PUP RETRIEVING AS A REINFORCER IN NULLIPAROUS MICE¹

SUSAN B. VAN HEMEL

JOHNS HOPKINS UNIVERSITY

Six nulliparous female mice were trained to bar press with bar pressing reinforced by the opportunity to retrieve pups to the nest. Then, responses on one bar produced the opportunity to retrieve pups, while responses on a second bar produced sensory contact with non-retrievable pups, presented behind a screen door. All subjects emitted more responses on the bar yielding retrievable pups. When the bar-pup contingency was reversed, five subjects learned to press the opposite bar for retrievable pups. The sixth subject showed extinction of responding on the bar that had previously yielded retrievable pups, but failed to press the other bar. A major portion of the reinforcing value of pup presentation resulted from the opportunity to perform the behavior of pup retrieving. This finding supports theoretical formulations which state that the performance of species-typical consummatory behaviors should have reinforcing properties.

Craig (1918) described the strengthening of appetitive behavior whenever it was followed immediately by the appetized stimulus and consummatory reaction. His formulation may be considered an operant conditioning paradigm, with appetitive behavior as the operant, and the appetized stimulus and consummatory reaction as the reinforcer. Recent theoretical articles have restated and expanded upon Craig's ideas, concluding that the performance of any species-typical consummatory behavior (Valenstein, Cox, and Kakolewski, 1970), or the activation of neural structures mediating such behavior (Glickman and Schiff, 1967) should be a reinforcing event.

Within the last several years, experiments have shown that a variety of species-typical behaviors will, in fact, serve as reinforcers. Although such behaviors as aggressive display (Thompson, 1963; 1964), aggression (Van Hemel, 1972) and sexual behavior (Sheffield, Wulff, and Backer, 1951) have been used as

reinforcers, few studies have attempted to use maternal behaviors in this way. This lack of research is somewhat surprising, since it has long been observed that maternal behavior is strongly motivated and persistent, and it could thus be expected to be a strong reinforcer. Only two recent studies have used maternal behavior as a reinforcer, one using rats as subjects and one using mice. Since it is impossible to present a behavior to a subject as a reinforcer, these experiments presented pups in a situation where retrieval was possible. Wilsoncroft (1969) showed that lactating rats will bar press for retrievable pups when each bar press is followed by presentation of a pup, and that the pups are invariably retrieved to the nest. Frieman (1965) showed that lactating mice would learn a light-dark discrimination in a choice apparatus to reach pups, which they retrieved to the nest. She also reported pilot data showing that both male and female mice would bar press for pups on a fixed-ratio schedule.²

The present experiment attempted to confirm Frieman's pilot finding that non-lactating mice can be trained to bar press for pups. Also, since it is known that mice will perform operants reinforced by environmental stimulus change (Kish, 1955), the study attempted to

¹This study represents part of a thesis submitted to the Johns Hopkins University in partial fulfillment of the requirements for the degree of Doctor of Philosophy, and was performed while the author held a NDEA fellowship. It was also supported in part by NSF grant No. GB8041 to Dr. James S. Myer. The author would like to thank Dr. Myer, her thesis advisor, for the advice and encouragement he provided during the planning and execution of this research. Reprints may be obtained from Susan B. Van Hemel, 401 Eden Road, Apt. R-1, Lancaster, Pennsylvania 17601.

²Frieman, J. P. Transcript of paper presented at 73rd Annual Convention, American Psychological Association, September 1965.

determine whether pup presentation with the opportunity to retrieve would be more reinforcing than the mere presentation of the pup stimuli. If the retrieving behavior, or more precisely, the stimuli produced by such behavior, were the prepotent reinforcer, subjects could be expected to prefer retrievable pups to non-retrievable pups in a choice situation.

METHOD

Subjects

Eight nulliparous female Swiss albino mice from the laboratory breeding colony were 12 weeks old at the start of the experiment. Swiss albino mouse pups weighing 2.5 g or less were used for the reinforcement operation. They were kept with their mothers except when they were being used in the experiment.

Apparatus

The individual home cages in which subjects were housed during the experiment were standard plastic mouse pans, Maryland Plastics E-0270, modified by the addition of a sliding metal door over a 3 by 3 in. (7.6 by 7.6 cm) opening in one end of the pan.

The floor of the operant chamber was trapezoidal, with an area of 16 in.² (106 cm²). One side was open and fitted snugly against the open door of the subject's home cage [see Figure 1 (A)]. The chamber had a 0.375 in. (0.7 cm) mesh hardware cloth floor, 3 in. (7.6 cm) high Plexiglas sides, and a Plexiglas top. The metal operant panel is shown in Figure 1 (B). There was a central reinforcement chute behind the panel. The bottom of this chute was directly behind an opening in the panel covered by two vertically sliding, hand-operated doors. The door nearest the inside of the chamber was of solid metal, and the outer door was of fine copper screening. On each side of the panel was a manually retractable bar operandum, constructed from a microswitch, above which was mounted an amber pilot light. The bars closed the microswitch contacts when they were depressed with a force of about 0.02 N. A foam-rubber-lined wooden enclosure around three sides and the top of the apparatus provided some sound shielding, and a speaker inside the enclosure provided constant masking noise. Electromechanical equipment recorded bar presses and controlled the bar pilot lights.

Fig. 1. (A) Floor plan of apparatus. 1—home cage; 2—operant chamber; 3—panel. (B) Diagram of operant panel. 4—chute opening, covered by doors; 5—bar pilot light; 6—bar operandum.

Procedure

Maintenance. The subjects were weaned at about 25 days of age into same-sex group cages, where they remained until they were isolated into individual home cages for the experiment. Food and water were continuously available, except during experimental sessions, and the cages were supplied with Sanicel bedding and some wood shavings as nesting material. The animals were maintained on a 12-hr on, 12-hr off light cycle, with experimental sessions conducted during the light phase. Temperature in the colony and experimental rooms was maintained at $23 \pm 1^\circ \text{C}$.

Adaptation and pretraining. A five-day adaptation and pretraining period began when the eight subjects were chosen at random from the colony stock and transferred to individual home cages. They were given 48 hr (Day 1 and Day 2) to adapt to the home cages and to the experimental room with masking noise present.

On Day 3, each subject was given 30 min of adaptation in the apparatus. The door between the home cage and the operant chamber was open throughout this and all subsequent sessions, allowing the subject to move freely between the cage and the chamber. If a bar was pressed during adaptation, the bar lights

went off for a 20-sec timeout period, during which responses had no scheduled consequences. On Day 4, three pups were placed in the home cage with each subject, 3 to 4 hr before the subject was to be run. The subjects then were given 30 min in the apparatus as on Day 3, except that two of the three pups were removed from the nest and placed on the chamber floor at the beginning of the session, and retrieving was noted. The number of pups used here and in other phases of the experiment was chosen after preliminary work indicated that three or four pups were sufficient to ensure maternal behavior, and that one pup remaining in the nest would reduce the likelihood of the nest being destroyed or moved during a session.

On Day 5, the same procedure was followed as on Day 4, up to the beginning of the session, when all three pups were placed on the floor of the operant chamber. If all three pups were retrieved to the nest within 5 min, magazine training was begun immediately. The one subject that did not meet this retrieving criterion was discarded. Magazine training consisted of the presentation of 20 pups, one at a time. Each pup was deposited in the chute directly behind the panel opening. On the first few presentations, the chute doors were held open as long as was necessary for the subject to retrieve the pup, but subjects soon took pups promptly as the chute doors were raised. After each retrieval, one pup was removed from the nest and the chute was reloaded.

A pup presentation followed every recorded bar press during the shaping and training sessions, and consisted of raising both doors of the pup chute to allow the subject access to the pup, and then lowering them when the pup had been taken, or after a maximum of about 5 sec. Each bar press was also followed by a timeout. If a pup had been retrieved, one pup was removed from the nest during the timeout, and the pup chute was reloaded. During the sessions, extra reinforcer pups were kept in a pan of shavings warmed by a 25-w red lamp.

Shaping. Beginning on Day 6, and for the remainder of the experiment, four pups were placed in the home cage with each subject 3 to 4 hr before each daily session. Three of these pups were removed from the nest immediately before the session began. Starting on Day 6, successive approximations to bar pressing were

followed by pup presentation and a 10-sec timeout. Both bars were present and both pilot lights on when shaping began, and this and every subsequent session began with the presentation of one "free" pup in the chute opening. Once responding was established, a pup presentation and timeout followed each recorded bar press. As soon as five responses were recorded on one bar, it was retracted and its light was turned off. Successive approximations to pressing the other bar were then reinforced until five responses had been recorded on the other bar. Thereafter, one bar with its light was presented at a time, alternating sides after every fifth bar press. A shaping session was ended after 20 recorded responses or a maximum of 20 min. Only one shaping session was needed to achieve reliable responding on both bars for five subjects, and a sixth subject responded reliably after two sessions. The seventh animal showed persistent avoidance of the operant chamber, and was discarded after four unsuccessful shaping sessions.

Training and preference testing. During the five days of training that followed shaping, a pup presentation and a 20-sec timeout followed each recorded bar press. One bar at a time, with its light, was presented, alternating after every fifth response, so that subjects emitted 10 responses on each bar in each 20-response session. On alternate days, alternate bars were presented first.

Following the five days of training, a one-day bar-preference test was given. This was identical to a training session, except that both bars were present (with lights operating) throughout the session. Responses on each bar were followed by pup presentation and the 20-sec timeout was used.

Discrimination and reversal. Five days of discrimination sessions followed the preference test. Since no subject had indicated a strong bar preference, the left bar was arbitrarily designated "correct" for all six subjects. During discrimination sessions, both bars were continuously present, and presses on each were followed by the 20-sec timeout with both lights off. Only presses on the left bar were followed by lifting of both chute doors, providing an opportunity to retrieve a pup from the chute. Presses on the right bar were followed by lifting of the solid door for 3 to 5 sec, leaving the screen door between the subject and the pup. The subject thus presumably re-

ceived some stimuli from the pup, such as the ultrasonic cries recorded by Noirot (1966), but was prevented from retrieving the pup. Each session ended after 20 recorded responses or a maximum of 30 min.

Following the five discrimination sessions, five daily sessions of reversal training were conducted. The procedure was identical to that in discrimination, except that presses on the right bar yielded access to the pup and presses on the left bar yielded sensory contact through the screen door. Again, each session ended after 20 recorded responses or a maximum of 30 min.

RESULTS

The six subjects that completed shaping all pressed reliably on both bars, and emitted 20 bar presses in 7 to 9 min on the last training day. In the bar-preference test session, the

subjects emitted 45% of their responses on the left bar, and 55% on the right, with no subject showing a preference stronger than 70% for either bar. When the reinforcement contingency of the discrimination sessions was introduced, the subjects all rapidly developed a strong preference for the left bar, which yielded retrievable pups. Figure 2 (A) shows the mean number of responses on the left "correct" bar and right "incorrect" bar on the five discrimination days. Every subject emitted 20 responses in each session during this period. The number of correct responses increased over days until, on the fifth discrimination day, the animals emitted a mean of 17.8 responses on the left bar and 2.2 on the right. A Friedman two-way analysis of variance showed the increase in correct responses over the five discrimination days to be significant ($X_r^2 = 14.8$, $df = 4$, $p < 0.01$). Table 1 shows the data from each of the six subjects on each day of

Fig. 2. Mean responses on correct bar (retrievable pups) and incorrect bar (non-retrievable pups). (A) discrimination; (B) reversal.

Table 1
Daily Responses on Left Bar (L) and Right Bar (R) by Each Subject

		Subjects											
Condition	Day	¹		²		³		⁴		⁷		⁸	
		L	R	L	R	L	R	L	R	L	R	L	R
Preference test	1	11	9	6	14	10	10	7	13	9	11	11	9
Discrimination L "correct"	1	8	12	5	15	10	10	12	8	11	9	12	8
	2	14	6	14	6	17	3	13	7	19	1	15	5
	3	18	2	15	5	18	2	16	4	18	2	16	4
	4	17	3	20	0	19	1	18	2	13	7	18	2
	5	17	3	20	0	19	1	20	0	16	4	15	5
Reversal R "correct"	1	14	6	9	1	14	0	18	2	16	4	13	7
	2	8	12	13	7	15	1	17	3	9	11	6	14
	3	6	14	10	4	8	0	4	16	2	18	5	15
	4	5	15	6	14	0	6	4	16	0	20	2	18
	5	3	17	3	17	9	0	2	18	0	20	6	14

discrimination and reversal. It is clear from these data that all subjects showed some preference for the left bar by the second day of discrimination sessions.

Figure 2 (B) shows the mean number of responses on the right "correct" bar and the left "incorrect" bar during the five days of reversal training. All six subjects showed at least partial extinction of responding on the left bar, but only five learned to press the now-correct right bar within five days. The reversal learning was generally slower than the original discrimination. The increase in correct responses over the five days was found to be significant by the Friedman two-way analysis of variance ($X_r^2 = 12.3$, $df = 4$, $p < 0.02$) and the decrease in incorrect responses was also significant by this test ($X_r^2 = 16.8$, $df = 4$, $p < 0.01$). As Table 1 indicates, the difference in final performance between discrimination and reversal conditions was almost entirely due to the one subject (3) that never learned the correct response in reversal.

Besides the subject that did not learn the reversal and never completed 20 responses within the 30-min time limit, one other subject failed on two days to complete 20 responses in 30 min. All other subjects emitted 20 responses on all five reversal days, although the time required to do so was quite variable, ranging from 7 to 25 min, compared with 7 to 16 min in discrimination.

Most subjects showed more variable behavior in the reversal situation than in the discrimination sessions. This behavior included biting the bars, digging in the bedding mate-

rial, and avoiding the operant chamber. Most of the subjects that actively attacked the bars soon pressed the correct bar, and quickly acquired the reversal, whereas those that avoided the chamber and spent much time on the nest were slow to acquire the new behavior. The one animal that failed to acquire the reversal spent nearly all of the reversal session time on the nest.

During training and discrimination sessions, every subject retrieved every pup. In reversal sessions, one subject (8) occasionally failed to carry pups all the way to the nest, but this animal, as Table 1 shows, continued to emit 20 responses in every session, and acquired the reversal.

DISCUSSION

The present results clearly support the formulations (Craig, 1918; Glickman and Schiff, 1967; Valenstein, *et al.*, 1970) that predict that consummatory species-specific behaviors should have reinforcing value. The present findings also confirm and extend Friedman's pilot findings² that non-lactating mice will bar press for pups. The opportunity to perform the retrieving response was clearly preferred to mere sensory contact with pups that could not be retrieved, and the retrievable pups were virtually always retrieved.

To state that a behavior is reinforcing is, in effect, to state that the *stimuli* produced by that behavior are reinforcing. It would appear then, in the present experiment, that the stimuli of mere visual, auditory, and olfactory

contact with pups were less reinforcing than the combination of these stimuli and the stimuli produced by the retrieving response. The possibility remains that the additional reinforcing effect resulted from additional contact stimuli provided by the opportunity for subjects merely to touch the retrievable pups. The regularity with which subjects retrieved these pups argues against such an interpretation. It seems more probable that the stimuli produced by the retrieving behavior provided the additional reinforcing value.

It remains to be shown that the reinforcing effects here are specific to mouse pups; that is, that other retrievable or transportable objects would not have served as well, especially since these subjects were not lactating. Gandelman, Zarrow, and Denenberg (1970) observed that virgin mice discriminated between mouse pups and rubber dolls in a retrieving situation, and retrieved only the mouse pups. However, their study found that lactating mice often retrieved the rubber dolls. The total behavior pattern shown by the present subjects included nest-building when pups were presented in the home cage, licking the pups, and assuming a lactation position over the pups in the nest. This pattern strongly suggests that the retrieving observed was part of a "maternal" behavior sequence, and not merely an indiscriminate object-carrying behavior.

It is quite possible that the carrying of objects other than pups, when not part of a pattern of maternal behavior, is reinforcing. Further research might be done to attempt to differentiate between the reinforcing value of retrievable pups, and of other small transportable objects. The findings of Gandelman, *et al.*, (1970) that virgin mice but not lactating

mice retrieved pups but not other objects suggest that hormonal factors would have to be considered in any such experiment.

REFERENCES

- Craig, W. Appetites and aversions as constituents of instincts. *Biological Bulletin*, 1918, **34**, 91-107.
- Frieman, J. P. The use of pups as positive reinforcement in mice. *Proceedings, 73rd Annual Convention, American Psychological Association*, 1965, 131-132.
- Gandelman, R., Zarrow, M. X., and Denenberg, V. H. Maternal behavior: differences between mother and virgin mice as a function of the testing procedure. *Developmental Psychobiology*, 1970, **3**, 207-214.
- Glickman, S. E. and Schiff, B. B. A biological theory of reinforcement. *Psychological Review*, 1967, **74**, 81-103.
- Kish, G. B. Learning when the onset of illumination is used as reinforcing stimulus. *Journal of Comparative and Physiological Psychology*, 1955, **48**, 261-264.
- Noirot, E. Ultra-sounds in young rodents. I. Changes with age in albino mice. *Animal Behaviour*, 1966, **14**, 459-462.
- Sheffield, F. D., Wulff, J. J., and Backer, R. Reward value of copulation without sex drive reduction. *Journal of Comparative and Physiological Psychology*, 1951, **44**, 3-8.
- Thompson, T. I. Visual reinforcement in Siamese fighting fish. *Science*, 1963, **141**, 55-57.
- Thompson, T. I. Visual reinforcement in fighting cocks. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 45-49.
- Valenstein, E. S., Cox, V. C., and Kakolewski, J. W. Reexamination of the role of the hypothalamus in motivation. *Psychological Review*, 1970, **77**, 16-31.
- Van Hemel, P. E. Aggression as a reinforcer: operant behavior in the mouse-killing rat. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 237-245.
- Wilsoncroft, W. E. Babies by bar-press: maternal behavior in the rat. *Behavior Research Methods and Instrumentation*, 1969, **1**, 229-230.

Received 10 April 1972.

(Final Acceptance 12 September 1972.)