

AGGRESSION AS A REINFORCER: OPERANT BEHAVIOR IN THE MOUSE-KILLING RAT¹

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Two experiments examined mouse killing as a reinforcer of key pressing by rats that killed mice. In Experiment I, mouse-killing rats performed the key-pressing response when each press was reinforced with presentation of a mouse. Offered a choice between a key that yielded presentation of mice and one that did not, the rats preferred the key that yielded mice. When the contingency was reversed, the rats preferred the other key and continued to kill mice. In Experiment II, mouse-killing rats that did not kill rat pups performed a key-pressing response reinforced with presentation of mice on a variable-interval schedule. In tests for responding reinforced on that schedule with presentation of normal mice, anesthetized mice, dead mice, or rat pups, these rats that killed mice but not rat pups exhibited a decline in response rate when rat pups were the reinforcer. Altering the condition of the mice did not significantly affect performance.

A traditional view of aggression has been that it is a secondary result of defensive behavior patterns, rather than a goal in itself (Craig, 1921; Scott, 1966, 1968). Motivation to perform aggressive acts has been thought to depend upon previous reinforcement of aggressive behavior with such reinforcers as food, sex, or escape from pain (Dollard, Doob, Miller, Mowrer, Sears, Ford, Hovland, and Sollenberger, 1939; Feshbach, 1964). However, recent experiments have shown that when aggressive motivation is aroused by intracranial stimulation (Roberts and Kiess, 1964) or by external aversive stimulation (Azrin, Hutchinson, and McLaughlin, 1965; Dreyer and Church, 1970), aggressive acts resulting from such arousal can be reinforcing. A number of studies suggest that, even in the absence of attack-inducing stimulation, some animals may perform responses that have been reinforced by natural stimuli that elicit aggressive acts (Myer and White, 1965; Tellegen, Horn, and Legrand, 1969).

Some rats "spontaneously" and consistently attack and kill mice placed with them (Karli, 1956), and the killing is maintained in the absence of any conventional reinforcer, such as feeding on the bodies of the killed mice (Myer, 1964). Myer and White (1965) showed that the opportunity to attack and kill mice can be used to produce stimulus control over the behavior of mouse-killing rats in a T-maze. The present experiments explored the use of the opportunity to attack and kill mice as a reinforcer in an operant paradigm. The first experiment sought to determine whether rats that reliably and quickly killed mice would learn to press a key when that response was reinforced with mouse presentation, whether such rats would prefer a key that yielded mouse presentation to one that did not, and whether they would learn a reversal when the contingency was reversed. The second experiment explored the relative reinforcing powers of normal mice, anesthetized mice, dead mice, and rat pups for key pressing by rats that killed mice but did not kill rat pups. Rate of key pressing on a VI 1-min schedule with a 2-min timeout was used as a measure of reinforcing power in Experiment II.

EXPERIMENT I: DISCRIMINATION

METHOD

Subjects and Maintenance Conditions

Eight Long-Evans male hooded rats, approximately 1 yr old at the beginning of the

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experiment, were individually housed in the laboratory colony area with continuous access to food and water. Each rat had killed a minimum of 20 mice in a previous study of the development of mouse-killing behavior, but none had ever been food-deprived or allowed to feed on the bodies of killed mice.

Apparatus

The rats were trained and tested in four 8 by 9.5 by 7.75 in. (20 by 23.5 by 19 cm) high experimental chambers in an experimental room illuminated by a 25-w red light bulb, with white masking noise present throughout the study. Foam rubber shielding between the chambers prevented light transfer and provided sound attenuation. A flat, transparent Plexiglas key was mounted flush with the outside of each end of each chamber over a 1-in. (2.54 cm) diameter hole. In each chamber, an opaque vertical stripe on one key and a horizontal stripe on the other enhanced the discriminability of the two keys, and a small light transilluminated each key. A force greater than 5 g (0.05N) displaced the key 2 to 3 mm, closing a circuit that activated scheduling and recording equipment in an adjacent room. Impulse counters recorded presses on each key and Rustrak event recorders monitored presses as they occurred during an experimental session. A 14-in. (35 cm) diameter motorized wheel with small wire mesh compartments delivered single mice to an opening 2.75 in. (6.5 cm) high and 3 in. (7.5 cm) wide in the side of each chamber. A small light behind each wheel transilluminated the opening.

Procedure

Selection and pretraining. Twelve days of pretraining tests selected those rats that would attack mice with consistently short latencies and accustomed them to killing mice in the experimental chamber. On each of the first three days of selection training, one mouse was presented to each rat in its home cage. Each rat that killed the mouse was placed in a darkened experimental chamber and left for a 2-hr adaptation period with food and water present. During these and all subsequent tests, bodies of killed mice were removed within 1 min of the kill.

For the remaining nine days of selection testing, test mice were presented through the

opening in the side of the experimental chamber and the wheel light was illuminated during the attack and kill. If no attack occurred, the light remained on for 5 min, after which the mouse was removed. On each of the three days following the home cage tests, each rat was placed in the darkened experimental chamber for 1 hr with food and water present, and a single mouse was presented to each rat at the end of the hour. On each of the next three days, each rat was presented a single mouse at the end of a 30-min period in the chamber. On each of the last three days of selection testing, each rat was presented three mice, one at a time at 10-min intervals during a 30-min session. Four rats that quickly and consistently killed mice throughout the pretraining period were selected for further study.

Baseline determination. For the remainder of the experiment, daily sessions began with the turning on of the lights behind both keys. Upon presentation of each mouse, the key lights were turned off for 1 min to allow time for the rat to kill the mouse. During the 1-min timeout, the wheel light was illuminated and key presses were not recorded. Mice were invariably killed in less than 1 min, and the body of the killed mouse was removed during the last 10 sec of the timeout.

On the day following the last day of selection testing, the four rats underwent a 30-min session during which operant rate of pressing the lighted keys was measured, with 10 mice presented on a random schedule, not contingent upon key pressing. This measure is not the same as conventional operant rate of responding in the absence of reinforcement because, unlike conventional operant rate, it was influenced by the activation resulting from mouse delivery in the absence of reinforcement dependency.

Shaping. During two to eight daily 30-min shaping sessions, presentation of a single mouse immediately followed every press on either lighted key. Subsequently, each rat received such continuous mouse-presentation reinforcement for pressing either lighted key during three daily sessions. Each session terminated after reinforcement of the tenth press, and the number of presses on each key was recorded.

Discrimination training. After shaping, each rat underwent seven days of discrimination

training. For two rats, continuous reinforcement with mouse presentation followed only presses on the key preferred during the previous three daily sessions, and for the other two rats, similar reinforcement followed only presses on the non-preferred key. No wheel advancement or mouse presentation followed a press on the incorrect key, but the 1-min timeout and its associated light changes did follow such a press.

Reversal training. For the next seven days of training, the reinforcement contingency was reversed for each rat. For both discrimination and reversal training, the daily sessions terminated for each rat after the tenth reinforced press.

RESULTS AND DISCUSSION

Baseline Determination and Shaping

During measurement of operant rate in the presence of non-contingent mouse presentation, the four rats made a total of 187 responses, 70 on the vertically striped key and 117 on the horizontally striped key. In that ses-

sion, before mouse presentation was made contingent upon key pressing, three of the four rats exhibited rates higher than 30 responses in 30 min. Thus, operant rate in the presence of non-contingent mouse presentation was higher than the possible rate in a session during which mouse presentation and the 1-min timeout followed each key press. This high rate was probably due in part to the activation resulting from the random presentation of mice, and in part to a kind of "auto-shaping" similar to that demonstrated for food-motivated responding in rats (Davidson, Davis, and Cook, 1971; Smith, Borgen, Davis, and Pace, 1971). In fact, three of the rats were responding reliably after two sessions of contingent mouse presentation, and only one rat required manual shaping.

Discrimination Training and Reversal

Figure 1 shows the number of errors made by each rat before the tenth response reinforced with mouse presentation on each day of discrimination and reversal. As the figure

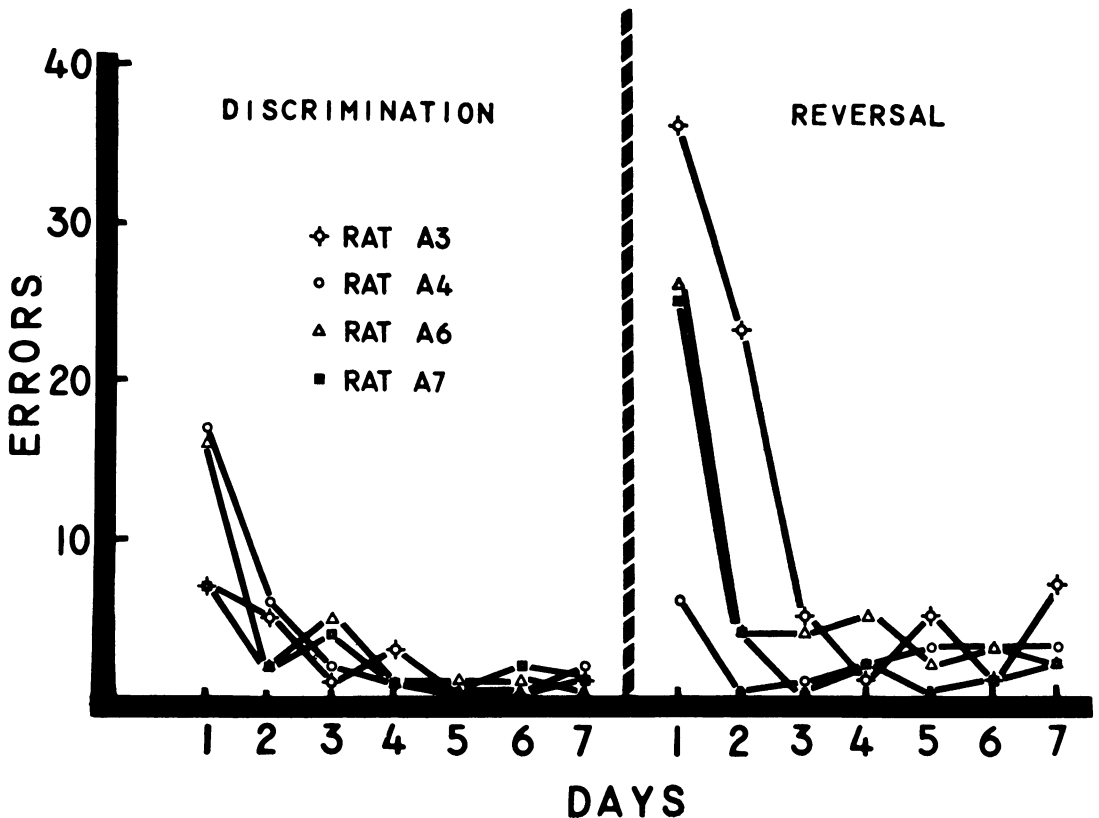


Fig. 1. Number of errors made by each rat each day before the tenth response reinforced by mouse presentation during discrimination and reversal training.

shows, every rat made fewer errors in obtaining 10 mouse-killing opportunities on each of the last six days of discrimination training than on the first day, and every rat made fewer errors on each of the last six days of reversal training than on the first day of reversal training.

The rats usually pressed one of the keys quickly when the keylights were turned on at the beginning of a session or after a timeout. Figure 2 shows the mean latency of correct response for each rat on each day of discrimination training and reversal. Every rat averaged shorter latencies of correct responses on each of the last six days of discrimination training than on the first day, and every rat averaged shorter latencies of correct response on the last six days of reversal training than on the first day of reversal training. No consistent trend was evident in the error latencies. The average latency for incorrect responses was 26.3 sec on the first day of discrimination training and the daily aver-

ages ranged from 21.8 sec to 110 sec during the last six days of discrimination. The average latency for incorrect responses was 18.5 sec on the first day of reversal training and the daily averages ranged from 8.7 sec to 26 sec during the last six days of reversal training.

EXPERIMENT II: EFFECTIVE REINFORCERS

Experiment I demonstrated discrimination and reversal learning reinforced by presentation of mice to mouse-killing rats in an operant conditioning paradigm. One possible source of the reinforcing power of mouse presentation is the motor feedback from performance of the act of killing the mouse (Valenstein, Cox, and Kakolewski, 1970). Variations in the amounts of consummatory behavior involved in a reinforcing activity can produce a magnitude of reward effect (Wolfe and Kaplon, 1946; Sheffield and Roby, 1950). Experiment II was an attempt to produce

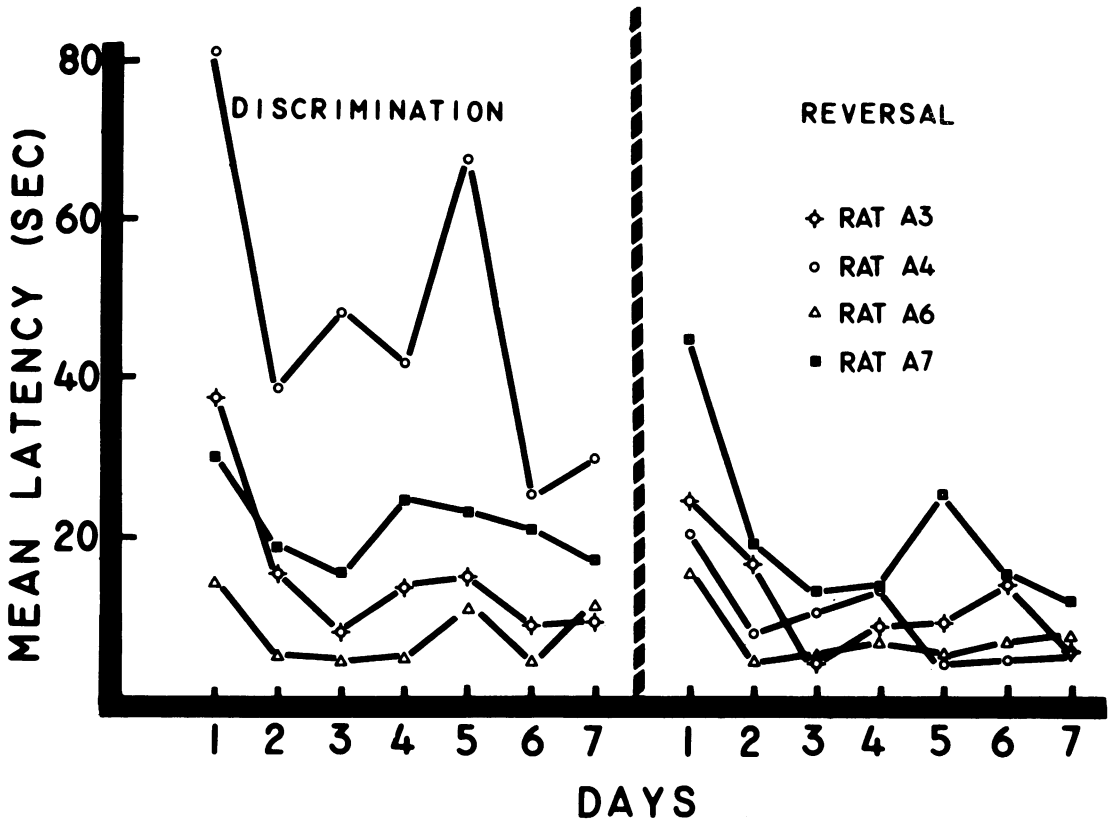


Fig. 2. Mean latency of correct response for each rat on each day of discrimination and reversal training. Each point is the average of the time elapsed between illumination of the keylights and the pressing of a key for the 10 presses that yielded mice.

variations in the amount of consummatory killing behavior, and thereby to obtain a magnitude of reinforcement effect, by using normal mice, anesthetized mice, dead mice, and rat pups as reinforcers for rats that killed mice but did not kill rat pups.

METHOD

Subjects and Maintenance Conditions

Six Long-Evans male hooded rats, approximately 1 yr old at the beginning of the experiment, were selected from 21 rats that had killed a minimum of 20 mice in a previous study of the development of mouse killing. They were individually housed in the laboratory colony area with continuous access to food and water. None of the rats had ever been food-deprived or allowed to feed on the bodies of killed mice.

Apparatus

The apparatus was the same as that used in Experiment I, except that only one transparent lighted key was present in each experimental chamber, and variable-interval (VI) schedules were added to the equipment.

Procedure

Selection and pretraining. Twenty-one rats underwent pretraining tests to select those that would attack mice with consistently short latencies but would not kill rat pups, and to accustom them to killing mice in the experimental chambers. On each of the first three days of selection testing, one mouse was presented to each rat in its home cage. During these and all subsequent tests, bodies of killed mice were removed within 1 min of the kill. If the rat killed the mouse, the rat was placed in the darkened experimental chamber for a 1-hr adaptation period with food and water present. Four rats were discarded after the first three days, one that failed to kill within 5 min on one of the three tests, and three that exhibited no attack latencies of 1 sec or less on any of the three tests. On the fourth day, each rat was presented three mice at 10-min intervals in the home cage. If the rat killed all three mice, it was given a 30-min period in the experimental chamber with food and water present. On the following day, each rat similarly received three test presentations in the home cage, but on the second presentation, a 25-day-old rat pup was presented in-

stead of a mouse. Four rats that killed rat pups and one that failed to kill one of the two mice were discarded. The remaining rats, that killed the mice but did not kill the rat pups, were each given a 30-min period in the experimental chamber with food and water present.

For the remaining 10 days of selection testing, test mice were presented through the opening in the side of the experimental chamber, and the wheel light was illuminated during the attack and kill. If no attack occurred, the light was left on for 5 min, after which the mouse was removed. As in Experiment I, each day the rats were presented mice after a period of time with food and water present in the experimental chamber. On each of the last three days of selection testing, three mice were presented to each rat, one at a time at 10-min intervals during a 30-min session. Six rats that quickly and consistently killed mice throughout the pretraining period were selected for further study.

Development of VI performance. For the remainder of the experiment, daily sessions began with the turning on of the keylight. Upon presentation of each stimulus animal, the keylight was turned off for 2 min during which key presses were not recorded. During the first minute of the timeout, the wheel light was illuminated while the rat killed the mouse or otherwise responded to the stimulus animal. Whether or not it had been killed, the stimulus animal was removed 50 to 60 sec after the beginning of the timeout, and the wheel light was turned off, leaving the chamber dark. At the end of the remaining part of the 2-min timeout, the keylight was turned on again.

As in Experiment I, key-press responding was established during sessions in which presentation of a single mouse followed every press. Subsequently, the six rats received training with variable-interval reinforcement schedules, and the average interval was gradually increased to 1 min as the session length gradually increased to 45 min. A 45-min session of reinforcement on a 1-min variable-interval schedule with a 2-min timeout for each reinforcement allowed a maximum of 15 mouse-killing opportunities. The rats received 20 days of training on that schedule, and three rats were assigned to each of two groups, matched on the basis of median response rate on the last nine days of that training.

Testing with different types of reinforcers. Following training, the rats were tested during 45-min sessions for responding under reinforcement with the different stimulus animals on the 1-min variable-interval schedule with the 2-min timeout. The stimulus animals used in the tests were normal adult albino mice, mice heavily anesthetized with intraperitoneal injection of pentobarbital, mice killed by the rats in the previous day's session, and 14- to 25-day-old rat pups. For one group of three rats, responding was first reinforced with presentation of normal mice, then with anesthetized mice, next with dead mice, and finally with rat pups. For the other group of three rats, the stimulus animals were presented in the reverse order. Responding was reinforced on the 1-min variable-interval schedule with each type of stimulus animal for six consecutive days, with three-day control periods of reinforcement with normal mice interspersed between successive test periods to reestablish baseline responding. Testing continued until both order groups had undergone a six-day period with each type of stimulus animal.

Extinction. After a three-day period of reinforcement with normal mice following the last test period for each group, the responding of both groups underwent a six-day period of extinction. During extinction, the rats experienced daily sessions identical to those of the previous test periods, except that the compartments of the wheel were empty. Key presses were followed by presentation of empty compartments on the 1-min variable-interval schedule with the 2-min timeout, and the experimenter executed a sham mouse removal, as if reinforcement had occurred.

RESULTS AND DISCUSSION

Training

Three of the rats readily acquired the key-pressing response when mice were presented on a continuous reinforcement schedule, and the other three required very little manual shaping to learn the response. All rats continued to press the key when shifted to variable-interval schedules of reinforcement with mouse presentation, but the response rates varied a great deal from day to day both within and between subjects. During the last nine days of training on the 1-min variable-interval schedule, the individual mean rates ranged from 87.6 to 361.4 responses per session, and

the individual standard deviations ranged from 28.6 to 104.5.

Behavior in the Presence of the Stimulus Animals

Normal mice were attacked and killed in the same manner as that described by others (Karli, 1956; Myer, 1964). The rats consistently seized every mouse by the nape of the neck and killed it by biting through the spinal cord. Usually, cessation of movement by the mouse was followed by cessation of the biting attack. Anesthetized mice were attacked and killed in the same manner as were normal mice, although the anesthetized mice did not move in response to an attack. It was impossible to distinguish the bodies of mice that had been anesthetized before they were killed from those of mice not anesthetized before they were killed. Surprisingly, even the dead mice elicited a vigorous attack. The rats pulled such mice from the wheel, bit them, and dragged them around the chamber. As expected, the rats did not attack rat pups when they were presented in the experimental chambers. The rats often sniffed at the pups, pulled them from the wheel and licked them, but no rat ever injured a rat pup.

Responding Reinforced with the Stimulus Animals

Figure 3 shows the mean number of responses per minute for each day of the six-day test period of reinforcement with each of the various stimulus animals, and the individual data provided by one rat from each of the two order groups. Response rates were quite variable within test periods of reinforcement with normal, anesthetized, and dead mice. The only consistent effect of type of reinforcer appeared to be the sharp reduction of rate of responding reinforced with rat pups, which were a poor reinforcer throughout the test period. Under reinforcement with anesthetized or dead mice, response rates were elevated at the beginning of the test periods and declined slightly toward the baseline response rate as the test periods continued. Order of presentation of the reinforcers had no discernible effect.

Extinction

The data obtained during extinction are presented in Figure 4, which shows for each

TYPE OF REINFORCER:
 ○—○ NORMAL MICE
 ●—● ANESTHETIZED MICE
 ●—● DEAD MICE
 ◇—◇ RAT PUPS
 - - - - - NORMAL MICE BASELINE

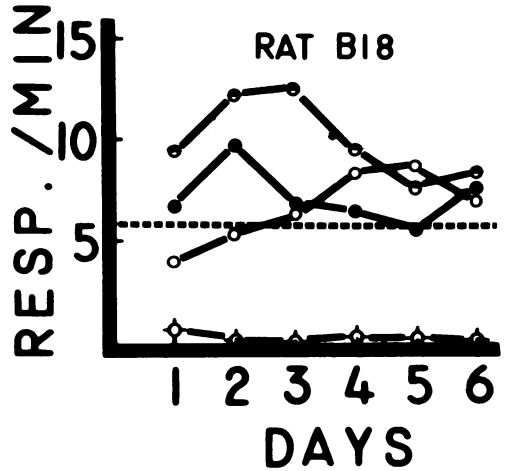
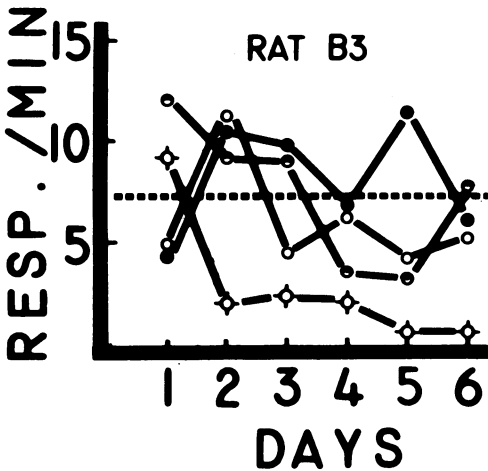
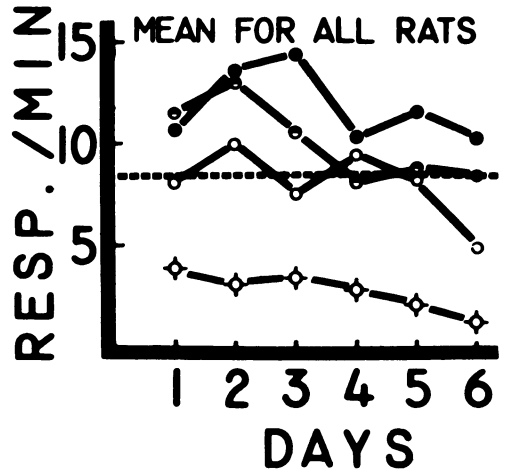


Fig. 3. Response rates during each of the six days of reinforcement with each of the stimulus animals. The points represent responses per minute of time available for responding. Shown for comparison is a baseline rate (dashed lines) for control days, which represents the average rate obtained under reinforcement with mice on the day immediately preceding each test period and the extinction test.

rat the number of responses on the last day of reinforcement with mouse presentation and on each day of the six-day extinction period. The mean number of responses dropped from 131 on the first day of extinction to less than five on the last day. The decline in rate exhibited by every rat is evident in the figure.

GENERAL DISCUSSION

The present results confirm and extend the findings of the T-maze study by Myer and White (1965). In Experiment I, rats that reliably killed mice learned a key-pressing re-

sponse when every press was followed with presentation of an opportunity to attack and kill a mouse. Offered a choice between a key that yielded presentation of mice and one that did not, the rats preferred the key that yielded mice. When the contingency was reversed, the rats learned the reversal and continued to obtain mice. In Experiment II, rats that reliably and quickly killed mice but did not kill rat pups learned a key-pressing response reinforced on a variable-interval schedule with the opportunity to attack and kill mice. When the rats were tested for responding on

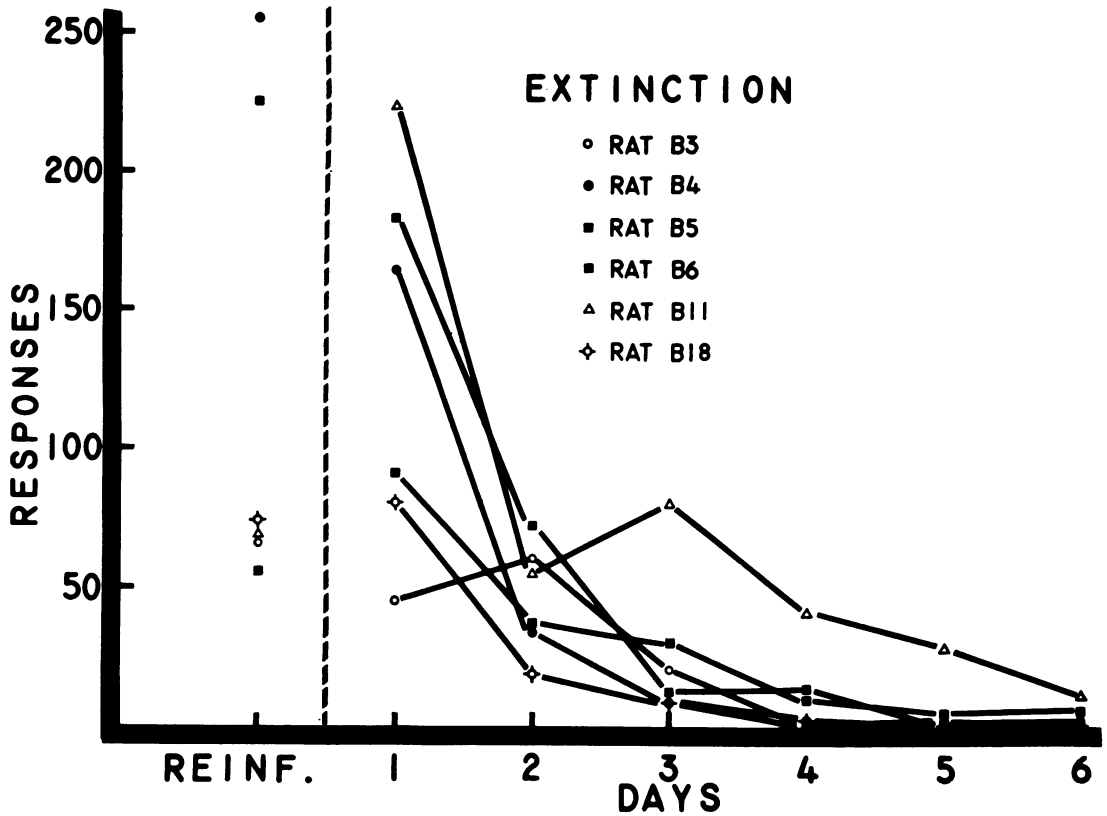


Fig. 4. Number of responses made by each rat on the last day of reinforcement with mouse presentation and on each of the six days of extinction training.

that schedule under reinforcement with normal mice, anesthetized mice, dead mice, or rat pups, response rates were maintained by reinforcement with each of the three different kinds of mice, but declined under reinforcement with rat pups.

It is possible that reinforcement in the present experiments resulted mainly from stimuli associated with presentation of a mouse, rather than, as Valenstein, *et al.*, (1970) might propose, from the consummatory behavior involved in attacking and killing the mouse. However, in Experiment II, the rats encountered a variety of attack-eliciting stimuli from the various stimulus animals employed as reinforcers. Even rat pups provide stimuli that elicit attack, although the attack is inhibited (Myer, 1964). Clear differences in reinforcing power, expressed as differences in response rates, were absent, except for the sharp decline under reinforcement with rat pups. It could be argued that inhibition of attack in the presence of attack-eliciting stimuli is aver-

sive, and that therefore presentation of rat pups to mouse-killing rats was punishing. However, the fact that rats that do not kill mice choose the arm of a T-maze containing a rat pup in preference to the arm containing a mouse (Myer and White, 1965) suggests that contact with rat pups is not aversive to rats. More importantly, the decline in response rate under reinforcement with rat pups in the present study was not as severe as the decline in rate during extinction, which indicates that contact with rat pups is somewhat reinforcing rather than aversive for rats that kill mice. Even though the eliciting stimuli and the behavior directed toward those stimuli were somewhat confounded in the present study, it is clear that those stimuli that were attacked maintained response rates, and that the one that was not attacked did not maintain response rates. A much stronger case could have been made if rat pups were shown to be a positive reinforcer for those rats that killed them, but within the limita-

tions of the present study it was not possible to include such rats.

A simple explanation of the absence of differences in rates of responding reinforced by the different kinds of mice might be merely that there were no large differences in the attack behavior directed toward the mice by the rats. Anesthetized mice and dead mice were attacked as readily as were normal mice, which provides support for the assertion of Craig (1921) that the aim of aggressive behavior is not destruction. Rather, it is evident that the behavior of attacking or the eliciting stimulus is itself an incentive; it is sufficient incentive to maintain the strength of an operant, as the experiments demonstrate.

Many species-typical behaviors have been shown to be reinforcers. The list includes gnawing in rats (Roberts and Carey, 1965), sexual behavior (Caggiula, 1970), and maternal behavior (Wilsoncroft, 1969; Van Hemel, 1970), as well as various forms of aggressive behavior (Thompson, 1963, 1964; Roberts and Kiess, 1964; Azrin, *et al.*, 1965; Dreyer and Church, 1970). The present findings, taken with those of Myer and White (1965), make it clear that mouse killing by rats belongs in this list.

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