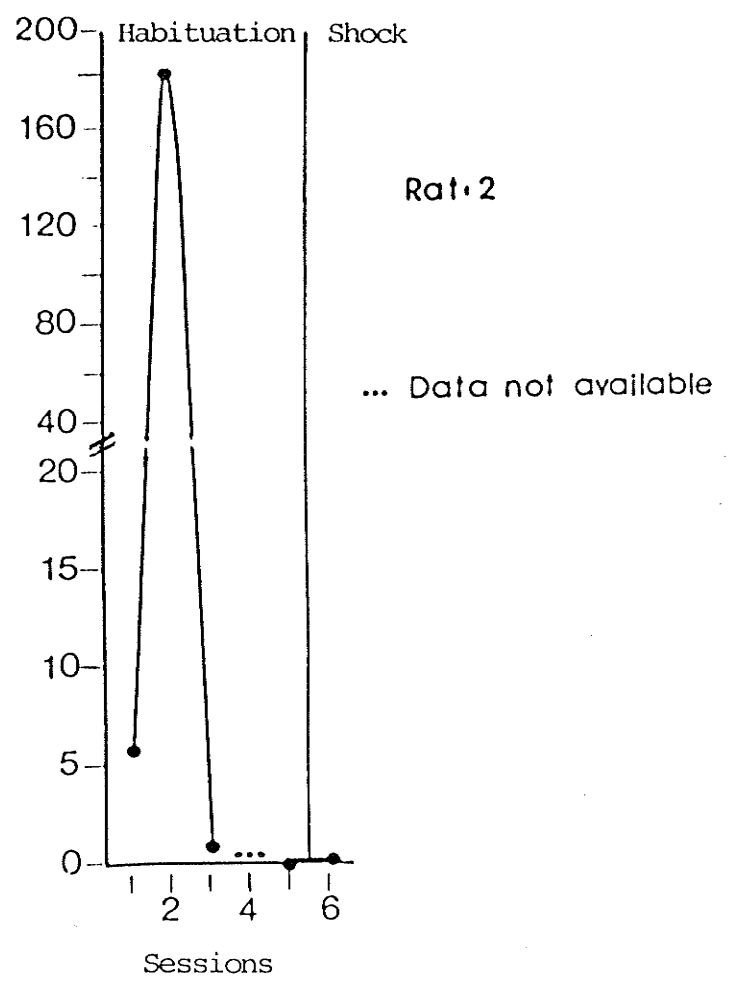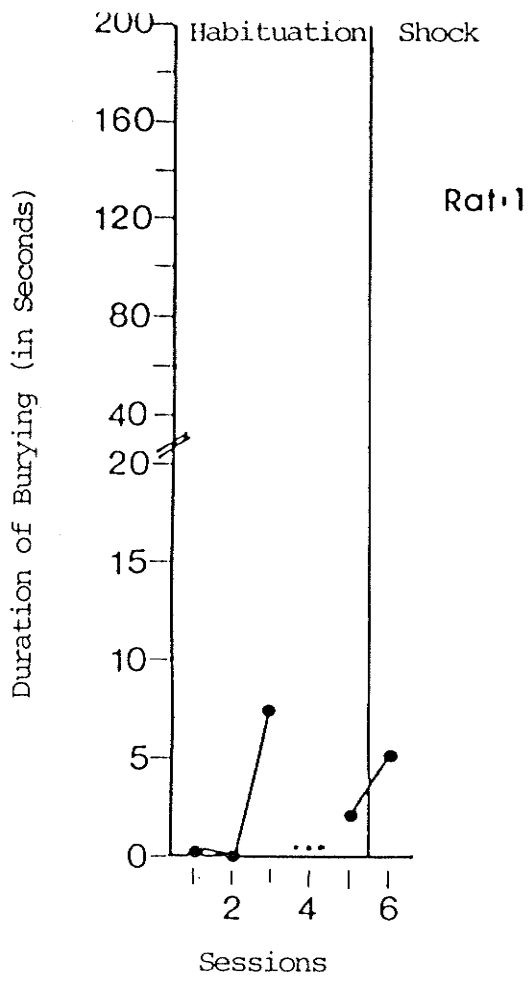
Rat 3 showed a substantial increase in the amount of time spent burying in the sixth session, compared to that in sessions 1 through 5 (see Figure 1). For Rat 4, although the amount of time spent burying in the sixth session had been exceeded in the first three of the five habituation sessions, duration of burying in the sixth session increased substantially over that observed in Sessions 4 and 5, and this increase was in a direction opposite to the decreasing trend observed in the previous four sessions (see Figure 1).
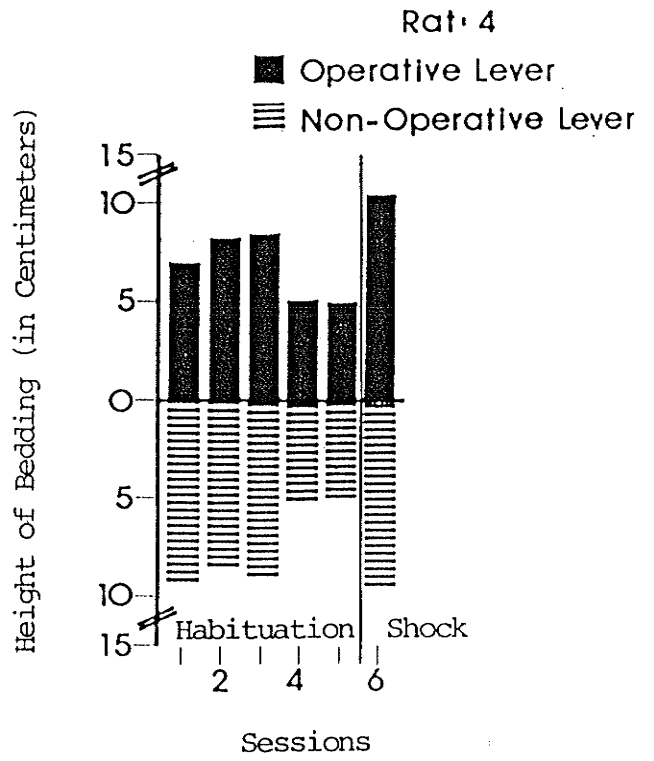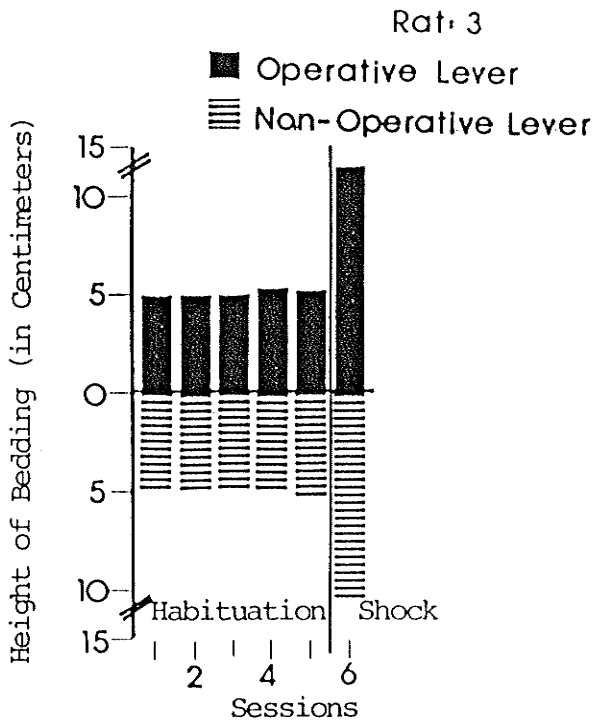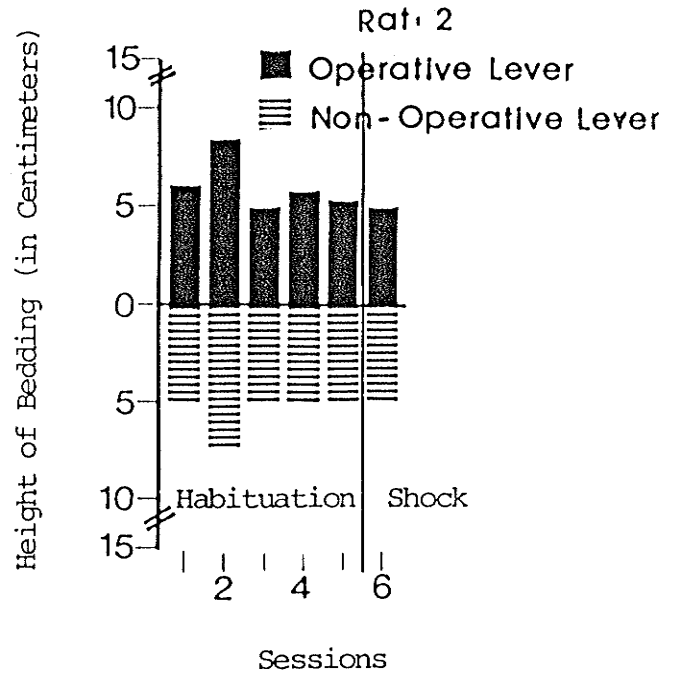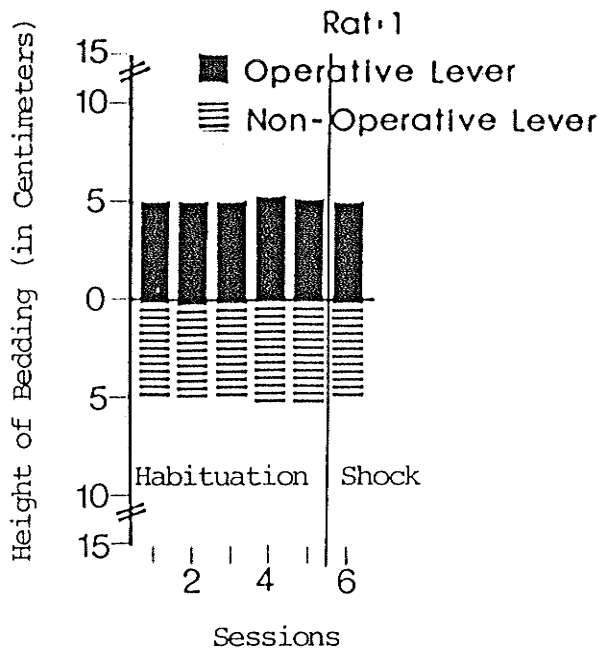
It should be noted that for all four subjects, the duration of burying indicated in Session 6 in Figure 1 represents burying that occurred in the 30-minute period after the last shock was received.

For Rats 1 and 2, the left lever was the operative lever, that is, the lever through which the shock was delivered; for Rats 3 and 4, the right lever was the operative lever.

For Rats 1 and 2, in Session 6, the height of bedding material was the same at both the operative and non operative levers, and did not increase over that observed in the previous five sessions. For Rats 3 and 4, in Session 6, the height of bedding material at both the operative and nonoperative levers increased over that observed in the preceding sessions, and for both subjects the height of bedding material was greater at the operative lever than at the nonoperative lever (see Figure 2).

Although latency to bury following shock presentation was not precisely measured, time spent burying was recorded in 5-minute

Figure 2. Maximum height of bedding material (in centimeters) at
the operative and nonoperative levers, at the end of each session
for rats 1, 2, 3 and 4. For rats 1 and 2, the left lever was the
operative lever. For rats 3 and 4, the right lever was the
operative lever.

Rat 1

Operative Lever
Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation | Shock

Sessions

Rat 2

Operative Lever
Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation | Shock

Sessions

Rat 3

Operative Lever
Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation | Shock

Sessions

Rat 4

Operative Lever
Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation | Shock

Sessions

intervals following shock. Examination of this data does not indicate any consistency across subjects concerning when burying first occurs. There also does not appear to be any relationship between the number of shocks received, and in which 5-minute interval burying is first observed. For Rat 1, burying was first observed in the second 5-minute interval, but occurred primarily in the third interval. For Rat 2, the minimal burying that was observed (0.23 sec) occurred in the first interval. For Rat 3, substantial amounts of burying were observed in intervals 3 and 5. For Rat 4, burying occurred first and predominantly in the third 5-minute interval, with lesser amounts in intervals 5 and 6.

Thus, two of four subjects showed an increase in duration of burying following shock and for both of these subjects, height of bedding material was greater at the operative lever than at the nonoperative lever.

The correlation coefficient for interobserver reliability was .98, as calculated with 15 pairs of data points.

Discussion

The results of Experiment 1 indicate that conditioned burying of a shock source is observed when the shock source is a response lever.

That only two of four subjects (50%) in this experiment showed increased burying after shock is discrepant with earlier data. Hudson (1950), for example, reported that pushing of wood shavings, a response topographically similar to burying, occurred

in 95% of adult subjects following shock. Pinel and Treit (1979) reported burying following shock in 29 of 30 subjects in Experiment 1, and in 18 of 20 subjects in Experiment 2.

It seems probable that the increased burying after shock in only two of four subjects in this study is attributable to a difference in the intensity of the shock experienced on the left and right levers. Although the experimenter determined prior to the shock session for Rats 1 and 2 that contact with the left lever produced a shock, in testing the right lever prior to the shock session for Rats 3 and 4, it was the experimenter's subjective assessment that the shock from the right lever was more intense. This difference would also account for the observation that increased burying after shock occurred only in those subjects for which the operative manipulandum was the right lever.

It should also be noted that under these experimental conditions, increased burying following shock does not appear to be related to the number of shocks received.

Experiment 2

As discussed in the review of the literature, since shock generates both aggressive behavior and burying, and since aggressive behavior has been observed to occur in conjunction with extinction, it is possible that burying like aggressive behavior, may also be observed in conjunction with extinction. Experiment 2 was conducted to determine if burying of a lever, on which a continuous reinforcement schedule was previously programmed, would

be observed under conditions of extinction, when burying materials were available in the experimental chamber.

Although two levers were present in the chamber, in the continuous reinforcement condition, reinforcement was programmed on only one lever, in order to determine whether any burying that might be observed under conditions of extinction was a directed activity, that is, directed toward the lever previously associated with reinforcement.

Method

Subjects

Four experimentally naive, male, adult Long Evans hooded rats (Canadian Breeding Laboratories, La Prairie, Quebec) served as subjects. Subjects were individually housed in wire mesh cages under a 16 hour light/8 hour dark cycle. Rats 5, 7, and 8 were maintained at 85% of their ad lib. weight. Rat 6 was maintained at 80% of his ad lib. weight.

Apparatus

The apparatus was the same as in Experiment 1, with the exception that 0.59 N of pressure was required to record a lever press.

Procedure

Sessions were conducted on a daily basis, and were 30 minutes in duration. Subjects were always placed individually in the chamber facing the wall opposite that on which the levers were located.

Subjects were preexposed to the experimental chamber individually for four 30-minute sessions. The levers were present

in the chamber during these four sessions, but no reinforcement was available for lever pressing. Subjects were then magazine trained, and lever pressing was established by reinforcing with food successive approximations to the lever press response. For each subject, presses on only one lever produced food (the left lever for Rats 5 and 6; the right lever for Rats 7 and 8). Noyes 45 mg precision food pellets were used as reinforcers. Lever pressing was maintained on a continuous reinforcement schedule. When lever press behavior was stable on the operative lever (i.e., the response rate on each of three consecutive days could vary within a range of ±5% of the average response rate for that three day period and show no apparent decreasing trend), reinforcement was discontinued; that is, lever pressing was put on extinction. The minimum number of sessions in the continuous reinforcement condition was set at five; in the event of any equipment malfunction, the count for this 5 day minimum was reset to one, beginning with the subsequent session.

All sessions were videotaped. Duration of burying, and frequency of lever presses and lever bites on both levers were recorded throughout each session. The height of the bedding material at both levers was measured at the end of each session.

Dependent Measures

The dependent measures were the same as in Experiment 1.

Interobserver Reliability

Thirty-five percent of all sessions were randomly selected for inter observer reliability after tapes had been viewed, and

duration of burying recorded by the experimenter. Interobserver
reliability measures were calculated in the same manner as in
Experiment 1.

Results

For Rats 5 and 6, the left lever was the operative lever,
that is, the lever on which continuous reinforcement was
programmed for lever pressing. For Rats 7 and 8, the right lever
was the operative lever.

Rats 5 and 7 contracted pneumonia prior to the end of this
experiment, and their participation in this study was terminated.
Rat 5 was terminated prior to the extinction phase; Rat 7 was run
for two sessions in the extinction phase, but because this animal
was already sick at this time, this data is not considered valid.
For the most part, therefore, the data from these two animals will
not be considered.

Lever biting was rarely observed. No lever bites were
recorded for Rats 6 and 7 throughout this experiment; one bite on
the left lever was recorded in Session 1 for Rat 5; six bites,
five on the right lever and one on the left lever, were recorded
for Rat 8 (these bites were summed across Sessions 1, 8 and 24).
Anecdotal evidence, however, indicates that Rat 6 was observed to
be gnawing on one lever in the second extinction session, and that
Rat 8 was observed to be gnawing on the left lever in extinction
Sessions 3, 4, and 6. Gnawing is defined as the rat's mouthing
the lever, but with insufficient force to close the microswitch
which recorded bites. This definition applies to any further
reference to gnawing in this manuscript.

Lever pressing was stable (as defined by the stability criterion described above) in the continuous reinforcement phase, prior to extinction for Rats 6, 7 and 8. During extinction, lever pressing decreased to zero or to a very low rate.

While Rat 6 showed a slight increase in the amount of time spent burying in the first two sessions of extinction, before returning to zero, Rat 8 showed no burying in the extinction phase (see Figures 3 and 4). It should be noted that the burying exhibited by Rat 6 in extinction Session 1 was directed primarily, if not entirely, toward the back wall.

It is interesting to note that although Rat 8 did not bury during extinction, in extinction Sessions 2, 3 and 4, this subject dug out hollows in various corners of the chamber. It is possible that this "backward digging" response may share some properties with burying.

During extinction, no substantial change from that in the continuous reinforcement phase was observed in the height of the bedding material at either the operative or the nonoperative lever, for both Rat 6 and Rat 8 (see Figures 5 and 6).

For Rat 6, the only subject which demonstrated any burying during extinction, in both the first and second sessions of extinction, the burying observed occurred in the second 5-minute interval of the session.

Thus, burying was minimal or absent in the two subjects exposed to the extinction condition.

It is interesting that although little or no burying was observed in the extinction phase of this experiment, burying was

Figure 3. Total duration of burying (in seconds) for each session
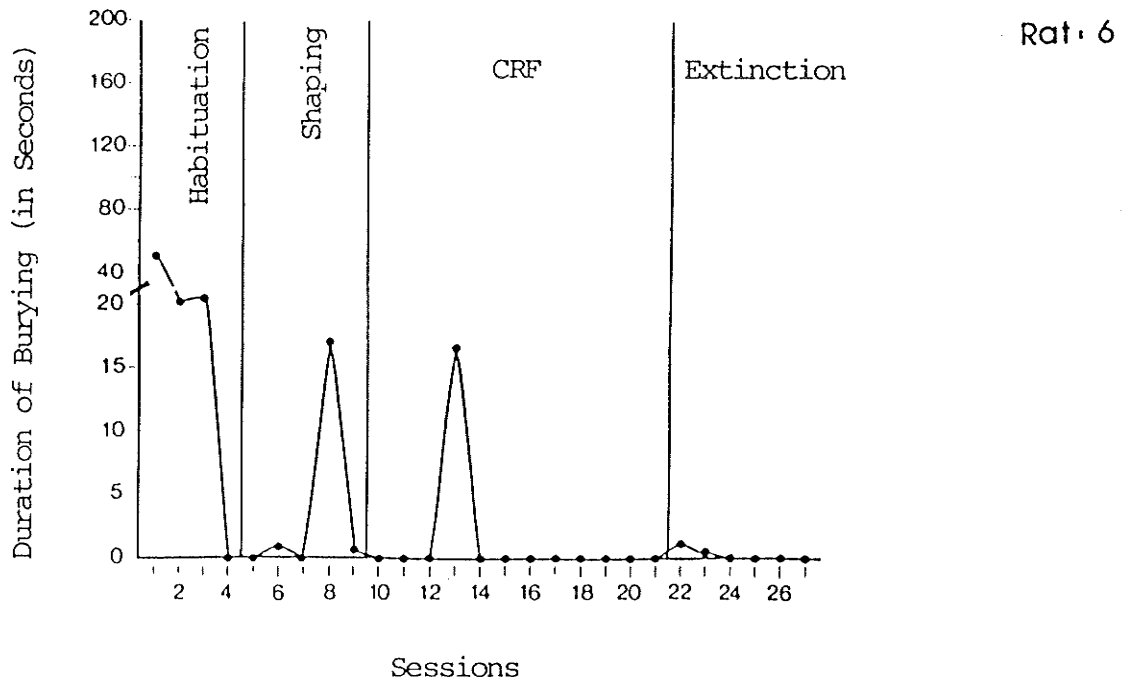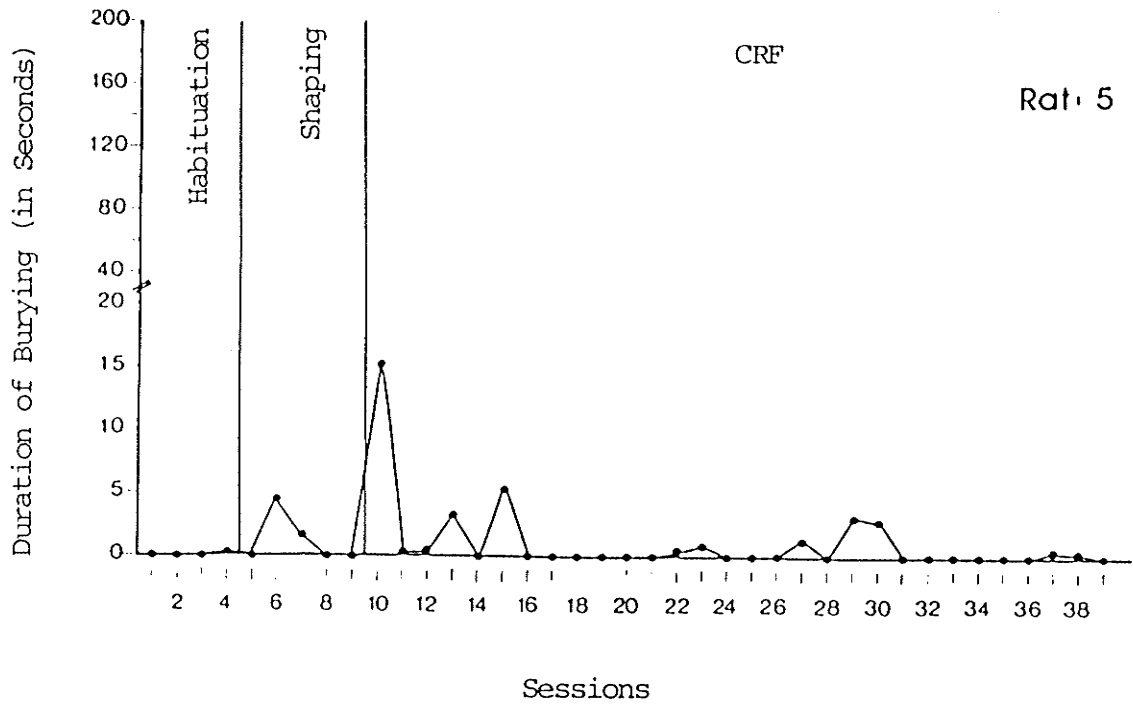
for rats 5 and 6.

Figure 4. Total duration of burying (in seconds) for each session
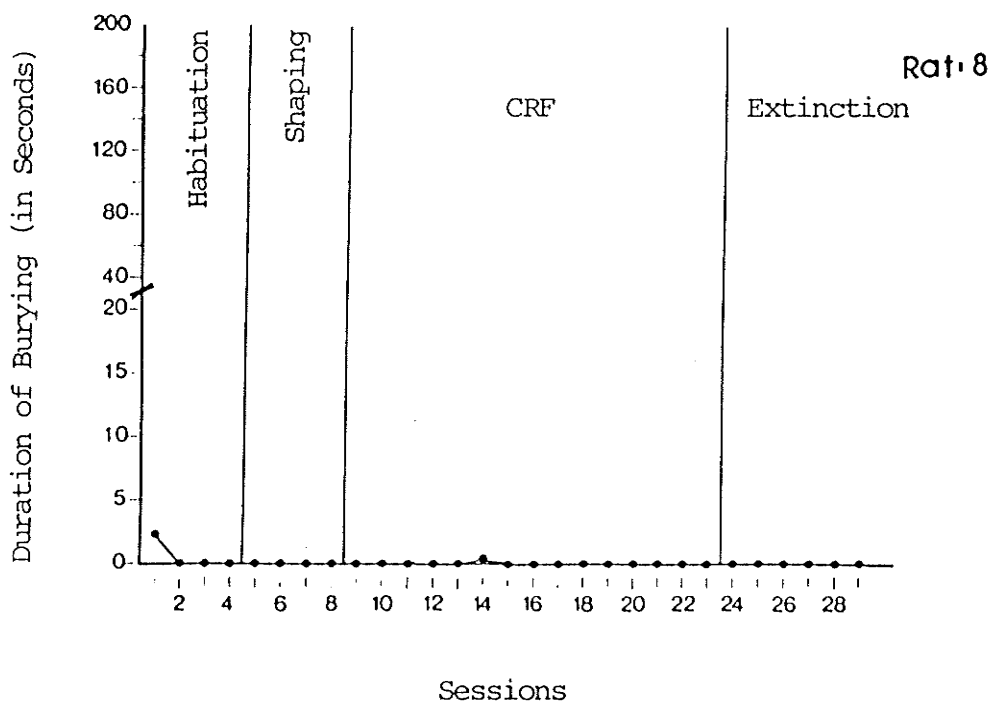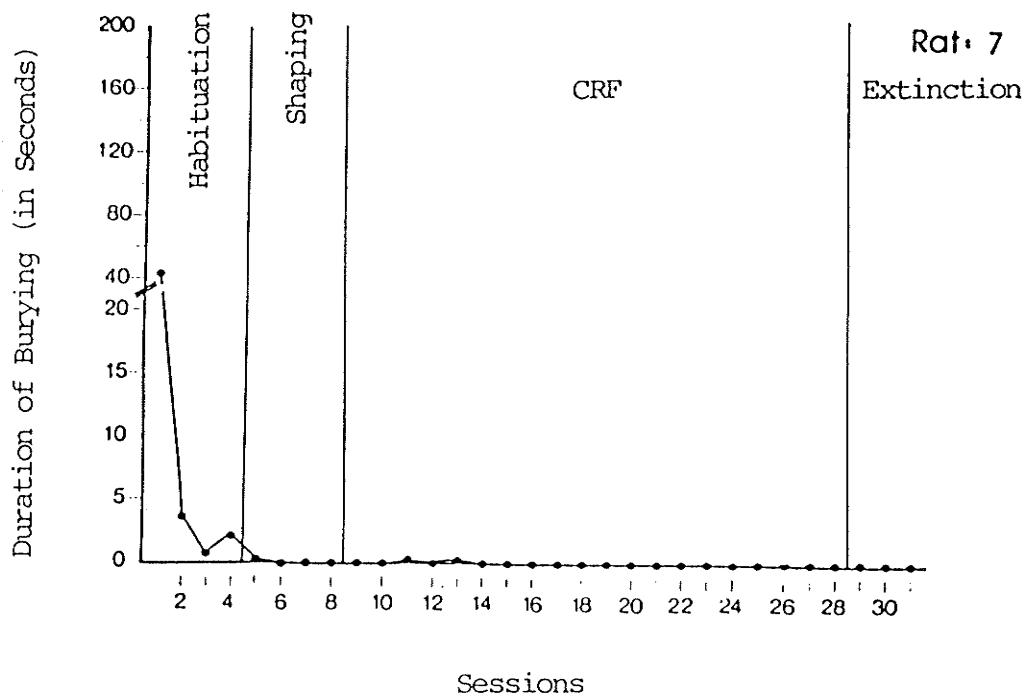
for rats 7 and 8.

Figure 5. Maximum height of bedding material (in centimeters) at

the operative and nonoperative levers, at the end of each session

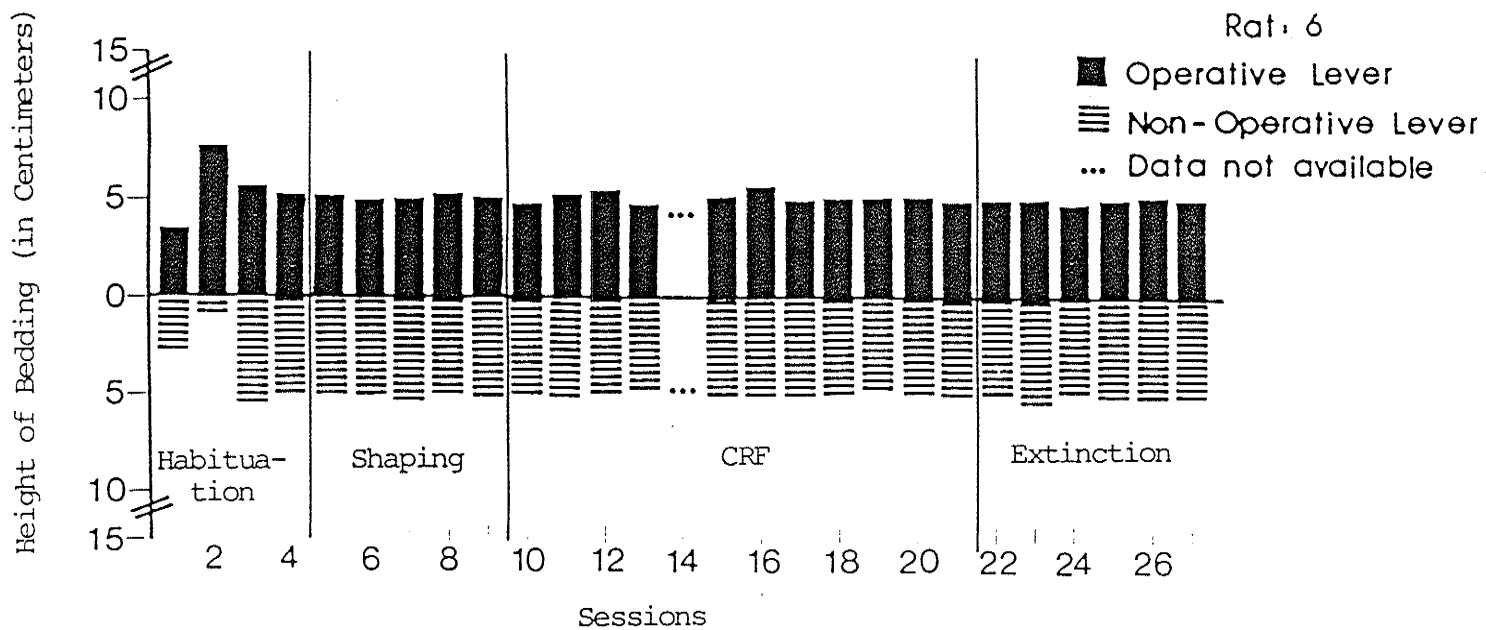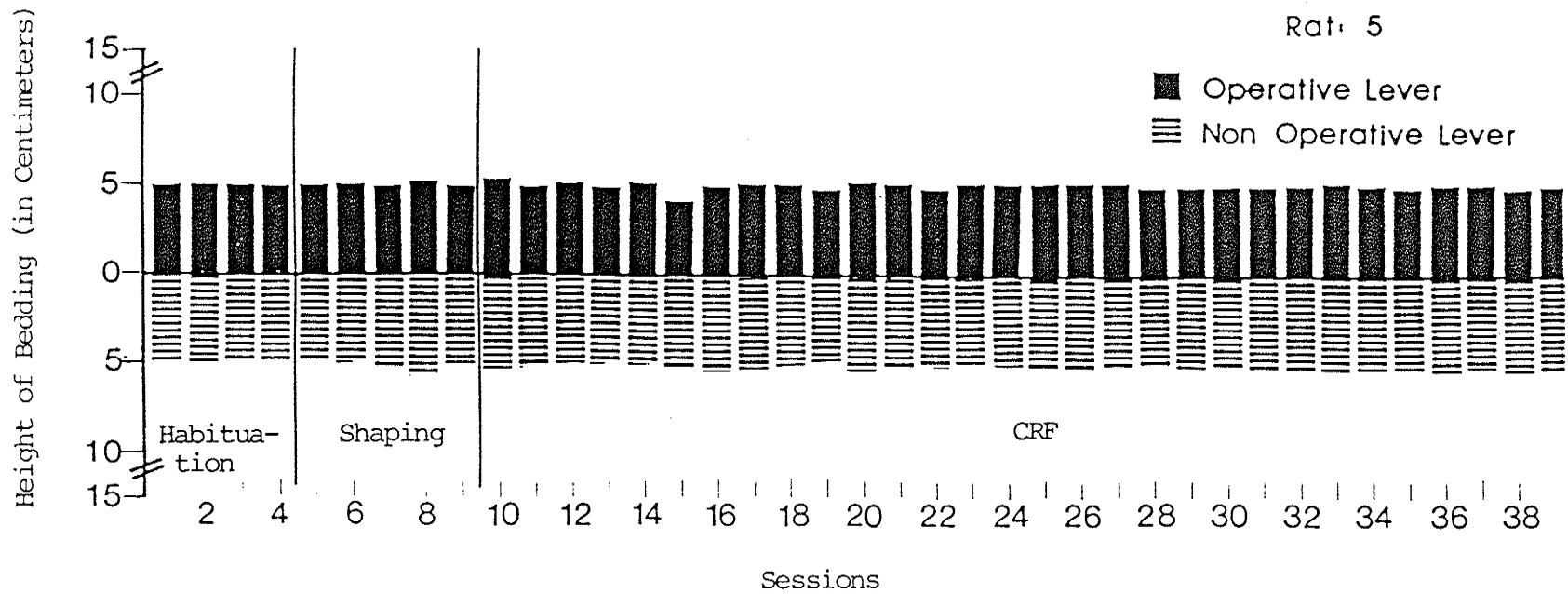for rats 5 and 6, for which the left lever was the operative
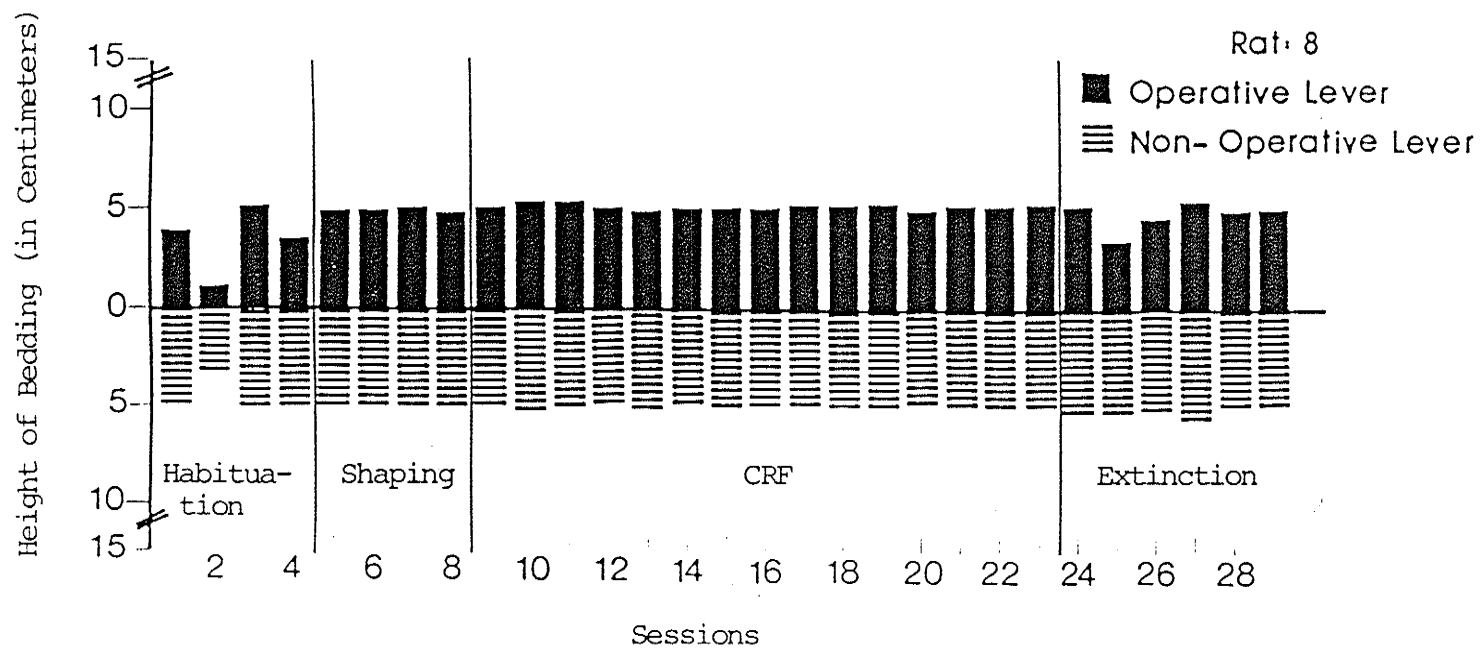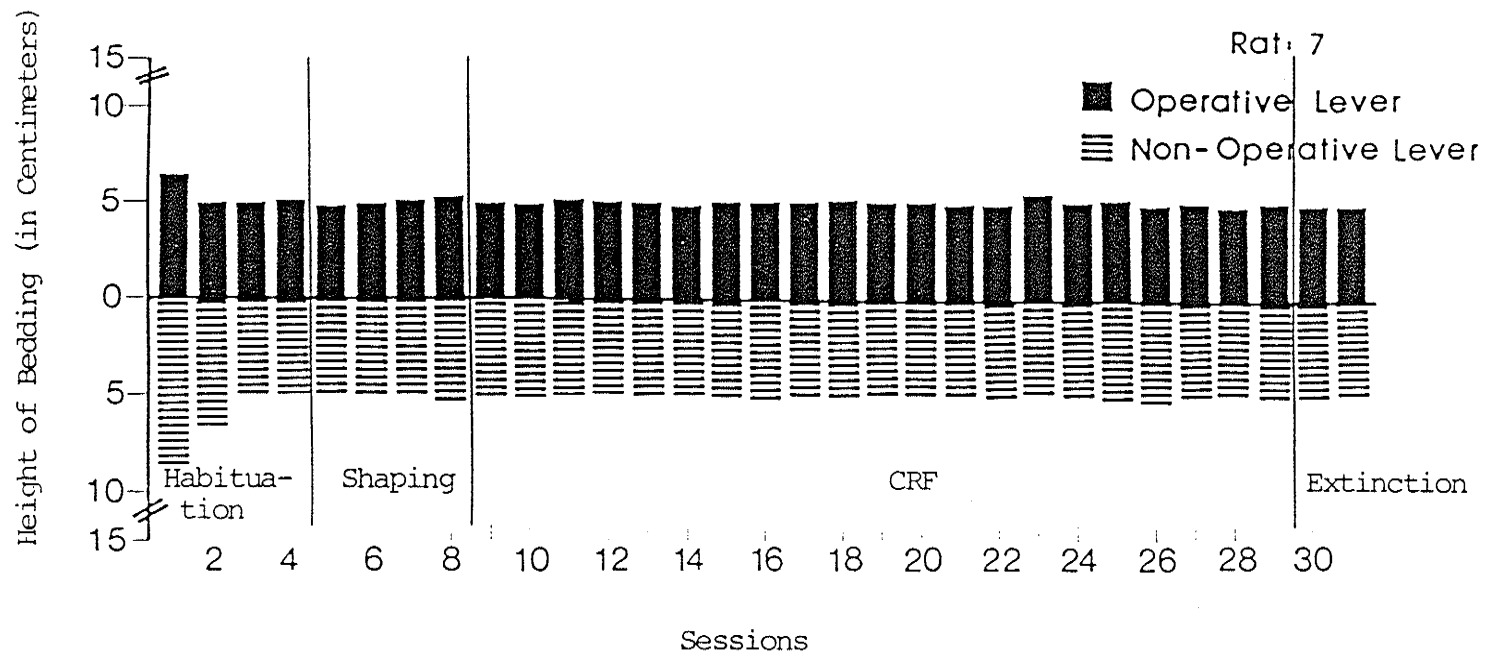
lever.

Figure 6. Maximum height of bedding material (in centimeters) at
the operative and nonoperative levers, at the end of each session
for rats 7 and 8, for which the right lever was the operative
lever.

Figure showing two bar charts for Rat 7 and Rat 8. Y-axis: Height of Bedding (in Centimeters), ranging from 15 to 0 to 15. X-axis: Sessions. Legend: Operative Lever (solid), Non-Operative Lever (lined). Phases labeled: Habituation, Shaping, CRF, Extinction.

sometimes observed during sessions of magazine training and shaping, conditions under which reinforcement density is typically low (e.g., Rat 5 - Session 6; Rat 6 - Session 8). On occasion, burying was also observed during sessions in which the operative lever malfunctioned such that presses were reinforced only some of the time. This equipment failure produced a condition simulating intermittent reinforcement with its concomitant extinction properties. This phenomenon was observed for Rat 5 in Session 15, and for Rat 6 in Session 13. In both instances, the burying observed was directed primarily toward the back of the chamber.

It should be noted, however, that increased duration of burying was sometimes observed in the absence of a malfunctioning lever, and that no increase in duration of burying was sometimes observed in the presence of a malfunctioning lever.

The correlation coefficient for interobserver reliability was .97, as calculated with 18 pairs of data points.

Discussion

Burying of stimuli associated with various sources of aversive stimulation, e.g., shock (Pinel & Treit, 1978, 1979; Terlecki et al., 1979); a blast of air, a light flash, physical impact (Terlecki et al., 1979); toxic food (Wilkie et al., 1979); noxious food (Poling et al., 1981; Wilkie et al., 1979), has been demonstrated to be a reliable phenomenon. The present research, however, suggests that not all aversive stimulus conditions may be sufficient to generate burying. The results of Experiment 2 indicate that for the two subjects exposed to all phases of this

experiment, extinction following continuous food reinforcement for lever pressing does not produce conditioned defensive burying. That extinction is aversive has been indicated by research demonstrating that subjects will respond to terminate conditions of extinction (Terrace, 1971; Thomas & Sherman, 1965; Thompson, 1964), and will engage in aggressive behavior under conditions of extinction (e.g., Azrin et al., 1966; Thompson & Bloom, 1966). It should be noted that in Experiment 2 only two of the four subjects were exposed to all phases of this experiment. Given that in Experiment 1 only two of four subjects showed conditioned burying of a shock source, it is possible that had more subjects completed all phases of Experiment 2 some of them may have shown burying during the extinction phase. Although this remains an empirical question, defensive burying under conditions of extinction seems improbable in light of the work of Goldberg, Ghezzi, and Cheney (1983) who failed to find defensive burying under conditions of extinction, and also because there is no clearly defined discrete stimulus associated with extinction. Conditioned defensive burying is an activity that is directed toward a specific source of aversive stimulation (e.g. Pinel & Treit, 1978, 1979; Pinel, Treit & Wilkie, 1980; Poling et al., 1981; Terlecki et al., 1979; Wilkie et al., 1979).

Alternatively, the findings of the present research may be interpreted as suggesting the possibility that conditioned defensive burying may not be a species-specific defense reaction in rats because in this study, as well as that of Goldberg et al.

(1983), it was not observed under conditions of extinction, conditions under which the species-specific defense reactions of escape and aggression have been observed (Azrin et al., 1966; Terrace, 1971; Thomas & Sherman, 1965; Thompson, 1964; Thompson & Bloom, 1966). A less extreme possibility is that conditioned defensive burying is a species-specific defense reaction, but that not all species-specific defense reactions occur in all situations. For example, burying is attenuated both when the size of the chamber is increased and when the chamber is divided such that the shock source is contained in one-half of the chamber, thereby making the other half of the chamber a "safe" environment (Moser & Tait, 1983; Pinel, Treit, Ladak, & MacLennan, 1980). In addition, although there is a substantial body of literature documenting the occurrence of the species-specific defense reaction of attack following shock (e.g. Azrin et al., 1964; Azrin et al., 1967; Pear et al., 1972; Ulrich & Azrin, 1962; Ulrich & Craine, 1964), in Experiment 1 of this study no bites were recorded after shock on either lever for any of the four subjects. Similarly, biting of shock prods was not mentioned in other studies investigating defensive burying (e.g. McKim & Lett, 1979; Pinel, Treit, Ladak, & MacLennan, 1980; Terlecki et al., 1979). Further, Pinel and Treit (1978) noted the absence of "aggressive behavior directed at the prod" (p. 712). Also, in Experiment 2 of this research, lever biting was rarely observed. Perhaps under the conditions of Experiment 2, extinction was not sufficiently aversive to generate either aggression or burying.

The data of Experiment 2 are also open to the interpretation that the absence of conditioned defensive burying during extinction is attributable to attenuation of the response following extended exposure to the experimental situation prior to the extinction phase. McKim and Lett (Experiment 3, 1979) found that 4 sessions of habituation to the experimental situation reduced not only unconditioned burying, but also, to a lesser extent, conditioned burying of a shock source. Moser, Tait, and Kirby (1980) also examined defensive burying as a function of number of days of habituation to the experimental situation prior to shock. Subjects received 0, 1, 2, 3, or 4 15-minute habituation sessions prior to the test day when a single 7mA shock was delivered. Measures of burying on the shock day indicated that frequency of burying and duration of burying were an inverse function of the number of sessions of habituation, while the latency measure showed no significant difference with number of days of habituation.

In Experiment 2 of this study, the number of sessions spent in the habituation, magazine training and shaping, and continuous reinforcement phases prior to extinction, were 21 sessions for Rat 6, 29 sessions for Rat 7, and 23 sessions for Rat 8. Given that McKim and Lett (1979) and Moser et al. (1980) observed a decrease in conditioned burying after only 4 sessions of habituation, the argument that conditioned defensive burying during extinction has been attenuated by extended exposure to the experimental situation seems plausible. The credibility of this position, however, is

weakened by the findings of Goldberg et al. (1983). In their

first experiment, following three days of habituation to the

experimental situation, conditioned defensive burying of a shock

source was observed following a single 10mA shock. In the third

experiment, at least three sessions of extinction followed eight

sessions of continuous water reinforcement for lever pressing.

Although lever pressing decreased in the extinction phase, burying

was not demonstrated by any of the three subjects. It is

important to note that the rats in both Experiments 1 and 3 were

not experimentally naive. All of these subjects had served

approximately three months earlier in a study in which continuous

water reinforcement for lever pressing was followed by an

extinction phase. This earlier study was comprised of

approximately 13 sessions, 30 to 60 minutes in duration.

That rats in the work of Goldberg et al. (1983) buried a

shock source, even with extended previous exposure to the

experimental situation, and rats with a similar history did not

show burying during extinction following continuous water

reinforcement for lever pressing, suggests that the lack of

burying in Experiment 2 of the present research is attributable to

the nature of the aversive stimulus, that is, extinction, rather

than to extended exposure to the experimental chamber prior to

extinction. The finding in Experiment 2 that burying was minimal

or absent in the two subjects exposed to the extinction condition,

lends support to the conclusions of Goldberg et al. (1983) that

defensive burying requires the presentation of a "discrete

aversive stimulus" (p. 198), and that extinction does not meet

this criterion.

Experiment 3

As discussed in the review of the literature, shock generates burying. Conditioned burying was not observed during extinction in Experiment 2. Therefore, in Experiment 3, lever pressing was continuously reinforced with food; once lever pressing was stable, a shock was delivered through that lever. The purpose of this experiment was to determine if burying of the shock source would still be observed when shock was delivered through the manipulandum, on which continuous food reinforcement for lever pressing was concurrently programmed.

As in Experiment 2, reinforcement was programmed on only one of the two levers. Shock was delivered through that same lever, in order to determine whether any observed postshock burying was a directed activity (i.e., directed toward the lever that was the shock source).

Method

Subjects

Four experimentally naive, male, adult Long Evans hooded rats (obtained from the University of Manitoba) served as subjects. Subjects were individually housed in wire mesh cages under a 16 hour light/8 hour dark cycle. Rats 9, 11 and 12 were maintained at 85% of their ad lib. weights. Rat 10 was maintained at 80% of his ad lib. weight.

Apparatus

The apparatus was the same as in Experiment 2.

Procedure

Sessions were conducted on a daily basis, and were 30 minutes in duration. Subjects were always placed individually in the chamber facing the wall opposite that on which the levers were located.

Subjects were preexposed to the experimental chamber individually for four 30-minute sessions. The levers were present in the chamber during these four sessions but no reinforcement was available for lever pressing. Subjects were then magazine trained, and lever pressing was established by reinforcing with food, successive approximations to the lever press response. For each subject, presses on only one lever produced food (the left lever for Rats 9 and 10; the right lever for Rats 11 and 12). Forty-five mg "dustless" precision pellets (Bioserv Inc.) were used as reinforcers. Lever pressing was maintained on a continuous reinforcement schedule.

The initial criterion for shock delivery was stable lever pressing. Lever pressing on the operative lever was considered stable when the response rate on each of three consecutive days varied within a range of ±5% of the average response rate for that three day period, and showed no apparent increasing trend. The minimum number of sessions in the continuous reinforcement condition was set at five; in the event of any equipment malfunction, the count for this 5 day minimum was reset to one, beginning with the subsequent session. This criterion for shock delivery was maintained for Rats 9 and 11. After 35 and 34

sessions for Rats 10 and 12 respectively, when the stability criterion had not been obtained, it was decided to deliver shock since the rate of lever pressing showed no decreasing trends in the data. This course of action was considered appropriate, as the behavior of interest was burying, and not lever pressing.

During the "shock" session, for each subject the operative lever was electrified approximately 10 minutes after the start of the session. The shock was approximately 8mA in intensity, and was received when the subject pressed the lever. Shock was terminated when the subject broke contact with the lever. The intent of this experiment was to examine the effects of a single shock through the lever within a context of continuous reinforcement for presses to that lever. Two of the four subjects, however, received two shocks. For Rat 9, it is possible that a shock was received shortly after the lever was electrified at 10 minutes after the start of the session. The lack of a clearly visible reaction (i.e., responses such as freezing, jumping), however, prompted the experimenter to turn the shock on again two minutes later. The subject's subsequent response (i.e., jumping) indicated that a shock had definitely been received. For Rat 10, the lever was electrified approximately 10 minutes after the start of the session. This animal touched the lever twice in rapid succession, before the experimenter was able to turn off the switch.

No shock was delivered through the second lever. For each subject, the "shock" session continued until 30 minutes had

elapsed since the last shock had been received. Following the "shock" session the continuous reinforcement condition was reinstated. For Rats 10, 11 and 12 three more sessions of continuous reinforcement for lever pressing, without any shock delivery, were conducted. For Rat 9 four more sessions of continuous reinforcement were conducted.

All sessions were videotaped. Duration of burying, and frequency of lever presses and lever bites on both levers were recorded throughout each session. The height of the bedding material at both levers was measured at the end of each session.

Dependent Measures

The dependent measures were the same as in Experiment 1.

Interobserver Reliability

Thirty-nine percent of all sessions were randomly selected for interobserver reliability after tapes had been viewed, and duration of burying recorded by the experimenter. Interobserver reliability measures were calculated in the same manner as in Experiment 1.

Results

For Rats 9 and 10, the left lever was the operative lever, that is, the lever on which continuous reinforcement was programmed for lever pressing, and through which shock was delivered in the "shock" session; for Rats 11 and 12, the right lever was the operative lever.

Lever biting was rarely observed. No lever bites were recorded for Rat 9 throughout this experiment; one bite on the

left lever was recorded in Session 27 for Rat 10; 4 bites on the right lever were recorded in Session 7 for Rat 11; two bites on the right lever were recorded in Session 1 for Rat 12. Anecdotal evidence indicated that all subjects were occasionally observed to gnaw on the levers. These observations are of limited value, however, as they were not recorded in a systematic manner.

Cumulative records of lever pressing for the two sessions prior to the "shock" session, the "shock" session, and three postshock sessions are indicated in Figures 7, 8, 9, and 10 for Rats 9, 10, 11, and 12. Shock presentation only minimally disrupted lever press performance, and the behavior was rapidly resumed. Following the last shock, (Rats 9 and 10 received two shocks) Rat 9 resumed lever pressing within approximately 35 seconds (see Figure 7); Rat 10 within approximately 9 seconds (see Figure 8); Rat 11 within approximately 23 seconds (see Figure 9); Rat 12 within approximately 58 seconds (see Figure 10).

As indicated in Figure 11, Rat 9 showed no burying following shock in Session 23, or in the first postshock session, and very minimal burying in the three subsequent postshock sessions. (It should be noted that for all four subjects the duration of burying indicated in the "shock" session represents burying that occurred in the 30 minute period after the last shock was received.) Further, the burying observed in postshock Sessions 2, 3 and 4 was not directed toward the operative (left) lever, but rather toward the back, the right side and right front of the chamber. Rat 10 showed minimal burying following shock in Session 36, and a

Figure 7. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, the

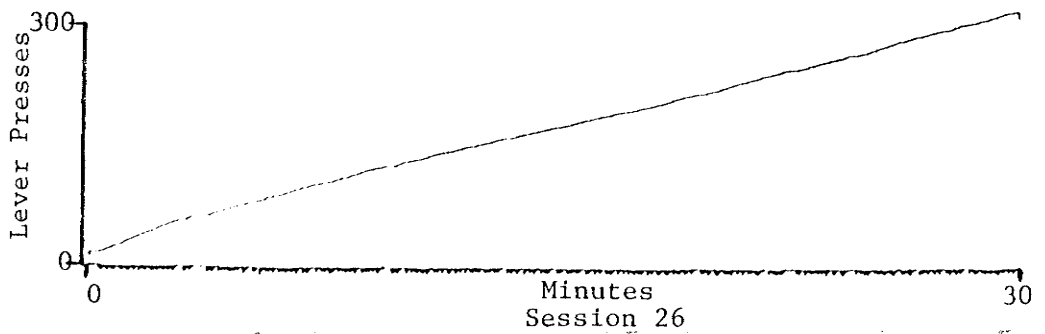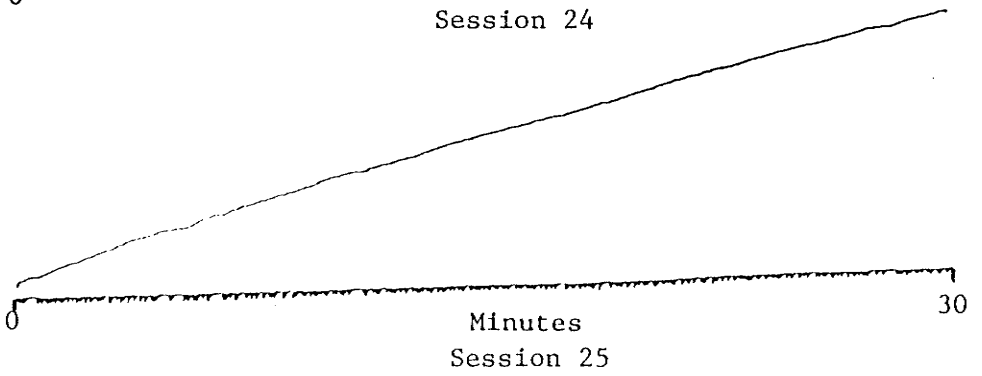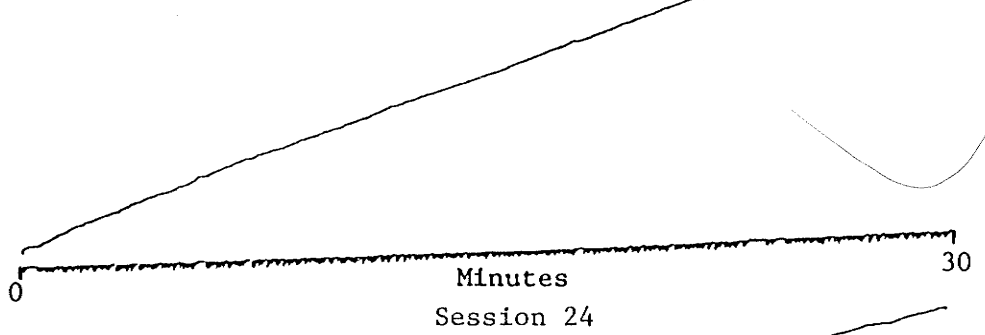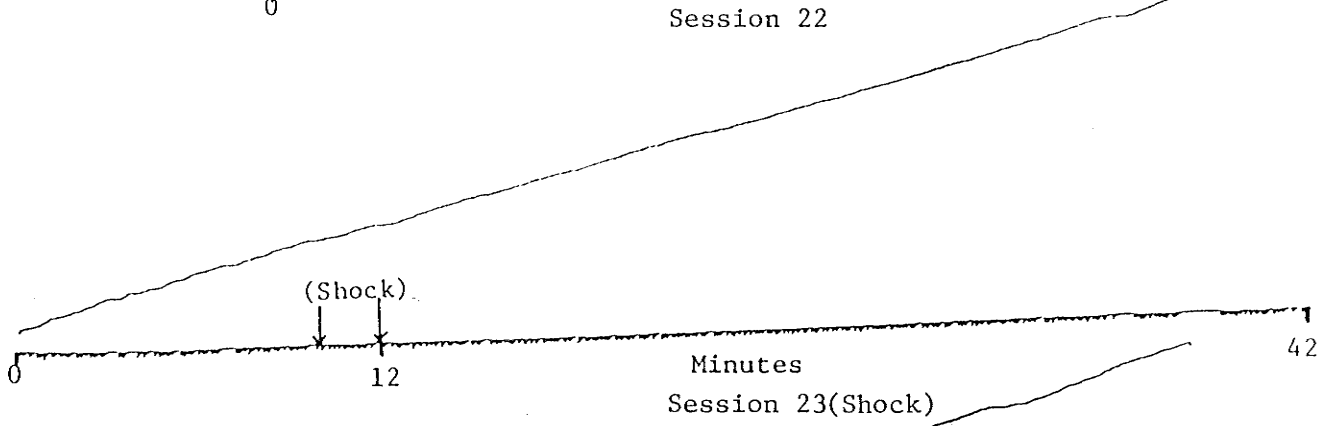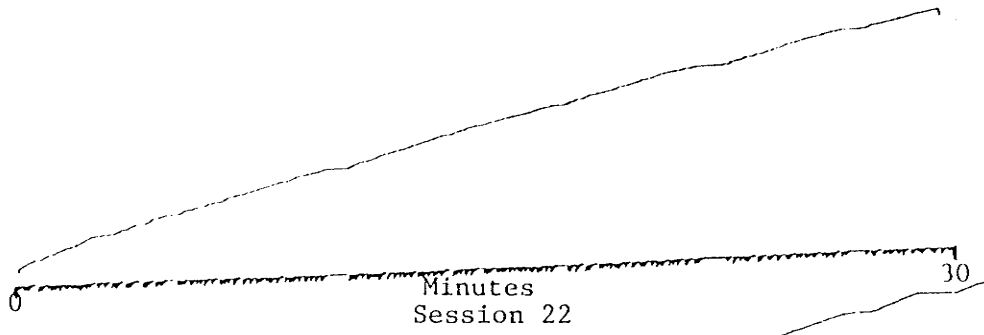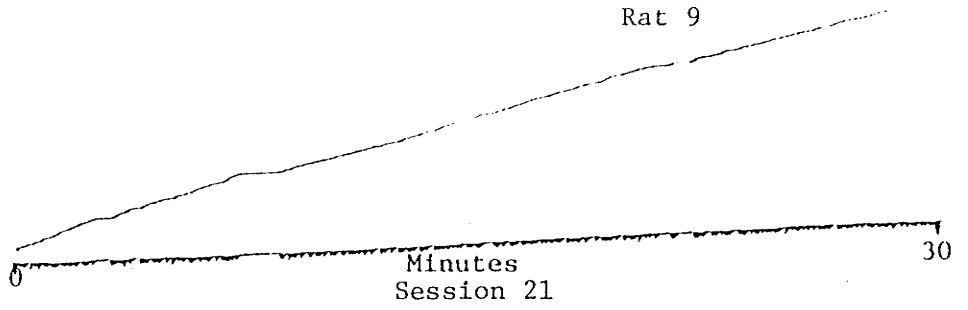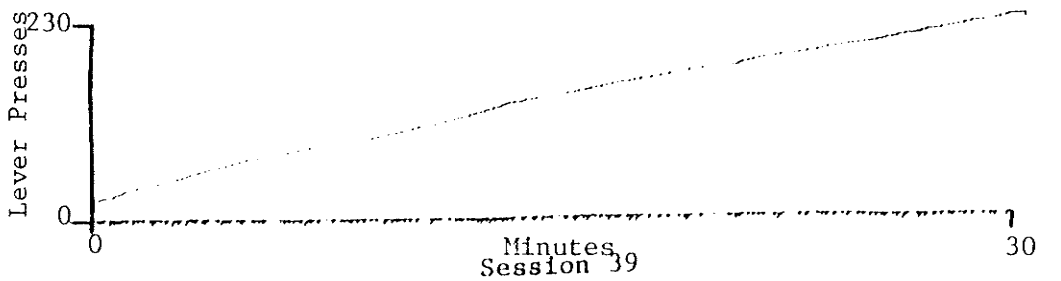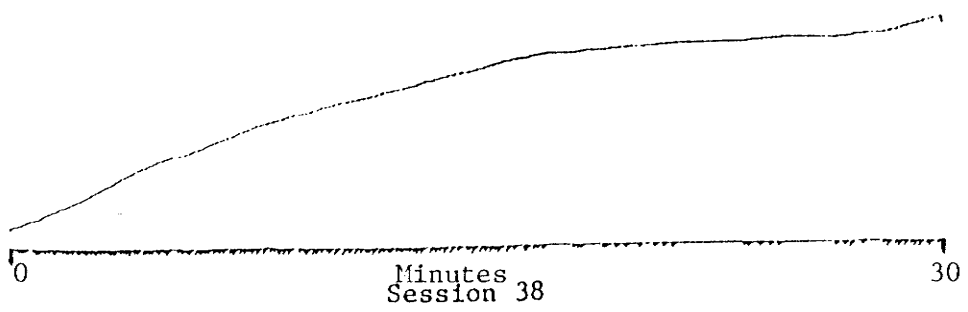"shock" session, and three postshock sessions for rat 9.

Rat 9

Minutes
Session 21

Minutes
Session 22

(Shock)

Minutes
12
Session 23(Shock)

42

Minutes
Session 24

30

Minutes
Session 25

30

300

Lever Presses

0

0
Minutes
Session 26

30

Figure 8. Cumulative records of lever pressing for the two

sessions prior to the "shock" session, the "shock" session, and

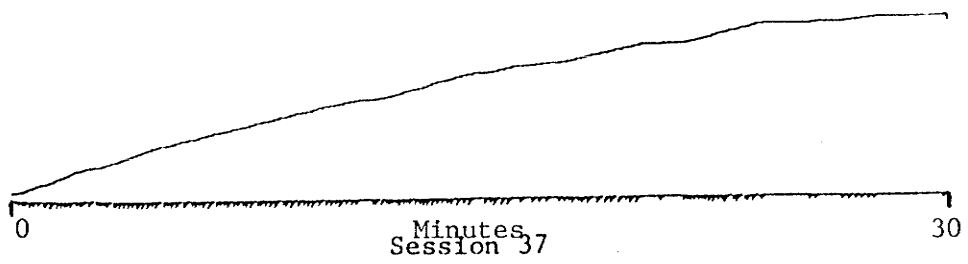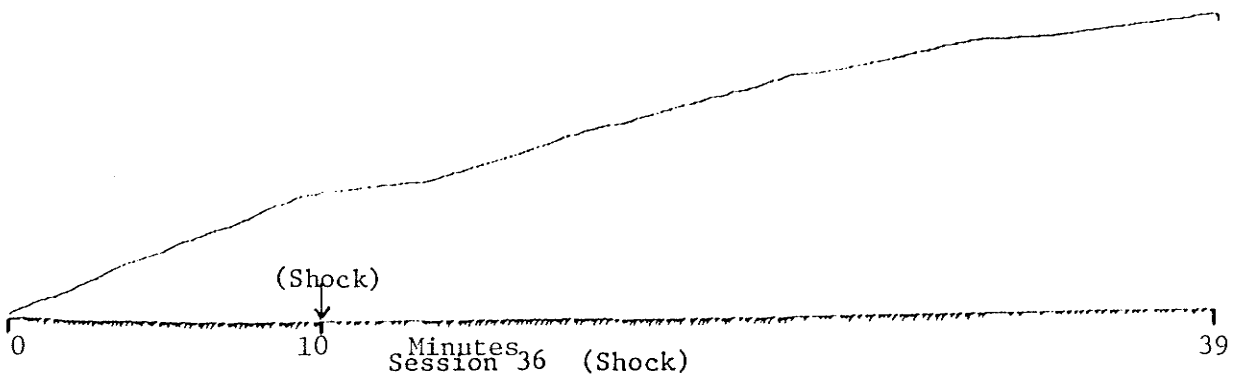three postshock sessions for rat 10.

Rat 10

Minutes
Session 34

Minutes
Session 35

(Shock)

Minutes
Session 36   (Shock)

Minutes
Session 37

Minutes
Session 38
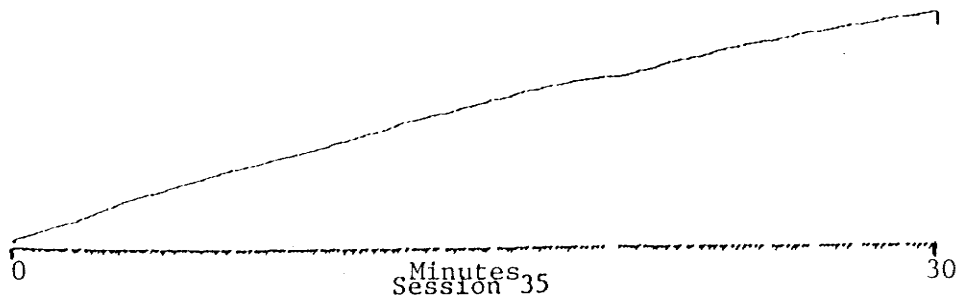
Lever Presses
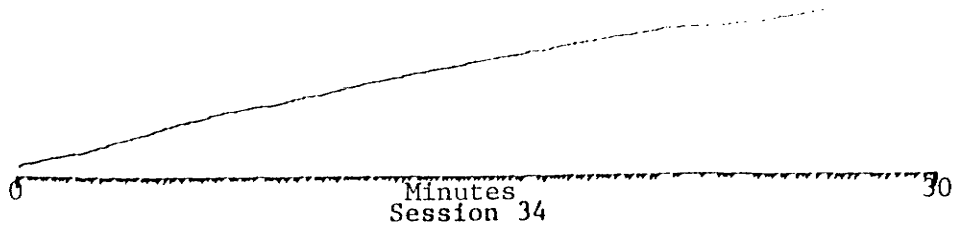
230

0

Minutes
Session 39

Figure 9. Cumulative records of lever pressing on the operative lever for the two sessions prior to the "shock" session, the "shock" session, and three postshock sessions for rat 11.
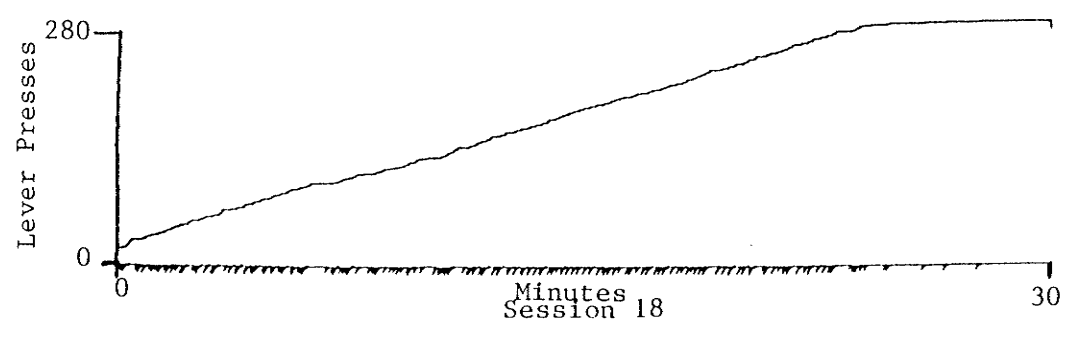
Rat 11

0   Minutes   30
                    Session 13

0   Minutes   30
                    Session 14

(Shock)
                      ↓
0   11   Minutes   41
                    Session 15 (Shock)

0   Minutes   30
                    Session 16

0   Minutes   30
                    Session 17

280

Lever Presses

0
 0   Minutes   30
                    Session 18

Figure 10. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, the

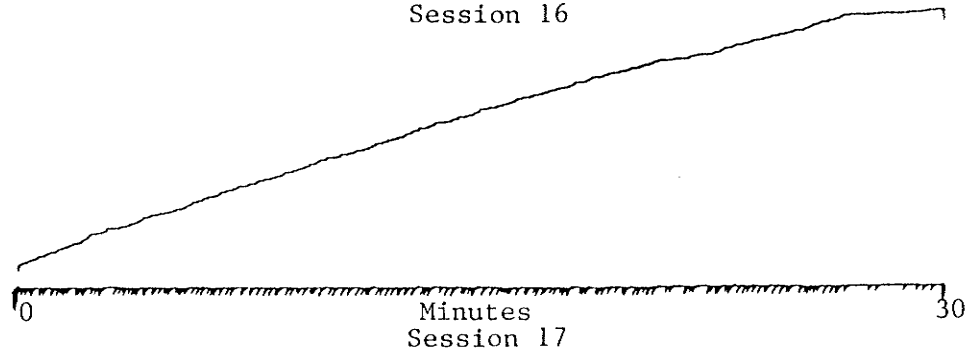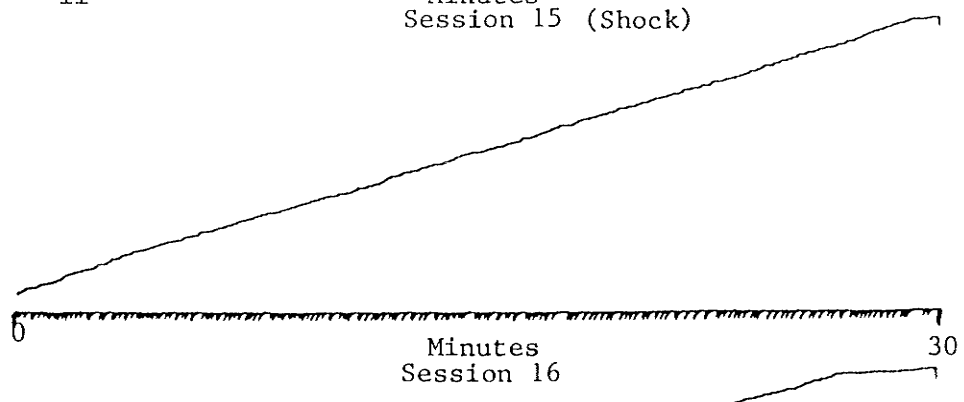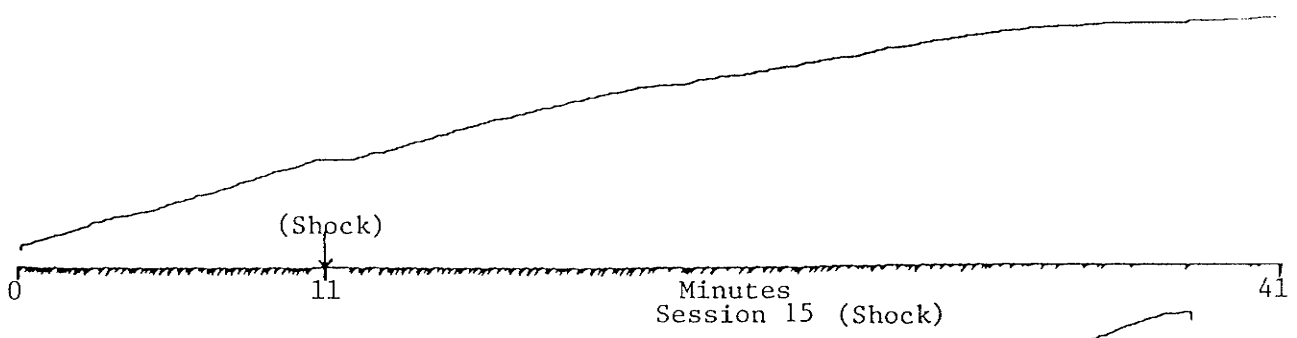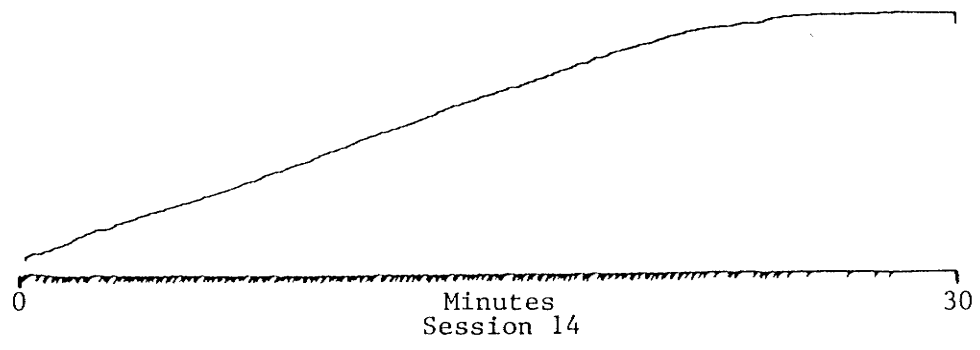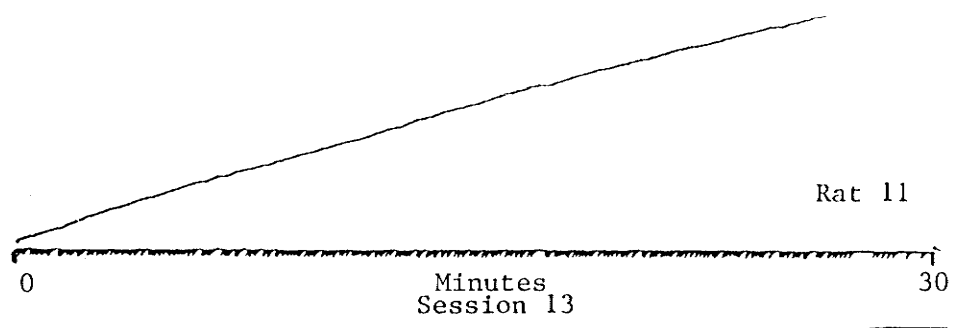"shock" session, and three postshock sessions for rat 12.

Rat 12

Minutes
Session 33

Minutes
Session 34

(Shock)

0   10   Minutes
                    Session 35 (Shock)   39

Minutes
Session 36

Minutes
Session 37

340

Lever Presses

0

0   Minutes   30
        Session 38
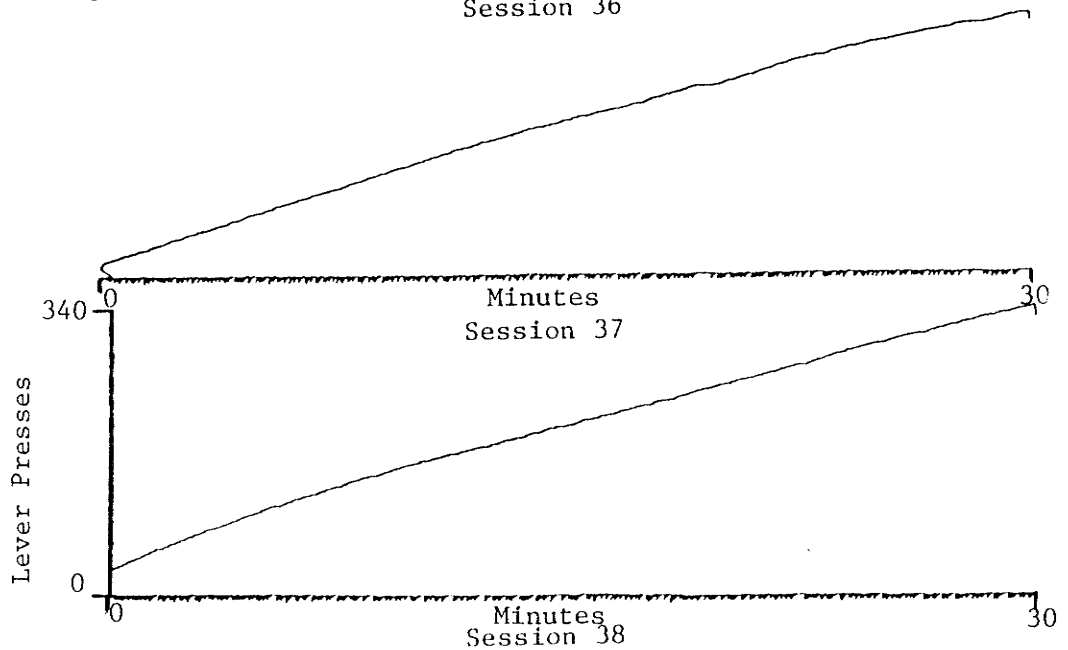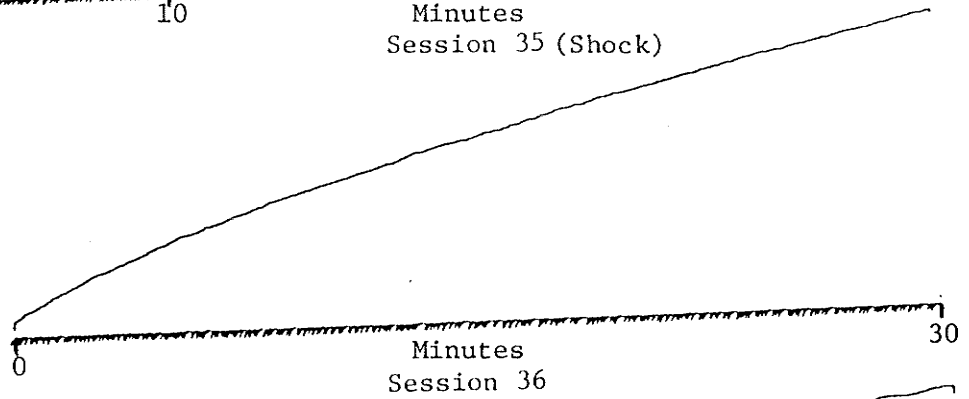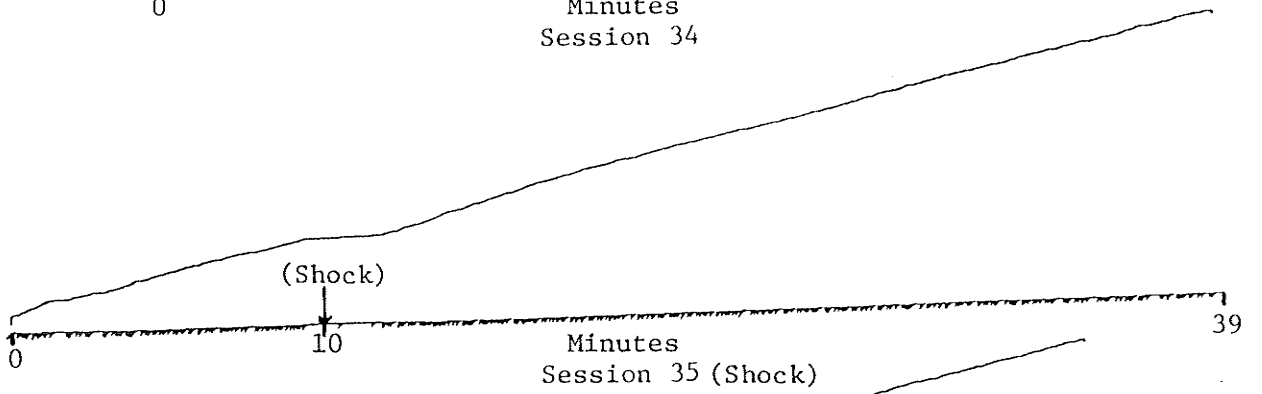
Figure 11. Total duration of burying (in seconds), for each session for rats 9 and 10.

slightly greater amount in the second postshock session (see

Figure 11). No burying was observed in the first and third

postshock sessions. In the second postshock session, the first

two instances of burying were directed towards the back wall, the

next three instances toward the left side wall, but near the front

of the chamber, (i.e., near the left lever).

For Rat 9, the maximum height of bedding at the operative
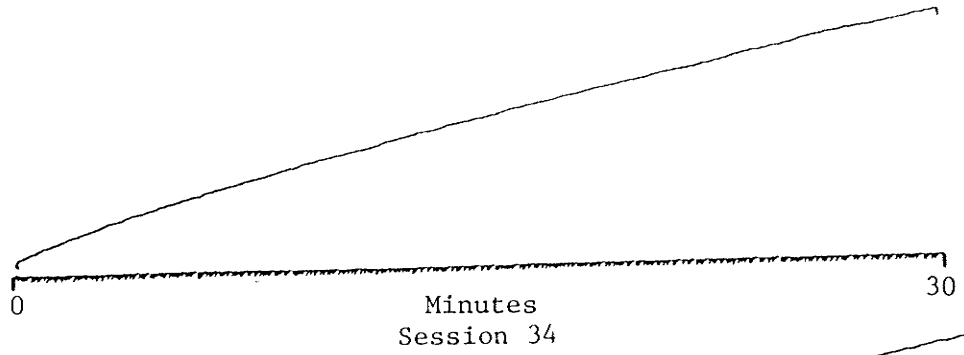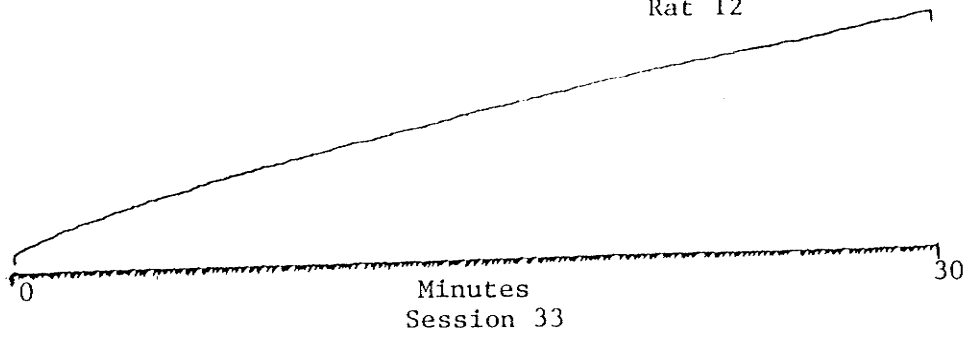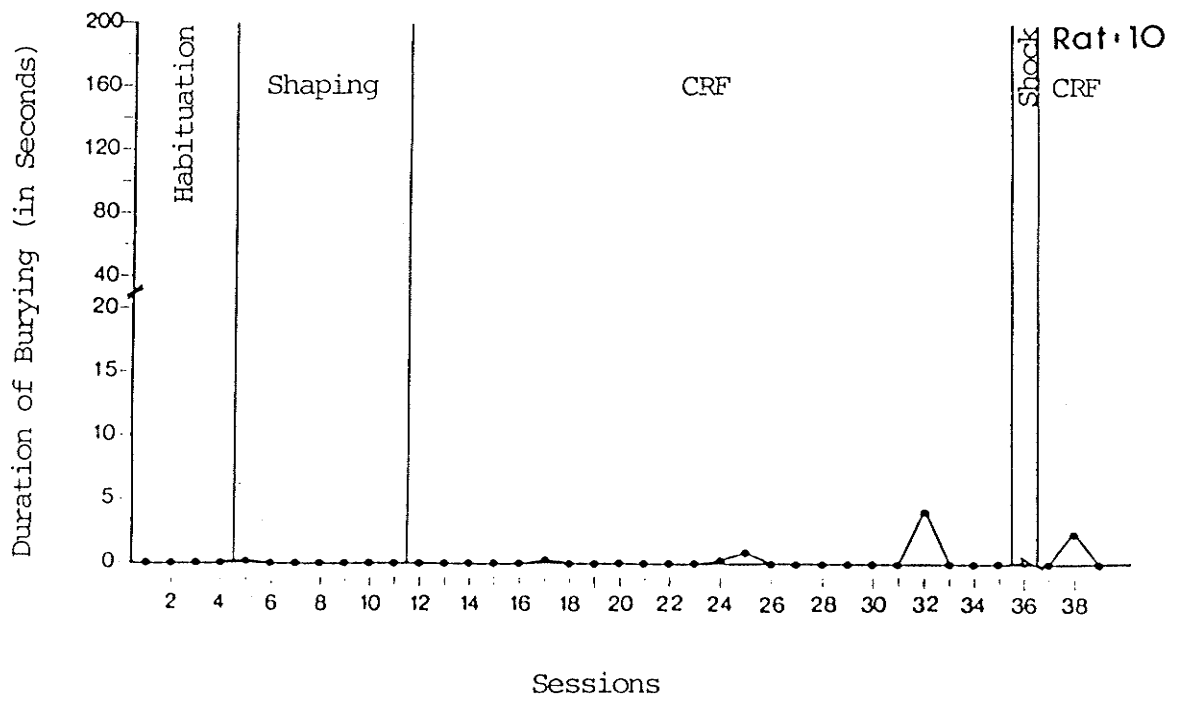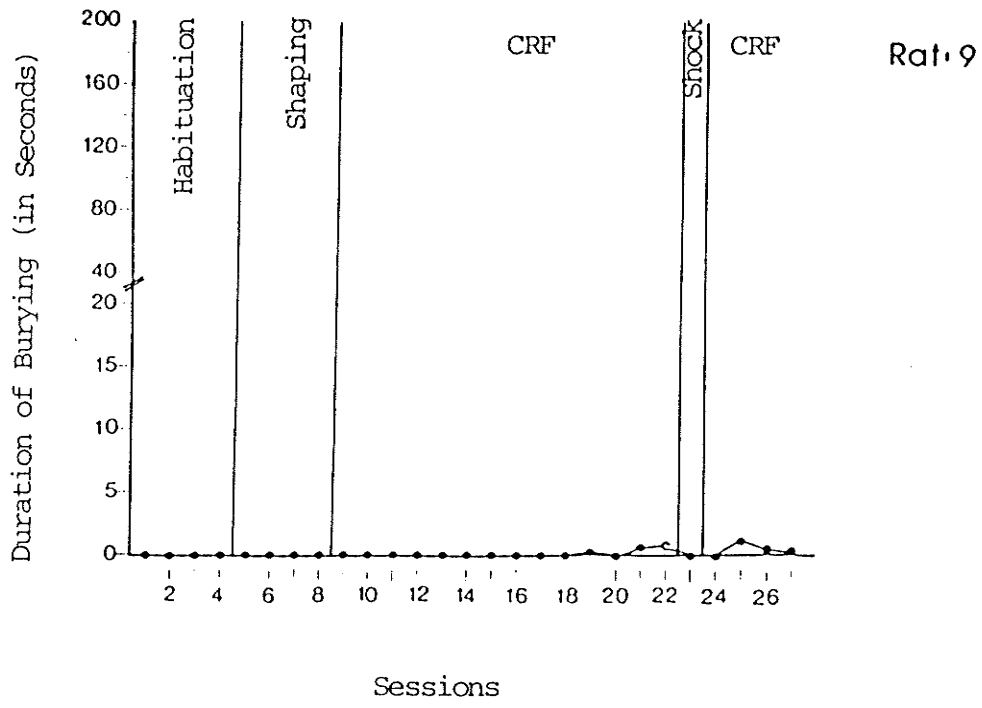
lever was slightly higher for the "shock" session and postshock

Sessions 1 and 4, than for the sessions immediately preceding the

"shock" session. (The height of bedding data for Session 13 for

Rat 9 are unavailable. It was determined at the end of the

session that the chamber was not level. Therefore, both the pre

and postsession measures of height of sawdust were in error.) For

Rat 10, the maximum height of bedding at the operative lever

showed a slight increase for the "shock" session and postshock

Sessions 1 and 2, over that observed for the two sessions

immediately preceding shock. The maximum height of bedding at the

nonoperative lever for Rat 10 however, showed a similar pattern

(see Figure 12).

As indicated in Figure 13, Rats 11 and 12 showed no burying

during the "shock" session, or the subsequent postshock sessions.

For Rat 11, the maximum height of bedding at the operative

lever for the postshock sessions is slightly higher than for the

sessions immediately preceding shock. This pattern is replicated

for the nonoperative lever. For Rat 12, the maximum height of

bedding at the operative lever is slightly higher for postshock

Figure 12. Maximum height of bedding material (in centimeters) at the operative and nonoperative levers at the end of each session for rats 9 and 10, for which the left lever was the operative lever.
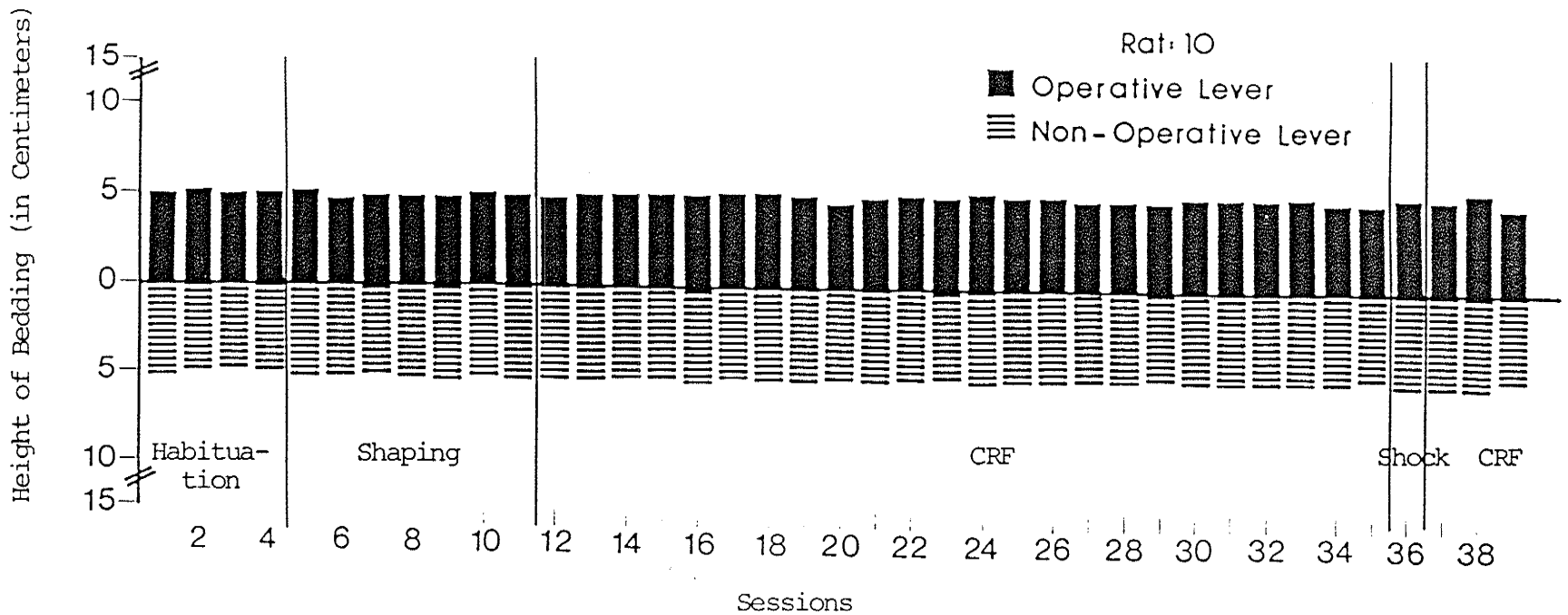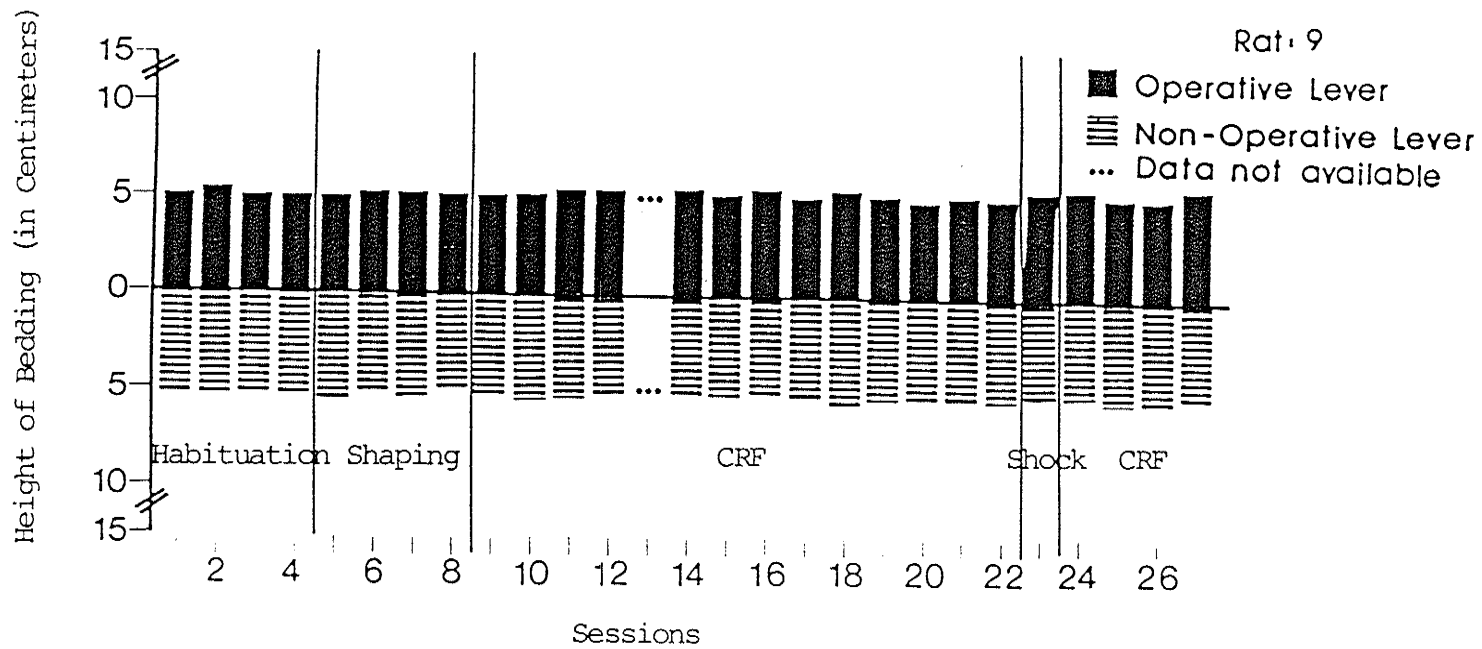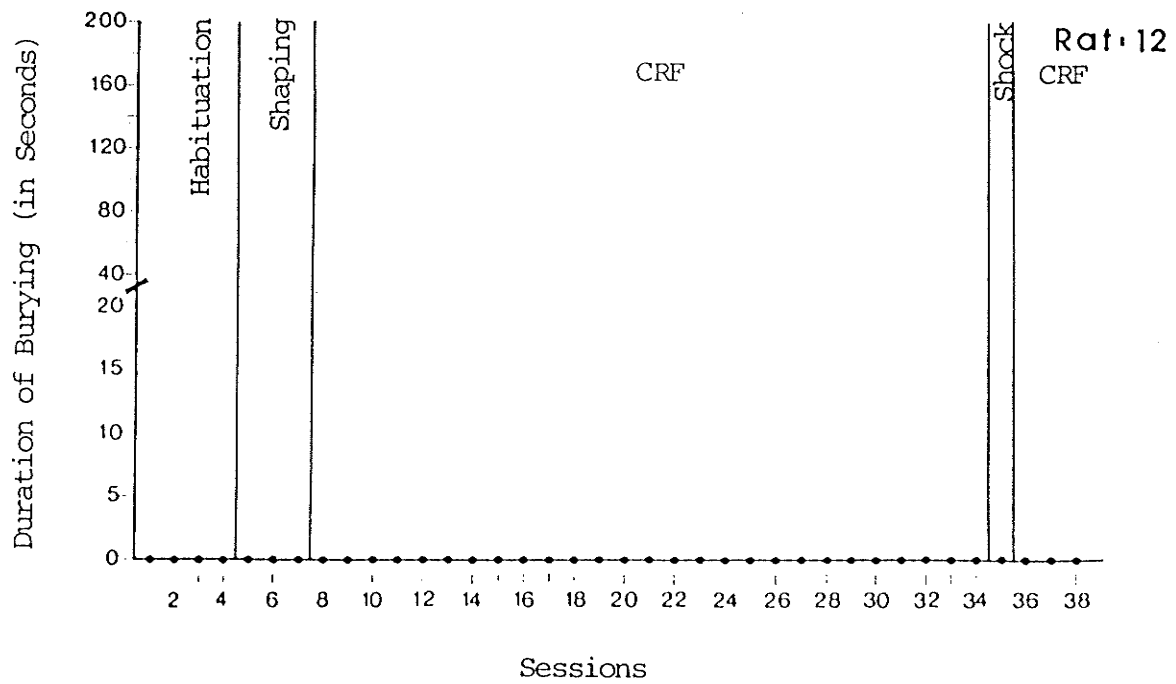
Figure 13. Total duration of burying (in seconds) for each

session for rats 11 and 12.
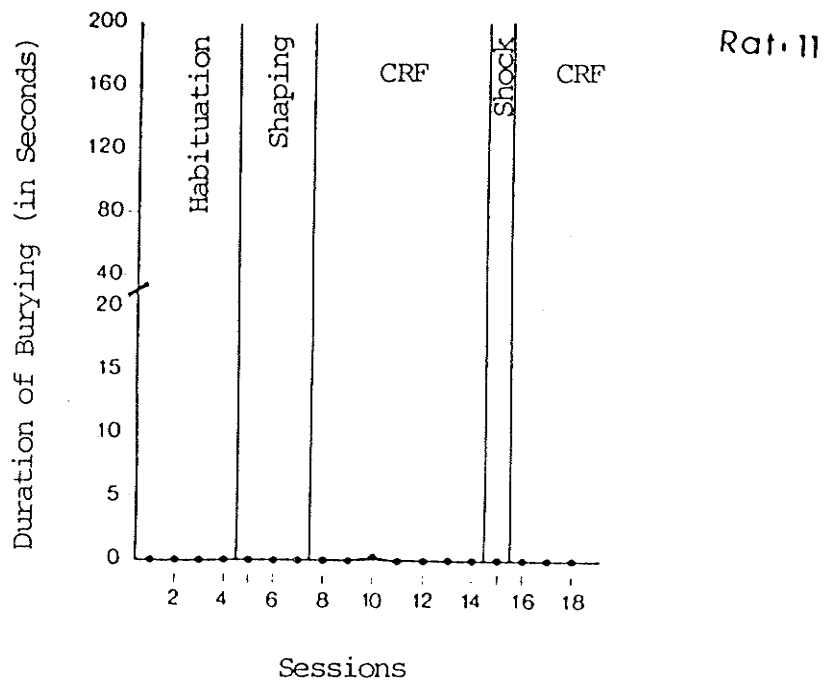
Session 1, than for the "shock" session, and the sessions immediately preceding it.

The maximum height of bedding at the nonoperative lever for postshock session 2 is slightly higher than that shown for the "shock" session, and the session immediately preceding it (see Figure 14).

For Rats 9 and 10, which showed small amounts of burying following shock, there was no consistent temporal pattern concerning when during the session burying occurred.

The correlation coefficient for interobserver reliability was .95, as calculated with 9 pairs of data points.

Discussion

Experiment 3 indicated that presentation of shock through a response lever, on which continuous reinforcement for lever pressing is concurrently programmed, generates minimal burying at best. This is discrepant with a relatively large body of literature that has demonstrated that conditioned defensive burying of a shock source, following a single shock, is a reliable phenomenon (e.g., Hudson, 1950; McKim & Lett, 1979; Pinel & Treit, 1978, 1979; Pinel, Treit, Ladak, & MacLennan, 1980).

As with Experiment 2, the data of Experiment 3 are subject to the interpretation that the paucity of conditioned defensive burying observed following shock is due to attenuation of the burying response following extended exposure to the experimental situation prior to shock delivery. It has been demonstrated that conditioned burying is reduced by habituation to the experimental situation (McKim & Lett, 1979; Moser et al., 1980).

Figure 14. Maximum height of bedding material (in centimeters) at

the operative and nonoperative levers at the end of each session

for rats 11 and 12, for which the right lever was the operative

lever.

Rat 11
■ Operative Lever
≡ Non-Operative Lever

Habitua-tion Shaping CRF Shock CRF

Height of Bedding (in Centimeters)

2 4 6 8 10 12 14 16 18

Sessions

Rat 12
■ Operative Lever
≡ Non-Operative Lever

Habitua-tion Shaping CRF Shock CRF

Height of Bedding (in Centimeters)

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38

Sessions
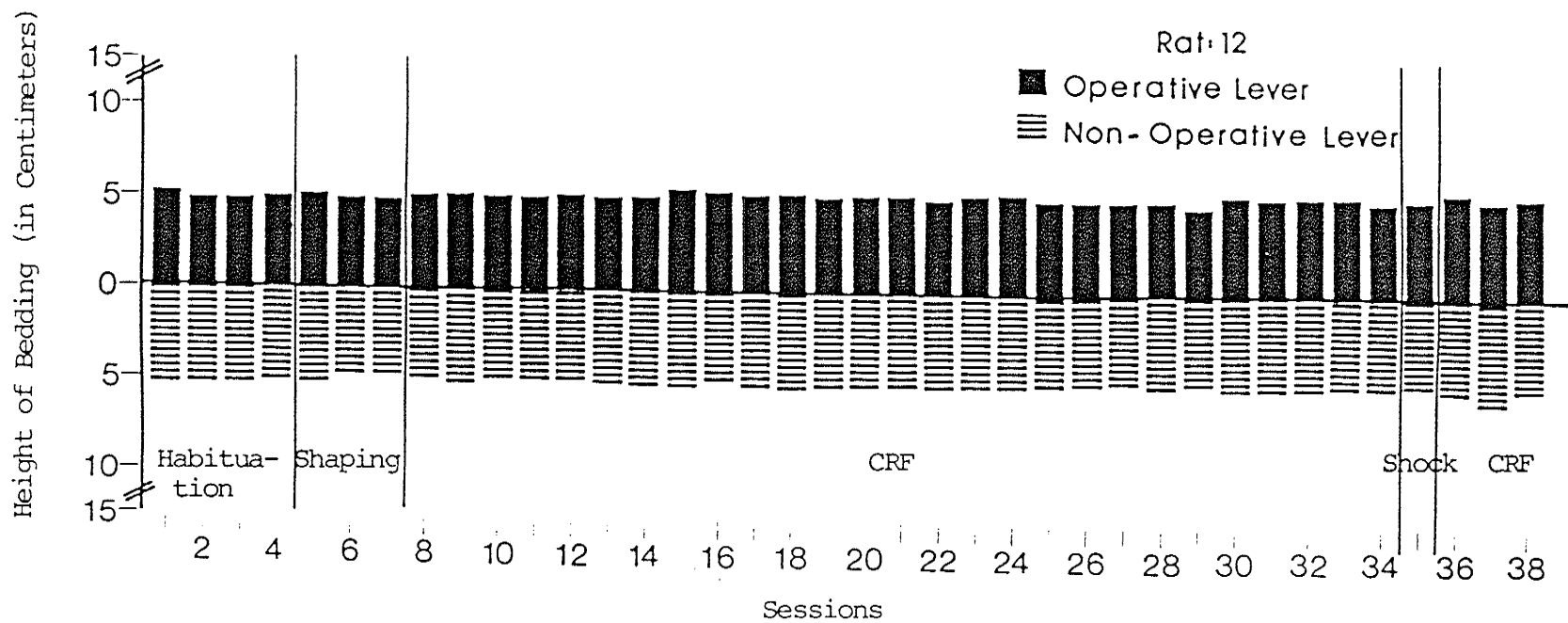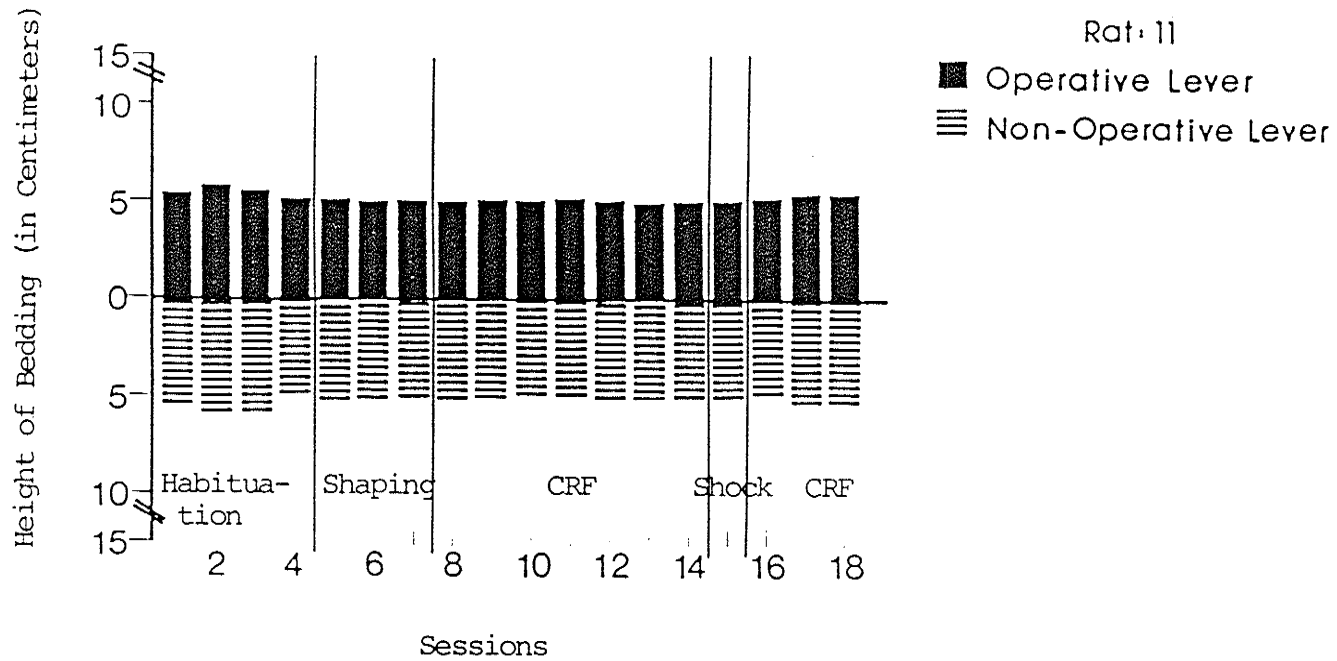
Goldberg et al. (Experiment 1, 1983), however, observed that rats with a history of extended previous exposure to the experimental situation, buried a shock source following a single 10mA shock. This finding detracts from the credibility of the habituation hypothesis. Further, Goldberg et al. (Experiment 2, 1983) found that when rats were continuously reinforced with water for lever pressing, only one of three subjects showed burying after one shock had been delivered through the lever, whereas all subjects buried after two shocks. (It should be noted that in the present research, Rats 9 and 10 in this experiment showed minimal burying following shock, while Rats 11 and 12 did not. Rats 9 and 10 each received two shocks, whereas Rats 11 and 12 each received only one.) The subjects in the second experiment of Goldberg et al. (1983), like those in their first experiment, also had a history of extended habituation to the experimental situation, prior to serving in the second experiment of Goldberg et al. (1983). Again, extended prior exposure to the experimental situation was not sufficient to eliminate conditioned burying. Given that rats in both of these experiments by Goldberg et al. (1983) had been exposed to the experimental setting for an extended period of time, and conditioned burying was still observed, suggests that extended prior exposure alone is not a sufficient condition to eliminate defensive burying in all cases.

A second interpretation is that it is the history of food reinforcement contingent on lever pressing that is responsible for the attenuation of conditioned burying of a shock source, when

that shock source is also the manipulandum, and hence, a food source for food deprived subjects. In Experiment 3 rats did not bury a lever through which shock had been delivered when food reinforcement for lever pressing was also programmed on that lever. In Experiment 1, however, two of four rats did engage in burying when shock was presented through a lever not associated with any reinforcement schedule.

Thus, it appears that there are certain conditions, such as reinforcement programmed via the shock source, that alter the probability of burying of a shock source. In their second experiment, Goldberg et al. (1983), found that although two shocks reliably produced burying, one shock delivered through a lever on which water reinforcement for lever pressing and shock were simultaneously programmed, generated very little burying. Further support for this notion is provided by Buchanan (1981). A prod was established as a conditioned aversive stimulus, by pairing it with shock. The prod was then placed in either the bar press chamber or the food chamber of a maze. Only three of 11 subjects engaged in burying. It is possible that the conditioned burying response was attenuated due to the association of the shock prod with the maze, which had to be traversed to obtain food.

This line of reasoning suggests that it is the history of reinforcement associated with the shock source that is responsible for the minimal burying observed in Experiment 3 of the present research.

As indicated above, it should be noted that Rats 9 and 10 did show at least minimal burying in sessions following shock, while

Rats 11 and 12 did not. The difference between the performance of Rats 9 and 10, and those of Rats 11 and 12 warrants consideration. Interpretation of this difference raises at least two possibilities. The first of these is that, as indicated in Figures 11 and 13, Rats 9 and 10 spent more time burying in the sessions prior to shock than did Rats 11 and 12 and that this difference was replicated in the sessions following shock. A second possibility is that the difference between the burying behavior of Rats 9 and 10, and that of Rats 11 and 12 was due to the fact that Rats 9 and 10 each received two shocks, whereas Rats 11 and 12 each received only one. In the work of Goldberg et al. (Experiment 2, 1983), following continuous water reinforcement for lever pressing in rats, two shocks were delivered through the lever. Although one subject showed minimal burying following one shock, all three subjects showed considerable burying of the lever ranging from 140 to 380 seconds, after delivery of two shocks.

Although the present experiment for Rats 9 and 10 is similar to that of Goldberg et al. (1983) in that both studies presented two shocks through a response lever on which continuous reinforcement for lever pressing was concurrently programmed, the amount of burying observed in the two studies differed dramatically. Also, in the present study it was noted that the burying observed was not necessarily directed toward the operative lever. Pinel and Treit (1978) suggest that in order for burying to be considered as a defense reaction, it "must be shown to occur in response to aversive stimulation" (p. 710) and "must be

adaptive; that is, it must potentially afford the animal some protection from the noxious agent...it must be directed at the source of aversive stimulation." (p. 711).

The discrepancy between the data of Experiment 3 and that of Goldberg et al. (1983) is perhaps a function of a difference in the number of sessions of exposure to the experimental situation prior to shock. The rats in the second experiment of Goldberg et al. (1983) were not experimentally naive. These subjects had served approximately three months earlier in a study in which continuous water reinforcement for lever pressing was followed by an extinction phase. This earlier study was comprised of approximately 13 sessions, 30 to 60 minutes in duration. In addition to these 13 sessions, the rats in the second experiment of Goldberg et al. (1983) were exposed to 5 additional sessions of continuous reinforcement for lever pressing prior to the first "shock" session. Thus, the total number of sessions of exposure to the experimental setting before shock was 18. In Experiment 3 of the present research, each rat was exposed to the experimental situation for a varying number of sessions: Rat 9 - 27 sessions; Rat 10 - 39 sessions; Rat 11 - 18 sessions; Rat 12 - 38 sessions. Given that in Experiment 3 of this series of experiments, although the number of sessions prior to shock varied for each subject, duration of burying and height of bedding at the operative lever on the "shock" day was similar for each of the subjects. Thus it appears that any effect due to number of sessions of prior exposure had reached asymptote by 18 days (the minimum number of

sessions for any of the subjects in Experiment 3). Since the number of sessions of previous exposure before shock in Experiment 2 of Goldberg et al. (1983) was also 18, it seems unlikely that this factor is responsible for the disparity between the data of Experiment 3 of this research and that of Goldberg et al. (1983).

A second possibility is that this discrepancy is a function of the type of reinforcer used, that is, food or water. It is possible that behavior maintained by water reinforcement is more easily disrupted than behavior maintained by food reinforcement. In addition to the relatively long durations of burying, Goldberg et al. (1983) showed that during the "shock" session lever pressing was greatly reduced, although it recovered in subsequent sessions. As indicated in Figures 7, 8, 9 and 10, shock presentation in the present study only minimally disrupted lever press performance during the "shock" session.

Experiment 4

Experiment 3 indicated that a single shock was not sufficient to generate conditioned burying of a shock source by food-deprived rats, when that shock source was also a manipulandum, responses to which were reinforced on a continuous schedule. Experiments 4a and 4b therefore were conducted to answer two questions arising from Experiment 3.

First, Experiment 3 demonstrated that defensive burying did not result after one shock. Since the continuous reinforcement was also programmed on the lever, it is possible that one

lever/shock pairing was insufficient to counteract the effects of positive reinforcement. Accordingly, Experiment 4a examined the effects of presentation of multiple shocks through the response lever, using subjects with a reinforcement history similar to those of Experiment 3.

Second, if as suggested earlier, it was the history of food reinforcement contingent on lever pressing that was responsible for the minimal conditioned burying of the "shock" lever in Experiment 3, then the noncontingent presentation of food should not interfere with defensive burying of a shock source. Therefore, in Experiment 4b food was delivered on a fixed time basis, independently of any response. In the subsequent phase, shock was delivered through the lever. Experiment 4b, then, addressed the issue of the importance for conditioned burying of the lever press contingency for food.

In Experiment 4a food was presented contingent on the rat pressing one of two available levers. In Experiment 4b food was presented noncontingently. For both Experiments 4a and 4b, in the "shock" session, shock was presented contingent on the rat making contact with one of two available levers. In Experiment 4a shock and food presentation were programmed on the same lever. Having two levers but employing only one provided the opportunity to observer whether the burying following shock was a directed activity (i.e., directed toward the shock source). This determination is required to show that the postshock burying is conditioned, since it has been noted repeatedly (e.g. Pinel &

Treit, 1978, 1979) that the conditioned burying response is clearly directed toward a specific source.

Method

Experiment 4a

Subjects

Four experimentally naive, male, adult Long Evans hooded rats (obtained from the University of Manitoba) served as subjects. Subjects were individually housed in wire mesh cages under a 16 hour light/8 hour dark cycle. Animals were maintained at 85% of their ad lib. weights.

Apparatus

The apparatus was the same as in Experiment 2.

Procedure

Sessions were conducted on a daily basis, and each session was terminated after 225 reinforcers had been delivered, or 30 minutes had elapsed, whichever came first. At the beginning of each session, the subjects were always placed individually in the chamber facing the wall opposite that on which the levers were located.

Rats 14, 15, and 16 were preexposed to the experimental chamber individually for five 30-minute sessions, and Rat 13 for six 30-minute sessions. The levers were present in the chamber during these sessions but no reinforcement was available for lever pressing. Subjects were then magazine trained, and lever pressing was established by reinforcing with food, successive approximations to the lever press response. For each subject

presses on only one lever produced food (the left lever for Rats 13 and 14; the right lever for Rats 15 and 16). Forty-five mg "dustless" precision pellets (Bioserv Inc.) were used as reinforcers. Lever pressing was maintained on a continuous reinforcement schedule.

Subsequent to the continuous reinforcement phase, one "shock" session was conducted. During the "shock" session, for each subject the operative lever was electrified approximately one minute after the start of the session and remained in that condition for the duration of the session. The shock was approximately 8mA in intensity and was received each time the subject touched the lever. Each shock was terminated when the subject broke contact with the lever. The continuous reinforcement contingency for lever pressing remained in effect during the "shock" session.

No shock was delivered through the second lever. For each subject, the "shock" session continued until thirty minutes had elapsed since the first shock had been received.

A second continuous reinforcement phase was conducted following the "shock" session. For Rats 13, 14, and 15, three continuous reinforcement sessions were conducted after the "shock" session. For Rat 16, four such sessions were conducted.

All sessions were videotaped. Duration of burying, and frequency of lever presses and lever bites on both levers were recorded throughout each session. The height of the bedding material at both levers was measured at the end of each session.

Dependent Measures

The dependent measures were the same as in Experiment 1.

Interobserver Reliability

Twenty-seven percent of all sessions were randomly selected for interobserver reliability after tapes had been viewed and duration of burying recorded by the experimenter. Interobserver reliability measures were calculated in the same manner as in Experiment 1.

Experiment 4b

Subjects

Four experimentally naive, male, adult Long Evans hooded rats (obtained from the University of Manitoba) served as subjects. Subjects were individually housed in wire mesh cages under a 16 hour light/8 hour dark cycle. Animals were maintained at 85% of their ad lib. weights.

Apparatus

The apparatus was the same as in Experiment 2.

Procedure

Sessions were conducted on a daily basis, and each session was terminated after 225 reinforcers had been delivered or 30 minutes had elapsed, whichever came first. Subjects were always placed individually in the chamber facing the wall opposite that on which the levers were located. Rats 18, 19 and 20 were preexposed to the experimental chamber individually for five 30-minute sessions, and Rat 17 for six 30-minute sessions.

The levers were present in the chamber for the duration of the experiment, but no reinforcement was available for lever

pressing. Food pellets were delivered on a fixed time basis, with no response contingency in effect. For purposes of determining the fixed time interval for noncontingent food presentation, each rat in Experiment 4b was paired with one from Experiment 4a; Rat 13 with Rat 17, Rat 14 with Rat 18, Rat 15 with Rat 19, and Rat 16 with Rat 20. The fixed time interval was determined for each rat in Experiment 4b for each session by dividing the total number of reinforcers received by its counterpart in Experiment 4a, by the length of the session.

Subsequent to the fixed time phase, one "shock" session was conducted. During the "shock" session, for each subject the operative lever was electrified approximately one minute after the start of the session, and remained in that condition for the duration of the session. (For Rats 17 and 18, the left lever was the operative lever; for Rats 19 and 20 the right lever was the operative lever). The shock was approximately 8mA in intensity, and was received each time the subject touched the lever. Each shock was terminated when the subject broke contact with the lever. To enhance the likelihood of the subjects in Experiment 4b touching the lever, no food pellets were delivered after the lever had been electrified. The only exception to this was Rat 19, for which 10 pellets were delivered after the shock was turned on. Since this subject did not receive shock until approximately 8.5 minutes after the lever was electrified, it is probable that these 10 pellets were consumed prior to shock.

No shock was delivered through the second lever. For Rats 17, 18 and 19, the "shock" session continued until thirty minutes

had elapsed since the first shock. For Rat 20, the "shock" session continued thirty minutes past the second shock, which was received 54 seconds after the first one.

A second fixed time phase was conducted following the "shock" session. For Rats 17, 18 and 19, three fixed time sessions were conducted after the "shock" session. For Rat 20, four such sessions were conducted.

All sessions were videotaped. Duration of burying and frequency of lever presses and lever bites on both levers were recorded throughout each session. The height of the bedding material at both levers was measured at the end of each session.

Dependent Measures

The dependent measures were the same as in Experiment 1.

Interobserver Reliability

Twenty-two percent of all session were randomly selected for interobserver reliability after tapes had been viewed and duration of burying recorded by the experimenter. Interobserver reliability measures were calculated in the same manner as in Experiment 1.

Results

Experiment 4a

For Rats 13 and 14, the left lever was the operative lever, that is, the lever on which continuous reinforcement was programmed for lever pressing, and through which shock was delivered in the "shock" session; for Rats 15 and 16, the right lever was the operative lever.

With the exception of Rat 16, lever biting was rarely observed. For Rat 16, 70 bites on the left lever were recorded in Session 3, 11 in Session 4, as well as other occasional bites to the left or the right lever. Anecdotal evidence indicated that Rats 15 and 16 were occasionally observed to gnaw on the levers. These observations are of limited value, as they were not recorded in a systematic manner.

Cumulative records of lever pressing for Rats 13, 14, 15, and 16, (see Figures 15, 16, 17, and 18), indicate the disruptive effects of shock on lever pressing. For Rat 13, in the two sessions prior to shock, lever pressing occurred at a steady rate (see Figure 15). During the shock session, lever pressing was disrupted, but not immediately after the first shock. For Rat 13, it should be noted that this subject received several shocks that appeared "mild," as determined by his reaction (i.e., minimal responses such as freezing or jumping). At approximately 14 minutes into the session, it appeared that a more intense shock had been received as indicated by responses like freezing and jumping. The steady performance prior to shock was recovered on postshock Days 1, 2, and 3.

For Rat 14, in the two sessions prior to shock, lever pressing occurred at a steady rate (see Figure 16). This performance was completely disrupted during the "shock" session. On the first postshock day performance began to recover, but did not show the preshock steady rate. Cumulative records of the second and third postshock sessions are not available, due to

Figure 15. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, the

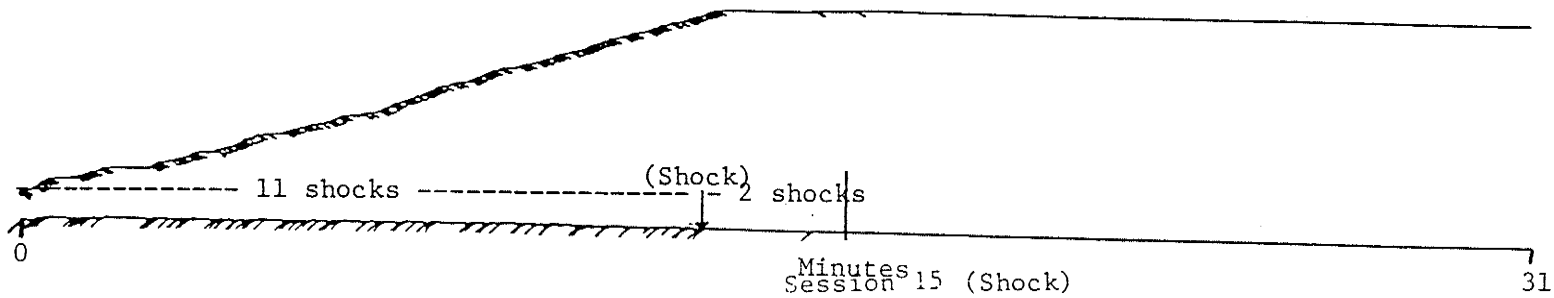"shock" session, and two postshock sessions for rat 13.

Rat 13

Minutes
13
Session 13

Minutes
13
Session 16

Minutes
15
Session 14

230

Lever Presses

0

Minutes
12
Session 17

11 shocks ———————— (Shock) 2 shocks
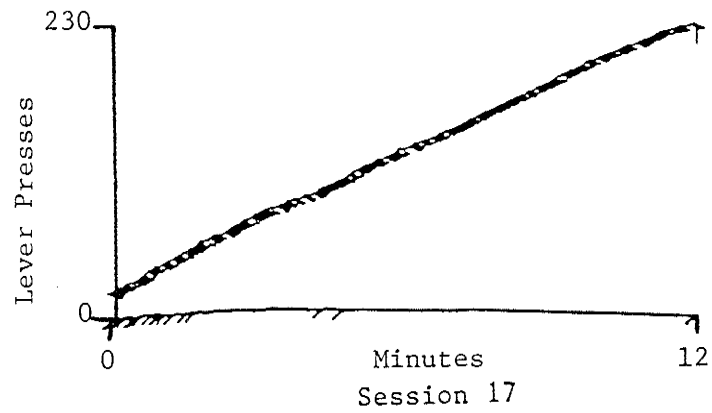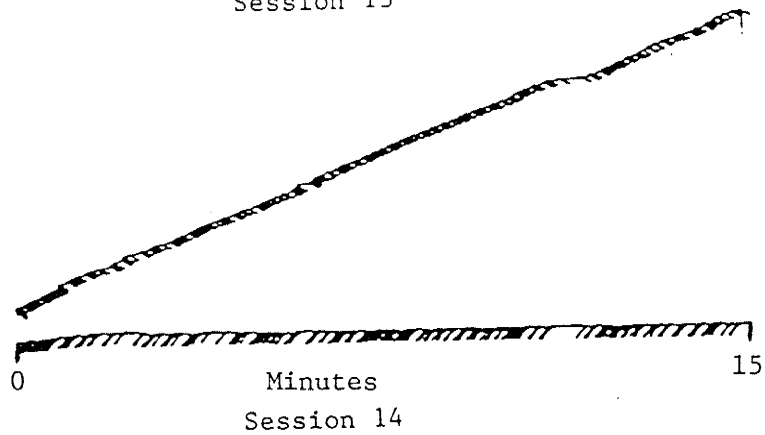
Minutes
Session 15 (Shock)
31

Figure 16. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, the

"shock" session, and the first postshock session, for rat 14.

Session 11

Session 12

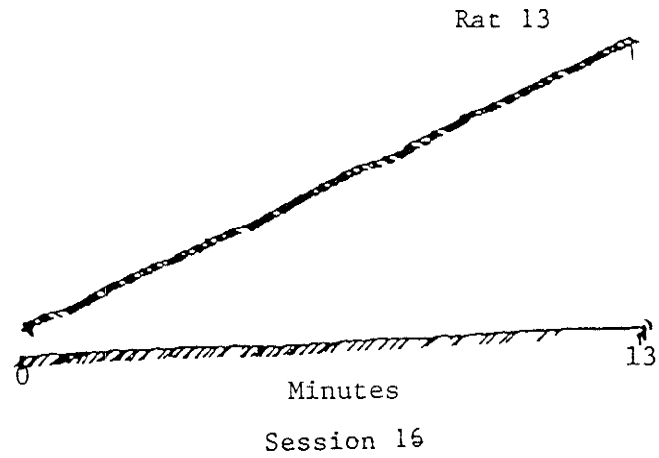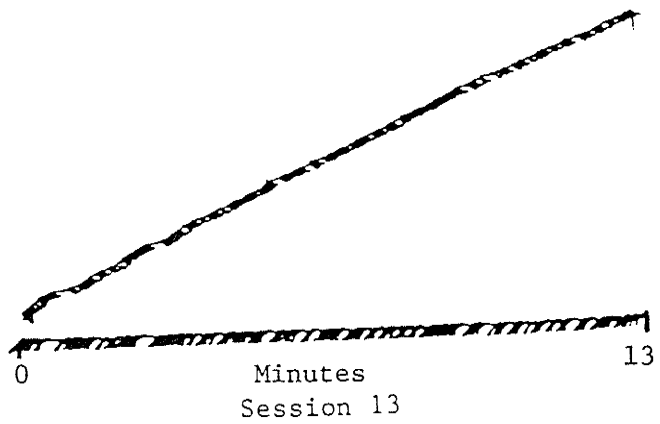Session 13 (Shock)

Rat 14

Session 14

Figure 17. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, the

"shock" session, and the three postshock sessions, for rat 15.

Rat 15

0 Minutes 13
Session 12

0 Minutes 14
Session 15

0 Minutes 13
Session13

(Several (Shock) (Shock)
shocks)
Minutes
Session 14 (Shock)

0 Minutes 13
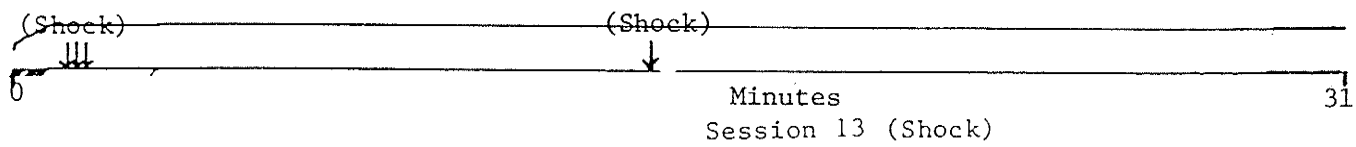Session 16

240

Lever Presses

0

0 Session 17 Minutes 12
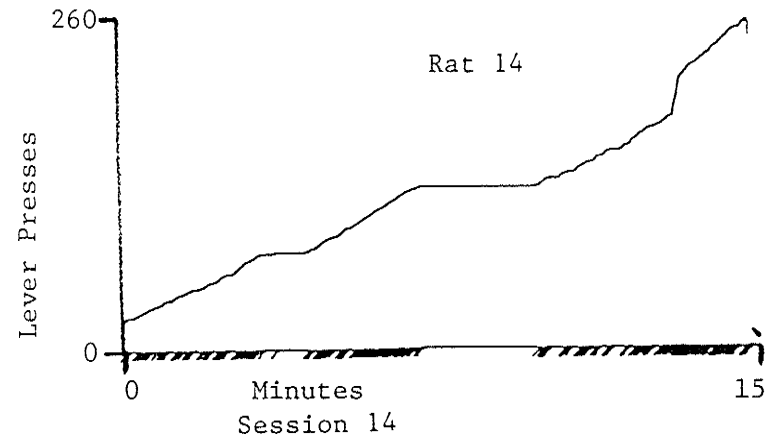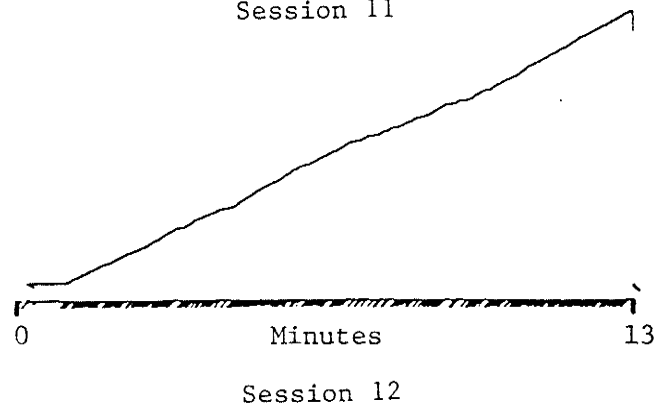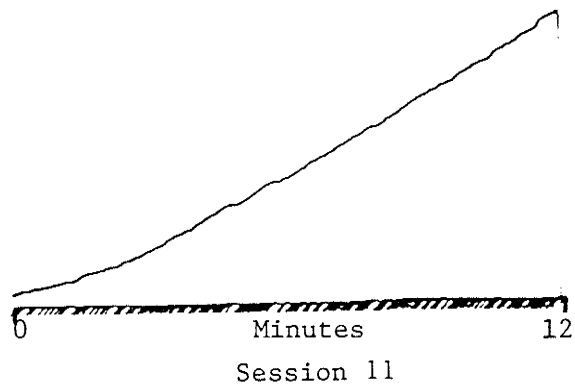
Figure 18. Cumulative records of lever pressing on the operative

lever for the two sessions prior to the "shock" session, and the

"shock" session for rat 16.

Rat 16

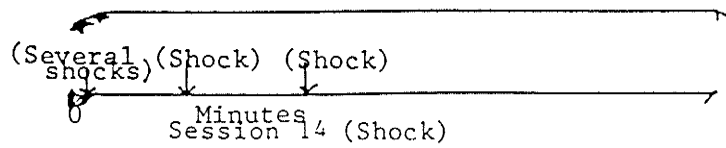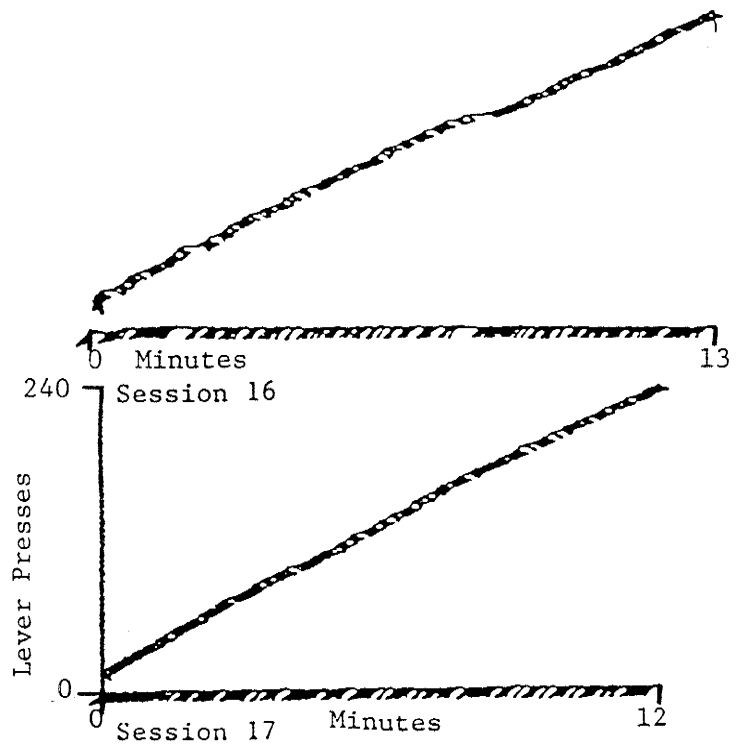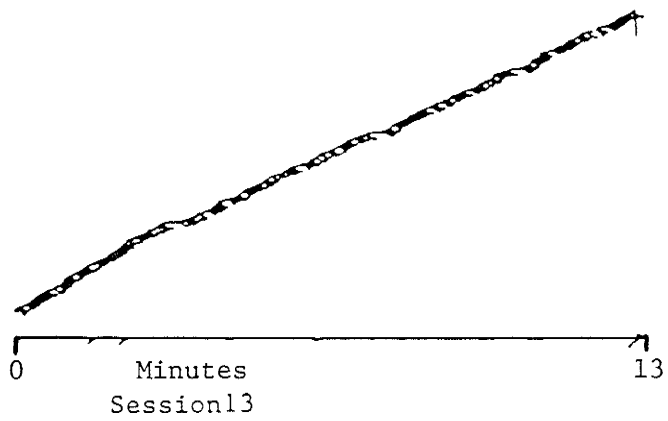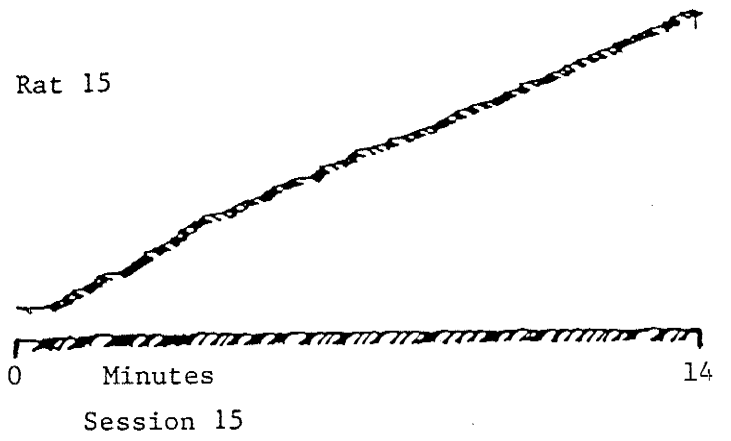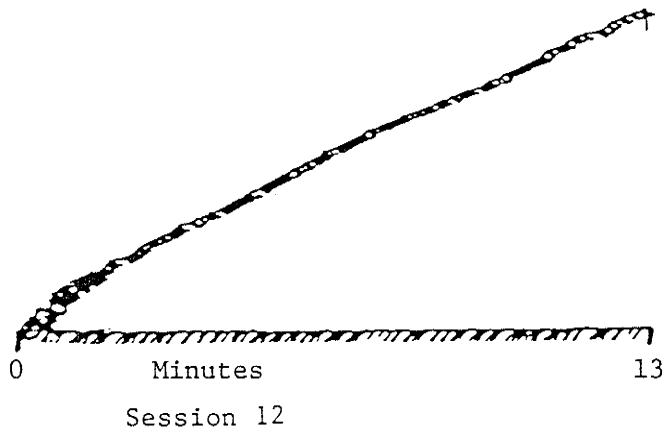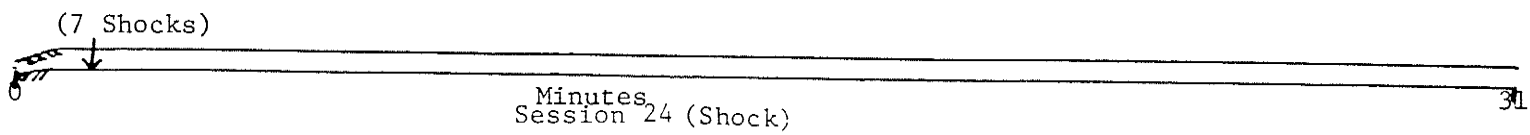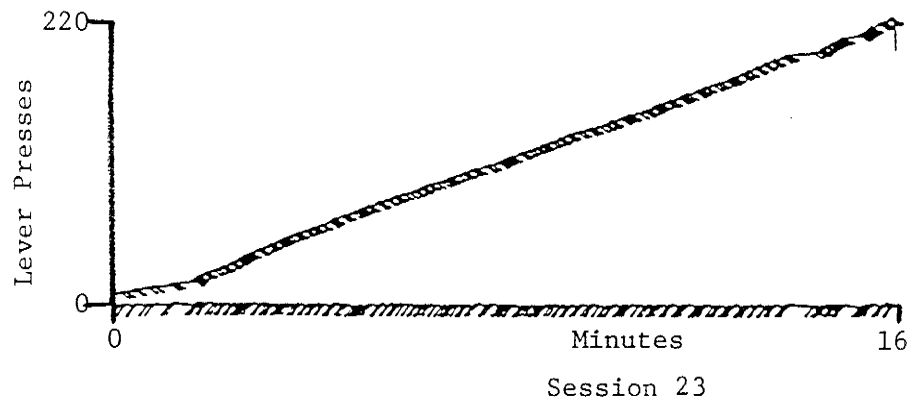Minutes   18

Session 22

Lever Presses

220

0

0   Minutes   16

Session 23

(7 Shocks)

Minutes
Session 24 (Shock)   31
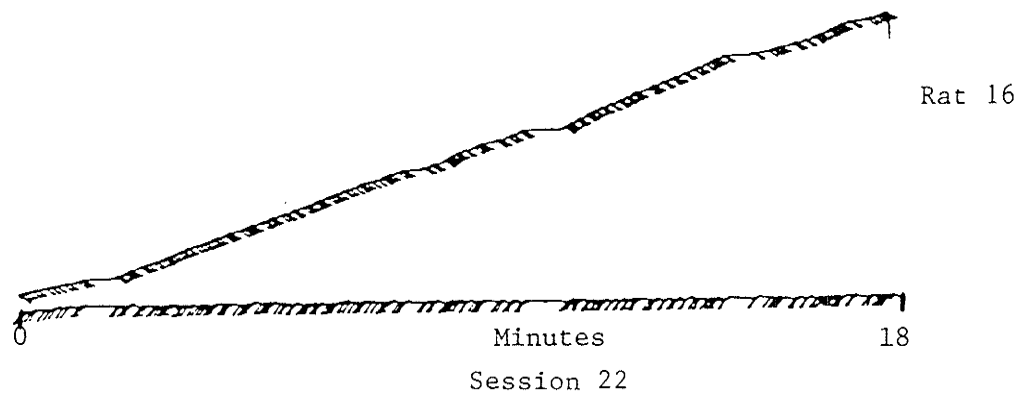
malfunctioning of the cumulative recorder, but the lever press data indicate that lever press response rate returned to its previous high level.

For Rat 15, in the two sessions prior to shock, and in the three postshock sessions, lever pressing occurred at a steady rate, while performance on the "shock" day was seriously disrupted (see Figure 17). For Rat 16, in the two sessions prior to shock, lever pressing occurred at a steady rate (see Figure 18). This performance was completely disrupted during the "shock" session. Cumulative records of the postshock sessions are not available due to malfunctioning of the cumulative recorder. The lever press data, however, indicate that in the first postshock session, Rat 16 did not begin lever pressing again until approximately 24 minutes and 45 seconds had elapsed since the start of the session, but that lever pressing then occurred at a high rate. Latency to lever press was shorter on each subsequent session, and the rate of response for postshock Sessions 2, 3 and 4 returned to its previous high rate.

During the "shock" session, all subjects received multiple shocks, and all showed a considerable increase in duration of burying over that observed in the continuous reinforcement phase (see Figures 19 and 20). (It should be noted that for all four subjects in Experiment 4a, the duration of burying indicated in the "shock" session represents burying that occurred in the 30-minute period after the first shock was received.)

Rat 13 failed to show any burying after a single shock, and received approximately 12 shocks before beginning to bury. No

Figure 19. Total duration of burying (in seconds) for each session for rats 13 and 14.
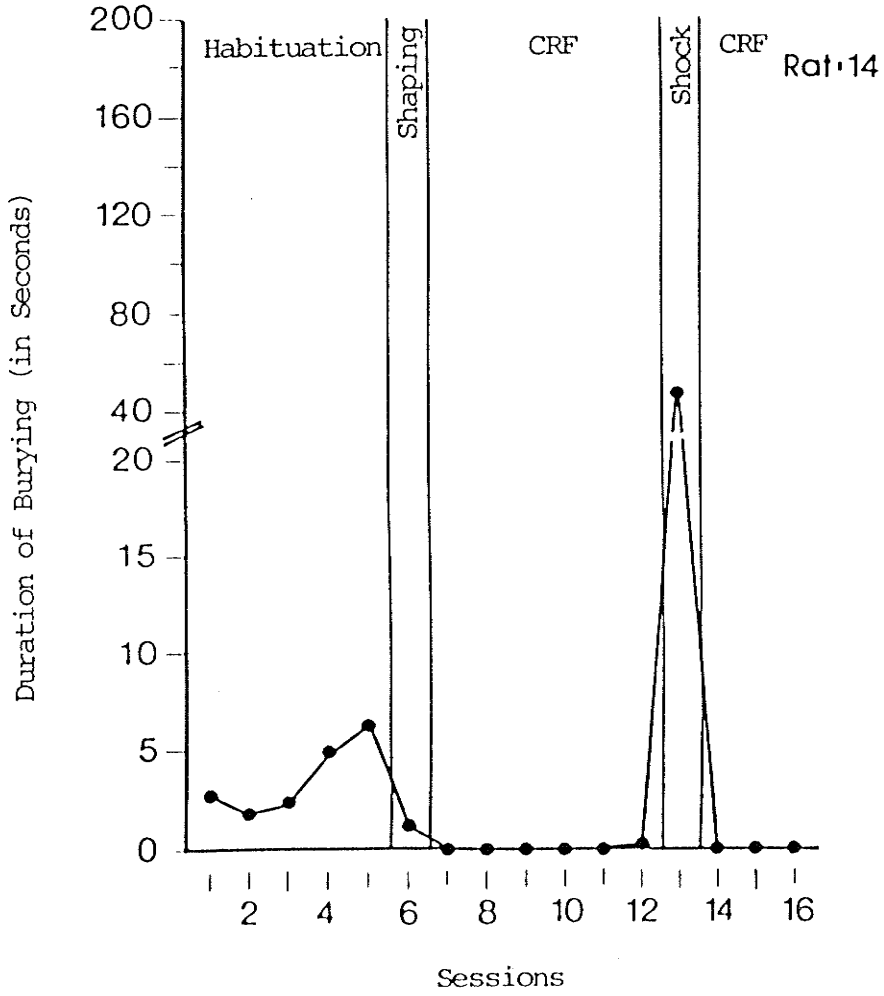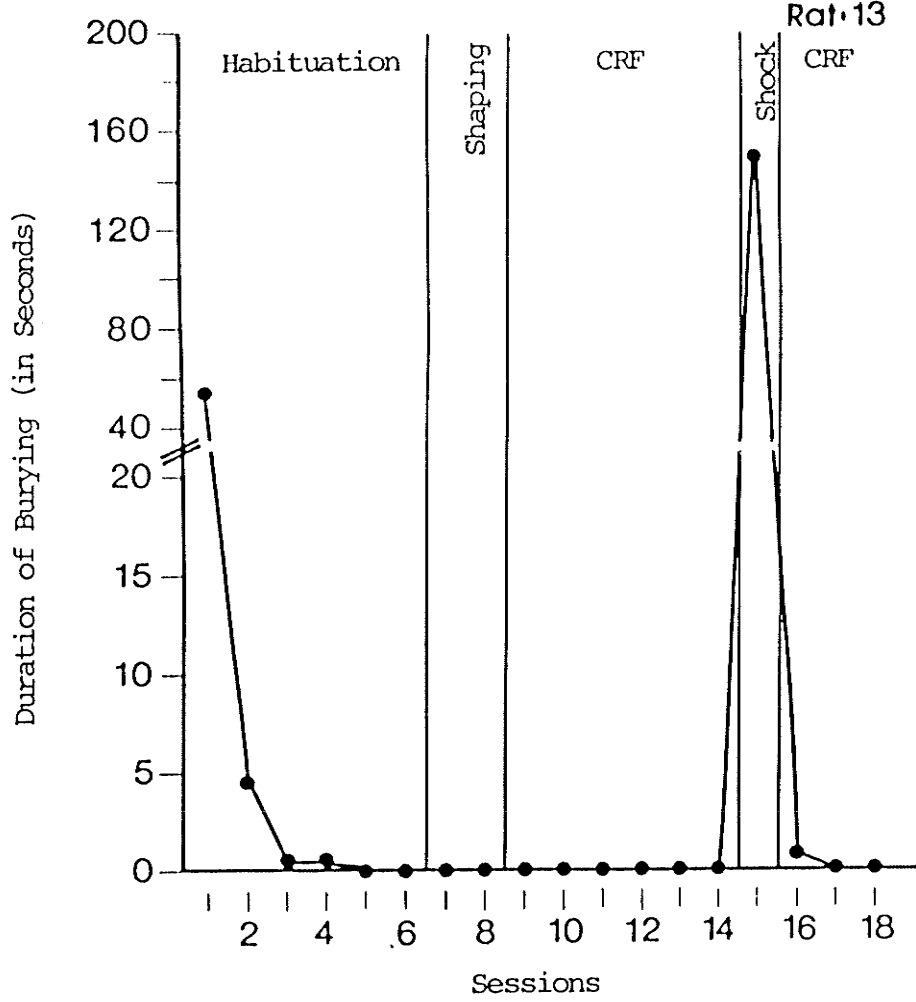
Figure 20. Total duration of burying (in seconds) for each

session for rats 15 and 16.
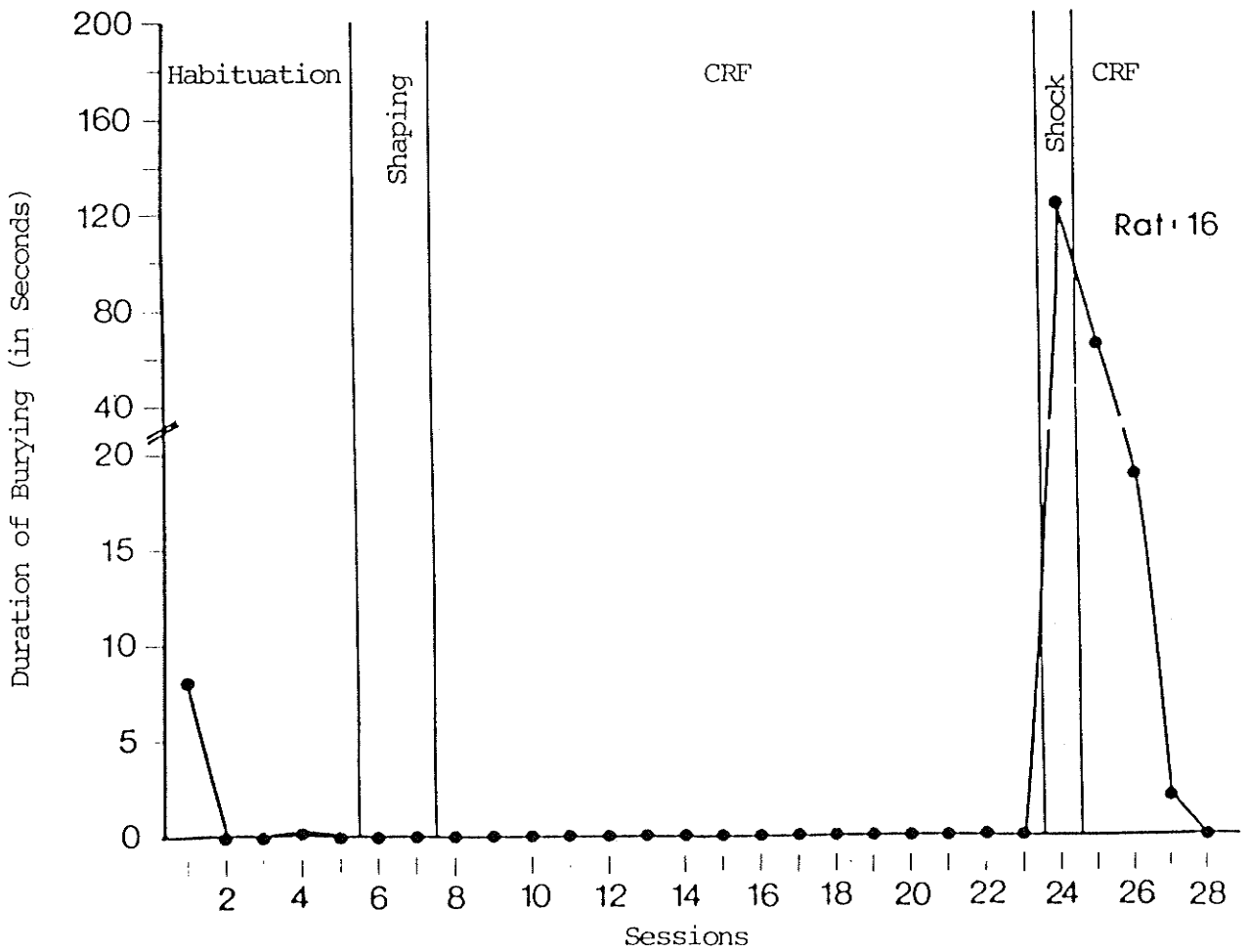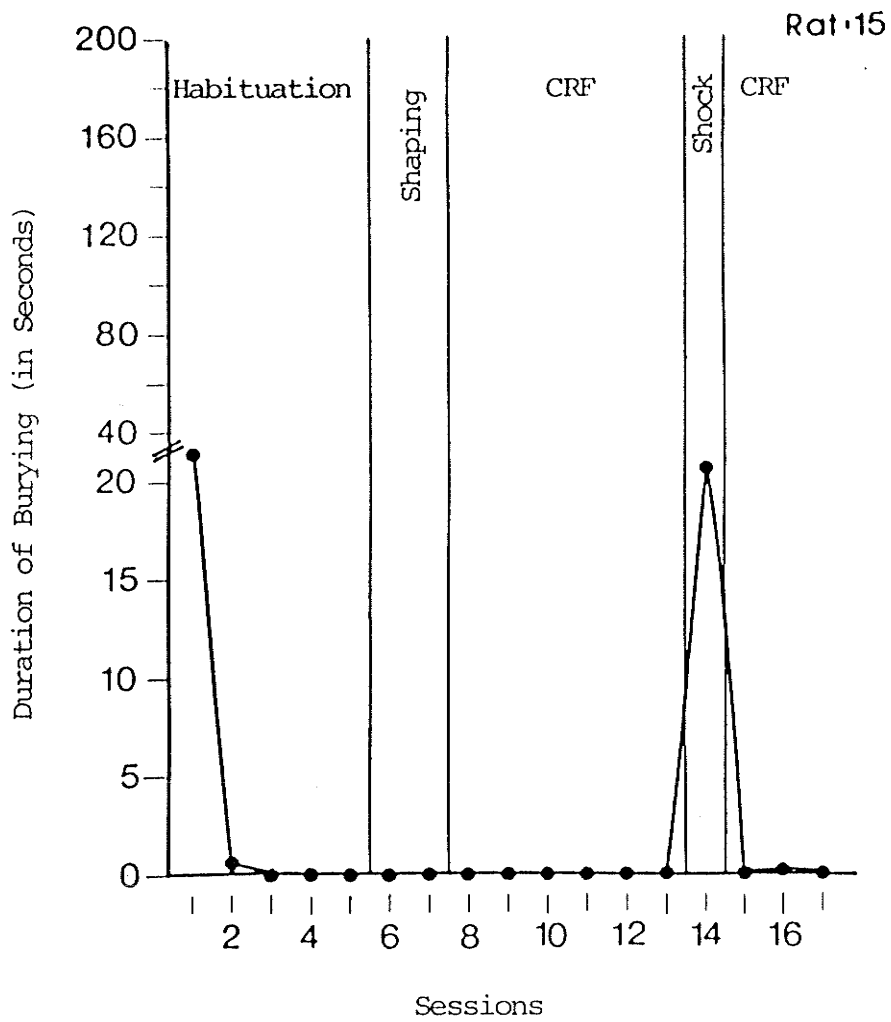
burying was recorded until the fourth 5-minute interval since the first shock. As determined by the responses of the animal (e.g., freezing, jumping), Rat 13 appeared to receive several "mild" shocks, and a more intense one at approximately 14 minutes after the first one. It should be noted that this subject appeared to find places on that lever that could be pressed with no shock delivery; that is, Rat 13 received several shocks, but continued pressing between them. In the first postshock session, the little burying that was observed was directed toward the back wall of the chamber, and not toward the wall on which the levers were located. Figure 21 shows an increase compared to the continuous reinforcement phase, in the height of bedding at each lever at the end of the "shock" session for Rat 13. Although this increase occurred at both levers, the height of bedding at the operative lever is greater than that at the nonoperative lever.

Rat 14 also failed to show any burying after a single shock, and received three shocks in rapid succession (within approximately 20 seconds) before beginning to bury. A fourth shock was received approximately 14 minutes after the first one. No burying was recorded until the second 5-minute interval since the first shock. While some burying was recorded in both the second and third 5-minute intervals, most of the burying was recorded in the fourth 5-minute interval. Figure 21 shows little difference in height of bedding at either lever during the "shock" session compared to that in the continuous reinforcement sessions for Rat 14. A great deal of the burying observed during the

Figure 21. Maximum height of bedding material (in centimeters) at the operative and nonoperative levers at the end of each session for rats 13 and 14, for which the left lever was the operative lever.

Rat·13
■ Operative Lever
≡ Non-Operative Lever

Rat·14
■ Operative Lever
≡ Non-Operative Lever
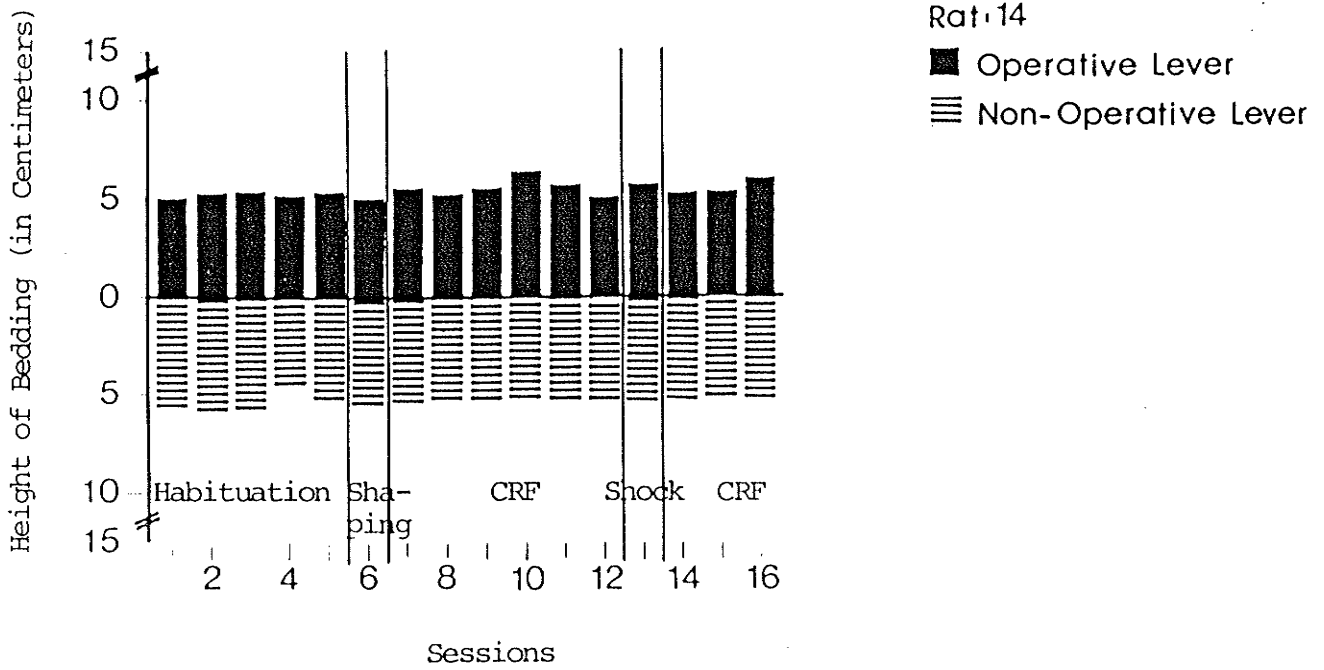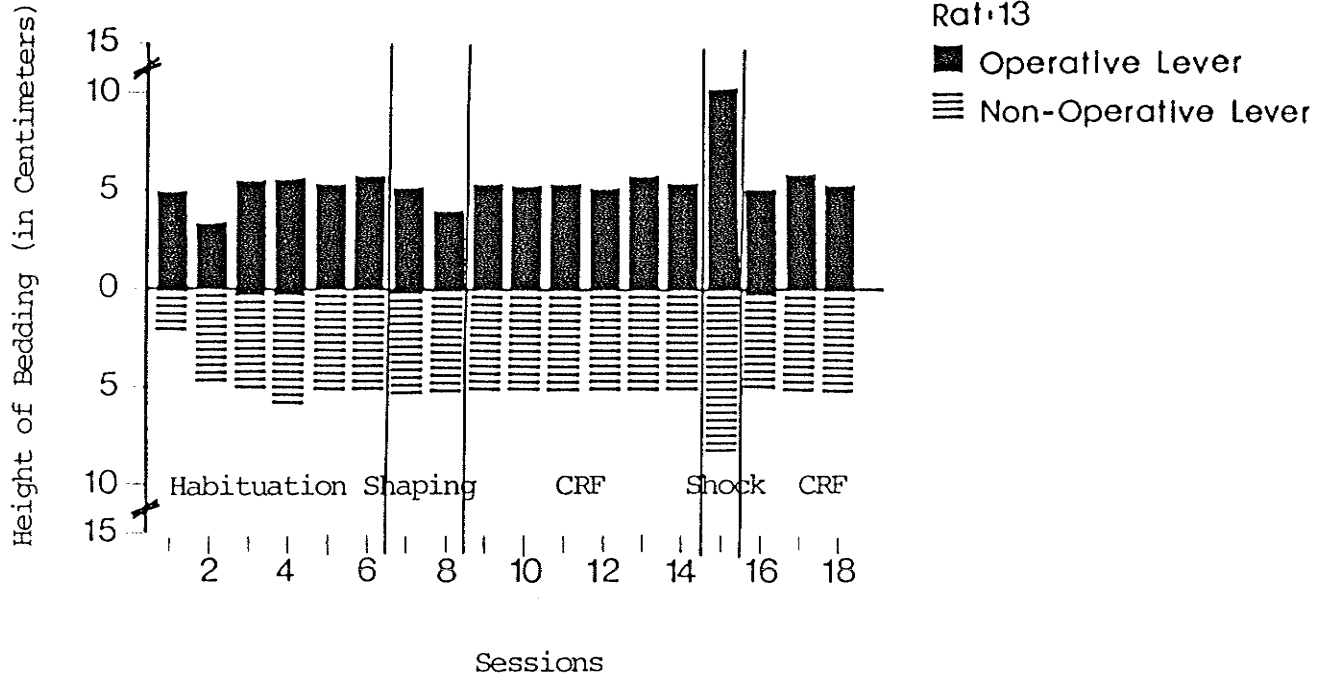
"shock" session for this subject was directed toward the front of the chamber, or toward the operative (left) lever in particular. This burying was often initiated at a point in the chamber some distance from the left lever; thus, sawdust was not accumulating at the lever.

Rat 15 similarly failed to show any burying after a single shock. This subject received approximately 12 shocks in rapid succession. No burying was recorded before the second 5-minute interval after the first shock. The burying in this interval was minimal (0.66 seconds). The majority of the burying was recorded in the third and fourth 5-minute intervals. Burying soon after the first shock was minimal and not directed toward the lever. Burying initiated approximately 14 minutes after the start of the session was directed toward the operative lever. At this time, Rat 15 accumulated sawdust to the top of the right lever, to a greater height in the right corner, and then uncovered the lever by 17 minutes after the start of the session. This pattern of burying is reflected in the decreased height of bedding at both levers at the end of the "shock" session, compared to that during continuous reinforcement for Rat 15 (see Figure 22). At the end of the session, although sawdust remained on the top of the right lever, the sawdust was piled toward the back of the chamber, such that the height of bedding in the front of the chamber was much lower than that in the back of the chamber.

As with Rats 13, 14, and 15, Rat 16 failed to show any burying after a single shock. This subject received 7 shocks in

Figure 22. Maximum height of bedding material (in centimeters) at the operative and nonoperative levers at the end of each session for rats 15 and 16, for which the right lever was the operative lever.
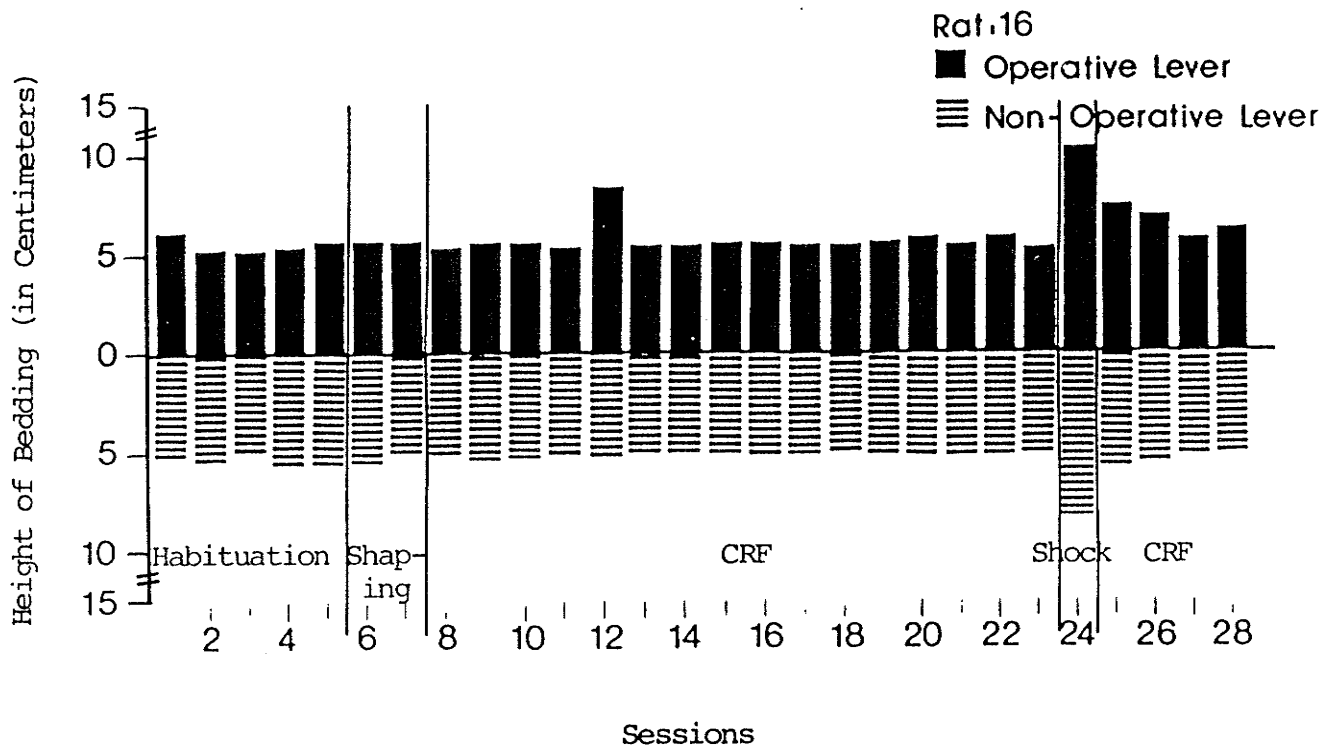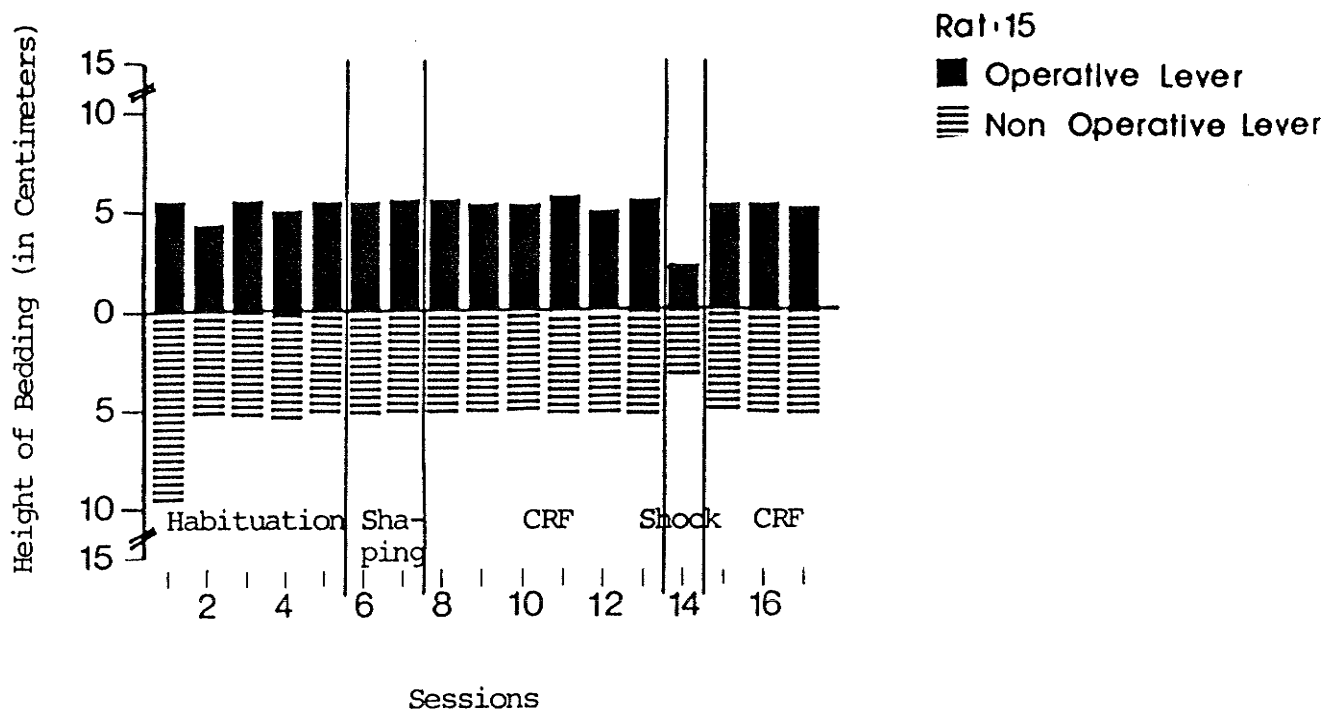
rapid succession within approximately 40 seconds after the lever was electrified, and showed no burying until after those 7 shocks had been received. Burying began approximately 2.5 minutes after the first shock, and burying was recorded predominantly during the first, second, and sixth 5-minute intervals after the first shock. This subject completely covered the nonoperative (left) lever with sawdust first, and later completely covered the operative (right) lever as well. At approximately 28 minutes after the start of the session, Rat 16 uncovered the left lever. At the end of the "shock" session, the operative lever was completely covered, and the nonoperative lever was partially covered. Figure 22 shows an increase, compared to the continuous reinforcement phase, in the height of bedding material at both levers at the end of the "shock" session for Rat 16. Although this increase was recorded at both levers, the height of bedding at the operative lever is greater than that at the nonoperative lever. In the first postshock session, Rat 16 again buried both levers, uncovered them, almost covered the right lever again, and then uncovered it.

Thus, none of these four subjects with a history of reinforcement for lever pressing, showed burying after one shock when that shock was delivered through the lever. All subjects showed burying after receiving multiple shocks. Rat 13 received approximately 12 shocks prior to burying, Rat 14 - three shocks, Rat 15 - approximately 12 shocks, and Rat 16 - seven shocks.

The correlation coefficient for interobserver reliability was .9996, as calculated with 8 pairs of data points.

Experiment 4b

For Rats 17 and 18, the left lever was the operative lever, that is, the lever through which shock was delivered in the "shock" session. For Rats 19 and 20, the right lever was the operative lever.

In all four rats, lever biting was rarely observed. Anecdotal evidence indicated that Rat 20 was occasionally observed to gnaw on the levers but such observations were not recorded in a systematic manner.

During the "shock" session, all subjects showed increases of varying amounts in total session time spent burying compared to that in the fixed time phase (see Figures 23 and 24). (It should be noted that for all four subjects in Experiment 4b, the duration of burying indicated in the "shock" session represents burying that occurred in the 30-minute period after the first shock was received).

Rat 17 showed burying after receiving a single shock. Approximately 5.5 minutes elapsed between shock occurrence and initiation of burying. This subject subsequently received multiple shocks. Burying was recorded in the second through the sixth 5-minute intervals following the first shock. At the end of the session, the operative (left) lever was completely covered. Figure 25 shows an increase, compared to the fixed time phase, in the height of bedding material at each lever at the end of the "shock" session for Rat 17. Although this increase occurred at both levers, the height of bedding at the operative lever is greater than that at the nonoperative lever.

Figure 23. Total duration of burying (in seconds) for each

session for rats 17 and 18.
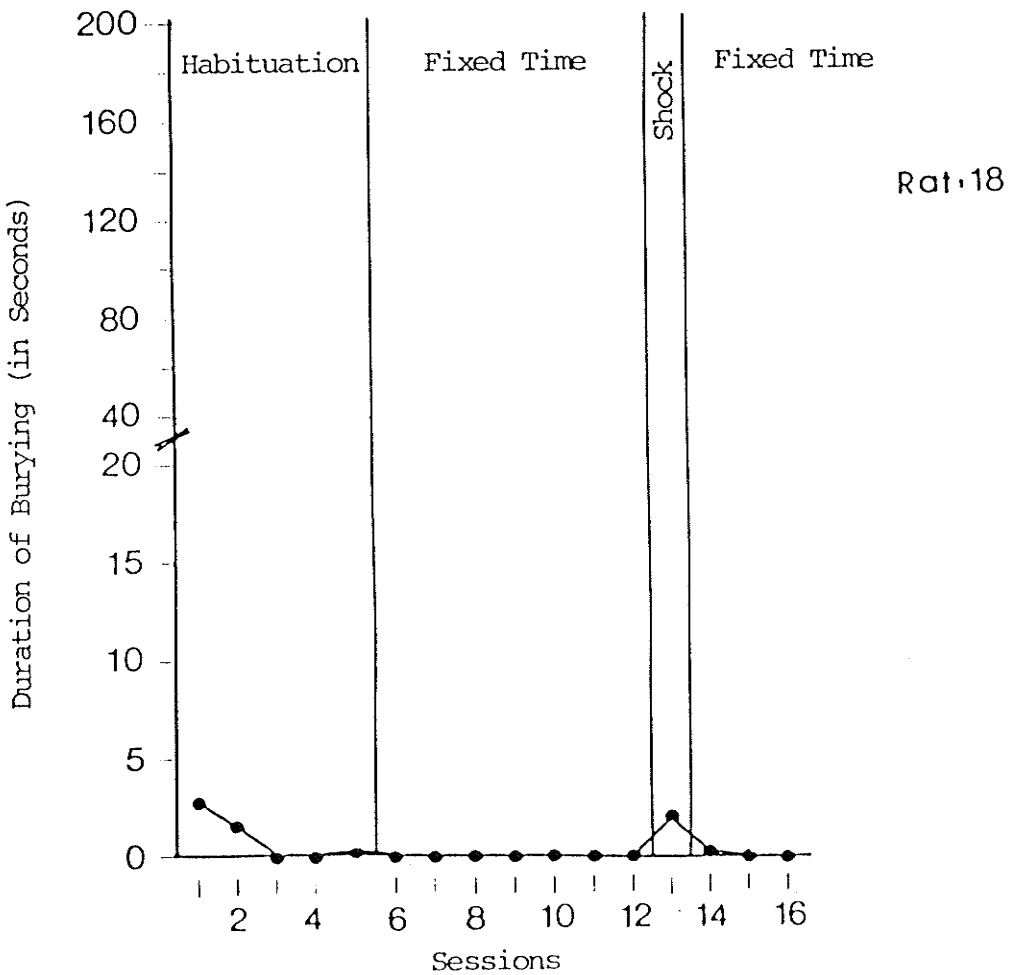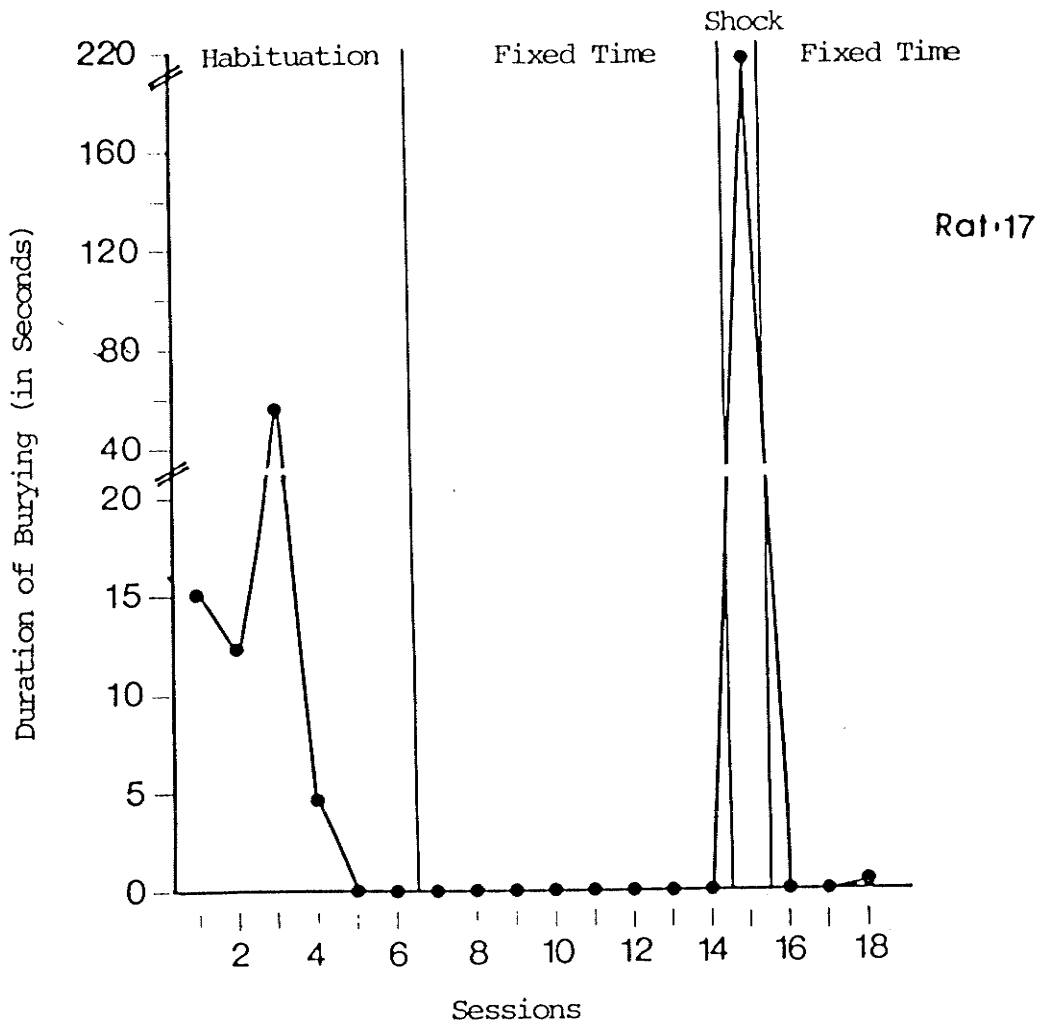
Figure 24. Total duration of burying (in seconds) for each session for rats 19 and 20.
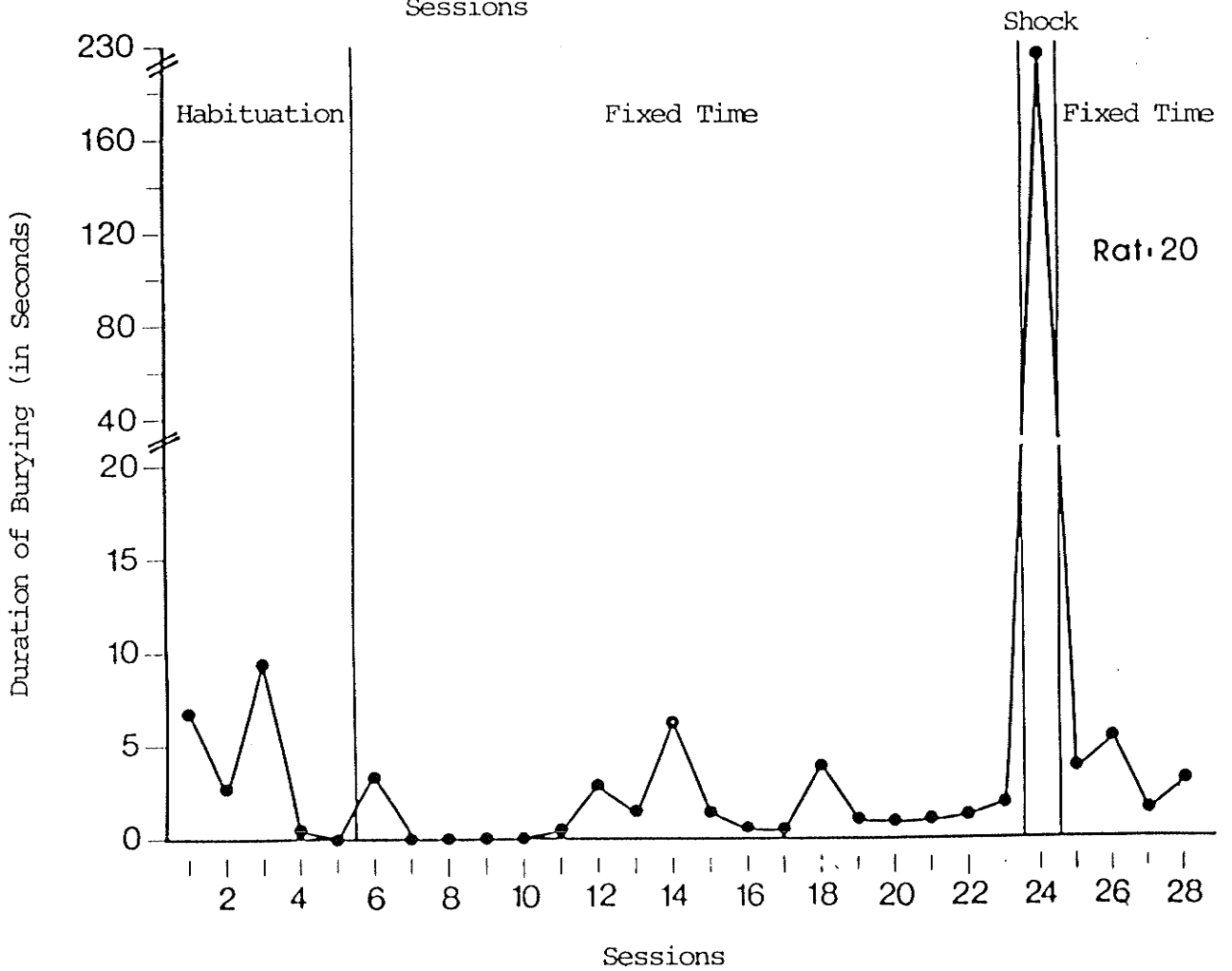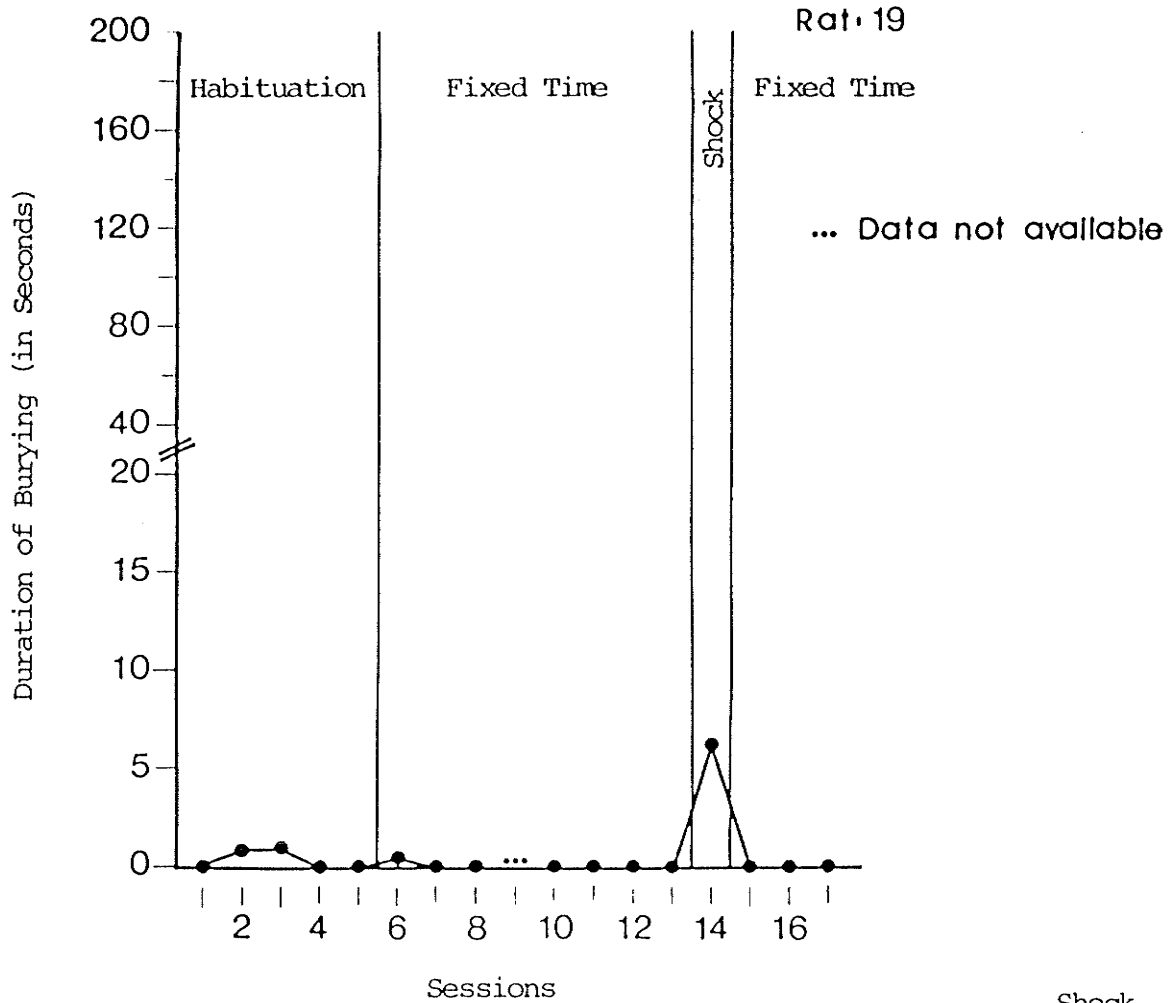
Figure 25. Maximum height of bedding material (in centimeters) at

the operative and nonoperative levers at the end of each session

for rats 17 and 18, for which the left lever was the operative

lever.

Rat·17
■ Operative Lever
≡ Non-Operative Lever

Rat·18
■ Operative Lever
≡ Non Operative Lever
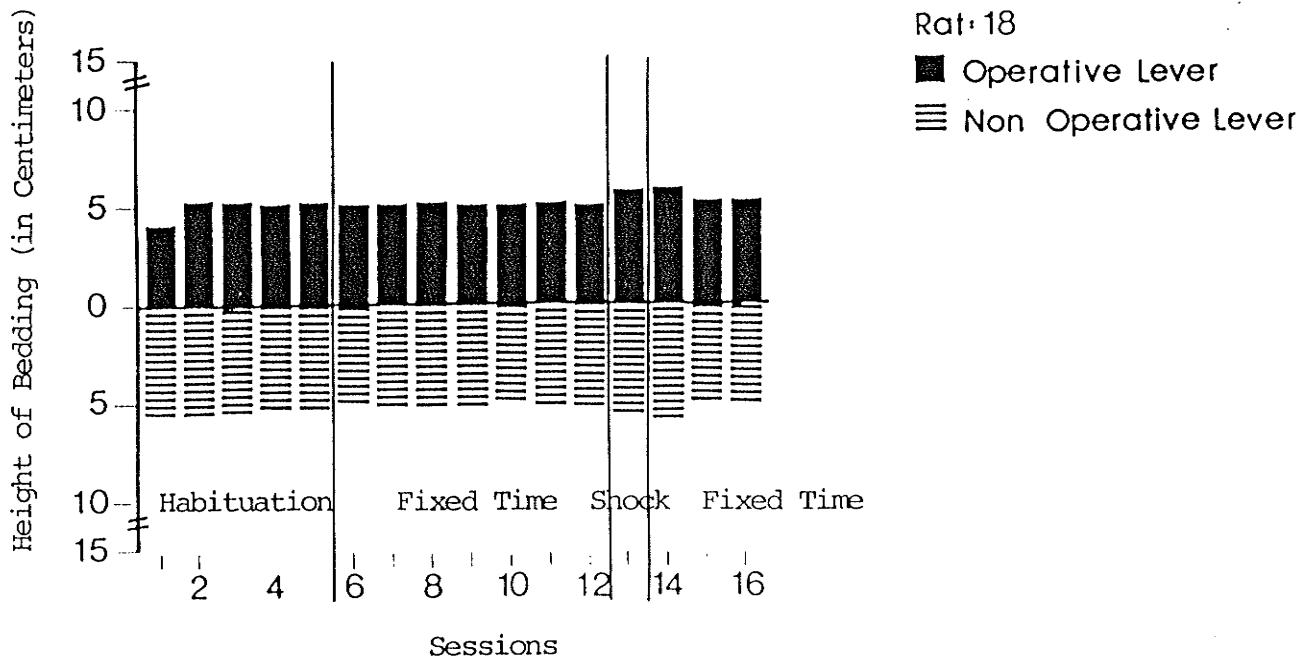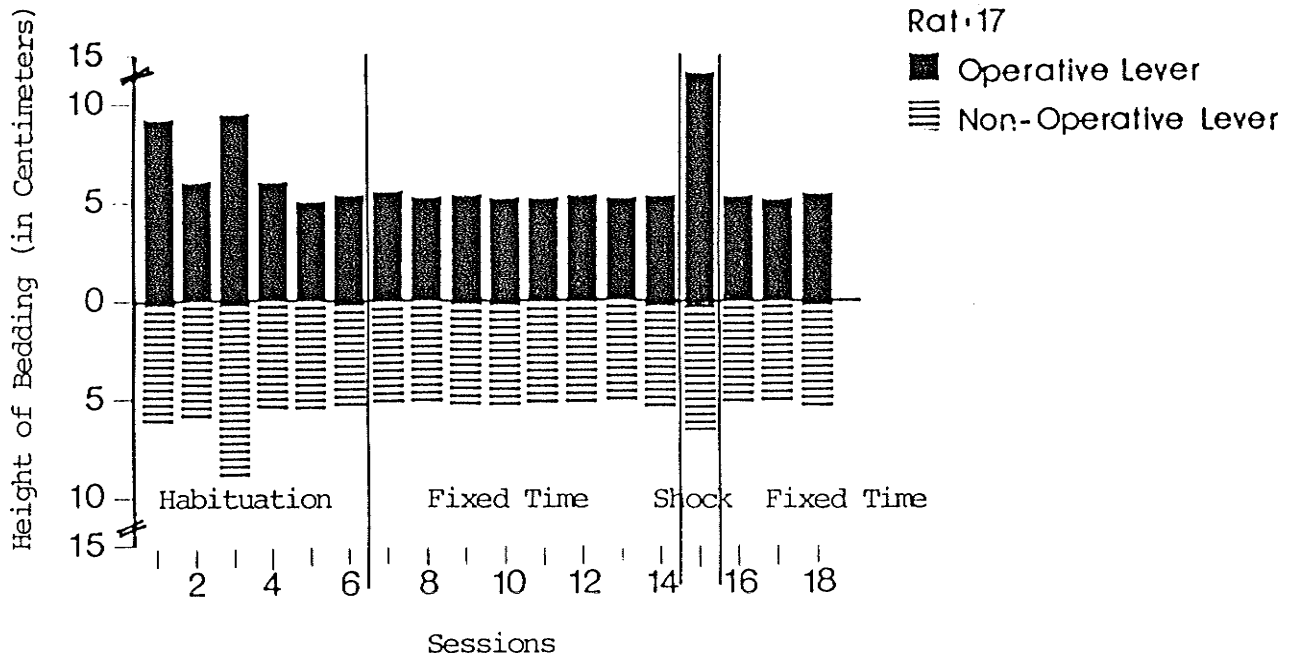
Rat 18 did not exhibit burying until 5 shocks had been delivered. The minimal burying that did occur was not recorded until the fifth and sixth 5-minute intervals after the first shock. Although Figure 25 shows a slight increase in height of bedding material at the operative lever at the end of the "shock" session, compared to the fixed time phase, this increase is approximately equal to that observed at the nonoperative lever.

Rat 19, like Rat 17, showed burying after receiving a single shock, and in fact received only one shock. Burying was initiated approximately 1.3 minutes after the shock was received. Although this subject did not exhibit a great deal of burying, and in general, it was not directed toward the right lever, Figure 26 indicates that the height of bedding at the operative lever was higher than that observed in the fixed time phase. The height of bedding at the operative lever on the "shock" day was also higher than that at the nonoperative lever. It is interesting that near the end of the "shock" session, this subject spent considerable time sitting in front of the left lever, facing the left side wall, that is, with his back to the right lever. (The duration data for Session 9 for Rat 19 is unavailable. The data was not scored while the session was in progress. When the videotape was later viewed, it was impossible to see the activity of the subject.)

Rat 20 did not exhibit burying until 3 shocks had been received. These three shocks occurred within 57 seconds and burying was initiated approximately 20-25 seconds later. The

Figure 26. Maximum height of bedding material (in centimeters) at

the operative and nonoperative levers at the end of each session

for rats 19 and 20, for which the right lever was the operative

lever.

Rat·19
■ Operative Lever
≡ Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation   Fixed Time   Shock   Fixed Time

Sessions

Rat· 20
■ Operative Lever
≡ Non-Operative Lever

Height of Bedding (in Centimeters)

Habituation   Fixed Time   Shock   Fixed Time

Sessions
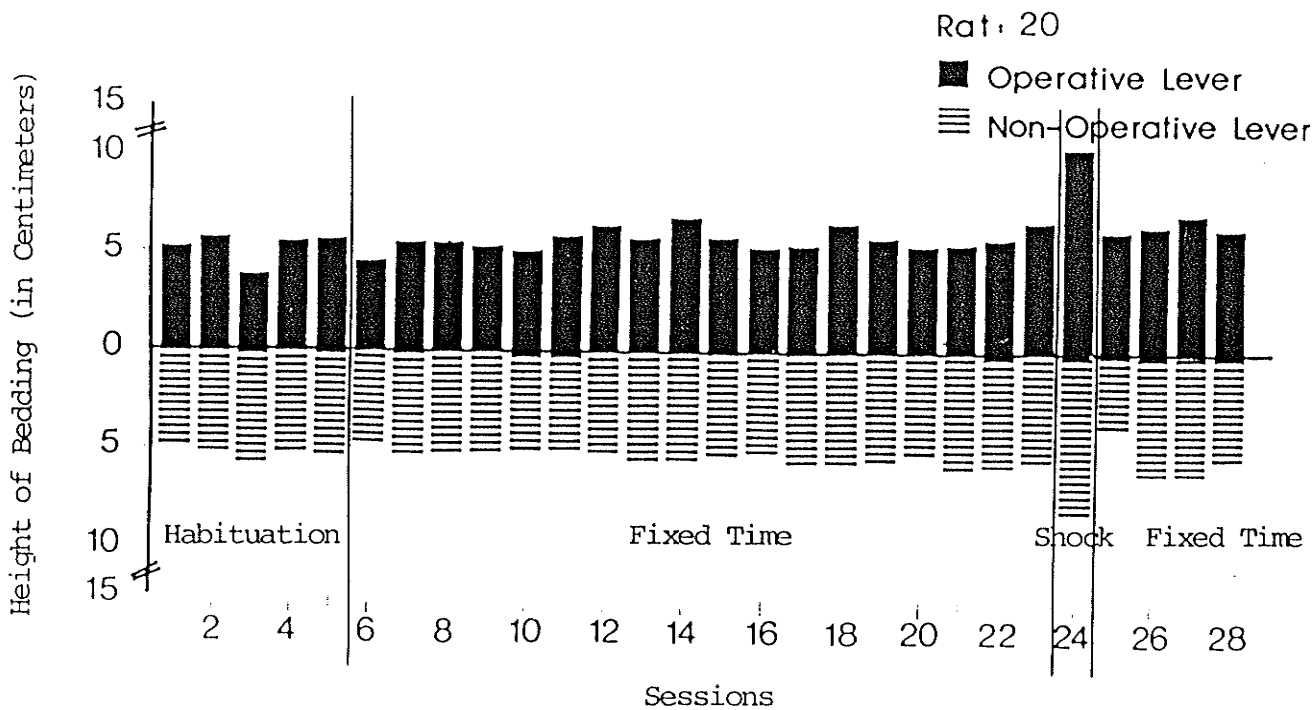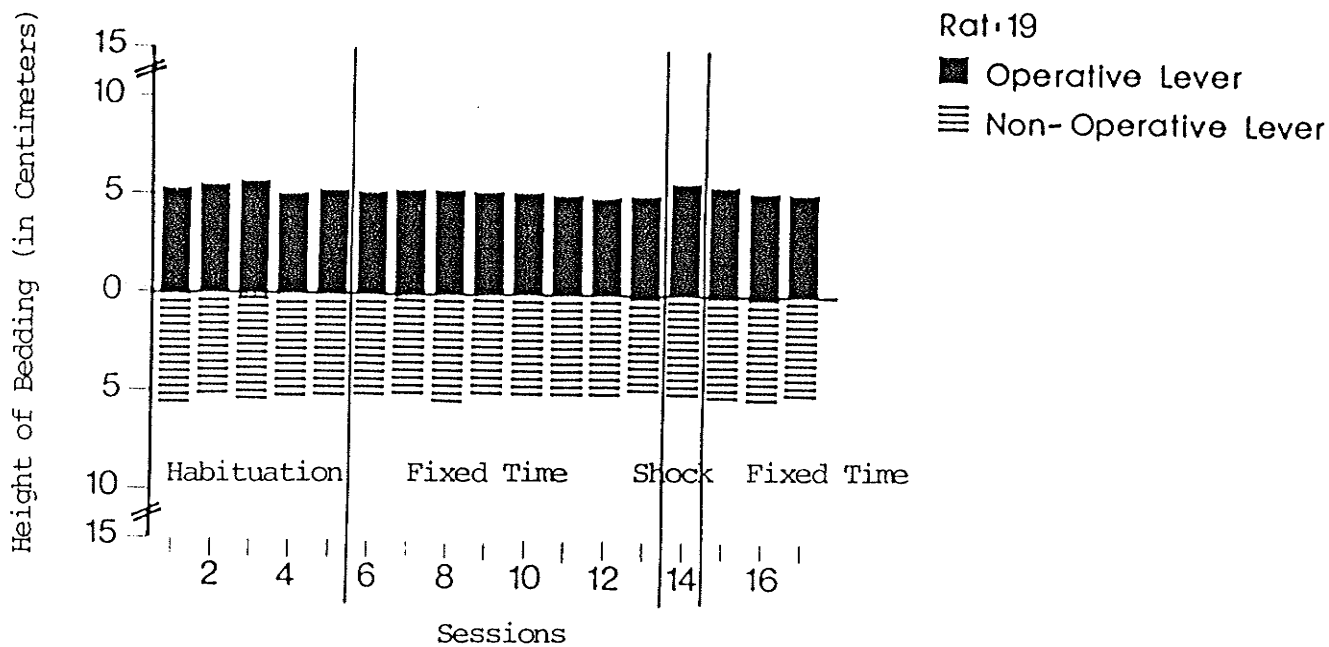
majority of burying was recorded in the first and second 5-minute intervals after the first shock, although some burying was also recorded in the third, fourth, and fifth 5-minute intervals. Initially, burying was directed toward the front of the chamber, and then primarily toward the right lever, although not all burying was directed toward the right lever. At the end of the "shock" session, the operative (right) lever was completely covered with sawdust, and the nonoperative lever was partially covered. As indicated in Figure 26, the height of bedding material at both levers at the end of the "shock" session was considerably higher than that recorded during the fixed time phase. Also, the height of bedding at the operative lever on the "shock" day was greater than that at the nonoperative lever. It should be noted that Rat 20 was the only subject of the four to exhibit any burying prior to shock delivery on the "shock" day. This burying activity was minimal, 0.91 seconds.

Thus, of these four subjects, for which food was delivered on a fixed time basis, and not contingent on lever pressing, two subjects (Rats 17 and 19) showed burying after one shock. The remaining two subjects received multiple shocks prior to burying Rat 18 - 5 shocks, and Rat 20 - 3 shocks.

The correlation coefficient for interobserver reliability was .99, as calculated with 23 pairs of data points.

Discussion

Given that a single shock was insufficient to produce defensive burying of the "shock" lever in Experiment 3, when

continuous reinforcement for lever pressing was concurrently

programmed on that lever, Experiment 4a was conducted to examine

the effects on defensive burying of multiple shock delivery under

similar conditions. The results of Experiment 4a indicated that

none of the four subjects in this experiment, all of which had a

history of continuous reinforcement for lever pressing, showed

burying after a single shock was delivered through that lever.

All subjects, however, showed burying after receiving multiple

shocks.

These results are consistent with those of Anderson, Nash,

Weaver, and Davis (1983), who found that in rats, measures of both

duration of burying and bedding material accumulated, were greater

following multiple shocks than following a single shock. The

results of the present study also extend these findings in

indicating that similar effects are obtained with multiple vs. a

single shock, when the shock source is a manipulandum, on which

reinforcement for lever pressing is concurrently programmed.

In the work of Anderson et al. (1983) the subjects in the

multiple shock condition received an average of 2.37 shocks.

Goldberg et al. (1983) similarly observed that when shock was

delivered through a lever on which pressing was reinforced with

water, not only did burying occur, but also, after a second shock,

none of the subjects pressed the lever again.

In the present study, rats received from 3 to 12 shocks,

indicating that they contacted the "shock" lever that frequently.

It is possible that this discrepancy is due to a difference in the

reinforcer used, that is, food vs. water. This possibility is supported by the observations of Goldberg et al. (1983) showing that during the "shock" session, lever pressing was greatly reduced, whereas in Experiment 3 of this study, lever press performance during the "shock" session was only minimally disrupted. In addition, in Experiment 4a, it was demonstrated that disruption of food-reinforced lever pressing occurred when subjects received a greater number of shocks (i.e., 3 to 12 shocks).

In both Experiment 3 and Experiments 4a and 4b of this study, and in the work of Anderson et al. (1983), defensive burying was decreased rapidly in subsequent sessions with no shock presentation. This is discrepant with Pinel and Treit (1978) who reported burying up to 20 days following the shock trial. Anderson et al. (1983) suggested three procedural differences that might account for this discrepancy. First, Anderson et al. (1983) used albino rats as opposed to the hooded rats used by Pinel and Treit (1978). The present research also used hooded rats, and found a rapid decrease in burying. Thus, strain of rats could not be the critical factor. Second, Anderson et al. (1983) used a lower shock intensity (5mA) than Pinel and Treit (1978) (7.9 mA). The present research, however, used an 8mA shock and found results similar to those of Anderson et al. (1983). Therefore, shock intensity would not appear to be the critical factor. Third, in the study by Anderson et al. (1983) subjects were not removed from the experimental chamber immediately after shock, as were the

subjects in the study by Pinel and Treit (1978). Thus, in the

work of Anderson et al. (1983), rats had the opportunity to bury

immediately after shock delivery. Anderson et al. (1983) argued

that because subjects had already buried in the "shock" session,

burying in subsequent sessions was reduced. The same argument

applies to this research.

In addition, it should be noted that in Experiments 3 and 4a

of the present research the probability of subjects' approaching

the shock source again was increased, as pressing the lever

produced food reinforcement for food-deprived subjects. In

contrast, the subjects in the work of Pinel and Treit (1978) were

not food deprived. Further, for these subjects contact with the

shock source had never been associated with food delivery. Thus,

in the present research, the shock source (i.e., the lever) had

been paired with both positive reinforcement (food delivery

contingent on lever pressing), and aversive stimulation (shock).

In contrast, in the work of Pinel and Treit (1978), the prod had

been paired only with aversive stimulation (shock). This

difference could account for the discrepancy in persistence of

burying between the present experiment and that of Pinel and Treit

(1978). Whereas in the present study approaching the lever (for

food reinforcement) could compete with avoidance or burying of the

"shock" lever, no such conflict existed in the study by Pinel and

Treit (1978).

Experiment 4b was conducted to determine if, in Experiment 3,

it was the history of food reinforcement contingent on lever

pressing that was responsible for the minimal conditioned burying of the "shock" lever. Thus, in Experiment 4b food was delivered on a fixed time basis, independently of any response. In the subsequent phase, shock was delivered through the lever.

Whereas in Experiment 4a, none of the subjects buried after one shock (Rat 13 received approximately 12 shocks prior to burying; Rat 14 - 3 shocks; Rat 15 - approximately 12 shocks; rat 16 - 7 shocks), in Experiment 4b two subjects buried after one shock (Rats 17 and 19), one subject after 3 shocks (Rat 20), and one subject after 5 shocks (Rat 18). These data indicate a trend suggesting that with continuous reinforcement contingent on lever pressing, a greater number of shocks, when delivered through the lever, are required to generate burying. Comparison of the mean number of shocks received prior to burying by rats in Experiment 4a with the mean number of shocks received prior to burying by rats in Experiment 4b indicated that the mean number of shocks received by the rats for which food was contingent on lever pressing (Experiment 4a) was significantly higher than that received by the rats for which food was not contingent on any response ($\underline{t}(6) = 2.521$, $\underline{p} < .05$).

That none of the subjects in Experiment 4a buried after one shock, that two subjects in Experiment 4b buried after one shock, as well as the observed differences in the number of shocks received by subjects in Experiment 4a compared to subjects in Experiment 4b before burying occurred, supports the position that it was the reinforcement contingency in Experiment 3 that interfered with burying when only a single shock was delivered.

On numerous occasions in this series of experiments, a response that for purposes of this discussion will be labelled "digging" has been noted frequently. This response consists of the animal digging into the sawdust in front of him, and spraying it backwards behind him. Although this response was not systematically monitored, several notations in Experiments 4a and 4b suggest that it might be worthy of investigation in future research. This "digging" response seems to occur frequently in conjunction with burying, suggesting perhaps that they are both members of the same response class, or both comprise components of a response chain.

General Discussion

Experiment 1 indicated that conditioned burying of a shock source is observed in some subjects when the shock source is a response lever, thus replicating results of earlier investigations (e.g. Hudson, 1950; Pinel & Treit, 1978, 1979; Pinel, Treit, Ladak, & MacLennan, 1980; Terlecki et al., 1979), and extending those results to a shock source somewhat different in form.

Experiment 2 replicated the findings of Goldberg et al. (1983) that burying is not observed under conditions of extinction. If we assume that burying is a defense reaction, the implication is that extinction is not aversive since, according to one of the criteria provided by Pinel and Treit (1978), in order for a behavior to be considered a defense reaction, it "must be shown to occur in response to aversive stimulation" (p. 710). Extinction, however, meets the criteria of an aversive stimulus

provided earlier in this manuscript; that is, aversive stimulation
is defined as a stimulus against which organisms will agress
and/or as stimulus conditions which organisms will respond to
escape from or terminate. There is considerable evidence
demonstrating that aggressive behavior occurs in conjunction with
extinction (e.g., Azrin et al., 1966; Hutchinson et al., 1968;
Knutson, 1970; Thompson & Bloom, 1966). It has also been
repeatedly demonstrated that organisms will respond to escape from
or terminate conditions of extinction (Terrace, 1971; Thomas &
Sherman, 1965; Thompson, 1964). Given then that extinction is
aversive, the implication is that burying may not be a defensive
response according to the criterion of Pinel and Treit (1978)
provided above.

A less extreme position is that conditioned defensive burying
is a species-specific defense reaction, but that not all
species-specific defense reactions occur in all situations; that
is, burying may be a defensive response, and extinction may be an
aversive stimulus. An extinction condition, however, may not have
the qualities necessary to generate the defensive response of
burying. Conditioned defensive burying may not be a high
probability event during extinction because extinction does not
provide a clearly defined, discrete stimulus that seems conducive
to defensive burying. It has been documented repeatedly that
conditioned defensive burying is an activity that is directed
toward a specific source of aversive stimulation (e.g., Pinel &
Treit, 1978, 1979; Pinel, Treit, & Wilkie, 1980; Poling et al.,
1981; Terlecki et al., 1979; Wilkie et al., 1979).

It should also be noted that bites on the levers were rarely recorded in any of the experiments in this study. Similarly, biting of shock prods was not mentioned in other studies investigating defensive burying (e.g., McKim & Lett, 1979; Pinel, Treit, Ladak, & MacLennan, 1980; Terlecki et al., 1979). Further, Pinel and Treit (1978) noted the absence of "aggressive behavior directed at the prod" (p. 712). The absence of aggression in these studies is an important observation, since attack is one of the three defense reactions identified by Bolles (1970), and because there is a substantial body of literature documenting the occurrence of the species-specific defense reaction of attack following shock (e.g. Azrin et al., 1964; 1967; Pear et al., 1972; Ulrich & Azrin, 1962; Ulrich & Craine, 1964). This inconsistency may in part be due to an insufficient analysis of agonistic behavior in a large portion of the relevant literature. Blanchard, Blanchard, and Takahashi (1977, 1978) have dichotomized agonistic behaviors according to their function into aggressive behaviors and defensive behaviors. Blanchard et al. (1977) measured the following agonistic responses in rats under two conditions: "boxing"; "on-the-back"; "freezing"; "lateral display"; "strike"; "bite"; "piloerection". In one condition these behaviors were measured in response to shock (i.e., reflexive fighting) where rats were placed in the chamber in pairs. In a second condition these behaviors were measured in both a dominant male rat in a colony and a stranger or intruder rat introduced into the colony. Dominant rats were observed to

show more aggressive behaviors such as biting and lateral display, while both intruder rats, and those in the reflexive fighting condition, showed more defensive behaviors such as boxing, on-the-back, and freezing. Blanchard et al. (1978), in a comparison of the behavior of dominant rats and intruder rats in a colony situation, a reflexive fighting condition, and a second colony condition similarly found that in the colony conditions dominant rats showed more attack behaviors and intruder rats showed more defensive behaviors, while in the reflexive fighting condition dominant rats showed decreased attack behavior and increased defensive behavior. The agonistic behaviors of the intruder rats did not change substantially across experimental conditions. Thus, shock-elicited aggression may be better characterized as a defensive response (Blanchard et al., 1977). Under the particular experimental conditions of the studies cited above (McKim & Lett, 1979; Pinel & Treit, 1978; Pinel, Treit, Ladak, & MacLennan, 1980; Terlecki et al., 1979) then, the defensive response of burying following shock was observed, while that of aggression following shock was not.

The observation that not all species-specific defense reactions necessarily occur in all situations is worthy of examination. According to Bolles (1975), the order in which defensive responses in the rat will appear in the presence of an aversive stimulus are: (1) flight (or escape); (2) freezing; (3) attack. In contrast, Moser and Tait (1983), in a series of experiments observed that when experimental conditions were such that the three responses of escape, freezing and burying were all

possible, the "average post shock defensive response network for each experiment consisted of first freezing, second escaping and then, much later, burying." (p. 349). In the traditional experimental situation, there is typically no manipulable material on the floor (Pinel & Treit, 1978), thereby excluding the possibility of a burying response. It is possible, therefore, that, as in the research discussed above (in which burying was observed following shock, but aggression was not), if burying is a viable response, defensive burying may be prepotent over defensive aggression.

The results of Experiment 3 were somewhat surprising, and suggested that there are some restrictions defining the conditions under which burying of a shock source is observed. In this third experiment it was demonstrated that presentation of shock through a response lever, on which continuous reinforcement for lever pressing is concurrently programmed, generates minimal burying at best. These findings are discrepant with those of numerous studies demonstrating that conditioned defensive burying of a shock source is a reliable phenomenon (e.g., Hudson, 1950; Pinel & Treit, 1978, 1979). In those studies, however, the prod was solely the source of shock, and never the source of positive reinforcement. Thus, a history of continuous reinforcement associated with the shock source, can be added to the list of environmental conditions under which burying is attenuated or not observed: large chamber size (Pinel, Treit, Ladak, & MacLennan, 1980); extinction (see Experiment 2 of this study; Goldberg et al., 1983).

The results of Experiment 4a and 4b contribute to clarification of the results of Experiment 3 by examining certain variables that may interfere with, or enhance defensive burying. It appears that conditioned burying is sometimes observed when shock is delivered through a response lever, responses to which are reinforced. Under such conditions, burying is observed if the subject experiences multiple shocks through the response lever. The observation that in these circumstances, burying is not observed following a single shock, but is observed following several shocks suggests that the aversive stimulation required for burying is increased, when that aversive stimulation is pitted against reinforcement in an appetitive paradigm.

Further, in Experiment 4b, when food was presented independently of lever pressing, fewer shocks were required to generate burying than in Experiment 4a. It seems that it was indeed the reinforcement contingency concurrently programmed on the "shock" lever, that interfered with burying when only a single shock was delivered in Experiment 4a. In Experiment 4a the operative lever had been paired with both positive reinforcement (food pellets contingent on lever pressing), and aversive stimulation (shock). In Experiment 4b, on the other hand, the operative lever had been paired only with aversive stimulation (shock). Thus, for the subjects in Experiment 4a, the lever was a salient cue for food, whereas for the subjects in Experiment 4b, it was not. Therefore, in Experiment 4a, the probability that subjects would approach the lever repeatedly and thus receive

multiple shocks was greater than in Experiment 4b, in which the lever was a cue only for shock.

Thus, it appears that conditioned burying of a source of aversive stimulation is not an equally robust phenomenon under all conditions. Research has suggested that size of the chamber influences conditioned burying (Pinel, Treit, Ladak, & MacLennan, 1980), as does the nature of the aversive stimulus, for example, extinction (see Experiment 2 of this study; Goldberg et al., 1983). To those variables can be added that of a history of reinforcement associated with the source of aversive stimulation. The boundaries defining the conditions under which conditioned burying is or is not observed have then, been further delineated, as have the variables responsible for observed differences in the persistence of conditioned burying (e.g., Experiment 4a of this study; Anderson et al., 1983; Pinel & Treit, 1978). The results of Experiment 4a supported the argument of Anderson et al. (1983) that when rats are not removed from the experimental chamber immediately after shock (as was the case for subjects in the work of Pinel and Treit (1978), and have already buried in the "shock" session, burying in subsequent sessions is reduced. Further, in Experiment 4a, the reinforcement contingency was always in effect. In sessions subsequent to the "shock" session, when the lever was no longer electrified, repeated burying was rapidly eliminated.

Although this research has assisted in the further delineation of the circumstances under which conditioned burying is or is not observed, it has also raised questions concerning the

functions of defensive burying, as well as the validity of

Bolles' (1970) classification of species-specific defense

reactions. Burying does appear to be a defensive response

directed toward sources of aversive stimulation such as a shock

prod (e.g., Hudson, 1950; Pinel & Treit, 1978; 1979; Pinel, Treit,

& Wilkie, 1980; Terlecki et al., 1979), a blast of air, a light

flash, a source of physical impact (Terlecki et al., 1979), and

aversive food sources (Poling et al., 1981; Wilkie et al., 1979).

As discussed above, however, conditioned burying is influenced by

a number of factors such as size of the chamber (Pinel, Treit,

Ladak, & MacLennan, 1980), the nature of the aversive condition,

for example, extinction (see Experiment 2 of this study; Goldberg

et al., 1983), a history of reinforcement associated with the

source of aversive stimulation. Thus, there appear to be certain

constraints on the phenomenon of conditioned defensive burying.

Also, Whillans and Shettleworth (1981) have pointed out first that

burying an aversive stimulus may place the animal doing the

burying at risk, and second, given that rats rapidly avoid noxious

food sources, the function of burying that food source is unclear.

Whillans and Shettleworth (1981) have suggested that one

interpretation that could be placed on their findings that hooded

rats (a social species) bury a shock source, while golden hamsters

(a nonsocial species) do not, is that the origin of burying may

lie in a possible altruistic function, in protecting other members

of the species from the aversive stimulus.

Bolles' (1970) classification identifies the species-specific defense reactions of rats as flight, freezing and aggression. It would appear that this classification requires revision. First, there is a substantial body of literature suggesting that this classification should be expanded to include the response of conditioned defensive burying (Pinel & Treit, 1978 1979; Pinel, Treit, & Wilkie, 1980; Terlecki et al., 1979; Wilkie et al., 1979). Second, the function of agonistic behaviors requires reexamination. The work of Blanchard et al. (1977, 1978) has suggested that certain forms of agonistic behavior may serve a defensive function, and that others are better classified as aggressive behaviors. The literature investigating conditions under which attack by rats is observed (e.g., shock, extinction, intermittent reinforcement) requires review, in light of the findings of Blanchard et al. (1977, 1978) that differences in function correspond to differences in the topography of the attack response.

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Appendix

Appendix

In research employing shock as a source of aversive stimulation for rats, traditionally the shock is delivered through a wire grid floor. In certain situations, however, as in this research, it may be necessary to deliver the shock through the manipulandum. Using the procedures described below, it is possible to modify any standard response lever such that when the animal touches the lever, shock is delivered.

The lever used in this case was a modified "bite" lever of the type described by Pear, Moody, and Persinger (1972), the major difference being that the width of the lever was substantially decreased. The width of the modified lever was 2.5 cm.

All surfaces of the lever were first sprayed with urethane. A strip of phenolic circuit board, approximately 0.5 cm wide, and 4.0 cm long was glued across the width of both the upper and lower surfaces of the lever, approximately 3.0 cm from the front of the lever. It was positioned such that one end of the strip was flush with one side of the lever and extended approximately 1.0 cm. past the other side of the lever. Strips of adhesive copper tape, approximately 1.0 mm wide, and separated from each other by a distance of approximately 4.0 mm, were then placed along the sides, top, and bottom of the upper surface of the lever. These strips of copper tape, extended over the front of the lever, along the horizontal surface of the lever, and over the top of the strip of circuit board. Strips of adhesive copper tape were also applied to the lower surface of the lever in the same manner. A

layer of solder was applied on top of the circuit board strip, over the strips of copper tape.

For both the upper and lower surfaces of the lever a second strip of circuit board of similar dimensions to the first, was glued on top of the first strip such that one end of the strip was flush with the opposite side of the lever, and extended approximately 1.0 cm past the end of the first strip.

Additional strips of copper tape were then placed along the sides, top, and bottom of the lever between the first set of copper strips on the upper surface of the lever. These strips of copper tape also extended over the front of the lever, along the horizontal surface of the lever, and over the top of the second strip of circuit board. Copper tape was applied to the lower surface of the lever in the same manner. Again, a layer of solder was applied on top of the second circuit board strip, over the strips of copper tape.

One small hole was drilled in the protruding end of each piece of circuit board prior to their being attached to the lever.

The strips of phenolic circuit board extending past the edge of the lever on the left side of the upper and lower surfaces of the lever were connected with 24 guage stranded wire. The strips of phenolic circuit board extending past the edge of the lever on the right side of the upper and lower surfaces of the lever were also connected with 24 guage stranded wire. It is important that the strips of circuit board be positioned at a sufficient distance from the front of the lever to ensure that when the lever is

mounted in the chamber, these strips do not interfere with the
movement of the lever.

Next, a piece of uninsulated 28 guage solid wire was soldered
on top of each strip of copper tape, extending from the front end
of the lever to a distance of approximately 0.5 cm from the
circuit board strips. These pieces of wire should extend far
enough toward the back of the lever to ensure that when the lever
is mounted in the chamber, all of the copper strips on the
surfaces of the lever extending into the chamber are covered by
the wire.

A piece of 24 guage stranded wire approximately 12 cm long, was
then attached to the end (i.e., the end extending past the lever)
of each strip of circuit board. These wires were attached to a
terminal strip to ensure that the weight of the wire did not
increase the amount of pressure required to close the microswitch
to record a lever press. Two more pieces of 24 guage stranded
wire, approximately 1.5 metres long were then attached to the
corresponding points on the terminal strip. Male connectors
compatible with the female connectors attached to the power cord
of a Coulbourn Instruments solid state shocker/distributor (Model
Number E13-16), were then attached to the other end of these
pieces of wire.

When the modifications to the lever were damaged, for example,
by the subject's gnawing on the lever, it was relatively simple to
repair the damage. The lever was lightly sanded to remove any
dust, glue, etc. The surface of the lever excepting the soldered

strips of wire was coated with clear nail polish. Then, the damaged copper strips were replaced ensuring that there was overlap between the new and the remaining copper strips. Again, pieces of uninsulated 24 guage wire were soldered over the copper strips.